User's Manual

16

M16C/6C Group

User's Manual: Hardware

RENESAS MCU

M16C Family / M16C/60 Series

Renesas Electronics
www.renesas.com

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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/6C 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/6C Group Datasheet	R01DS0034EJ0210
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/6C 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

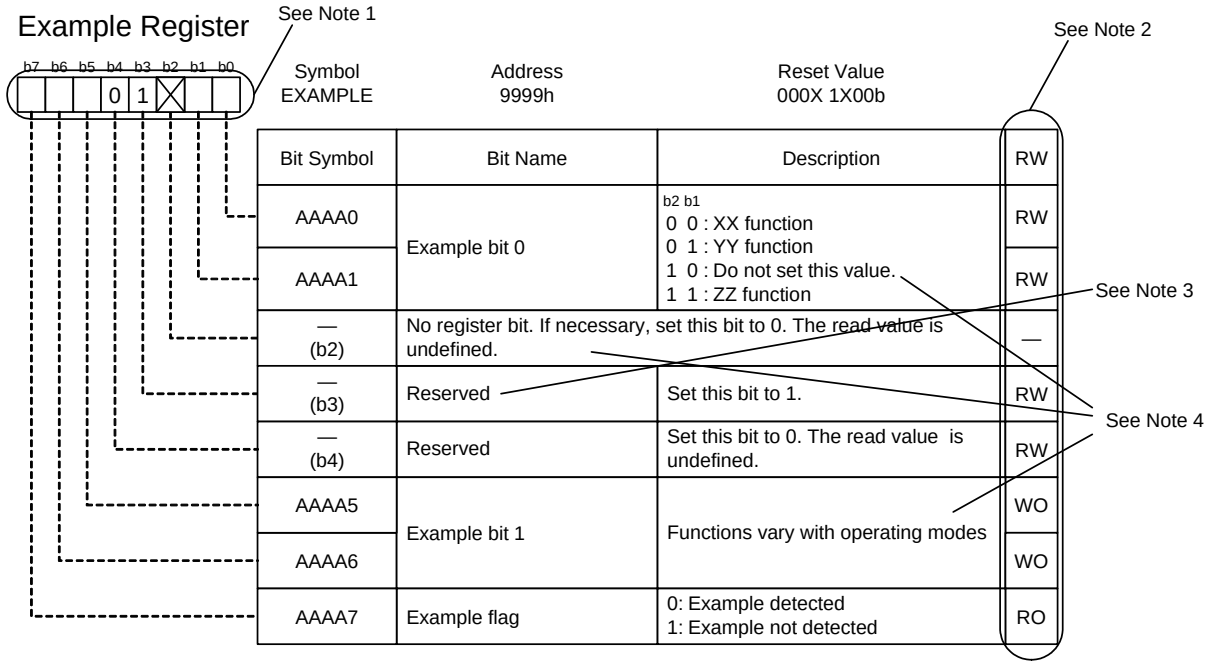
The following explains the denotations used in this manual for registers, bits, pins and various numbers.

(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.



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	52
0005h	Processor Mode Register 1	PM1	142
0006h	System Clock Control Register 0	CM0	92
0007h	System Clock Control Register 1	CM1	94
0008h	Chip Select Control Register	CSR	148
0009h			
000Ah	Protect Register	PRCR	46
000Bh			
000Ch	Oscillation Stop Detection Register	CM2	96
000Dh			
000Eh			
000Fh			
0010h	Program 2 Area Control Register	PRG2C	144
0011h			
0012h	Peripheral Clock Select Register	PCLKR	98
0013h			
0014h			
0015h	Clock Prescaler Reset Flag	CPSRF	257
0016h			
0017h			
0018h	Reset Source Determine Register	RSTFR	53
0019h	Voltage Detector 2 Flag Register	VCR1	69
001Ah	Voltage Detector Operation Enable Register	VCR2	70
001Bh	Chip Select Expansion Control Register	CSE	149
001Ch	PLL Control Register 0	PLC0	99
001Dh	PLLFCK Control Register	PLCF	101
001Eh	Processor Mode Register 2	PM2	102
001Fh			
0020h			
0021h			
0022h	40 MHz On-Chip Oscillator Control Register 0	FRA0	103
0023h			
0024h			
0025h			
0026h	Voltage Monitor Function Select Register	VWCE	71
0027h			
0028h			
0029h			
002Ah	Voltage Monitor 0 Control Register	VW0C	72
002Bh	Voltage Monitor 1 Control Register	VW1C	73
002Ch	Voltage Monitor 2 Control Register	VW2C	75
002Dh			
002Eh			
002Fh			
0030h to 003Fh			
0040h			
0041h			
0042h	$\overline{\text{INT7}}$ Interrupt Control Register	INT7IC	196
0043h	$\overline{\text{INT6}}$ Interrupt Control Register	INT6IC	196
0044h	$\overline{\text{INT3}}$ Interrupt Control Register	INT3IC	196
0045h	Timer B5 Interrupt Control Register	TB5IC	196
0046h	Timer B4 Interrupt Control Register UART1 Bus Collision Detection Interrupt Control Register	TB4IC U1BCNIC	195
0047h	Timer B3 Interrupt Control Register UART0 Bus Collision Detection Interrupt Control Register	TB3IC U0BCNIC	195
0048h	$\overline{\text{INT5}}$ Interrupt Control Register	INT5IC	196

Address	Register	Symbol	Page
0049h	$\overline{\text{INT4}}$ Interrupt Control Register	INT4IC	196
004Ah	UART2 Bus Collision Detection Interrupt Control Register	BCNIC	195
004Bh	DMA0 Interrupt Control Register	DM0IC	195
004Ch	DMA1 Interrupt Control Register	DM1IC	195
004Dh	Key Input Interrupt Control Register, A/D Conversion (A/D1) Interrupt Control Register	KUPIC, ADEIC	195
004Eh	A/D Conversion (A/D0) Interrupt Control Register	ADIC	196
004Fh	UART2 Transmit Interrupt Control Register	S2TIC	195
0050h	UART2 Receive Interrupt Control Register	S2RIC	195
0051h	UART0 Transmit Interrupt Control Register	S0TIC	195
0052h	UART0 Receive Interrupt Control Register	S0RIC	195
0053h	UART1 Transmit Interrupt Control Register	S1TIC	195
0054h	UART1 Receive Interrupt Control Register	S1RIC	195
0055h	Timer A0 Interrupt Control Register	TA0IC	195
0056h	Timer A1 Interrupt Control Register	TA1IC	195
0057h	Timer A2 Interrupt Control Register	TA2IC	195
0058h	Timer A3 Interrupt Control Register	TA3IC	195
0059h	Timer A4 Interrupt Control Register	TA4IC	195
005Ah	Timer B0 Interrupt Control Register	TB0IC	195
005Bh	Timer B1 Interrupt Control Register	TB1IC	195
005Ch	Timer B2 Interrupt Control Register	TB2IC	195
005Dh	$\overline{\text{INT0}}$ Interrupt Control Register	INT0IC	196
005Eh	$\overline{\text{INT1}}$ Interrupt Control Register	INT1IC	196
005Fh	$\overline{\text{INT2}}$ Interrupt Control Register	INT2IC	196
0060h to 0068h			
0069h	DMA2 Interrupt Control Register	DM2IC	195
006Ah	DMA3 Interrupt Control Register	DM3IC	195
006Bh	UART5 Bus Collision Detection Interrupt Control Register	U5BCNIC	195
006Ch	UART5 Transmit Interrupt Control Register	S5TIC	195
006Dh	UART5 Receive Interrupt Control Register	S5RIC	195
006Eh	UART4 Bus Collision Detection Interrupt Control Register, Real-Time Clock Periodic Interrupt Control Register	U4BCNIC RTCTIC	195
006Fh	UART4 Transmit Interrupt Control Register, Real-Time Clock Compare Interrupt Control Register	S4TIC, RTCCIC	195
0070h	UART4 Receive Interrupt Control Register	S4RIC	195
0071h	UART3 Bus Collision Detection Interrupt Control Register	U3BCNIC	195
0072h	UART3 Transmit Interrupt Control Register	S3TIC	195
0073h	UART3 Receive Interrupt Control Register	S3RIC	195
0074h			
0075h			
0076h	USB Interrupt 0 Control Register	USBINT0IC	195
0077h	USB Interrupt 1 Control Register	USBINT1IC	195
0078h	USB RESUME Interrupt Control Register	USBRSMIC	195
0079h	IC/OC Interrupt 0 Control Register	ICOC0IC	195
007Ah	IC/OC Channel 0 Interrupt Control Register	ICOCH0IC	195
007Bh	IC/OC Interrupt 1 Control Register, I2C-bus Interface Interrupt Control Register	ICOC1IC, IICIC	195
007Ch	SCL/SDA Interrupt Control Register, IC/OC Channel 1 Interrupt Control Register	SCLDAIC, ICOCH1IC	195
007Dh	IC/OC Channel 2 Interrupt Control Register	ICOCH2IC	195
007Eh	IC/OC Channel 3 Interrupt Control Register	ICOCH3IC	195
007Fh	IC/OC Base Timer Interrupt Control Register	BTIC	195

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
0080h to 013Fh			
0140h	A/D1 Register 0	AD10	644
0141h			
0142h	A/D1 Register 1	AD11	644
0143h			
0144h	A/D1 Register 2	AD12	644
0145h			
0146h	A/D1 Register 3	AD13	644
0147h			
0148h			
0149h			
014Ah			
014Bh			
014Ch			
014Dh			
014Eh			
014Fh			
0150h			
0151h			
0152h	A/D1 Trigger Control Register	AD1TRGCON	645
0153h			
0154h	A/D1 Control Register 2	AD1CON2	646
0155h			
0156h	A/D1 Control Register 0	AD1CON0	647
0157h	A/D1 Control Register 1	AD1CON1	649
0158h			
0159h			
015Ah			
015Bh			
015Ch			
015Dh			
015Eh			
015Fh			
0160h			
0161h			
0162h			
0163h			
0164h			
0165h			
0166h			
0167h			
0168h			
0169h			
016Ah			
016Bh			
016Ch			
016Dh			
016Eh			
016Fh			
0170h			
0171h			
0172h			
0173h			
0174h			
0175h			
0176h			
0177h			
0178h			
0179h			
017Ah			
017Bh			
017Ch			
017Dh			
017Eh			
017Fh			

Address	Register	Symbol	Page
0180h	DMA0 Source Pointer	SAR0	238
0181h			
0182h			
0183h			
0184h	DMA0 Destination Pointer	DAR0	238
0185h			
0186h			
0187h			
0188h	DMA0 Transfer Counter	TCR0	239
0189h			
018Ah			
018Bh			
018Ch	DMA0 Control Register	DM0CON	240
018Dh			
018Eh			
018Fh			
0190h	DMA1 Source Pointer	SAR1	238
0191h			
0192h			
0193h			
0194h	DMA1 Destination Pointer	DAR1	238
0195h			
0196h			
0197h			
0198h	DMA1 Transfer Counter	TCR1	239
0199h			
019Ah			
019Bh			
019Ch	DMA1 Control Register	DM1CON	240
019Dh			
019Eh			
019Fh			
01A0h	DMA2 Source Pointer	SAR2	238
01A1h			
01A2h			
01A3h			
01A4h	DMA2 Destination Pointer	DAR2	238
01A5h			
01A6h			
01A7h			
01A8h	DMA2 Transfer Counter	TCR2	239
01A9h			
01AAh			
01ABh			
01ACh	DMA2 Control Register	DM2CON	240
01ADh			
01AEh			
01AFh			
01B0h	DMA3 Source Pointer	SAR3	238
01B1h			
01B2h			
01B3h			
01B4h	DMA3 Destination Pointer	DAR3	238
01B5h			
01B6h			
01B7h			
01B8h	DMA3 Transfer Counter	TCR3	239
01B9h			
01BAh			
01BBh			
01BCh	DMA3 Control Register	DM3CON	240
01BDh			
01BEh			
01BFh			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
01C0h	Timer B0-1 Register	TB01	308
01C1h			
01C2h	Timer B1-1 Register	TB11	308
01C3h			
01C4h	Timer B2-1 Register	TB21	308
01C5h			
01C6h	Pulse Period/Pulse Width Measurement Mode Function Select Register 1	PPWFS1	309
01C7h			
01C8h	Timer B Count Source Select Register 0	TBCS0	310
01C9h	Timer B Count Source Select Register 1	TBCS1	310
01CAh			
01CBh	Timer AB Division Control Register 0	TCKDIVC0	258
01CCh			
01CDh			
01CEh			
01CFh			
01D0h	Timer A Count Source Select Register 0	TACS0	259
01D1h	Timer A Count Source Select Register 1	TACS1	259
01D2h	Timer A Count Source Select Register 2	TACS2	259
01D3h			
01D4h	16-bit Pulse Width Modulation Mode Function Select Register	PWMFS	260
01D5h	Timer A Waveform Output Function Select Register	TAPOFS	261
01D6h			
01D7h			
01D8h	Timer A Output Waveform Change Enable Register	TAOW	262
01D9h			
01DAh	Three-Phase Protect Control Register	TPRC	343
01DBh			
01DCh			
01DDh			
01DEh			
01DFh			
01E0h	Timer B3-1 Register	TB31	308
01E1h			
01E2h	Timer B4-1 Register	TB41	308
01E3h			
01E4h	Timer B5-1 Register	TB51	308
01E5h			
01E6h	Pulse Period/Pulse Width Measurement Mode Function Select Register 2	PPWFS2	309
01E7h			
01E8h	Timer B Count Source Select Register 2	TBCS2	310
01E9h	Timer B Count Source Select Register 3	TBCS3	310
01EAh			
01EBh			
01ECh			
01EDh			
01EEh			
01EFh			
01F0h			
01F1h			
01F2h			
01F3h			
01F4h			
01F5h			
01F6h			
01F7h			
01F8h			
01F9h			
01FAh			
01FBh			
01FCh			
01FDh			
01FEh			
01FFh			

Address	Register	Symbol	Page
0200h			
0201h			
0202h			
0203h			
0204h			
0205h	Interrupt Source Select Register 3	IFSR3A	198
0206h	Interrupt Source Select Register 2	IFSR2A	199
0207h	Interrupt Source Select Register	IFSR	200
0208h			
0209h			
020Ah			
020Bh			
020Ch			
020Dh			
020Eh	Address Match Interrupt Enable Register	AIER	201
020Fh	Address Match Interrupt Enable Register 2	AIER2	201
0210h	Address Match Interrupt Register 0	RMAD0	202
0211h			
0212h			
0213h			
0214h	Address Match Interrupt Register 1	RMAD1	202
0215h			
0216h			
0217h			
0218h	Address Match Interrupt Register 2	RMAD2	202
0219h			
021Ah			
021Bh			
021Ch	Address Match Interrupt Register 3	RMAD3	202
021Dh			
021Eh			
021Fh			
0220h	Flash Memory Control Register 0	FMR0	687
0221h	Flash Memory Control Register 1	FMR1	690
0222h	Flash Memory Control Register 2	FMR2	120
0223h			
0224h			
0225h			
0226h			
0227h			
0228h			
0229h			
022Ah			
022Bh			
022Ch			
022Dh			
022Eh			
022Fh			
0230h	Flash Memory Control Register 6	FMR6	692
0231h			
0232h			
0233h			
0234h			
0235h			
0236h			
0237h			
0238h			
0239h			
023Ah			
023Bh			
023Ch			
023Dh			
023Eh			
023Fh			
0240h			
0241h			
0242h			
0243h			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
0244h	UART0 Special Mode Register 4	U0SMR4	466
0245h	UART0 Special Mode Register 3	U0SMR3	468
0246h	UART0 Special Mode Register 2	U0SMR2	469
0247h	UART0 Special Mode Register	U0SMR	470
0248h	UART0 Transmit/Receive Mode Register	U0MR	458
0249h	UART0 Bit Rate Register	U0BRG	459
024Ah	UART0 Transmit Buffer Register	U0TB	459
024Bh			
024Ch	UART0 Transmit/Receive Control Register 0	U0C0	460
024Dh	UART0 Transmit/Receive Control Register 1	U0C1	462
024Eh	UART0 Receive Buffer Register	U0RB	463
024Fh			
0250h	UART Transmit/Receive Control Register 2	UCON	465
0251h			
0252h	UART Clock Select Register	UCLKSEL0	457
0253h			
0254h	UART1 Special Mode Register 4	U1SMR4	466
0255h	UART1 Special Mode Register 3	U1SMR3	468
0256h	UART1 Special Mode Register 2	U1SMR2	469
0257h	UART1 Special Mode Register	U1SMR	470
0258h	UART1 Transmit/Receive Mode Register	U1MR	458
0259h	UART1 Bit Rate Register	U1BRG	459
025Ah	UART1 Transmit Buffer Register	U1TB	459
025Bh			
025Ch	UART1 Transmit/Receive Control Register 0	U1C0	460
025Dh	UART1 Transmit/Receive Control Register 1	U1C1	462
025Eh	UART1 Receive Buffer Register	U1RB	463
025Fh			
0260h			
0261h			
0262h			
0263h			
0264h	UART2 Special Mode Register 4	U2SMR4	466
0265h	UART2 Special Mode Register 3	U2SMR3	468
0266h	UART2 Special Mode Register 2	U2SMR2	469
0267h	UART2 Special Mode Register	U2SMR	470
0268h	UART2 Transmit/Receive Mode Register	U2MR	458
0269h	UART2 Bit Rate Register	U2BRG	459
026Ah	UART2 Transmit Buffer Register	U2TB	459
026Bh			
026Ch	UART2 Transmit/Receive Control Register 0	U2C0	460
026Dh	UART2 Transmit/Receive Control Register 1	U2C1	462
026Eh	UART2 Receive Buffer Register	U2RB	463
026Fh			
0270h			
0271h			
0272h			
0273h			
0274h			
0275h			
0276h			
0277h			
0278h			
0279h			
027Ah			
027Bh			
027Ch			
027Dh			
027Eh			
027Fh			
0280h			
0281h			
0282h			
0283h			
0284h	UART5 Special Mode Register 4	U5SMR4	466
0285h	UART5 Special Mode Register 3	U5SMR3	468
0286h	UART5 Special Mode Register 2	U5SMR2	469
0287h	UART5 Special Mode Register	U5SMR	470

Address	Register	Symbol	Page
0288h	UART5 Transmit/Receive Mode Register	U5MR	458
0289h	UART5 Bit Rate Register	U5BRG	459
028Ah	UART5 Transmit Buffer Register	U5TB	459
028Bh			
028Ch	UART5 Transmit/Receive Control Register 0	U5C0	460
028Dh	UART5 Transmit/Receive Control Register 1	U5C1	462
028Eh	UART5 Receive Buffer Register	U5RB	463
028Fh			
0290h			
0291h			
0292h			
0293h			
0294h	UART4 Special Mode Register 4	U4SMR4	466
0295h	UART4 Special Mode Register 3	U4SMR3	468
0296h	UART4 Special Mode Register 2	U4SMR2	469
0297h	UART4 Special Mode Register	U4SMR	470
0298h	UART4 Transmit/Receive Mode Register	U4MR	458
0299h	UART4 Bit Rate Register	U4BRG	459
029Ah	UART4 Transmit Buffer Register	U4TB	459
029Bh			
029Ch	UART4 Transmit/Receive Control Register 0	U4C0	460
029Dh	UART4 Transmit/Receive Control Register 1	U4C1	462
029Eh	UART4 Receive Buffer Register	U4RB	463
029Fh			
02A0h			
02A1h			
02A2h			
02A3h			
02A4h	UART3 Special Mode Register 4	U3SMR4	466
02A5h	UART3 Special Mode Register 3	U3SMR3	468
02A6h	UART3 Special Mode Register 2	U3SMR2	469
02A7h	UART3 Special Mode Register	U3SMR	470
02A8h	UART3 Transmit/Receive Mode Register	U3MR	458
02A9h	UART3 Bit Rate Register	U3BRG	459
02AAh	UART3 Transmit Buffer Register	U3TB	459
02ABh			
02ACh	UART3 Transmit/Receive Control Register 0	U3C0	460
02ADh	UART3 Transmit/Receive Control Register 1	U3C1	462
02AEh	UART3 Receive Buffer Register	U3RB	463
02AFh			
02B0h	I2C0 Data Shift Register	S00	525
02B1h			
02B2h	I2C0 Address Register 0	S0D0	526
02B3h	I2C0 Control Register 0	S1D0	527
02B4h	I2C0 Clock Control Register	S20	529
02B5h	I2C0 Start/Stop Condition Control Register	S2D0	531
02B6h	I2C0 Control Register 1	S3D0	532
02B7h	I2C0 Control Register 2	S4D0	536
02B8h	I2C0 Status Register 0	S10	538
02B9h	I2C0 Status Register 1	S11	543
02BAh	I2C0 Address Register 1	S0D1	526
02BBh	I2C0 Address Register 2	S0D2	526
02BCh			
02BDh			
02BEh			
02BFh			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
02C0h	Time Measurement Register 0, Waveform Generation Register 0	G1TM0, G1PO0	375
02C1h			
02C2h	Time Measurement Register 1, Waveform Generation Register 1	G1TM1, G1PO1	375
02C3h			
02C4h	Time Measurement Register 2, Waveform Generation Register 2	G1TM2, G1PO2	375
02C5h			
02C6h	Time Measurement Register 3, Waveform Generation Register 3	G1TM3, G1PO3	375
02C7h			
02C8h	Time Measurement Register 4, Waveform Generation Register 4	G1TM4, G1PO4	375
02C9h			
02CAh	Time Measurement Register 5, Waveform Generation Register 5	G1TM5, G1PO5	375
02CBh			
02CCh	Time Measurement Register 6, Waveform Generation Register 6	G1TM6, G1PO6	375
02CDh			
02CEh	Time Measurement Register 7, Waveform Generation Register 7	G1TM7, G1PO7	375
02CFh			
02D0h	Waveform Generation Control Register 0	G1POCR0	377
02D1h	Waveform Generation Control Register 1	G1POCR1	377
02D2h	Waveform Generation Control Register 2	G1POCR2	377
02D3h	Waveform Generation Control Register 3	G1POCR3	377
02D4h	Waveform Generation Control Register 4	G1POCR4	377
02D5h	Waveform Generation Control Register 5	G1POCR5	377
02D6h	Waveform Generation Control Register 6	G1POCR6	377
02D7h	Waveform Generation Control Register 7	G1POCR7	377
02D8h	Time Measurement Control Register 0	G1TMCR0	377
02D9h	Time Measurement Control Register 1	G1TMCR1	377
02DAh	Time Measurement Control Register 2	G1TMCR2	377
02DBh	Time Measurement Control Register 3	G1TMCR3	377
02DCh	Time Measurement Control Register 4	G1TMCR4	377
02DDh	Time Measurement Control Register 5	G1TMCR5	377
02DEh	Time Measurement Control Register 6	G1TMCR6	377
02DFh	Time Measurement Control Register 7	G1TMCR7	377
02E0h	Base Timer Register	G1BT	381
02E1h			
02E2h	Base Timer Control Register 0	G1BCR0	382
02E3h	Base Timer Control Register 1	G1BCR1	383
02E4h	Time Measurement Prescaler Register 6	G1TPR6	384
02E5h	Time Measurement Prescaler Register 7	G1TPR7	384
02E6h	Function Enable Register	G1FE	384
02E7h	Function Select Register	G1FS	385
02E8h	Base Timer Reset Register	G1BTRR	386
02E9h			
02EAh	Count Source Divide Register	G1DV	386
02EBh			
02ECh	Waveform Output Master Enable Register	G1OER	387
02EDh			
02EEh	Timer S I/O Control Register 0	G1IOR0	388
02EFh	Timer S I/O Control Register 1	G1IOR1	389
02F0h	Interrupt Request Register	G1IR	390
02F1h	Interrupt Enable Register 0	G1IE0	391
02F2h	Interrupt Enable Register 1	G1IE1	392
02F3h			
02F4h			
02F5h			
02F6h			
02F7h			
02F8h			
02F9h			
02FAh			
02FBh			
02FCh			
02FDh			
02FEh			
02FFh			

Address	Register	Symbol	Page
0300h	Timer B3/B4/B5 Count Start Flag	TBSR	312
0301h			
0302h	Timer A1-1 Register	TA11	264
0303h			
0304h	Timer A2-1 Register	TA21	264
0305h			
0306h	Timer A4-1 Register	TA41	264
0307h			
0308h	Three-Phase PWM Control Register 0	INVC0	335
0309h	Three-Phase PWM Control Register 1	INVC1	337
030Ah	Three-Phase Output Buffer Register 0	IDB0	339
030Bh	Three-Phase Output Buffer Register 1	IDB1	339
030Ch	Dead Time Timer	DTT	339
030Dh	Timer B2 Interrupt Generation Frequency Set Counter	ICTB2	340
030Eh	Position-Data-Retain Function Control Register	PDRF	342
030Fh			
0310h	Timer B3 Register	TB3	307
0311h			
0312h	Timer B4 Register	TB4	307
0313h			
0314h	Timer B5 Register	TB5	307
0315h			
0316h			
0317h			
0318h	Port Function Control Register	PFCR	343
0319h			
031Ah			
031Bh	Timer B3 Mode Register	TB3MR	313
031Ch	Timer B4 Mode Register	TB4MR	313
031Dh	Timer B5 Mode Register	TB5MR	313
031Eh			
031Fh			
0320h	Count Start Flag	TABSR	264
0321h			
0322h	One-Shot Start Flag	ONSF	265
0323h	Trigger Select Register	TRGSR	266
0324h	Increment/Decrement Flag	UDF	267
0325h			
0326h	Timer A0 Register	TA0	263
0327h			
0328h	Timer A1 Register	TA1	263
0329h			
032Ah	Timer A2 Register	TA2	263
032Bh			
032Ch	Timer A3 Register	TA3	263
032Dh			
032Eh	Timer A4 Register	TA4	263
032Fh			
0330h	Timer B0 Register	TB0	307
0331h			
0332h	Timer B1 Register	TB1	307
0333h			
0334h	Timer B2 Register	TB2	307
0335h			
0336h	Timer A0 Mode Register	TA0MR	268
0337h	Timer A1 Mode Register	TA1MR	268
0338h	Timer A2 Mode Register	TA2MR	268
0339h	Timer A3 Mode Register	TA3MR	268
033Ah	Timer A4 Mode Register	TA4MR	268

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
033Bh	Timer B0 Mode Register	TB0MR	313
033Ch	Timer B1 Mode Register	TB1MR	313
033Dh	Timer B2 Mode Register	TB2MR	313
033Eh	Timer B2 Special Mode Register	TB2SC	341
033Fh			
0340h	Real-Time Clock Second Data Register	RTCSEC	426
0341h	Real-Time Clock Minute Data Register	RTCMIN	427
0342h	Real-Time Clock Hour Data Register	RTCHR	428
0343h	Real-Time Clock Day Data Register	RTCWK	429
0344h	Real-Time Clock Control Register 1	RTCCR1	430
0345h	Real-Time Clock Control Register 2	RTCCR2	432
0346h	Real-Time Clock Count Source Select Register	RTCCSR	434
0347h			
0348h	Real-Time Clock Second Compare Data Register	RTCCSEC	435
0349h	Real-Time Clock Minute Compare Data Register	RTCCMIN	436
034Ah	Real-Time Clock Hour Compare Data Register	RTCCHR	437
034Bh			
034Ch			
034Dh			
034Eh			
034Fh			
0350h			
0351h			
0352h			
0353h			
0354h			
0355h			
0356h			
0357h			
0358h			
0359h			
035Ah			
035Bh			
035Ch			
035Dh			
035Eh			
035Fh			
0360h	Pull-Up Control Register 0	PUR0	179
0361h	Pull-Up Control Register 1	PUR1	180
0362h	Pull-Up Control Register 2	PUR2	181
0363h			
0364h			
0365h			
0366h	Port Control Register	PCR	182
0367h			
0368h			
0369h	NMI/SD Digital Filter Register	NMIDF	204
036Ah			
036Bh			
036Ch			
036Dh			
036Eh			
036Fh			
0370h			
0371h			
0372h			
0373h			
0374h			
0375h			
0376h			

Address	Register	Symbol	Page
0377h			
0378h			
0379h			
037Ah			
037Bh			
037Ch	Count Source Protection Mode Register	CSPR	227
037Dh	Watchdog Timer Refresh Register	WDTR	228
037Eh	Watchdog Timer Start Register	WDTS	228
037Fh	Watchdog Timer Control Register	WDC	229
0380h			
0381h			
0382h			
0383h			
0384h			
0385h			
0386h			
0387h			
0388h			
0389h			
038Ah			
038Bh			
038Ch			
038Dh			
038Eh			
038Fh			
0390h	DMA2 Source Select Register	DM2SL	241
0391h			
0392h	DMA3 Source Select Register	DM3SL	241
0393h			
0394h			
0395h			
0396h			
0397h			
0398h	DMA0 Source Select Register	DM0SL	241
0399h			
039Ah	DMA1 Source Select Register	DM1SL	241
039Bh			
039Ch			
039Dh			
039Eh			
039Fh			
03A0h			
03A1h			
03A2h			
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	679
03B5h			
03B6h	CRC Mode Register	CRCMR	680
03B7h			
03B8h			
03B9h			
03BAh			
03BBh			
03BCh	CRC Data Register	CRCD	680
03BDh			
03BEh	CRC Input Register	CRCIN	680
03BFh			
03C0h	A/D0 Register 0	AD00	638
03C1h			
03C2h	A/D0 Register 1	AD01	638
03C3h			
03C4h	A/D0 Register 2	AD02	638
03C5h			
03C6h	A/D0 Register 3	AD03	638
03C7h			
03C8h	A/D0 Register 4	AD04	638
03C9h			
03CAh	A/D0 Register 5	AD05	638
03CBh			
03CCh	A/D0 Register 6	AD06	638
03CDh			
03CEh	A/D0 Register 7	AD07	638
03CFh			
03D0h			
03D1h			
03D2h	A/D0 Trigger Control Register	AD0TRGCON	639
03D3h			
03D4h	A/D0 Control Register 2	AD0CON2	640
03D5h			
03D6h	A/D0 Control Register 0	AD0CON0	641
03D7h	A/D0 Control Register 1	AD0CON1	643
03D8h	D/A0 Register	DA0	675
03D9h			
03DAh	D/A1 Register	DA1	675
03DBh			
03DCh	D/A Control Register	DACON	675
03DDh			
03DEh			
03DFh			
03E0h	Port P0 Register	P0	183
03E1h	Port P1 Register	P1	183
03E2h	Port P0 Direction Register	PD0	184
03E3h	Port P1 Direction Register	PD1	184
03E4h	Port P2 Register	P2	183
03E5h	Port P3 Register	P3	183
03E6h	Port P2 Direction Register	PD2	184
03E7h	Port P3 Direction Register	PD3	184
03E8h	Port P4 Register	P4	183
03E9h	Port P5 Register	P5	183
03EAh	Port P4 Direction Register	PD4	184
03EBh	Port P5 Direction Register	PD5	184
03ECh	Port P6 Register	P6	183
03EDh	Port P7 Register	P7	183
03EEh	Port P6 Direction Register	PD6	184
03EFh	Port P7 Direction Register	PD7	184

Address	Register	Symbol	Page
03F0h	Port P8 Register	P8	183
03F1h	Port P9 Register	P9	183
03F2h	Port P8 Direction Register	PD8	184
03F3h	Port P9 Direction Register	PD9	184
03F4h	Port P10 Register	P10	183
03F5h			
03F6h	Port P10 Direction Register	PD10	184
03F7h			
03F8h			
03F9h			
03FAh			
03FBh			
03FCh			
03FDh			
03FEh			
03FFh			
D000h to D0FFh			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
D100h	USB Interrupt Flag Register 0	USBIFR0	572
D101h	USB Interrupt Flag Register 1	USBIFR1	574
D102h	USB Interrupt Flag Register 2	USBIFR2	576
D103h	USB Interrupt Flag Register 3	USBIFR3	578
D104h			
D105h			
D106h			
D107h			
D108h	USB Interrupt Enable Register 0	USBIER0	580
D109h	USB Interrupt Enable Register 1	USBIER1	581
D10Ah	USB Interrupt Enable Register 2	USBIER2	581
D10Bh	USB Interrupt Enable Register 3	USBIER3	582
D10Ch			
D10Dh			
D10Eh			
D10Fh			
D110h	USB Interrupt Select Register 0	USBISR0	583
D111h	USB Interrupt Select Register 1	USBISR1	584
D112h	USB Interrupt Select Register 2	USBISR2	585
D113h	USB Interrupt Select Register 3	USBISR3	586
D114h			
D115h			
D116h			
D117h			
D118h			
D119h			
D11Ah			
D11Bh			
D11Ch			
D11Dh			
D11Eh			
D11Fh			
D120h	USB Endpoint 0 IN Data Register	USBEPDR0I	587
D121h			
D122h			
D123h			
D124h	USB Endpoint 0 OUT Data Register	USBEPDR0O	587
D125h			
D126h			
D127h			
D128h	USB Endpoint 0 S Data Register	USBEPDR0S	588
D129h			
D12Ah			
D12Bh			
D12Ch			
D12Dh			
D12Eh			
D12Fh			
D130h	USB Endpoint 1 Data Register	USBEPDR1	589
D131h			
D132h			
D133h			
D134h	USB Endpoint 2 Data Register	USBEPDR2	590
D135h			
D136h			
D137h			
D138h	USB Endpoint 3 Data Register	USBEPDR3	590
D139h			
D13Ah			
D13Bh			
D13Ch			
D13Dh			
D13Eh			
D13Fh			

Address	Register	Symbol	Page
D140h	USB Endpoint 4 Data Register	USBEPDR4	589
D141h			
D142h			
D143h			
D144h	USB Endpoint 5 Data Register	USBEPDR5	590
D145h			
D146h			
D147h			
D148h	USB Endpoint 6 Data Register	USBEPDR6	590
D149h			
D14Ah			
D14Bh			
D14Ch			
D14Dh			
D14Eh			
D14Fh			
D150h to D17Fh			
D180h	USB Endpoint 0 OUT Receive Data Size Register	USBEPSZ0O	591
D181h	USB Endpoint 1 Receive Data Size Register	USBEPSZ1	591
D182h	USB Endpoint 4 Receive Data Size Register	USBEPSZ4	591
D183h			
D184h			
D185h			
D186h			
D187h			
D188h	USB Data Status Register 0	USBDASTS0	592
D189h	USB Data Status Register 1	USBDASTS1	592
D18Ah	USB Data Status Register 2	USBDASTS2	592
D18Bh			
D18Ch			
D18Dh			
D18Eh			
D18Fh			
D190h	USB Trigger Register 0	USBTRG0	593
D191h	USB Trigger Register 1	USBTRG1	594
D192h	USB Trigger Register 2	USBTRG2	594
D193h			
D194h			
D195h			
D196h			
D197h			
D198h	USB FIFO Clear Register 0	USBFCLR0	595
D199h	USB FIFO Clear Register 1	USBFCLR1	596
D19Ah	USB FIFO Clear Register 2	USBFCLR2	596
D19Bh			
D19Ch			
D19Dh			
D19Eh			
D19Fh			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
D1A0h	USB Endpoint Stall Register 0	USBEPSTL0	597
D1A1h	USB Endpoint Stall Register 1	USBEPSTL1	598
D1A2h	USB Endpoint Stall Register 2	USBEPSTL2	598
D1A3h			
D1A4h			
D1A5h			
D1A6h			
D1A7h			
D1A8h			
D1A9h	USB Stall Status Register 1	USBSTLSR1	600
D1AAh	USB Stall Status Register 2	USBSTLSR2	600
D1ABh			
D1ACh			
D1ADh			
D1AEh			
D1AFh			
D1B0h	USB DMA Transfer Setting Register	USBDMAR	602
D1B1h			
D1B2h			
D1B3h			
D1B4h	USB Configuration Value Register	USBCVR	603
D1B5h			
D1B6h			
D1B7h			
D1B8h	USB Control Register	USBCTLR	604
D1B9h			
D1BAh			
D1BBh			
D1BCh			
D1BDh			
D1BEh			
D1BFh			
D1C0h	USB Endpoint Information Register	USBEPIR	605
D1C1h			
D1C2h			
D1C3h			
D1C4h			
D1C5h			
D1C6h			
D1C7h			
D1C8h			
D1C9h			
D1CAh			
D1CBh			
D1CCh	USB Module Control Register	USBMC	609
D1CDh			
D1CEh			
D1CFh			

The blank areas are reserved. No access is allowed.

FFFFFh	Optional Function Select Address 1	OFS1	694

OFS1 address is not an SFR.

1. Overview

1.1 Features

The M16C/6C 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 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 personal computer peripherals (USB compatible products), audio components, cameras, televisions, household appliances, office equipment, communication devices, mobile devices, industrial equipment, and other applications.

Note: This product has been designed and developed for the purpose of being used in consumer products. It cannot be used with products that require a high level of quality such as automotive electronics.

1.2 Specifications

The M16C/6C Group is available in a 100-pin package. Table 1.1 and Table 1.2 list Specifications.

Table 1.1 Specifications (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 1.3 “Product List”
Voltage Detection	Voltage detector	• Power-on reset • 3 voltage detection points (detection level of voltage detection 0 selectable)
Clock	Clock generator	• 5 circuits: Main clock, sub clock, low-speed on-chip oscillator (125 kHz), high-speed on-chip oscillator (40 MHz ±10%), 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 3 waits inserted, 4 chip select outputs, 3 V and 5 V interfaces • Bus format: Separate bus or multiplexed bus selectable, data bus width (8 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: 55 • Transfer modes: 2 (single transfer, repeat transfer)

Table 1.2 Specifications (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
	Timer S (Input capture/output compare)	• Input base timer: 16 bits X 1 • I/O: 8 channels • Time measurement register, Waveform generation register: 16 bits X 8
Serial Interface	UART0 to UART5	Clock synchronous/asynchronous × 6 channels I^2C-bus, IEBus, special mode 2 SIM (UART2)
Multi-master I^2C-bus Interface		1 channel

USB Functions		• Full speed (12 Mbps, USB 2.0 compliant)
		• Transfer type: Control IN/OUT, Bulk IN x 2, Bulk OUT x 2, Interrupt IN x 2
		• FIFO size: 584 bytes
		  • Setup 8 bytes
		  • Control IN 16 bytes
		  • Control OUT 16 bytes
		  • Interrupt IN 16 bytes: 2 channels
		  • Bulk IN 64 bytes x 2: 2 channels
		  • Bulk OUT 64 bytes x 2: 2 channels

A/D Converter		10-bit resolution × 26 channels (2 circuits), 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		Described in Electrical Characteristics
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 1.3 “Product List” for the operating temperature.

1.3 Product List

Table 1.3 lists Product List. Figure 1.1 shows Part No., with Memory Size and Package, and Figure 1.2 shows Marking Diagram (Top View).

Table 1.3 Product List As of July 2012

Part No.	ROM Capacity			RAM Capacity	Package Code	Remarks
	Program ROM 1	Program ROM 2	Data flash			
R5F36CAMNFA	512 KB	16 KB	4 KB × 2 blocks	31 KB	PRQP0100JD-B	Operating temperature -20°C to 85°C
R5F36CAMNFB					PLQP0100KB-A	
R5F36CAMDFA					PRQP0100JD-B	Operating temperature -40°C to 85°C
R5F36CAMDFB					PLQP0100KB-A	
R5F36CAKNFA	384 KB	16 KB	4 KB × 2 blocks	31 KB	PRQP0100JD-B	Operating temperature -20°C to 85°C
R5F36CAKNFB					PLQP0100KB-A	
R5F36CAKDFA					PRQP0100JD-B	Operating temperature -40°C to 85°C
R5F36CAKDFB					PLQP0100KB-A	
R5F36CAENFA	256 KB	16 KB	4 KB × 2 blocks	20 KB	PRQP0100JD-B	Operating temperature -20°C to 85°C
R5F36CAENFB					PLQP0100KB-A	
R5F36CAEDFA					PRQP0100JD-B	Operating temperature -40°C to 85°C
R5F36CAEDFB					PLQP0100KB-A	
R5F36CA6NFA	128 KB	16 KB	4 KB × 2 blocks	12 KB	PRQP0100JD-B	Operating temperature -20°C to 85°C
R5F36CA6NFB					PLQP0100KB-A	
R5F36CA6DFA					PRQP0100JD-B	Operating temperature -40°C to 85°C
R5F36CA6DFB					PLQP0100KB-A	

(D): Under development
(P): Planning
Previous package codes are as follows:
PRQP0100JD-B: 100P6F-A
PLQP0100KB-A: 100P6Q-A

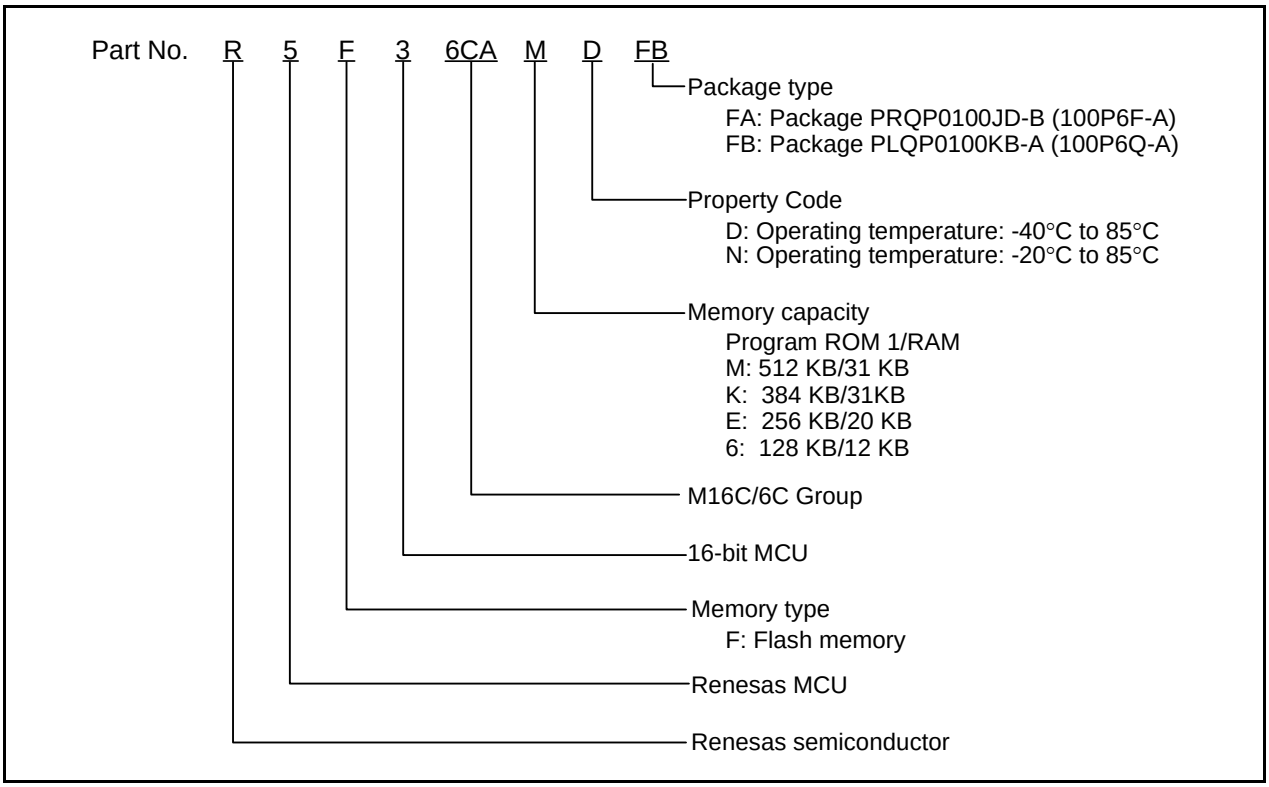


Figure 1.1 Part No., with Memory Size and Package

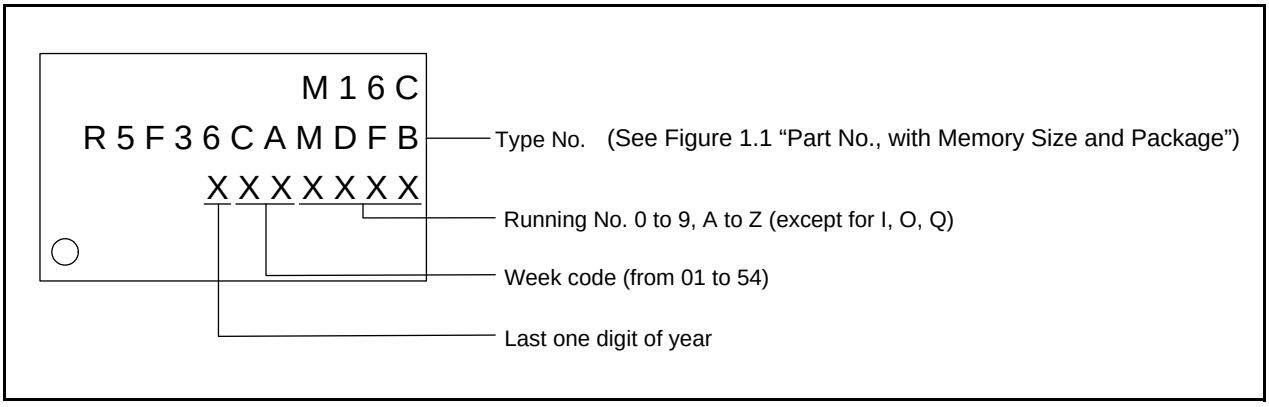
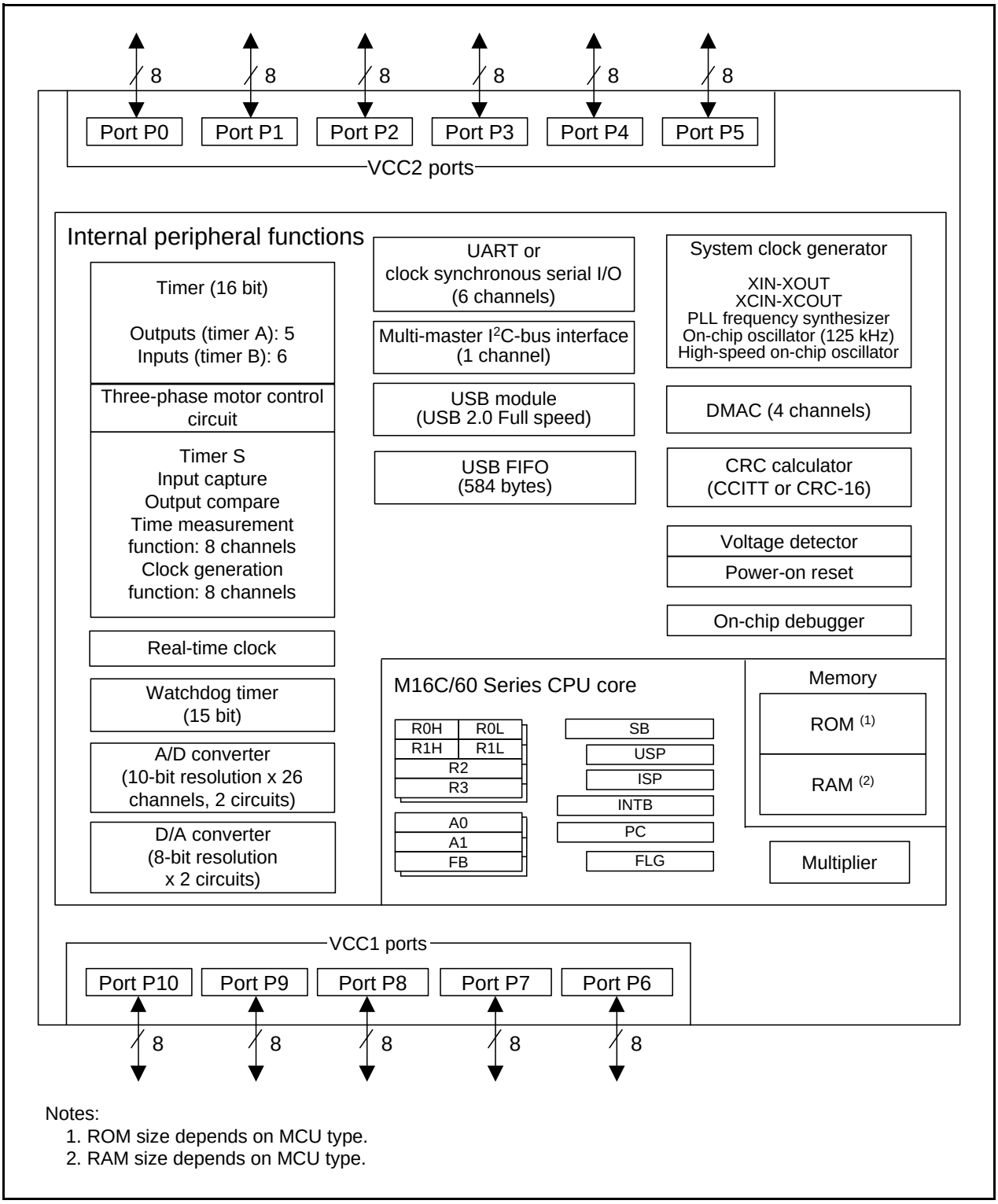


Figure 1.2 Marking Diagram (Top View)

1.4 Block Diagram

Figure 1.3 shows Block Diagram.

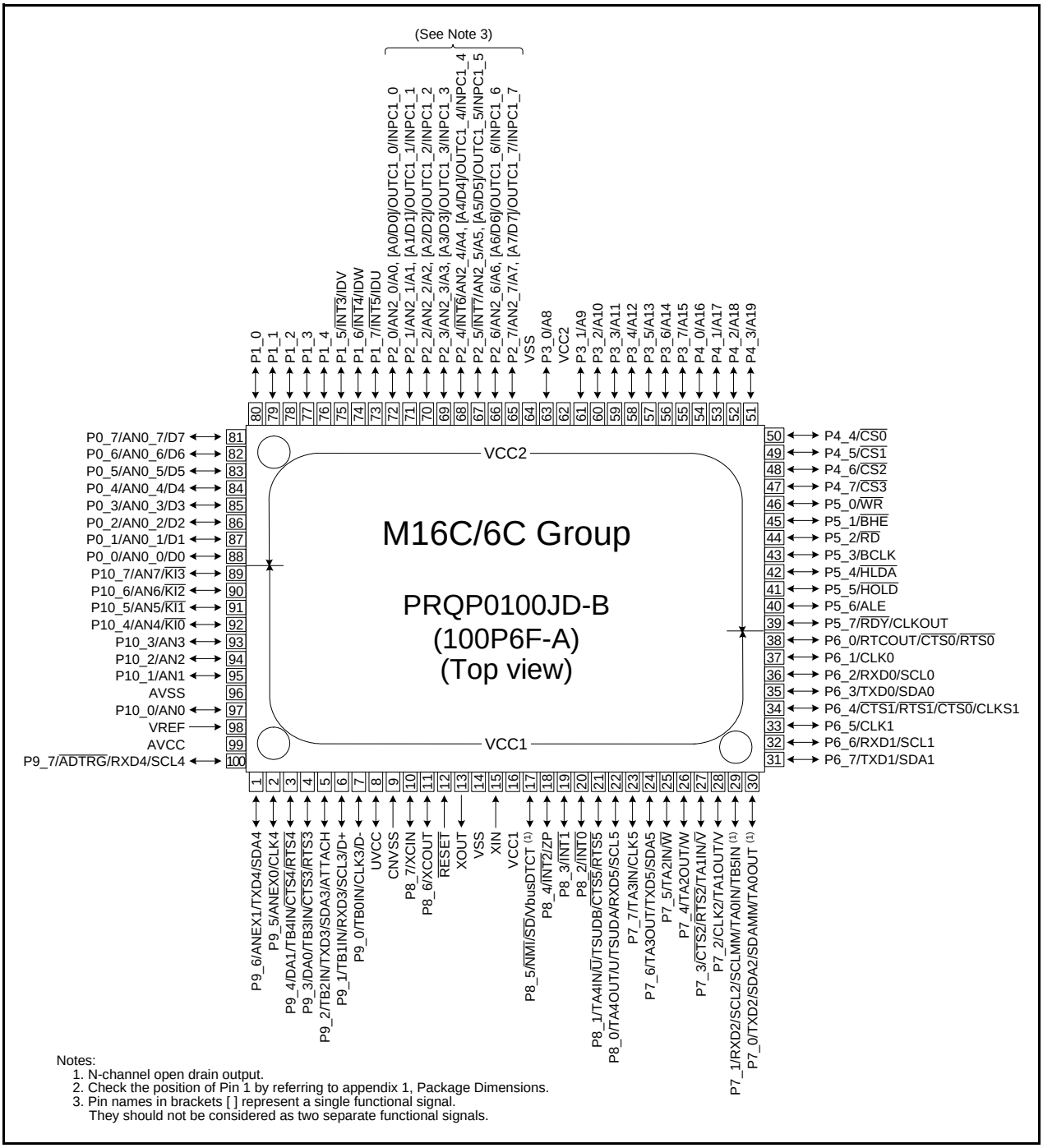


Notes:
1. ROM size depends on MCU type.
2. RAM size depends on MCU type.

Figure 1.3 Block Diagram

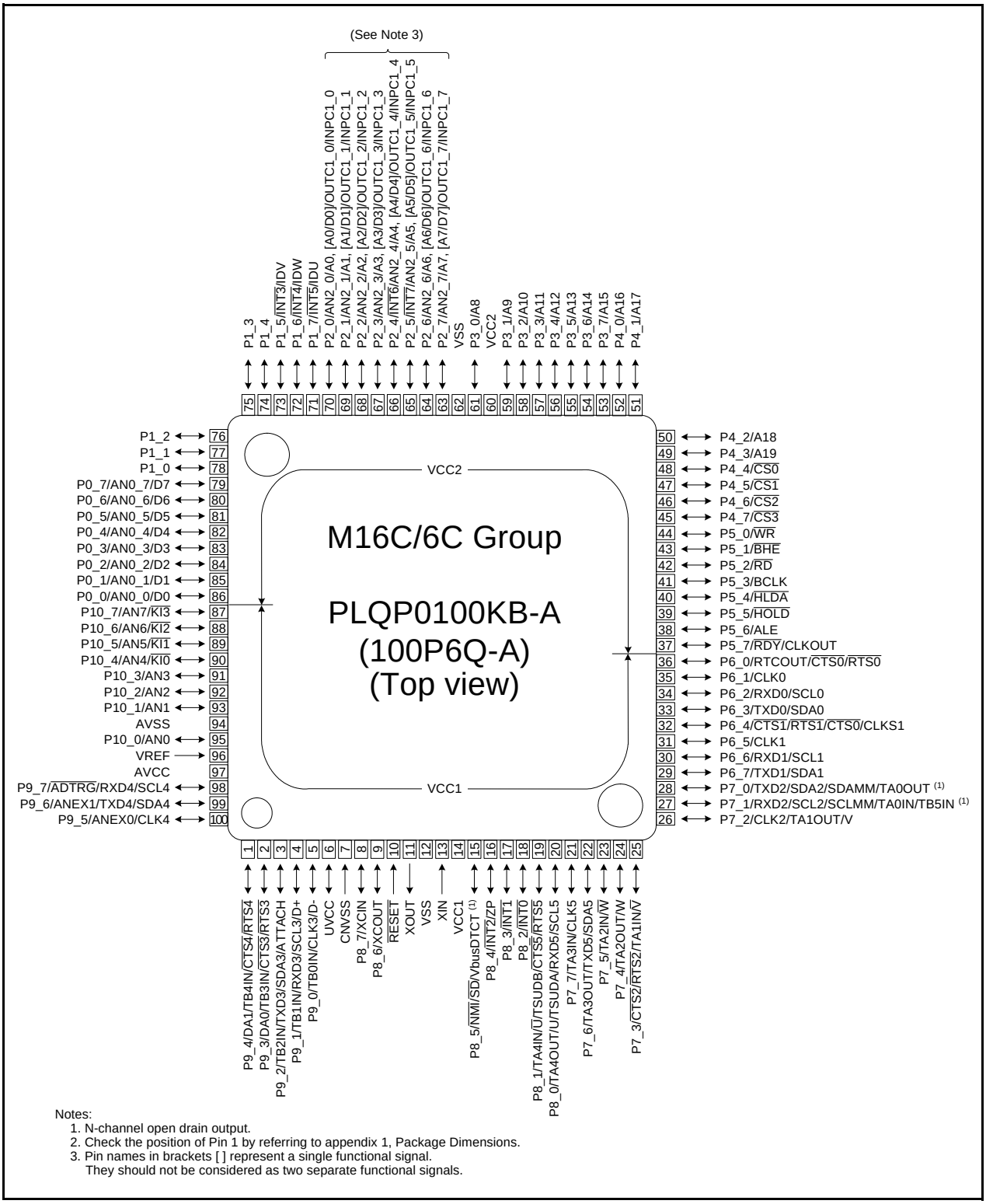
1.5 Pin Assignment

Figure 1.4 and Figure 1.5 show Pin Assignment. Table 1.4 and Table 1.5 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 1.4 Pin Assignment



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

Table 1.4 Pin Names (1/2)

Pin No.		Control Pin	Port	I/O Pin for Peripheral Function				Bus Control Pin
FA	FB			Interrupt	Timer	Serial interface, USB	A/D converter, D/A converter	
1	99		P9_6			TXD4/SDA4	ANEX1	
2	100		P9_5			CLK4	ANEX0	
3	1		P9_4		TB4IN	$\overline{CTS4}$/$\overline{RTS4}$	DA1	
4	2		P9_3		TB3IN	$\overline{CTS3}$/$\overline{RTS3}$	DA0	
5	3		P9_2		TB2IN	TXD3/SDA3/ATTACH		
6	4		P9_1		TB1IN	RXD3/SCL3/D+		
7	5		P9_0		TB0IN	CLK3/D-		
8	6					UVCC		
9	7	CNVSS						
10	8	XCIN	P8_7					
11	9	XCOUT	P8_6					
12	10	$\overline{RESET}$						
13	11	XOUT						
14	12	VSS						
15	13	XIN						
16	14	VCC1						
17	15		P8_5	$\overline{NMI}$	$\overline{SD}$	VbusDTCT		
18	16		P8_4	$\overline{INT2}$	ZP			
19	17		P8_3	$\overline{INT1}$				
20	18		P8_2	$\overline{INT0}$				
21	19		P8_1		TA4IN/$\overline{U}$/TSUDB	$\overline{CTS5}$/$\overline{RTS5}$		
22	20		P8_0		TA4OUT/U/TSUDA	RXD5/SCL5		
23	21		P7_7		TA3IN	CLK5		
24	22		P7_6		TA3OUT	TXD5/SDA5		
25	23		P7_5		TA2IN/$\overline{W}$			
26	24		P7_4		TA2OUT/W			
27	25		P7_3		TA1IN/$\overline{V}$	$\overline{CTS2}$/$\overline{RTS2}$		
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			$\overline{CTS1}$/$\overline{RTS1}$/$\overline{CTS0}$/ CLKS1		
35	33		P6_3			TXD0/SDA0		
36	34		P6_2			RXD0/SCL0		
37	35		P6_1			CLK0		
38	36		P6_0		RTCOUT	$\overline{CTS0}$/$\overline{RTS0}$		
39	37		P5_7					$\overline{RDY}$/CLKOUT
40	38		P5_6					ALE
41	39		P5_5					$\overline{HOLD}$
42	40		P5_4					$\overline{HLDA}$
43	41		P5_3					BCLK
44	42		P5_2					$\overline{RD}$
45	43		P5_1					$\overline{BHE}$
46	44		P5_0					$\overline{WR}$
47	45		P4_7					$\overline{CS3}$
48	46		P4_6					$\overline{CS2}$
49	47		P4_5					$\overline{CS1}$
50	48		P4_4					$\overline{CS0}$

Table 1.5 Pin Names (2/2)

Pin No.		Control Pin	Port	I/O Pin for Peripheral Function				Bus Control Pin
FA	FB			Interrupt	Timer	Serial interface, USB	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
64	62	VSS						
65	63		P2_7		OUTC1_7/INPC1_7		AN2_7	A7, [A7/D7]
66	64		P2_6		OUTC1_6/INPC1_6		AN2_6	A6, [A6/D6]
67	65		P2_5	$\overline{INT7}$	OUTC1_5/INPC1_5		AN2_5	A5, [A5/D5]
68	66		P2_4	$\overline{INT6}$	OUTC1_4/INPC1_4		AN2_4	A4, [A4/D4]
69	67		P2_3		OUTC1_3/INPC1_3		AN2_3	A3, [A3/D3]
70	68		P2_2		OUTC1_2/INPC1_2		AN2_2	A2, [A2/D2]
71	69		P2_1		OUTC1_1/INPC1_1		AN2_1	A1, [A1/D1]
72	70		P2_0		OUTC1_0/INPC1_0		AN2_0	A0, [A0/D0]
73	71		P1_7	$\overline{INT5}$	IDU			
74	72		P1_6	$\overline{INT4}$	IDW			
75	73		P1_5	$\overline{INT3}$	IDV			
76	74		P1_4					
77	75		P1_3					
78	76		P1_2					
79	77		P1_1					
80	78		P1_0					
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	$\overline{KI3}$			AN7	
90	88		P10_6	$\overline{KI2}$			AN6	
91	89		P10_5	$\overline{KI1}$			AN5	
92	90		P10_4	$\overline{KI0}$			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			RXD4/SCL4	$\overline{ADTRG}$	

1.6 Pin Functions

Table 1.6 Pin Functions (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). Input 0 V to VSS.(1)
Analog power supply input	AVCC, AVSS	I	VCC1	This is the power supply for the A/D converter. 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. Connect the CNVSS pin to VSS via a resistor.
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.
	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.
	$\overline{\text{CS0}}$ to $\overline{\text{CS3}}$	O	VCC2	Outputs chip-select signals $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$ to specify an external area.
	$\overline{\text{WR}}$ $\overline{\text{BHE}}$ $\overline{\text{RD}}$	O	VCC2	Outputs $\overline{\text{WR}}$, $\overline{\text{BHE}}$, and $\overline{\text{RD}}$ signals. • 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.
	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.

Note:
1. VCC means VCC1 unless otherwise noted.

Table 1.7 Pin Functions (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.
$\overline{INT}$ interrupt input	$\overline{INT0}$ to $\overline{INT2}$	I	VCC1	Input for the $\overline{INT}$ interrupt.
	$\overline{INT3}$ to $\overline{INT7}$	I	VCC2	
$\overline{NMI}$ interrupt input	$\overline{NMI}$	I	VCC1	Input for the $\overline{NMI}$ interrupt.
Key input interrupt input	$\overline{KI0}$ to $\overline{KI3}$	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, $\overline{U}$, V, $\overline{V}$, W, $\overline{W}$	O	VCC1	Output for the three-phase motor control timer.
	$\overline{SD}$	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.
Timer S	INPC1_0 to INPC1_7	I	VCC2	Input for the time measurement function.
	OUTC1_0 to OUTC1_7	O	VCC2	Output for the waveform generation function.
	TSUDA, TSUDB	I	VCC1	Input for two-phase pulse.
Serial interface UART0 to UART5	$\overline{CTS0}$ to $\overline{CTS5}$	I	VCC1	Input pins to control data transmission.
	$\overline{RTS0}$ to $\overline{RTS5}$	O	VCC1	Output pins to control data reception.
	CLK0 to CLK5	I/O	VCC1	Transmit/receive clock I/O.
	RXD0 to RXD5	I	VCC1	Serial data input.
	TXD0 to TXD5	O	VCC1	Serial data output. (2)
	CLKS1	O	VCC1	Output for the transmit/receive clock multiple-pin output function.
UART0 to UART5 I^2C mode	SDA0 to SDA5	I/O	VCC1	Serial data I/O.(2)
	SCL0 to SCL5	I/O	VCC1	Transmit/receive clock I/O.(2)

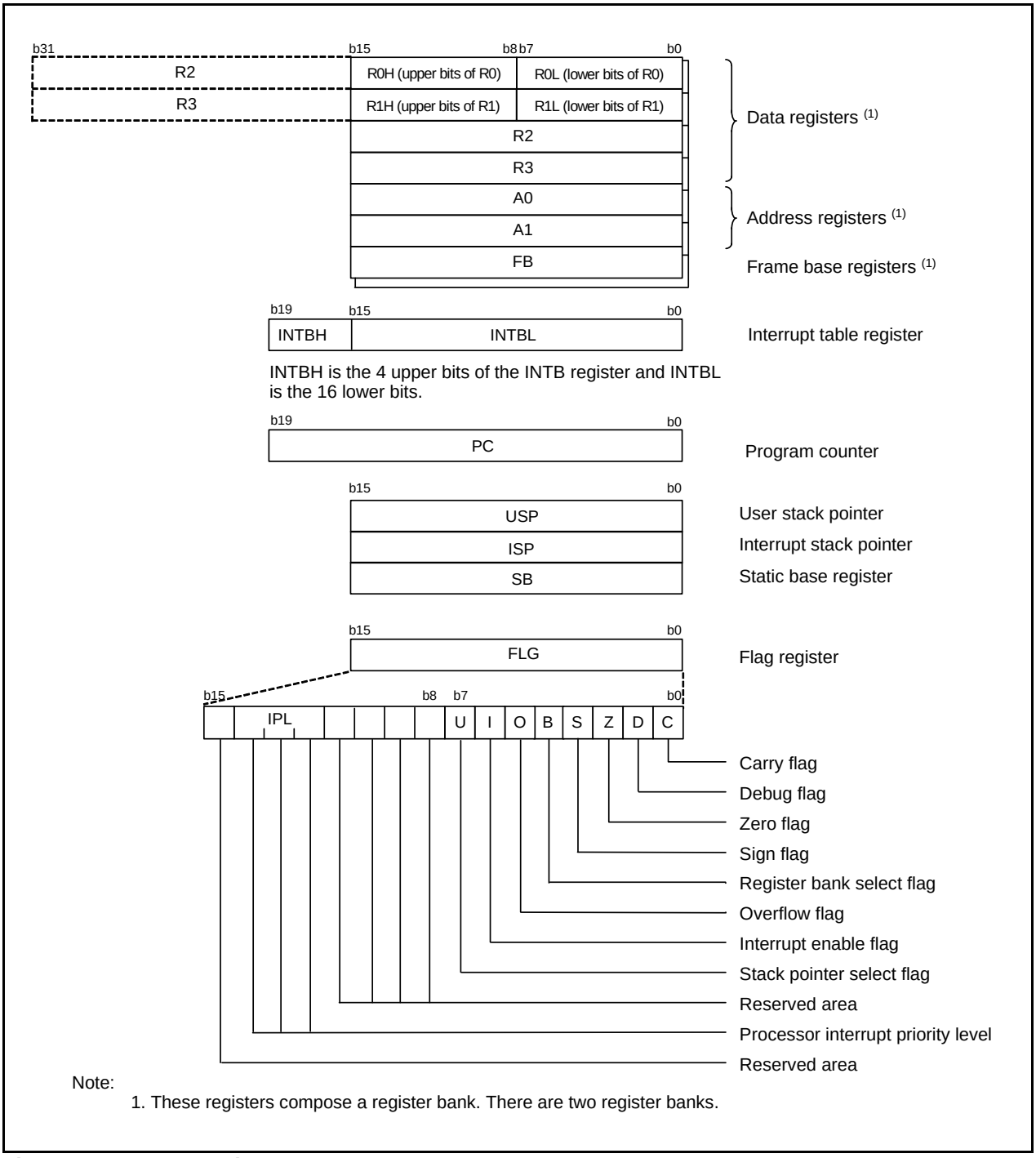
Notes:
1. Contact the manufacturer of crystal/ceramic resonator regarding the oscillation characteristics.
2. TXD2, SDA2, and SCL2 are N-channel open drain output pins. TXDi, SDAi, and SCLi can be selected as CMOS output pins or N-channel open drain output pins. (i = 0, 1, 3 to 5)

Table 1.8 Pin Functions (3/3)

Signal Name	Pin Name	I/O	Power Supply	Description
Multi-master I^2C-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).
USB module	ATTACH	O	UVCC	Output used for D+ 1.5 kΩ pull-up
	VbusDTCT	I	UVCC	Input the power supply signal from a host PC
	UVCC	I/O		Input power supply for pins ATTACH, D+, and D-
	D+	I/O	UVCC	USB D+ input/output
	D-	I/O	UVCC	USB D- input/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/6C Group has a 1 MB address space from 00000h to FFFFFh. Figure 3.1 shows the Address Space. Areas that can be accessed vary depending on processor mode and the status of each control bit.

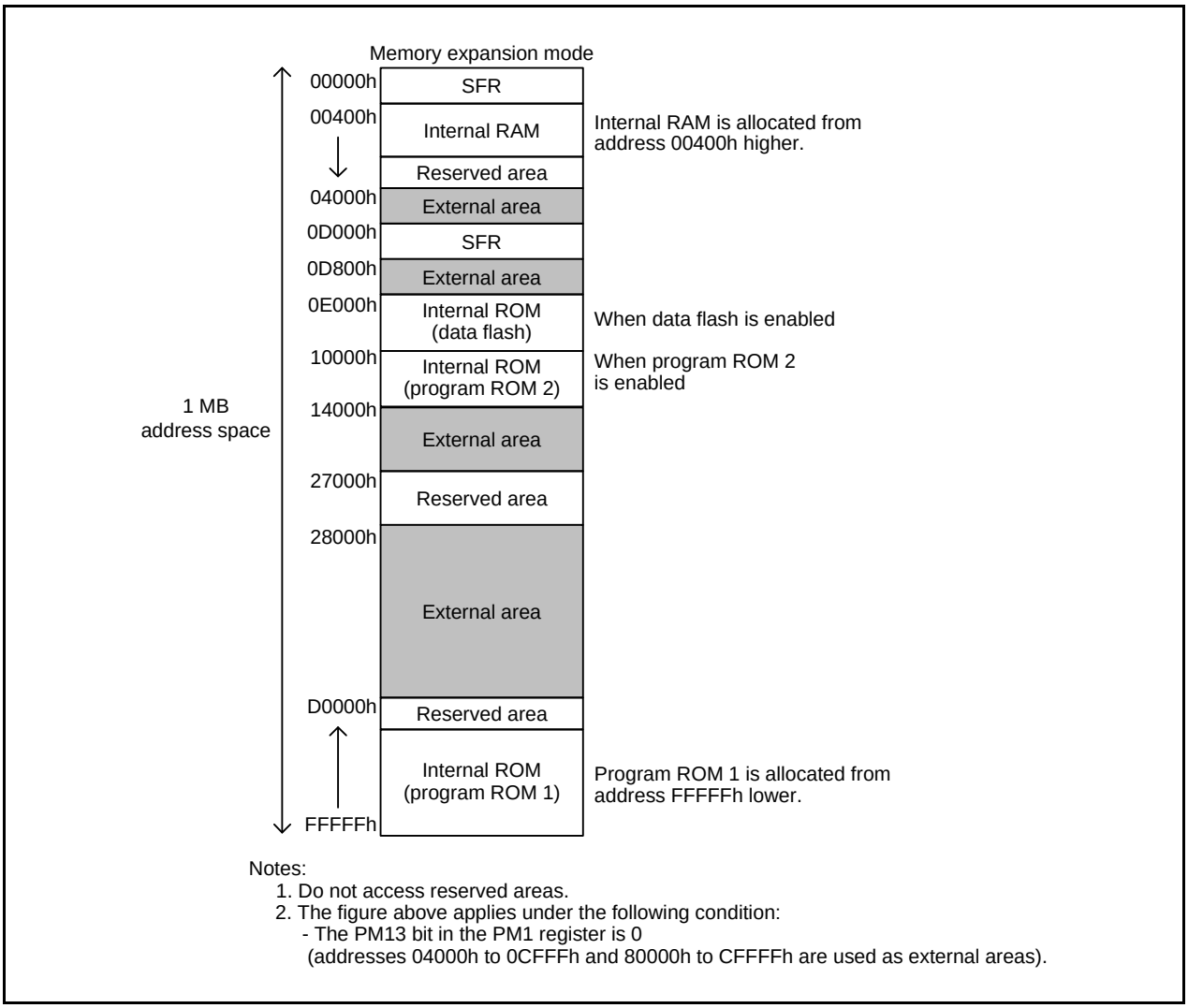


Figure 3.1 Address Space

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.

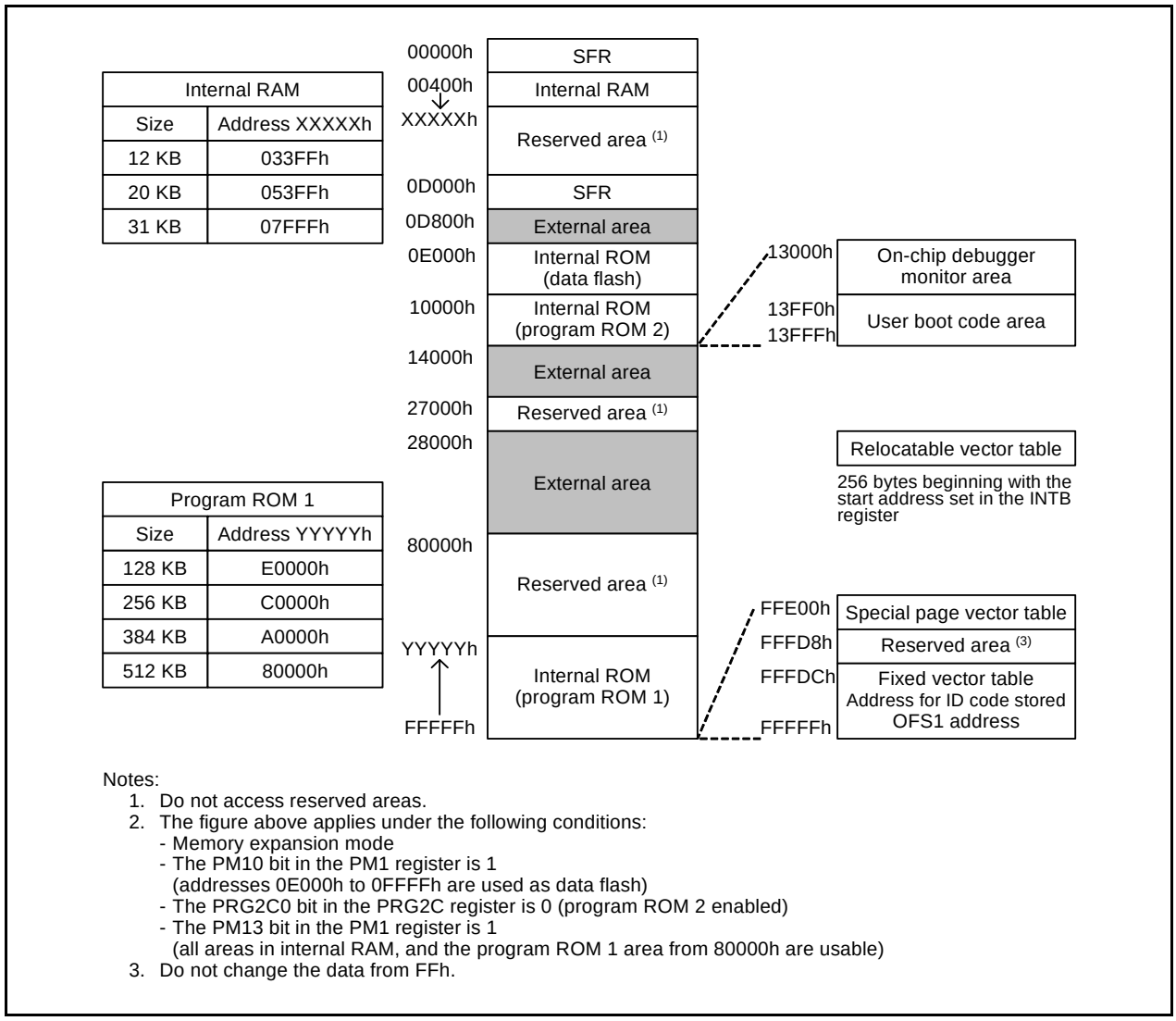
Program ROM 2 is allocated from 10000h to 13FFFh. Program ROM 1 is allocated from FFFFFh and lower, with the 64 KB program ROM 1 area allocated from address F0000h to FFFFFh.

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.

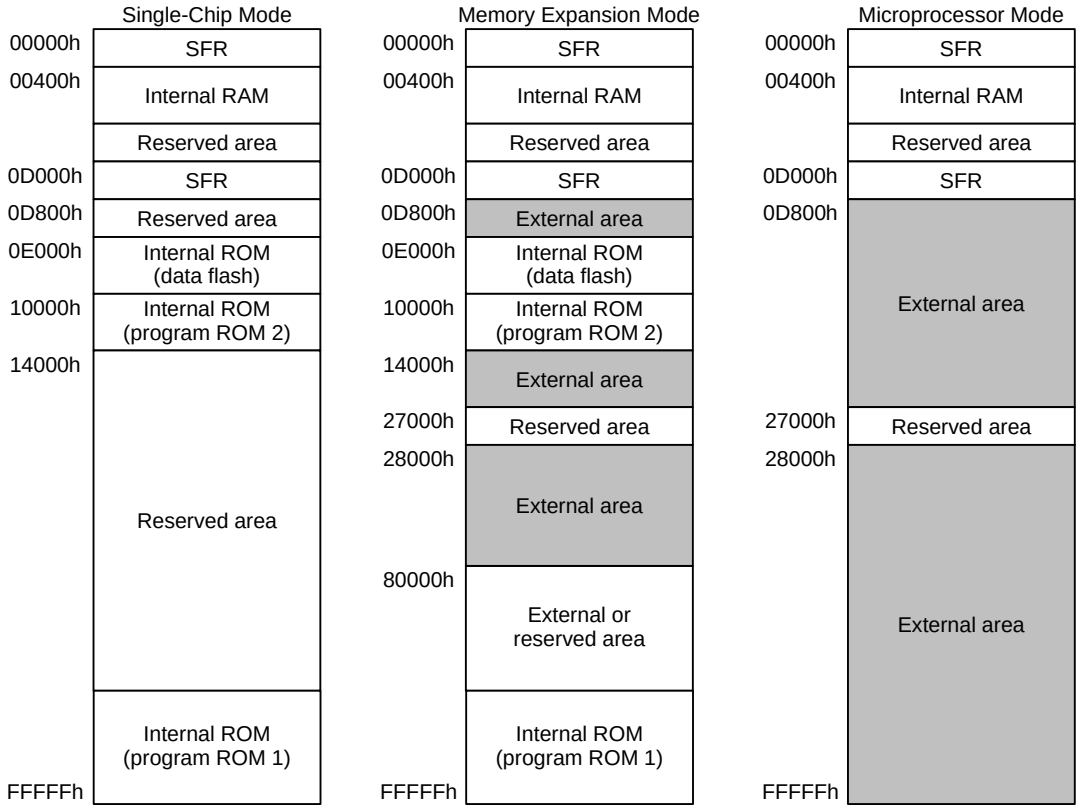


Notes:
1. Do not access reserved areas.
2. The figure above applies under the following conditions:
   - Memory expansion mode
   - The PM10 bit in the PM1 register is 1
     (addresses 0E000h to 0FFFFh are used as data flash)
   - The PRG2C0 bit in the PRG2C register is 0 (program ROM 2 enabled)
   - 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.
In microprocessor mode, the SFRs, internal RAM, and external areas can be accessed. 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)re usable).

   Microprocessor mode
   - The PM10 bit is 0 (addresses 0E000h to 0FFFFh are used as the $\overline{CS2}$ 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 (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			
000Ah	Protect Register	PRCR	00h
000Bh			
000Ch	Oscillation Stop Detection Register	CM2	0X00 0010b (3)
000Dh			
000Eh			
000Fh			
0010h	Program 2 Area Control Register	PRG2C	XXXX XX00b
0011h			
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
0013h			
0014h			
0015h	Clock Prescaler Reset Flag	CPSRF	0XXX XXXXb
0016h			
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	0001 X010b
001Dh	PLLFCK Control Register	PLCF	00h
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			
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	$\overline{\text{INT5}}$ Interrupt Control Register	INT5IC	XX00 X000b
0049h	$\overline{\text{INT4}}$ Interrupt Control Register	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 A/D Conversion (A/D1) Interrupt Control Register	KUPIC ADEIC	XXXX X000b
004Eh	A/D Conversion (A/D0) 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	U5BCNIC	XXXX X000b
006Ch	UART5 Transmit Interrupt Control Register	S5TIC	XXXX X000b
006Dh	UART5 Receive Interrupt Control Register	S5RIC	XXXX X000b
006Eh	UART4 Bus Collision Detection Interrupt Control Register Real-Time Clock Periodic Interrupt Control Register	U4BCNIC RTCTIC	XXXX X000b
006Fh	UART4 Transmit Interrupt Control Register Real-Time Clock Compare Interrupt Control Register	S4TIC RTCCIC	XXXX X000b
0070h	UART4 Receive Interrupt Control Register	S4RIC	XXXX X000b
0071h	UART3 Bus Collision Detection Interrupt Control Register	U3BCNIC	XXXX X000b
0072h	UART3 Transmit Interrupt Control Register	S3TIC	XXXX X000b
0073h	UART3 Receive Interrupt Control Register	S3RIC	XXXX X000b
0074h			
0075h			
0076h	USB Interrupt 0 Control Register	USBINT0IC	XXXX X000b
0077h	USB Interrupt 1 Control Register	USBINT1IC	XXXX X000b
0078h	USB RESUME Interrupt Control Register	USBRSMIC	XXXX X000b
0079h	IC/OC Interrupt 0 Control Register	ICOC0IC	XXXX X000b
007Ah	IC/OC Channel 0 Interrupt Control Register	ICOCH0IC	XXXX X000b
007Bh	IC/OC Interrupt 1 Control Register I2C-bus Interface Interrupt Control Register	ICOC1IC IICIC	XXXX X000b
007Ch	IC/OC Channel 1 Interrupt Control Register SCL/SDA Interrupt Control Register	ICOCH1IC SCLDAIC	XXXX X000b
007Dh	IC/OC Channel 2 Interrupt Control Register	ICOCH2IC	XXXX X000b
007Eh	IC/OC Channel 3 Interrupt Control Register	ICOCH3IC	XXXX X000b
007Fh	IC/OC Base Timer Interrupt Control Register	BTIC	XXXX X000b
0080h to 012Fh			

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
0130h			
0131h			
0132h			
0133h			
0134h			
0135h			
0136h			
0137h			
0138h			
0139h			
013Ah			
013Bh			
013Ch			
013Dh			
013Eh			
013Fh			
0140h	A/D1 Register 0	AD10	XXXX XXXXb
0141h			0000 00XXb
0142h	A/D1 Register 1	AD11	XXXX XXXXb
0143h			0000 00XXb
0144h	A/D1 Register 2	AD12	XXXX XXXXb
0145h			0000 00XXb
0146h	A/D1 Register 3	AD13	XXXX XXXXb
0147h			0000 00XXb
0148h			
0149h			
014Ah			
014Bh			
014Ch			
014Dh			
014Eh			
014Fh			
0150h			
0151h			
0152h	A/D1 Trigger Control Register	AD1TRGCON	XXXX 00XXb
0153h			
0154h	A/D1 Control Register 2	AD1CON2	0000 X00Xb
0155h			
0156h	A/D1 Control Register 0	AD1CON0	0000 0XXXb
0157h	A/D1 Control Register 1	AD1CON1	0000 X000b
0158h			
0159h			
015Ah			
015Bh			
015Ch			
015Dh			
015Eh			
015Fh			
0160h to 017Fh			

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
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 4.7 SFR Information (7) (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 4.8 SFR Information (8) (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			
01F1h			
01F2h			
01F3h			
01F4h			
01F5h			
01F6h			
01F7h			
01F8h			
01F9h			
01FAh			
01FBh			
01FCh			
01FDh			
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 4.9 SFR Information (9) (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			
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 4.10 SFR Information (10) (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 4.11 SFR Information (11) (1)

Address	Register	Symbol	Reset Value
0270h			
0271h			
0272h			
0273h			
0274h			
0275h			
0276h			
0277h			
0278h			
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	UART4 Special Mode Register 4	U4SMR4	00h
0295h	UART4 Special Mode Register 3	U4SMR3	000X 0X0Xb
0296h	UART4 Special Mode Register 2	U4SMR2	X000 0000b
0297h	UART4 Special Mode Register	U4SMR	X000 0000b
0298h	UART4 Transmit/Receive Mode Register	U4MR	00h
0299h	UART4 Bit Rate Register	U4BRG	XXh
029Ah	UART4 Transmit Buffer Register	U4TB	XXh
029Bh			XXh
029Ch	UART4 Transmit/Receive Control Register 0	U4C0	0000 1000b
029Dh	UART4 Transmit/Receive Control Register 1	U4C1	0000 0010b
029Eh	UART4 Receive Buffer Register	U4RB	XXh
029Fh			XXh

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
02A0h			
02A1h			
02A2h			
02A3h			
02A4h	UART3 Special Mode Register 4	U3SMR4	00h
02A5h	UART3 Special Mode Register 3	U3SMR3	000X 0X0Xb
02A6h	UART3 Special Mode Register 2	U3SMR2	X000 0000b
02A7h	UART3 Special Mode Register	U3SMR	X000 0000b
02A8h	UART3 Transmit/Receive Mode Register	U3MR	00h
02A9h	UART3 Bit Rate Register	U3BRG	XXh
02AAh	UART3 Transmit Buffer Register	U3TB	XXh
02ABh			XXh
02ACh	UART3 Transmit/Receive Control Register 0	U3C0	0000 1000b
02ADh	UART3 Transmit/Receive Control Register 1	U3C1	0000 0010b
02AEh	UART3 Receive Buffer Register	U3RB	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	Time Measurement Register 0	G1TM0	XXh
02C1h	Waveform Generation Register 0	G1PO0	XXh
02C2h	Time Measurement Register 1	G1TM1	XXh
02C3h	Waveform Generation Register 1	G1PO1	XXh
02C4h	Time Measurement Register 2	G1TM2	XXh
02C5h	Waveform Generation Register 2	G1PO2	XXh
02C6h	Time Measurement Register 3	G1TM3	XXh
02C7h	Waveform Generation Register 3	G1PO3	XXh
02C8h	Time Measurement Register 4	G1TM4	XXh
02C9h	Waveform Generation Register 4	G1PO4	XXh
02CAh	Time Measurement Register 5	G1TM5	XXh
02CBh	Waveform Generation Register 5	G1PO5	XXh
02CCh	Time Measurement Register 6	G1TM6	XXh
02CDh	Waveform Generation Register 6	G1PO6	XXh
02CEh	Time Measurement Register 7	G1TM7	XXh
02CFh	Waveform Generation Register 7	G1PO7	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
02D0h	Waveform Generation Control Register 0	G1POCR0	0X00 XX00b
02D1h	Waveform Generation Control Register 1	G1POCR1	0X00 XX00b
02D2h	Waveform Generation Control Register 2	G1POCR2	0X00 XX00b
02D3h	Waveform Generation Control Register 3	G1POCR3	0X00 XX00b
02D4h	Waveform Generation Control Register 4	G1POCR4	0X00 XX00b
02D5h	Waveform Generation Control Register 5	G1POCR5	0X00 XX00b
02D6h	Waveform Generation Control Register 6	G1POCR6	0X00 XX00b
02D7h	Waveform Generation Control Register 7	G1POCR7	0X00 XX00b
02D8h	Time Measurement Control Register 0	G1TMCR0	00h
02D9h	Time Measurement Control Register 1	G1TMCR1	00h
02DAh	Time Measurement Control Register 2	G1TMCR2	00h
02DBh	Time Measurement Control Register 3	G1TMCR3	00h
02DCh	Time Measurement Control Register 4	G1TMCR4	00h
02DDh	Time Measurement Control Register 5	G1TMCR5	00h
02DEh	Time Measurement Control Register 6	G1TMCR6	00h
02DFh	Time Measurement Control Register 7	G1TMCR7	00h
02E0h	Base Timer Register	G1BT	XXh
02E1h			XXh
02E2h	Base Timer Control Register 0	G1BCR0	00h
02E3h	Base Timer Control Register 1	G1BCR1	00h
02E4h	Time Measurement Prescaler Register 6	G1TPR6	00h
02E5h	Time Measurement Prescaler Register 7	G1TPR7	00h
02E6h	Function Enable Register	G1FE	00h
02E7h	Function Select Register	G1FS	00h
02E8h	Base Timer Reset Register	G1BTRR	XXh
02E9h			XXh
02EAh	Count Source Divide Register	G1DV	00h
02EBh			
02ECh	Waveform Output Master Enable Register	G1OER	00h
02EDh			
02EEh	Timer S I/O Control Register 0	G1IOR0	00h
02EFh	Timer S I/O Control Register 1	G1IOR1	00h
02F0h	Interrupt Request Register	G1IR	XXh
02F1h	Interrupt Enable Register 0	G1IE0	00h
02F2h	Interrupt Enable Register 1	G1IE1	00h
02F3h			
02F4h			
02F5h			
02F6h			
02F7h			
02F8h			
02F9h			
02FAh			
02FBh			
02FCh			
02FDh			
02FEh			
02FFh			

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
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 4.15 SFR Information (15) (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			
0351h			
0352h			
0353h			
0354h			
0355h			
0356h			
0357h			
0358h			
0359h			
035Ah			
035Bh			
035Ch			
035Dh			
035Eh			
035Fh			

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
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			
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			
0371h			
0372h			
0373h			
0374h			
0375h			
0376h			
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
 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 4.17 SFR Information (17) (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			
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 4.18 SFR Information (18) (1)

Address	Register	Symbol	Reset Value
03C0h	A/D0 Register 0	AD00	XXXX XXXXb
03C1h			0000 00XXb
03C2h	A/D0 Register 1	AD01	XXXX XXXXb
03C3h			0000 00XXb
03C4h	A/D0 Register 2	AD02	XXXX XXXXb
03C5h			0000 00XXb
03C6h	A/D0 Register 3	AD03	XXXX XXXXb
03C7h			0000 00XXb
03C8h	A/D0 Register 4	AD04	XXXX XXXXb
03C9h			0000 00XXb
03CAh	A/D0 Register 5	AD05	XXXX XXXXb
03CBh			0000 00XXb
03CCh	A/D0 Register 6	AD06	XXXX XXXXb
03CDh			0000 00XXb
03CEh	A/D0 Register 7	AD07	XXXX XXXXb
03CFh			0000 00XXb
03D0h			
03D1h			
03D2h	A/D0 Trigger Control Register	AD0TRGCON	XXXX 00XXb
03D3h			
03D4h	A/D0 Control Register 2	AD0CON2	0000 X00Xb
03D5h			
03D6h	A/D0 Control Register 0	AD0CON0	0000 0XXXb
03D7h	A/D0 Control Register 1	AD0CON1	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 4.19 SFR Information (19) (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			
03F6h	Port P10 Direction Register	PD10	00h
03F7h			
03F8h			
03F9h			
03FAh			
03FBh			
03FCh			
03FDh			
03FEh			
03FFh			

X: Undefined

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

Table 4.20 SFR Information (20) (1)

Address	Register	Symbol	Reset Value
D100h	USB Interrupt Flag Register 0	USBIFR0	00h
D101h	USB Interrupt Flag Register 1	USBIFR1	XXX0 0000b
D102h	USB Interrupt Flag Register 2	USBIFR2	XX00 0110b
D103h	USB Interrupt Flag Register 3	USBIFR3	XX00 0110b
D104h			
D105h			
D106h			
D107h			
D108h	USB Interrupt Enable Register 0	USBIER0	0000 00X0b
D109h	USB Interrupt Enable Register 1	USBIER1	XXX0 0000b
D10Ah	USB Interrupt Enable Register 2	USBIER2	XX00 0000b
D10Bh	USB Interrupt Enable Register 3	USBIER3	XX00 0000b
D10Ch			
D10Dh			
D10Eh			
D10Fh			
D110h	USB Interrupt Select Register 0	USBISR0	00X0 00X0b
D111h	USB Interrupt Select Register 1	USBISR1	XXX0 0000b
D112h	USB Interrupt Select Register 2	USBISR2	XX00 0000b
D113h	USB Interrupt Select Register 3	USBISR3	XX00 0000b
D114h			
D115h			
D116h			
D117h			
D118h			
D119h			
D11Ah			
D11Bh			
D11Ch			
D11Dh			
D11Eh			
D11Fh			
D120h	USB Endpoint 0 IN Data Register	USBEPDR0I	XXh
D121h			
D122h			
D123h			
D124h	USB Endpoint 0 OUT Data Register	USBEPDR0O	00h
D125h			
D126h			
D127h			
D128h	USB Endpoint 0 S Data Register	USBEPDR0S	00h
D129h			
D12Ah			
D12Bh			
D12Ch			
D12Dh			
D12Eh			
D12Fh			

X: Undefined

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

Table 4.21 SFR Information (21) (1)

Address	Register	Symbol	Reset Value
D130h	USB Endpoint 1 Data Register	USBEPDR1	00h
D131h			
D132h			
D133h			
D134h	USB Endpoint 2 Data Register	USBEPDR2	XXh
D135h			
D136h			
D137h			
D138h	USB Endpoint 3 Data Register	USBEPDR3	XXh
D139h			
D13Ah			
D13Bh			
D13Ch			
D13Dh			
D13Eh			
D13Fh			
D140h	USB Endpoint 4 Data Register	USBEPDR4	00h
D141h			
D142h			
D143h			
D144h	USB Endpoint 5 Data Register	USBEPDR5	XXh
D145h			
D146h			
D147h			
D148h	USB Endpoint 6 Data Register	USBEPDR6	XXh
D149h			
D14Ah			
D14Bh			
D14Ch			
D14Dh			
D14Eh			
D14Fh			
D150h to D17Fh			
D180h	USB Endpoint 0 OUT Receive Data Size Register	USBEPSZ0O	000X XXXXb
D181h	USB Endpoint 1 Receive Data Size Register	USBEPSZ1	0XXX XXXXb
D182h	USB Endpoint 4 Receive Data Size Register	USBEPSZ4	0XXX XXXXb
D183h			
D184h			
D185h			
D186h			
D187h			
D188h	USB Data Status Register 0	USBDASTS0	XXXX XXX0b
D189h	USB Data Status Register 1	USBDASTS1	XXXX X00Xb
D18Ah	USB Data Status Register 2	USBDASTS2	XXXX X00Xb
D18Bh			
D18Ch			
D18Dh			
D18Eh			
D18Fh			

X: Undefined

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

Table 4.22 SFR Information (22) (1)

Address	Register	Symbol	Reset Value
D190h	USB Trigger Register 0	USBTRG0	XXh
D191h	USB Trigger Register 1	USBTRG1	XXh
D192h	USB Trigger Register 2	USBTRG2	XXh
D193h			
D194h			
D195h			
D196h			
D197h			
D198h	USB FIFO Clear Register 0	USBFCLR0	XXh
D199h	USB FIFO Clear Register 1	USBFCLR1	XXh
D19Ah	USB FIFO Clear Register 2	USBFCLR2	XXh
D19Bh			
D19Ch			
D19Dh			
D19Eh			
D19Fh			
D1A0h	USB Endpoint Stall Register 0	USBEPSTL0	XXXX XXX0b
D1A1h	USB Endpoint Stall Register 1	USBEPSTL1	XXXX X000b
D1A2h	USB Endpoint Stall Register 2	USBEPSTL2	XXXX X000b
D1A3h			
D1A4h			
D1A5h			
D1A6h			
D1A7h			
D1A8h			
D1A9h	USB Stall Status Register 1	USBSTLSR1	X000 X000b
D1AAh	USB Stall Status Register 2	USBSTLSR2	X000 X000b
D1ABh			
D1ACh			
D1ADh			
D1AEh			
D1AFh			
D1B0h	USB DMA Transfer Setting Register	USBDMAR	XXX0 0X00b
D1B1h			
D1B2h			
D1B3h			
D1B4h	USB Configuration Value Register	USBCVR	0000 X000b
D1B5h			
D1B6h			
D1B7h			
D1B8h	USB Control Register	USBCTLR	0XX0 0001b
D1B9h			
D1BAh			
D1BBh			
D1BCh			
D1BDh			
D1BEh			
D1BFh			

X: Undefined

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

Table 4.23 SFR Information (23) (1)

Address	Register	Symbol	Reset Value
D1C0h	USB Endpoint Information Register	USBEPIR	XXh
D1C1h			
D1C2h			
D1C3h			
D1C4h			
D1C5h			
D1C6h			
D1C7h			
D1C8h			
D1C9h			
D1CAh			
D1CBh			
D1CCh	USB Module Control Register	USBMC	11X1 0000b
D1CDh			
D1CEh			
D1CFh			

X: Undefined

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

4.2 Notes on SFRs

4.2.1 Register Settings

Table 4.24 lists Registers with Write-Only Bits (1/2) 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 4.24 Registers with Write-Only Bits (1/2)

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
0289h	UART5 Bit Rate Register	U5BRG
028Bh to 028Ah	UART5 Transmit Buffer Register	U5TB
0299h	UART4 Bit Rate Register	U4BRG
029Bh to 029Ah	UART4 Transmit Buffer Register	U4TB
02A9h	UART3 Bit Rate Register	U3BRG
02ABh to 02AAh	UART3 Transmit Buffer Register	U3TB
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 4.25 Registers with Write-Only Bits (2/2)

Address	Register	Symbol
D120h	USB Endpoint 0 IN Data Register	USBEPDR0I
D134h	USB Endpoint 2 Data Register	USBEPDR2
D138h	USB Endpoint 3 Data Register	USBEPDR3
D144h	USB Endpoint 5 Data Register	USBEPDR5
D148h	USB Endpoint 6 Data Register	USBEPDR6
D190h	USB Trigger Register 0	USBTRG0
D191h	USB Trigger Register 1	USBTRG1
D192h	USB Trigger Register 2	USBTRG2
D198h	USB FIFO Clear Register 0	USBFCLR0
D199h	USB FIFO Clear Register 1	USBFCLR1
D19Ah	USB FIFO Clear Register 2	USBFCLR2
D1A0h	USB Endpoint Stall Register 0	USBEPSTL0
D1A1h	USB Endpoint Stall Register 1	USBEPSTL1
D1A2h	USB Endpoint Stall Register 2	USBEPSTL2
D1C0h	USB Endpoint Information Register	USBEPIR

Table 4.26 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

b7	b6	b5	b4	b3	b2	b1	b0
0		0	0				

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, PLCF, PCLKR, 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 the PD9 register 0 : Write protected 1 : Write enabled	RW
PRC3	Protect bit 3	Enable writing to registers VCR2, VWCE, 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) (D)
Watchdog timer reset	The watchdog timer underflows.	(B)
Software reset	Setting the PM03 bit in the PM0 register to 1.	(B)

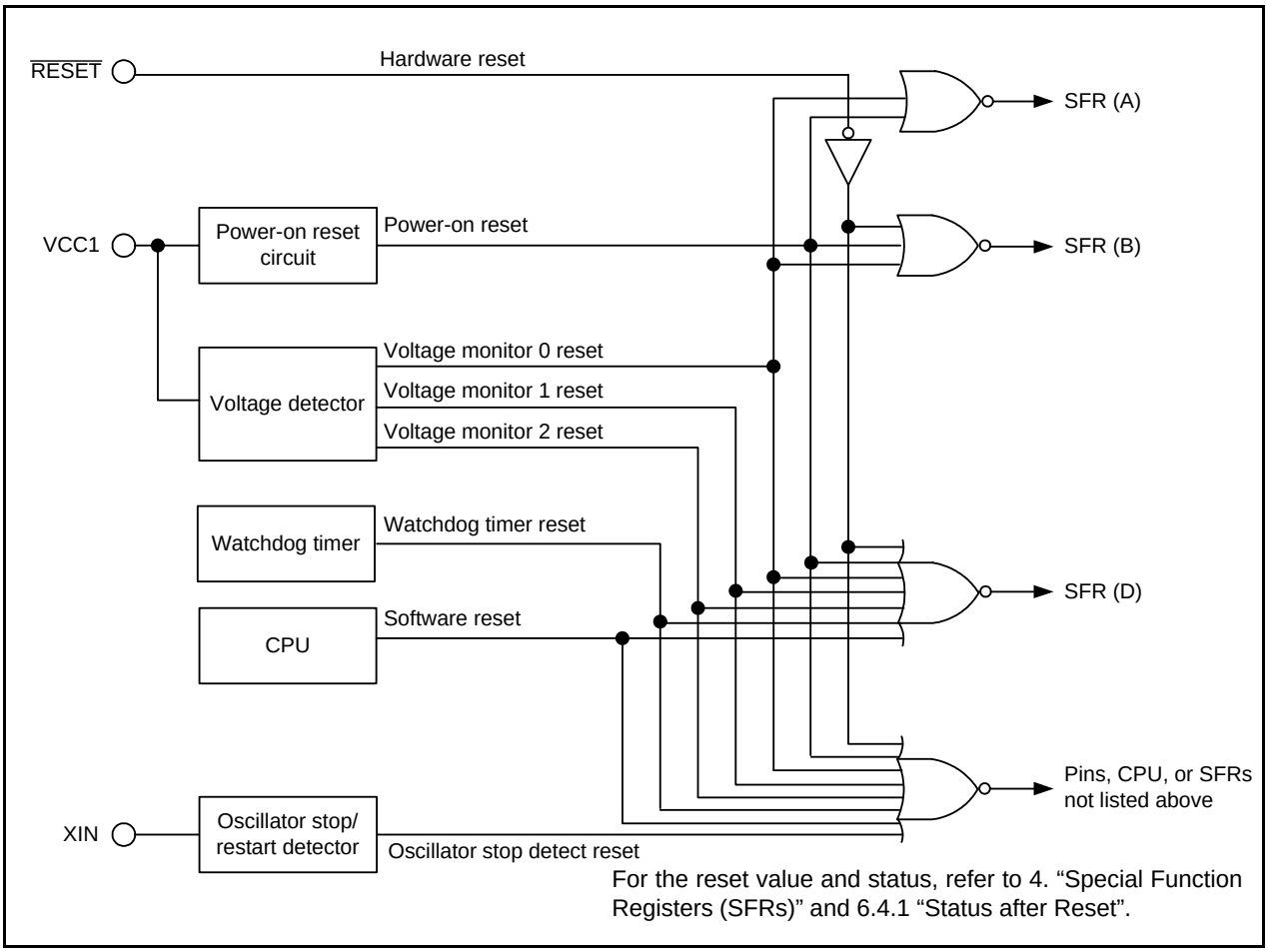


Figure 6.1 Reset Circuit Block Diagram

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 (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.

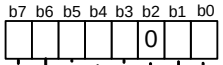
Table 6.4 Registers

Address	Register	Symbol	Reset Value
0004h	Processor Mode Register 0	PM0	0000 0000b
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

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
— (b2)	Reserved bit	Set to 0	RW
PM03	Software reset bit	Setting this bit to 1 resets the MCU. 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

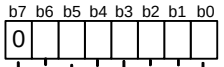
Write to this register after setting the PRC1 bit in the PRCR register to 1 (write enabled).
The software reset, watchdog timer reset, oscillator stop detect reset, voltage monitor 1 reset, and voltage monitor 2 reset have no effect on bits PM01 and PM00.
Bits PM05 to PM04, PM06, and PM07 are enabled 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: RSTFR
Address: 0018h
Reset Value: 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.

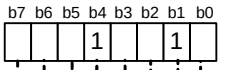
The optional function select area is not an SFR, and therefore cannot be rewritten by a program. Set an appropriate value when writing a program to flash memory. The entire optional function select area becomes FFh when the block including the optional function select area is erased.

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 $\overline{\text{RESET}}$ 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 $\overline{\text{RESET}}$ Pin Level is Low

Pin Name	Status (1)	
	Single-chip mode (CNVSS = VSS)	Boot mode (CNVSS = VCC1, P5_5 = low)
P0	Input port	Input port
P1	Input port	Input port
P2, P3, P4_0 to P4_3	Input port	Input port
P4_4	Input port	Input port
P4_5 to P4_7	Input port	Input port
P5_0	Input port	$\overline{\text{CE}}$ input (2)
P5_1	Input port	Input port
P5_2	Input port	Input port
P5_3	Input port	Input port
P5_4	Input port	Input port
P5_5	Input port	$\overline{\text{EPM}}$ input (3)
P5_6	Input port	Input port
P5_7	Input port	Input port
P6 to P10	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.

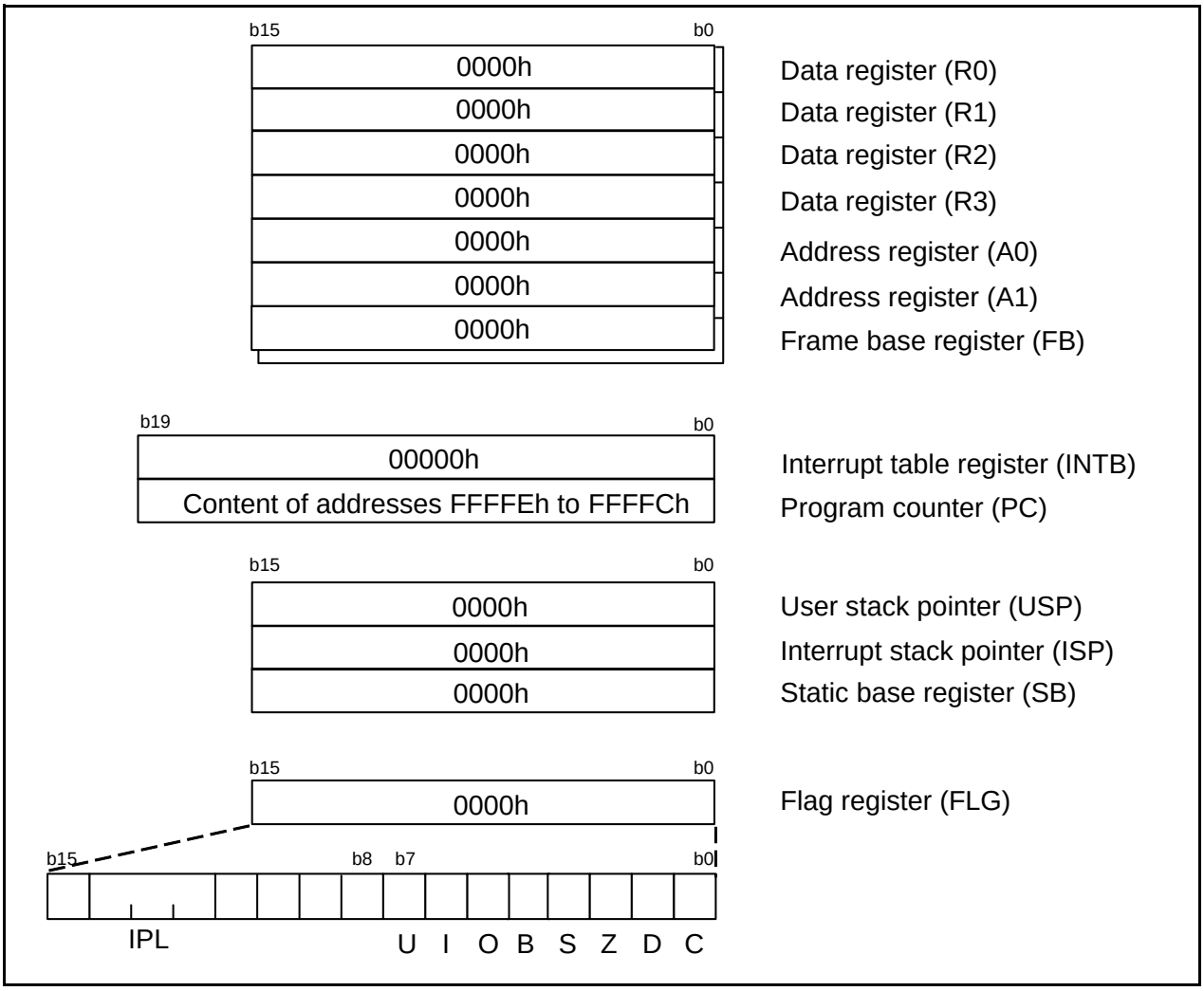


Figure 6.2 CPU Register Status after Reset

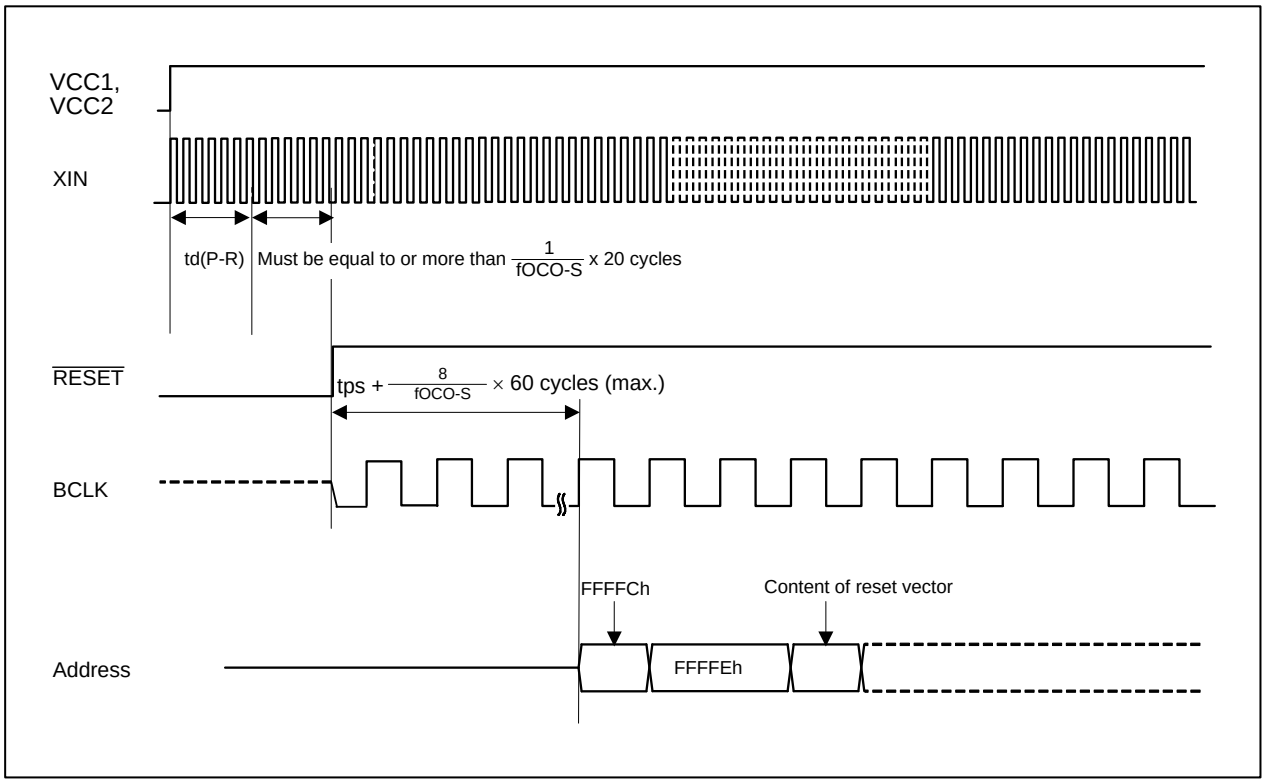


Figure 6.3 Reset Sequence

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:

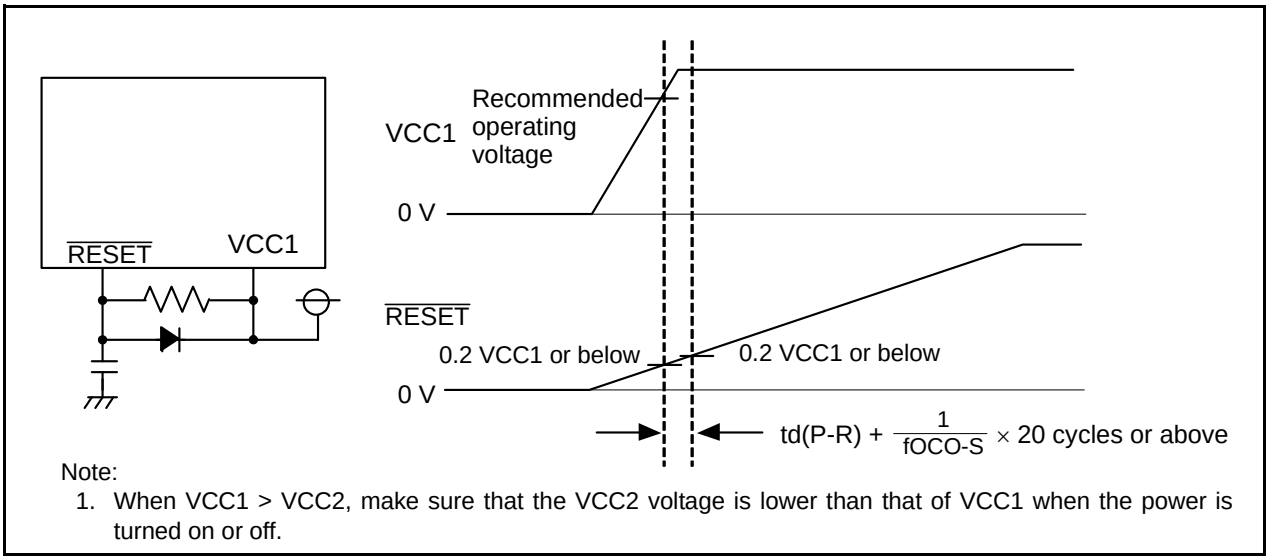
When the power supply is stable

(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 $\frac{1}{fOCO-S} \times 20$ cycles.
(5) Apply a high-level signal to the $\overline{\text{RESET}}$ pin.

Figure 6.4 shows an Reset Circuit Example.



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.

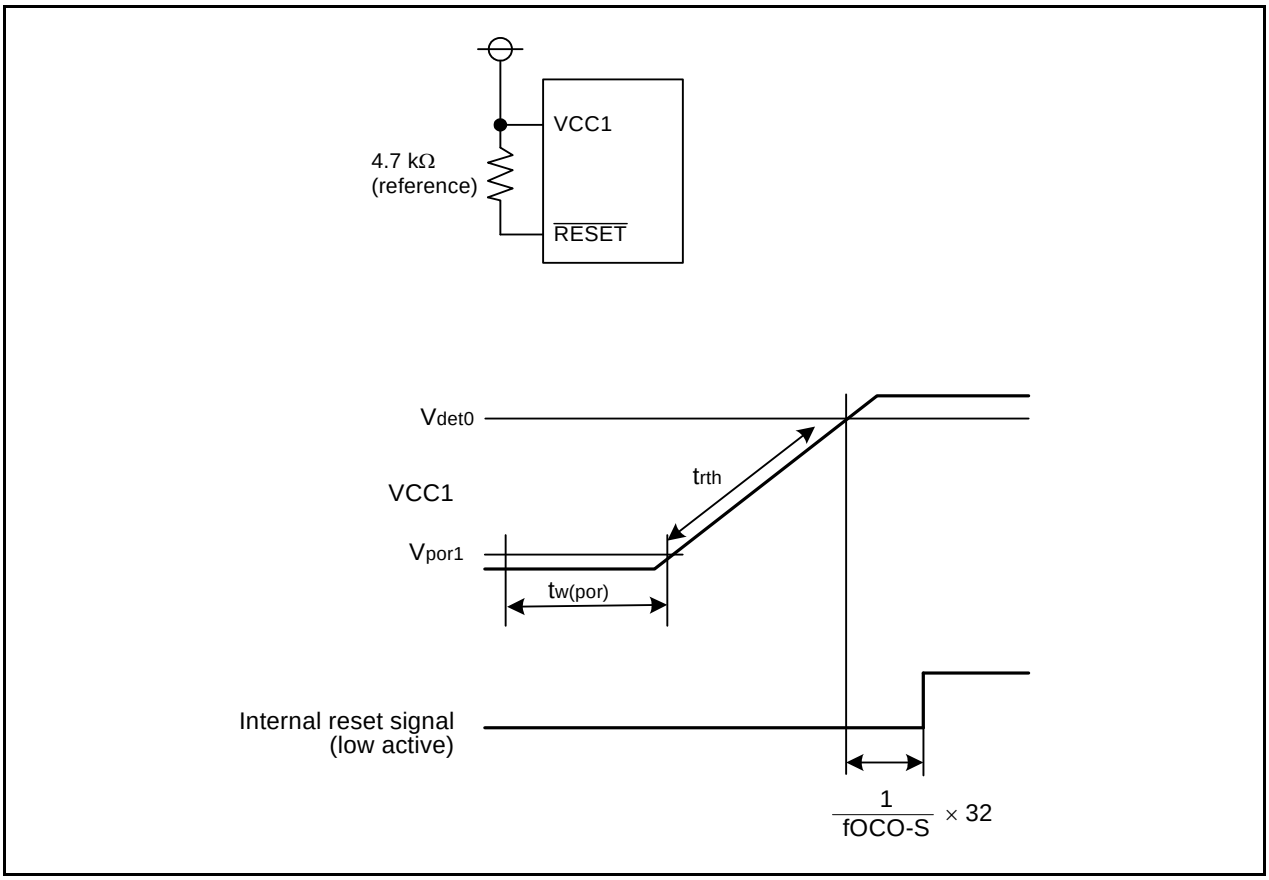


Figure 6.5 Power-On Reset Circuit and Operation Example

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.

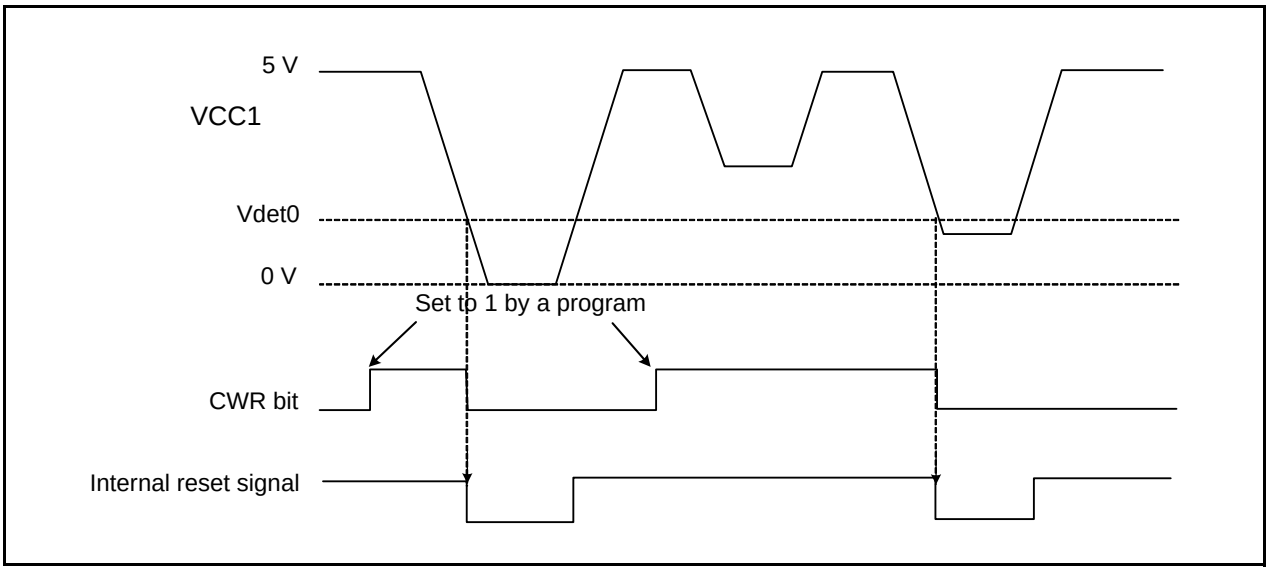


Figure 6.6 Cold/Warm Start Discrimination Example

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

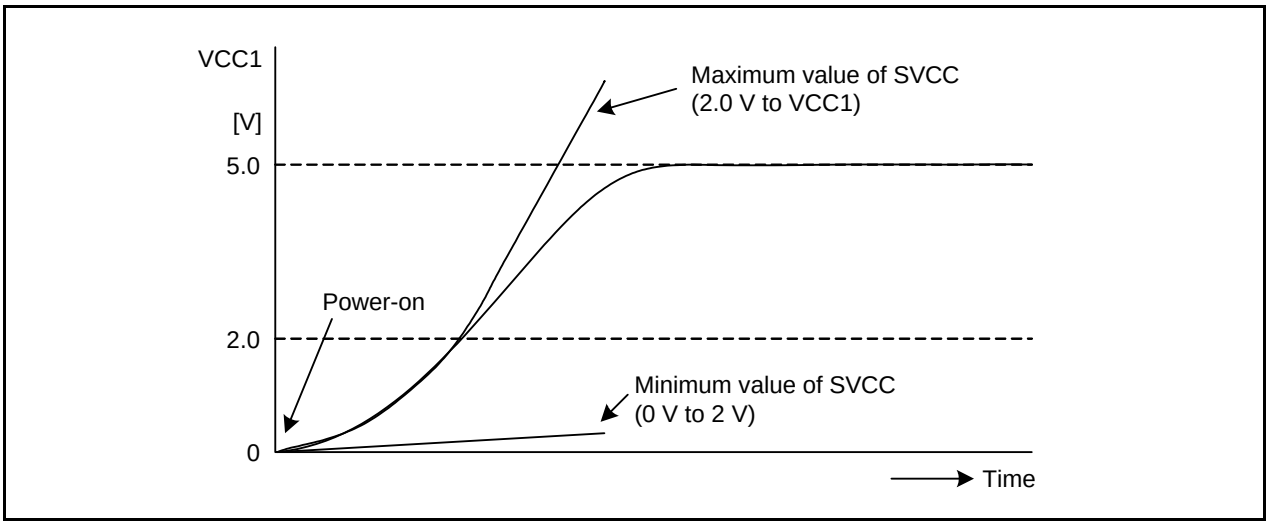


Figure 6.7 SVCC Timing (3.6 V < VCC1)

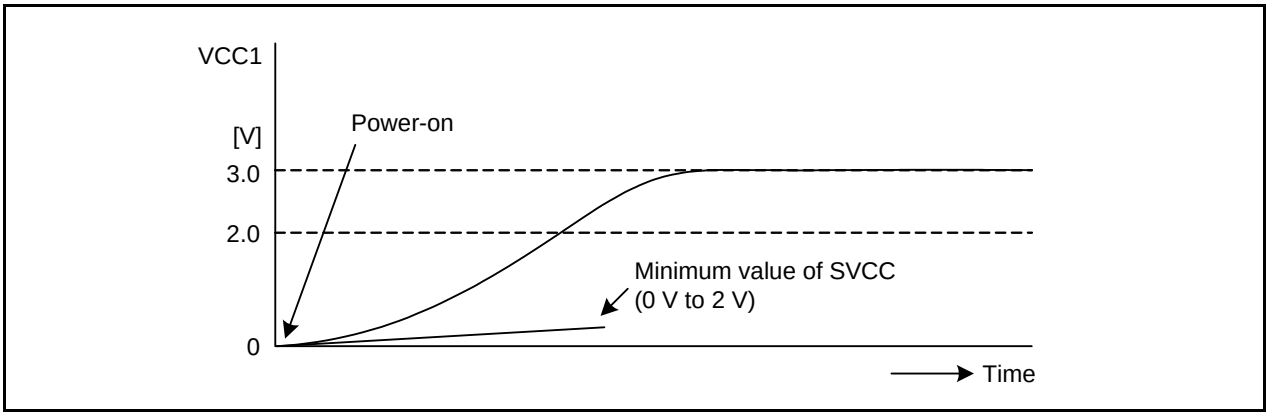


Figure 6.8 SVCC Timing (VCC1 ≤ 3.6 V)

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	Fixed level	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

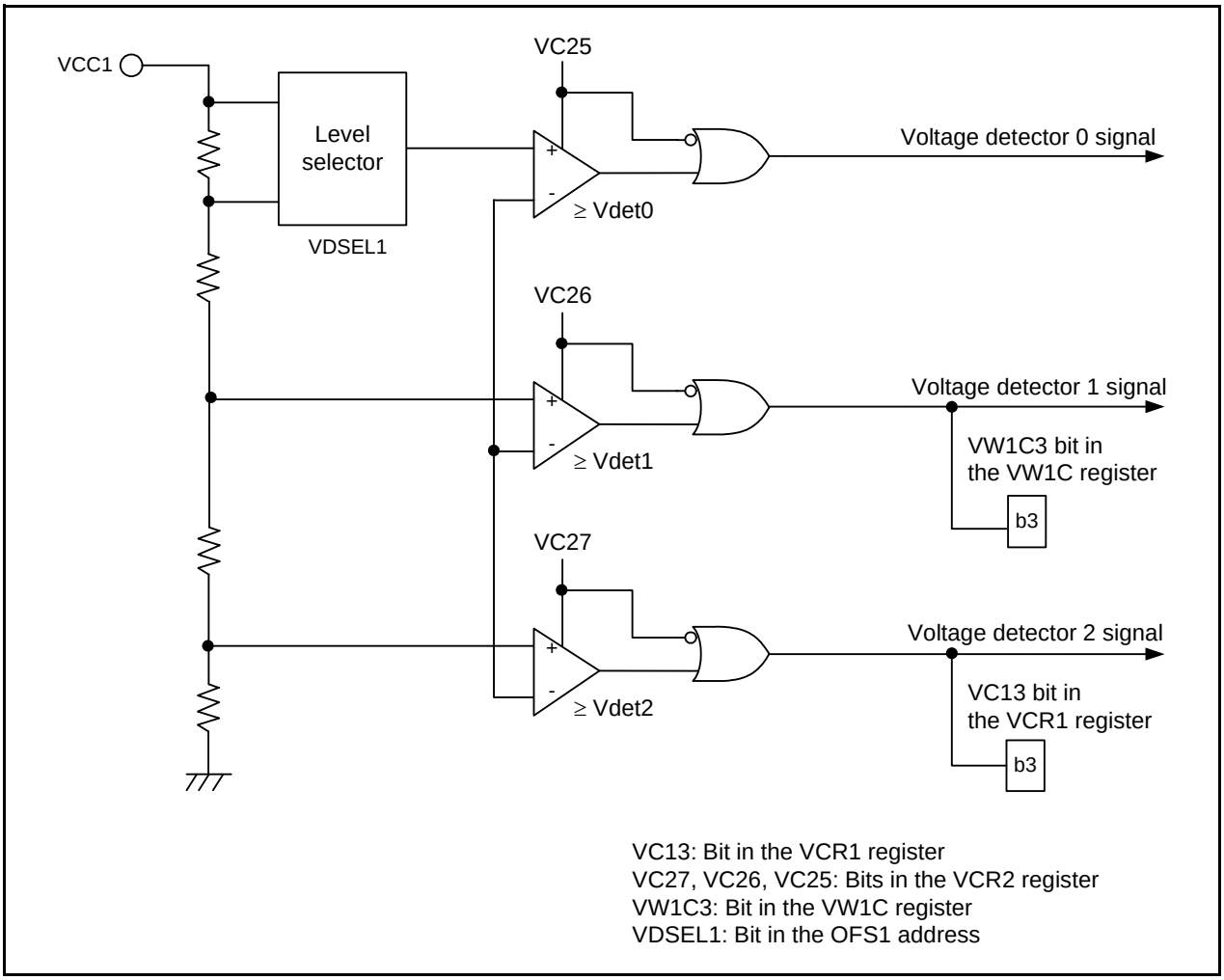


Figure 7.1 Voltage Detector Block Diagram

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
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

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

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:

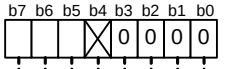
- VCC1 < Vdet2 (when the VW12E bit is 1 and the VC27 bit is 1)

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

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

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 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.

7.2.5 Voltage Monitor 1 Control Register (VW1C)

Voltage Monitor 1 Control Register

b7	b6	b5	b4	b3	b2	b1	b0	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 7.3 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).

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)

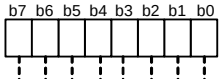
The voltage monitor 1 interrupt/reset generation condition can be selected by the VW1C7 bit when the VW1C6 bit is 0 (voltage monitor 1 interrupt at Vdet1 passage) and the VW1C1 bit is 1 (digital filter disabled).

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.

7.2.6 Voltage Monitor 2 Control Register (VW2C)

Voltage Monitor 2 Control Register



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 7.4 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)

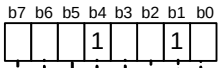
The voltage monitor 2 interrupt/reset generation condition can be selected by the VW2C7 bit when the VW2C6 bit is 0 (voltage monitor 2 interrupt at Vdet2 passage) and the VW2C1 bit is 1 (digital filter disabled).
When the VW2C6 bit is 1 (voltage monitor 2 reset at Vdet2 passage), set the VW2C7 bit to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



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.

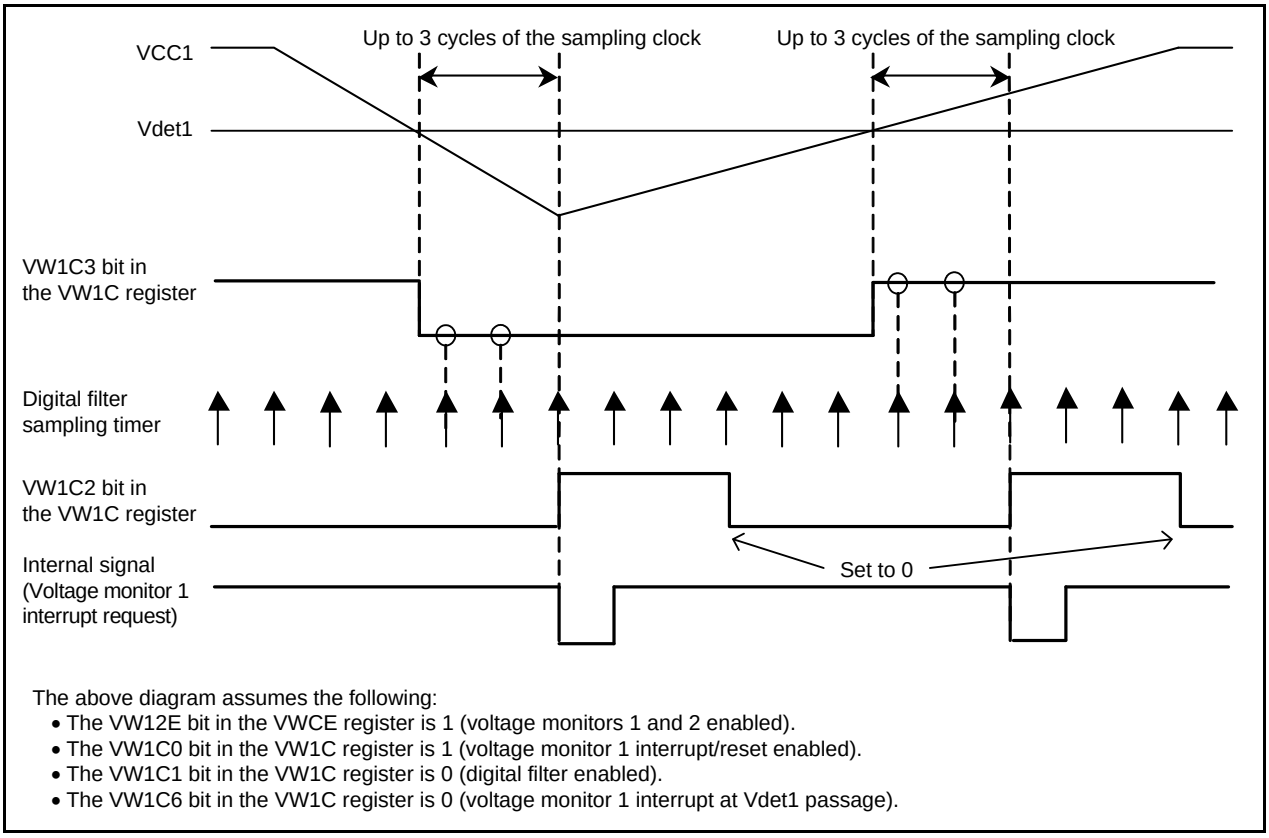


Figure 7.2 Digital Filter Operation Example

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.

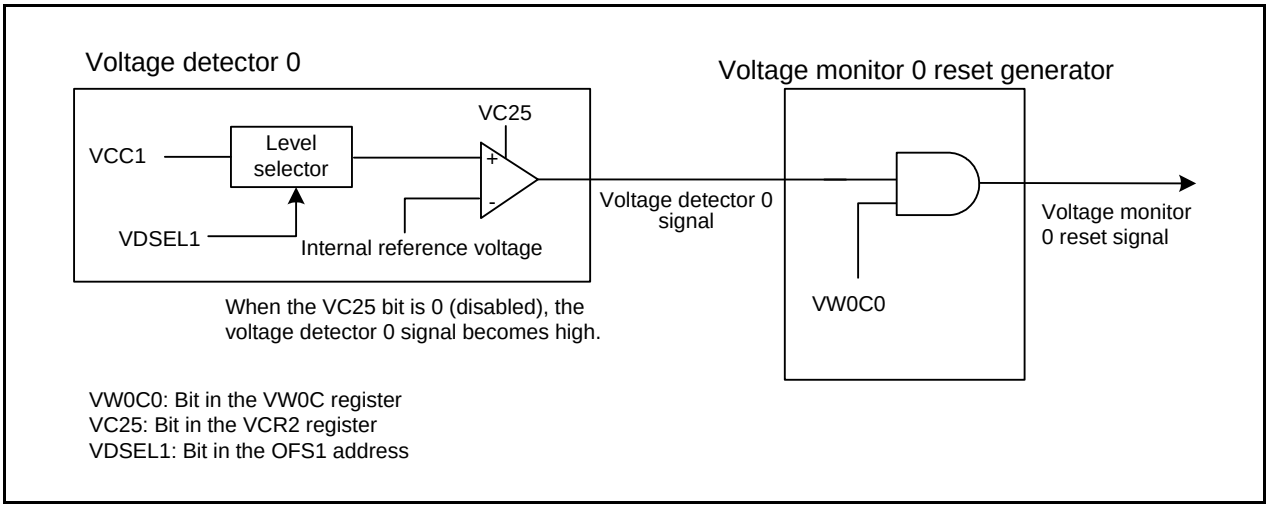


Figure 7.3 Voltage Monitor 0 Reset Generator Block Diagram

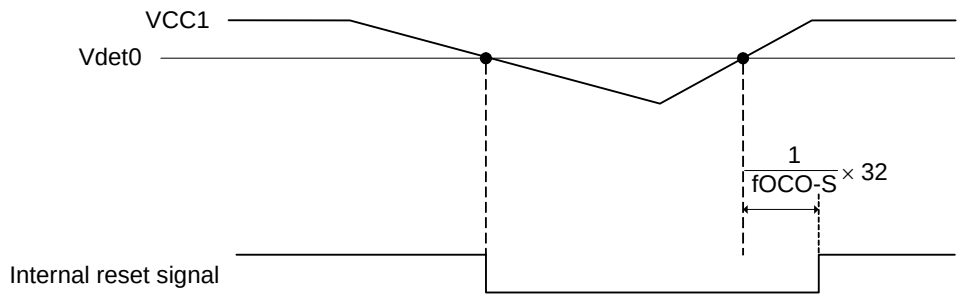
7.4.2.1 Voltage Monitor 0 Reset

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 7.5. When the LVDAS bit in the OFS1 address is 0 (voltage monitor 0 reset enabled after hardware reset), the procedure listed in Table 7.5 is unnecessary.

Table 7.5 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.

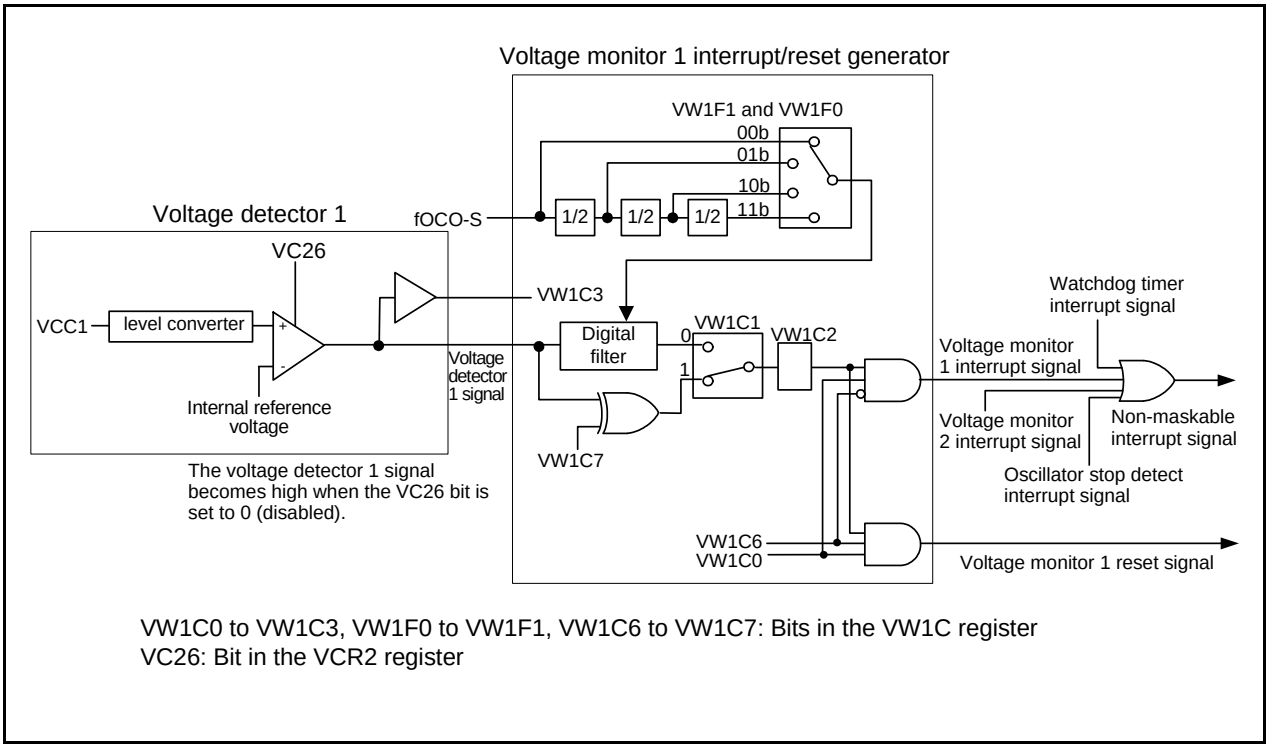


Figure 7.5 Voltage Monitor 1 Interrupt/Reset Generator

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

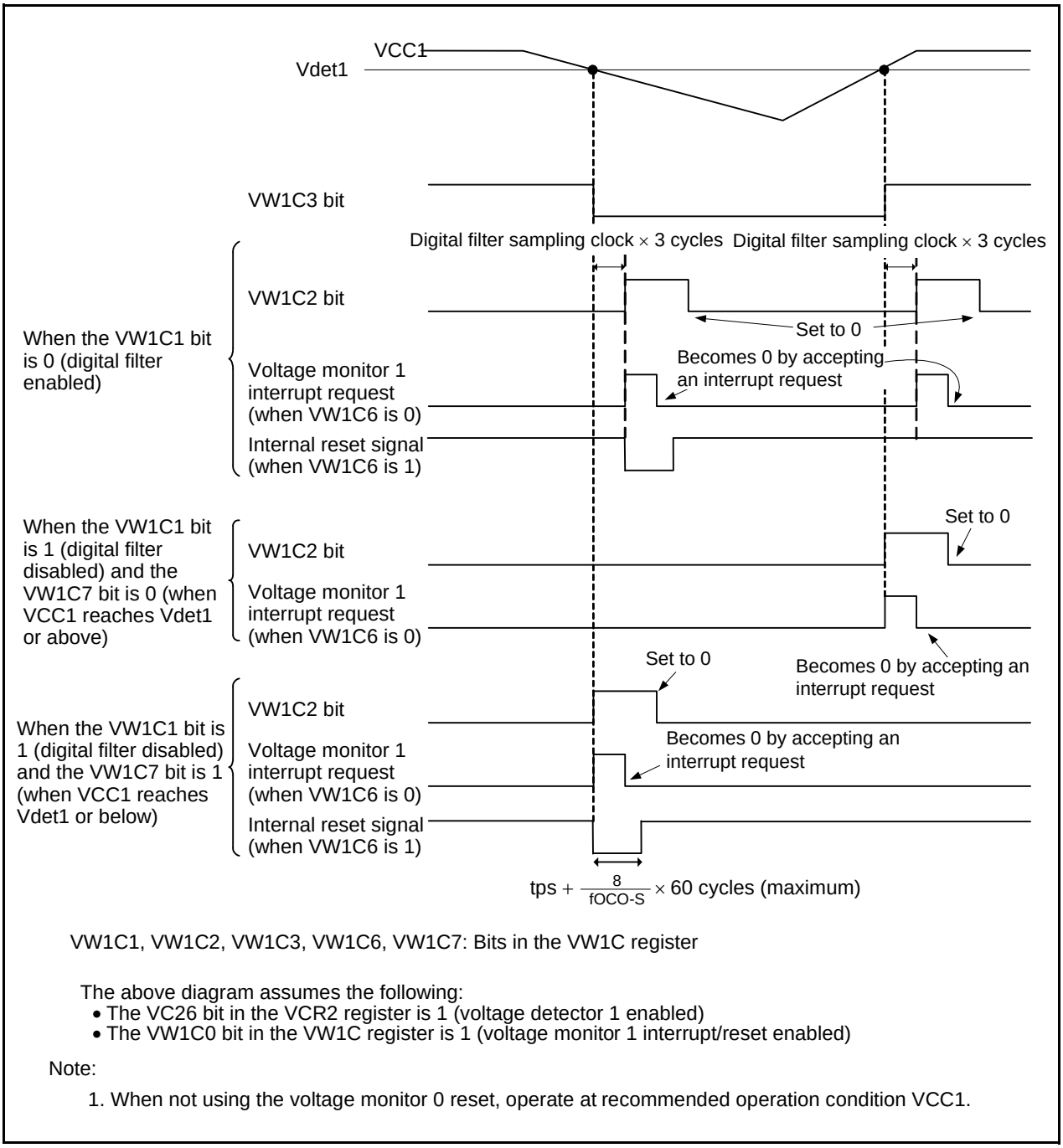
Table 7.6 Procedures for Setting Voltage Monitor 1 Interrupt/Reset Related Bits

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 the VC26 bit in the VCR2 register to 1 (voltage detector 1 enabled).			
3	Wait for td(E-A).			
4	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)	
5 (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).	
6 (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).
7	Set the VW1C2 bit in the VW1C register to 0 (Vdet1 passage not detected).			
8	Set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on)		-	
9	Wait for digital filter sampling clock x 3 cycles.		- (no wait time)	
10	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 4, 5, and 6 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 10), an interrupt does not occur. When VCC1 < Vdet1 (or VCC1 > Vdet1) is detected while executing steps 8 to 10, the VW1C2 bit becomes 1.
   When using this result detected between steps 8 and 10, read the VW1C2 bit after step 10. 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 8 and 10, set the VW1C2 bit to 0 after step 10.

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.



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.

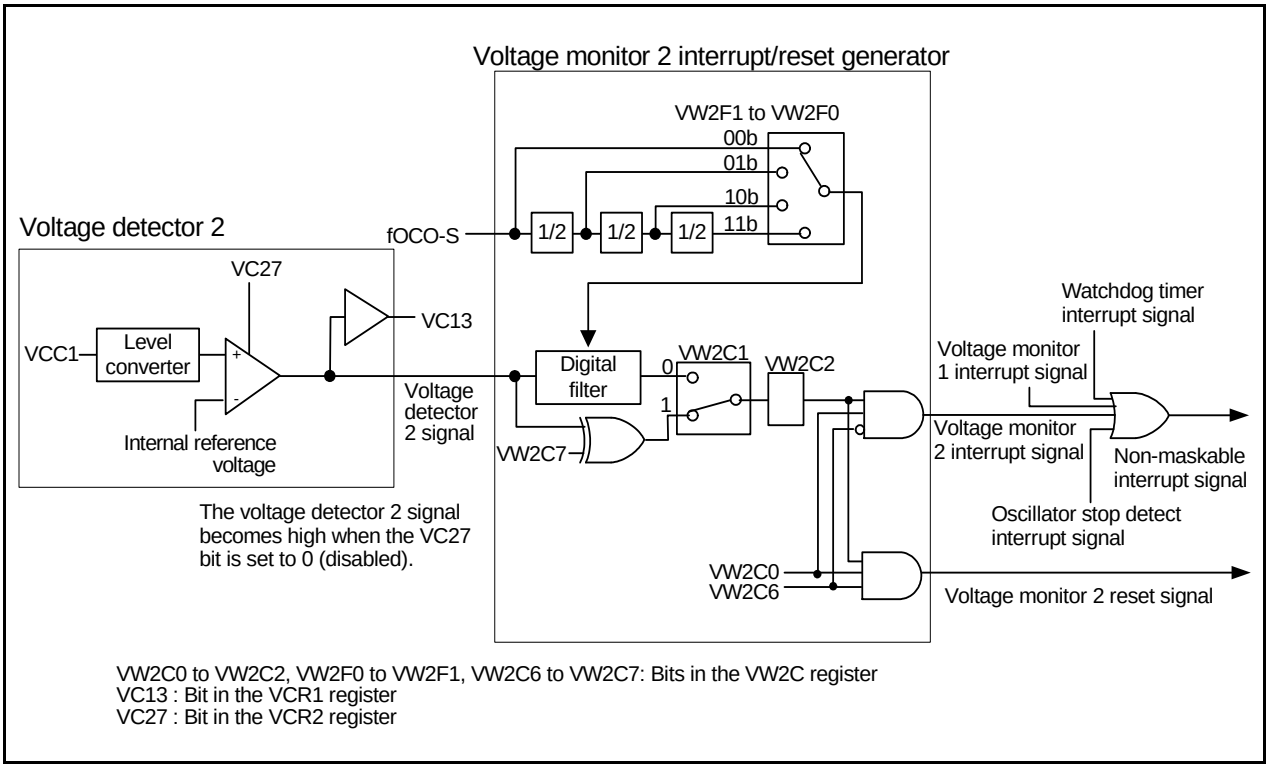


Figure 7.7 Voltage Monitor 2 Interrupt/Reset Generator

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

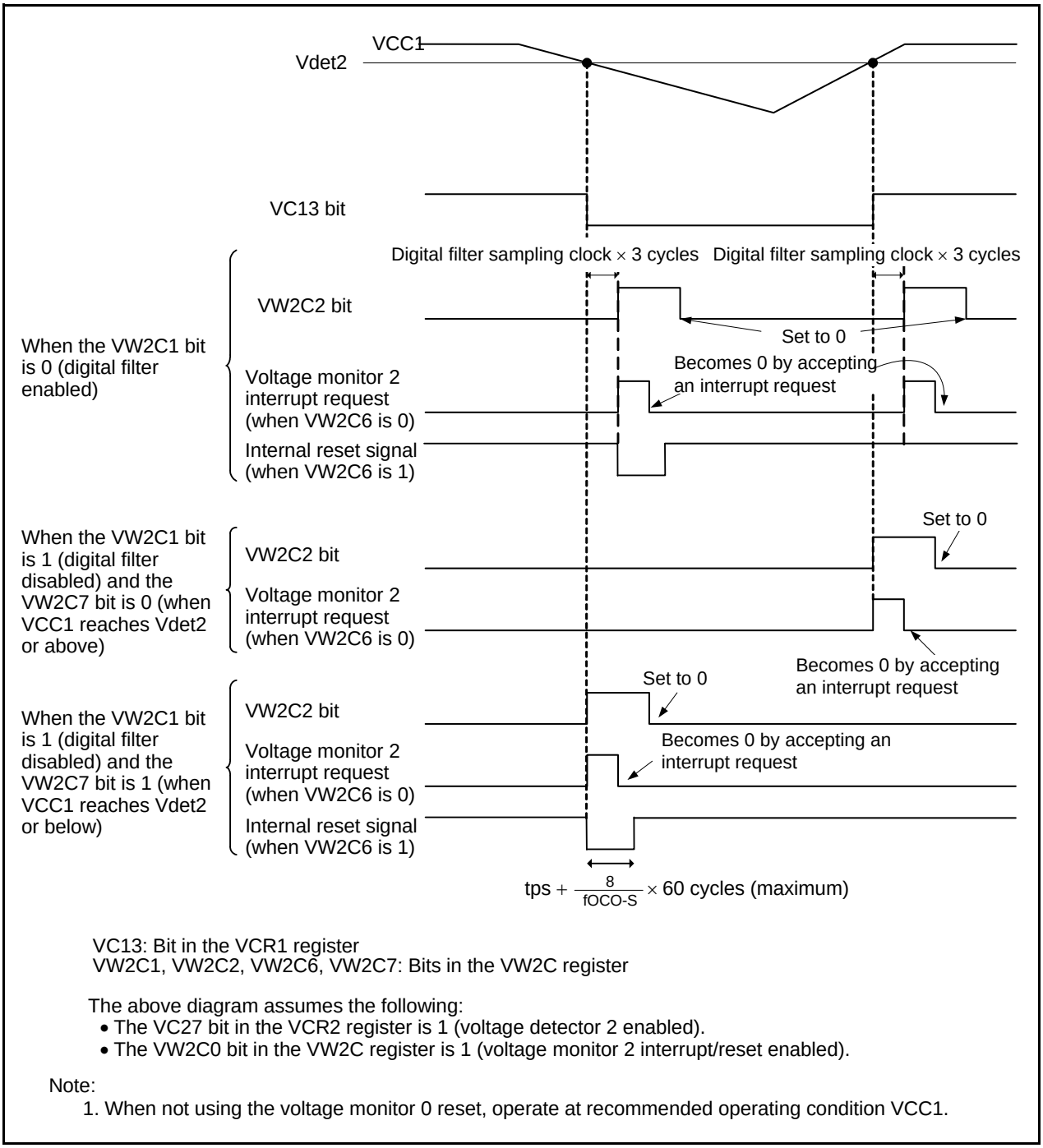
Table 7.7 lists Procedure for Setting Voltage Monitor 2 Interrupt/Reset Related Bits.

Table 7.7 Procedure for Setting Voltage Monitor 2 Interrupt/Reset Related Bits

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

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.



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.

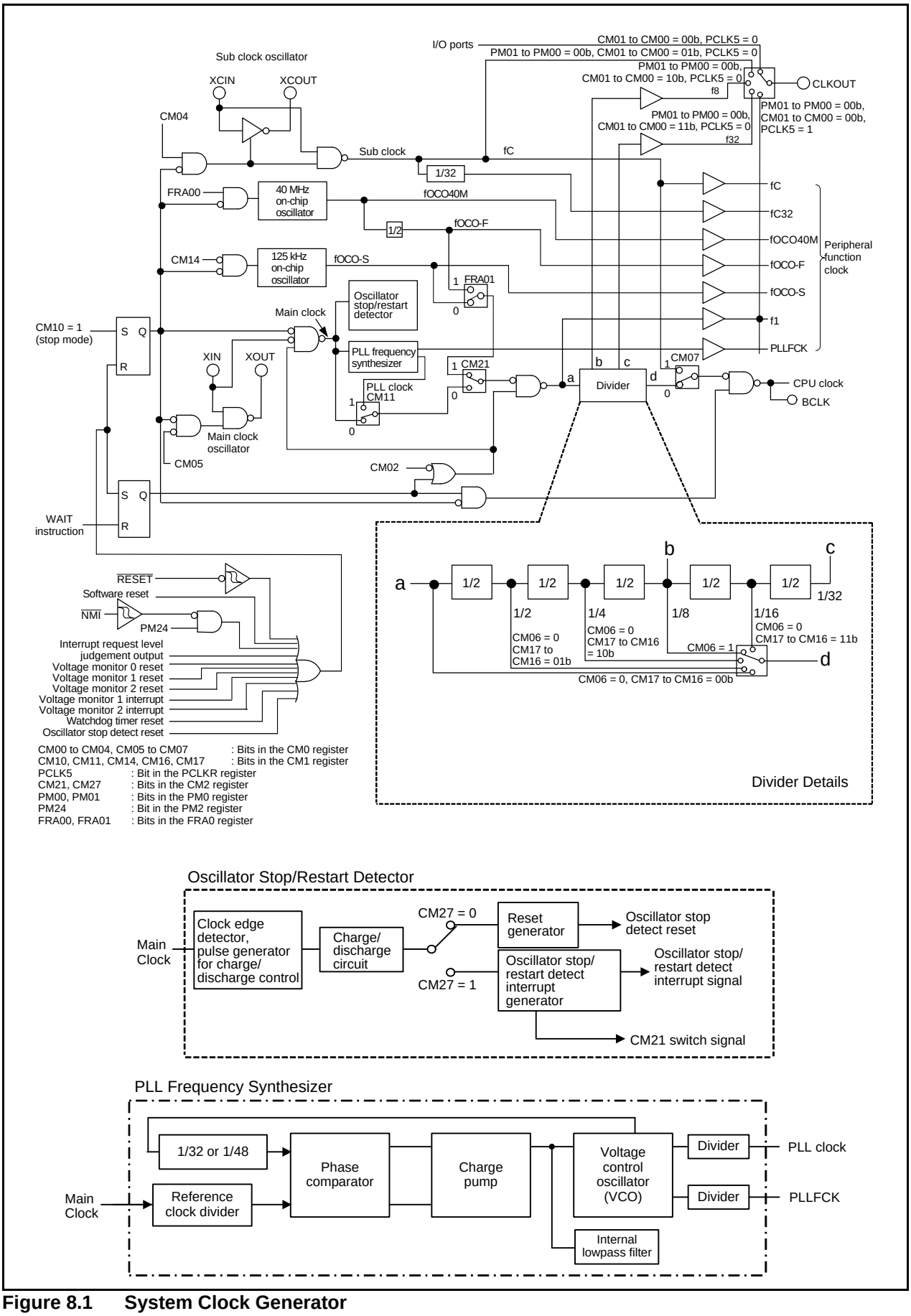


Figure 8.1 System Clock Generator

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

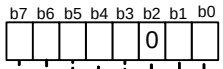
Table 8.3 Registers

Address	Register	Symbol	Reset Value
0004h	Processor Mode Register 0	PM0	0000 0000b
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
001Ch	PLL Control Register 0	PLC0	0001 X010b
001Dh	PLLFCK Control Register	PLCF	00h
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

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
— (b2)	Reserved bit	Set to 0	RW
PM03	Software reset bit	Setting this bit to 1 resets the MCU. 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 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

b7	b6	b5	b4	b3	b2	b1	b0
					0		

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):

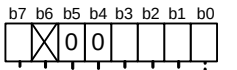
- Entering stop mode.
- The CM21 bit in the CM2 register is 0 (main clock or PLL clock) and the CM05 bit in the CM0 register is set to 1 (main clock stopped).

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

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	Reset Value
0	0		0	0	0			PCLKR	0012h	0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A, B and S clock select bit (clock source for timers A, B and S, the dead time timer, and multi-master I^2C-bus interface)	0: f2TIMAB/f2IIC/f2TIMS 1: f1TIMAB/f1IIC/f1TIMS	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART5)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function extension bit (valid in single-chip mode)	0: Selected by bits CM01 to CM00 in the CM0 register 1: Output f1	RW
— (b7-b6)	Reserved bits	Set to 0	RW

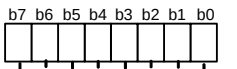
Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.

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 PLL Control Register 0 (PLC0)

PLL Control Register 0



Symbol: PLC0 | Address: 001Ch | Reset Value: 0001 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
PLC06	PLLFCK generation enable bit	0: PLLFCK generation disabled 1: PLLFCK generation enabled	RW
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)

Bits PLC02 to PLC00 are enabled when the PLC06 bit is 0 (PLLFCK generation disabled).
Write to these bits 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.

PLC06 (PLLFCK generation enable bit) (b6)

Write to bit PLC06 when the PLC07 bit is 0 (PLL off). Set the PLC06 bit to 1 (PLLFCK generate enabled) when using USB functions. When the PM21 bit in the PM2 register is 1 (clock change disabled), writing to PLC06 bit has no effect. Table 8.5 shows PLC06 Bit Functions.

Table 8.5 PLC06 Bit Functions

Item	PLC06 Bit	
	0	1
PLLFCK generation	Disabled	Enabled
PLC02 to PLC00 bit in the PLC0 register	Enabled	Disabled
PLCF register	Disabled	Enabled

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.

8.2.7 PLLFCK Control Register (PLCF)

PLLFCK Control Register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
PLCF	001Dh	00h

Bit Symbol	Bit Name	Function	RW
PLCF0	PLLFCK multiplying factor select bit	b1 b0 0 0 : Multiply by 8 0 1 : Multiply by 12 1 0 : Multiply by 16 1 1 : Multiply by 24	RW
PLCF1			RW
PLCF2	PLL clock select bit during PLLFCK enabled	b1 b0 0 0 : PLL clock not used 0 1 : Divide-by-3 1 0 : Divide-by-4 1 1 : Divide-by-8	RW
PLCF3			RW
— (b7-b4)	Reserved bits	Set to 0	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.
The PLCF register is enabled when the PLC06 bit in the PLC0 register is 1 (PLLFCK generation enabled).

PLCF1 to PLCF0 (PLLFCK multiplying factor select bit) (b1-b0)

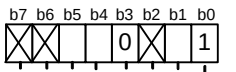
Set bits PLCF1 to PLCF0 so that PLLFCK is 48 MHz.
Write to these bits when the PLC07 bit is 0 (PLL off).
When the PM21 bit in the PM2 register is 1 (clock change disabled), writing to bits PLCF1 to PLCF0 has no effect.

PLCF3 to PLCF2 (PLLFCK clock select bit during PLLFCK enabled) (b3-b2)

When using the USB function and PLL clock, set one of the following: 01b (divide-by-3), 10b (divide-by-4), and 11b (divide-by-8). 00b can be set when the PLL clock is not used.
Write to these bits when the PLC07 bit is 0 (PLL off).
When the PM21 bit in the PM2 register is 1 (clock change disabled), writing to bits PLCF 3 to PLCF2 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

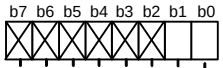
Do not execute the WAIT instruction when the PM21 bit is 1.
Once the PM21 bit is set to 1, it cannot be set to 0 by a program (writing 0 has no effect).

PM25 (Peripheral clock fC provide bit) (b5)

The PM25 bit provides fC to the real-time clock. (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

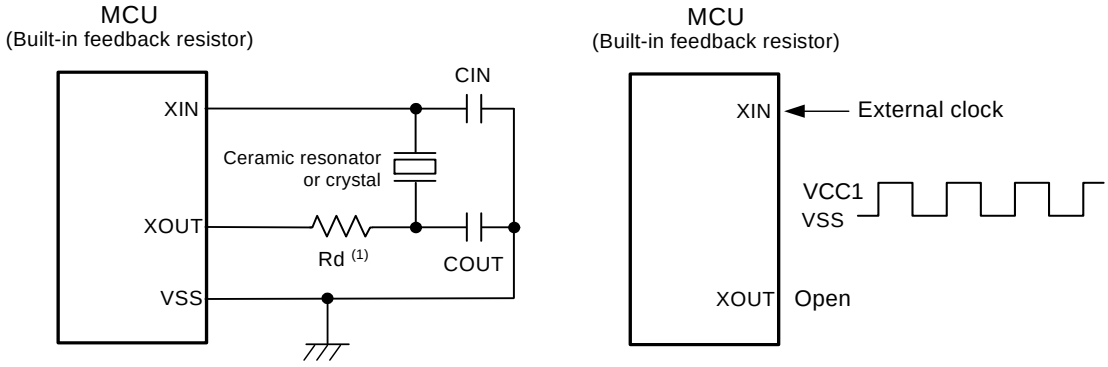
Clocks generated by the clock generators are described below.

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,

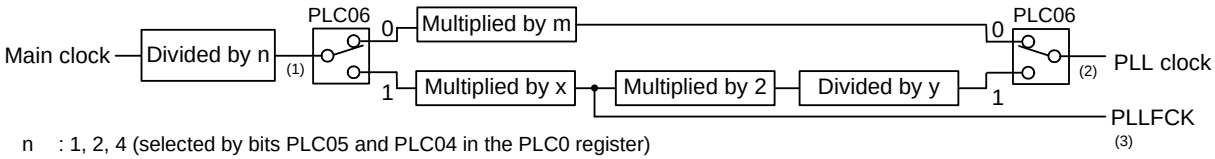
(1) Set the CM20 bit in the CM2 register to 0 (oscillator stop/restart detect function disabled).
(2) Set the CM05 bit to 1 (stop).
(3) Stop the external clock (when inputting the external clock through the XIN pin).

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 6 MHz. Figure 8.3 shows Relation between Main Clock and PLL Clock.



n : 1, 2, 4 (selected by bits PLC05 and PLC04 in the PLC0 register)
m : 2, 4, 6, 8 (selected by bits PLC02 to PLC00 in the PLC0 register)
x : 8, 12, 16, 24 (selected by bits PLCF1 to PLCF0 in the PLCF register)
y : 3, 4, 8 (selected by bits PLCF3 to PLCF2 in the PLCF register)

Notes:
1. Set the frequency divided by n to between 2 MHz and 6 MHz.
2. Set 10 MHz ≤ PLL clock frequency ≤ 32 MHz
3. Set the frequency to 48 MHz to use the USB function.

Figure 8.3 Relation between Main Clock and PLL Clock

Table 8.6 Example Settings for PLL Clock Frequencies (When the PLC06 Bit in the PLC0 Register is 0 (PLLFCK Disabled))

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	01b (divide-by-2)	010b (multiply-by-4)	24 MHz
6 MHz	00b (not divided)	010b (multiply-by-4)	
16 MHz	10b (divide-by-4)	100b (multiply-by-8)	32 MHz
8 MHz	01b (divide-by-2)	100b (multiply-by-8)	

Table 8.7 Example Settings for PLL Clock Frequencies (When the PLC06 Bit in the PLC0 Register is 1 (PLLFCK Enabled))

Frequency Divided by n	Bits in the PLCF Register		PLLFCK	PLL Clock
	PLCF1 to PLCF0	PLCF3 to PLCF2		
6 MHz	00b (multiplied by 8)	01b (divided by 3)	48 MHz	32 MHz
		10b (divided by 4)	48 MHz	24 MHz
4 MHz	01b (multiplied by 12)	01b (divided by 3)	48 MHz	32 MHz
		10b (divided by 4)	48 MHz	24 MHz
3 MHz	10b (multiplied by 16)	01b (divided by 3)	48 MHz	32 MHz
		10b (divided by 4)	48 MHz	24 MHz
2 MHz	11b (multiplied by 24)	01b (divided by 3)	48 MHz	32 MHz
		10b (divided by 4)	48 MHz	24 MHz

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).

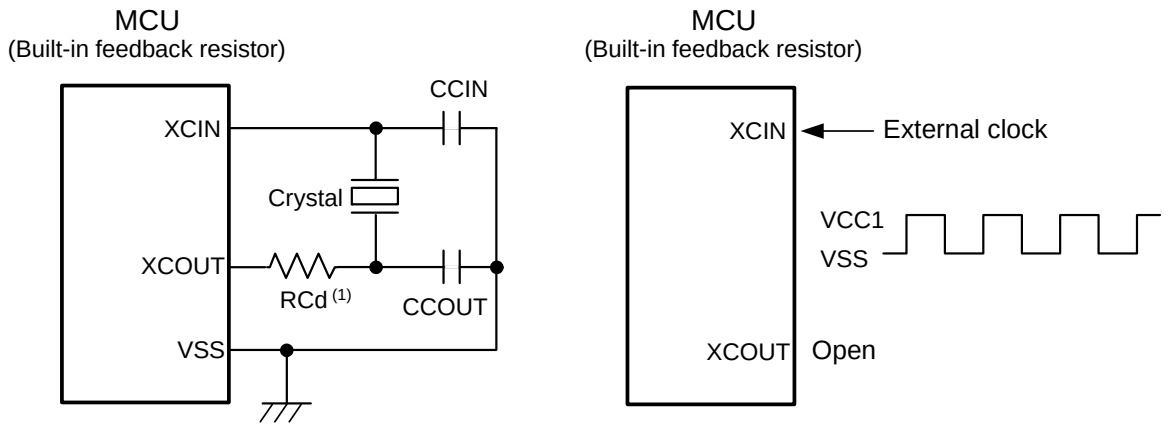
To start fOCO-S:

(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, and real-time clock.
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 $\overline{NMI}$/$\overline{SD}$ 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, PLLFCK)

f1, fOCO40M, fOCO-F, fOCO-S, fC32, and PLLFCK 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, B, and S, real-time clock, UART0 to UART5, 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, B, and S and UART0 to UART5.

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, watchdog timer, and the USB functions (when the internal power supply of USB is used). 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 when the PM25 bit in the PM2 register is 1 (peripheral clock fC provided). fC can be used when the sub clock is on.

The PLLFCK is used for USB communications operation clock of the USB function. PLLFCK can be used when the PLC06 bit in the PLC0 register is set to 1 (PLLFCK generation enabled). Set PLC0 register and PLCF register at more than 48 MHz of PLLFCK.

Figure 8.5 shows Peripheral Function Clocks.

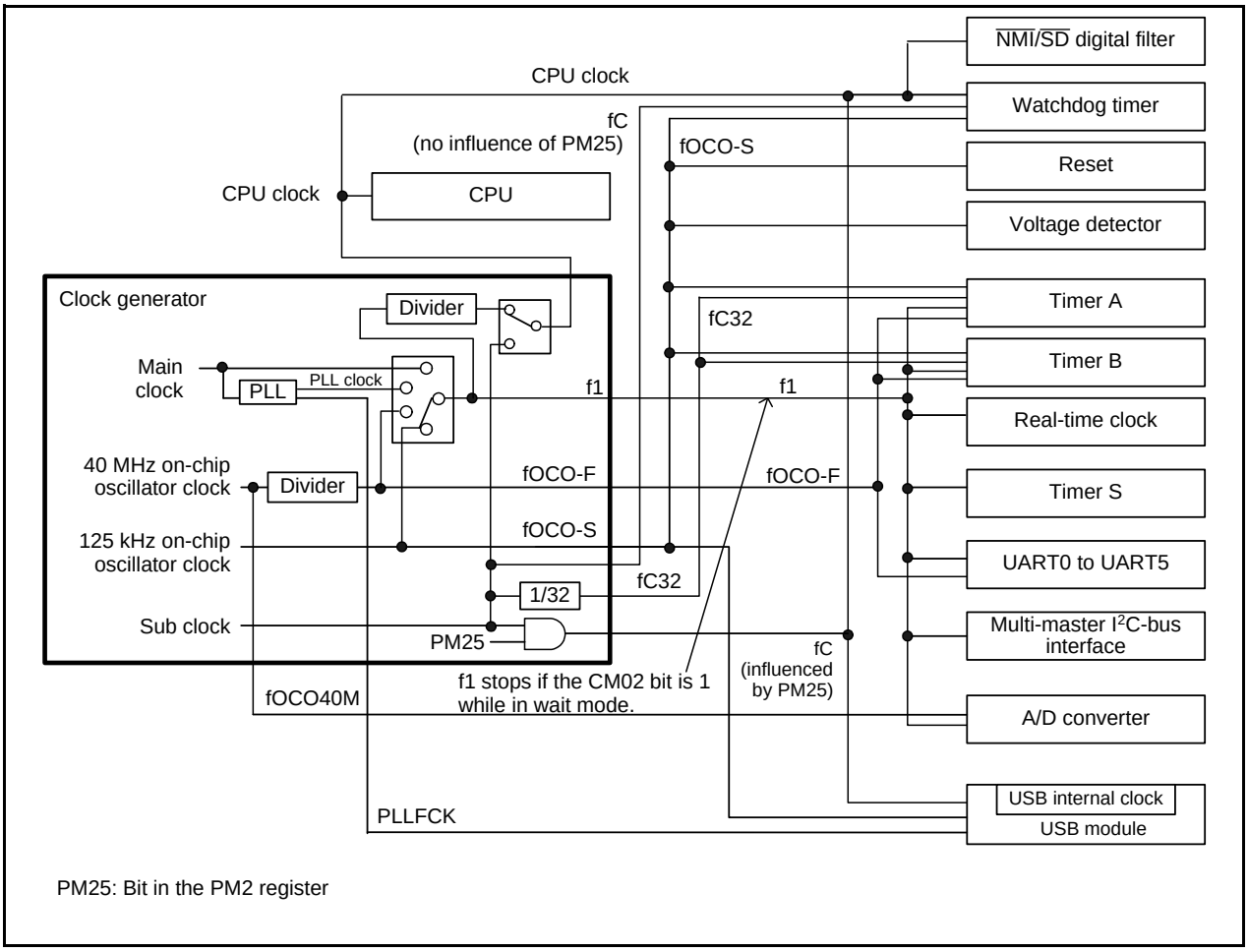


Figure 8.5 Peripheral Function Clocks

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 8.8 lists Oscillator Stop/Restart Detect Function Specifications.

Table 8.8 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 8.9 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 8.9 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.

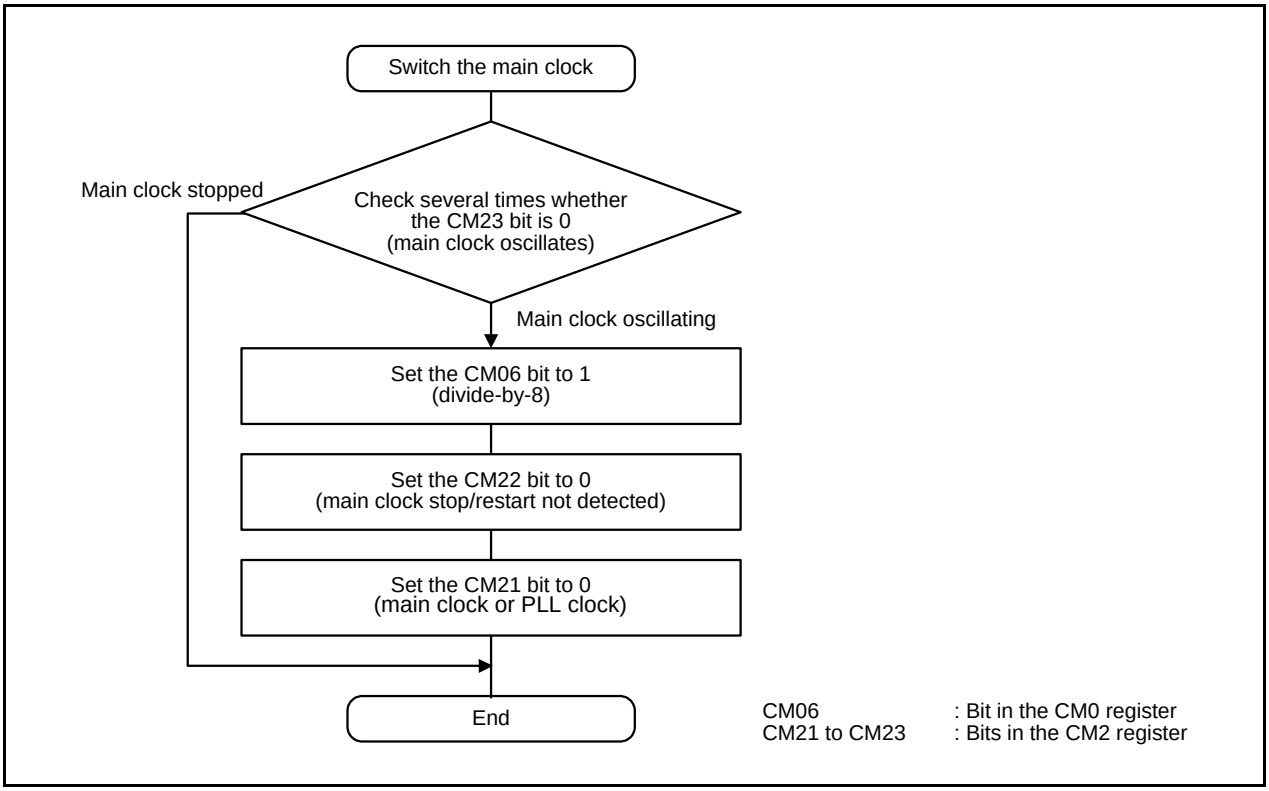


Figure 8.6 Switching from On-Chip Oscillator Clock to Main Clock

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/6C 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 8.10 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).

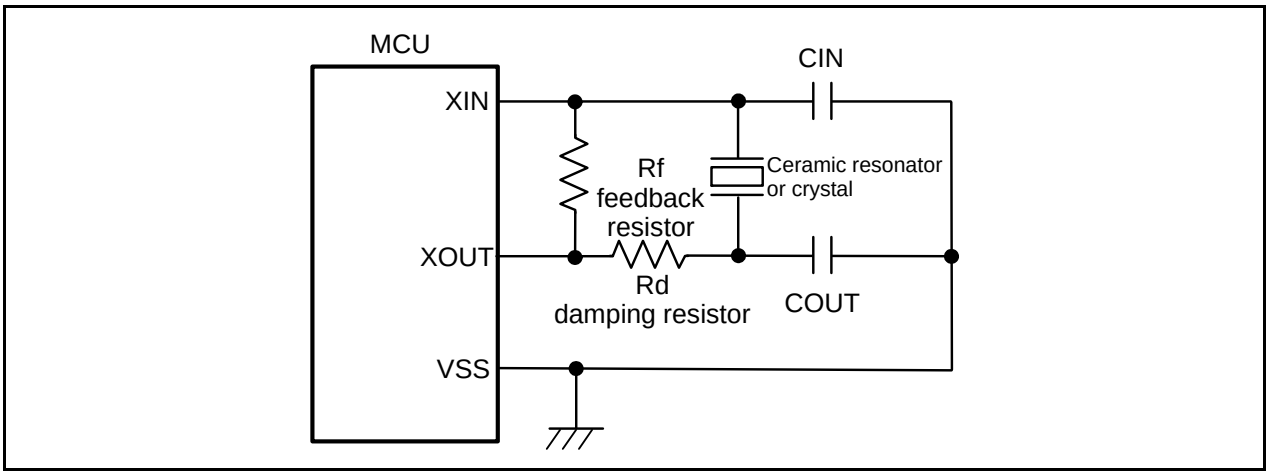


Figure 8.7 Oscillator Example

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).

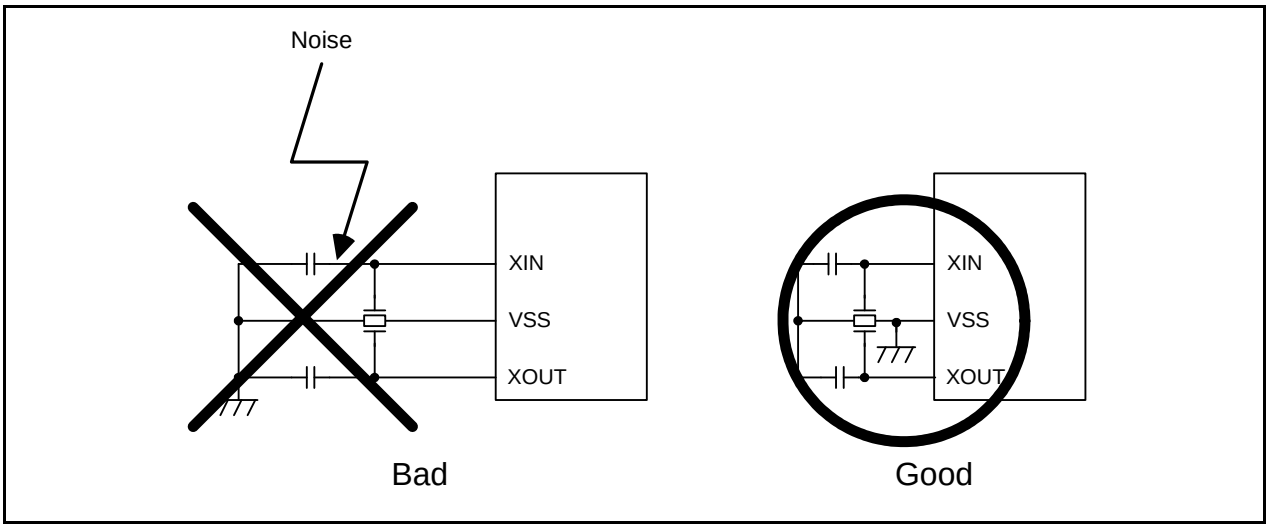


Figure 8.8 Clock I/O Pin Wiring

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.

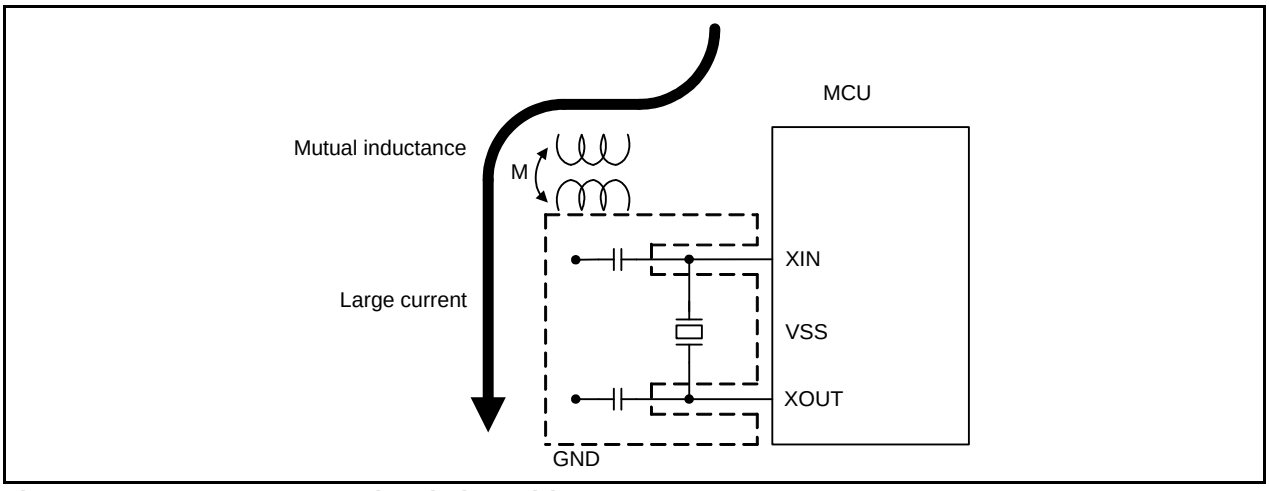


Figure 8.9 Large Current Signal Line Wiring

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.

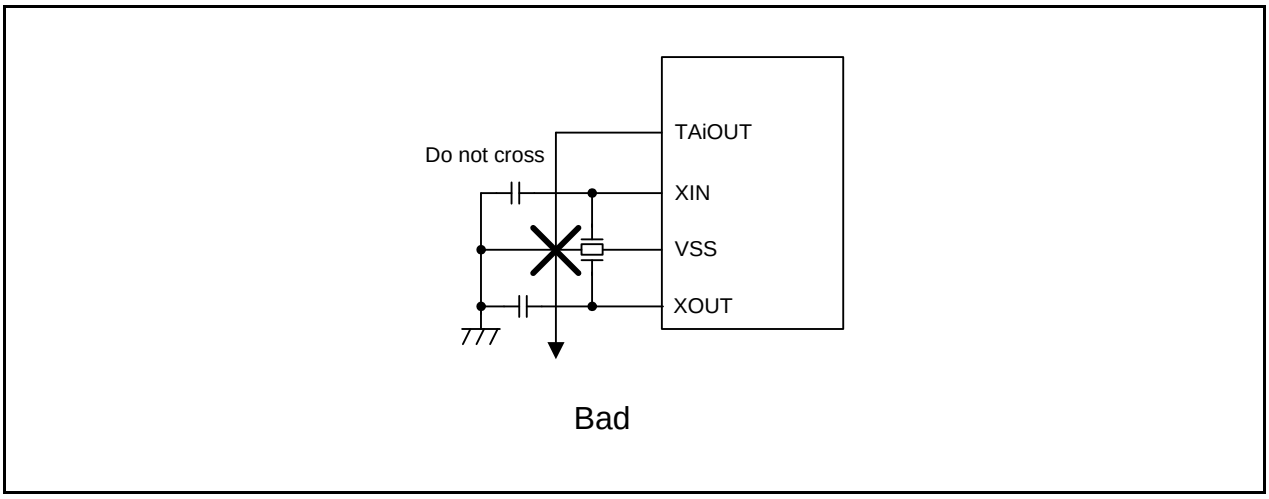


Figure 8.10 Wiring of Signal Line Whose Level Changes at High-Speed

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 8.11 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

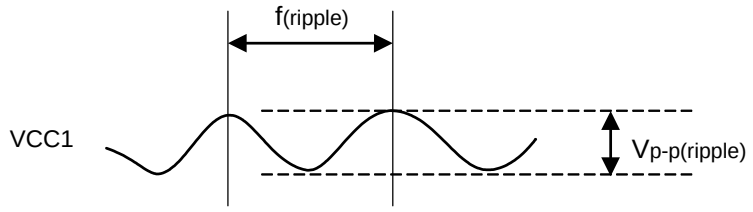


Figure 8.11 Voltage Fluctuation Timing

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

b7	b6	b5	b4	b3	b2	b1	b0
			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/$\overline{BY}$ 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 ($\overline{NMI}$ interrupt disabled) or high is input to the $\overline{NMI}$ 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.

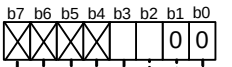
FMSTP (Flash memory stop bit) (b3)

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: FMR2 | Address: 0222h | Reset Value: 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-2	Approx. 20 MHz	00b (no division)	0
Divide-by-4	Approx. 10 MHz	01b (divide-by-2)	0
Divide-by-8	Approx. 5 MHz	10b (divide-by-4)	0
Divide-by-16	Approx. 2.5 MHz	-	1 (divide-by-8)
Divide-by-32	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.

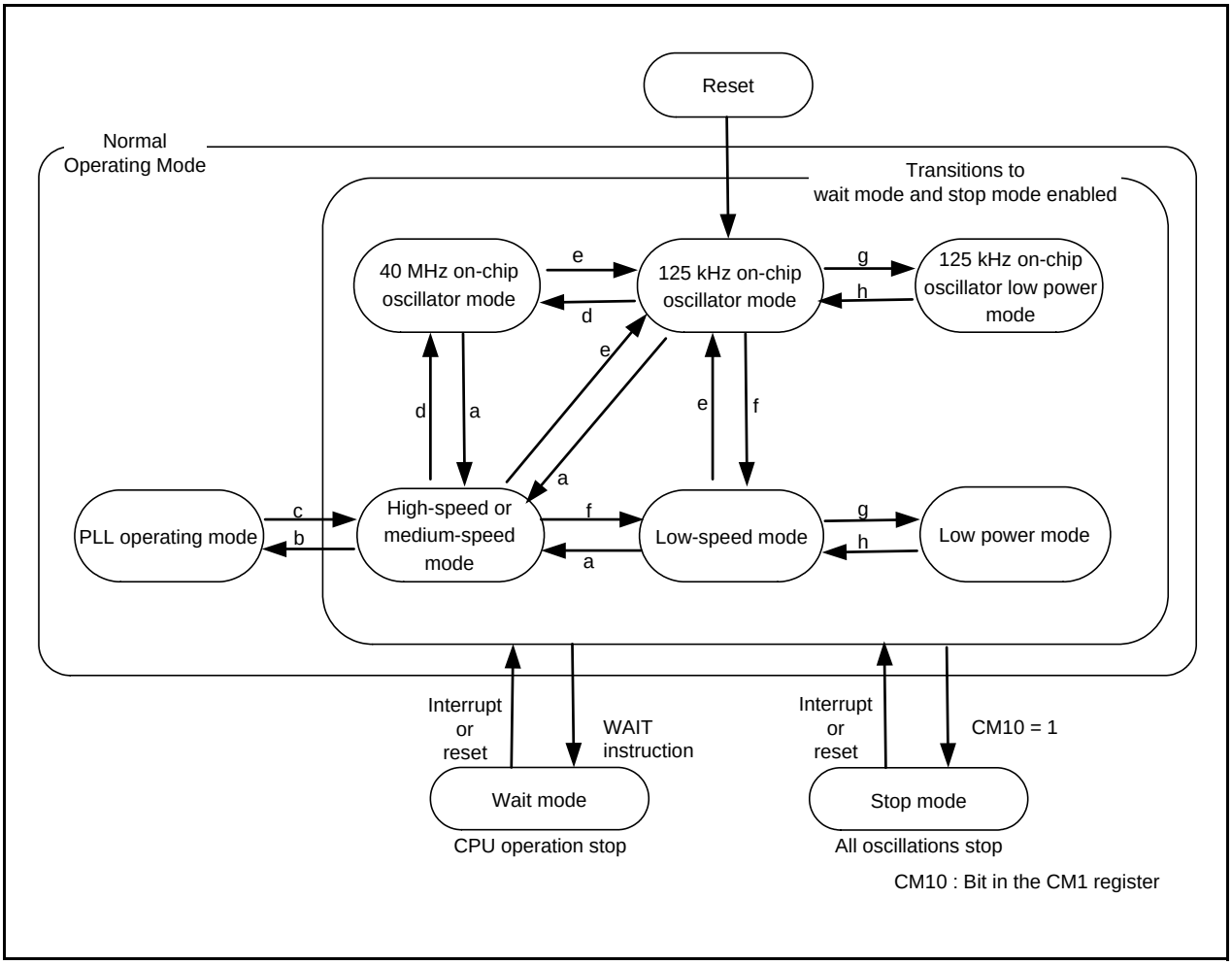


Figure 9.1 Clock Mode Transition

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)”.

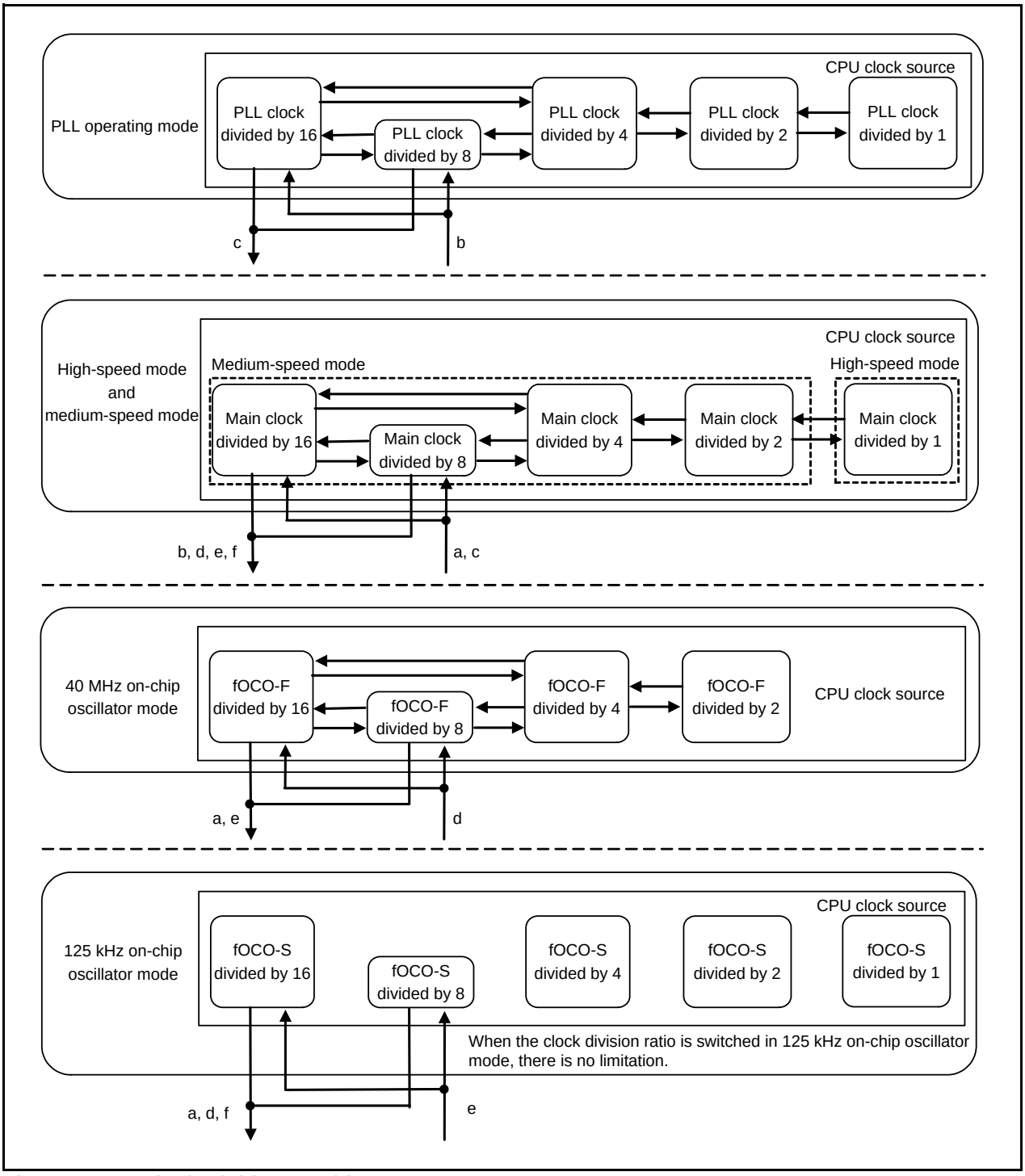


Figure 9.2 Clock Divide Transition

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, $\overline{NMI}$/$\overline{SD}$ digital filter, and USB functions 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).
Use the USB module in memory expansion mode or microprocessor mode. To enter wait mode, refer to 24.6.8 “Entering Wait mode or Stop Mode”.
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, $\overline{NMI}$ 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 D7, $\overline{CS0}$ to $\overline{CS3}$, $\overline{BHE}$		Retains the status just prior to entering wait mode	Cannot be used as a bus control pin
$\overline{RD}$, $\overline{WR}$		High	
$\overline{HLDA}$, 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.
		Timer S	Usable in all modes except the following: not usable in IC/OC interrupt 0 and 1	Not usable
		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^2C-bus interface	Both I^2C-bus interface interrupt and SCL/SDA interrupt are usable	SCL/SDA interrupt is usable
		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	
		USB functions	Usable only in USB RESUME Interrupt	
	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.

Use the USB module in memory expansion mode or microprocessor mode. To enter wait mode, refer to 24.6.8 “Entering Wait mode or 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, $\overline{\text{NMI}}$ 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 D7, $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$, $\overline{\text{BHE}}$		Retains status just prior to stop mode	Cannot be used as bus control pin
$\overline{\text{RD}}$, $\overline{\text{WR}}$		High	
$\overline{\text{HLDA}}$, 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	$\overline{INT}$	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^2C-bus interface	SCL/SDA interrupt is usable
		USB functions	Usable in USB RESUME Interrupt
	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)
	$\overline{NMI}$		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, $\overline{NMI}$ 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.

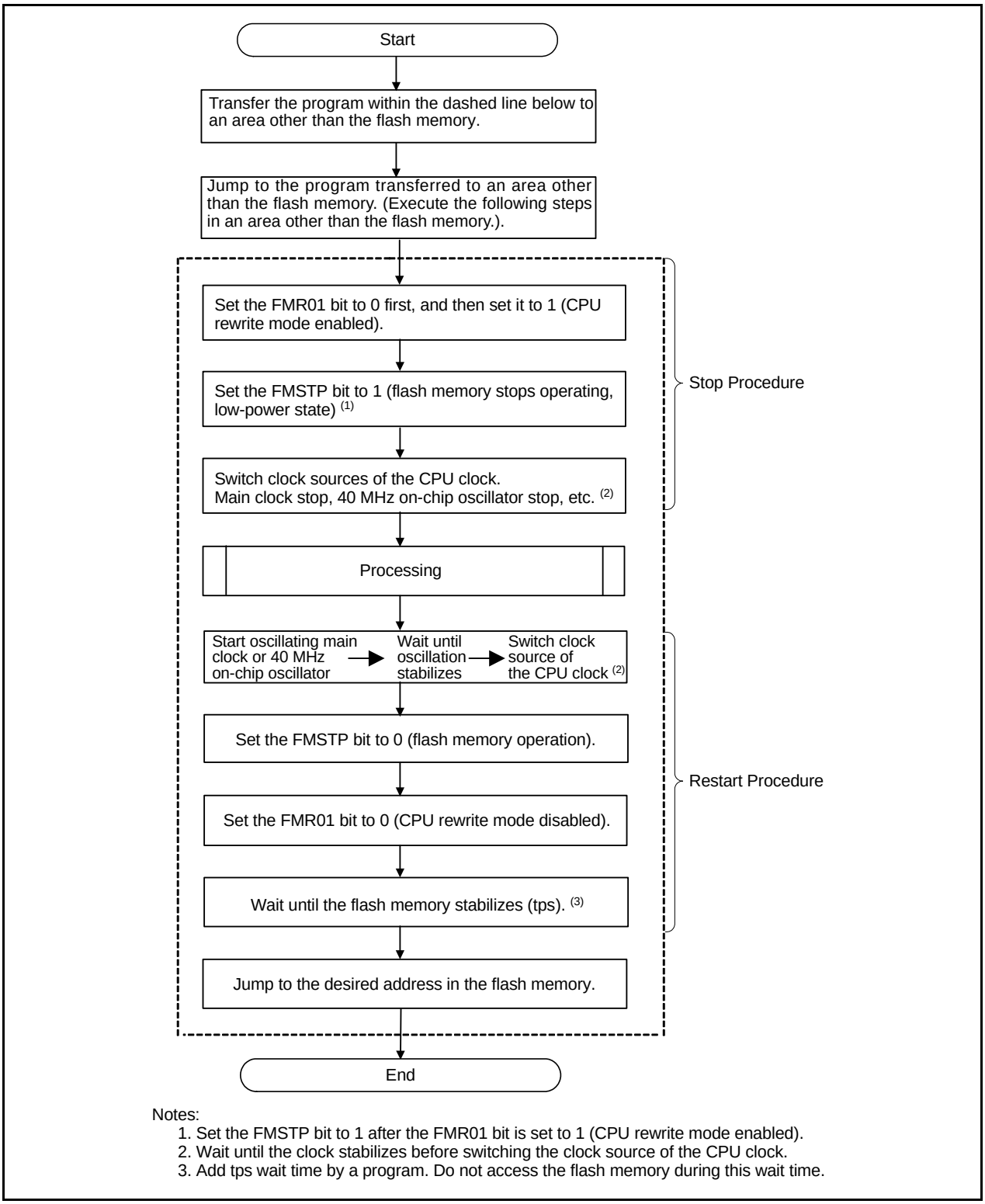
Table 9.10 CPU Clock After Exiting Stop Mode

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.



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).

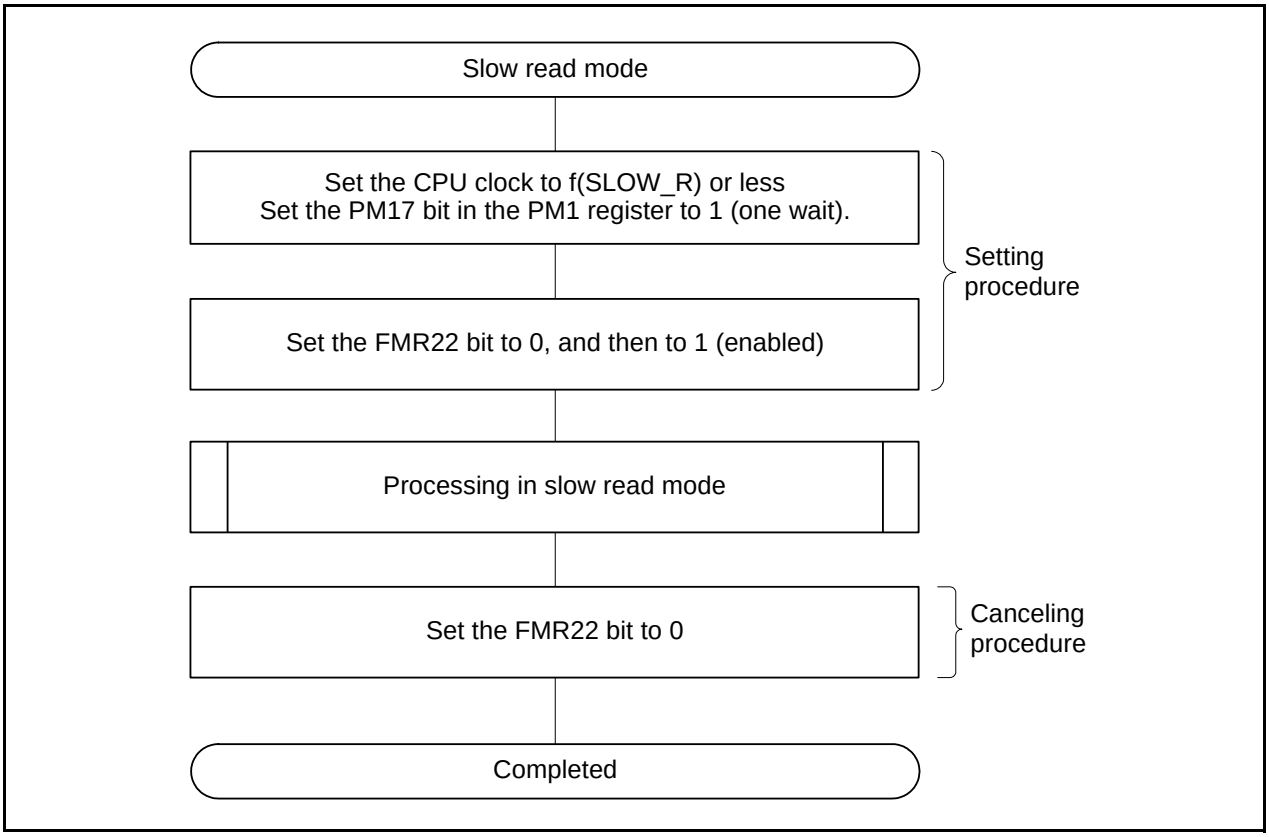
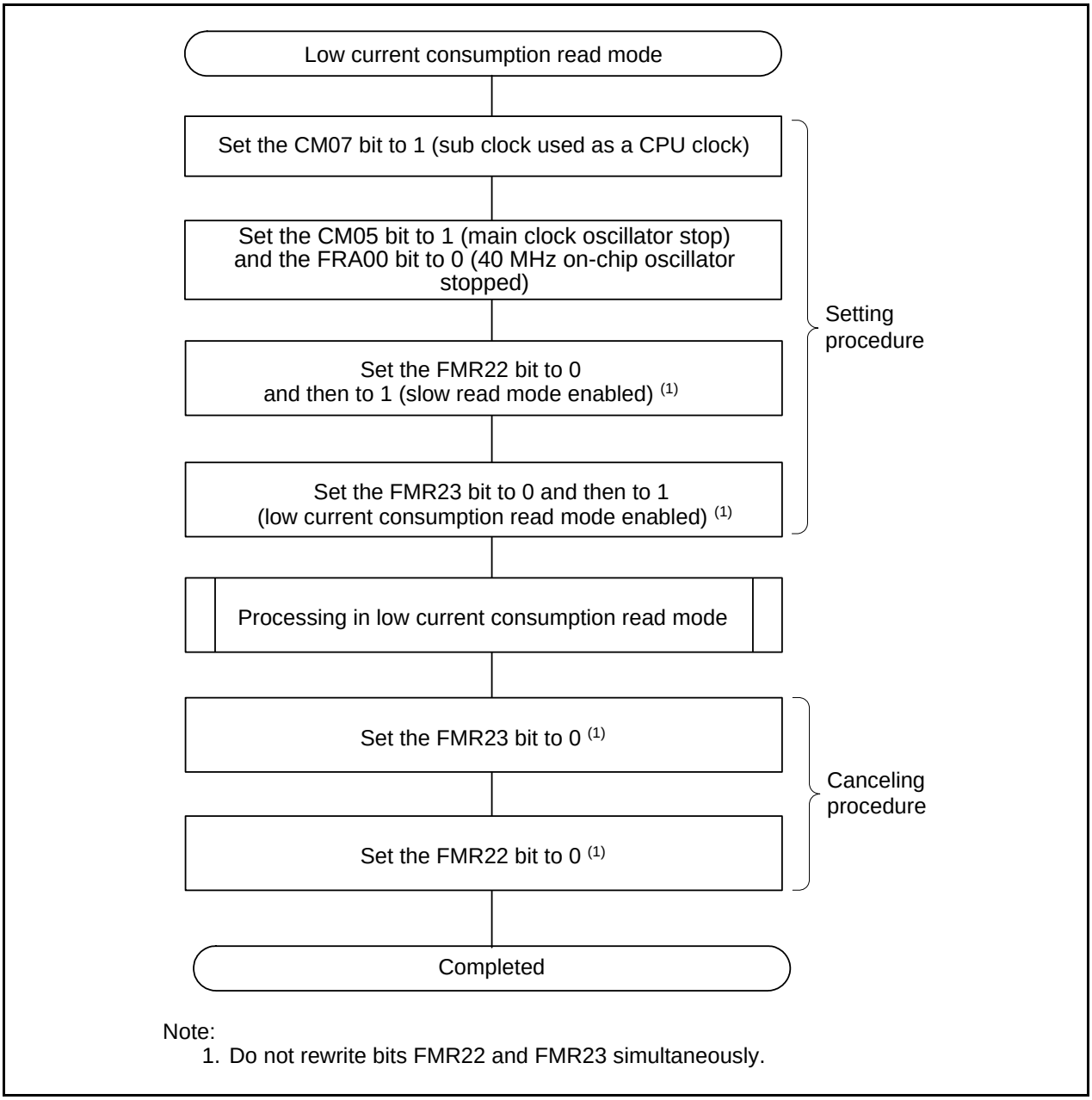


Figure 9.4 Setting and Canceling Slow Read Mode

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.



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 AD0CON1, AD1CON1 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 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.

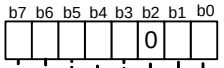
10.2 Registers

Table 10.2 Registers

Address	Register	Symbol	Reset Value
0004h	Processor Mode Register 0	PM0	0000 0000b
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

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
— (b2)	Reserved bit	Set to 0	RW
PM03	Software reset bit	Setting this bit to 1 resets the MCU. 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

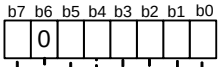
Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register.
Bits PM01 to PM00 do not change at software reset, watchdog timer reset, oscillator stop detect reset, voltage monitor 1 reset, or voltage monitor 2 reset.
Bits PM05 to PM04, PM06, and PM07 are enabled when bits 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	$\overline{CS2}$ area switch bit (data flash enable bit)	0 : $\overline{CS2}$ (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 : Do not set	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 ($\overline{CS2}$ area switch bit (data flash enable bit)) (b0)

This bit is used to select the function of addresses 0E000h to 0FFFFh. Table 10.3 lists Data Flash (Addresses 0E000h to 0FFFFh).

Table 10.3 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 10.4 lists the Functions of PM13 Bit and Table 10.5 lists Functions of Addresses 80000h to CFFFFh.

Table 10.4 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

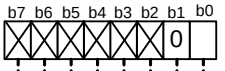
Table 10.5 Functions of Addresses 80000h to CFFFFh

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 10.6 lists Program ROM 2 (Addresses 10000h to 13FFFh).

Table 10.6 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 28.7.1 “User Boot Function” for details.

10.3 Operations

10.3.1 Processor Mode Settings

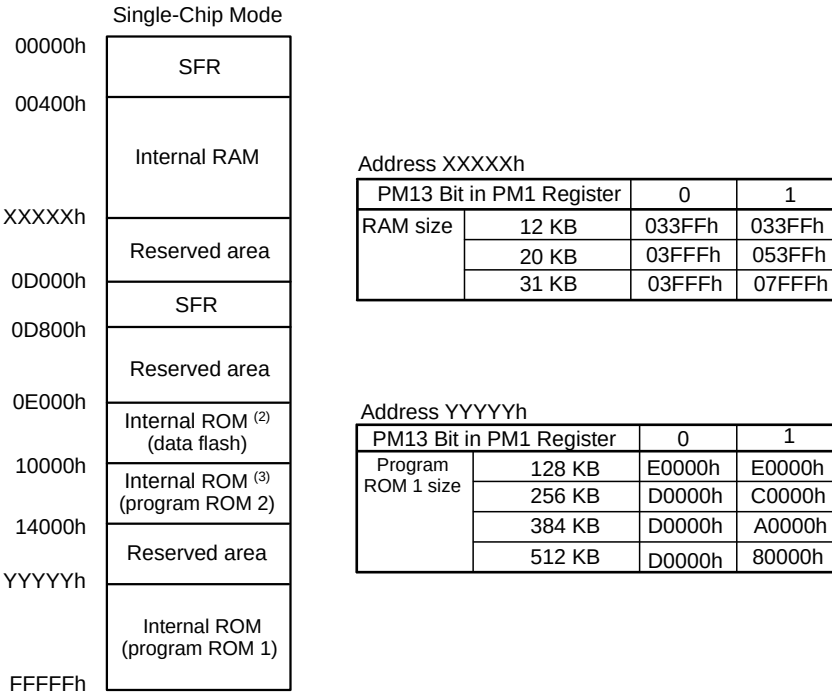
Set the processor mode using bits PM01 to PM00 in the PM0 register.
In hardware reset, power-on reset, or voltage monitor 0 reset, the processor mode is single-chip mode.

Table 10.7 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 10.7 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

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 the internal RAM and 192 KB of the 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 (8 bits) • Number of address buses selectable (12, 16, or 20 buses) • 4 chip select outputs $\overline{CS0}$ to $\overline{CS3}$ • $\overline{RDY}$ available • 0 to 3 software waits can be inserted • Memory area expansion function (refer to 12. “Memory Space Expansion Function”) • 3 V or 5 V interface

11.2 Registers

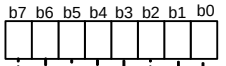
Table 11.2 lists bus related registers. Refer to 10. “Processor Mode” for registers PM0 and PM1. Refer to 28. “Flash Memory” for the FMR1 register.

Table 11.2 Registers

Address	Register	Symbol	Reset Value
0004h	Processor Mode Register 0	PM0	0000 0000b
0005h	Processor Mode Register 1	PM1	0000 1000b
0008h	Chip Select Control Register	CSR	01h
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



Symbol	Address	Reset Value
CSR	0008h	01h

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

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

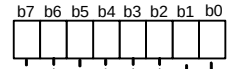
Set the CSiW bit to 0 (wait state) under the following conditions:

- The $\overline{RDY}$ signal is used in the area indicated by $\overline{CSi}$.
- The multiplexed bus is used in the area indicated by $\overline{CSi}$.
- 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	$\overline{CS0}$ 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 : Do not set.	RW
CSE01W			RW
CSE10W	$\overline{CS1}$ 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 : Do not set.	RW
CSE11W			RW
CSE20W	$\overline{CS2}$ 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 : Do not set.	RW
CSE21W			RW
CSE30W	$\overline{CS3}$ 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 : Do not set.	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.

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.

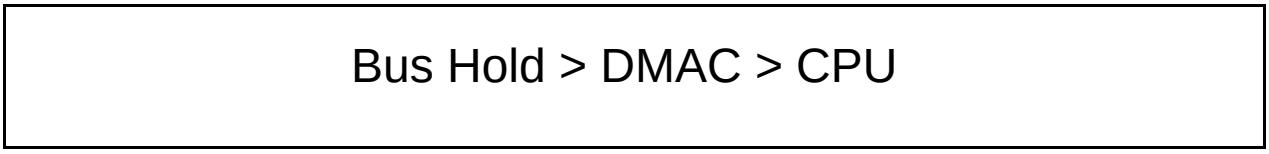


Figure 11.1 Bus Use Priority

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 D7, $\overline{CS0}$ to $\overline{CS3}$, $\overline{RD}$, $\overline{WR}$, $\overline{BHE}$, ALE, $\overline{RDY}$, $\overline{HOLD}$, $\overline{HLDA}$, 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. D0 to D7 and A0 to A7 are multiplexed.

Table 11.4 Difference between Separate Bus and Multiplexed Bus Modes

Pin Name (1)	Separate Bus	Multiplexed Bus
P0_0 to P0_7/D0 to D7	D0 to D7	(Note 2)
P2_0/A0 (/ D0 / -)	A0	A0 D0
P2_1 to P2_7/A1 to A7 (/ D1 to D7 / D0 to D6)	A1 to A7	A1 to A7 D1 to D7
P3_0/A8 (/ - / D7)	A8	A8

Notes:
1. See Table 11.7 “Pin Functions for Each Processor Mode”, for bus control signals other than the above.
2. Depends on the setting of PM05 and PM04 in the PM0 register, and area being accessed. See Table 11.7 “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

The data bus is comprised of eight lines (D0 to D7).

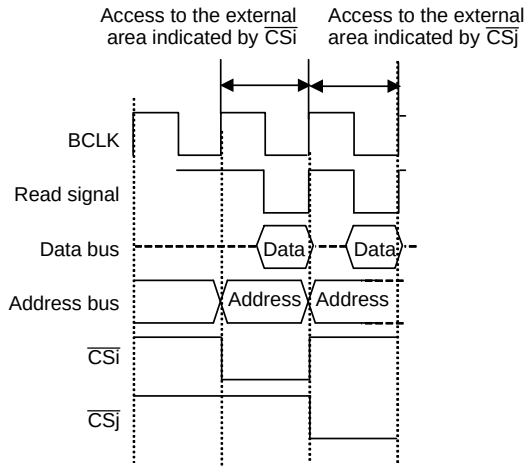
11.3.5.3 Chip Select Signal

The chip select signals (hereafter referred to as $\overline{CS}$) are output from the $\overline{CSi}$ pin (i = 0 to 3). These pins can be set to function as I/O ports or as $\overline{CS}$ 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 $\overline{CSi}$ signal. Figure 11.2 shows Examples of Address Bus and $\overline{CSi}$ Signal Output in 1-MB Mode.

Example 1

Accessing the external area indicated by $\overline{CSj}$ in the next cycle after accessing the external area indicated by $\overline{CSi}$.

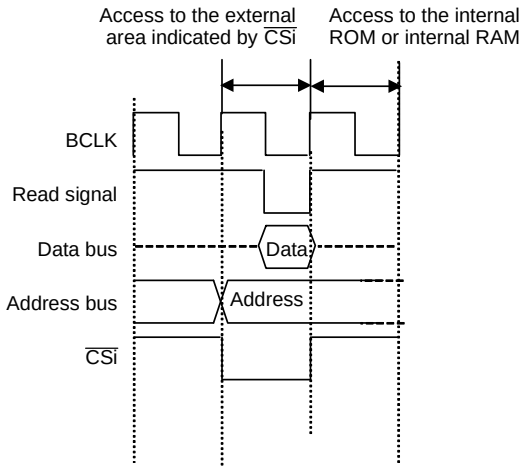
The address bus and chip select signal both change state between these two cycles.



Example 2

Accessing the internal ROM or internal RAM in the next cycle after accessing the external area indicated by $\overline{CSi}$.

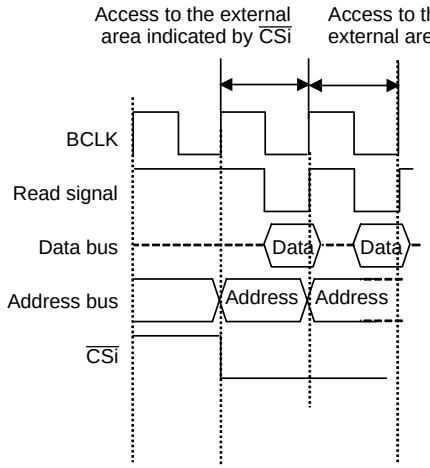
The chip select signal changes state, but the address bus does not.



Example 3

Accessing the external area indicated by $\overline{CSi}$ in the next cycle after accessing the external area indicated by the same $\overline{CSi}$.

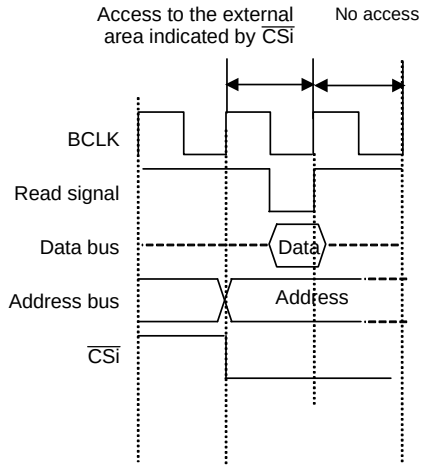
The address bus changes state, but the chip select signal does not.



Example 4

Not accessing any area (no instruction prefetch generated) in the next cycle after accessing the external area indicated by $\overline{CSi}$.

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 $i \neq j$, however)

Figure 11.2 Examples of Address Bus and $\overline{CSi}$ Signal Output in 1-MB Mode

11.3.5.4 Read and Write Signals

Table 11.6 lists Operation of the $\overline{RD}$, $\overline{WR}$ and $\overline{BHE}$ Signals.

Table 11.6 Operation of the $\overline{RD}$, $\overline{WR}$ and $\overline{BHE}$ Signals

Data Bus Width	$\overline{RD}$	$\overline{WR}$	$\overline{BHE}$	A0	Status of External Data Bus
8-bit	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.

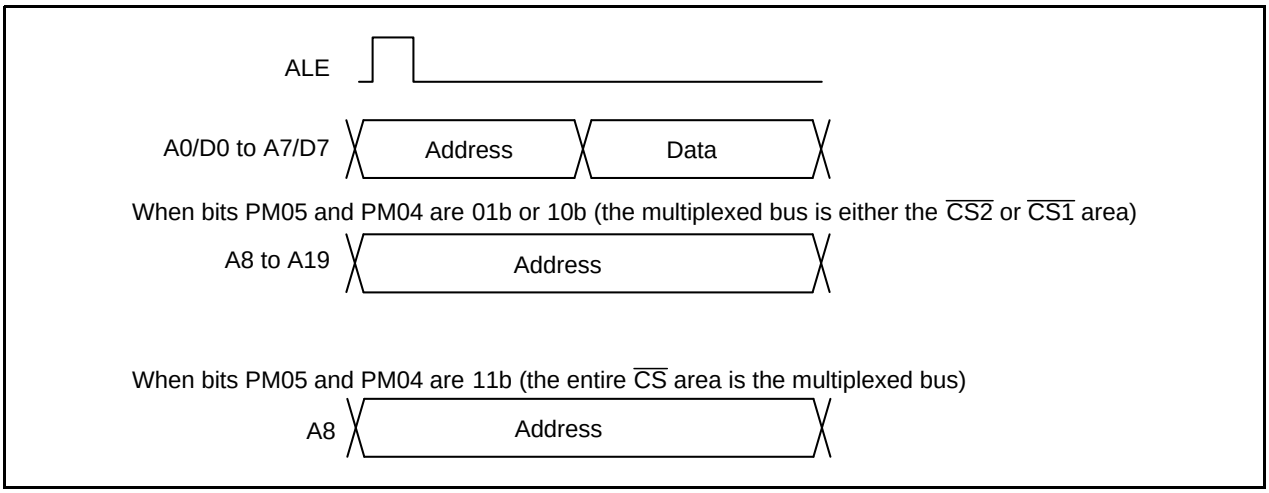
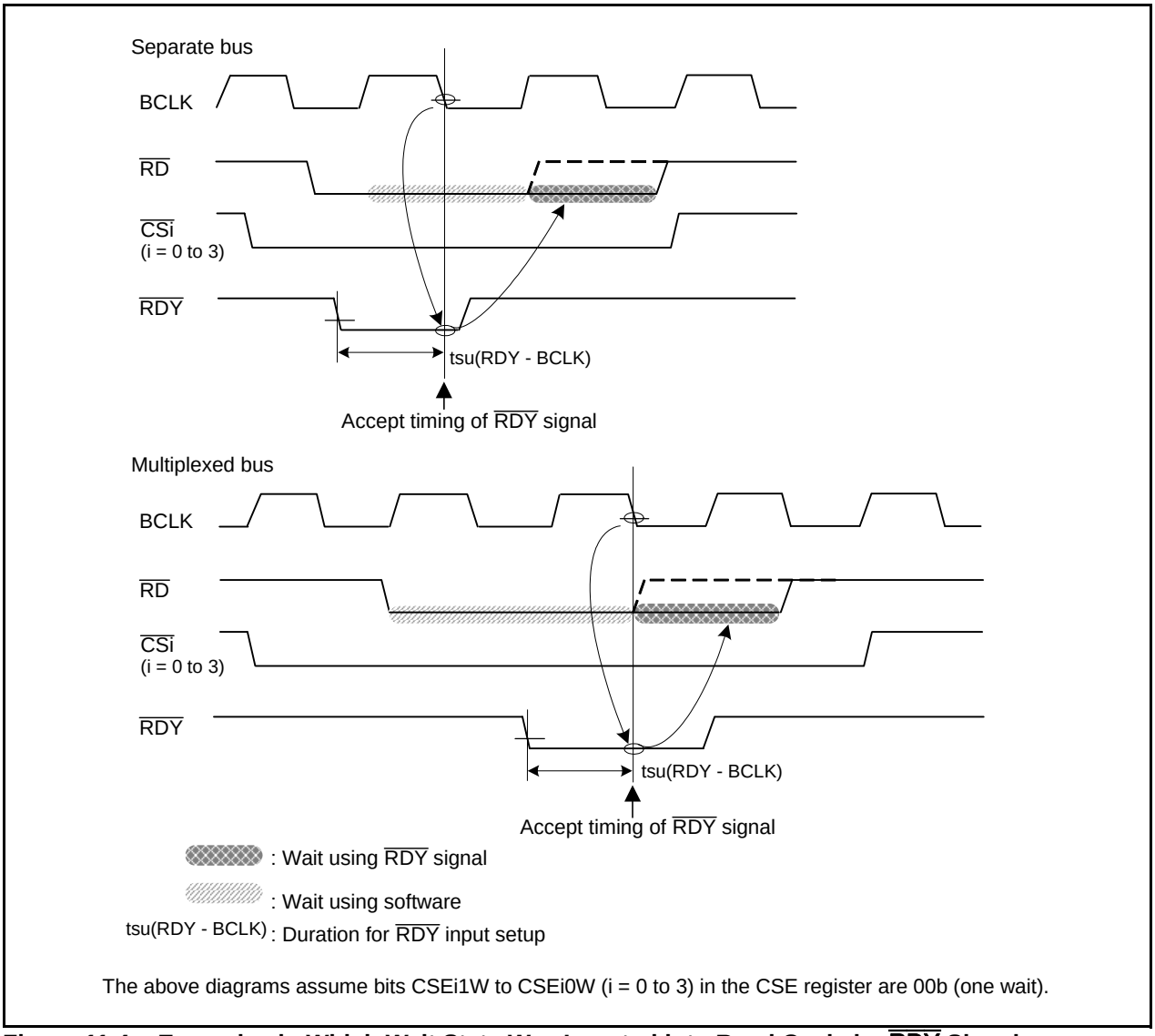


Figure 11.3 ALE Signal, Address Bus, and Data Bus

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 D7, $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$, $\overline{\text{RD}}$, $\overline{\text{WR}}$, $\overline{\text{BHE}}$, 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 11.7 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 ($\overline{CS2}$ is for multiplexed bus and the others are for separate bus) 10b ($\overline{CS1}$ is for multiplexed bus and the others are for separate bus)	11b (the entire $\overline{CS}$ space is for multiplexed bus) (1)
Data bus width		8 bits	8 bits	8 bits
P0_0 to P0_7		D0 to D7	D0 to D7 (3)	I/O ports
P1_0 to P1_7		I/O ports	I/O ports	I/O ports
P2_0		A0	A0/D0 (2)	A0/D0
P2_1 to P2_7		A1 to A7	A1 to A7 /D1 to D7 (2)	A1 to A7 /D1 to D7
P3_0		A8	A8	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	$\overline{CS0}$		
P4_5	CS1 = 0	I/O ports		
	CS1 = 1	$\overline{CS1}$		
P4_6	CS2 = 0	I/O ports		
	CS2 = 1	$\overline{CS2}$		
P4_7	CS3 = 0	I/O ports		
	CS3 = 1	$\overline{CS3}$		
P5_0		$\overline{WR}$		
P5_1		$\overline{BHE}$		
P5_2		$\overline{RD}$		
P5_3		BCLK		
P5_4		$\overline{HLDA}$		
P5_5		$\overline{HOLD}$		
P5_6		ALE		
P5_7		$\overline{RDY}$		

I/O port: Functions as I/O ports or peripheral function I/O pins.
PM11: Bit in the PM1 register
PM06, PM05 to PM04: Bits in the PM0 register
CS3 to CS0: Bits in the CSR register
Notes:
1. 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 $\overline{CS}$ is 256 bytes.
2. In separate bus mode, these pins serve as the address bus.
3. When accessing an area using a multiplexed bus, these pins output an undefined value while writing.

11.3.5.8 External Bus Status When Internal Area is Accessed

Table 11.8 lists the External Bus Status When an Internal Area is Accessed. Figure 11.5 shows the Typical Bus Timings When Accessing SFRs.

Table 11.8 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 D7	Read	High-impedance	High-impedance
	Write	Data output	Undefined
$\overline{RD}$, $\overline{WR}$		$\overline{RD}$, $\overline{WR}$ 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

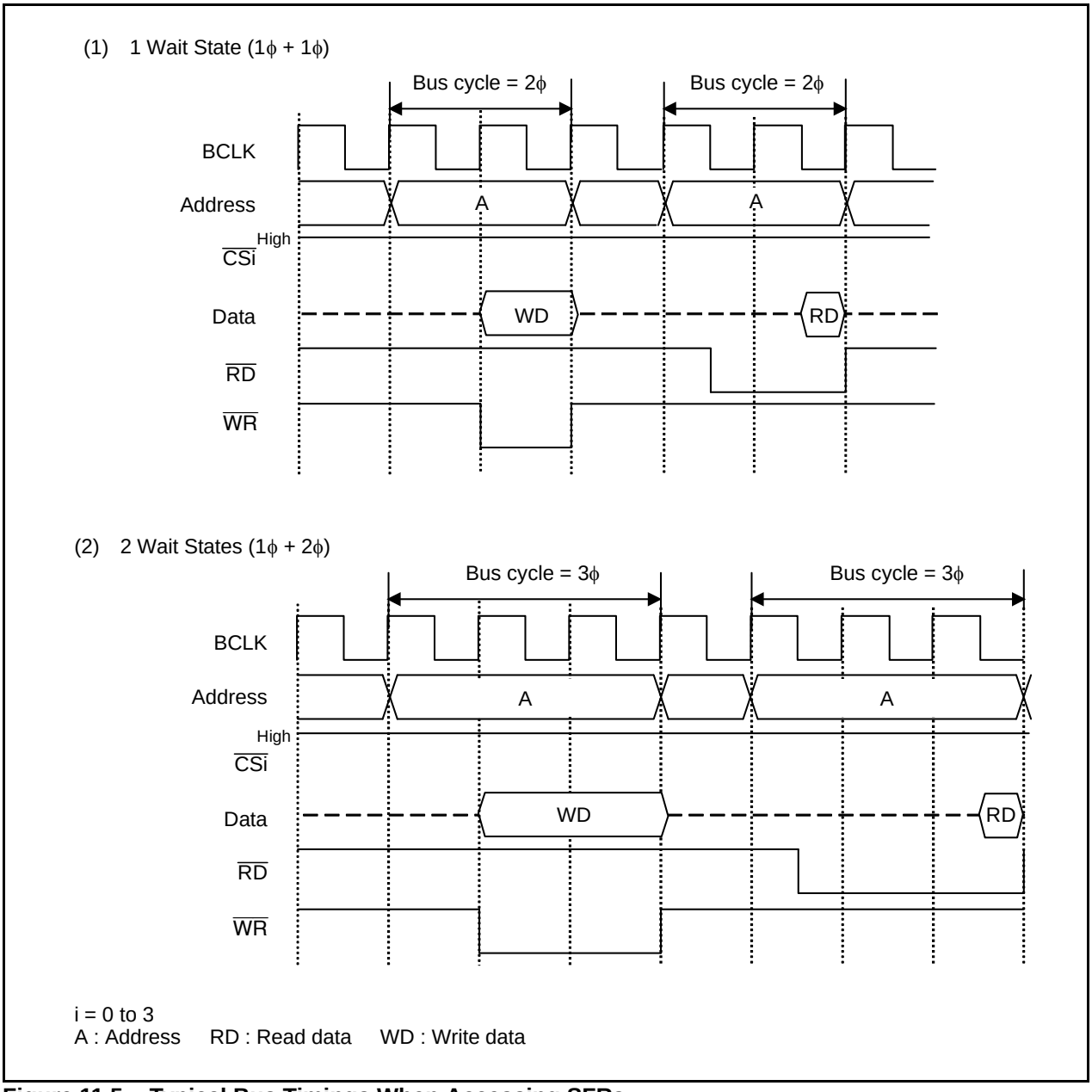


Figure 11.5 Typical Bus Timings When Accessing SFRs

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 $\overline{CSi}$ (i = 0 to 3). To use the $\overline{RDY}$ signal, set the corresponding CSiW bit to 0 (wait state). See Table 11.9 “Bits and Bus Cycles Related to Software Wait States (External Area)” for details.

Table 11.9 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		
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
		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

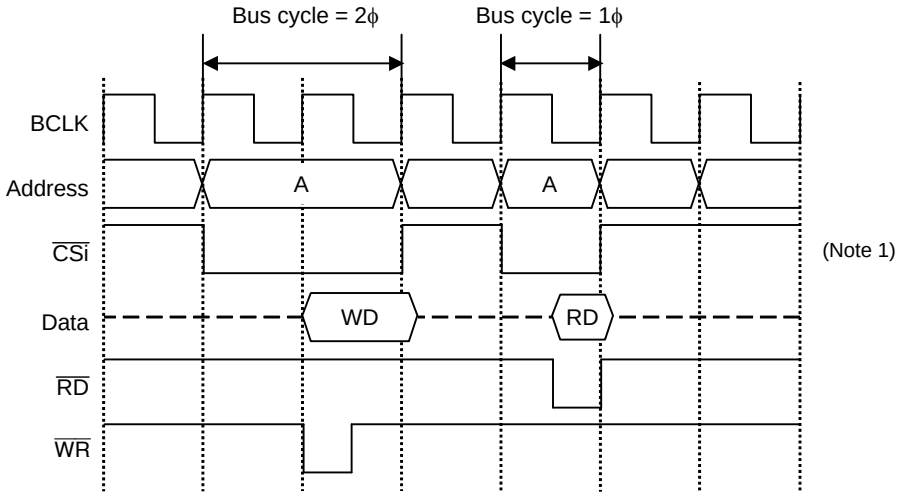
CSiW: Bits in the CSR register (1)

CSEi1W, CSEi0W: Bits in the CSE register

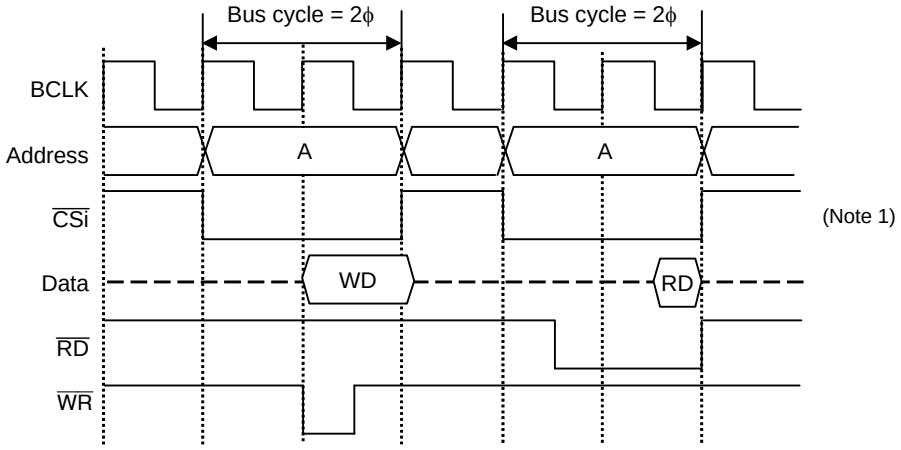
Notes:

1. To use the $\overline{RDY}$ signal, set the CSiW bit to 0 (wait state).
2. To access in multiplexed bus mode, 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 $\overline{CS0}$ to $\overline{CS3}$). Therefore, all external areas are accessed with one wait state.
5. When setting one wait in multiplexed bus, the bus cycle is the same as two waits.

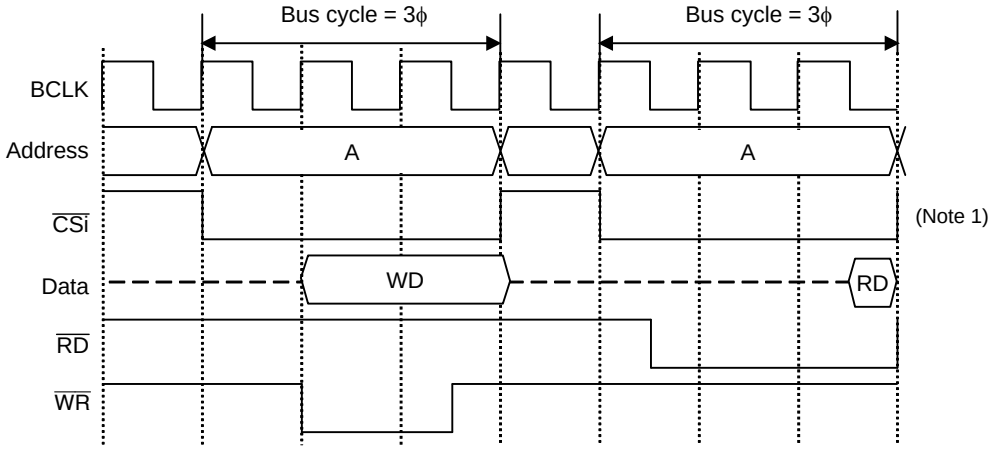
(1) Separate Bus, No Wait States



(2) Separate Bus, One Wait State (1ϕ + 1ϕ)



(3) Separate Bus, Two Wait States (1ϕ + 2ϕ)

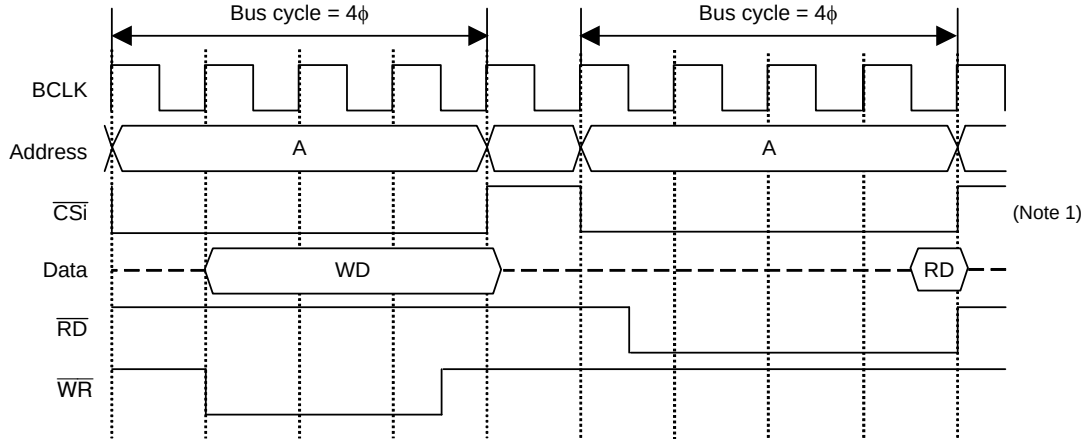


i = 0 to 3
A: Address RD: Read data (input) WD: Write data (output)

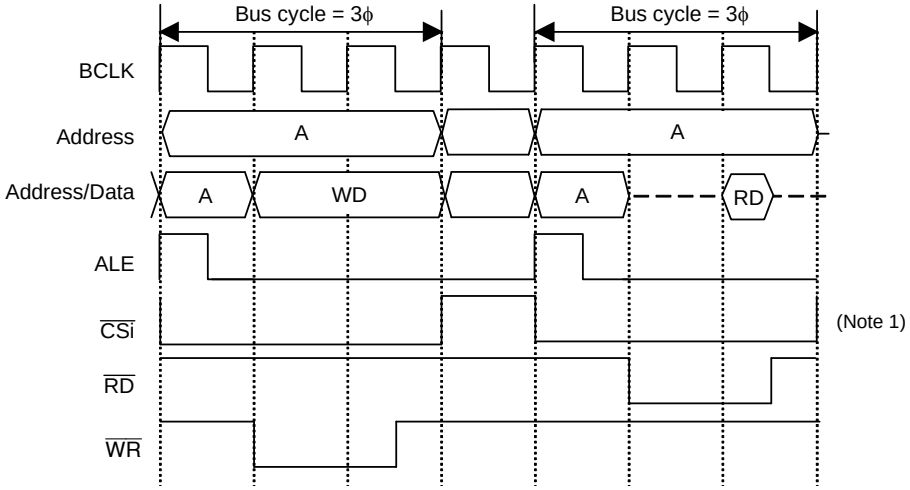
Note:
1. When consecutively accessing the same chip-select area, $\overline{CSi}$ continues outputting a low level.

Figure 11.6 Typical Bus Timings Using Software Wait States (1/2)

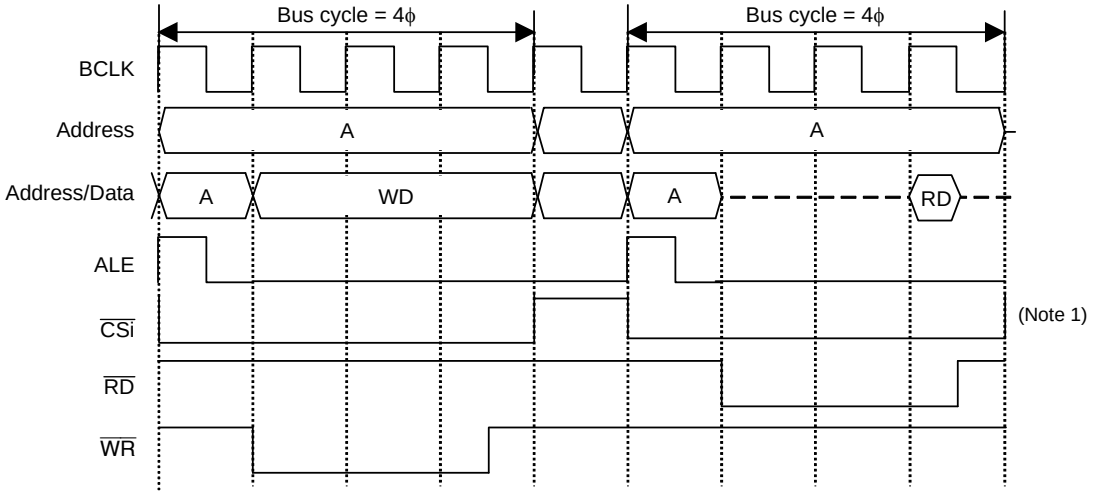
(1) Separate Bus, Three Wait States (1ϕ + 3ϕ)



(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, $\overline{CSi}$ continues outputting a low level.

Figure 11.7 Typical Bus Timings Using Software Wait States (2/2)

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 Access Immediately after Writing to the SFRs

When accessing an external device after writing to the SFRs, the write signal and $\overline{CSi}$ signal switch simultaneously. Thus, adjust the capacity of each signal so as not to delay the write signal.

11.4.3 $\overline{HOLD}$

$\overline{HOLD}$ input is unavailable. Connect the $\overline{HOLD}$ 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 $\overline{CSi}$ (i = 0 to 3) signal is referred to as the $\overline{CSi}$ area.

Table 12.1 Memory Space Expansion Function Specifications

Item	Specification
1-MB mode	• Memory space 1 MB (no expansion) • Specify the external area ($\overline{CSi}$ area) accessed by the $\overline{CSi}$ signal.

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.

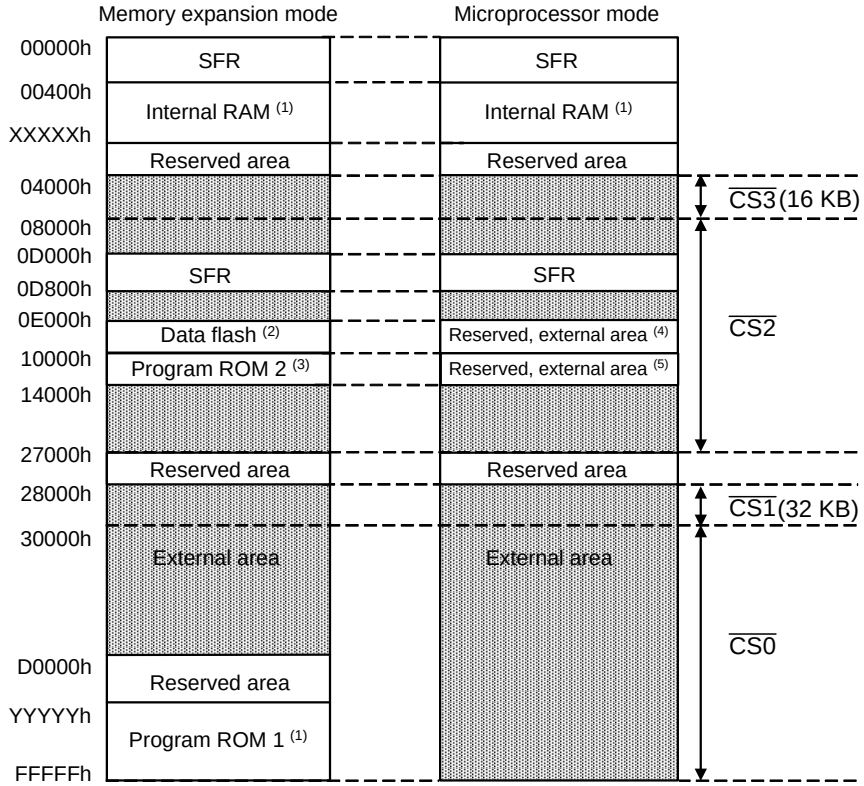
Table 12.2 Registers

Address	Register	Symbol	Reset Value
0005h	Processor Mode Register 1	PM1	0000 1000b

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:

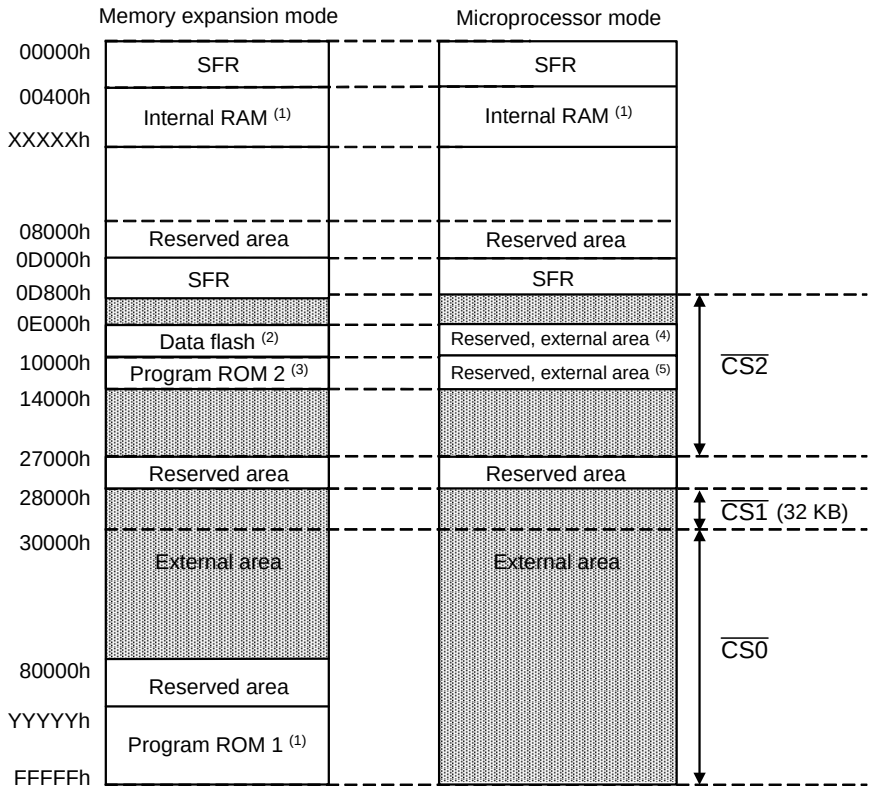
1. When the PM13 bit in the PM1 register is 0, 15 KB of the internal RAM and 192 KB of the internal ROM can be used. See the table below for addresses XXXXXh and YYYYYh.

Internal RAM	
Capacity	Address XXXXXh
12 KB	033FFh
20 KB	03FFFh
31 KB	03FFFh

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

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 $\overline{CS}$ Areas in 1-MB Mode (PM13 = 1)

13. Programmable I/O Ports

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

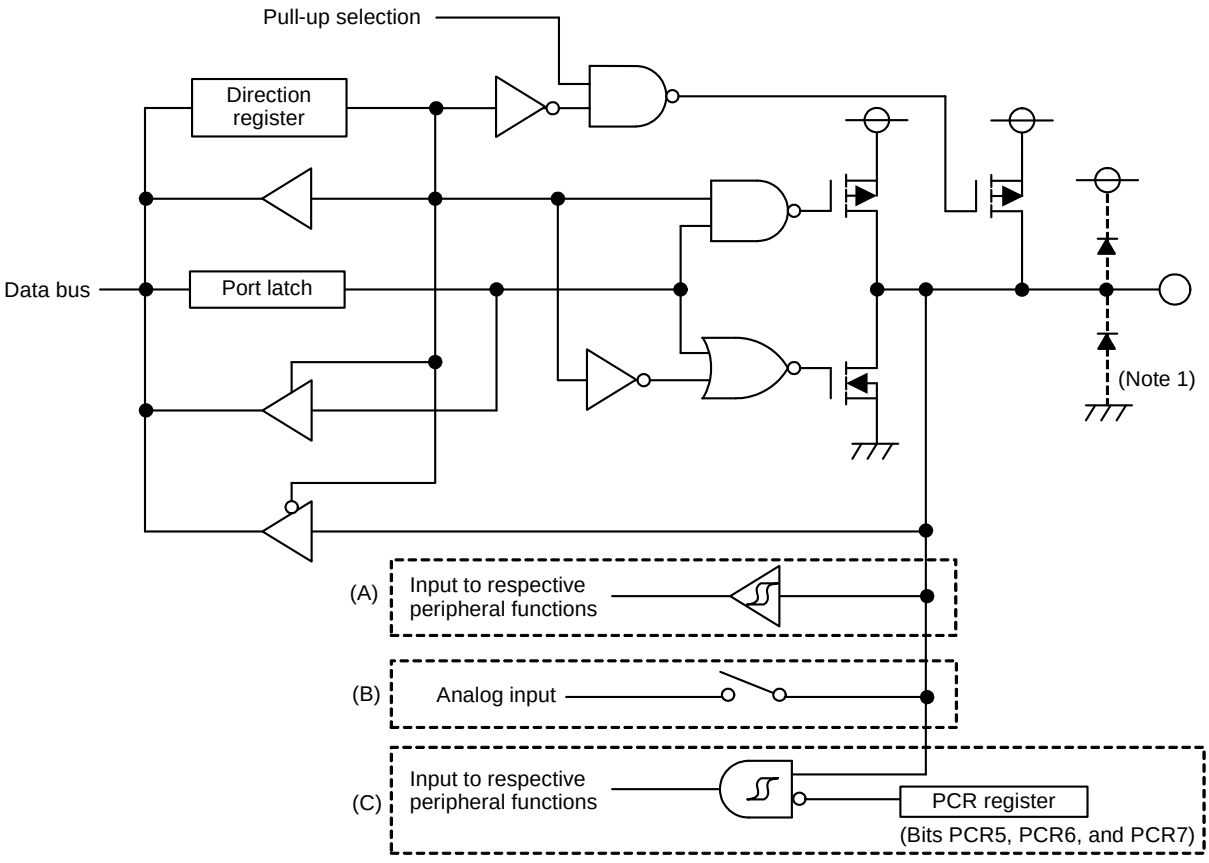
Item		Specification
Number of ports	Total	88
	CMOS output	85
	N-channel open drain output	3
Input/output	VCC2 level	P0 to P5
	VCC1 level	P6 to P10
Input/output level		Select input or output for each individual port by a program.
Select function		Select a pull-up resistor in 4-bit units.

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	I/O	Input/output port CMOS output, pull-up resistor selectable

13.2 I/O Ports and Pins

Figure 13.1 to Figure 13.10 and Table 13.3 to Table 13.8 show the I/O port configuration, and Figure 13.11 shows the I/O pin configuration.



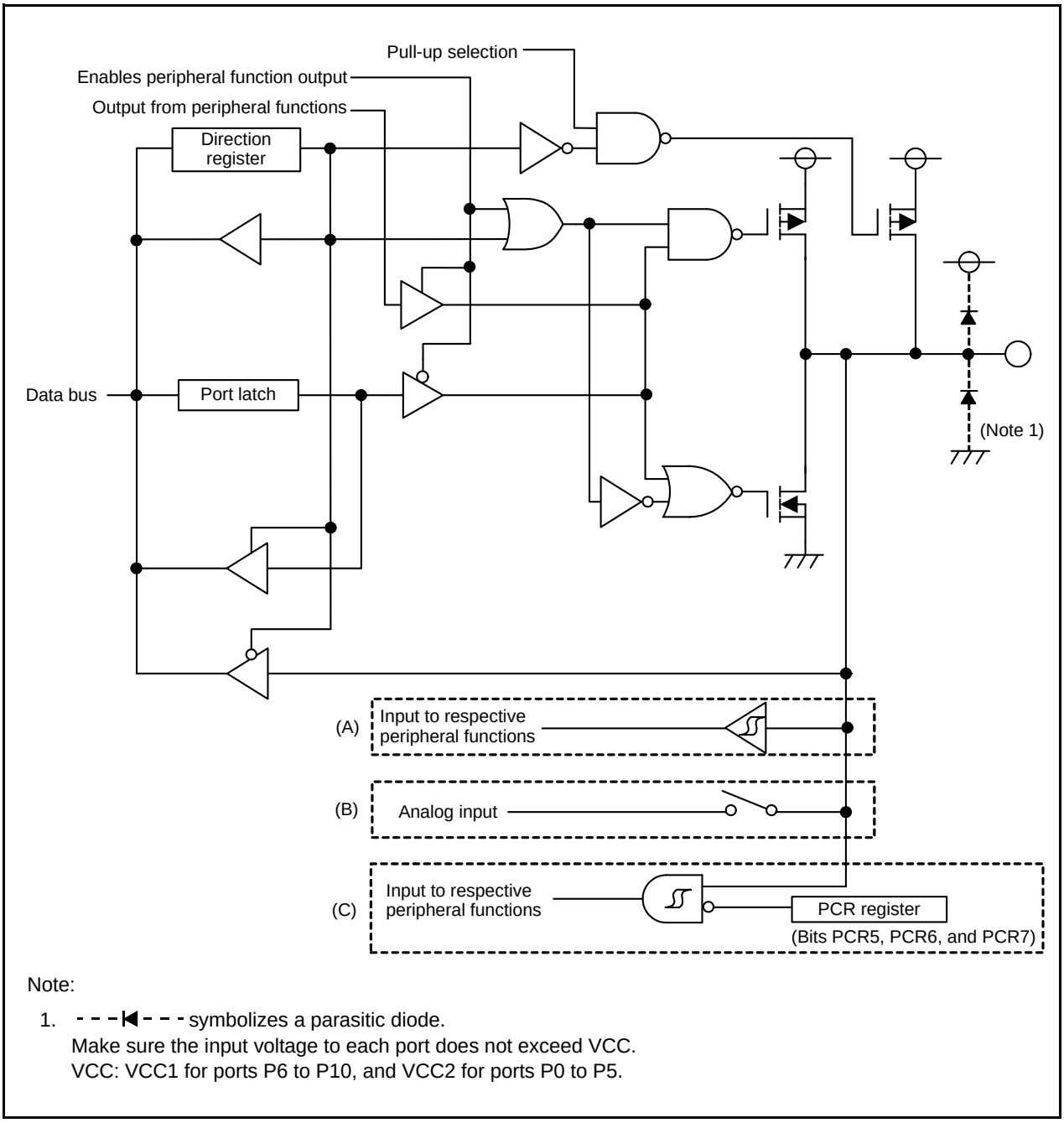
Note:

1. - - -|◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P10, and VCC2 for ports P0 to P5.

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_7, P5_0 to P5_4, P5_6,	N/A	N/A	N/A
P0_0 to P0_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	Available	N/A	N/A
P10_4 to P10_7	N/A	Available	Available



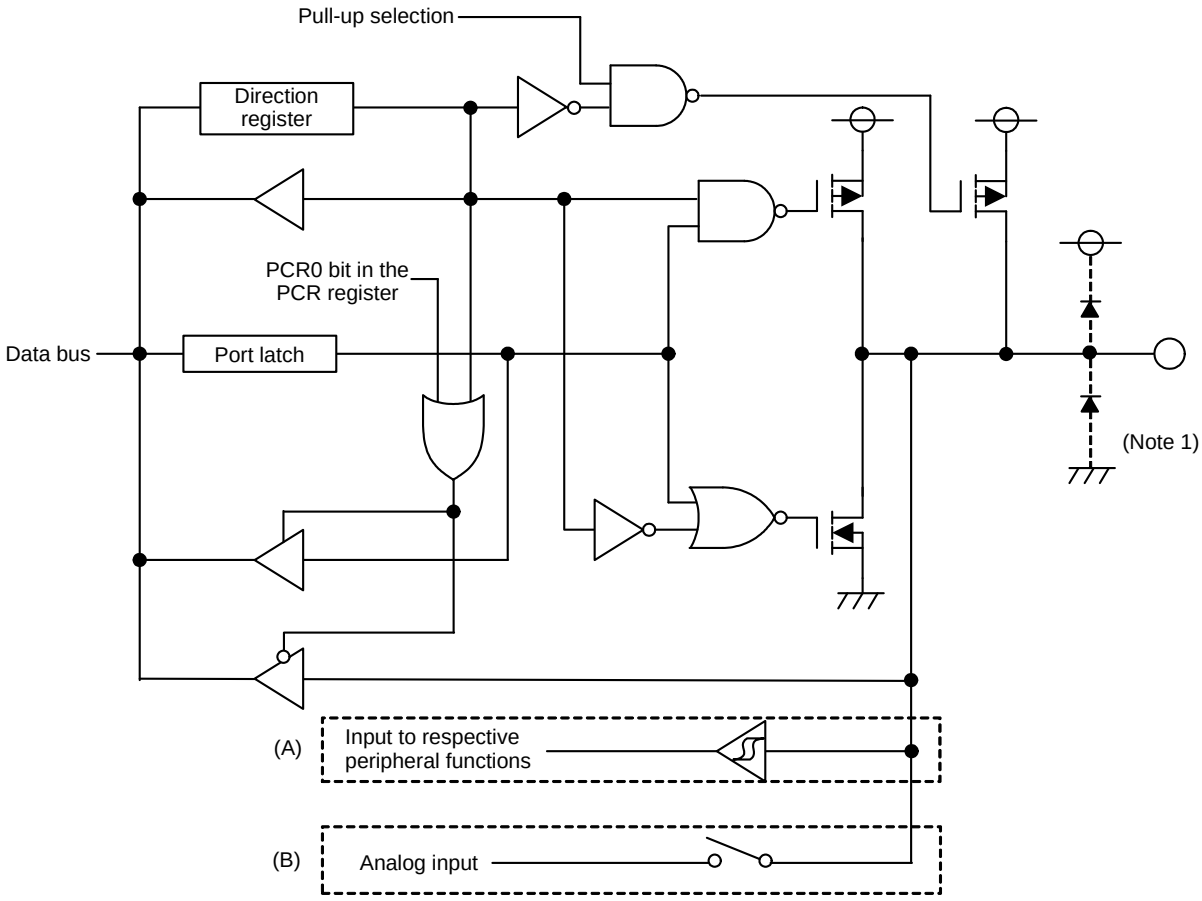
Note:

1. - - - ◀ - - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P10, and VCC2 for ports P0 to P5.

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	Peripheral function input (C) in Figure 13.2
P6_0, P6_4, P7_3 to P7_5, P8_1	Available	N/A	N/A
P2_4, P2_5	Available	Available	Available
P2_0 to P2_3, P2_6, P2_7	Available	Available	N/A
P5_7	Available ($\overline{RDY}$)	N/A	N/A



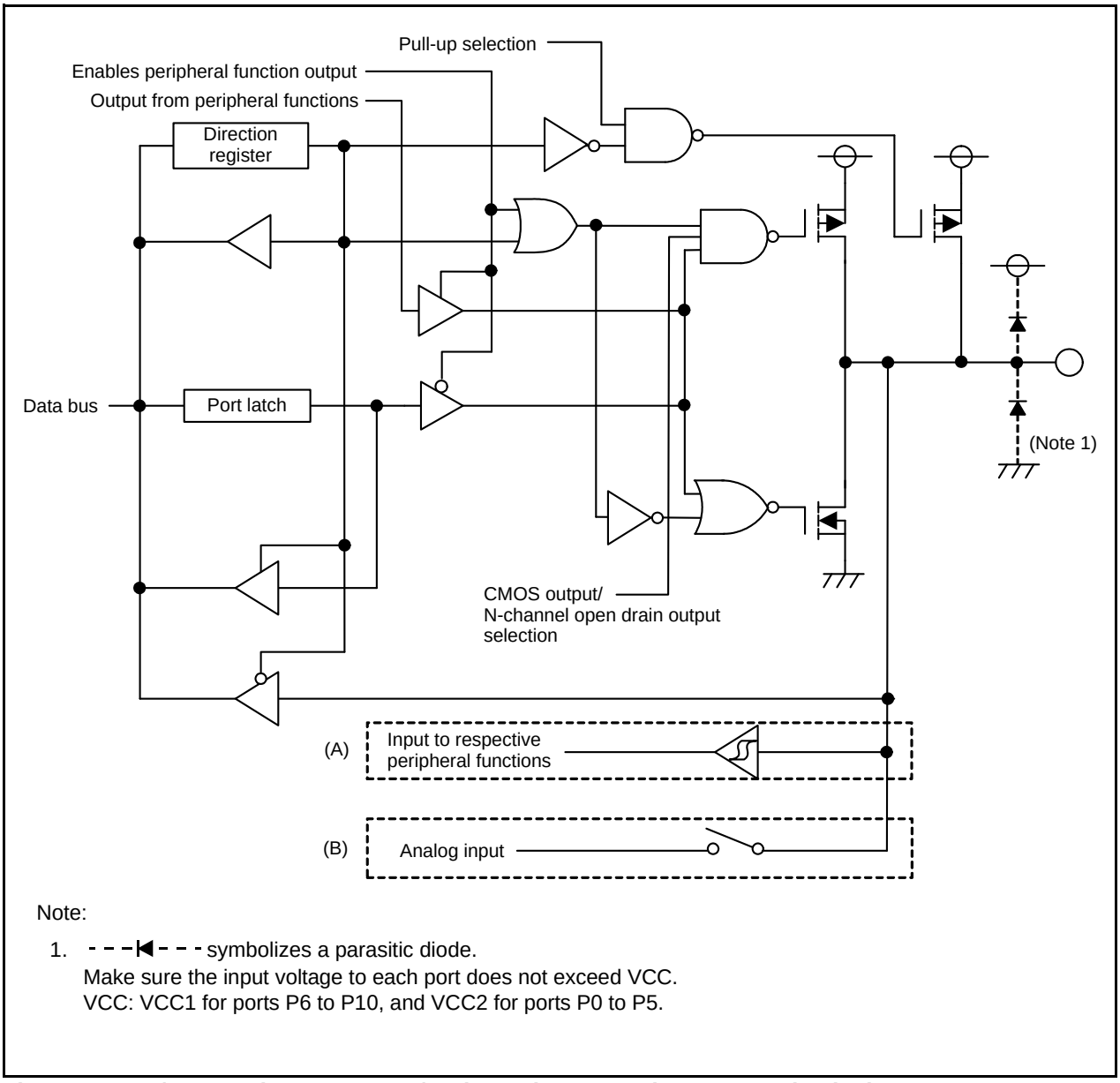
Note:

1. - - -|◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P10, and VCC2 for ports P0 to P5.

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_0 to P1_4	N/A	N/A
P1_5 to P1_7	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 P10, and VCC2 for ports P0 to P5.

Figure 13.4 I/O Ports (CMOS Output/N-channel Open Drain Output Selection)

Table 13.6 I/O Ports (CMOS Output/N-channel Open Drain Output Selection)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.4	Analog input (B) in Figure 13.4
P6_1 to P6_3, P6_5 to P6_7, P7_2, P7_6, P7_7, P8_0, P9_7	Available	N/A
P9_5, P9_6	Available	Available

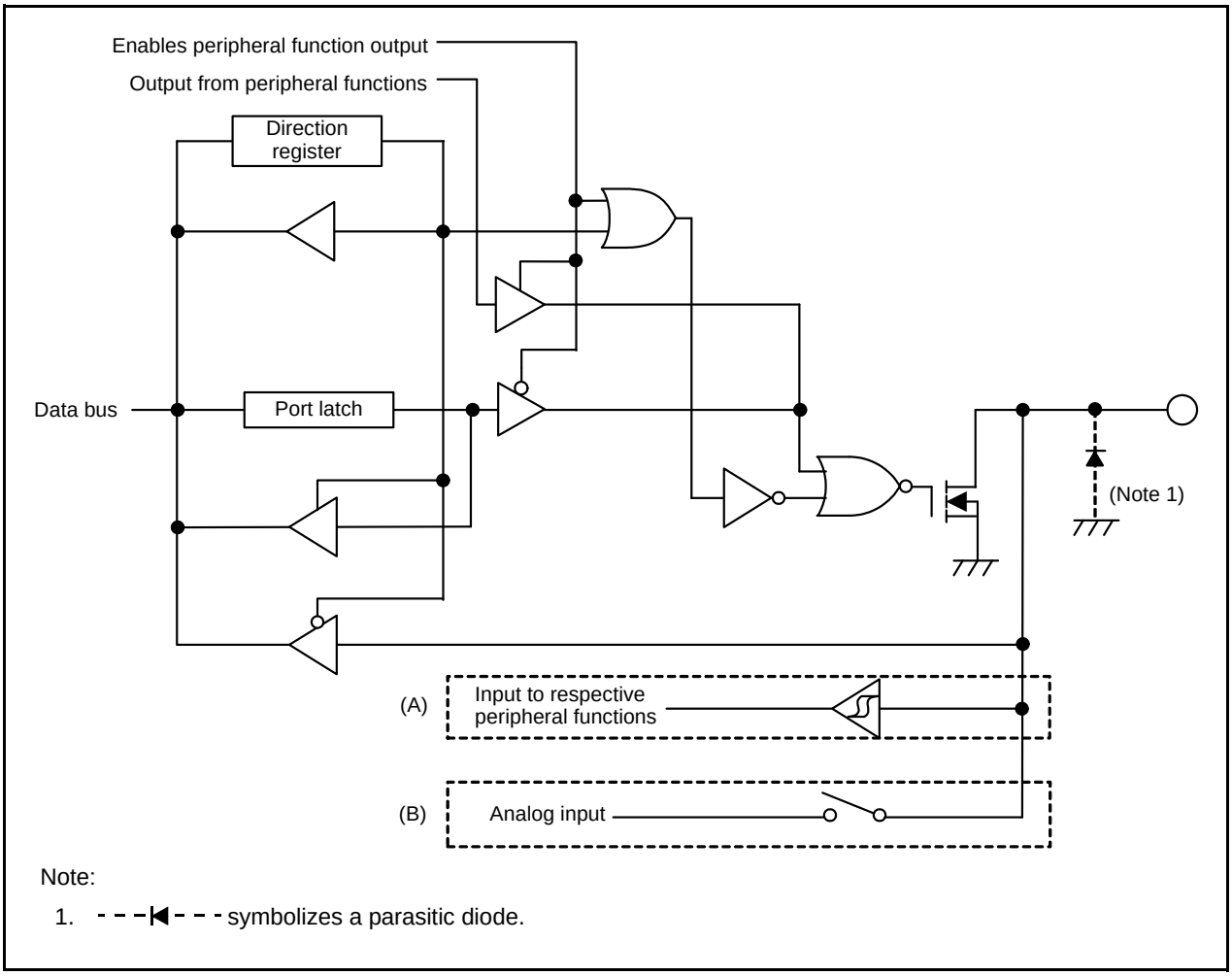
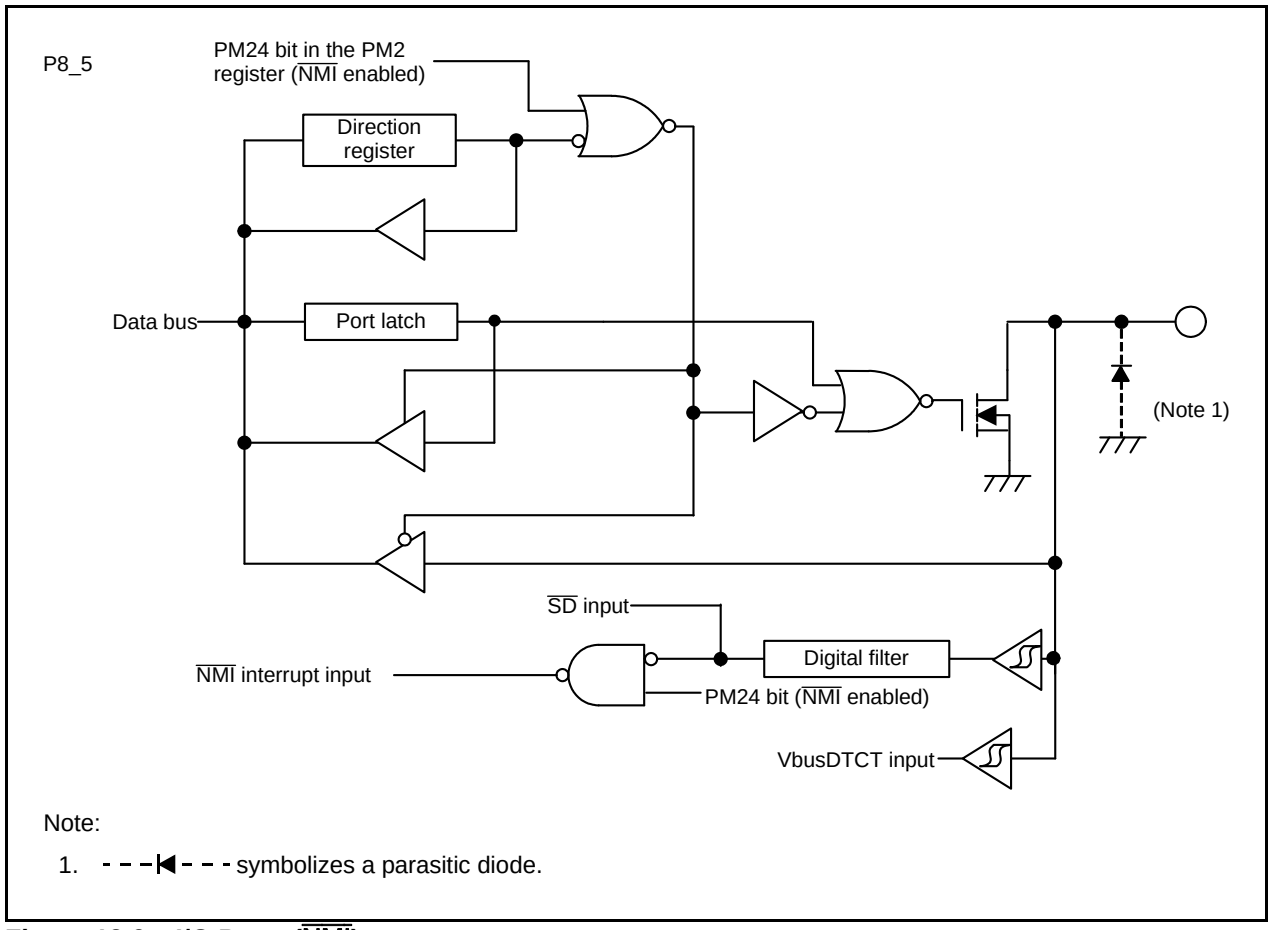


Figure 13.5 I/O Ports (N-channel Open Drain Output)

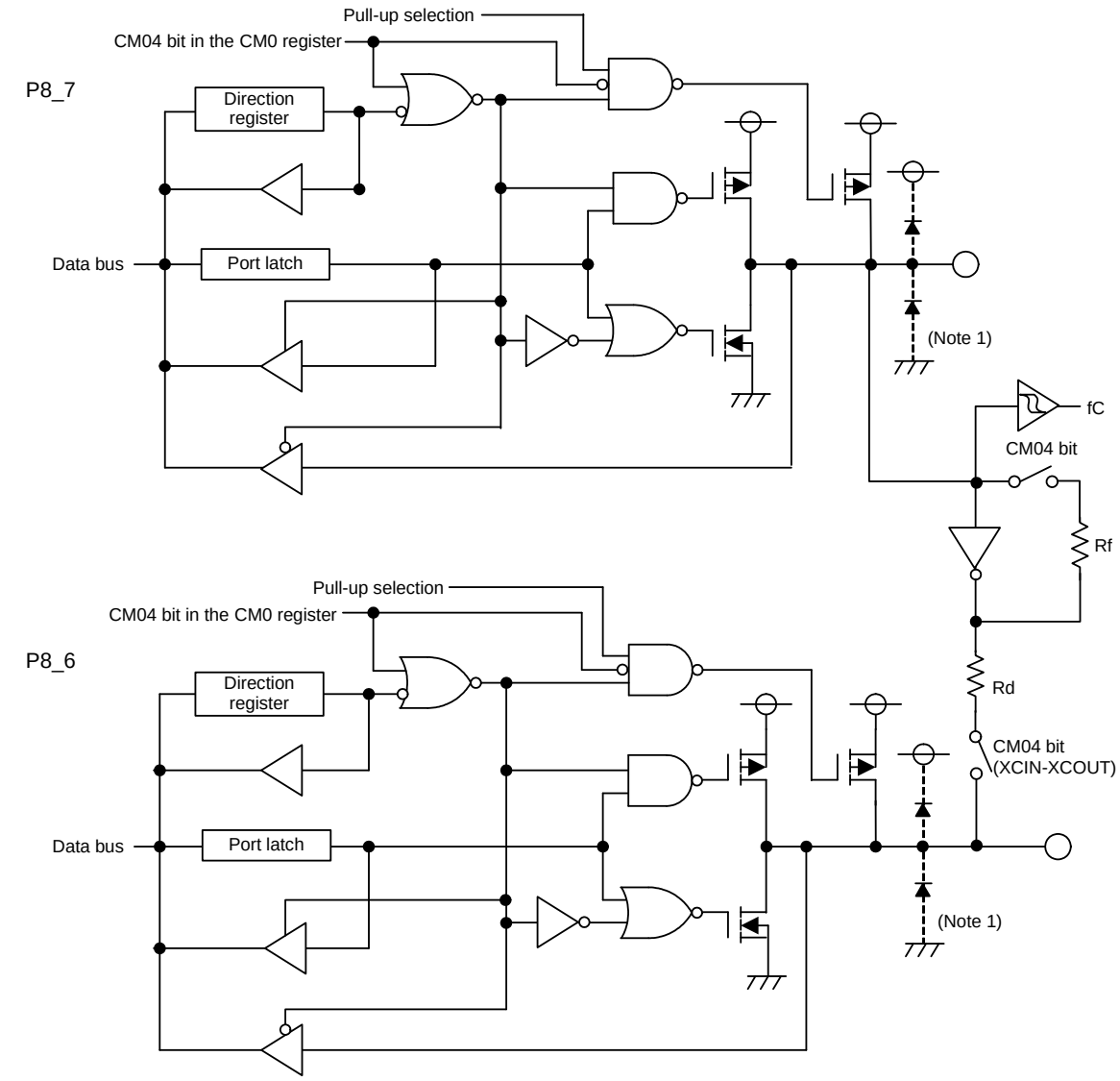
Table 13.7 I/O Ports (N-channel Open Drain Output)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.5	Analog input (B) in Figure 13.5
P7_0, P7_1	Available	N/A



Note:
1. - - - ◀ - - - symbolizes a parasitic diode.

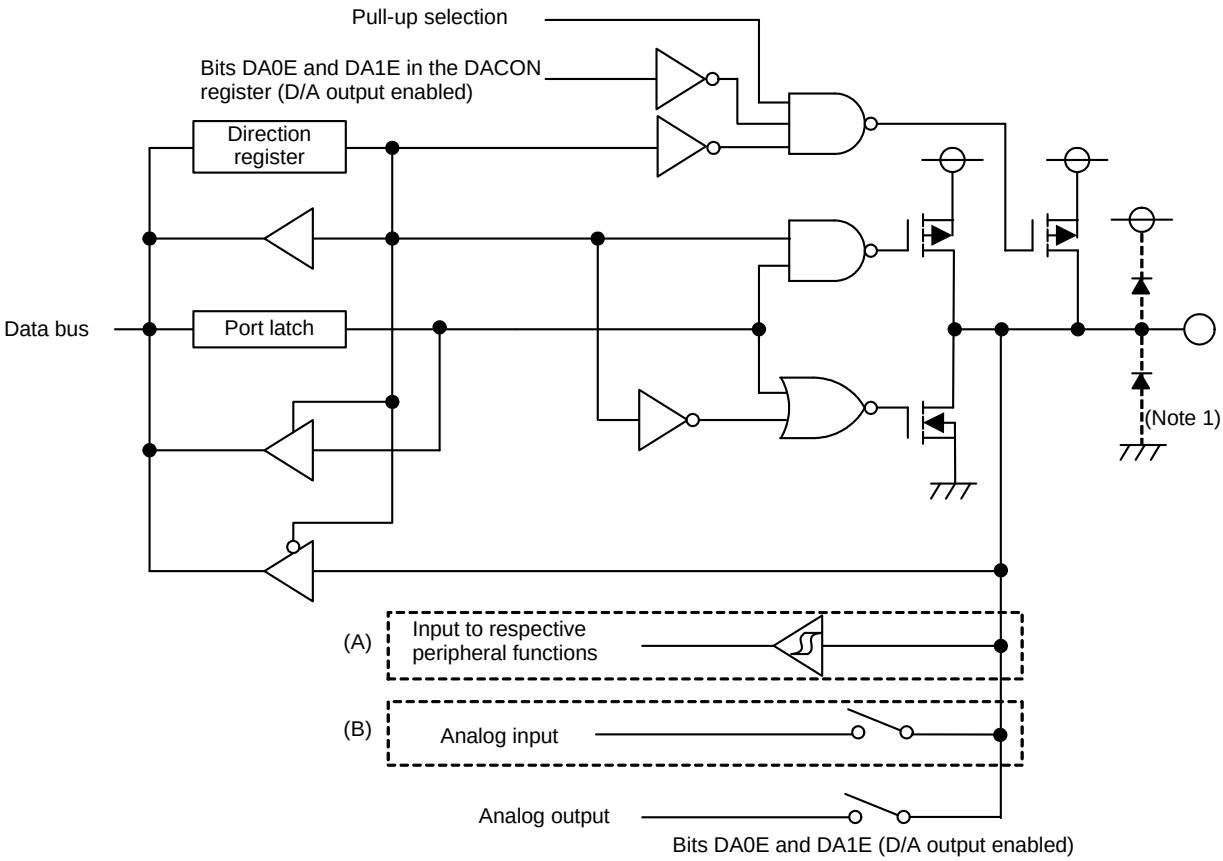
Figure 13.6 I/O Ports ($\overline{\text{NMI}}$)



Note:

1. - - -◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P10, and VCC2 for ports P0 to P5.

Figure 13.7 I/O Ports (XC)



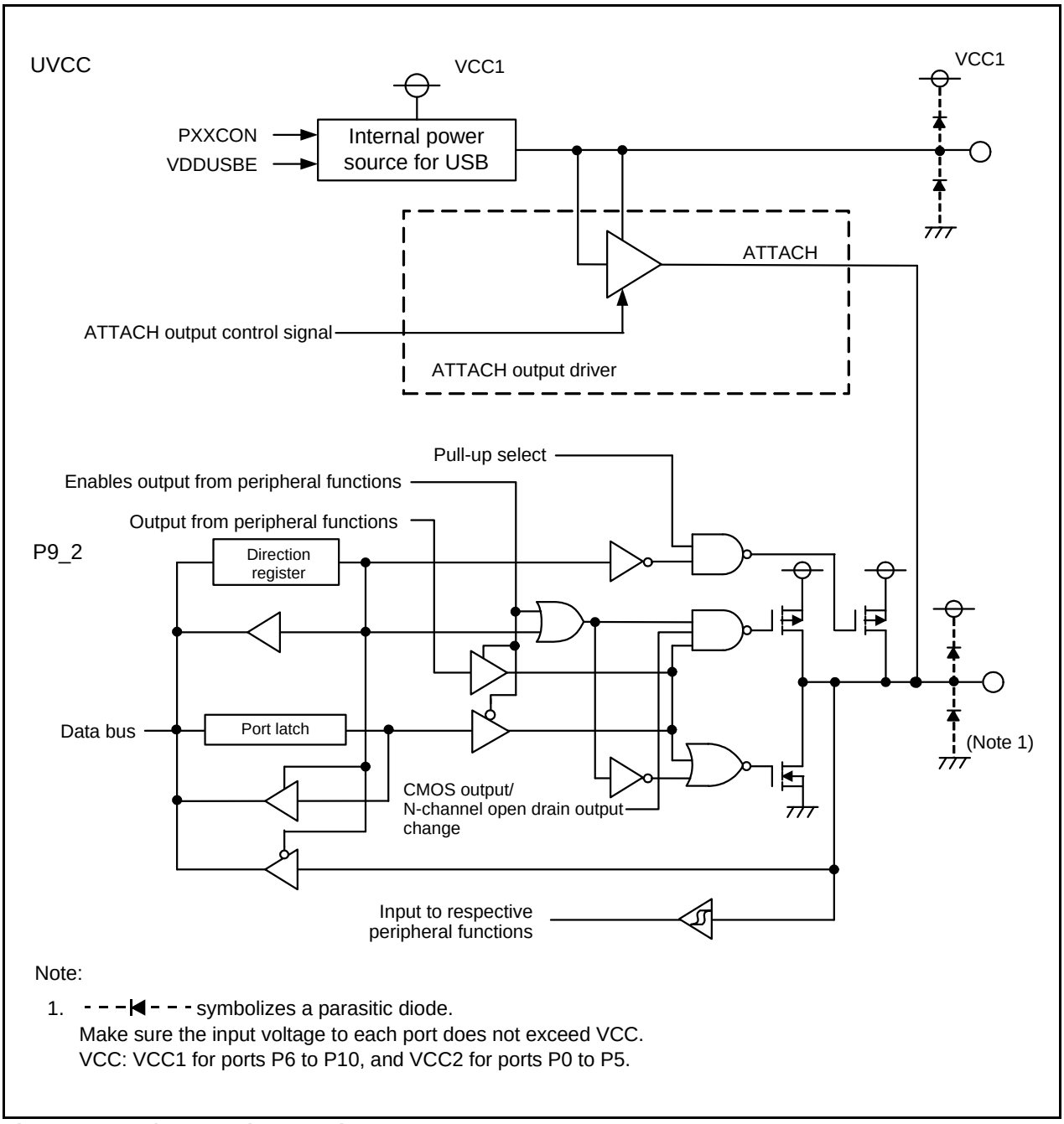
Note:

1. - - -◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P10, and VCC2 for ports P0 to P5.

Figure 13.8 I/O Ports (D/A)

Table 13.8 I/O Ports (D/A)

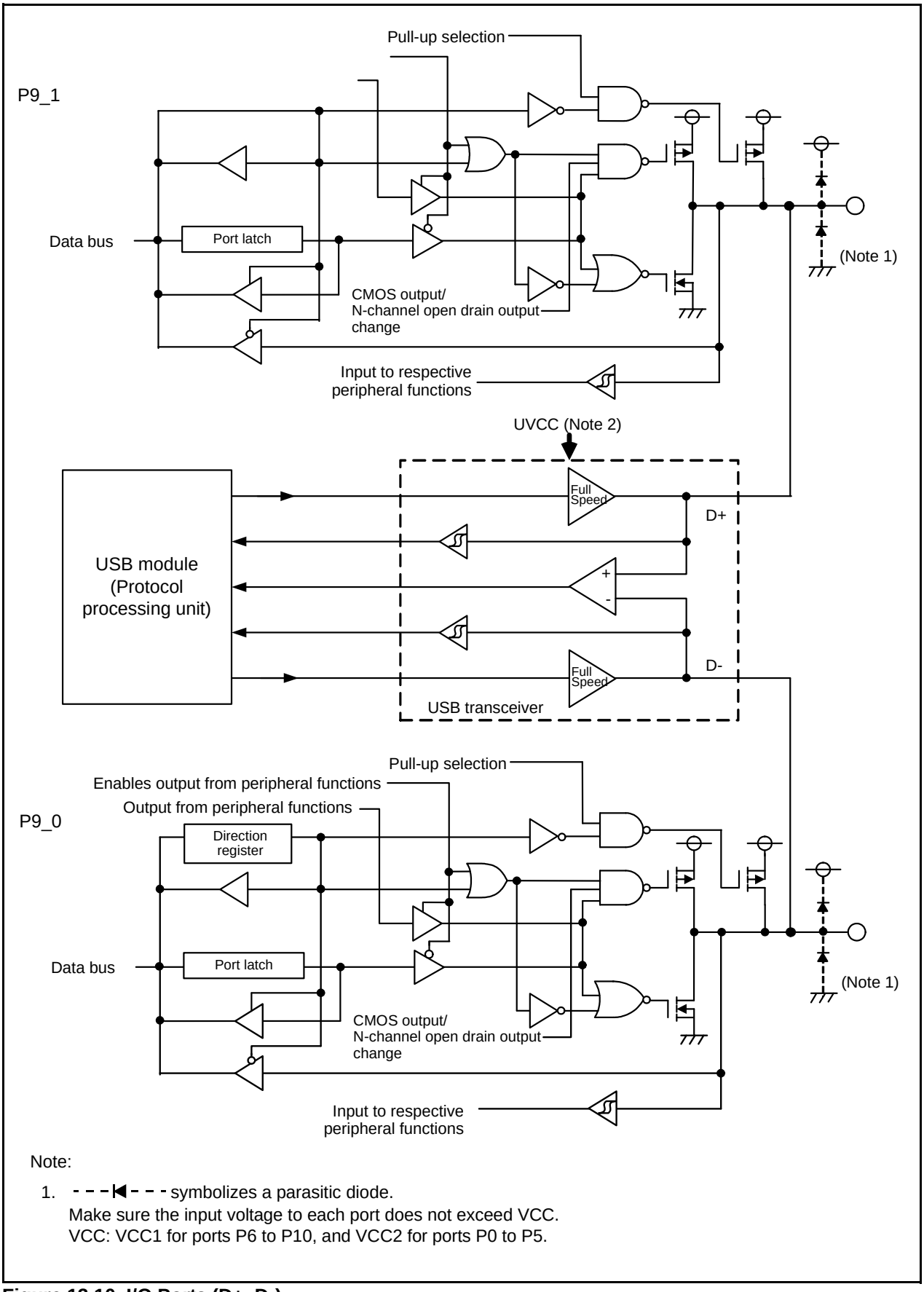
Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.8	Analog input (B) in Figure 13.8
P9_3, P9_4	Available	N/A



Note:

1. - - -◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P10, and VCC2 for ports P0 to P5.

Figure 13.9 I/O Ports (ATTACH)



Note:

1. - - - ◀ - - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P10, and VCC2 for ports P0 to P5.

Figure 13.10 I/O Ports (D+, D-)

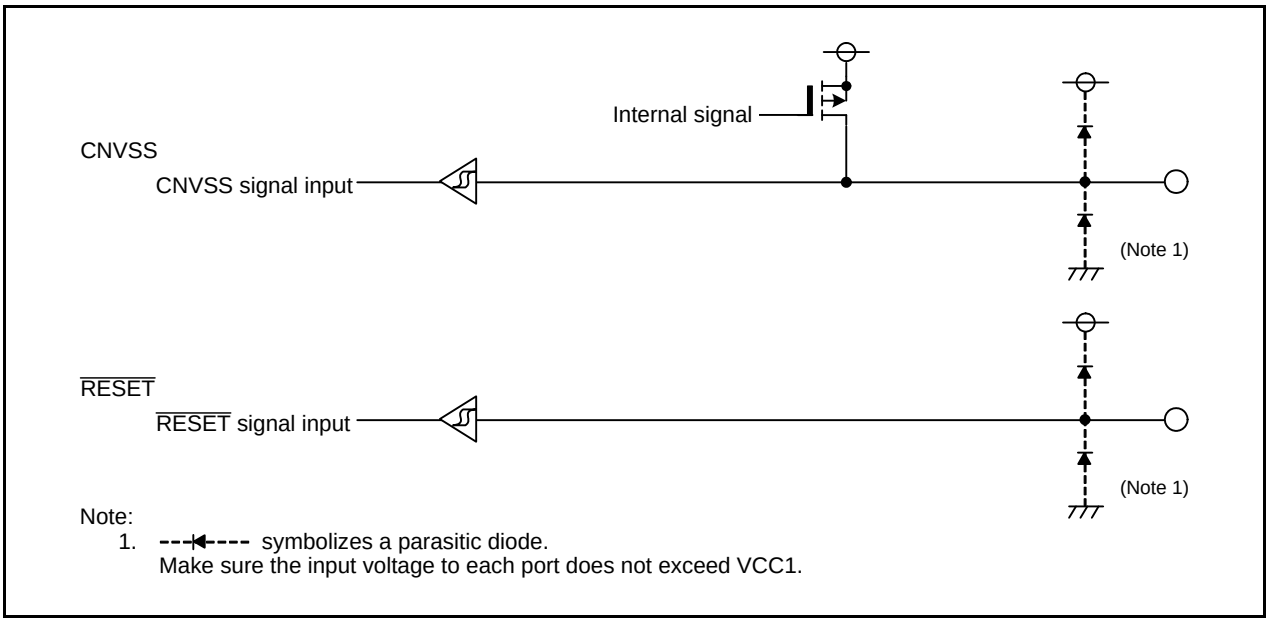


Figure 13.11 I/O Pins

13.3 Registers

Table 13.9 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
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
03F6h	Port P10 Direction Register	PD10	00h

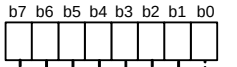
Note:

1. Values after hardware reset, power-on reset, or voltage monitor 0 reset are as follows:
   - 00000000b

   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: PUR0 | Address: 0360h | Reset Value: 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

b7	b6	b5	b4	b3	b2	b1	b0

Symbol: PUR1 — Address: 0361h — Reset Value: 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

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)

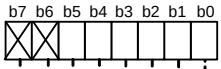
When the PU1i (i = 4, 5, 7) bit is 1 (pulled high) and the direction bit is 0 (input mode), the corresponding pin is pulled high.

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: PUR2 | Address: 0362h | Reset Value: 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)

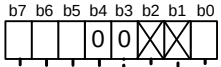
When the PU2i (i = 0, 2 to 5) bit is 1 (pulled high) and the direction bit is 0 (input mode), the corresponding pin is pulled high.

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 Port Control Register (PCR)

Port Control Register



Symbol: PCR | Address: 0366h | Reset Value: 0000 0XX0b

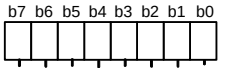
Bit Symbol	Bit Name	Function	RW
PCR0	Port P1 control bit	Operation performed when the P1 register is read 0 : When the port is set to input, the input levels of pins P1_0 to P1_7 are read. When set to output, the port latch is read. 1 : The port latch is read regardless of whether the port is set to 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
— (b4)	Reserved bit	Set to 0.	RW
PCR5	$\overline{INT6}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR6	$\overline{INT7}$ 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.

13.3.5 Port Pi Register (Pi) (i = 0 to 10)

Port Pi Register (i = 0 to 10)



Symbol	Address	Reset Value
P0 to P3	03E0h, 03E1h, 03E4h, 03E5h	XXh
P4 to P7	03E8h, 03E9h, 03ECh, 03EDh	XXh
P8 to P10	03F0h, 03F1h, 03F4h	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

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.

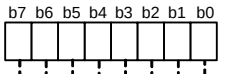
In memory expansion and microprocessor modes, the Pi register for the pins functioning as bus control pins (A0 to A19, D0 to D7, $\overline{CS0}$ to $\overline{CS3}$, $\overline{RD}$, $\overline{WR}$, $\overline{BHE}$, ALE, $\overline{RDY}$, $\overline{HOLD}$, $\overline{HLDA}$, and BCLK) cannot be modified (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.

13.3.6 Port Pi Direction Register (PDi) (i = 0 to 10)

Port Pi Direction Register (i = 0 to 10)



Symbol	Address	Reset Value
PD0 to PD3	03E2h, 03E3h, 03E6h, 03E7h	00h
PD4 to PD7	03EAh, 03EBh, 03EEh, 03EFh	00h
PD8 to PD10	03F2h, 03F3h, 03F6h	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

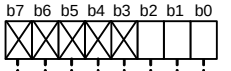
Write to the PD9 register in the next instruction after setting the PRC2 bit in the PRCR register to 1 (write enabled).

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 D7, $\overline{CS0}$ to $\overline{CS3}$, $\overline{RD}$, $\overline{WR}$, $\overline{BHE}$, ALE, $\overline{RDY}$, $\overline{HOLD}$, $\overline{HLDA}$, and BCLK) cannot be modified (writing a value has no effect).

13.3.7 $\overline{NMI}/\overline{SD}$ Digital Filter Register (NMIDF)

$\overline{NMI}/\overline{SD}$ Digital Filter Register



Symbol	Address	Reset Value
NMIDF	0369h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
NMIDF0	$\overline{NMI}/\overline{SD}$ 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 ($\overline{NMI}$ 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 ($\overline{NMI}$ 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 1.4 to Table 1.5 “Pin Names, Pin Package”). Some peripheral function I/O are affected by a port direction bit which shares the same pin. Table 13.10 lists Setting of Direction Bits Functioning as Peripheral Function I/O. For peripheral function settings, see descriptions of each function.

Table 13.10 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	D/A converter	Set to 0 (input mode).
	USB module (ATTACH)	Set to 0 (input mode).
	Others	Set to either 0 or 1 (outputs regardless of the direction bit setting).
I/O	USB module (D+, D-)	Set to 0 (input mode).

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 $\overline{\text{NMI}}/\overline{\text{SD}}$ Digital Filter

The $\overline{\text{NMI}}/\overline{\text{SD}}$ input function includes a digital filter. A sampling clock can be selected by bits NMIDF2 to NMIDF0 in the NMIDF register. The $\overline{\text{NMI}}$ 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 $\overline{\text{NMI}}/\overline{\text{SD}}$ digital filter, do not enter wait mode or stop mode.
Port P8_5 is not affected by the digital filter.
Figure 13.12 shows $\overline{\text{NMI}}/\overline{\text{SD}}$ Digital Filter, and Figure 13.13 shows $\overline{\text{NMI}}/\overline{\text{SD}}$ Digital Filter Operation Example.

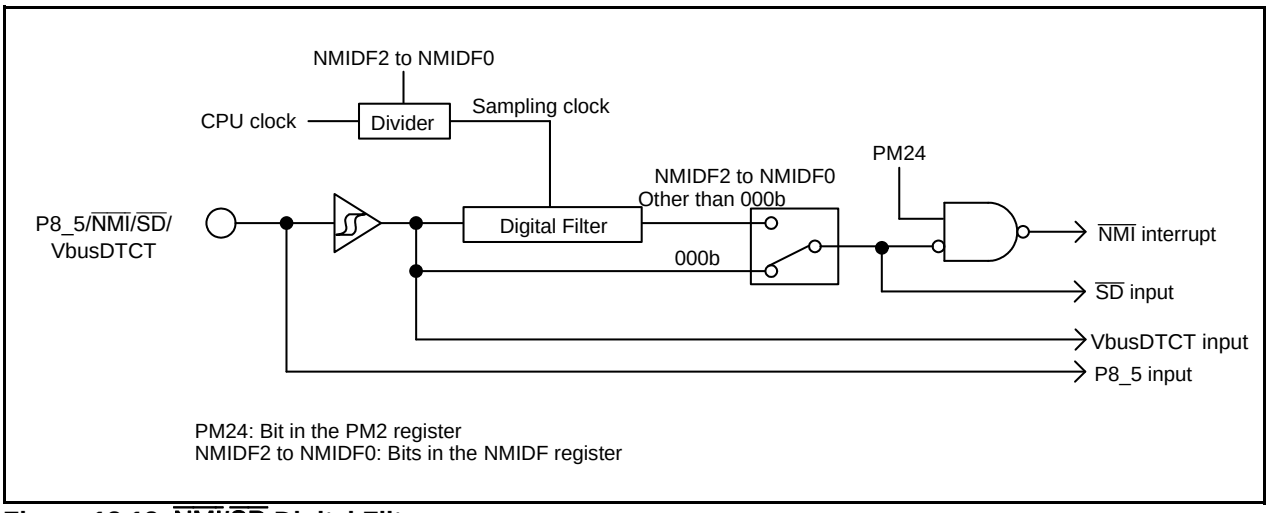


Figure 13.12 $\overline{\text{NMI}}/\overline{\text{SD}}$ Digital Filter

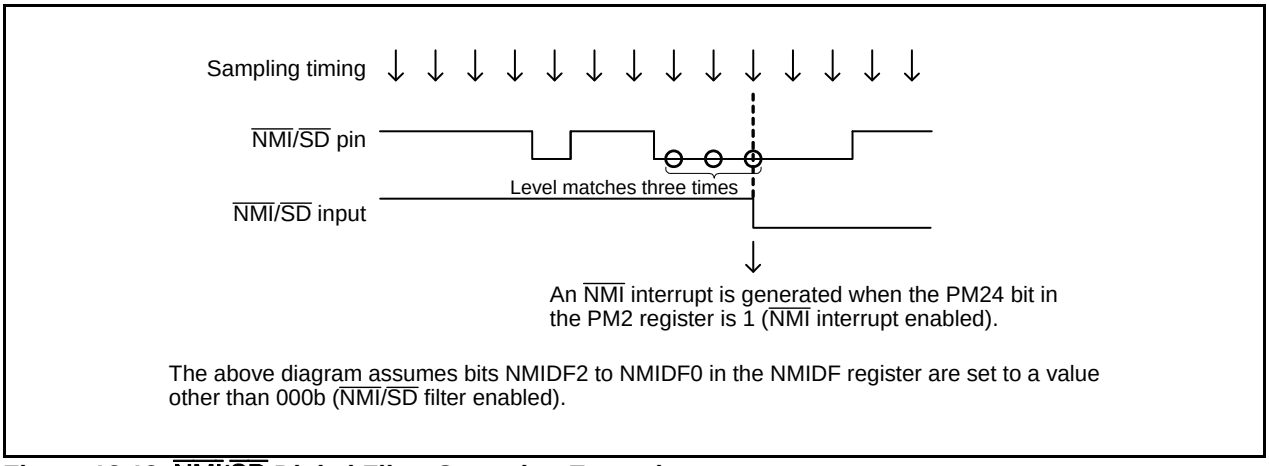


Figure 13.13 $\overline{\text{NMI}}/\overline{\text{SD}}$ Digital Filter Operation Example

13.4.4 CNVSS Pin

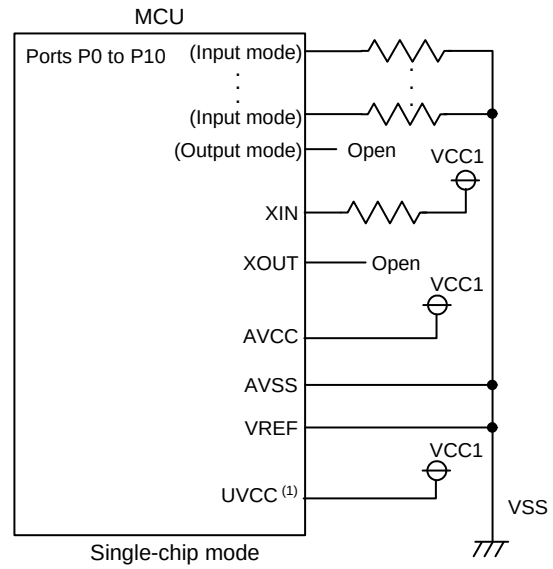
The built-in pull-up resistor of the CNVSS pin is activated after watchdog timer reset, hardware reset, power-on reset, or voltage monitor 0 reset. Thus, the CNVSS pin outputs a high-level signal up to two cycles of fOCO-S. Connect the CNVSS pin to VSS via a resistor to use it in single-chip mode.

13.5 Unassigned Pin Handling

Table 13.11 Unassigned Pin Handling in Single-Chip Mode

Pin Name	Connection (2)
Ports P0 to P5	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 P10	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	Connect to VSS
UVCC	Set PXXCON bit in the USBMC register 0 and do the following process. • Connect to VCC1

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.



Note:
1. Set the PXXCON bit in the USBMC register to 0.

Figure 13.14 Unassigned Pin Handling in Single-Chip Mode

Table 13.12 Unassigned Pin Handling in Memory Expansion Mode and Microprocessor Mode

Pin Name	Connection (2)
Ports P0 to P5	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 P10	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)
$\overline{BHE}$, ALE, $\overline{HLDA}$, XOUT (5), BCLK (6)	Open
$\overline{HOLD}$, $\overline{RDY}$	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
UVCC	Set PXXCON bit in the USBMC register 0 and do the following process. • Connect to VCC1

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).

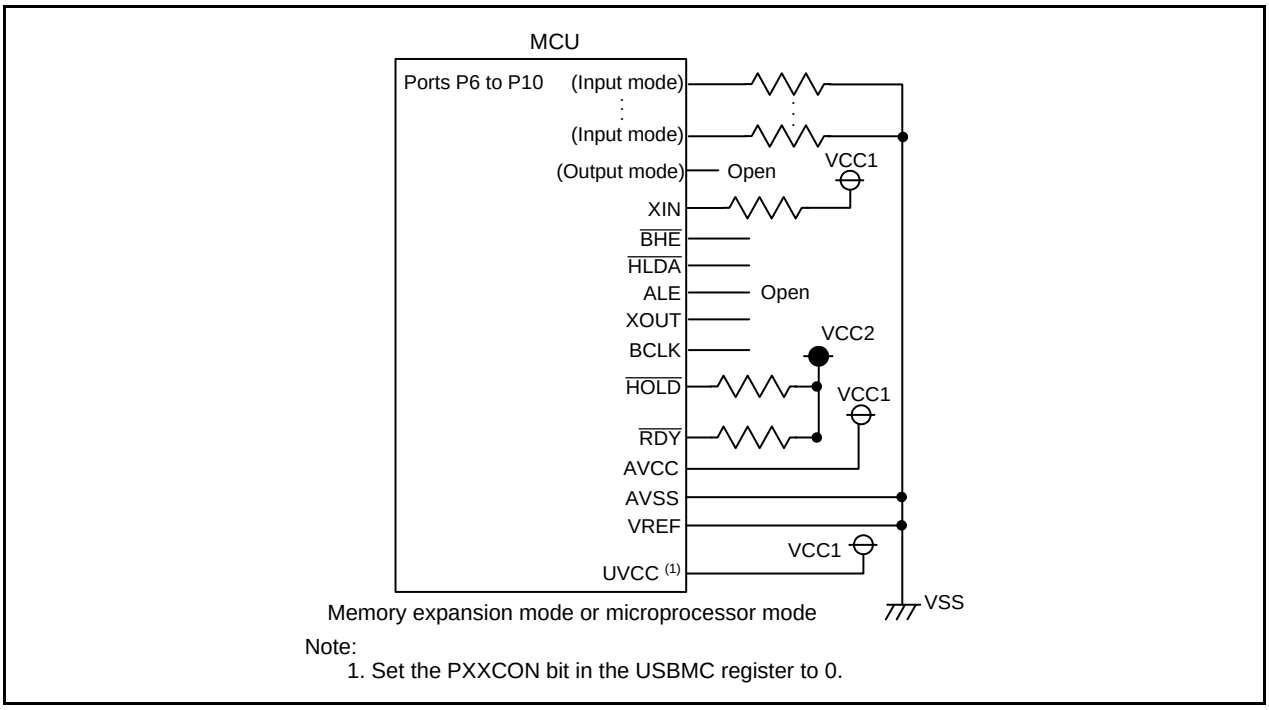


Figure 13.15 Unassigned Pin Handling in Memory Expansion Mode and Microprocessor Mode

13.6 Notes on Programmable I/O Ports

13.6.1 Influence of $\overline{SD}$

When a low-level signal is applied to the $\overline{SD}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{SD}$ pin enabled), the following pins become high-impedance: P7_2/CLK2/TA1OUT/V, P7_3/$\overline{CTS2}$/$\overline{RTS2}$/TA1IN/$\overline{V}$, P7_4/TA2OUT/W, P7_5/TA2IN/$\overline{W}$, P8_0/TA4OUT/RXD5/SCL5/U/TSUDA, P8_1/TA4IN/$\overline{CTS5}$/$\overline{RTS5}$/$\overline{U}$/TSUDB

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)

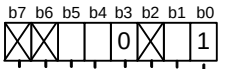
Address	Register	Symbol	Reset Value
001Eh	Processor Mode Register 2	PM2	XX00 0X01b
0042h	$\overline{\text{INT7}}$ Interrupt Control Register	INT7IC	XX00 X000b
0043h	$\overline{\text{INT6}}$ Interrupt Control Register	INT6IC	XX00 X000b
0044h	$\overline{\text{INT3}}$ Interrupt Control Register	INT3IC	XX00 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	$\overline{\text{INT5}}$ Interrupt Control Register	INT5IC	XX00 X000b
0049h	$\overline{\text{INT4}}$ Interrupt Control Register	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, A/D Conversion (A/D1) Interrupt Control Register	KUPIC, ADEIC	XXXX X000b
004Eh	A/D Conversion (A/D0) 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	U5BCNIC	XXXX X000b
006Ch	UART5 Transmit Interrupt Control Register	S5TIC	XXXX X000b
006Dh	UART5 Receive Interrupt Control Register	S5RIC	XXXX X000b
006Eh	UART4 Bus Collision Detection Interrupt Control Register, Real-Time Clock Periodic Interrupt Control Register	U4BCNIC, RTCTIC	XXXX X000b

Table 14.4 Registers (2/2)

Address	Register	Symbol	Reset Value
006Fh	UART4 Transmit Interrupt Control Register, Real-Time Clock Compare Interrupt Control Register	S4TIC, RTCCIC	XXXX X000b
0070h	UART4 Receive Interrupt Control Register	S4RIC	XXXX X000b
0071h	UART3 Bus Collision Detection Interrupt Control Register	U3BCNIC	XXXX X000b
0072h	UART3 Transmit Interrupt Control Register,	S3TIC,	XXXX X000b
0073h	UART3 Receive Interrupt Control Register	S3RIC	XXXX X000b
0076h	USB Interrupt 0 Control Register	USBINT0IC	XXXX X000b
0077h	USB Interrupt 1 Control Register	USBINT1IC	XXXX X000b
0078h	USB RESUME Interrupt Control Register	USBRSMIC	XXXX X000b
0079h	IC/OC Interrupt 0 Control Register	ICOC0IC	XXXX X000b
007Ah	IC/OC Channel 0 Interrupt Control Register	ICOCH0IC	XXXX X000b
007Bh	IC/OC Interrupt 1 Control Register I2C-bus Interface Interrupt Control Register	ICOC1IC IICIC	XXXX X000b
007Ch	IC/OC Channel 1 Interrupt Control Register SCL/SDA Interrupt Control Register	ICOCH1IC SCLDAIC	XXXX X000b
007Dh	IC/OC Channel 2 Interrupt Control Register	ICOCH2IC	XXXX X000b
007Eh	IC/OC Channel 3 Interrupt Control Register	ICOCH3IC	XXXX X000b
007Fh	IC/OC Base Timer Interrupt Control Register	BTIC	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: PM2 | Address: 001Eh | Reset Value: 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.		—

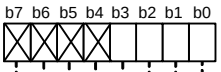
Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register.

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/ADEIC, ADIC, S0TIC to S2TIC, S0RIC to S2RIC, TA0IC to TA4IC, TB0IC to TB2IC, U5BCNIC, S5TIC, S3RIC to S5RIC, U4BCNIC/RTCTIC, S4TIC/RTCCIC, U3BCNIC,S3TIC, ICOC0IC, ICOCH0IC, ICOC1IC/IICIC, ICOCH1IC/SCLDAIC, ICOCH2IC to ICOCH3IC, BTIC)

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/ADEIC	004Dh
ADIC	004Eh
S0TIC	0051h
S1TIC	0053h
S2TIC	004Fh
S0RIC	0052h

Symbol	Address
S1RIC	0054h
S2RIC	0050h
TA0IC	0055h
TA1IC	0056h
TA2IC	0057h
TA3IC	0058h
TA4IC	0059h
TB0IC	005Ah
TB1IC	005Bh
TB2IC	005Ch
U5BCNIC	006Bh
S5TIC	006Ch
S3RIC	0073h
S4RIC	0070h
S5RIC	006Dh

Symbol	Address
U4BCNIC/RTCTIC	006Eh
S4TIC/RTCCIC	006Fh
U3BCNIC	0071h
S3TIC	0072h
ICOC0IC	0079h
ICOCH0IC	007Ah
ICOC1IC/IICIC	007Bh
ICOCH1IC/SCLDAIC	007Ch
ICOCH2IC	007Dh
ICOCH3IC	007Eh
BTIC	007Fh

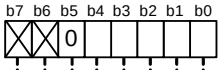
Rewrite these registers at a point where an interrupt request for the corresponding register is not generated.
When multiple interrupt sources share the register, select an interrupt source in registers IFSR2A and IFSR3A.

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, INT5IC, 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
INT5IC	0048h
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).

IR (Interrupt request bit) (b3)

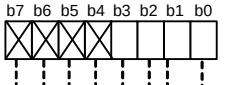
Do not set the IR bit to 1 when it is 0.

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).

14.2.4 Interrupt Control Register 3 (USBINT0IC, USBINT1IC, USBRSMIC)

Interrupt Control Register 3



Symbol

Address

Reset Value

Refer to the table below for symbols and addresses.

XXXXX000b

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	RO
— (b7-b4)	No register bits. If necessary, set to 0. The read value is undefined.		—

Symbol	Address
USBINT0IC	0076h
USBINT1IC	0077h
USBRSMIC	0078h

Rewrite these registers at a point where an interrupt request for the corresponding register is not generated.

IR (Interrupt request bit) (b3)

The IR bit in registers USBINT0IC, USBINT1IC, and USBRSMIC differs from the IR bit in other interrupt control registers. Refer to 24. “USB Function” for more information.

When a bit in the USBIFRj register is 1 and its corresponding bit in the USBIERj register is also 1 (interrupt enabled), the IR bit in the corresponding register becomes 1 (interrupt requested).

When either a bit in the USBIFRj register or its corresponding bit in the USBIERj register becomes 0, or bits in both registers become 0, the IR bit in the corresponding register becomes 0 (interrupt not requested). That is, while the IR bit is 1, interrupt requests are not retained even if an interrupt is not accepted. The IR bit does not become 0 even if written to 0.

Bits in the USBIFRj register do not become 0 automatically even if an interrupt is accepted. Therefore, the IR bit does not become 0 automatically when an interrupt are accepted. Set each bit in the USBIFRj register to 0 in the interrupt routine.

When setting multiple bits in the USBIERj register to 1, after the IR bit becomes 1 and another request source is confirmed, the IR bit does not change.

14.2.5 Interrupt Source Select Register 3 (IFSR3A)

Interrupt Source Select Register 3

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	Reset Value
0			0	0	0			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
— (b3)	Reserved bit	Set to 0	RW
— (b4)	Reserved bit	Set to 0	RW
IFSR35	Interrupt request source select bit	0 : UART4 start/stop condition detection, bus collision detection 1 : Real-time clock cycle	RW
IFSR36	Interrupt request source select bit	0 : UART4 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).

14.2.6 Interrupt Source Select Register 2 (IFSR2A)

Interrupt Source Select Register 2

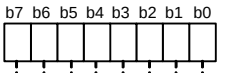
b7	b6	b5	b4	b3	b2	b1	b0
		0	0				0

Symbol	Address	Reset Value
IFSR2A	0206h	00h

Bit Symbol	Bit Name	Function	RW
— (b0)	Reserved bits	Set to 0	RW
IFSR21	Interrupt request source select bit	0 : Key input interrupt 1 : A/D conversion (A/D1) interrupt	RW
IFSR22	Interrupt request source select bit	0 : IC/OC interrupt 1 1 : I^2C-bus interface	RW
IFSR23	Interrupt request source select bit	0 : IC/OC channel interrupt 1 1 : SCL/SDA	RW
— (b4)	Reserved bits	Set to 0	RW
— (b5)	Reserved bits	Set to 0	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

14.2.7 Interrupt Source Select Register (IFSR)

Interrupt Source Select Register



Symbol	Address	Reset Value
IFSR	0207h	00h

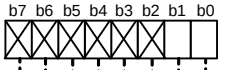
Bit Symbol	Bit Name	Function	RW
IFSR0	$\overline{INT0}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR1	$\overline{INT1}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR2	$\overline{INT2}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR3	$\overline{INT3}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR4	$\overline{INT4}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR5	$\overline{INT5}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR6	Interrupt request source select bit	0 : $\overline{INT4}$ interrupt not used 1 : $\overline{INT4}$	RW
IFSR7	Interrupt request source select bit	0 : $\overline{INT5}$ interrupt not used 1 : $\overline{INT5}$	RW

IFSR5-IFSR0 ($\overline{INT5}$-$\overline{INT0}$ 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).

14.2.8 Address Match Interrupt Enable Register (AIER)

Address Match Interrupt Enable Register

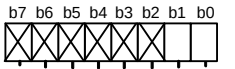


Symbol	Address	Reset Value
AIER	020Eh	XXXX XX00b

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.		—

14.2.9 Address Match Interrupt Enable Register 2 (AIER2)

Address Match Interrupt Enable Register 2

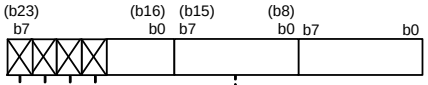


Symbol	Address	Reset Value
AIER2	020Fh	XXXX XX00b

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.		—

14.2.10 Address Match Interrupt Register i (RMADi) (i = 0 to 3)

Address Match Interrupt Register i (i = 0 to 3)

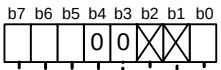


Symbol	Address	Reset Value
RMAD0	0212h to 0210h	X0 0000h
RMAD1	0216h to 0214h	X0 0000h
RMAD2	021Ah to 0218h	X0 0000h
RMAD3	021Eh to 021Ch	X0 0000h

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.		—

14.2.11 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
— (b4)	Reserved bit	Set to 0.	RW
PCR5	$\overline{INT6}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR6	$\overline{INT7}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR7	Key input enable bit	0 : Enabled 1 : Disabled	RW

PCR5 ($\overline{INT6}$ input enable bit) (b5)

To use the AN2_4 pin as an analog input pin, set the PCR5 bit to 1 ($\overline{INT6}$ input disabled).

PCR6 ($\overline{INT7}$ input enable bit) (b6)

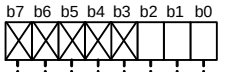
To use the AN2_5 pin as an analog input pin, set the PCR6 bit to 1 ($\overline{INT7}$ input disabled).

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).

14.2.12 $\overline{\text{NMI}}/\overline{\text{SD}}$ 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.

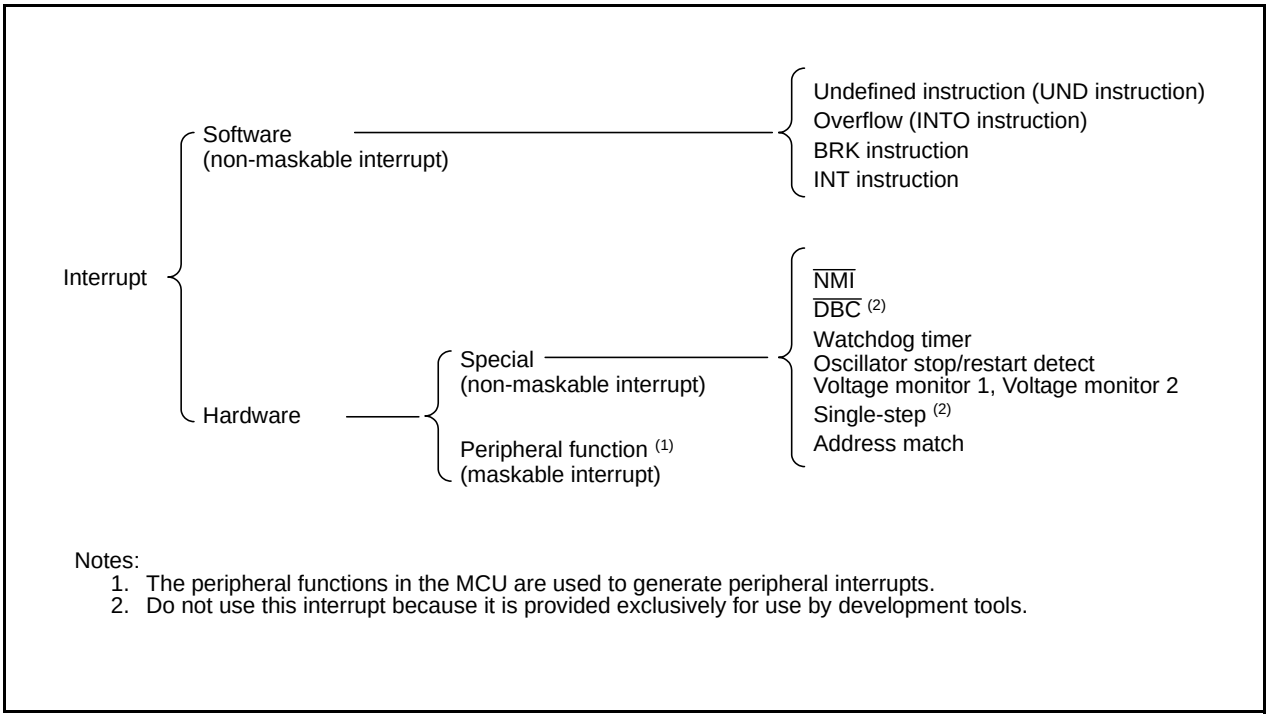


Figure 14.1 Types of Interrupts

- 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, and 54 to 63 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.

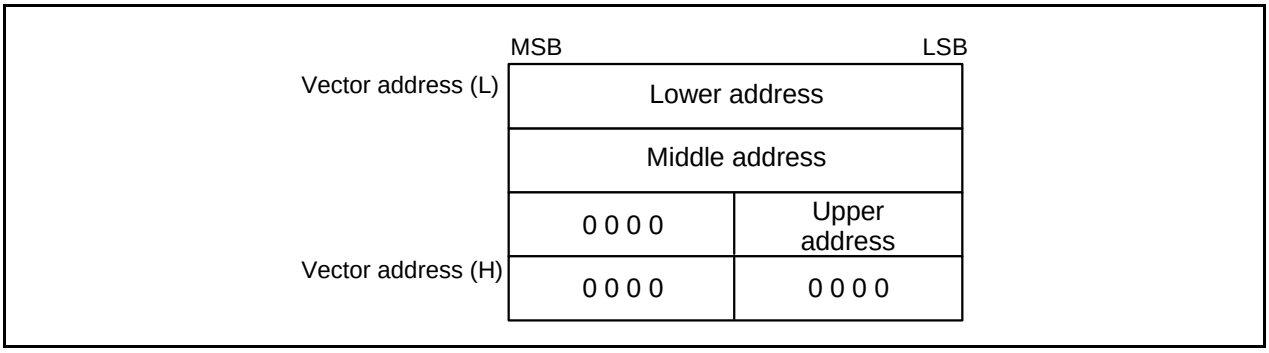


Figure 14.2 Interrupt Vector

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 28. “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 (6)	+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 (6)	+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	22. "Serial Interface UARTi (i = 0 to 5)"
$\overline{\text{INT5}}$ (2)	+32 to +35 (0020h to 0023h)	8	14.8 "$\overline{\text{INT}}$ Interrupt"
$\overline{\text{INT4}}$ (2)	+36 to +39 (0024h to 0027h)	9	
UART2 start/stop condition detection, bus collision detection (4)	+40 to +43 (0028h to 002Bh)	10	22. "Serial Interface UARTi (i = 0 to 5)"
DMA0	+44 to +47 (002Ch to 002Fh)	11	16. "DMAC"
DMA1	+48 to +51 (0030h to 0033h)	12	
Key input interrupt, A/D converter (A/D1) (5)	+52 to +55 (0034h to 0037h)	13	14.10 "Key Input Interrupt" 25. "A/D Converter"
A/D converter (A/D0)	+56 to +59 (0038h to 003Bh)	14	25. "A/D Converter"
UART2 transmit, NACK2 (3)	+60 to +63 (003Ch to 003Fh)	15	22. "Serial Interface UARTi (i = 0 to 5)"
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. Use bit IFSR21 in the IFSR2A register to select a source.
6. 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	+172 to +175 (00ACh to 00AFh)	43	22. "Serial Interface UARTi (i = 0 to 5)"
UART5 transmit, NACK5 (2)	+176 to +179 (00B0h to 00B3h)	44	
UART5 receive, ACK5 (2)	+180 to +183 (00B4h to 00B7h)	45	
UART4 start/stop condition detection, bus collision detection, real-time clock period (3)	+184 to +187 (00B8h to 00BBh)	46	21. "Real-Time Clock" 22. "Serial Interface UARTi (i = 0 to 5)"
UART4 transmit, NACK4, real-time clock compare (2, 3)	+188 to +191 (00BCh to 00BFh)	47	
UART4 receive, ACK4 (2)	+192 to +195 (00C0h to 00C3h)	48	
UART3 start/stop condition detection, bus collision detection	+196 to +199 (00C4h to 00C7h)	49	22. "Serial Interface UARTi (i = 0 to 5)"
UART3 transmit, NACK3 (2)	+200 to +203 (00C8h to 00CBh)	50	
UART3 receive, ACK3 (2)	+204 to +207 (00CCh to 00CFh)	51	
USB interrupt 0	+216 to +219 (00D8h to 00DBh)	54	24. "USB Function"
USB interrupt 1	+220 to +223 (00DCh to 00DFh)	55	
USB RESUME	+224 to +227 (00E0h to 00E3h)	56	
IC/OC interrupt 0 (0 to 7)	+228 to +231 (00E4h to 00E7h)	57	20. "Timer S" 23. "Multi-master I2C-bus Interface"
IC/OC channel 0	+232 to +235 (00E8h to 00EBh)	58	
IC/OC interrupt 1 (0 to 7), I2C-bus interrupt (4)	+236 to +239 (00ECh to 00EFh)	59	
IC/OC channel 1, SCL/SDA interrupt (4)	+240 to +243 (00F0h to 00F3h)	60	
IC/OC channel 2	+244 to +247 (00F4h to 00F7h)	61	
IC/OC channel 3	+248 to +251 (00F8h to 00FBh)	62	
IC/OC base timer	+252 to +255 (00FCh to 00FFh)	63	

Notes:
1. Address relative to address in INTB.
2. In I2C mode, NACK and ACK are the interrupt sources.
3. Use bits IFSR35 and IFSR36 in the IFSR3A register to select a source.
4. 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.

However, the IR bit behaves differently with interrupts in the USB function. Refer to 24.4.2 “USB Interrupt 0, USB Interrupt 1”.

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

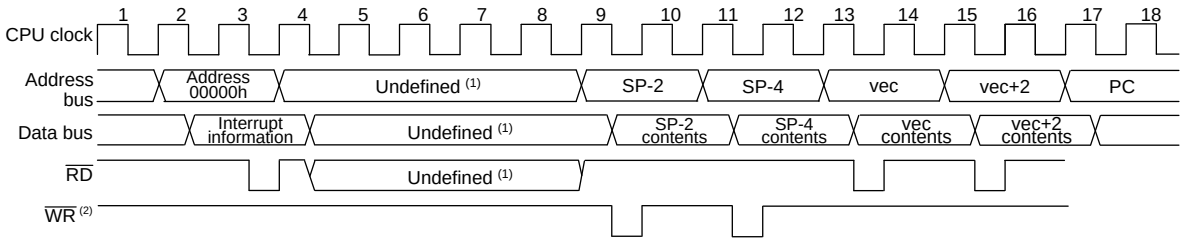
14.7.2 Interrupt Sequence

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.

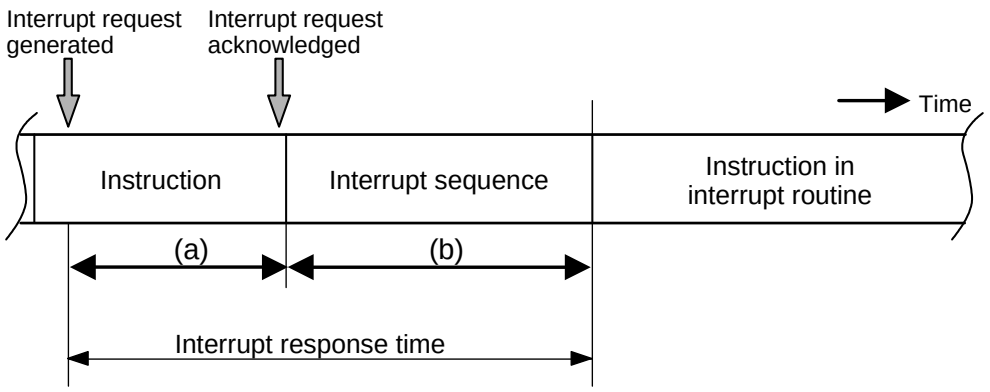


Notes:
1. The undefined state depends on the instruction queue buffer. A read cycle is generated when the instruction queue buffer is ready to prefetch.
2. The $\overline{WR}$ signal timing shown here applies when the stack is located in the internal RAM.

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).



(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 $\overline{\text{DBC}}$ 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, $\overline{\text{NMI}}$, oscillator stop/restart detect, voltage monitor 1, voltage monitor 2	7
Software, address match, $\overline{\text{DBC}}$, 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.

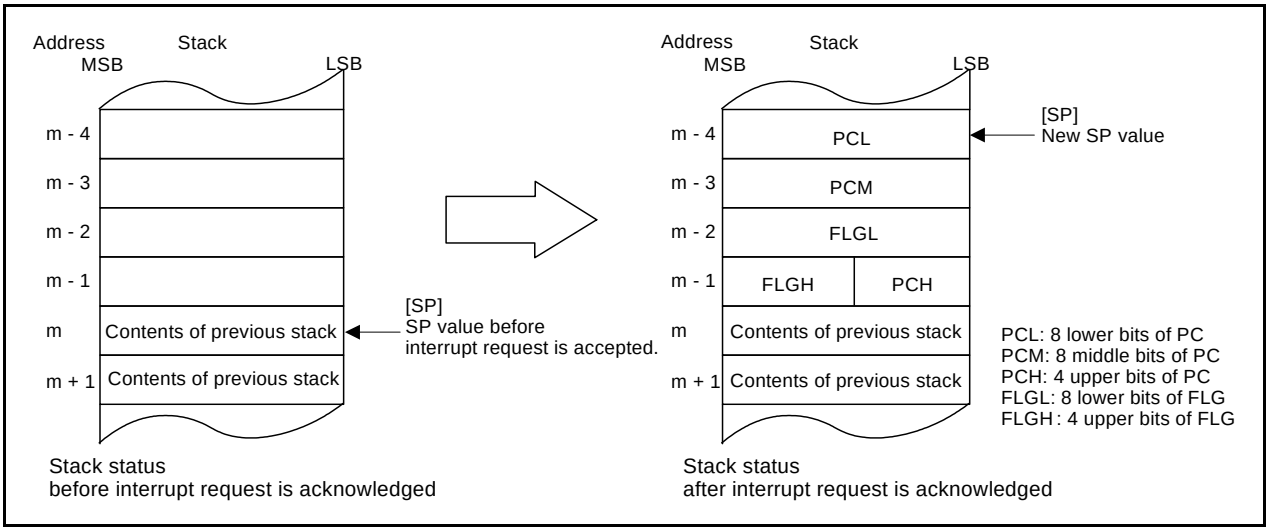


Figure 14.5 Stack Status Before and After Acceptance of Interrupt Request

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.

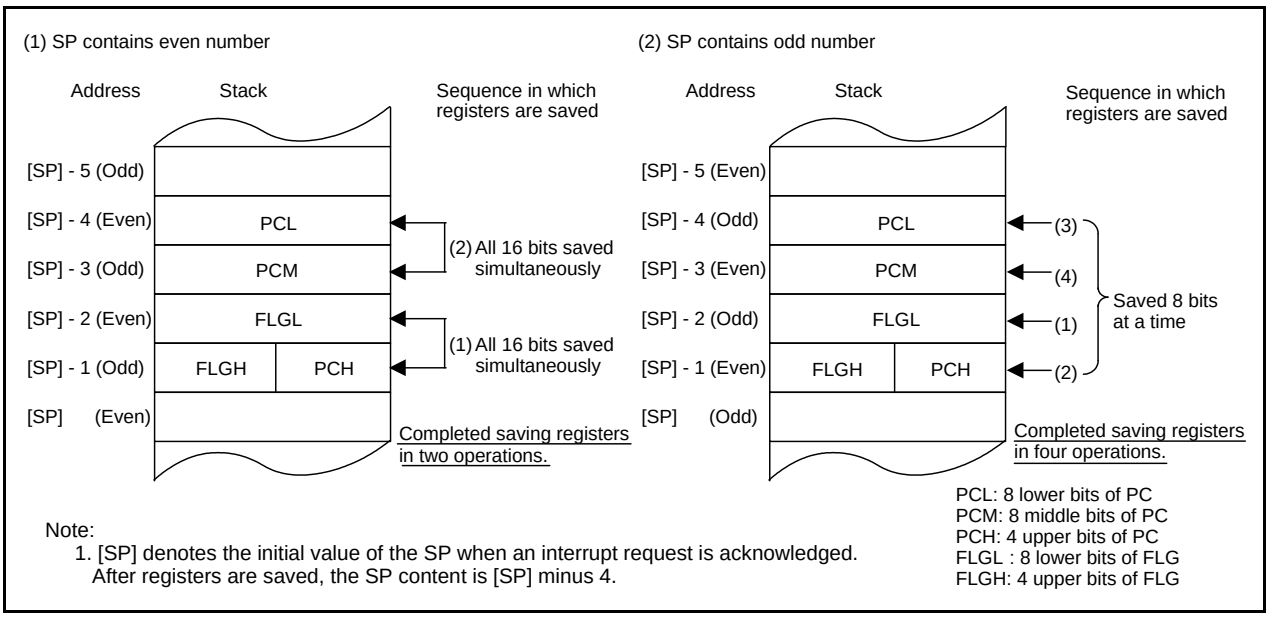


Figure 14.6 Register Save Operation

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.

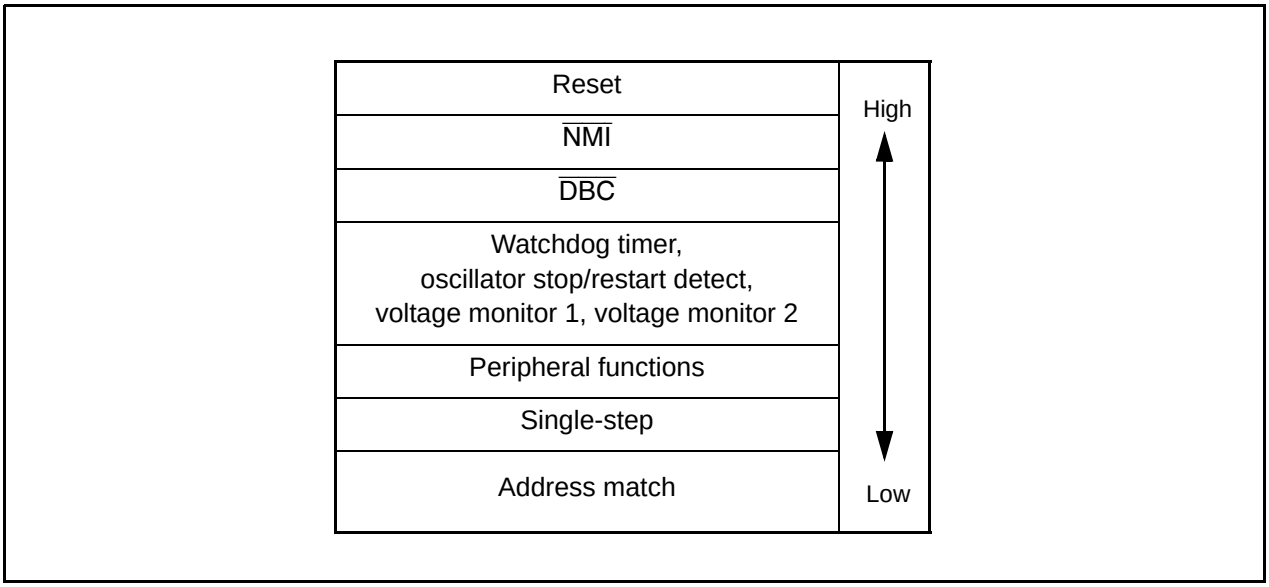


Figure 14.7 Hardware Interrupt Priority

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.

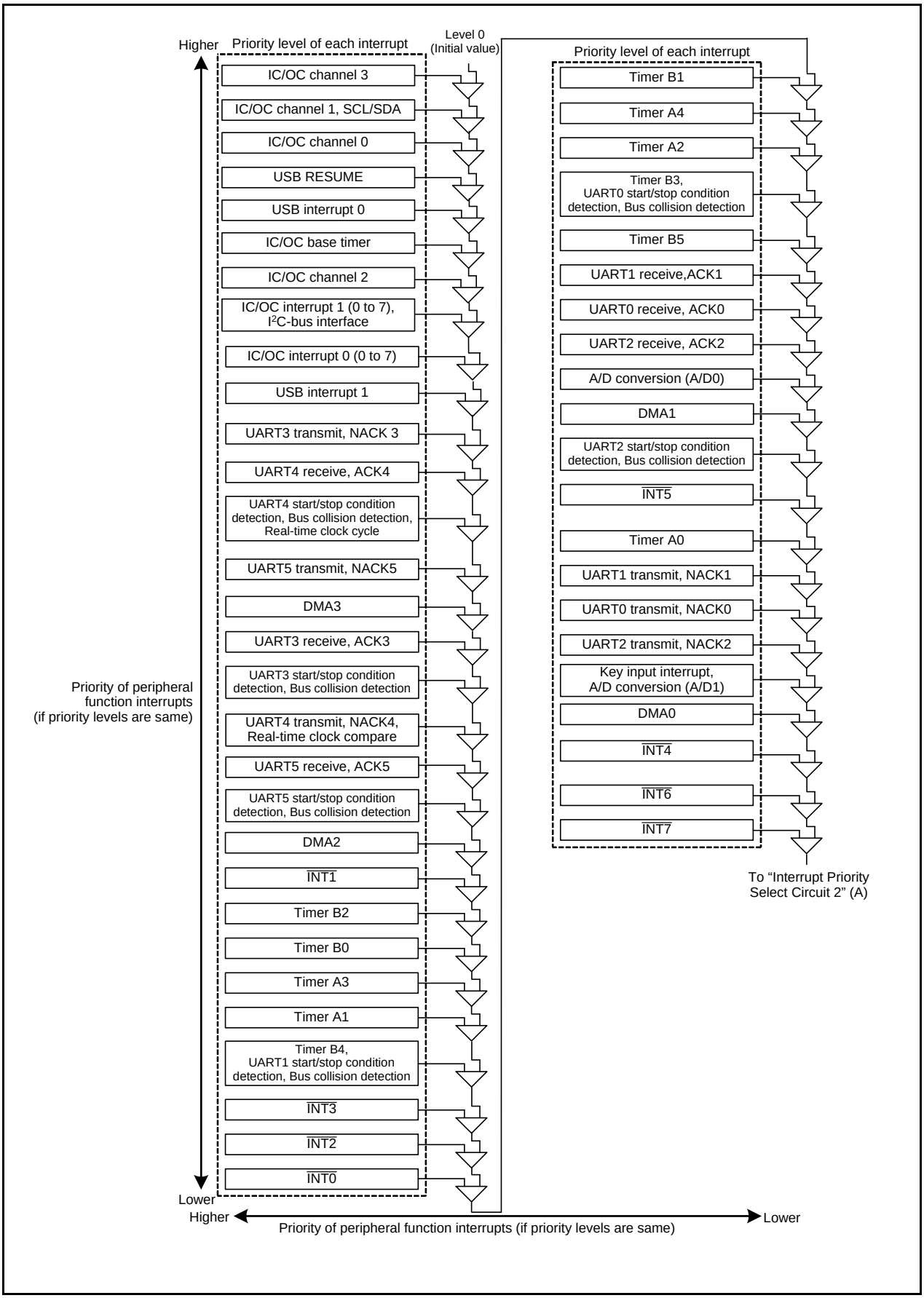


Figure 14.8 Interrupt Priority Select Circuit 1

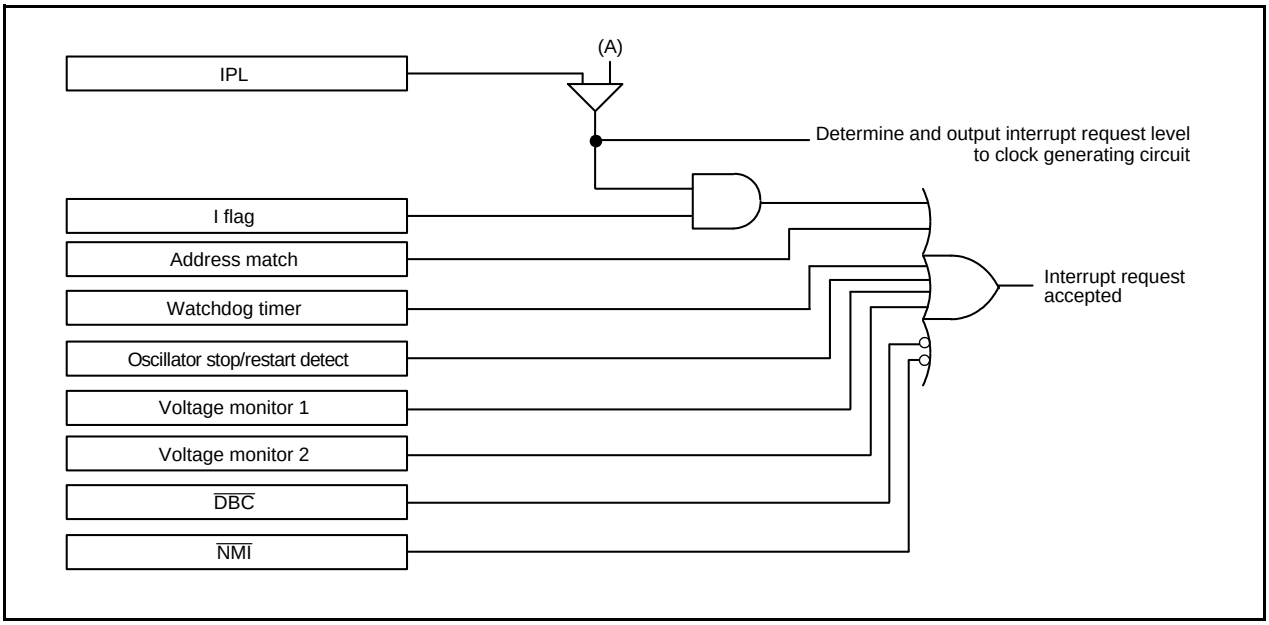


Figure 14.9 Interrupt Priority Select Circuit 2

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.

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.

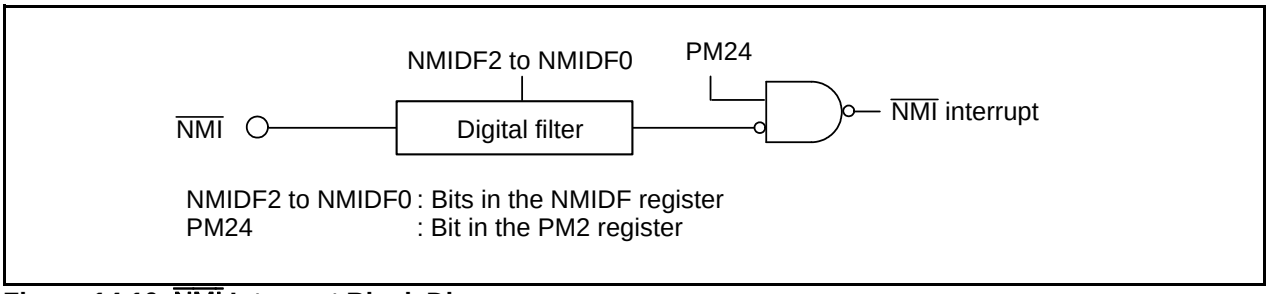


Figure 14.10 $\overline{\text{NMI}}$ Interrupt Block Diagram

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.

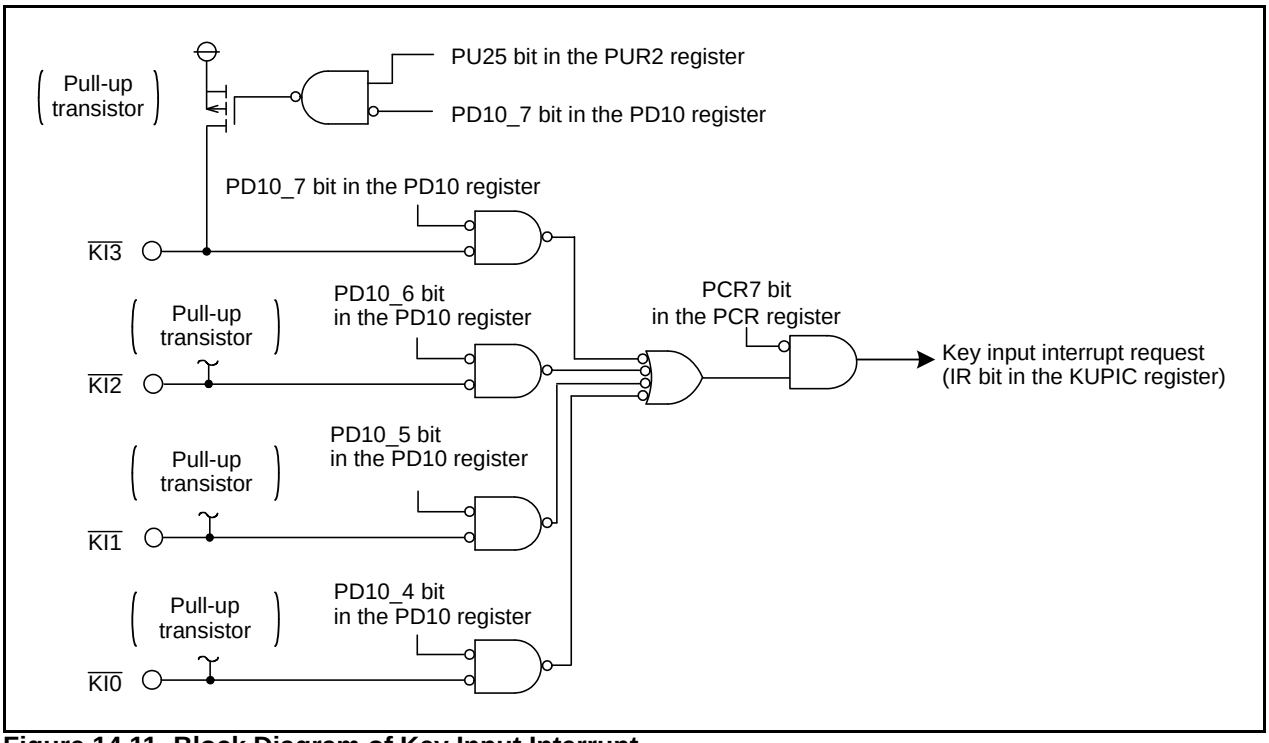


Figure 14.11 Block Diagram of Key Input Interrupt

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

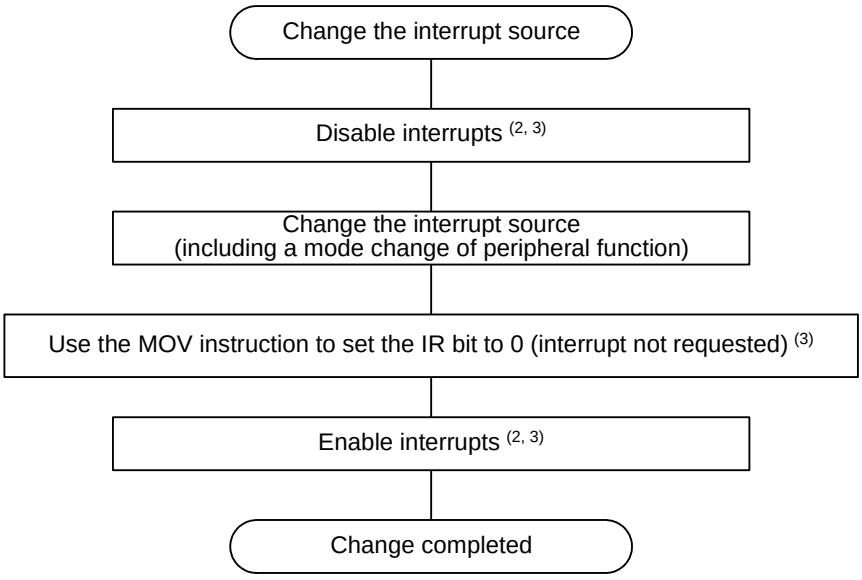
- When not using the $\overline{\text{NMI}}$ interrupt, set the PM24 bit in the PM2 register to 0 ($\overline{\text{NMI}}$ interrupt disabled).
- The $\overline{\text{NMI}}$ interrupt is disabled after reset. The $\overline{\text{NMI}}$ interrupt is enabled by setting the PM24 bit in the PM2 register 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.



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 $\overline{\text{INT}}$i interrupt (i = 0 to 7).
   For the interrupts from peripheral functions other than the $\overline{\text{INT}}$i 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.

14.13.8 IR bits in the USBINT0IC, USBINT1IC and USBRSMIC registers

The IR bit behavior differs with the interrupts used in the USB function and the behavior discussed in 14.7.1.2 “IR Bit”. Refer to 24.4.2 “USB Interrupt 0, USB Interrupt 1”.

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)	

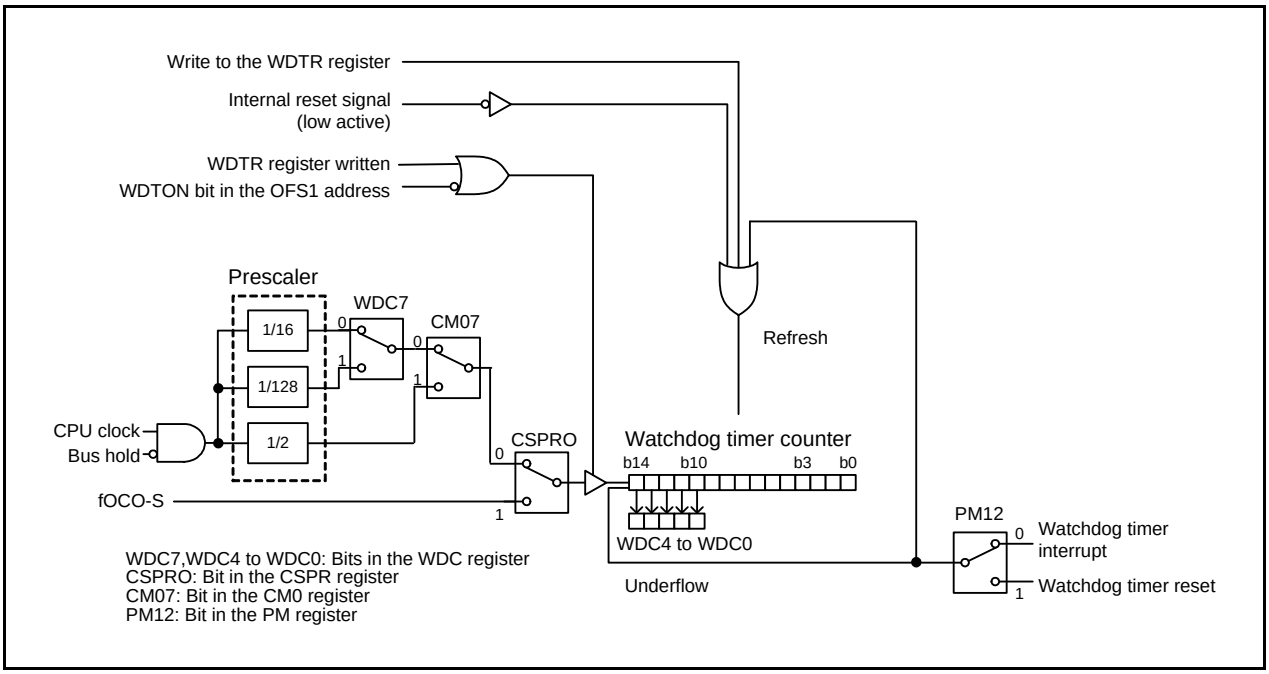


Figure 15.1 Watchdog Timer Block Diagram

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

b7 b6 b5 b4 b3 b2 b1 b0

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 VW2F1	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
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:

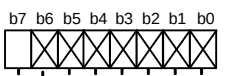
- Writing 0 by a program

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:

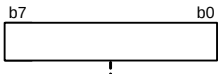
- Reset when the CSPROINI bit in the OFS1 address is 1.
  (This flag remains unchanged even if 0 is written by a program.)

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



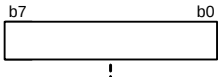
Symbol	Address	Reset Value
WDTR	037Dh	XXh

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

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	Reset Value
	0	X						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.

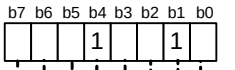
The optional function select area is not an SFR, and therefore cannot be rewritten by a program. Set an appropriate value when writing a program to flash memory. The entire optional function select area becomes FFh when the block including the optional function select area is erased.

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, 2)		55 sources Falling edge of $\overline{INT0}$ to $\overline{INT7}$ (8) Both edge of $\overline{INT0}$ to $\overline{INT7}$ (8) Timer A0 to timer A4 interrupt request (5) Timer B0 to timer B5 interrupt request (6) UART0 to UART5 transmission interrupt request (6) UART0 to UART5 reception/ACK interrupt request (6) IC/OC base timer interrupt request (1) IC/OC channel 0 to IC/OC channel 7 interrupt (8) A/D conversion (A/D0, A/D1) interrupt request (2) Software trigger (1) USB endpoint 1, 2, 4 and 5 DMA transfer request (4)
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

Notes:

1. The selectable sources of DMA requests differ for each channel.
2. Refer to 24.5 “DMA Transfer” for DMA transfer to USB endpoint 1, 2, 4, and 5.

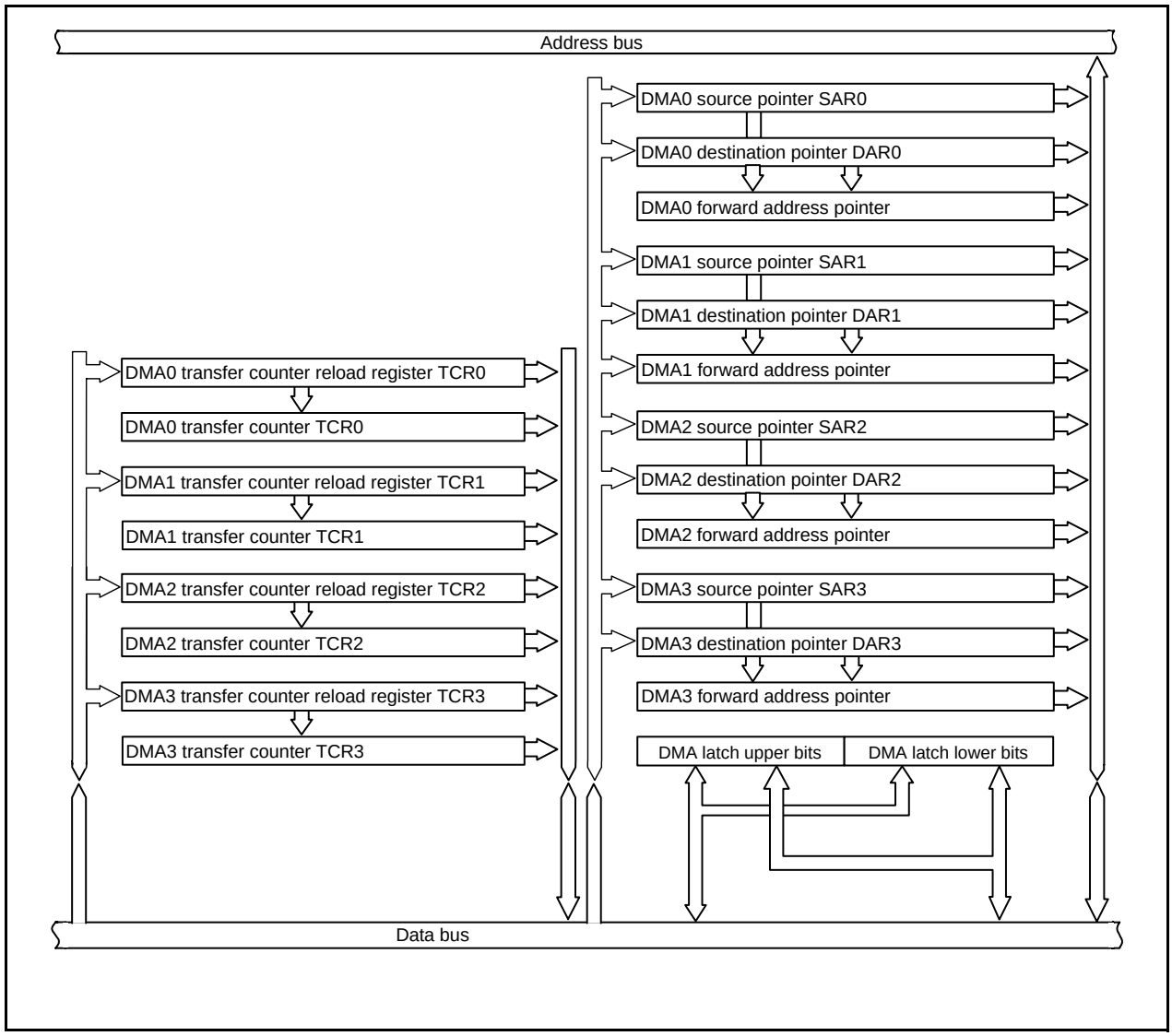


Figure 16.1 DMAC Block Diagram

16.2 Registers

Table 16.2 lists Registers (1). Do not access these registers using the DMAC.

Table 16.2 Registers (1)

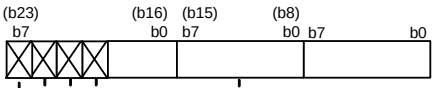
Address	Register	Symbol	Reset Value
0180h	DMA0 Source Pointer	SAR0	XXh
0181h			XXh
0182h			0Xh
0184h	DMA0 Destination Pointer	DAR0	XXh
0185h			XXh
0186h			0Xh
0188h	DMA0 Transfer Counter	TCR0	XXh
0189h			XXh
018Ch	DMA0 Control Register	DM0CON	0000 0X00b
0190h	DMA1 Source Pointer	SAR1	XXh
0191h			XXh
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

Note:

1. Set USB DMA Transfer Setting Register (USBDMAR) when executing DMA transfer to USB endpoint 1, 2, 4 and 5. Refer to 24.2.29 “USB DMA Transfer Setting Register (USBDMAR)”.

16.2.1 DMAi Source Pointer (SARi) (i = 0 to 3)

DMAi Source Pointer (i = 0 to 3)



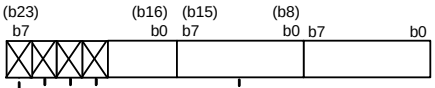
Symbol	Address	Reset Value
SAR0	0182h to 0180h	0X XXXXh
SAR1	0192h to 0190h	0X XXXXh
SAR2	01A2h to 01A0h	0X XXXXh
SAR3	01B2h to 01B0h	0X XXXXh

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)



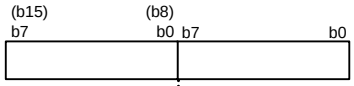
Symbol	Address	Reset Value
DAR0	0186h to 0184h	0X XXXXh
DAR1	0196h to 0194h	0X XXXXh
DAR2	01A6h to 01A4h	0X XXXXh
DAR3	01B6h to 01B4h	0X XXXXh

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

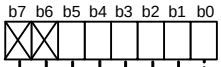
Function	Setting Range	RW
Set the number of transfers minus 1.	0000h to FFFFh	RW

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:

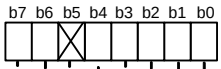
- Set the bit to 1.

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 $\overline{\text{INT0}}$ pin	IC/OC base timer
0 0 0 0 1 b	Software trigger	A/D converter (A/D1)
0 0 0 1 0 b	Timer A0	IC/OC channel 0
0 0 0 1 1 b	Timer A1	IC/OC channel 1
0 0 1 0 0 b	Timer A2	USB endpoint 1
0 0 1 0 1 b	Timer A3	USB endpoint 2
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	IC/OC channel 2
0 1 0 1 1 b	UART0 reception	IC/OC channel 3
0 1 1 0 0 b	UART2 transmission	IC/OC channel 4
0 1 1 0 1 b	UART2 reception	IC/OC channel 5
0 1 1 1 0 b	A/D converter (A/D0)	IC/OC channel 6
0 1 1 1 1 b	UART1 transmission	IC/OC channel 7
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	USB endpoint 4
1 0 0 1 1 b	UART4 transmission	USB endpoint 5
1 0 1 0 0 b	UART4 reception	–
1 0 1 0 1 b	UART3 transmission	–
1 0 1 1 0 b	UART3 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	IC/OC base timer
0 0 0 0 1 b	Software trigger	A/D converter (A/D1)
0 0 0 1 0 b	Timer A0	IC/OC channel 0
0 0 0 1 1 b	Timer A1	IC/OC channel 1
0 0 1 0 0 b	Timer A2	USB endpoint 1
0 0 1 0 1 b	Timer A3	USB endpoint 2
0 0 1 1 0 b	Timer A4	–
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	IC/OC channel 2
0 1 0 1 1 b	UART0 reception/ACK0	IC/OC channel 3
0 1 1 0 0 b	UART2 transmission	IC/OC channel 4
0 1 1 0 1 b	UART2 reception/ACK2	IC/OC channel 5
0 1 1 1 0 b	A/D converter (A/D0)	IC/OC channel 6
0 1 1 1 1 b	UART1 reception/ACK1	IC/OC channel 7
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	USB endpoint 4
1 0 0 1 1 b	UART4 transmission	USB endpoint 5
1 0 1 0 0 b	UART4 reception/ACK4	–
1 0 1 0 1 b	UART3 transmission	–
1 0 1 1 0 b	UART3 reception/ACK3	–
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	IC/OC base timer
0 0 0 0 1 b	Software trigger	A/D converter (A/D1)
0 0 0 1 0 b	Timer A0	IC/OC channel 0
0 0 0 1 1 b	Timer A1	IC/OC channel 1
0 0 1 0 0 b	Timer A2	USB endpoint 1
0 0 1 0 1 b	Timer A3	USB endpoint 2
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	IC/OC channel 2
0 1 0 1 1 b	UART0 reception	IC/OC channel 3
0 1 1 0 0 b	UART2 transmission	IC/OC channel 4
0 1 1 0 1 b	UART2 reception	IC/OC channel 5
0 1 1 1 0 b	A/D converter (A/D0)	IC/OC channel 6
0 1 1 1 1 b	UART1 transmission	IC/OC channel 7
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	USB endpoint 4
1 0 0 1 1 b	UART4 transmission	USB endpoint 5
1 0 1 0 0 b	UART4 reception	–
1 0 1 0 1 b	UART3 transmission	–
1 0 1 1 0 b	UART3 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	IC/OC base timer
0 0 0 0 1 b	Software trigger	A/D converter (A/D1)
0 0 0 1 0 b	Timer A0	IC/OC channel 0
0 0 0 1 1 b	Timer A1	IC/OC channel 1
0 0 1 0 0 b	Timer A2	USB endpoint 1
0 0 1 0 1 b	Timer A3	USB endpoint 2
0 0 1 1 0 b	Timer A4	–
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	IC/OC channel 2
0 1 0 1 1 b	UART0 reception/ACK0	IC/OC channel 3
0 1 1 0 0 b	UART2 transmission	IC/OC channel 4
0 1 1 0 1 b	UART2 reception/ACK2	IC/OC channel 5
0 1 1 1 0 b	A/D converter (A/D0)	IC/OC channel 6
0 1 1 1 1 b	UART1 reception/ACK1	IC/OC channel 7
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	USB endpoint 4
1 0 0 1 1 b	UART4 transmission	USB endpoint 5
1 0 1 0 0 b	UART4 reception/ACK4	–
1 0 1 0 1 b	UART3 transmission	–
1 0 1 1 0 b	UART3 reception/ACK3	–
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 $\overline{INT0}$ to $\overline{INT7}$ 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.

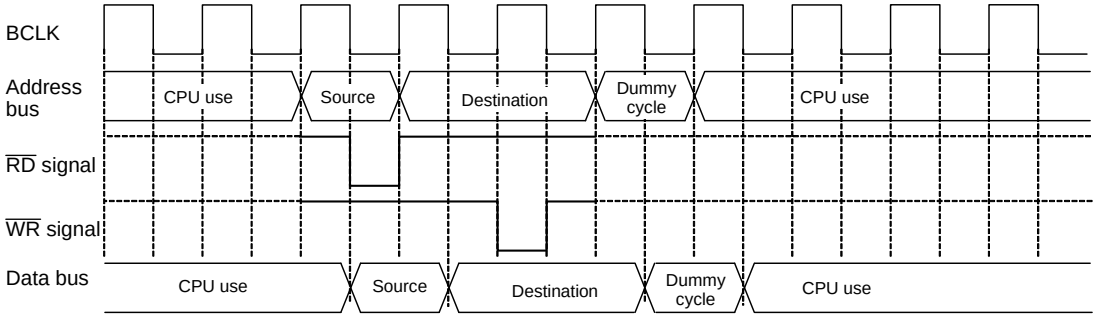
16.3.3.3 Memory Expansion Mode and Microprocessor Mode

In memory expansion or microprocessor mode, the bus cycle itself is extended by a software wait or $\overline{\text{RDY}}$ signal.

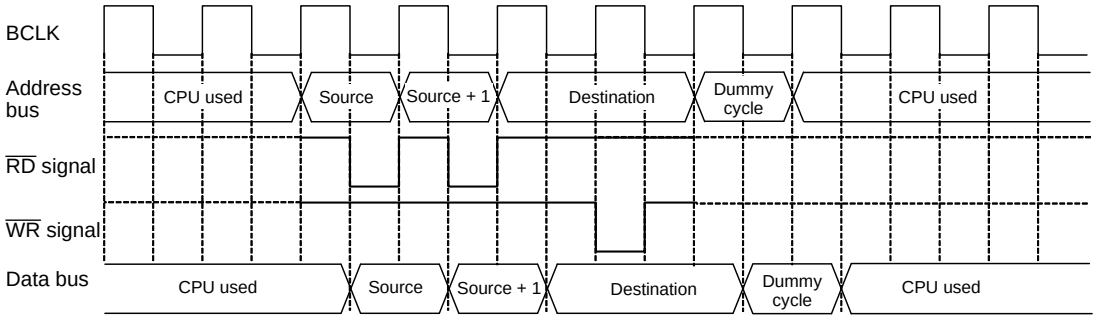
If 16 bits of data are transferred on an 8-bit data bus, the operation is accomplished by transferring 8 bits of data twice. Therefore, this operation requires two bus cycles to read data and two bus cycles to write data. Furthermore, if the DMAC accesses an internal area (internal ROM, internal RAM, or SFR), unlike in the case of the CPU, the DMAC uses the 8-bit data bus width.

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.

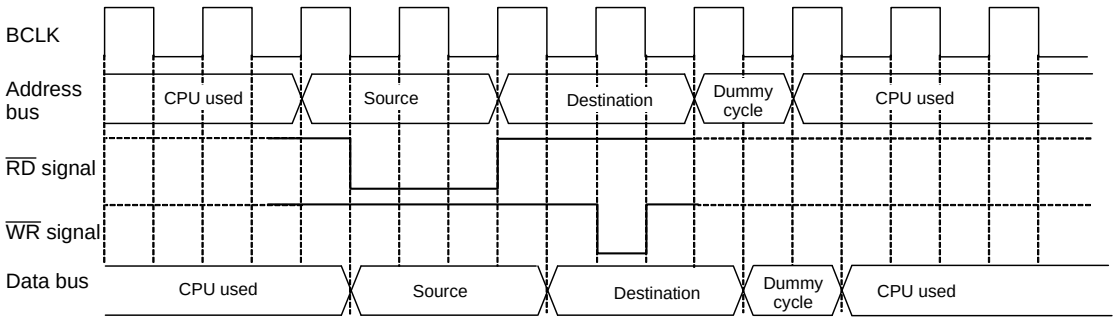
(1) Transfers are performed in 8-bit or 16-bit units, and the transfer source is an even address.



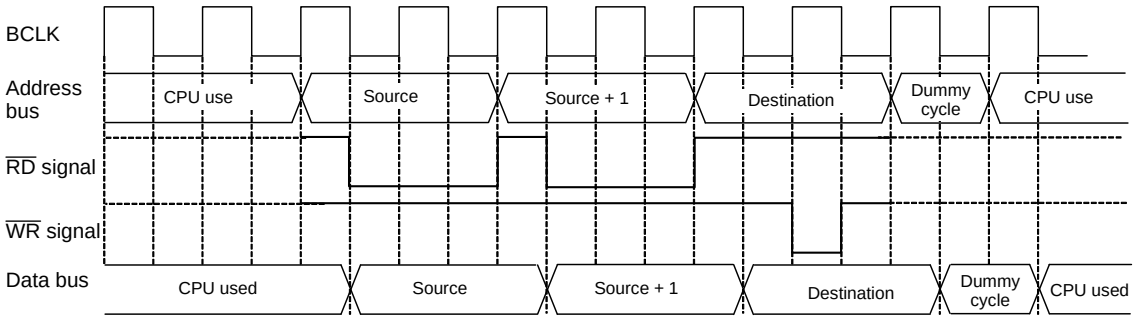
(2) Transfers are performed in 16-bit units, and the transfer source is an odd address.



(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	Even	1	1	N/A	N/A
		Odd	1	1	N/A	N/A
	8-bit	Even	N/A	N/A	1	1
		Odd	N/A	N/A	1	1
16-bit transfers (DMBIT = 0)	16-bit	Even	1	1	N/A	N/A
		Odd	2	2	N/A	N/A
	8-bit	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			
	No waits inserted	Wait states (1)		
		one wait inserted (1ϕ + 1ϕ)	two wait inserted (1ϕ + 2ϕ)	three wait inserted (1ϕ + 3ϕ)
j	1	2	3	4
k	2	2	3	4

Note:
1. Depends on the set values of the CSE register.

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.

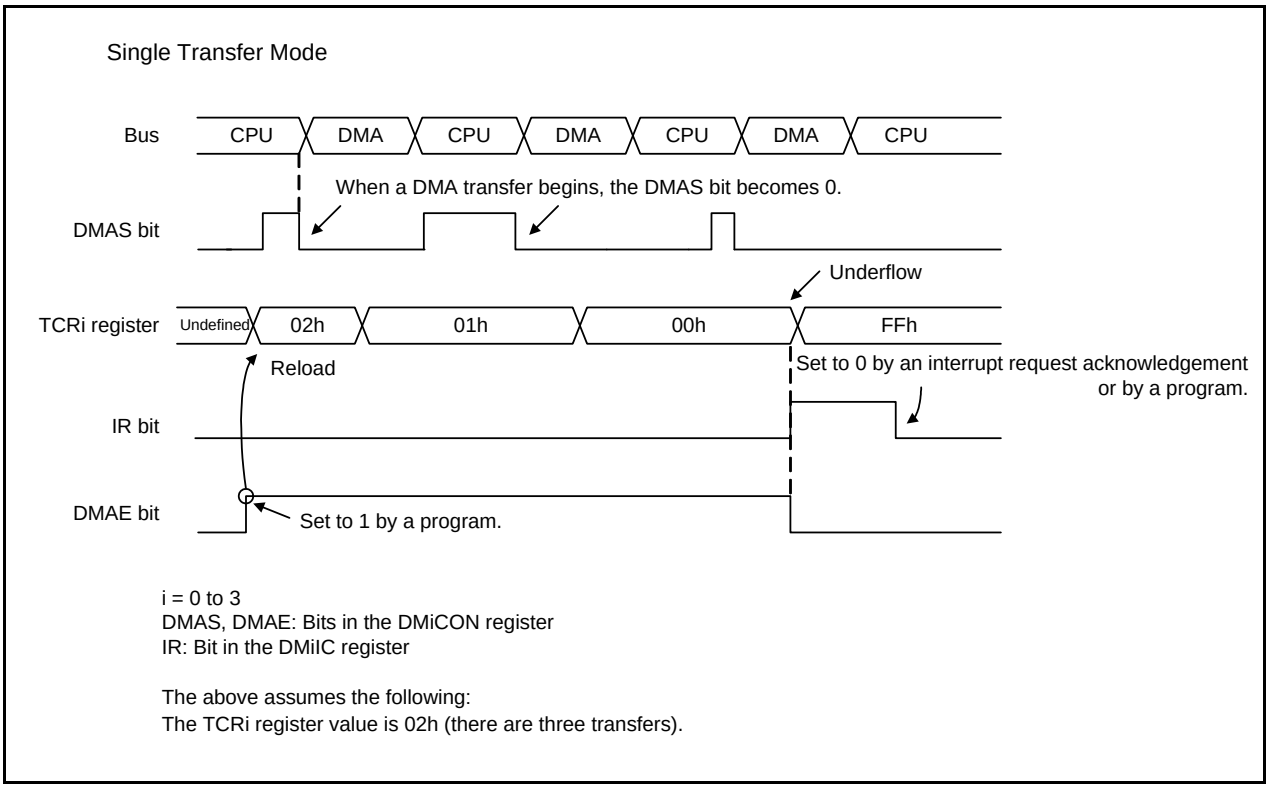


Figure 16.3 Operation Example in Single Transfer Mode

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.

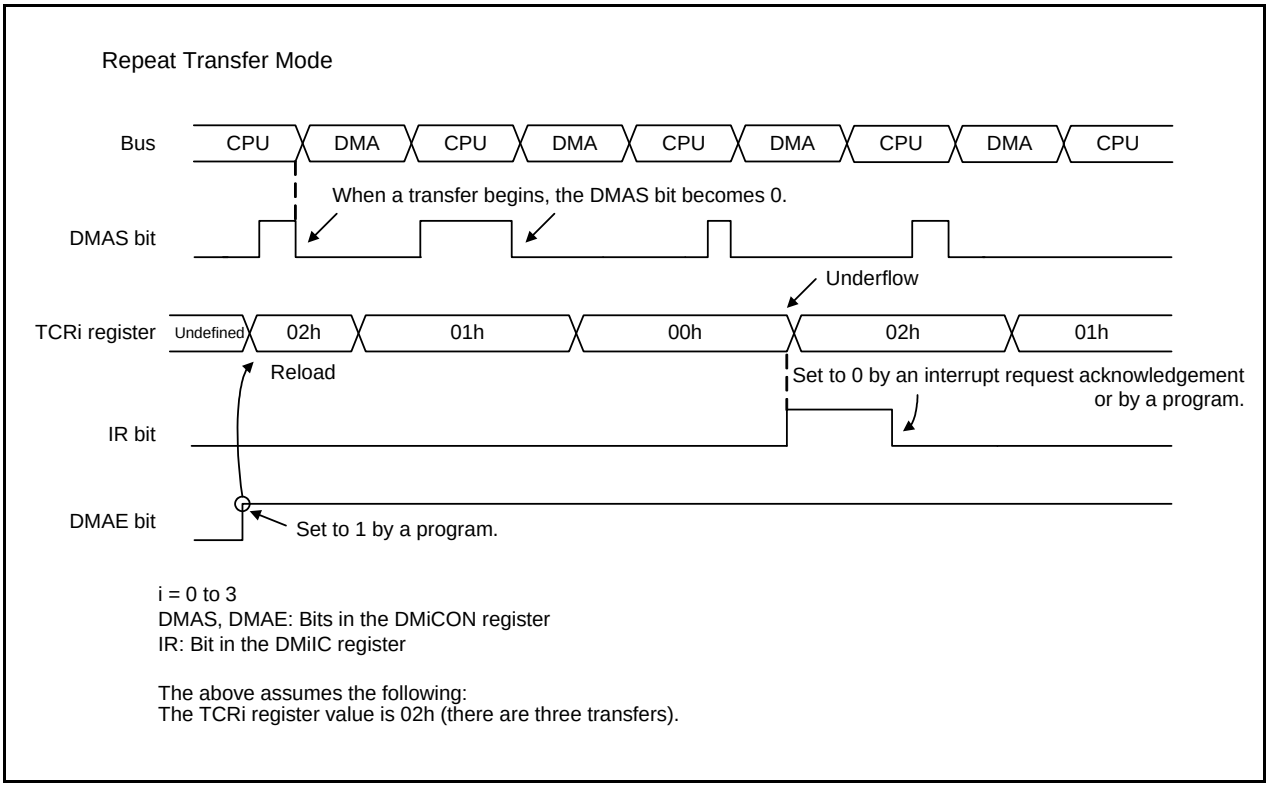


Figure 16.4 Operation Example in Repeat Transfer Mode

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.

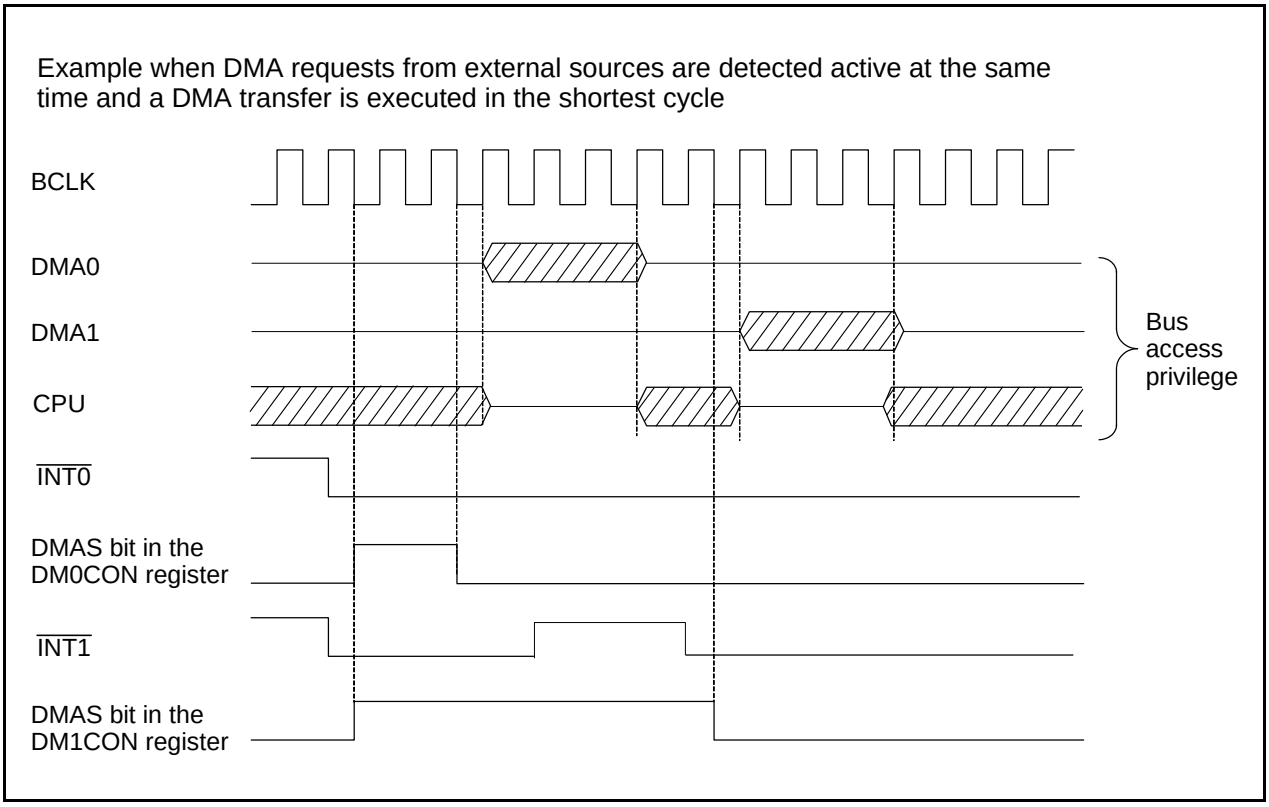


Figure 16.5 DMA Transfer Initiated by External Sources

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

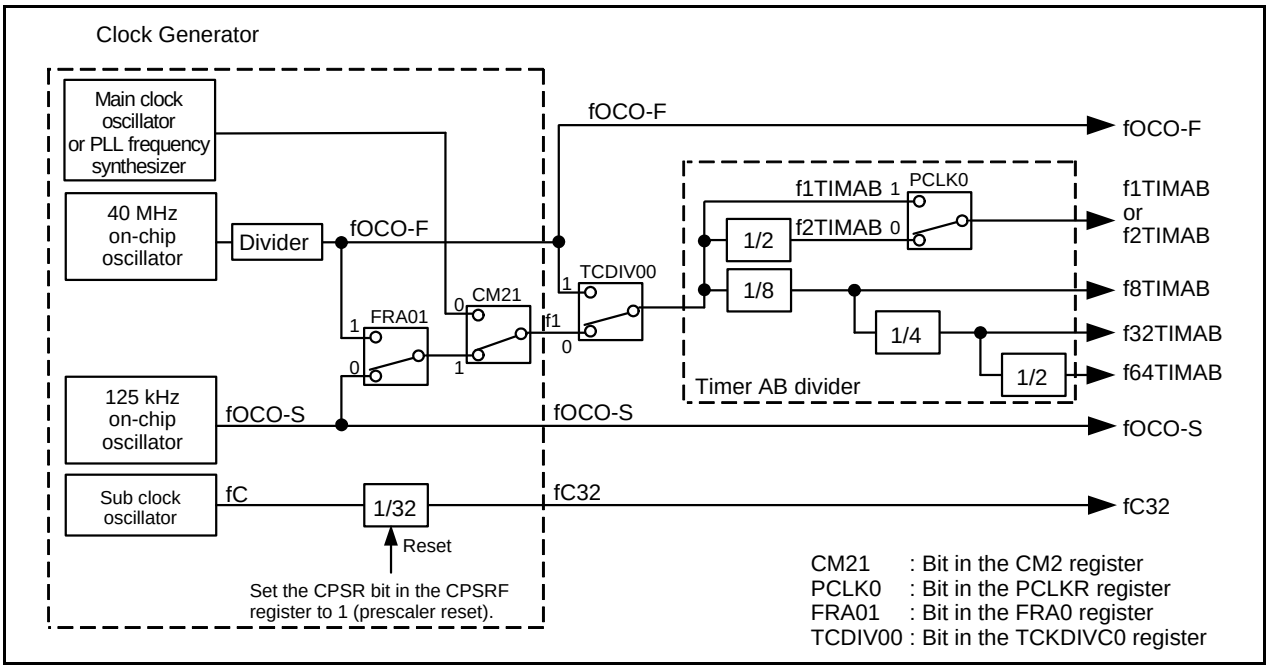
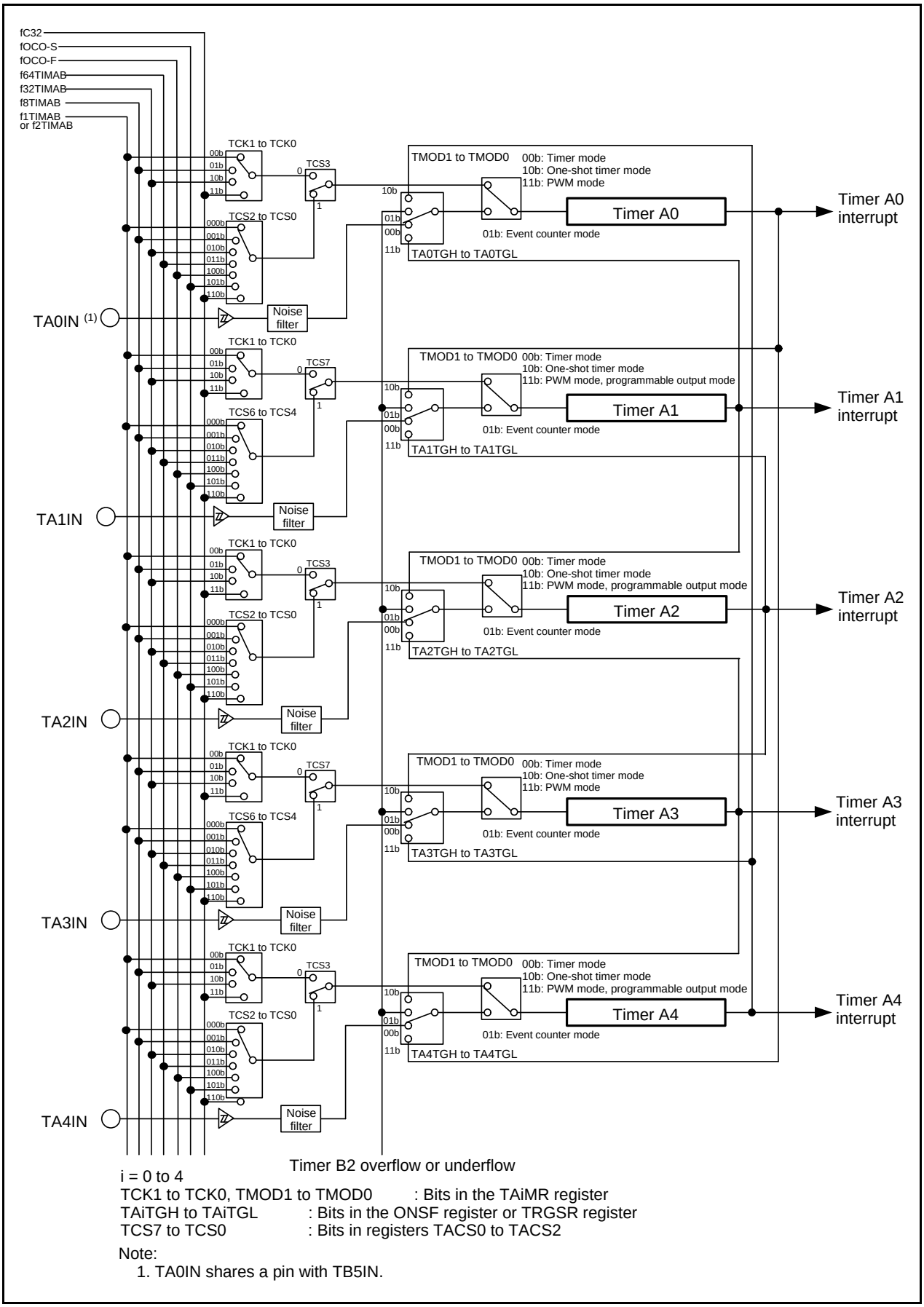


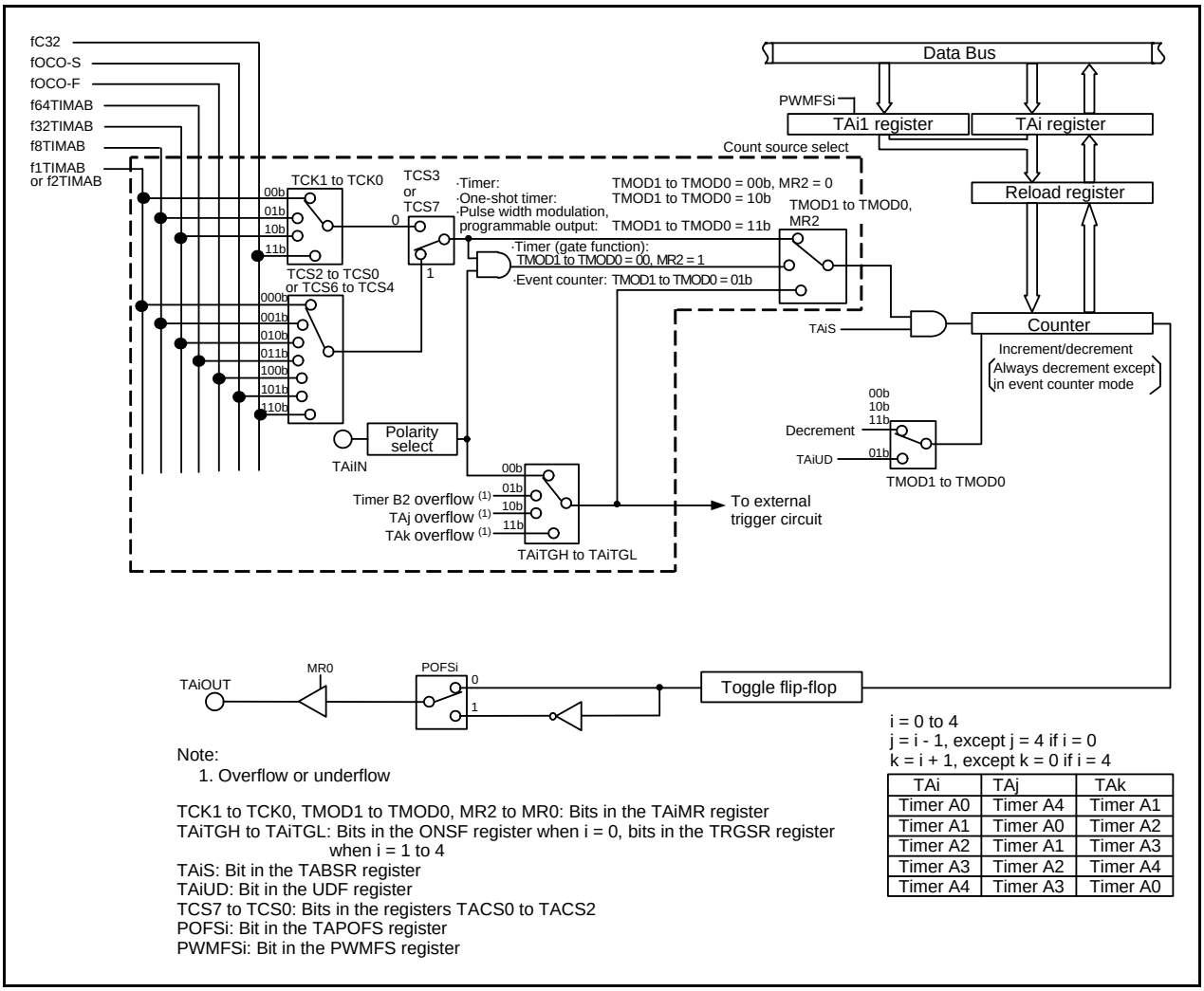
Figure 17.1 Timer A and B Count Sources



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



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

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
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

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

Symbol	Address	Reset Value
PCLKR	0012h	0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A, B and S clock select bit (clock source for timers A, B and S, the dead time timer, and multi-master I^2C-bus interface)	0: f2TIMAB/f2IIC/f2TIMS 1: f1TIMAB/f1IIC/f1TIMS	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART5)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function extension bit (valid in single-chip mode)	0: Selected by 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

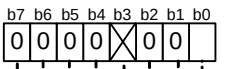
b7	b6	b5	b4	b3	b2	b1	b0
X	X	X	X	X	X	X	X

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 Timer AB Division Control Register 0 (TCKDIVC0)

Timer AB Division Control Register 0



Symbol: TCKDIVC0 | Address: 01CBh | Reset Value: 0000 X000b

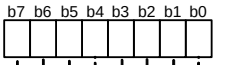
Bit Symbol	Bit Name	Function	RW
TCDIV00	Clock select prior to timer AB division bit	0 : f1 1 : fOCO-F	RW
— (b2-b1)	Reserved bits	Set to 0	RW
— (b3)	No register bit. If necessary, set to 0. The read value is undefined.		—
— (b7-b4)	Reserved bits	Set to 0	RW

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.

17.2.4 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

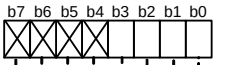


Symbol	Address	Reset Value
TACS0 to TACS1	01D0h to 01D1h	00h

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.

17.2.5 16-bit Pulse Width Modulation Mode Function Select Register (PWMFS)

16-bit Pulse Width Modulation Mode Function Select Register

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	Reset Value
0	X	X		X			X	PWMFS	01D4h	0XX0 X00Xb

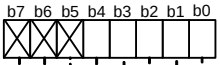
Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. The read value is undefined.		—
PWMFS1	Timer A1 programmable output mode select bit	0 : PWM mode 16-bit PWM 1 : Programmable output mode	RW
PWMFS2	Timer A2 programmable output mode select bit	0 : PWM mode 16-bit PWM 1 : Programmable 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).

17.2.6 Timer A Waveform Output Function Select Register (TAPOFS)

Timer A Waveform Output Function Select Register

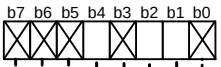


Symbol	Address	Reset Value
TAPOFS	01D5h	XXX0 0000b

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.		—

17.2.7 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.		—

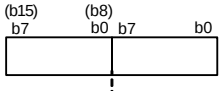
The TAOW register is enabled in programmable output mode.
To change cycles or width of the output waveform, follow the instructions below.

(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).

17.2.8 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)

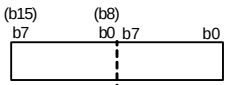
When the TAi register is set to 0000h, the counter does not work, the output level on the TAiOUT pin remains low, and timer Ai interrupt requests are not generated.

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.

17.2.9 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

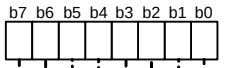
Mode	Function	Setting Range	RW
Programmable output mode	When n is a setting value of TAi1 register, and m is a setting value of TAi register, high-level duration: $\frac{m}{fj}$ low-level duration: $\frac{n}{fj}$	0001h to FFFFh	WO

fj: Count source frequency

Access the register in 16-bit units. Use the MOV instruction to write to the TAi1 register.

17.2.10 Count Start Flag (TABSR)

Count Start Flag

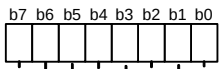


Symbol	Address	Reset Value
TABSR	0320h	00h

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

17.2.11 One-Shot Start Flag (ONSF)

One-Shot Start Flag



Symbol: ONSF
Address: 0322h
Reset Value: 00h

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.

17.2.12 Trigger Select Register (TRGSR)

Trigger Select Register

b7	b6	b5	b4	b3	b2	b1	b0

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:

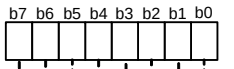
- An event in event counter mode (when not using two-phase pulse signal processing)
- A trigger in one-shot timer mode, PWM mode, or programmable output mode
  The above applies when the MR2 bit in the TAiMR register is 1 (trigger selected by setting bits TAiTGH to TAiTGL).

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.

17.2.13 Increment/Decrement Flag (UDF)

Increment/Decrement Flag



Symbol: UDF | Address: 0324h | Reset Value: 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.

17.2.14 Timer Ai Mode Register (TAiMR) (i = 0 to 4)

Timer Ai Mode Register (i = 0 to 4)

b7 b6 b5 b4 b3 b2 b1 b0	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.

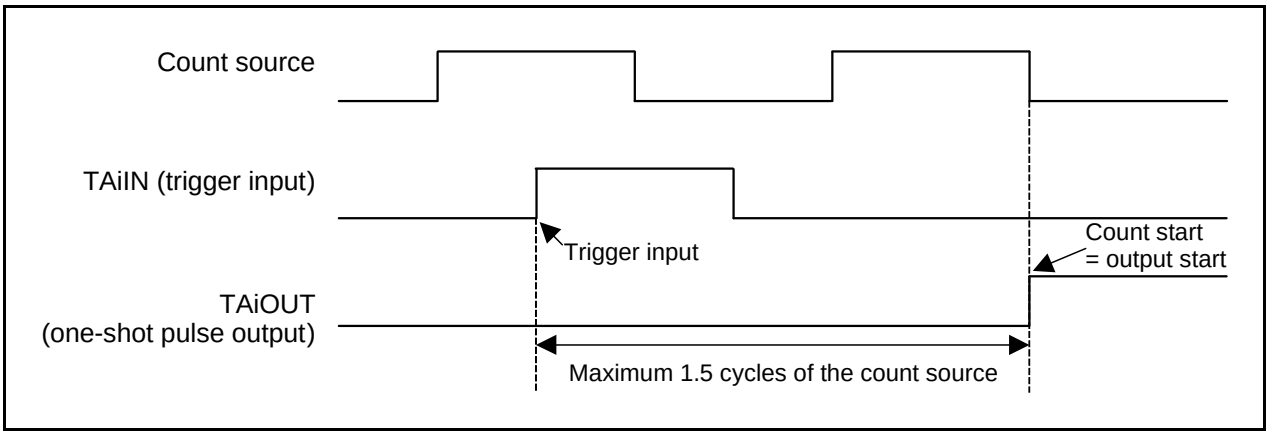


Figure 17.4 Output Example of One-Shot Timer Mode

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)

Table 17.5 Timer A 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 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.

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.
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)

b7	b6	b5	b4	b3	b2	b1	b0
		0				0	0

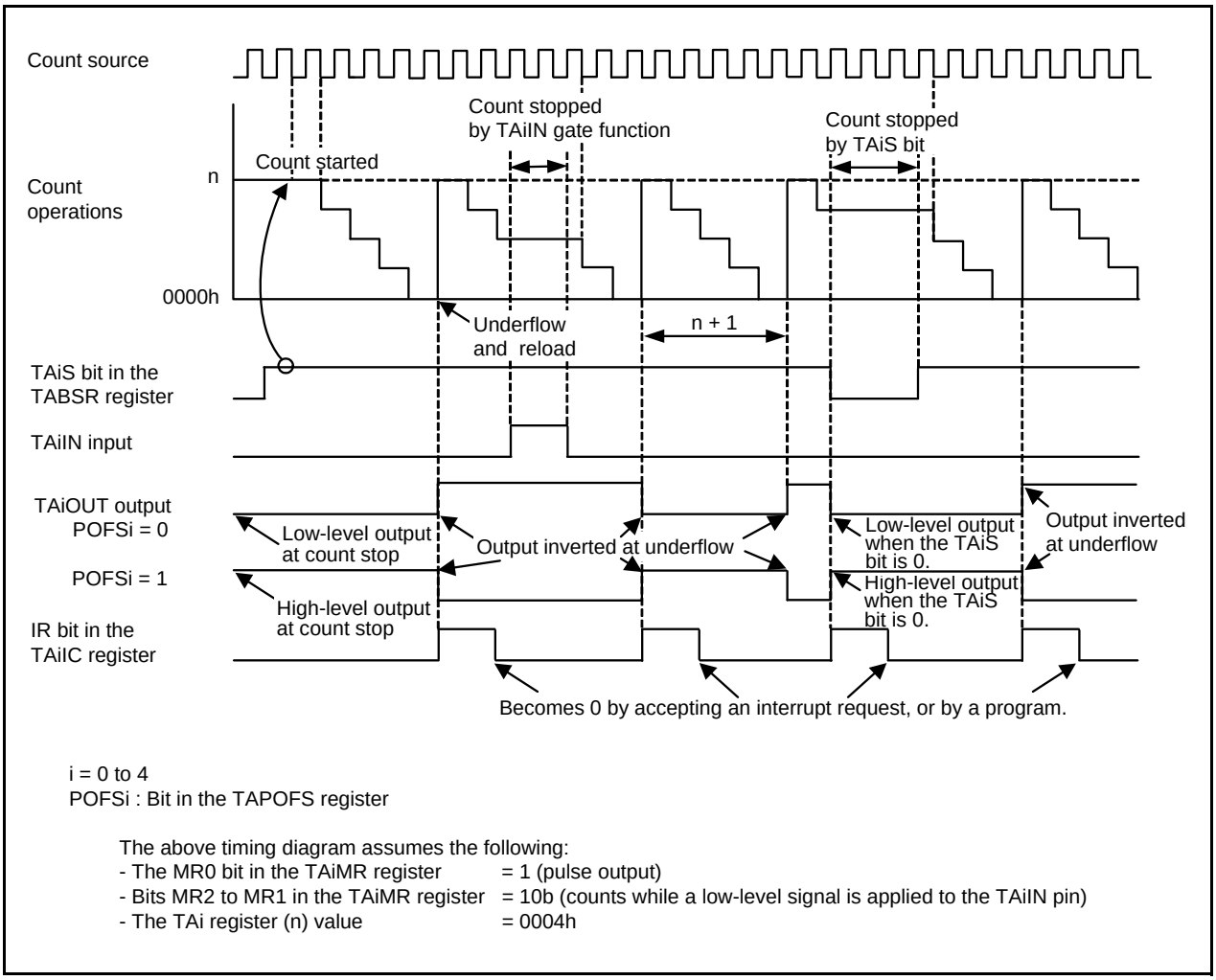
Symbol	Address	Reset Value
TA0MR to TA4MR	0336h to 033Ah	00h

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.



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.
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).

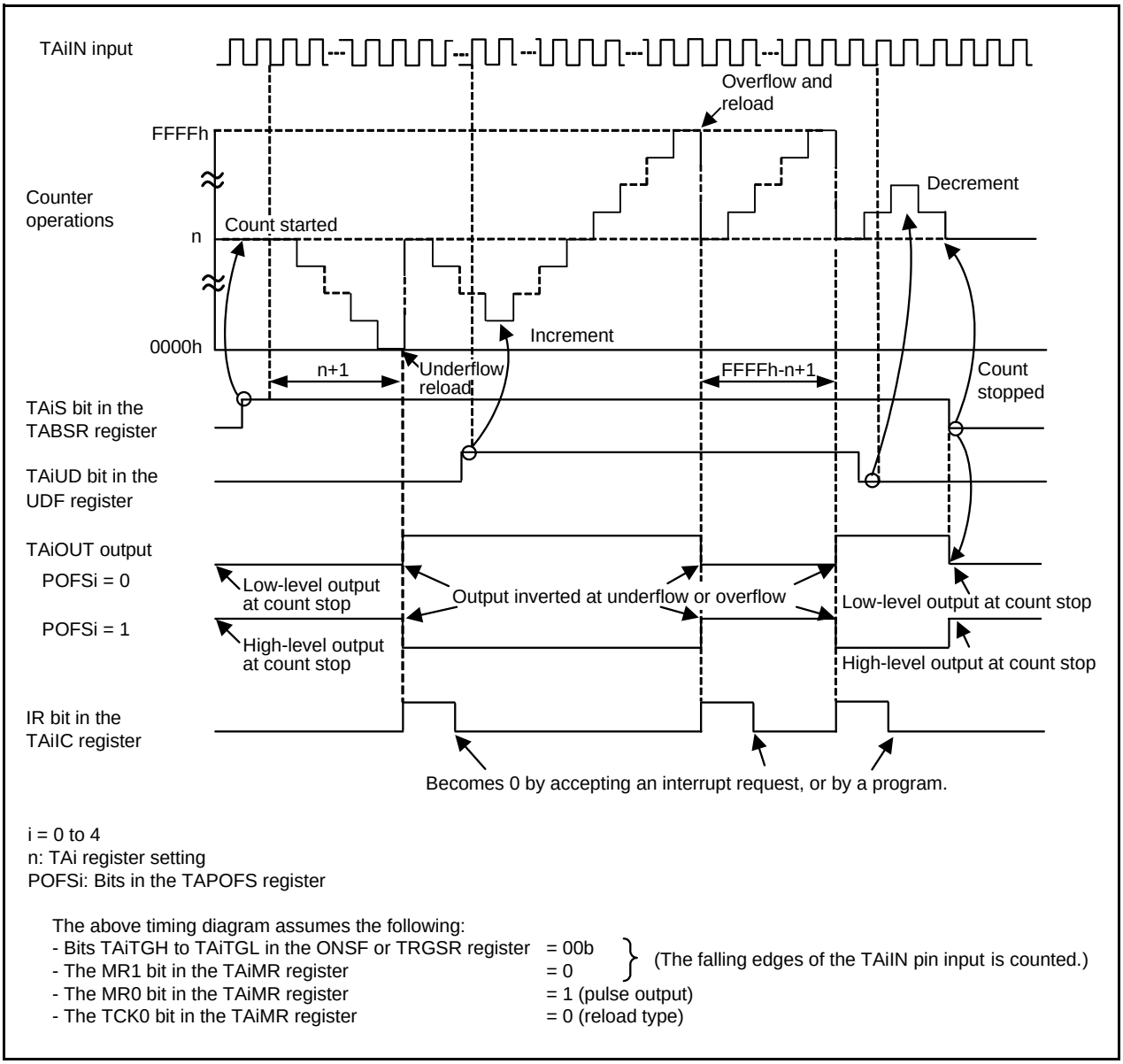


Figure 17.6 Operation Example in Event Counter Mode

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.
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.

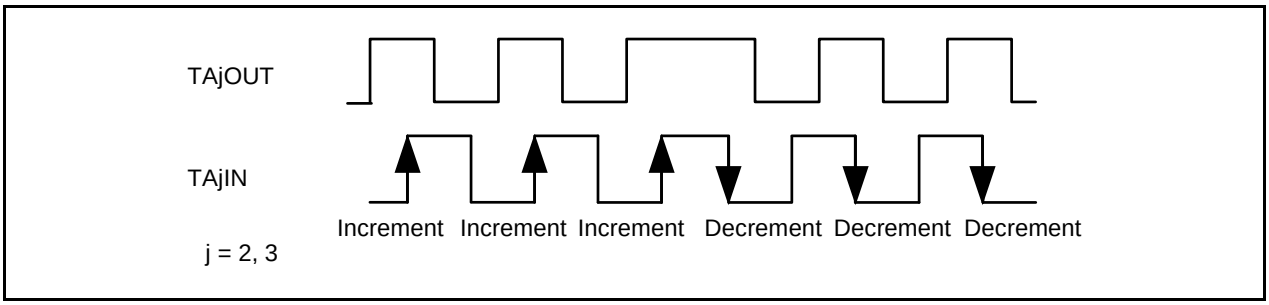


Figure 17.7 Normal Processing

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.

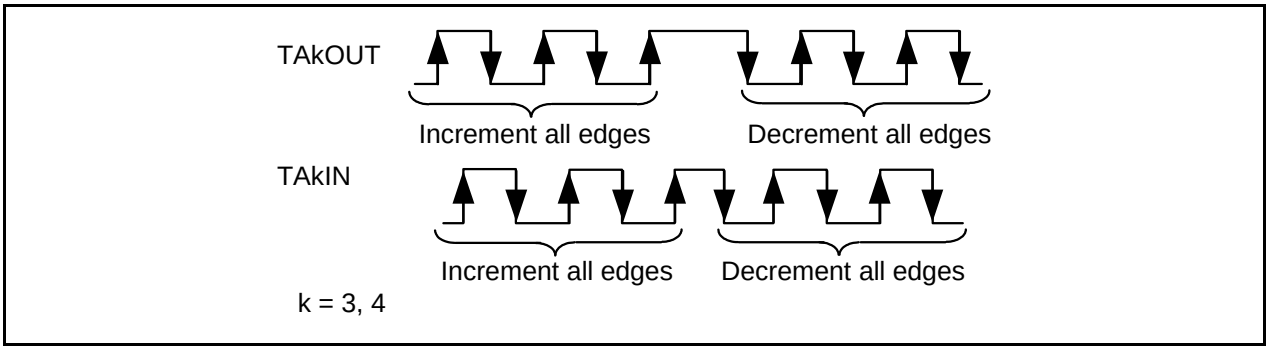


Figure 17.8 Multiply-by-4 Processing

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.

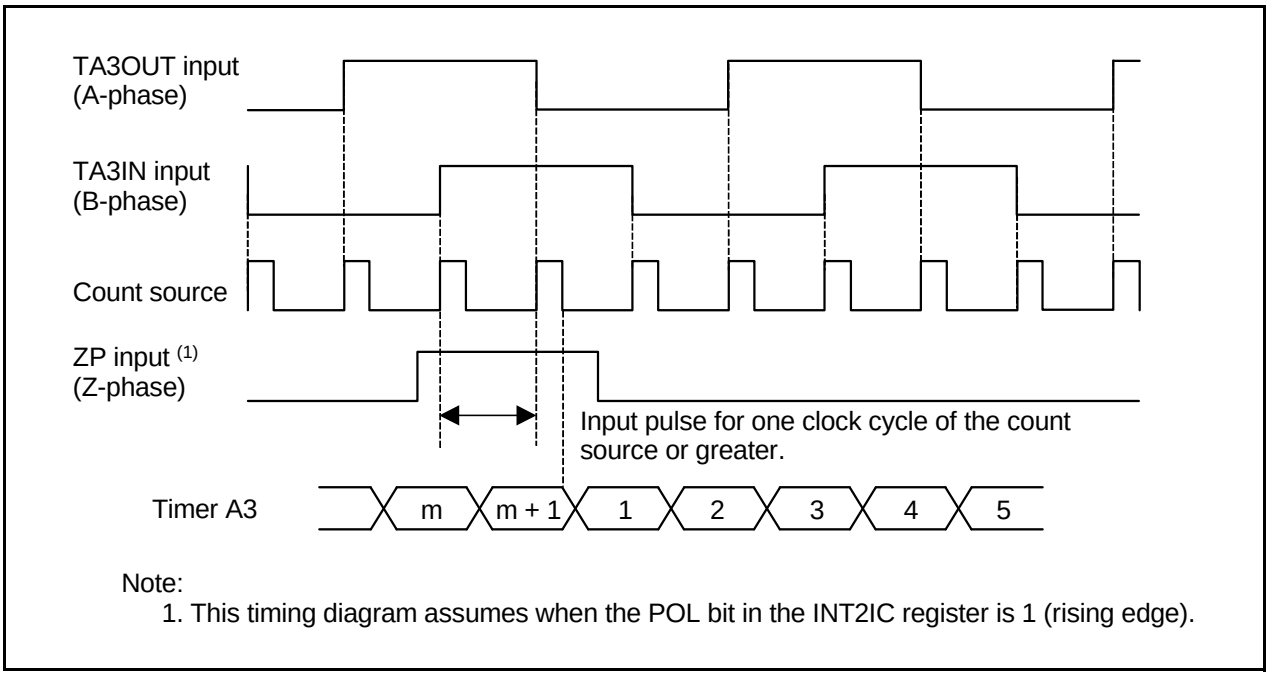
This function can only be used in timer A3 event counter mode during two-phase pulse signal processing, free-running type, multiply-by-4 processing, with Z-phase entered from the ZP pin.

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.
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)

b7	b6	b5	b4	b3	b2	b1	b0
		0				1	0

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			RW

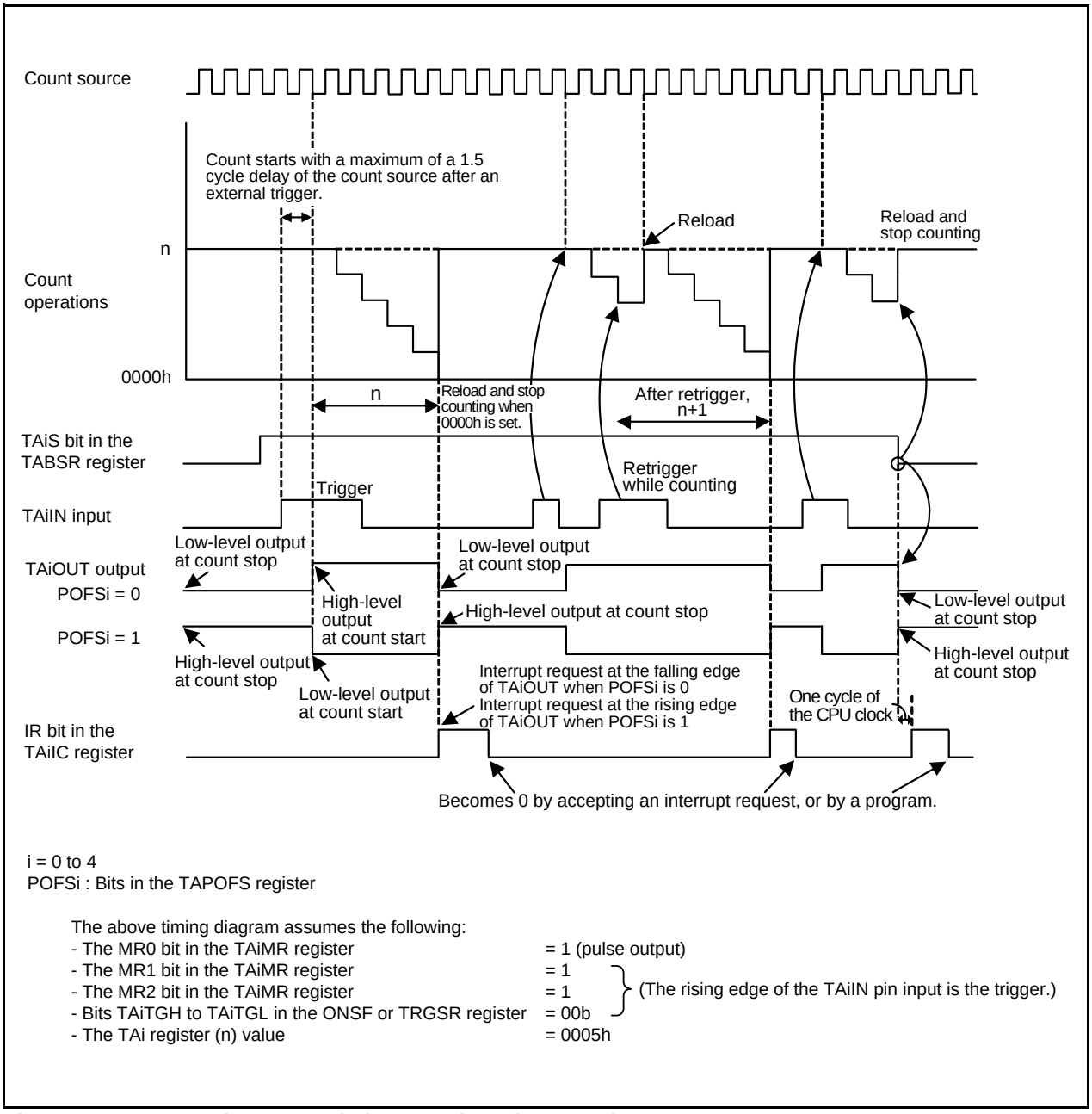
MR1 (External trigger select bit) (b3)

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.



i = 0 to 4
POFSi : Bits in the TAPOFS register

The above timing diagram assumes the following:

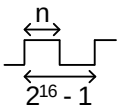
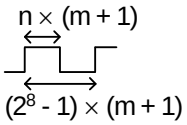
- The MR0 bit in the TAiMR register	= 1 (pulse output)	
- The MR1 bit in the TAiMR register	= 1	(The rising edge of the TAiIN pin input is the trigger.)
- The MR2 bit in the TAiMR register	= 1	
- Bits TAiTGH to TAiTGL in the ONSF or TRGSR register	= 00b	
- The TAi register (n) value	= 0005h	

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.
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)

b7	b6	b5	b4	b3	b2	b1	b0
						1	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 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			

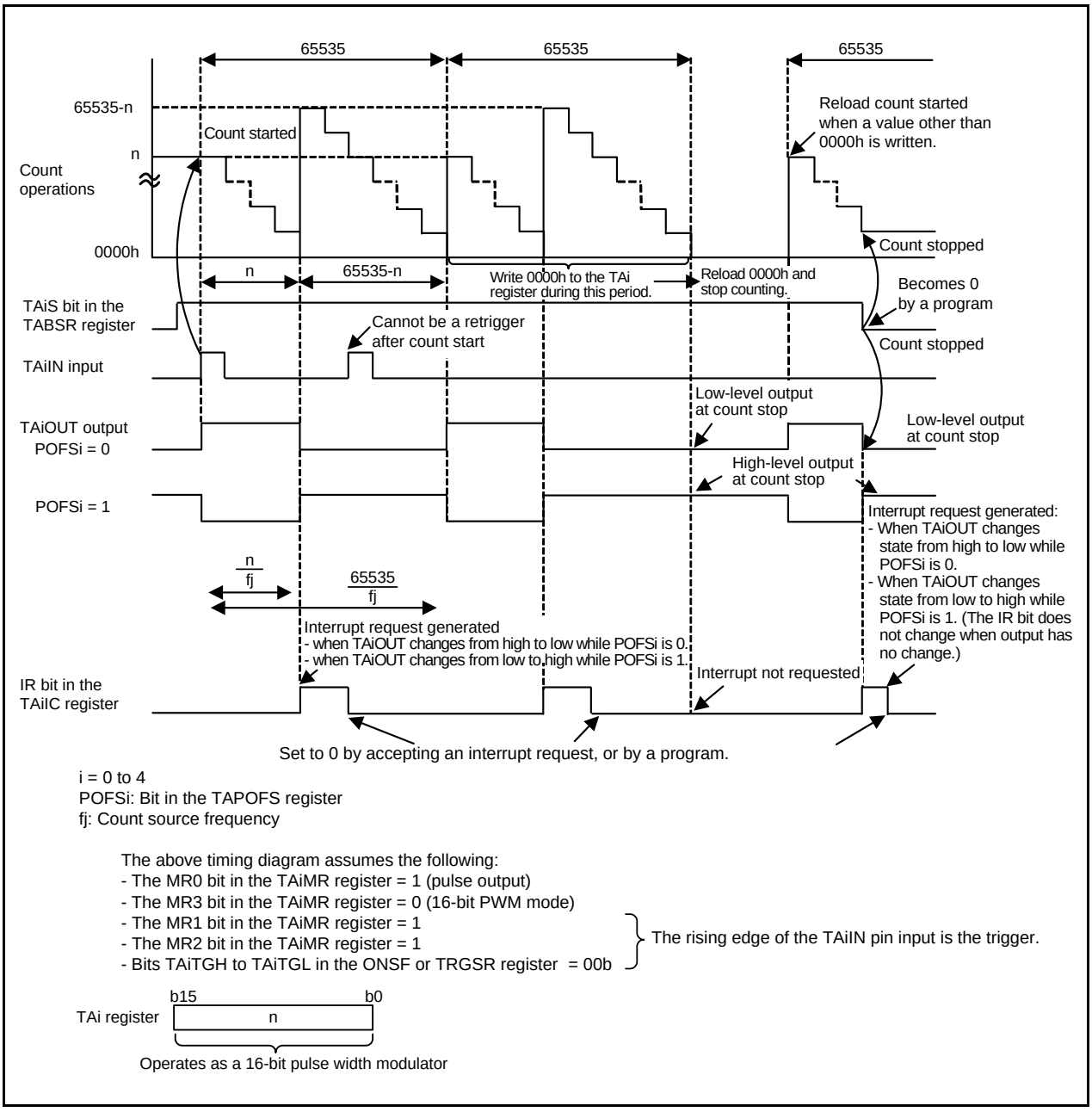
MR1 (External trigger select bit) (b3)

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.



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.

Operates as a 16-bit pulse width modulator

Figure 17.11 Operation Example in 16-Bit Pulse Width Modulation Mode

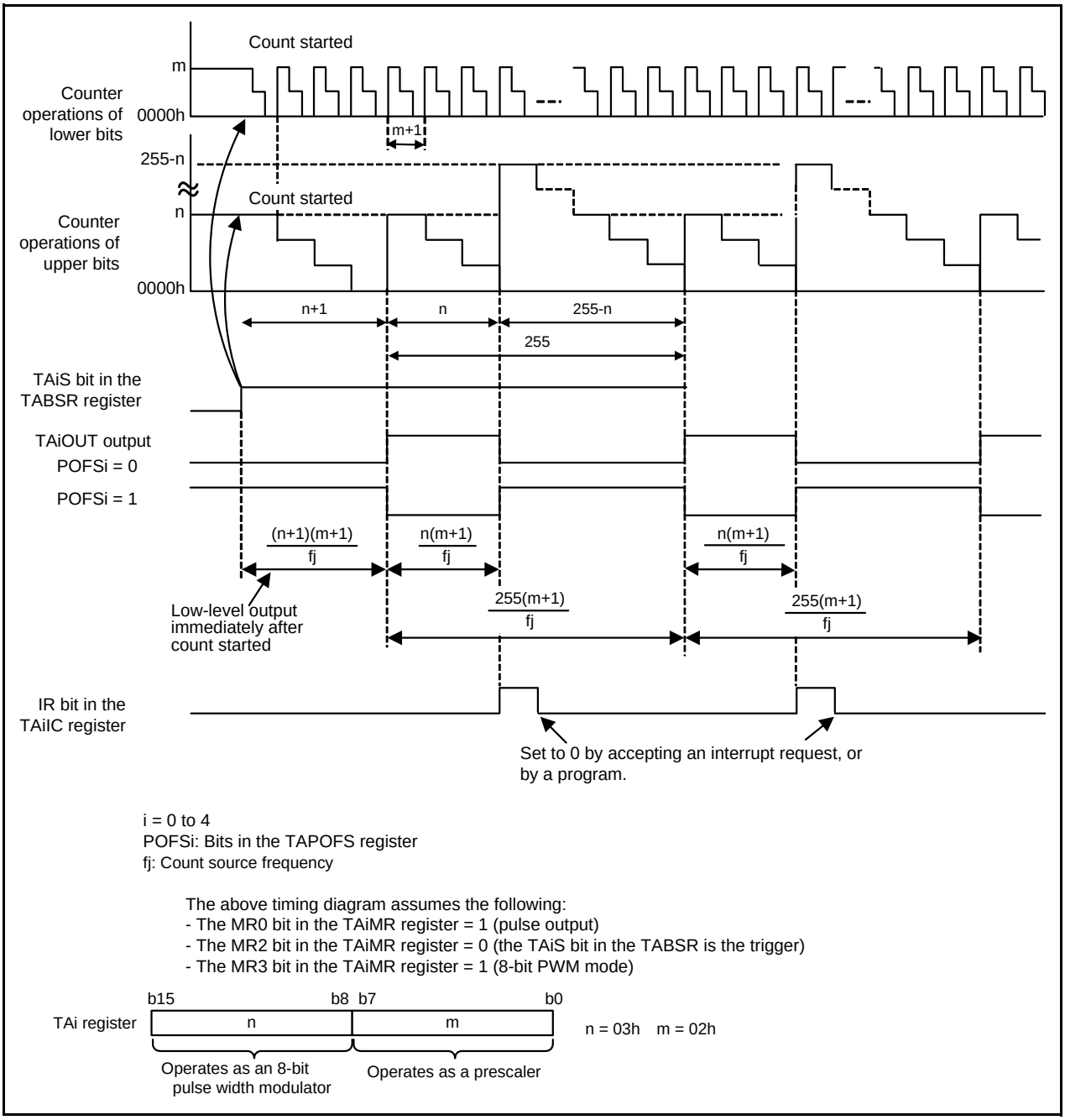
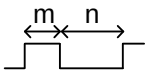


Figure 17.12 Operation Example in 8-Bit Pulse Width Modulation Mode

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.
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)

b7	b6	b5	b4	b3	b2	b1	b0
		0				1	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 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			

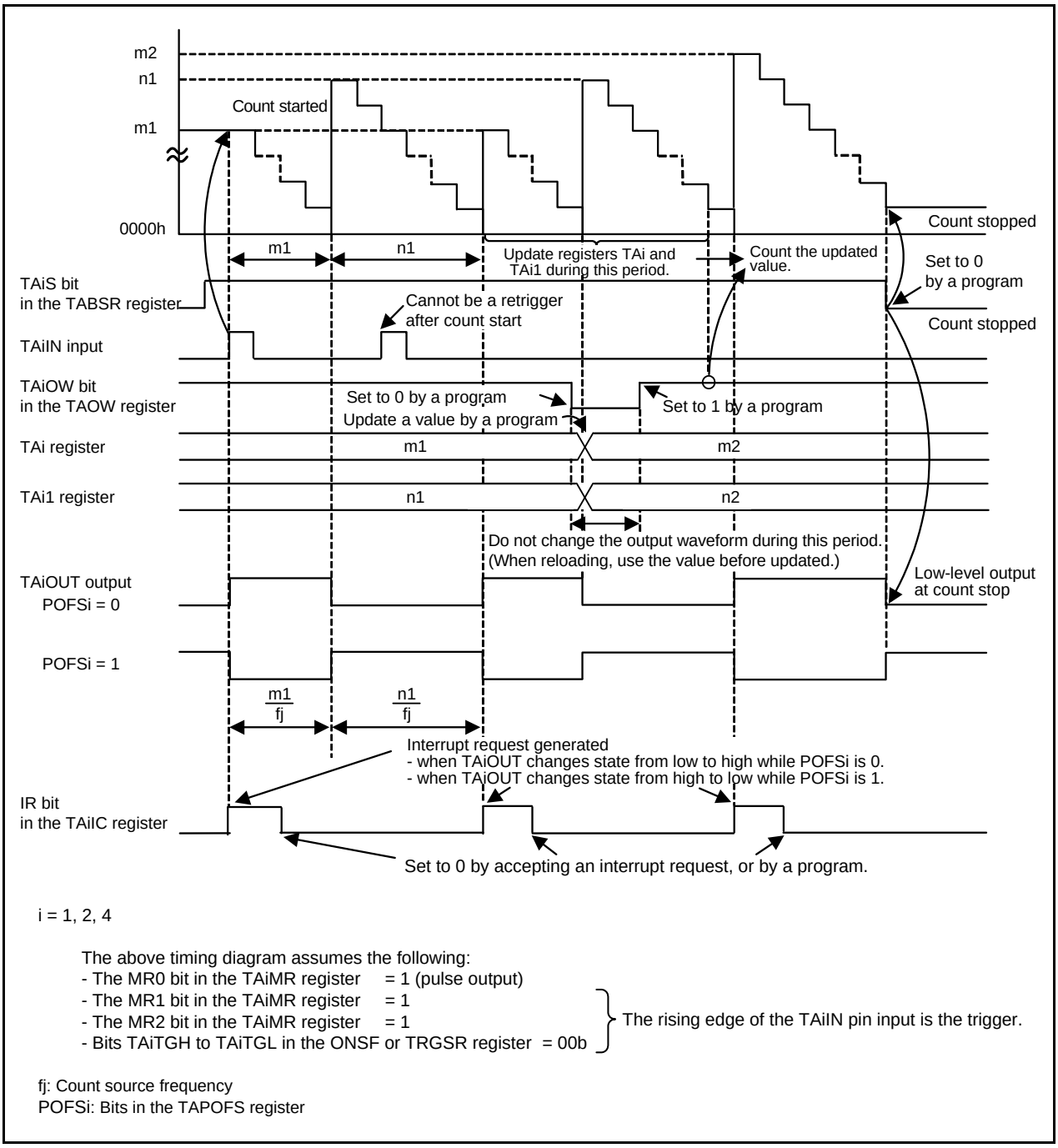
MR1 (External trigger select bit) (b3)

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.



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 $\overline{SD}$

When a low-level signal is applied to the $\overline{SD}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{SD}$ pin enabled), the following pins become high-impedance: P7_2/CLK2/TA1OUT/V, P7_3/$\overline{CTS2}$/$\overline{RTS2}$/TA1IN/$\overline{V}$, P7_4/TA2OUT/W, P7_5/TA2IN/$\overline{W}$, P8_0/TA4OUT/RXD5/SCL5/U/TSUDA, P8_1/TA4IN/$\overline{CTS5}$/$\overline{RTS5}$/$\overline{U}$/TSUDB

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

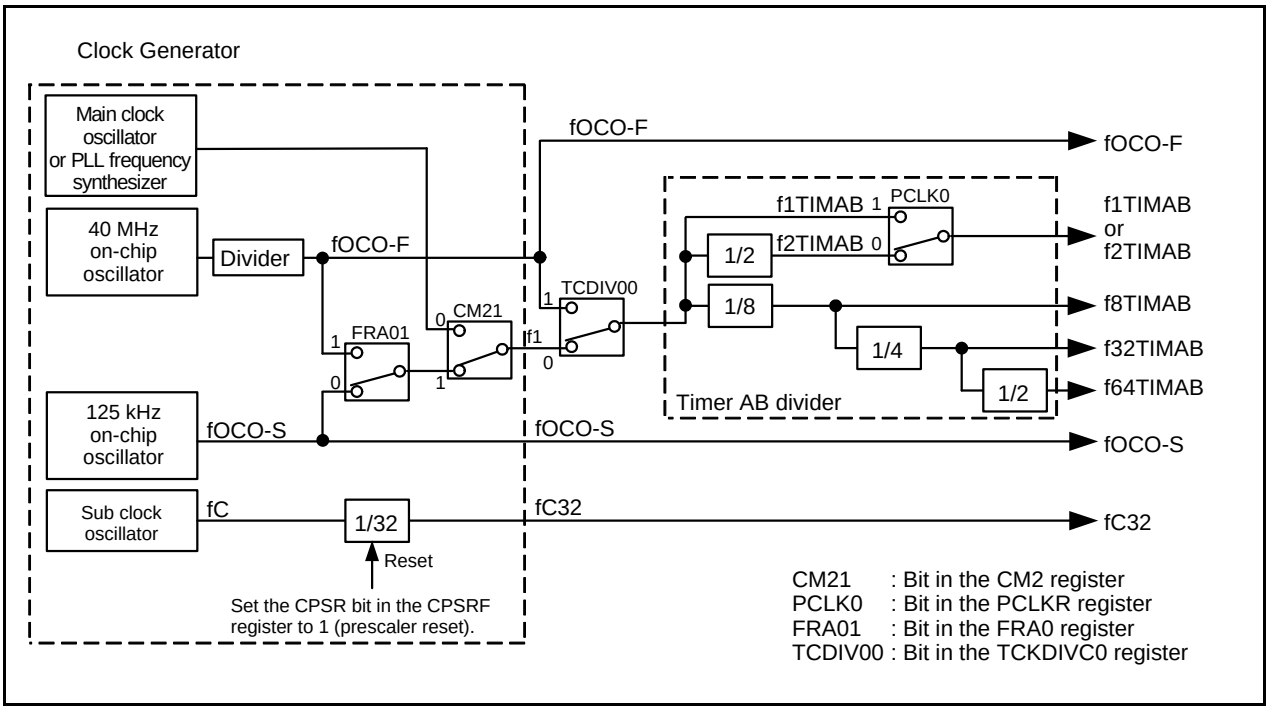


Figure 18.1 Timer A and B Count Sources

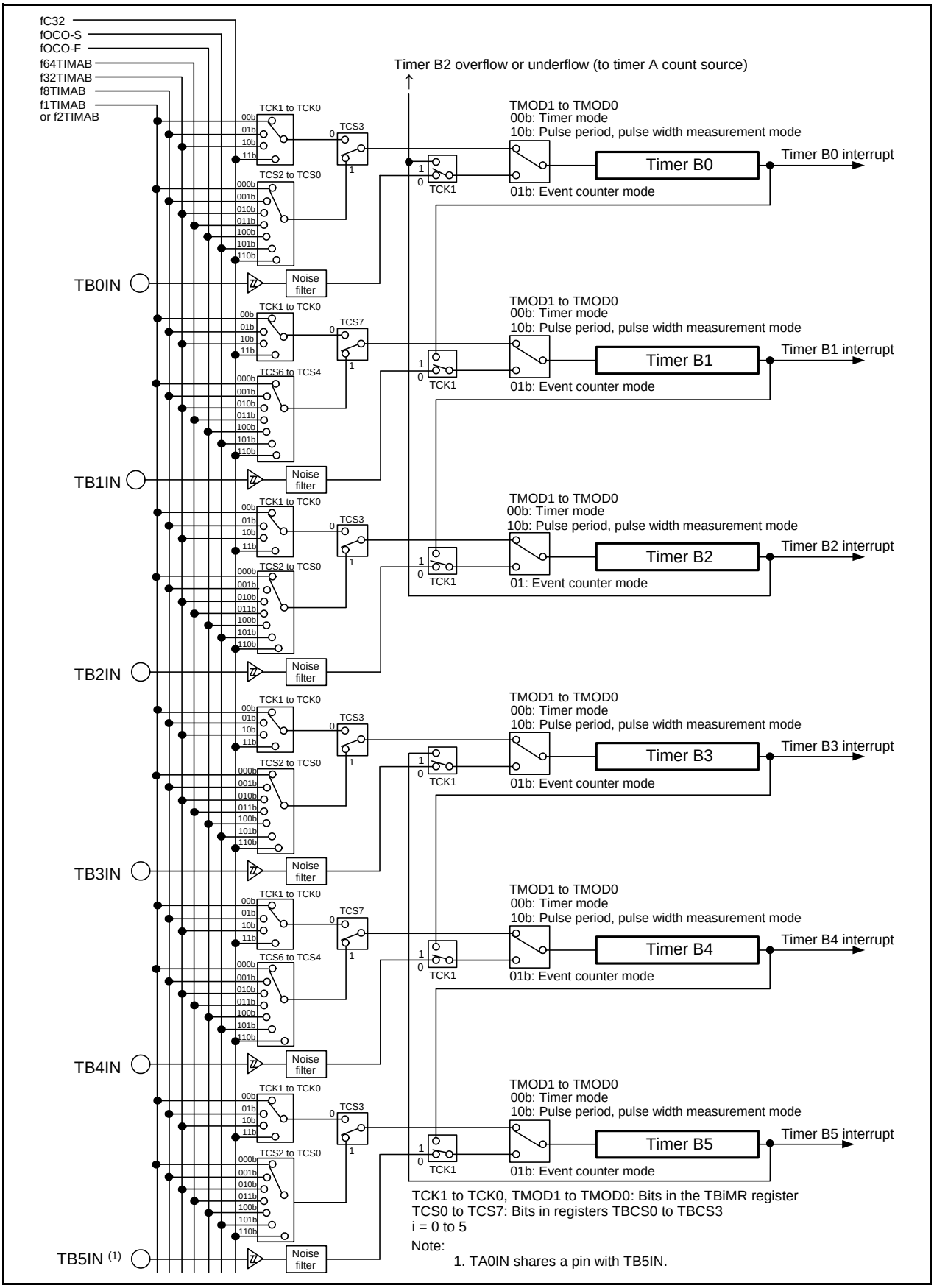
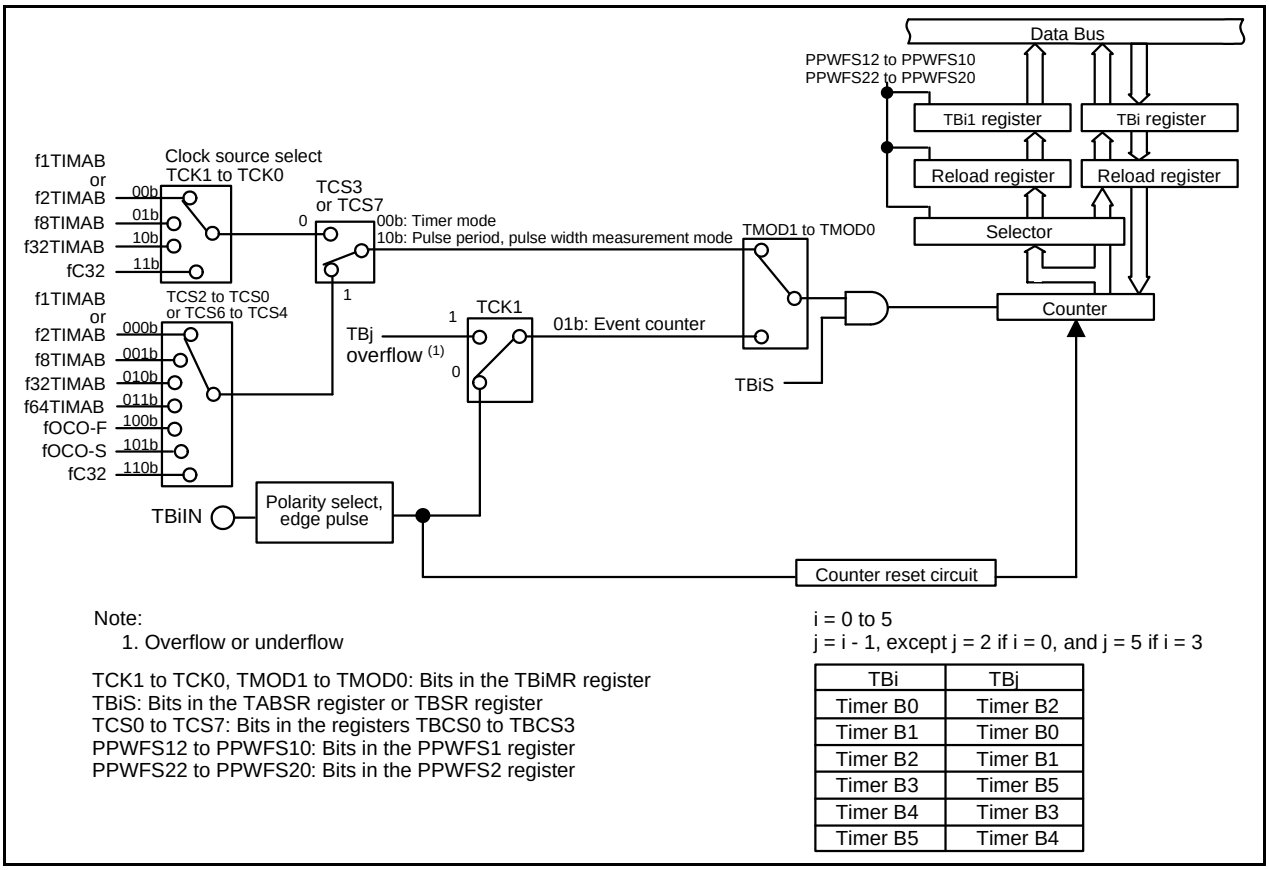


Figure 18.2 Timer B Configuration



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
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

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

Symbol: PCLKR | Address: 0012h | Reset Value: 0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A, B and S clock select bit (clock source for timers A, B and S, the dead time timer, and multi-master I^2C-bus interface)	0: f2TIMAB/f2IIC/f2TIMS 1: f1TIMAB/f1IIC/f1TIMS	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART5)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function extension bit (valid in single-chip mode)	0: Selected by 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

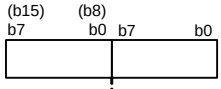
b7	b6	b5	b4	b3	b2	b1	b0
X	X	X	X	X	X	X	X

Symbol: CPSRF | Address: 0015h | Reset Value: 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 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

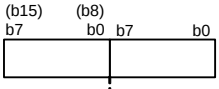
The timer counts pulses from an external device, or overflows or underflows of other timers.

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.

18.2.4 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

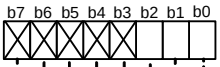
Mode	Function	Setting Range	RW
Pulse period measurement mode Pulse width measurement mode	Measures a pulse period or width	0000h to FFFFh	RO

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.

18.2.5 Pulse Period/Pulse Width Measurement Mode Function Select Register i (PPWFSi) (i = 1, 2)

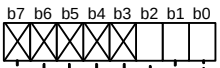
Pulse Period/Pulse Width Measurement Mode Function Select Register 1



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.

18.2.6 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

b7 b6 b5 b4 b3 b2 b1 b0

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

b7 b6 b5 b4 b3 b2 b1 b0

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.

18.2.7 Timer AB Division Control Register 0 (TCKDIVC0)

Timer AB Division Control Register 0

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

Symbol: TCKDIVC0 | Address: 01CBh | Reset Value: 0000 X000b

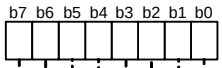
Bit Symbol	Bit Name	Function	RW
TCDIV00	Clock select prior to timer AB division bit	0 : f1 1 : fOCO-F	RW
— (b2-b1)	Reserved bits	Set to 0	RW
— (b3)	No register bit. If necessary, set to 0. The read value is undefined.		—
— (b7-b4)	Reserved bits	Set to 0	RW

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.

18.2.8 Count Start Flag (TABSR)
Timer B3/B4/B5 Count Start Flag (TBSR)

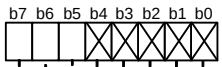
Count Start Flag



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

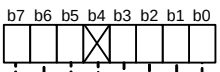


Symbol	Address	Reset Value
TBSR	0300h	000X XXXXb

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

18.2.9 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)

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.

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.
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)

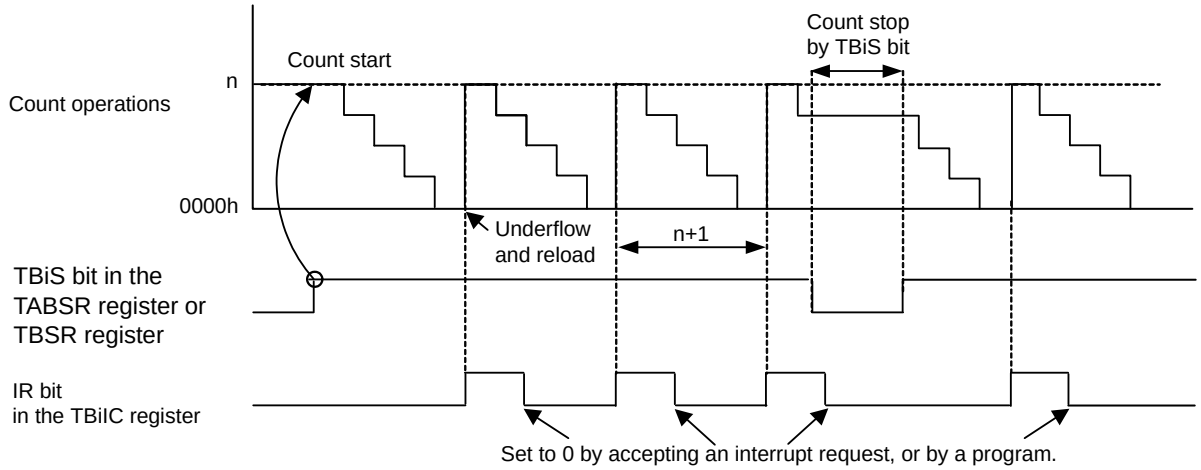
b7	b6	b5	b4	b3	b2	b1	b0
			X	0	0	0	0

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

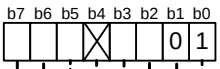
Table 18.8 Registers and Settings in Event Counter Mode (1)

Register	Bit	Function and Setting
PCLKR	PCLK0	- (setting unnecessary)
CPSRF	CPSR	Write 1 to reset the clock prescaler.
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

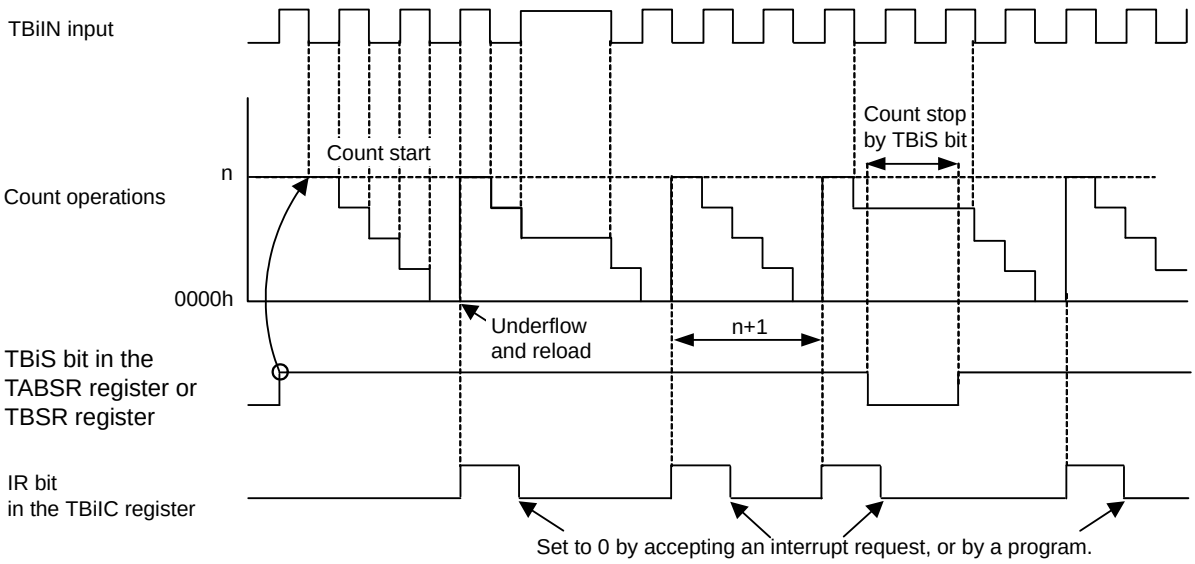
Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 0 1 : Event counter mode	RW
TMOD1			RW
MR0	Count polarity select bit	b3 b2 0 0 : Counts falling edges of an external signal 0 1 : Counts rising edges of an external signal 1 0 : Counts falling and rising edges of an external signal 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)

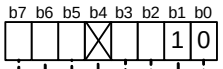
Register	Bit	Function and Setting
PCLKR	PCLK0	Select the count source.
CPSRF	CPSR	Write 1 to reset the clock prescaler.
TBi1	15 to 0	Measurement result can be read when the bits in the PPWFS1 or PPWFS2 register corresponding to timer Bi are 1.
PPWFS1 to PPWFS2	PPWFS12 to PPWFS10 PPWFS22 to PPWFS20	Set 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.

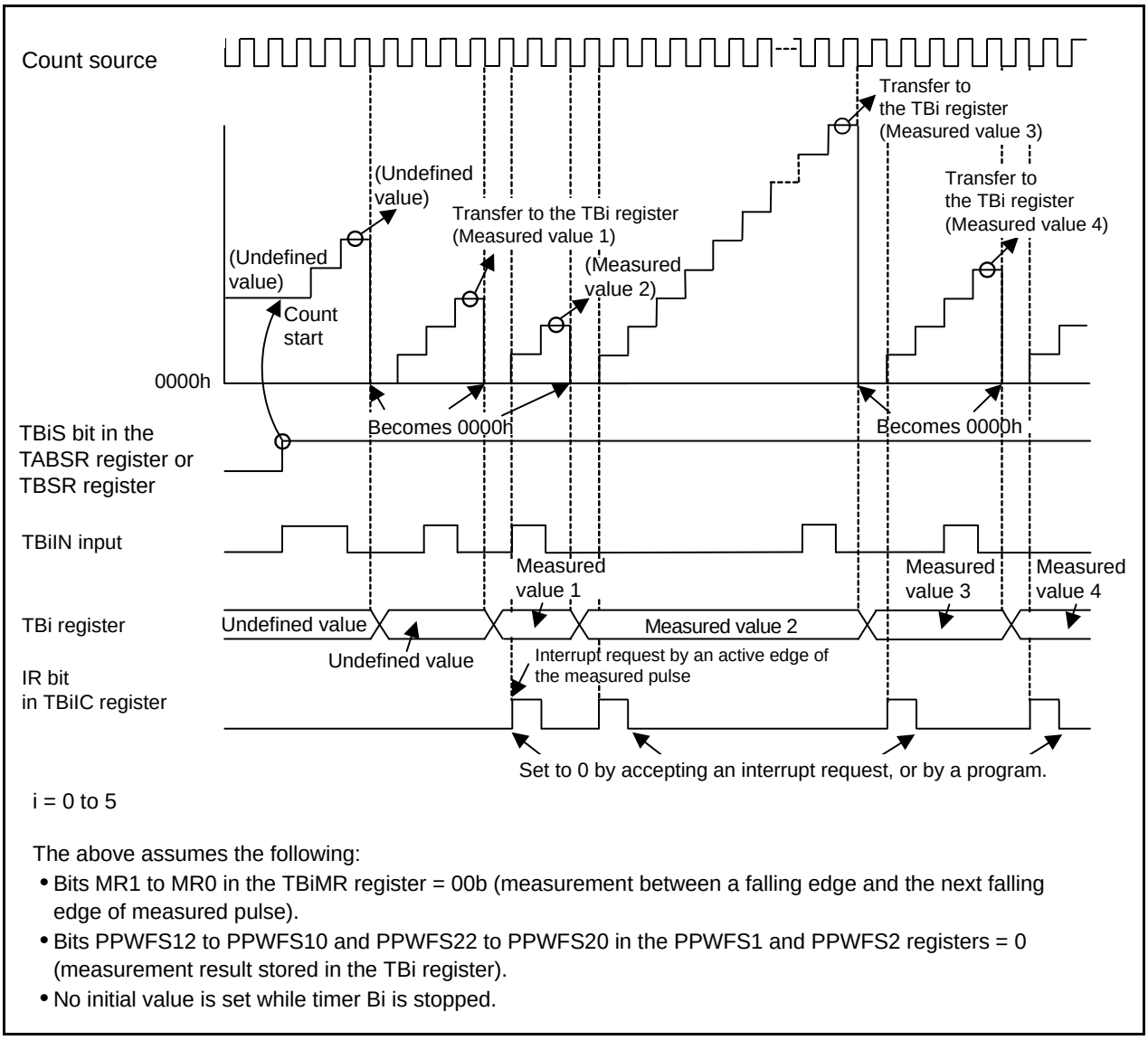
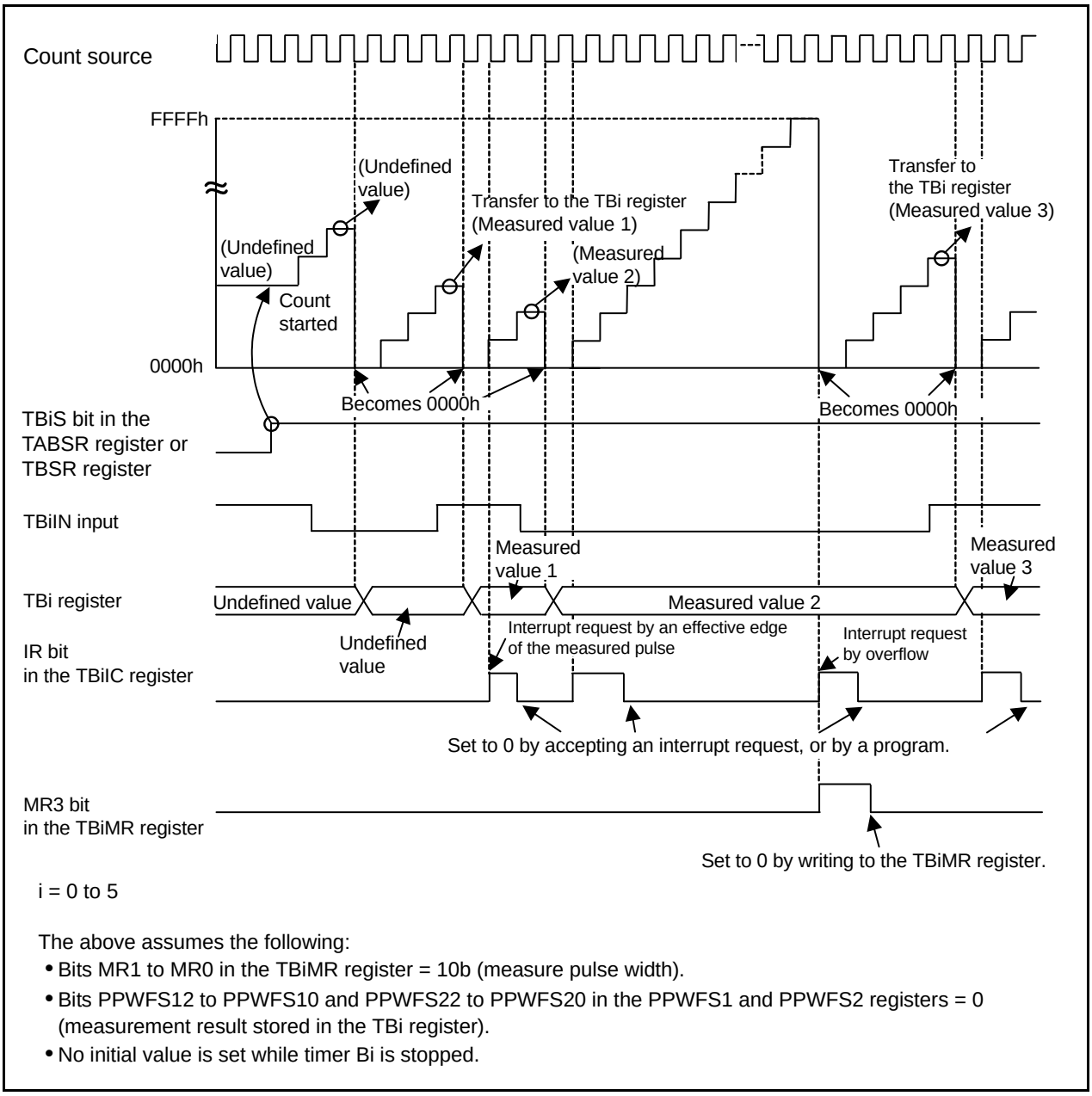


Figure 18.6 Operation Example in Pulse Period Measurement Mode



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.

18.5.2 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

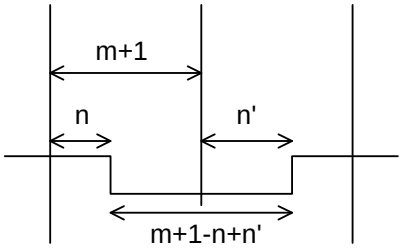
19.1 Introduction

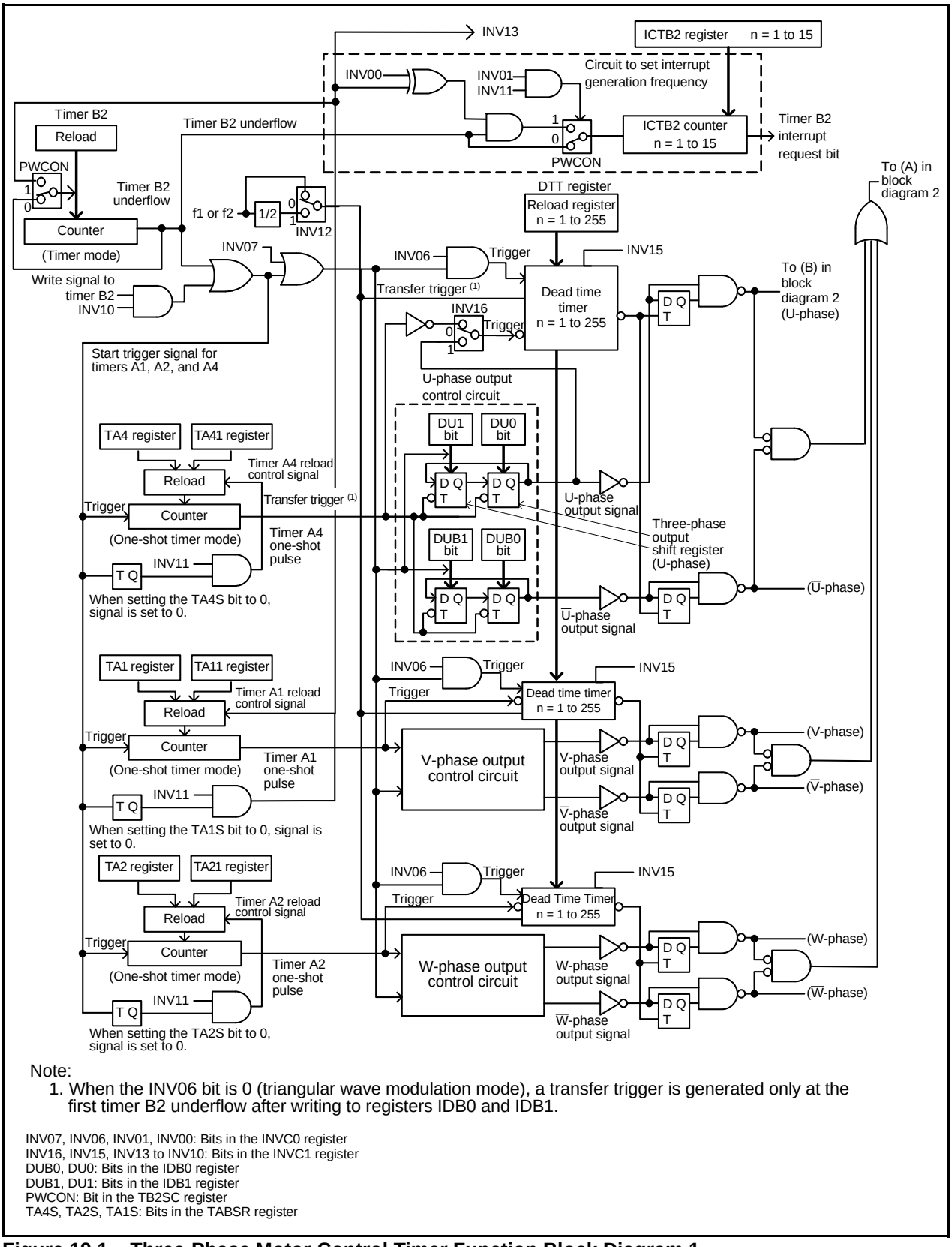
Timers A1, A2, A4, and B2 can be used to output three-phase motor drive waveforms.
Table 19.1 and Table 19.2 list Three-Phase Motor Control Timer Function Specifications. Three-Phase Motor Control Timer Function Block Diagrams are shown in Figure 19.1 and Figure 19.2. Table 19.3 lists I/O Ports.

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, $\overline{U}$, V, $\overline{V}$, W, $\overline{W}$)
Forced cutoff input	Input a low-level signal to the $\overline{SD}$ pin
Used timers	Timers A4, A1, A2 (used in one-shot timer mode) Timer A4: U-/$\overline{U}$-phase waveform control Timer A1: V-/$\overline{V}$-phase waveform control Timer A2: W-/$\overline{W}$-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

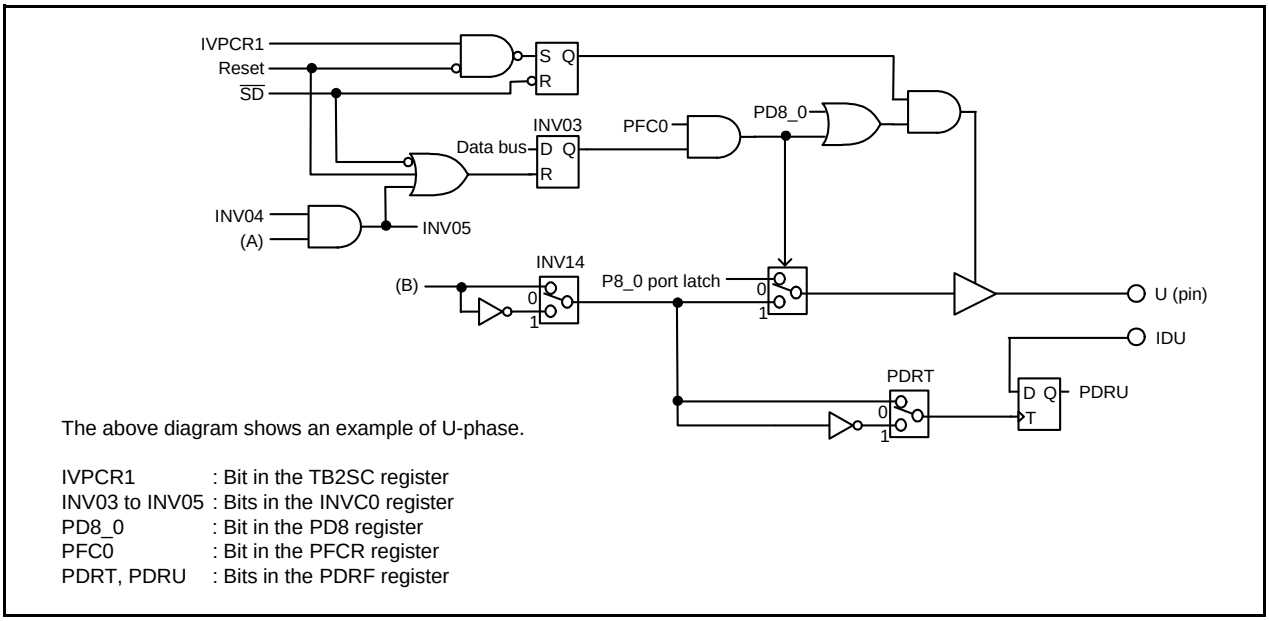


Figure 19.2 Three-Phase Motor Control Timer Function Block Diagram 2

Table 19.3 I/O Ports

Pin Name	I/O	Function
U, $\overline{U}$, V, $\overline{V}$, W, $\overline{W}$	Output	Three-phase PWM waveform output
$\overline{SD}$	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 $\overline{SD}$ 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	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
0318h	Port Function Control Register	PFCR	0011 1111b
0328h	Timer A1 Register	TA1	XXh
0329h			XXh
032Ah	Timer A2 Register	TA2	XXh
032Bh			XXh
032Eh	Timer A4 Register	TA4	XXh
032Fh			XXh
0334h	Timer B2 Register	TB2	XXh
0335h			XXh
033Eh	Timer B2 Special Mode Register	TB2SC	X000 0000b

19.2.1 Timer B2 Register (TB2)

Timer B2 Register

(b15) (b8)
b7 b0 b7 b0

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)

(b15) (b8)
b7 b0 b7 b0

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 $\overline{SD}$ 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

b7	b6	b5	b4	b3	b2	b1	b0
0							

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)

b7 b6 b5 b4 b3 b2 b1 b0

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

b7 b0

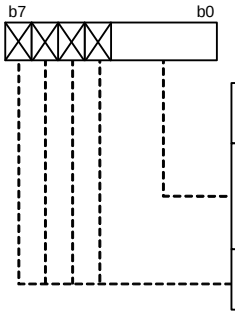
Symbol	Address	Reset Value
DTT	030Ch	Undefined

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

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	Reset Value
X	0	0						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
TB0EN	Timer B0 operation mode select bit	0 : Other than A/D trigger mode 1 : A/D trigger mode	RW
TB1EN	Timer B1 operation mode select bit	0 : Other than A/D trigger mode 1 : A/D trigger mode	RW
TB2SEL	Trigger select bit	0 : Timer B2 underflow 1 : ICTB2 register underflow	RW
— (b6-b5)	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)

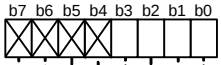
Related pins are U, $\overline{U}$, V, $\overline{V}$, W, and $\overline{W}$.

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

b7 b6 b5 b4 b3 b2 b1 b0

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

b7 b6 b5 b4 b3 b2 b1 b0

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.

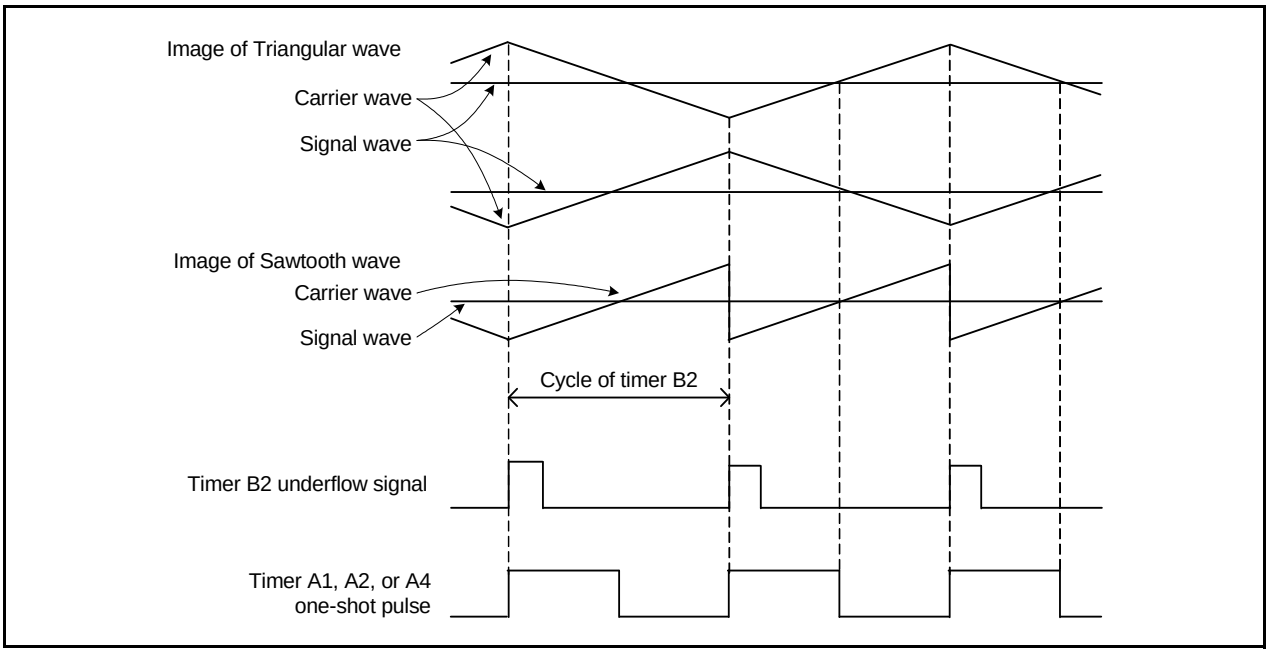


Figure 19.3 Relationship between the Carrier Wave Cycle and Timer B2

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.

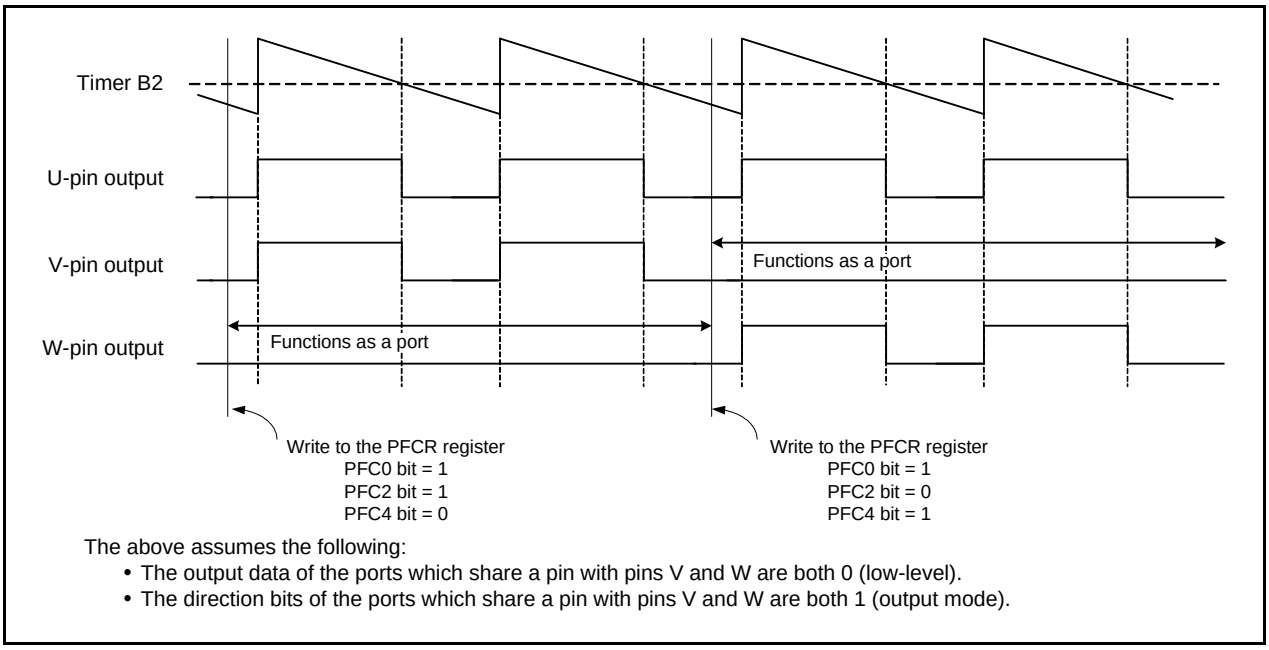
19.3.1.7 Three-Phase PWM Output Pin Select

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 $\overline{SD}$ pin, the INV03 bit in the INVC0 register becomes 0 (three-phase motor control timer output disabled), and pins corresponding to U, $\overline{U}$, V, $\overline{V}$, W and $\overline{W}$ 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 $\overline{SD}$ 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, $\overline{U}$, V, $\overline{V}$, W and $\overline{W}$ outputs. Table 19.8 lists State of Pins U, $\overline{U}$, V, $\overline{V}$, W, and $\overline{W}$.

Table 19.8 State of Pins U, $\overline{U}$, V, $\overline{V}$, W, and $\overline{W}$ (1)

State of Bit and Pin		Function or State of Pins U, $\overline{U}$, V, $\overline{V}$, W and $\overline{W}$
IVPCR1 bit in the TB2SC register	$\overline{SD}$ 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 $\overline{SD}$ pin. When the value of bits NMIDF2 to NMIDF0 in the NMIDF register is not 000b (digital filter enabled), $\overline{SD}$ 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 "$\overline{NMI}$/$\overline{SD}$ 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 $\overline{SD}$ 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 $\overline{SD}$ input to 0 (input port), and apply a high-level signal to the $\overline{SD}$ pin.
The same pin is used for both $\overline{SD}$ input and $\overline{NMI}$ input. To disable the $\overline{NMI}$ interrupt, set the PM24 bit in the PM2 register to 0 ($\overline{NMI}$ 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.

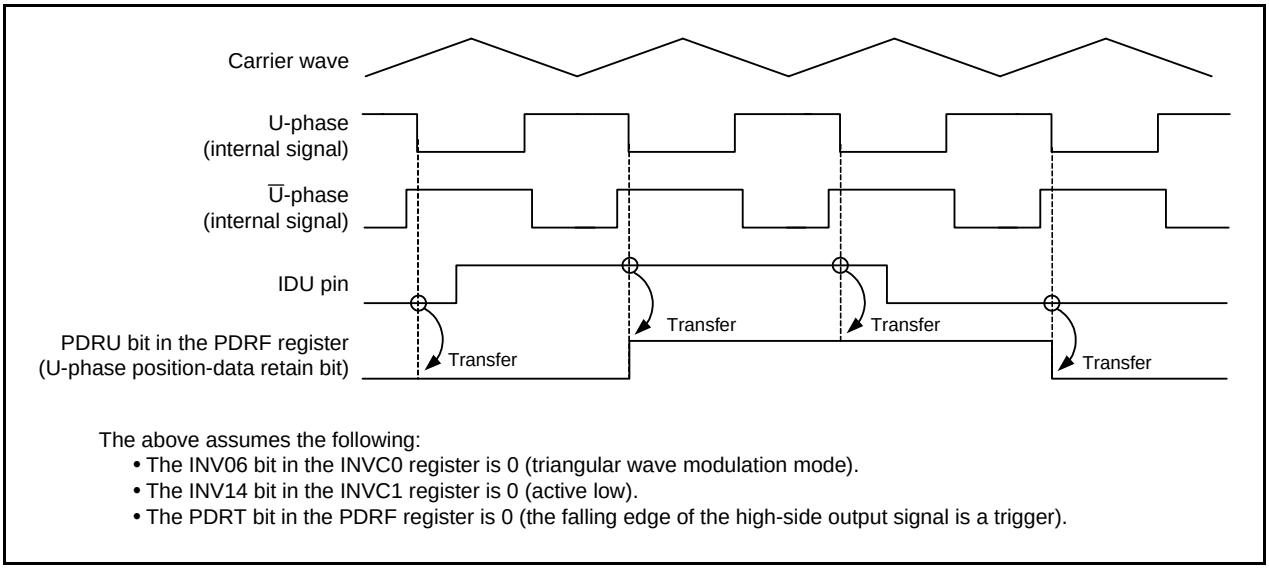
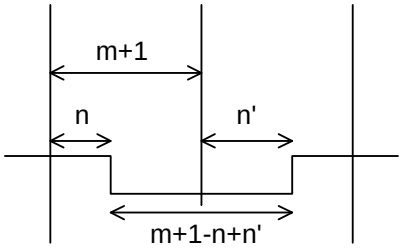


Figure 19.5 Position-Data-Retain Function (U-Phase) Operation

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.
	TB0EN	Set to 1 when using the Timer B0 to trigger A/D conversion.
	TB1EN	Set to 1 when using the Timer B1 to trigger A/D conversion.
	TB2SEL	Select a trigger timing when using the Timer B2 to trigger A/D conversion.
	b7 to b5	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.

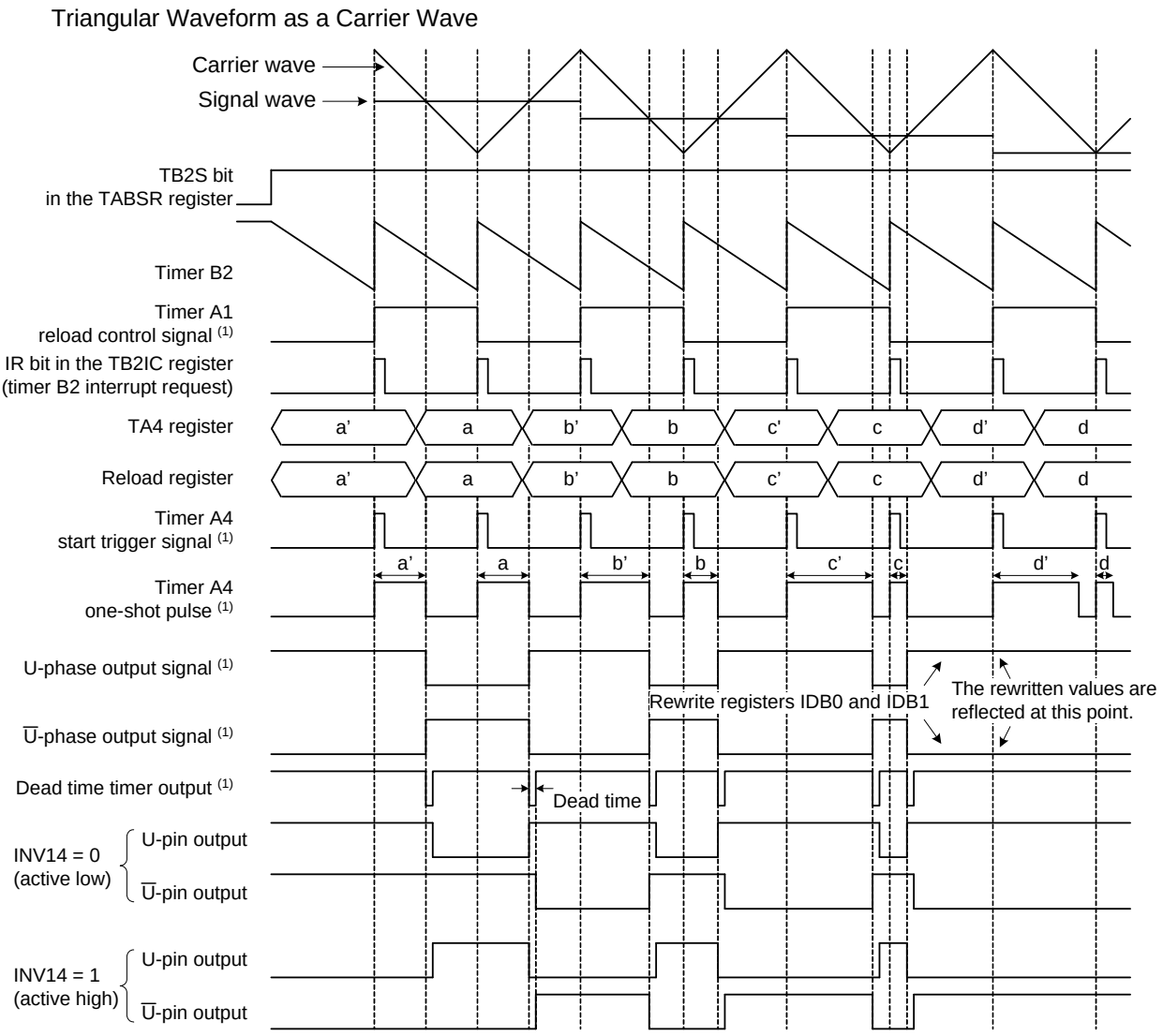
Table 19.11 Registers and Settings in Three-Phase Mode 0 (2/2) (1)

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.
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.



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.

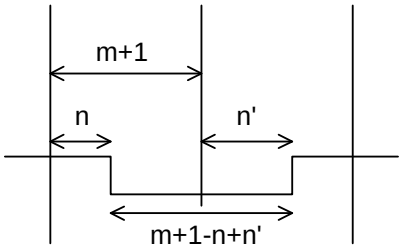
A transfer trigger is generated under the following conditions:

- 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.
	TB0EN	Set to 1 when using the Timer B0 to trigger A/D conversion.
	TB1EN	Set to 1 when using the Timer B1 to trigger A/D conversion.
	TB2SEL	Select a trigger timing when using the Timer B2 to trigger A/D conversion.
	b7 to b5	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.

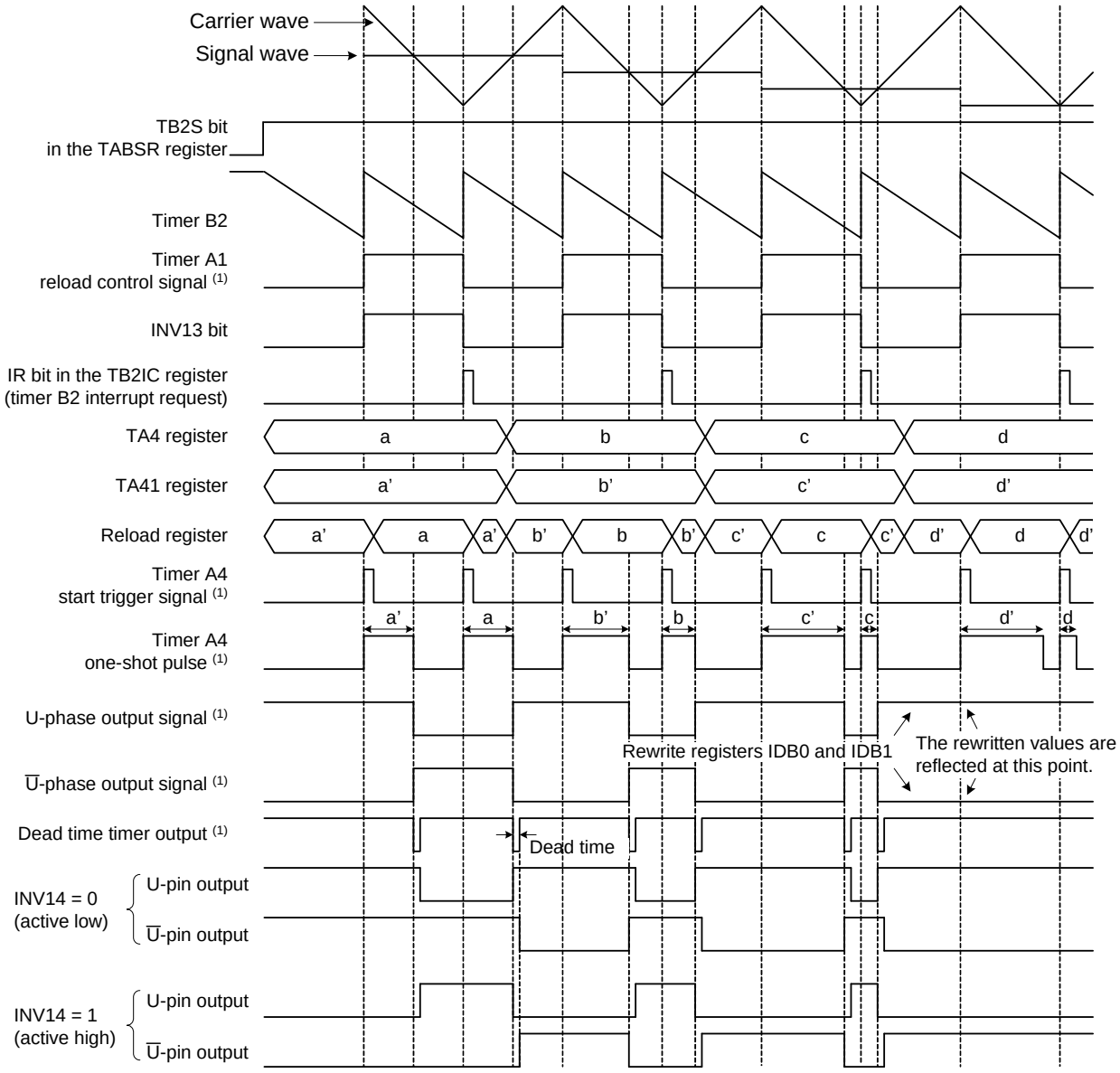
Table 19.14 Registers and Settings in Three-Phase Mode 1 (2/2) (1)

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.
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.



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-, U̅-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 / Timer A1 reload control signal	1	0
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.

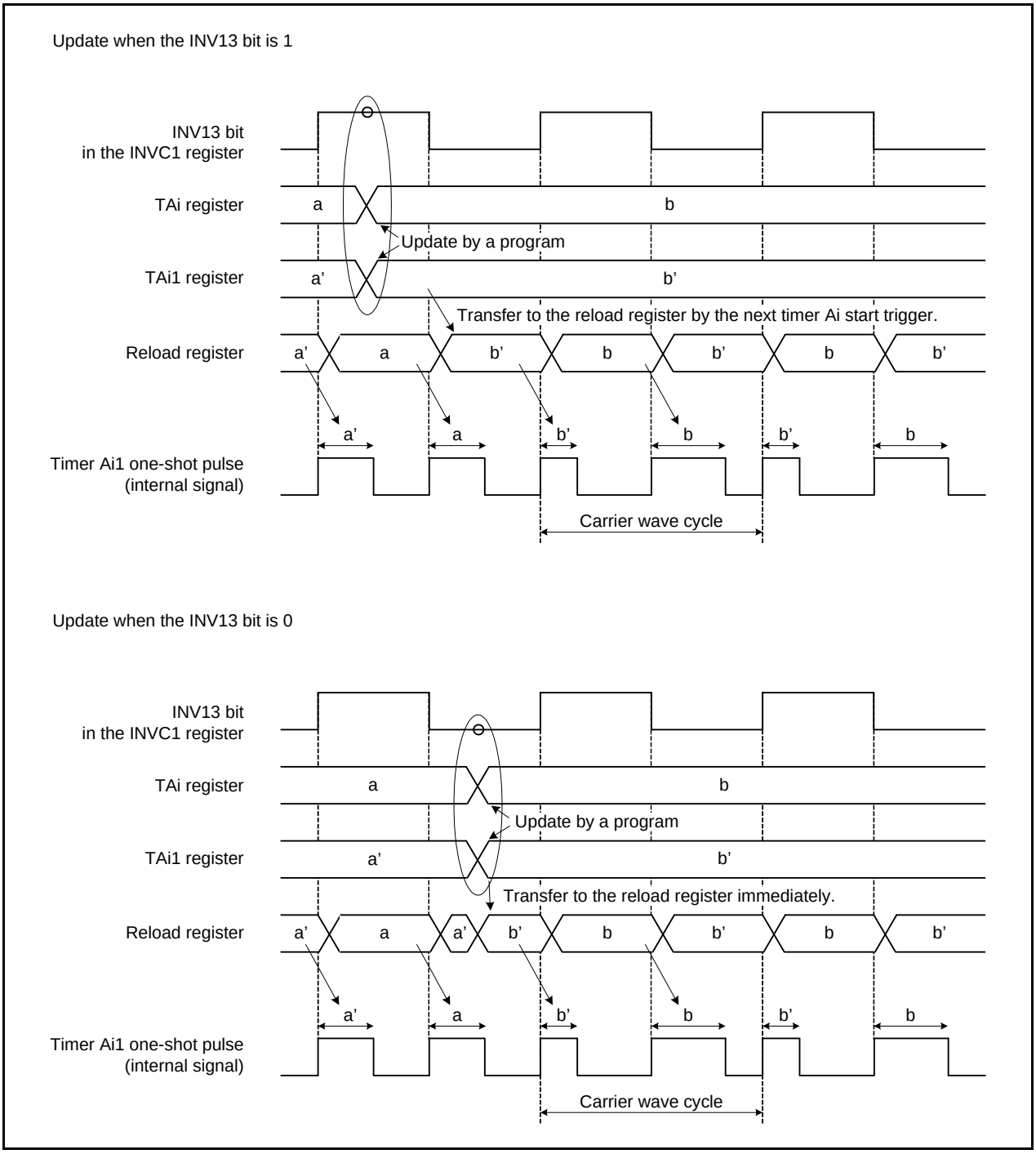


Figure 19.8 Update Timing of Registers TAi and TAi1 in Three-Phase Mode 1

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.
	TB0EN	Set to 1 when using the Timer B0 to trigger A/D conversion.
	TB1EN	Set to 1 when using the Timer B1 to trigger A/D conversion.
	TB2SEL	Select a trigger timing when using the Timer B2 to trigger A/D conversion.
	b7 to b5	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.

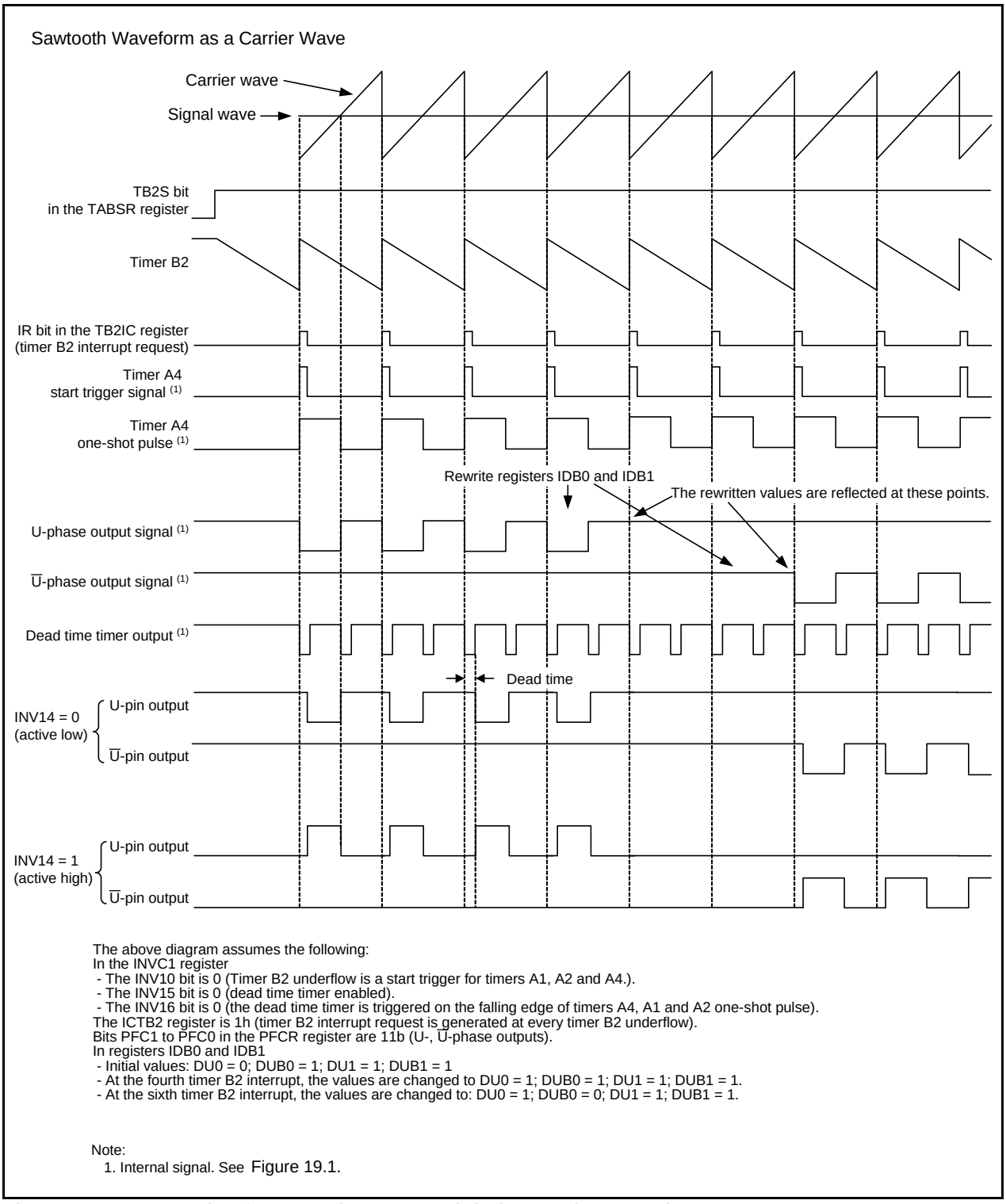
Table 19.18 Registers and Settings in Sawtooth Wave Modulation Mode (2/2) (1)

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.
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.



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-, U-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 $\overline{SD}$

When a low-level signal is applied to the $\overline{SD}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{SD}$ pin enabled), the following pins become high-impedance: P7_2/CLK2/TA1OUT/V, P7_3/$\overline{CTS2}$/$\overline{RTS2}$/TA1IN/$\overline{V}$, P7_4/TA2OUT/W, P7_5/TA2IN/$\overline{W}$, P8_0/TA4OUT/RXD5/SCL5/U/TSUDA, P8_1/TA4IN/$\overline{CTS5}$/$\overline{RTS5}$/$\overline{U}$/TSUDB

20. Timer S

20.1 Introduction

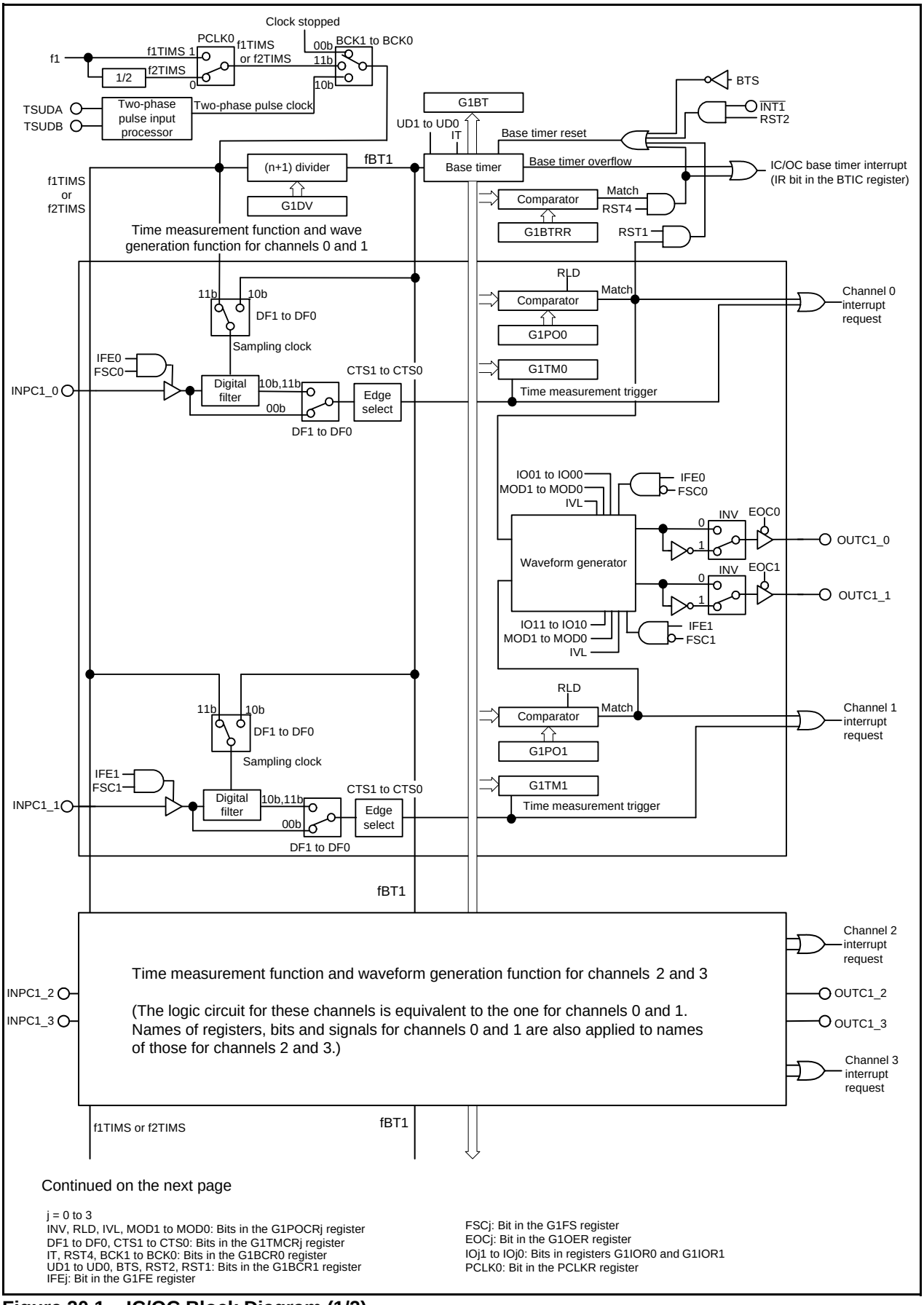
Timer S has an input capture/output compare function (IC/OC). The input capture (IC) is used for time measurement and the output compare (OC) is used for waveform generation. The IC/OC has one 16-bit free-running base timer and eight channels for time measurement and waveform generation.
Table 20.1 lists the specifications of the IC/OC.

Table 20.1 IC/OC Specifications

Item		Specification
Time measurement function (1)	Measurement channels	8 channels (channels 0 to 7)
	Trigger input edges	Selectable from rising edge, falling edge, or both edges of the INPC1_j pin
	Digital filter function	8 channels (channels 0 to 7)
	Prescaler function	2 channels (channels 6 and 7)
	Gate function	2 channels (channels 6 and 7)
Waveform generation function (1)	Waveform generating channels	8 channels (channels 0 to 7)
	Waveform generation functions	Single-phase waveform output, inverted waveform output, and SR waveform output
	Output level select function when there is a compare-match	The output level can be changed from low to high or high to low.
	Selectable port function	Waveform output port or programmable I/O port selectable
	Other functions	Selectable initial output level Invertible output waveform
Base timer	Bit length	16 bits
	Count sources	f1TIMS or f2TIMS divided by (n + 1), two-phase pulse input divided by (n + 1) n is a G1DV register setting value from 0 to 255. There is no division when n = 0.
	Count operations	Increment, increment/decrement, two-phase pulse signal processing
	Base timer reset conditions	• Base timer value matches the G1PO0 register value (RST1) • Low is input to external interrupt pin $\overline{\text{INT1}}$ (RST2) • Base timer value matches the G1BTRR register value (RST4)
Interrupts	IC/OC channel interrupts	6 (IC/OC channel 0 interrupt, IC/OC channel 1 interrupt, IC/OC channel 2 interrupt, IC/OC channel 3 interrupt, IC/OC interrupt 0 (channels 0 to 7), IC/OC interrupt 1 (channels 0 to 7))
	IC/OC base timer interrupts	1 (The base timer interrupt is generated by base timer overflow, or by a base timer reset request that occurs when the G1BTRR register matches the base timer.)

j = 0 to 7

Note:
1. The time measurement function shares pins with the waveform generation function. Either the time measurement function or waveform generation function is selectable for each channel.



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j = 0 to 3
INV, RLD, IVL, MOD1 to MOD0: Bits in the G1POCRj register
DF1 to DF0, CTS1 to CTS0: Bits in the G1TMCRj register
IT, RST4, BCK1 to BCK0: Bits in the G1BCR0 register
UD1 to UD0, BTS, RST2, RST1: Bits in the G1BCR1 register
IFEj: Bit in the G1FE register

FSCj: Bit in the G1FS register
EOCj: Bit in the G1OER register
IOj1 to IOj0: Bits in registers G1IOR0 and G1IOR1
PCLK0: Bit in the PCLKR register

Figure 20.1 IC/OC Block Diagram (1/2)

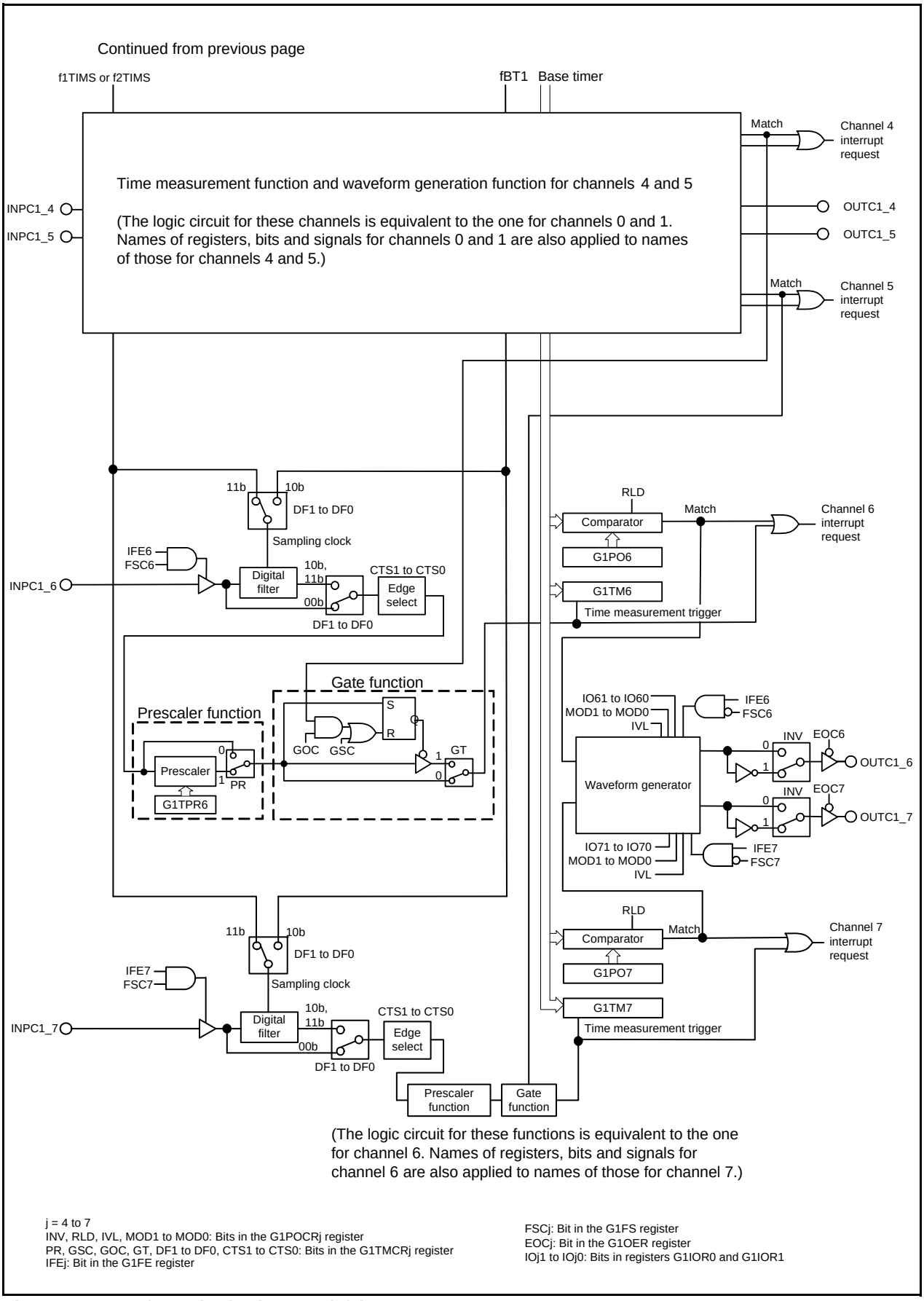


Figure 20.2 IC/OC Block Diagram (2/2)

Table 20.2 I/O Pins

Pin Name	I/O	Function
INPC1_0	Input (1)	Input pins for the time measurement function
INPC1_1	Input (1)	
INPC1_2	Input (1)	
INPC1_3	Input (1)	
INPC1_4	Input (1)	
INPC1_5	Input (1)	
INPC1_6	Input (1)	
INPC1_7	Input (1)	
OUTC1_0	Output	Output pins for the waveform generation function
OUTC1_1	Output	
OUTC1_2	Output	
OUTC1_3	Output	
OUTC1_4	Output	
OUTC1_5	Output	
OUTC1_6	Output	
OUTC1_7	Output	
TSUDA	Input (1)	A-phase input of two-phase pulse input signal processing
TSUDB	Input (1)	B-phase input of two-phase pulse input signal processing
$\overline{\text{INT1}}$	Input (1)	Z-phase input of two-phase pulse input signal processing

Notes:
1. When pins are used as input, set the port direction bits sharing pins to 0 (input mode).
2. Refer to 20.3.4 “I/O Port Select Function” for details on selecting the INPC1_j or OUTC1_j pin (j = 0 to 7).

20.2 Registers

Table 20.3 Registers (1/2)

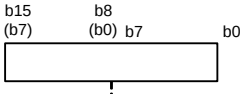
Address	Register Name	Register Symbol	Reset Value
02C0h	Time Measurement Register 0, Waveform Generation Register 0	G1TM0, G1PO0	XXh
02C1h			XXh
02C2h	Time Measurement Register 1, Waveform Generation Register 1	G1TM1, G1PO1	XXh
02C3h			XXh
02C4h	Time Measurement Register 2, Waveform Generation Register 2	G1TM2, G1PO2	XXh
02C5h			XXh
02C6h	Time Measurement Register 3, Waveform Generation Register 3	G1TM3, G1PO3	XXh
02C7h			XXh
02C8h	Time Measurement Register 4, Waveform Generation Register 4	G1TM4, G1PO4	XXh
02C9h			XXh
02CAh	Time Measurement Register 5, Waveform Generation Register 5	G1TM5, G1PO5	XXh
02CBh			XXh
02CCh	Time Measurement Register 6, Waveform Generation Register 6	G1TM6, G1PO6	XXh
02CDh			XXh
02CEh	Time Measurement Register 7, Waveform Generation Register 7	G1TM7, G1PO7	XXh
02CFh			XXh
02D0h	Waveform Generation Control Register 0	G1POCR0	0X00 XX00b
02D1h	Waveform Generation Control Register 1	G1POCR1	0X00 XX00b
02D2h	Waveform Generation Control Register 2	G1POCR2	0X00 XX00b
02D3h	Waveform Generation Control Register 3	G1POCR3	0X00 XX00b
02D4h	Waveform Generation Control Register 4	G1POCR4	0X00 XX00b
02D5h	Waveform Generation Control Register 5	G1POCR5	0X00 XX00b
02D6h	Waveform Generation Control Register 6	G1POCR6	0X00 XX00b
02D7h	Waveform Generation Control Register 7	G1POCR7	0X00 XX00b
02D8h	Time Measurement Control Register 0	G1TMCR0	00h
02D9h	Time Measurement Control Register 1	G1TMCR1	00h
02DAh	Time Measurement Control Register 2	G1TMCR2	00h
02DBh	Time Measurement Control Register 3	G1TMCR3	00h
02DCh	Time Measurement Control Register 4	G1TMCR4	00h
02DDh	Time Measurement Control Register 5	G1TMCR5	00h
02DEh	Time Measurement Control Register 6	G1TMCR6	00h
02DFh	Time Measurement Control Register 7	G1TMCR7	00h
02E0h	Base Timer Register	G1BT	XXh
02E1h			XXh
02E2h	Base Timer Control Register 0	G1BCR0	00h
02E3h	Base Timer Control Register 1	G1BCR1	00h
02E4h	Time Measurement Prescaler Register 6	G1TPR6	00h
02E5h	Time Measurement Prescaler Register 7	G1TPR7	00h
02E6h	Function Enable Register	G1FE	00h
02E7h	Function Select Register	G1FS	00h
02E8h	Base Timer Reset Register	G1BTRR	XXh
02E9h			XXh
02EAh	Count Source Divide Register	G1DV	00h
02ECh	Waveform Output Master Enable Register	G1OER	00h
02EEh	Timer S I/O Control Register 0	G1IOR0	00h

Table 20.4 Registers (2/2)

Address	Register Name	Register Symbol	Reset Value
02EFh	Timer S I/O Control Register 1	G1IOR1	00h
02F0h	Interrupt Request Register	G1IR	XXh
02F1h	Interrupt Enable Register 0	G1IE0	00h
02F2h	Interrupt Enable Register 1	G1IE1	00h

20.2.1 Time Measurement Register j (G1TMj) (j = 0 to 7)

Time Measurement Register j (j = 0 to 7)



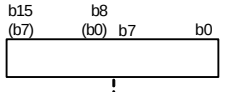
Symbol	Address	Reset Value
G1TM0 to G1TM2	02C1h to 02C0h, 02C3h to 02C2h, 02C5h to 02C4h	XXXXh
G1TM3 to G1TM5	02C7h to 02C6h, 02C9h to 02C8h, 02CBh to 02CAh	XXXXh
G1TM6 to G1TM7	02CDh to 02CCh, 02CFh to 02CEh	XXXXh

Function	RW
Data register for the base timer. The base timer value is stored at every measurement timing.	RO

Read the G1TMj register in 16-bit units.

20.2.2 Waveform Generation Register j (G1POj) (j = 0 to 7)

Waveform Generation Register j (j = 0 to 7)



Symbol	Address	Reset Value
G1PO0 to G1PO2	02C1h to 02C0h, 02C3h to 02C2h, 02C5h to 02C4h	XXXXh
G1PO3 to G1PO5	02C7h to 02C6h, 02C9h to 02C8h, 02CBh to 02CAh	XXXXh
G1PO6 to G1PO7	02CDh to 02CCh, 02CFh to 02CEh	XXXXh

Function	Setting Range	RW
• When the RLD bit in the G1POCRj register is 0, the value written to the G1POj register is immediately reloaded to an internal buffer and reflected in the output waveform. • When the RLD bit in the G1POCRj register is 1 and the base timer is reset, the value is reloaded.	0000h to FFFFh	RW

Write to the G1POj register in 16-bit units.

The value written to this register is reflected to the internal buffer when the clock is synchronized with the base timer count source (fBT1). When the waveform generation function is used, the output waveform is changed when this register matches with the base timer. Refer to 20.3.3.1 “Single-Phase Waveform Output Mode”, 20.3.3.2 “Inverted Waveform Output Mode” and 20.3.3.3 “Set/Reset Waveform Output Mode (SR Waveform Output Mode)” for details.

When the base timer value matches the G1PO0 register value while the RST1 bit in the G1BCR1 register is 1, the base timer becomes 0000h. When this function is used, the value of the G1POj register (j = 1 to 7) used to generate output waveforms should be smaller than the value of the G1PO0 register. Do not set the G1PO0 register to 0000h. While the RST1 bit is 1, rewrite the G1PO0 register when the BTS bit in the G1BCR1 register is 0 (base timer reset). Refer to 20.3.1.4 “Base Timer Reset While the Base Timer is Counting” for details.

When the base timer value matches the G1POk register value (k = j - 2), while bits GT and GOC in the G1TMCRj register (j = 6, 7) are both 1 (GT = 1: gate function used), the gate function is released. When this function is used, the value set in the G1POk register should be smaller than the maximum value of the base timer.

When the base timer reset is used with the G1BTRR register, set the register values as follows:

G1POk value < G1BTTR value

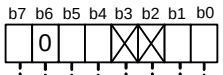
When the base timer reset is used with the G1PO0 register, set the register values as follows:

G1POk value < G1PO0 value

Refer to 20.3.2.1 “Gate Function (Channel 6 and 7)” for details.

20.2.3 Waveform Generation Control Register j (G1POCRj) (j = 0 to 7)

Waveform Generation Control Register j (j = 0 to 7)



Symbol	Address	Reset Value
G1POCR0 to G1POCR3	02D0h, 02D1h, 02D2h, 02D3h	0X00 XX00b
G1POCR4 to G1POCR7	02D4h, 02D5h, 02D6h, 02D7h	0X00 XX00b

Bit Symbol	Bit Name	Function	RW
MOD0	Operating mode select bit	b1 b0 0 0: Single waveform output mode 0 1: SR waveform output mode 1 0: Inverted waveform output mode 1 1: Do not set.	RW
MOD1			RW
— (b3-b2)	No register bits. If necessary, set to 0. The read value is undefined.		—
IVL	Default output value select bit	0: Output low as default value 1: Output high as default value	RW
RLD	G1POj register value reload timing select bit	0: Reload the G1POj register on a write access 1: Reload the G1POj register when the base timer is reset	RW
— (b6)	Reserved	Set to 0.	RW
INV	Output level inversion select bit	0: Output level not inverted 1: Output level inverted	RW

Rewrite the G1POCRj register when the BTS bit in the G1BCR1 is 0 (base timer reset), the FSCj bit in the G1FS register is 0 (waveform generation function selected), and the IFEj bit in the G1FE register is 0 (channel j function disabled). When the G1POCRj register is rewritten, set the BTS bit to 1 after one or more fBT1 cycles.

MOD1 and MOD0 (Operating mode select bit) (b1-b0)

To select SR waveform output mode, set bits MOD1 and MOD0 of an even channel (channel j (j = 0, 2, 4, or 6)) and bits MOD1 and MOD0 of the next odd channel (channel j + 1) both to 01b. The waveform is output from the OUT1_j pin of an even channel. In SR waveform output mode, set EOCj + 1 bit in the G1OER register to 1 (output disabled).

IVL (Output default select bit) (b4)

When a value is written to the IVL bit, the FSCj bit (j = 0 to 7) in the G1FS register is set to 0 (waveform generation function selected), and the IFEj bit in the G1FE register is set to 1 (channel j function enabled), the set level is output.

RLD (G1POj register value reload timing select bit) (b5)

For SR waveform output mode, set both even channels (channel j (j = 0, 2, 4, or 6)) and odd channels (channel j+1).
When writing a value to the G1POj register (j = 0 to 7) while the BTS bit is 0 (base timer reset) and the RLD bit is 1 (reload the G1POj register when the base timer is reset), the written value will not be reloaded to a buffer.
Therefore, when the BTS bit is 0, set the RLD bit to 0 (reload on a write access), write a value to the G1POj register, and then set the RLD bit to 1 after one or more fBT1 cycles.
When the RLD bit is set to 1, the value will not be reloaded at the following timings:

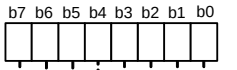
- When the base timer counter changes from FFFFh to 0000h immediately after writing FFFFh to the base timer while incrementing in increment mode or increment/decrement mode.
- When the base timer counter changes from 0000h to FFFFh immediately after writing 0000h to the base timer while decrementing in increment/decrement mode.

INV (Output level inversion select bit) (b7)

The output level inversion function is located at the final step of waveform generation circuit. When the INV bit is set to 1 (output level inverted), the default output value becomes high if the IVL bit is set to 0, and the default output value becomes low if the IVL bit is set to 1.

20.2.4 Time Measurement Control Register j (G1TMCRj) (j = 0 to 7)

Time Measurement Control Register j (j = 0 to 7)



Symbol	Address	Reset Value
G1TMCR0 to G1TMCR3	02D8h, 02D9h, 02DAh, 02DBh	00h
G1TMCR4 to G1TMCR7	02DCh, 02DDh, 02DEh, 02DFh	00h

Bit Symbol	Bit Name	Function	RW
CTS0	Time measurement trigger select bit	b1 b0 0 0: No time measurement 0 1: Rising edge 1 0: Falling edge 1 1: Both edges	RW
CTS1			RW
DF0	Digital filter select bit	b3 b2 0 0: No digital filter 0 1: Do not set. 1 0: Digital filter used. Sampling clock is fBT1. 1 1: Digital filter used Sampling clock is f1TIMS or f2TIMS.	RW
DF1			RW
GT	Gate function select bit	0: Gate function not used 1: Gate function used	RW
GOC	Gate function release select bit	0: Gate function release is disabled. 1: Gate function release is enabled by matching the base timer with the G1POk register. k = 4 when j = 6, k = 5 when j = 7	RW
GSC	Gate function release bit	No gating when 1 is written to this bit	RW
PR	Prescaler select bit	0: Prescaler not used 1: Prescaler used	RW

When writing to registers G1TMCR6 and G1TMCR7, use the MOV instruction. To release the gate during a write access, set the GSC bit to 1; otherwise, set it to 0.

CTS1 and CTS0 (Time measurement trigger select bit) (b1-b0)

Rewrite these bits when the BTS bit in the G1BCR1 register is 0 (base timer reset).

DF1 and DF0 (Digital filter select bit) (b3-b2)

Rewrite these bits when the BTS bit is 0.
When the PCLK0 bit in the PCLKR register is 0 while bits DF1 and DF0 are 11b, f2TIMS is selected as the sampling clock, and when the PCLK0 bit is 1, f1TIMS is selected as the sampling clock.
The two-phase pulse clock does not become a sampling clock of digital filter even if bits BCK1 and BCK0 are 10b (two-phase pulse clock).

GT (Gate function select bit) (b4)

The GT bit is only available in registers G1TMCR6 and G1TMCR7. Set bits 7 to 4 in registers G1MCR0 to G1TMCR5 to 0000b.
The value written to this bit is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1).

GOC (Gate function release select bit) (b5)

The GOC bit is only available in registers G1TMCR6 and G1TMCR7. Set bits 7 to 4 in registers G1MCR0 to G1TMCR5 to 0000b.
The GOC bit is enabled only when the GT bit is 1.
Refer to 20.2.2 “Waveform Generation Register j (G1POj) (j = 0 to 7)” for details on the G1POk register (k = 4 when j = 6; k = 5 when j = 7).
The value written to this bit is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1).

GSC (Gate function release bit) (b6)

The GSC bit is only available in registers G1TMCR6 and G1TMCR7. Set bits 7 to 4 in registers G1MCR0 to G1TMCR5 to 0000b.
The GSC bit is enabled only when the GT bit is 1.
Set this bit to 1 when the gate function is released; otherwise set it to 0.
The value written to this bit is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1).

PR (Prescaler select bit) (b7)

Rewrite the PR bit when bits BCK1 and BCK0 in the G1BCR0 register are 00b (clock stops).
The PR bit is only available in registers G1TMCR6 and G1TMCR7. Set bits 7 to 4 in registers G1MCR0 to G1TMCR5 to 0000b.

20.2.5 Base Timer Register (G1BT)

Base Timer Register

b15 (b7) b8 (b0) b7 b0

Symbol	Address	Reset Value
G1BT	02E1h to 02E0h	XXXXh

Function	RW
- While the base timer is running (when the BTS bit in the G1BCR1 register is 1 and bits BCK1 and BCK0 in the G1BCR0 register are values other than 00b): When reading this register, the current base timer value is returned. When the base timer is reset, this register becomes 0000h. - When the BTS bit in the G1BCR1 register is 0: This register becomes 0000h. When reading this register, an undefined value is returned.	RW

Read the G1BT register in 16-bit units. Do not write to this register.

While the base timer is counting, the base timer value is stored to this register, and synchronized with the base timer count source (fBT1).

The base timer stops counting only when bits BCK1 and BCK0 in the G1BCR0 register are 00b (clock stopped). When bits BCK1 and BCK0 are not 00b, the base timer operates.

When the BTS bit in the G1BCR1 register is 0 (base timer reset), the G1BT register is held in the reset state (0000h). The counter stays in this state without counting. When the BTS bit is set to 1, the state is released and the base timer starts counting.

20.2.6 Base Timer Control Register 0 (G1BCR0)

Base Timer Control Register 0

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

Symbol: G1BCR0 | Address: 02E2h | Reset Value: 00h

Bit Symbol	Bit Name	Function	RW
BCK0	Count source select bit	b1 b0 0 0: Clock stopped 0 1: Do not set. 1 0: Two-phase pulse clock 1 1: f1TIMS or f2TIMS	RW
BCK1			RW
RST4	Base timer reset source select bit 4	0: The base timer is not reset when the base timer and G1BTRR register values match. 1: The base timer is reset when the base timer and G1BTRR register values match.	RW
— (b5-b3)	Reserved	Set to 0.	RW
— (b6)	Reserved	Set to 0.	RW
IT	Base timer interrupt select bit	0: Overflow of bit 15 1: Overflow of bit 14	RW

Rewrite the G1BCR0 register when the BTS bit in the G1BCR1 register is 0 (base timer reset).

BCK1 and BCK0 (Count source select bit) (b1-b0)

After rewriting bits BCK1 and BCK0 from 00b (clock stopped) to another value, before rewriting these bits to another value, first set them to 00b, wait four or more cycles of the previous count source, and then rewrite the bits.

The two-phase pulse clock (10b) can be used only when bits UD1 and UD0 in the G1BCR1 register are 10b (two-phase pulse signal processing). Do not set bits BCK1 and BCK0 to 10b with other count operations.

When bits BCK1 and BCK0 are 11b and the PCLK0 bit in the PCLKR register is 0, f2TIMS is selected. When the PCLK0 bit is 1, f1TIMS is selected. Change the PCLK0 bit when bits BCK1 and BCK0 are 00b.

RST4 (Base timer reset source select bit 4) (b2)

When the RST4 bit is 1, set the RST1 bit in the G1BCR1 register to 0.

IT (Base timer interrupt select bit) (b7)

While the IT bit is 0 (overflow of bit 15), when incrementing, if b15 of the base timer becomes 0 from 1 (i.e. the base timer value becomes 0000h from FFFFh) during counting, the base timer overflows. When decrementing, the base timer overflows if b15 of the base timer becomes 1 from 0 (i.e. 7FFFh from 8000h).

While the IT bit is 1 (overflow of bit 14), when incrementing, if b14 of the base timer becomes 0 from 1 during counting, the base timer overflows. When decrementing, the base timer overflows if b14 of the base timer becomes 1 from 0.

When the base timer overflows, the IR bit in the BTIC register becomes 1 (IC/OC base timer interrupt requested).

20.2.7 Base Timer Control Register 1 (G1BCR1)

Base Timer Control Register 1

b7	b6	b5	b4	b3	b2	b1	b0
0				0			0

Symbol	Address	Reset Value
G1BCR1	02E3h	00h

Bit Symbol	Bit Name	Function	RW
— (b0)	Reserved	Set to 0.	RW
RST1	Base timer reset source select bit 1	0: The base timer is not reset when the base timer and G1PO0 register values match. 1: The base timer is reset when the base timer and G1PO0 register values match.	RW
RST2	Base timer reset source select bit 2	0: The base timer is not reset when low is input to the $\overline{INT1}$ pin. 1: The base timer is reset when low is input to the $\overline{INT1}$ pin.	RW
— (b3)	Reserved	Set to 0.	RW
BTS	Base timer start bit	0: Base timer reset 1: Base timer starts counting	RW
UD0	Increment/decrement control bit	b6 b5 0 0: Increment 0 1: Increment/decrement 1 0: Two-phase pulse signal processing 1 1: Do not set.	RW
UD1			
— (b7)	Reserved	Set to 0.	RW

RST1 (Base timer reset source select bit 1) (b1)

To rewrite the RST1 bit, rewrite it while the BTS bit is 0 (base timer reset) and then change the BTS bit to 1 (base timer starts counting).

When the base timer value matches the G1PO0 register value while the RST1 bit is 1, the base timer is reset after two fBT1 cycles. Refer to 20.3.1.4 “Base Timer Reset While the Base Timer is Counting” for details. When the RST1 bit is 1, set the RST4 bit in the G1BCR0 register to 0 (the base timer is not reset when the base timer and G1BTRR register values match).

RST2 (Base timer reset source select bit 2) (b2)

To rewrite the RST2 bit, rewrite it while the BTS bit is 0 and then rewrite the BTS bit to 1.

BTS (Base timer start bit) (b4)

The value written to this bit is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1).

UD1 and UD0 (Increment/decrement control bit) (b6-b5)

To rewrite bits UD1 and UD0, rewrite them while the BTS bit is 0 and then rewrite the BTS bit to 1.

When single-waveform output mode or SR waveform output mode is selected, set bits UD1 and UD0 to 00b (increment). When inverted waveform output mode is selected, set these bits to 00b (increment) or 01b (increment/decrement).

20.2.8 Time Measurement Prescaler Register j (G1TPRj) (j = 6 and 7)

Time Measurement Prescaler Register j (j = 6 and 7)

b7 b0

Symbol	Address	Reset Value
G1TPR6	02E4h	00h
G1TPR7	02E5h	00h

Function	Set Value	RW
If the setting value is n, time measurement is performed every time a trigger input is counted (n + 1) times.	00h to FFh	RW

The value written to this register is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1).
After rewriting the PR bit in the G1TMCRj register to 1 (prescaler function used) from 0 (prescaler function not used), the first prescaler cycle may remain as n instead of being counted as (n + 1). In the subsequent prescaler cycles, the setting value n becomes (n + 1).

20.2.9 Function Enable Register (G1FE)

Function Enable Register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
G1FE	02E6h	00h

Bit Symbol	Bit Name	Function	RW
IFE0	Channel 0 function enable bit	0: Channel j function disabled 1: Channel j function enabled (j = 0 to 7)	RW
IFE1	Channel 1 function enable bit		RW
IFE2	Channel 2 function enable bit		RW
IFE3	Channel 3 function enable bit		RW
IFE4	Channel 4 function enable bit		RW
IFE5	Channel 5 function enable bit		RW
IFE6	Channel 6 function enable bit		RW
IFE7	Channel 7 function enable bit		RW

The value written to this register is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1). When the channel j (j = 0 to 7) function is disabled, the corresponding pins become programmable I/O ports.

20.2.10 Function Select Register (G1FS)

Function Select Register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol: G1FS
Address: 02E7h
Reset Value: 00h

Bit Symbol	Bit Name	Function	RW
FSC0	Channel 0 time measurement/ waveform generation function select bit	0: Waveform generation function selected 1: Time measurement function selected	RW
FSC1	Channel 1 time measurement/ waveform generation function select bit		RW
FSC2	Channel 2 time measurement/ waveform generation function select bit		RW
FSC3	Channel 3 time measurement/ waveform generation function select bit		RW
FSC4	Channel 4 time measurement/ waveform generation function select bit		RW
FSC5	Channel 5 time measurement/ waveform generation function select bit		RW
FSC6	Channel 6 time measurement/ waveform generation function select bit		RW
FSC7	Channel 7 time measurement/ waveform generation function select bit		RW

Rewrite the G1FS register when the BTS bit in the G1BCR1 register is 0 (base timer reset).

20.2.11 Base Timer Reset Register (G1BTRR)

Base Timer Reset Register

b15 (b7)	b8 (b0)	b7	b0	Symbol	Address	Reset Value
				G1BTRR	02E9h to 02E8h	XXXXh

Function	Setting Range	RW
When the RST4 bit in the G1BCR0 register is 1, the base timer is reset by matching the G1BTRR register value and base timer value.	0001h to FFFFh	RW

Write to the G1BTRR register in 16-bit units. The value written to this register is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1).
While the RST4 bit in the G1BCR0 register is 1, rewrite the G1BTRR register when the BTS bit in the G1BCR1 register is 0 (base timer reset).

20.2.12 Count Source Divide Register (G1DV)

Count Source Divide Register

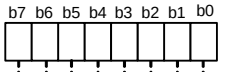
b7	b0	Symbol	Address	Reset Value
		G1DV	02EAh	00h

Function	Setting Range	RW
Divide f1TIMS, f2TIMS, or the two-phase input pulse clock by (n + 1) to generate fBT1. n: G1DV setting value	00h to FFh	RW

Rewrite the G1DV register when bits BCK1 and BCK0 in the G1BCR0 register are 00b (clock stopped).

20.2.13 Waveform Output Master Enable Register (G1OER)

Waveform Output Master Enable Register



Symbol	Address	Reset Value
G1OER	02ECh	00h

Bit Symbol	Bit Name	Function	RW
EOC0	OUTC1_0 output disable bit	0: Output enabled 1: Output disabled (OUTC1_0 pin is used as a programmable I/O port)	RW
EOC1	OUTC1_1 output disable bit	0: Output enabled 1: Output disabled (OUTC1_1 pin is used as a programmable I/O port)	RW
EOC2	OUTC1_2 output disable bit	0: Output enabled 1: Output disabled (OUTC1_2 pin is used as a programmable I/O port)	RW
EOC3	OUTC1_3 output disable bit	0: Output enabled 1: Output disabled (OUTC1_3 pin is used as a programmable I/O port)	RW
EOC4	OUTC1_4 output disable bit	0: Output enabled 1: Output disabled (OUTC1_4 pin is used as a programmable I/O port)	RW
EOC5	OUTC1_5 output disable bit	0: Output enabled 1: Output disabled (OUTC1_5 pin is used as a programmable I/O port)	RW
EOC6	OUTC1_6 output disable bit	0: Output enabled 1: Output disabled (OUTC1_6 pin is used as a programmable I/O port)	RW
EOC7	OUTC1_7 output disable bit	0: Output enabled 1: Output disabled (OUTC1_7 pin is used as a programmable I/O port)	RW

The EOCj bit (j = 0 to 7) is enabled only when the FSCj bit in the G1FS register is 0 (waveform generation function is selected) and the IFEj bit in the G1FE register is 1 (channel j function enabled). When an odd channel is selected in SR waveform output mode or the FSCj bit in the G1FS register is 1 (time measurement function is selected), set the EOCj bit to 1. The value written to the EOCj bit is immediately reflected in output waveforms, independently of fBT1.

20.2.14 Timer S I/O Control Register 0 (G1IOR0)

Timer S I/O Control Register 0

b7	b6	b5	b4	b3	b2	b1	b0

Symbol	Address	Reset Value
G1IOR0	02EEh	00h

Bit Symbol	Bit Name	Function	RW
IO00	OUTC1_0 output control bit	b1 b0 0 0: Outputs high or low, depending on the mode selected by bits MOD1 and MOD0 in the G1POCR0 register. 0 1: Outputs low by compare match with the G1PO0 register. 1 0: Outputs high by compare match with the G1PO0 register. 1 1: Do not set.	RW
IO01			RW
IO10	OUTC1_1 output control bit	b3 b2 0 0: Outputs high or low, depending on the mode selected by bits MOD1 and MOD0 in the G1POCR1 register. 0 1: Outputs low by compare match with the G1PO1 register. 1 0: Outputs high by compare match with the G1PO1 register. 1 1: Do not set.	RW
IO11			RW
IO20	OUTC1_2 output control bit	b5 b4 0 0: Outputs high or low, depending on the mode selected by bits MOD1 and MOD0 in the G1POCR2 register. 0 1: Outputs low by compare match with the G1PO2 register. 1 0: Outputs high by compare match with the G1PO2 register. 1 1: Do not set.	RW
IO21			RW
IO30	OUTC1_3 output control bit	b7 b6 0 0: Outputs high or low, depending on the mode selected by bits MOD1 and MOD0 in the G1POCR3 register. 0 1: Outputs low by compare match with the G1PO3 register. 1 0: Outputs high by compare match with the G1PO3 register. 1 1: Do not set.	RW
IO31			RW

The value written to this register is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1).
Set the corresponding output control bits IOj1 and IOj0 to 00b for the input channels selected by setting the FSCj bit (j = 0 to 3) in the G1FS register to 1 (time measurement function is selected).
In SR waveform output mode, set bits IOj1 and IOj0 to 00b for both odd and even channels.

20.2.15 Timer S I/O Control Register 1 (G1IOR1)

Timer S I/O Control Register 1

b7	b6	b5	b4	b3	b2	b1	b0

Symbol	Address	Reset Value
G1IOR1	02EFh	00h

Bit Symbol	Bit Name	Function	RW
IO40	OUTC1_4 output control bit	b1 b0 0 0: Outputs high or low, depending on the mode selected by bits MOD1 and MOD0 in the G1POCR4 register. 0 1: Output low by compare match with the G1PO4 register. 1 0: Outputs high by compare match with the G1PO4 register. 1 1: Do not set.	RW
IO41			RW
IO50	OUTC1_5 output control bit	b3 b2 0 0: Outputs high or low, depending on the mode selected by bits MOD1 and MOD0 in the G1POCR5 register. 0 1: Outputs low by compare match with the G1PO5 register. 1 0: Outputs high by compare match with the G1PO5 register. 1 1: Do not set.	RW
IO51			RW
IO60	OUTC1_6 output control bit	b5 b4 0 0: Outputs high or low, depending on the mode selected by bits MOD1 and MOD0 in the G1POCR6 register. 0 1: Outputs low by compare match with the G1PO6 register. 1 0: Outputs high by compare match with the G1PO6 register. 1 1: Do not set.	RW
IO61			RW
IO70	OUTC1_7 output control bit	b7 b6 0 0: Outputs high or low, depending on the mode selected by bits MOD1 and MOD0 in the G1POCR7 register. 0 1: Outputs low by compare match with the G1PO7 register. 1 0: Outputs high by compare match with the G1PO7 register. 1 1: Do not set.	RW
IO71			RW

The value written to this register is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1).
Set the corresponding output control bits IOj1 and IOj0 to 00b for the input channels determined by setting the FSCj bit (j = 4 to 7) in the G1FS register to 1 (time measurement function is selected).
In SR waveform output mode, set bits IOj1 and IOj0 to 00b for both odd and even channels.

20.2.16 Interrupt Request Register (G1IR)

Interrupt Request Register

b7	b6	b5	b4	b3	b2	b1	b0

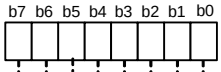
Symbol: G1IR
Address: 02F0h
Reset Value: XXh

Bit Symbol	Bit Name	Function	RW
G1IR0	Channel 0 interrupt request bit	0: Interrupt not requested 1: Interrupt requested	RW
G1IR1	Channel 1 interrupt request bit		RW
G1IR2	Channel 2 interrupt request bit		RW
G1IR3	Channel 3 interrupt request bit		RW
G1IR4	Channel 4 interrupt request bit		RW
G1IR5	Channel 5 interrupt request bit		RW
G1IR6	Channel 6 interrupt request bit		RW
G1IR7	Channel 7 interrupt request bit		RW

The G1IRj bit does not become 0 (interrupt not requested) automatically when an interrupt is received (j = 0 to 7).
To set the bit to 0, wait one or more fBT1 cycles after the G1IRj bit becomes 1 (interrupt requested), and perform the operation shown in 20.5.2 “Changing the G1IR Register”.
The value written to these bits is reflected to the internal circuit in synchronization with the CPU clock.

20.2.17 Interrupt Enable Register 0 (G1IE0)

Interrupt Enable Register 0

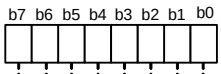


Symbol	Address	Reset Value
G1IE0	02F1h	00h

Bit Symbol	Bit Name	Function	RW
G1IE00	Channel 0 interrupt enable 0 bit	0: IC/OC interrupt 0 request disabled 1: IC/OC interrupt 0 request enabled	RW
G1IE01	Channel 1 interrupt enable 0 bit		RW
G1IE02	Channel 2 interrupt enable 0 bit		RW
G1IE03	Channel 3 interrupt enable 0 bit		RW
G1IE04	Channel 4 interrupt enable 0 bit		RW
G1IE05	Channel 5 interrupt enable 0 bit		RW
G1IE06	Channel 6 interrupt enable 0 bit		RW
G1IE07	Channel 7 interrupt enable 0 bit		RW

20.2.18 Interrupt Enable Register 1 (G1IE1)

Interrupt Enable Register 1



Symbol: G1IE1 | Address: 02F2h | Reset Value: 00h

Bit Symbol	Bit Name	Function	RW
G1IE10	Channel 0 interrupt enable 1 bit	0: IC/OC interrupt 1 request disabled 1: IC/OC interrupt 1 request enabled	RW
G1IE11	Channel 1 interrupt enable 1 bit		RW
G1IE12	Channel 2 interrupt enable 1 bit		RW
G1IE13	Channel 3 interrupt enable 1 bit		RW
G1IE14	Channel 4 interrupt enable 1 bit		RW
G1IE15	Channel 5 interrupt enable 1 bit		RW
G1IE16	Channel 6 interrupt enable 1 bit		RW
G1IE17	Channel 7 interrupt enable 1 bit		RW

20.3 Operations

20.3.1 Base Timer

The base timer is a free-running counter which counts an internally generated count source.
Table 20.5 lists the specifications of the base timer, Figure 20.3 shows the block diagram of the base timer, Table 20.6 lists the base timer associated registers and their settings, Figure 20.4 shows an operation example with incrementing, Figure 20.5 shows an operation example with incrementing/decrementing, and Figure 20.7 shows an operation example with two-phase pulse signal processing.

Table 20.5 Base Timer Specifications

Item	Specification
Count source (fBT1)	f1TIMS or f2TIMS divided by (n + 1), two-phase pulse clock divided by (n + 1) n is a G1DV register setting value from 0 to 255. However, when n is 0, there is no division.
Count operations	• Increment • Increment/decrement • Two-phase pulse signal processing
Count start condition	Set the BTS bit in the G1BCR1 register to 1 (base timer starts counting).
Count stop condition	Set the BTS bit in the G1BCR1 register to 0 (base timer reset).
Base timer reset conditions	• The base timer value matches the G1BTRR register value. • The base timer value matches the G1PO0 register value. • A low signal is input to the $\overline{\text{INT1}}$ external interrupt pin. • The BTS bit in the G1BCR1 register is 0 (base timer reset).
Base timer reset value	0000h
Interrupt requests	• Bit 14 or bit 15 in the G1BT register overflows. • The base timer value matches the G1BTRR register value.
Read from base timer	• The count value is returned when reading the G1BT register while the base timer is counting. • An undefined value is returned when reading the G1BT register while the base timer is being reset and the BTS bit is 0.

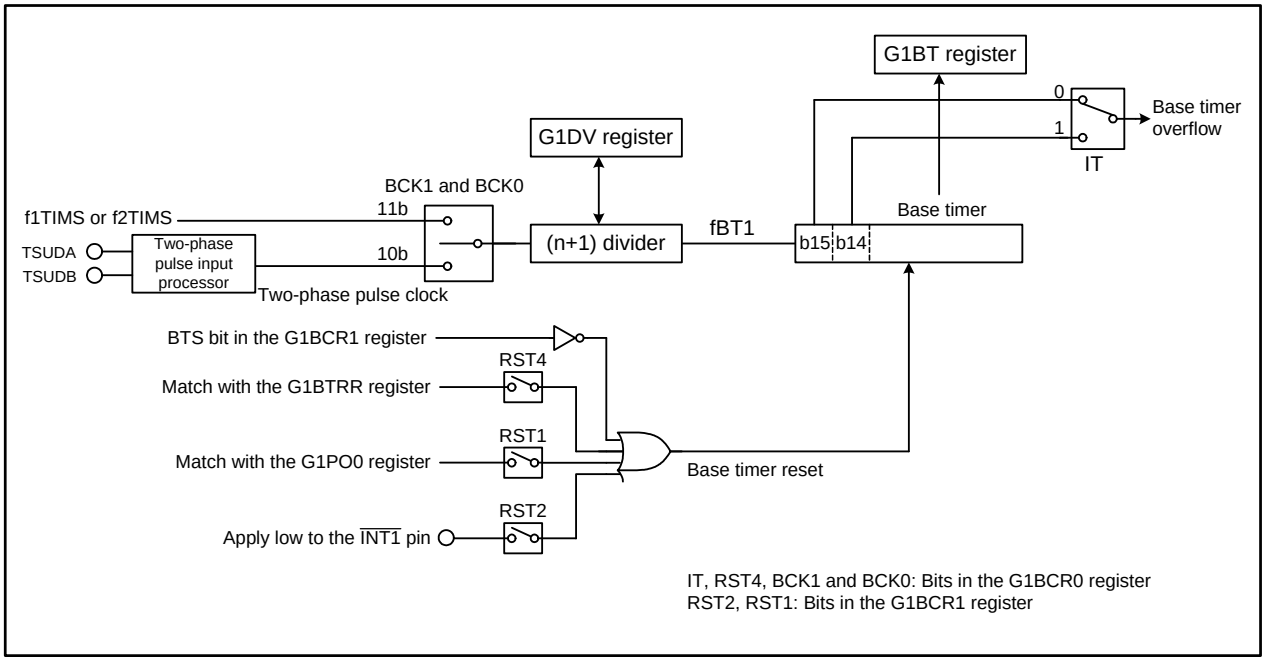


Figure 20.3 Base Timer Block Diagram

Table 20.6 Base Timer Associated Register Settings (1)

Register	Bit	Function and Setting Value		
		Base timer reset not used	Base timer reset by matching with the G1BTRR register	Base timer reset by matching with the G1PO0 register
G1BCR0	BCK1 and BCK0	Select a count source.	Select a count source.	Select a count source.
	RST4	Set to 0.	Set to 1.	Set to 0.
	IT	Select a timing of IC/OC base timer interrupt request.	Select a timing of IC/OC base timer interrupt request.	Select a timing of IC/OC base timer interrupt request.
G1BCR1	RST1	Set to 0.	Set to 0.	Set to 1.
	RST2	Select whether the $\overline{\text{INT1}}$ pin is used for base timer reset.	Select whether the $\overline{\text{INT1}}$ pin is used for base timer reset.	Select whether the $\overline{\text{INT1}}$ pin is used for base timer reset.
	BTS	Set to 1 to start the base timer count. Set to 0 to reset the base timer count.	Set to 1 to start the base timer count. Set to 0 to reset the base timer count.	Set to 1 to start the base timer count. Set to 0 to reset the base timer count.
	UD1 and UD0	Select a count operation.	Select a count operation.	Select a count operation.
G1BT	—	Base timer value can be read.	Base timer value can be read.	Base timer value can be read.
G1DV	—	Set a divide ratio of the count source.	Set a divide ratio of the count source.	Set a divide ratio of the count source.
G1BTRR	—	— (Do not use)	Set a base timer reset timing	— (Do not use)
G1POCR0	MOD1 and MOD0	— (Do not use for the base timer)		Set to 00b
G1PO0	—	— (Do not use for the base timer)		Set a base timer reset timing
G1FS	FSC0	— (Do not use for the base timer)		Set to 0.
G1FE	IFE0	— (Do not use for the base timer)		Set to 1.
G1IOR0	IO01 and IO00	— (Do not use for the base timer)		Set to 00b.

Note:
1. This table does not describe a procedure.

20.3.1.1 Increment

The counter starts incrementing from 0000h to FFFFh, then returns back to 0000h, and continues to increment.

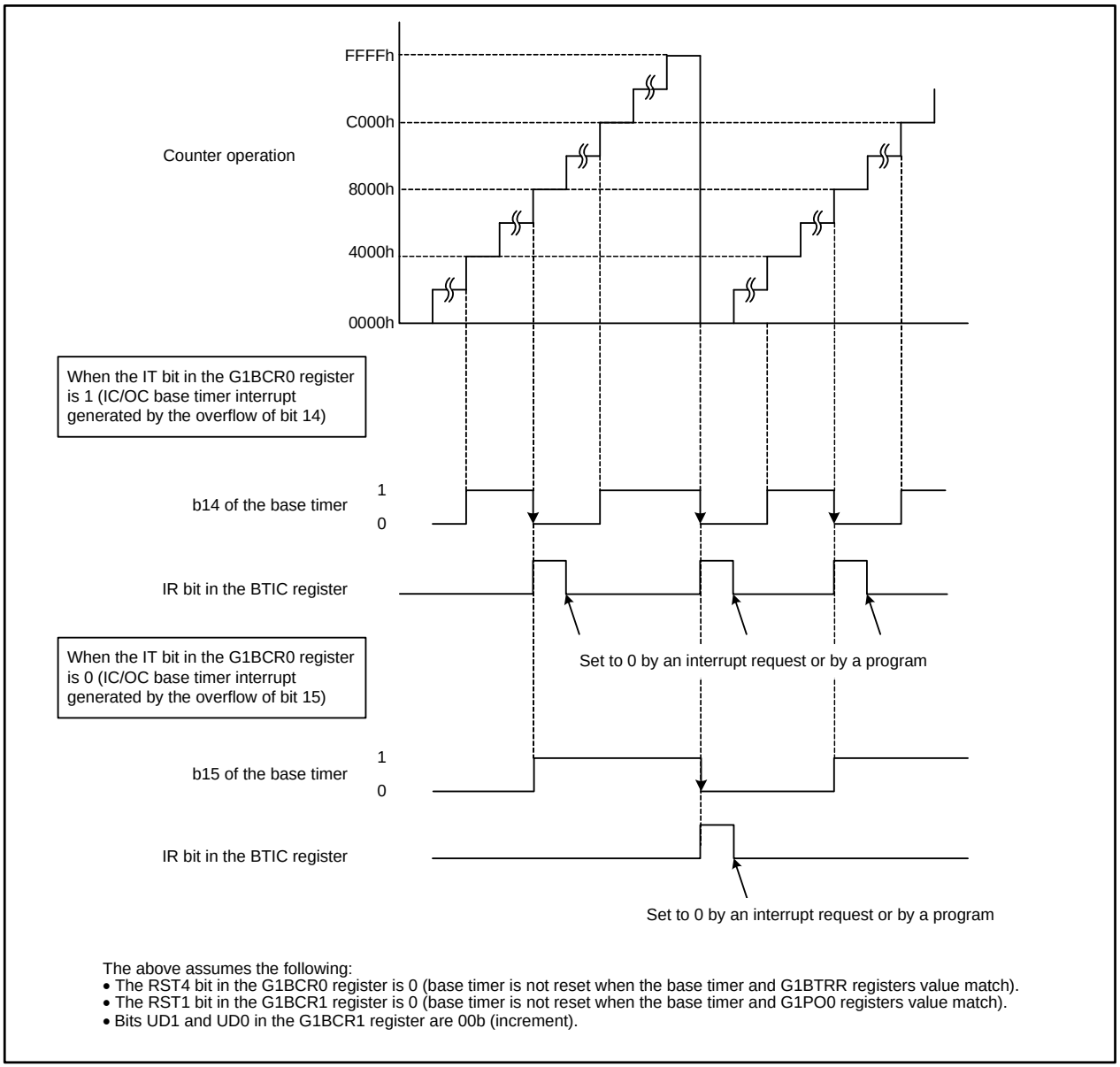


Figure 20.4 Increment

20.3.1.2 Increment/Decrement

The counter starts incrementing from 0000h to FFFFh, then decrements from FFFFh to 0000h. When the counter reaches 0000h, the base timer increments again.

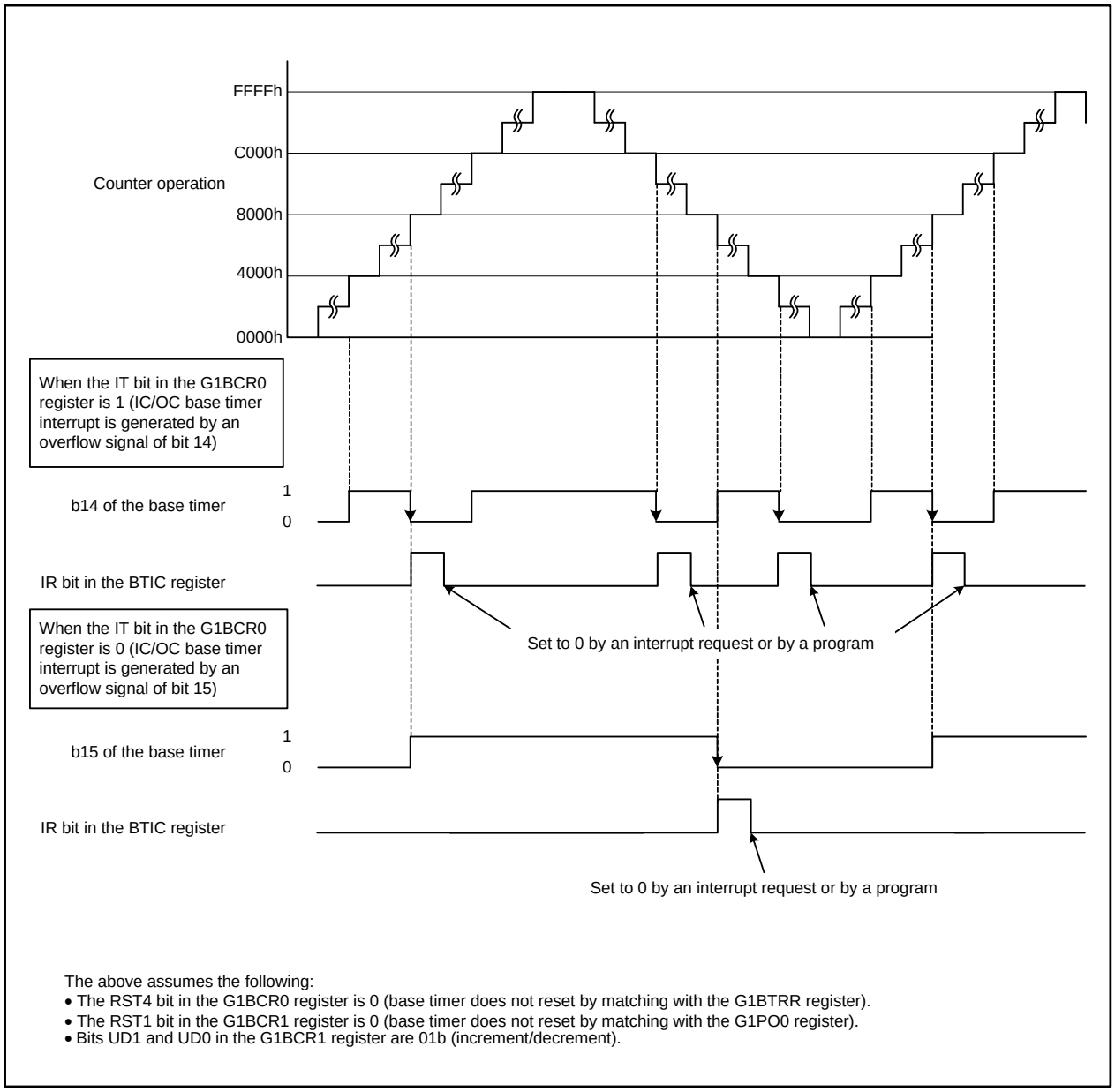


Figure 20.5 Increment/Decrement

20.3.1.3 Two-Phase Pulse Signal Processing

This count operation counts two-phase pulse input from pins TSUDA and TSUDB.
Set the following bits as shown below for two-phase pulse signal processing.

Bits BCK1 and BCK0 in the G1BCR0 register: 10b (two-phase pulse clock)
RST2 bit in the G1BCR1 register: 1 (the base timer is reset when low is input to the $\overline{\text{INT1}}$ pin.)
Bits UD1 to UD0 in the G1BCR1 register (two-phase pulse signal processing)

Figure 20.6 shows Two-Phase Pulse Signal Processing, and Figure 20.7 shows Two-Phase Pulse Signal Processing (When Using the Base Timer Reset).

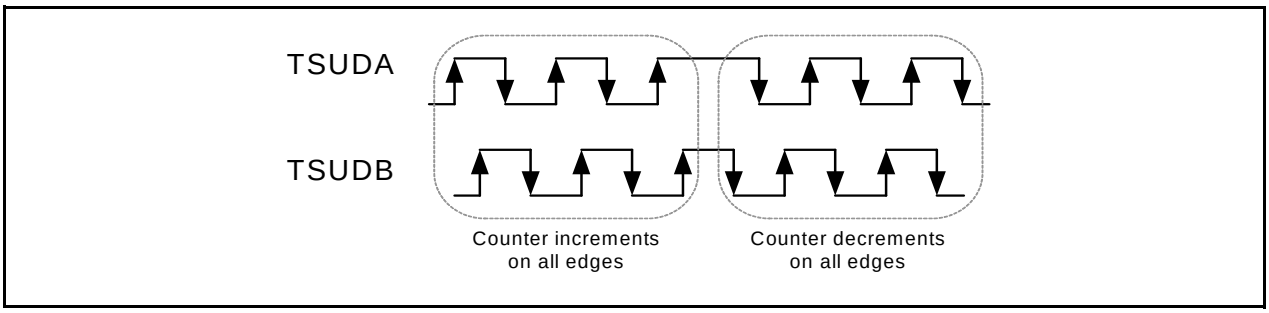
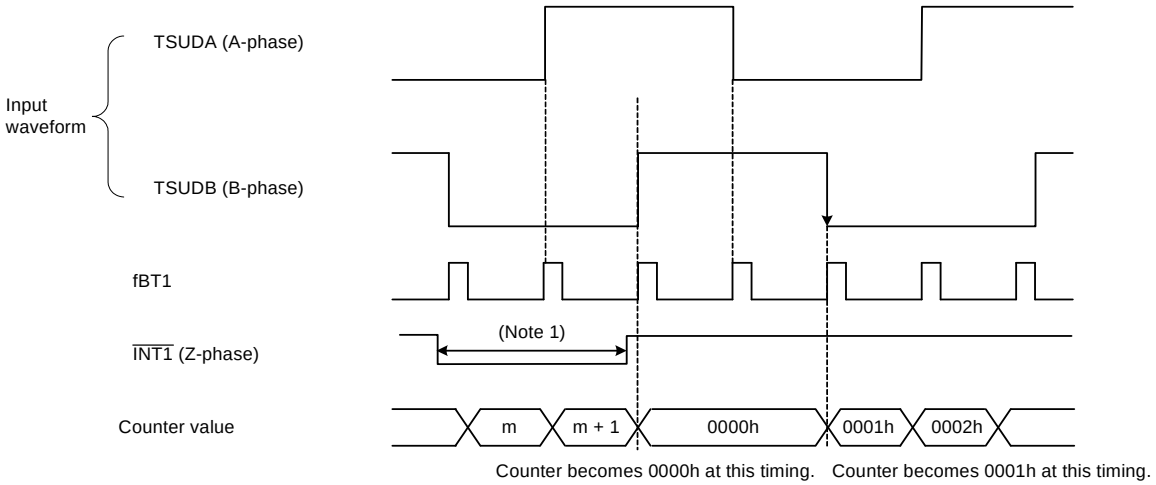
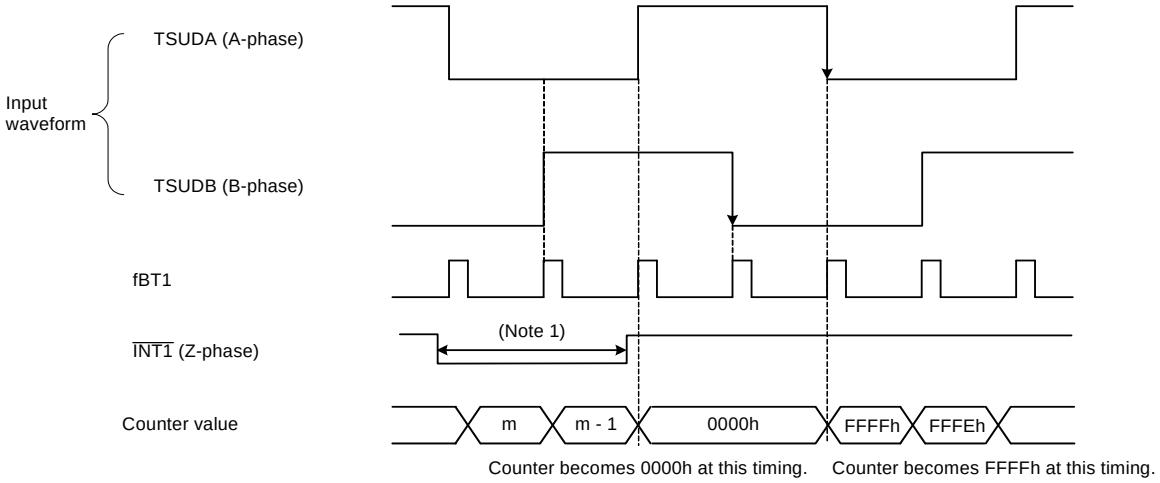


Figure 20.6 Two-Phase Pulse Signal Processing

(1) The base timer is reset while it is incrementing.



(2) The base timer is reset while it is decrementing.



The above assumes the following:
- The RST2 bit in the G1BCR1 register is 1 (base timer is reset by applying low to the INT1 pin).
- The G1DV register is 00b (no division).

Note:
1. The INT1 pin should be driven low for at least 1.5 fBT1 cycles.

Figure 20.7 Two-Phase Pulse Signal Processing (When Using the Base Timer Reset)

20.3.1.4 Base Timer Reset While the Base Timer is Counting

The base timer is reset by one of the following conditions:

- The G1BTRR register value matches the base timer value after setting the RST4 in the G1BCR0 register to 1 (the base timer is reset by matching with the G1BTRR register).
- The G1PO0 register value matches the base timer value after setting the RST1 bit in the G1BCR1 register to 1 (the base timer is reset by matching with the G1PO0 register).
- Apply a low signal to the $\overline{\text{INT1}}$ external interrupt pin after setting the RST2 bit in the G1BCR1 register to 1 (the base timer is reset by applying a low signal to the $\overline{\text{INT1}}$ pin).

Do not set bits RST4 and RST1 to 1 at the same time.
When the base timer counter is running, but not free-running, and the base timer is reset by matching the G1BTRR register, channel 0 can be used for the waveform generation function.

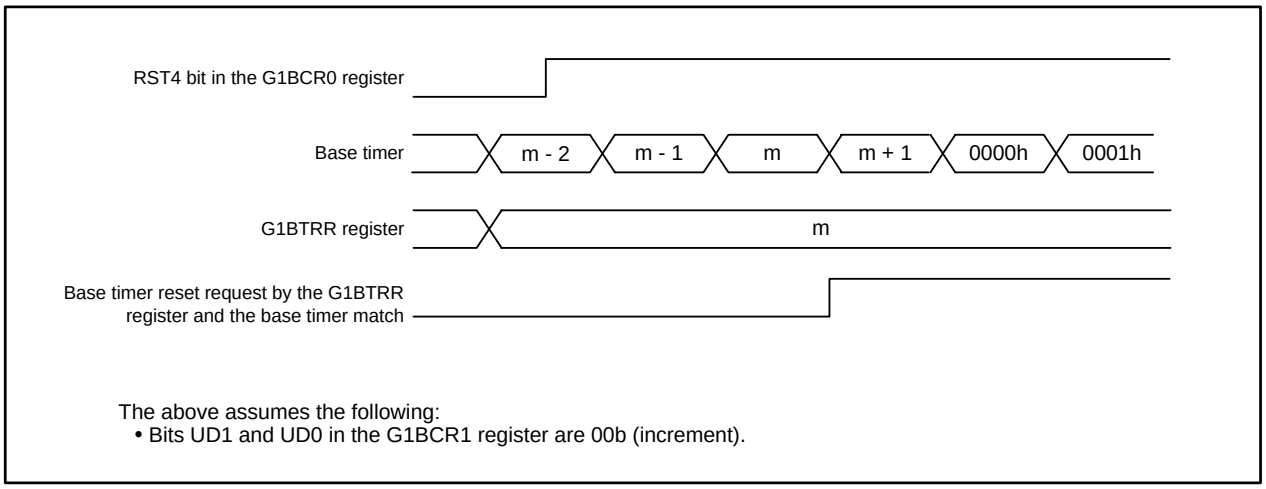


Figure 20.8 Base Timer Reset with the G1BTRR Register

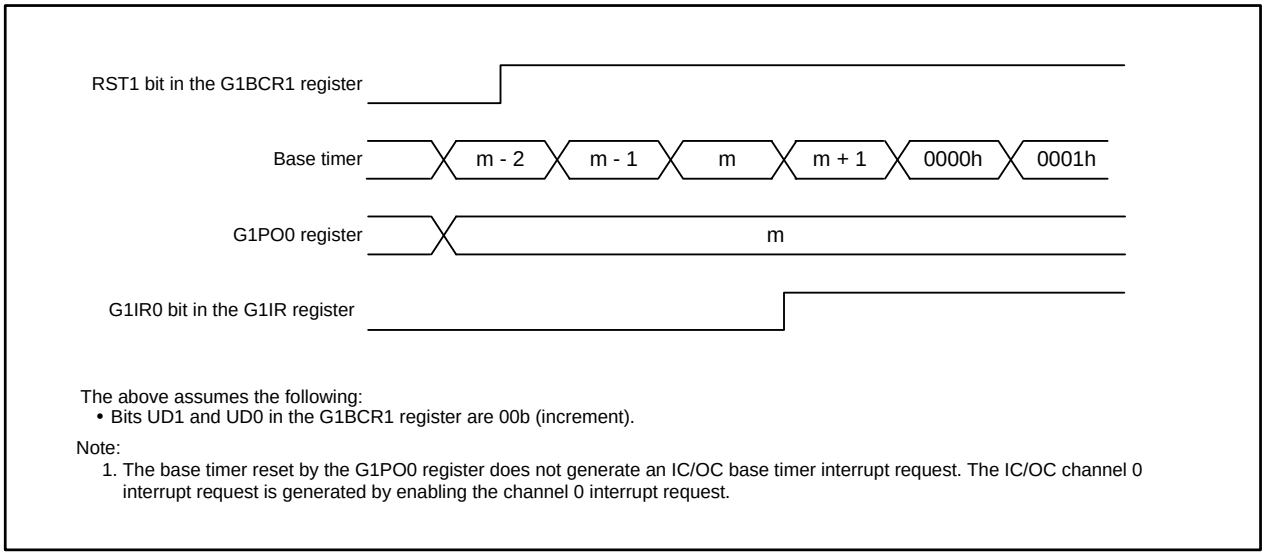
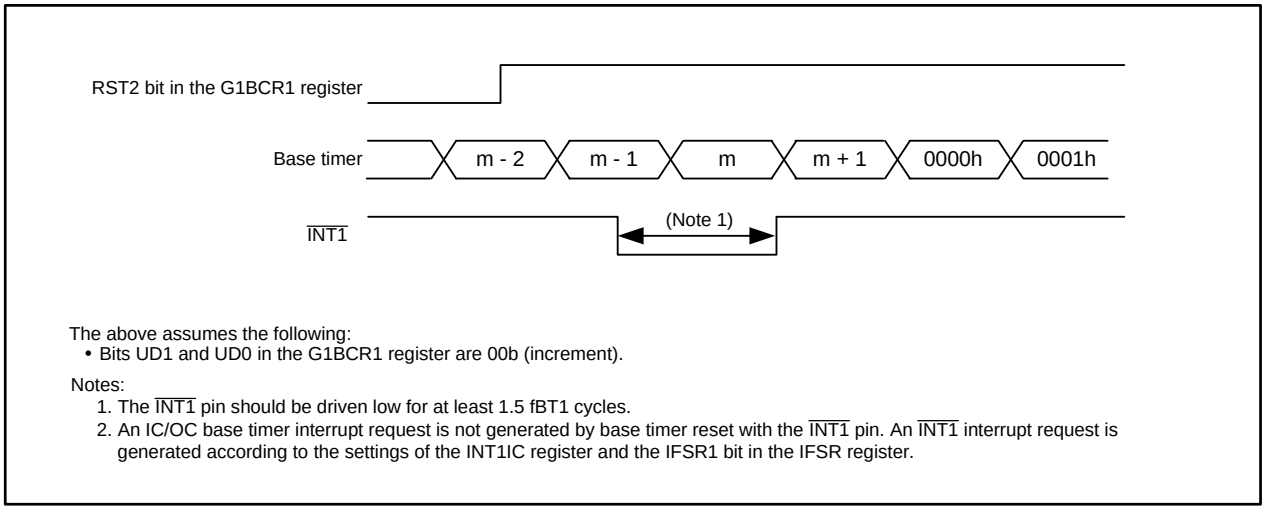


Figure 20.9 Base Timer Reset with the G1PO0 Register



The above assumes the following:
- Bits UD1 and UD0 in the G1BCR1 register are 00b (increment).

Notes:
1. The $\overline{INT1}$ pin should be driven low for at least 1.5 fBT1 cycles.
2. An IC/OC base timer interrupt request is not generated by base timer reset with the $\overline{INT1}$ pin. An $\overline{INT1}$ interrupt request is generated according to the settings of the INT1IC register and the IFSR1 bit in the IFSR register.

Figure 20.10 Base Timer Reset with $\overline{INT1}$ Pin Input

Table 20.7 to Table 20.9 list the relationship between base timer count operation and the count value when the base timer is reset.

Table 20.7 Increment

Reset Source	Count Direction	Count Value
RST1 reset	No change (increments)	0000h
RST2 reset	No change (increments)	0000h
RST4 reset	No change (increments)	0000h

Table 20.8 Increment/Decrement

Reset Source	Increment Operation		Decrement Operation	
	Count direction	Count value	Count direction	Count value
RST1 reset	Increment to decrement	— (count continues)	No change (decrements)	— (count continues)
RST2 reset	Increment to decrement	— (count continues)	No change (decrements)	— (count continues)
RST4 reset	Increment to decrement	— (count continues)	No change (decrements)	— (count continues)

Table 20.9 Two-Phase Pulse Signal Processing

Reset Source	Increment Operation		Decrement Operation	
	Count direction	Count value	Count direction	Count value
RST1 reset	No change (increments)	0000h	No change (decrements)	— (count continues)
RST2 reset	No change (increments)	0000h	No change (decrements)	0000h
RST4 reset	No change (increments)	0000h	No change (decrements)	— (count continues)

20.3.2 Time Measurement Function

The base timer value is stored in the G1TMj register (j = 0 to 7) using an external input as a trigger. Table 20.10 lists the specifications of the time measurement function. Table 20.11 lists the time measurement function associated registers and their settings. Figure 20.11 to Figure 20.12 show the operation examples of the time measurement function.
Figure 20.13 shows the operation example of the prescaler function and gate function.

Table 20.10 Time Measurement Function Specifications

Item	Specification
Measurement channels	Channels 0 to 7
Trigger input polarity	Selectable from rising edge, falling edge, or both edges of the INPC1_j pin input.
Measurement start condition	While the FSCj bit in the G1FS register is 1 (time measurement function selected), set the IFEj bit in the G1FE register to 1 (channel j function enabled).
Measurement stop condition	Set the IFEj bit to 0 (channel j function disabled).
Time measurement timing	• Without prescaler: every trigger input • With prescaler (channels 6 and 7): every (G1TPRk register value + 1) time a trigger is input
Interrupt request occurrence timing	At the time measurement timing
INPC1_ j pin function	Trigger input
Selectable functions	• Digital filter The digital filter judges a trigger input level at each sampling clock (f1TIMS, f2TIMS, or fBT1) and passes the pulse that matches its signal level three times. • Prescaler (channels 6 and 7) Time measurement is executed every (G1TPRk register value + 1) times a trigger is input. • Gate function (channels 6 and 7) After a time measurement is performed by the first trigger input, subsequent trigger inputs are disabled.

j = 0 to 7; k = 6 and 7

Table 20.11 Time Measurement Function Associated Registers (1)

Register	Bit	Function
G1TMj	—	Time measurement result can be read.
G1TMCRj	CTS1 and CTS0	Select a time measurement trigger.
	DF1 and DF0	Select whether the digital filter function is used. If used, select a sampling clock to use for the function.
G1TMCRk	GT, GOC, GSC	Select if the gate function is used.
	PR	Select whether the prescaler function is used.
G1TPRk	—	Set a value if the prescaler function is used.
G1FS	FSCj	Set to 1 (time measurement function selected).
G1FE	IFEj	Set to 1 (channel j function enabled).
G1POCRp	MOD1 and MOD0	Set to 00b. (2)
G1POp	—	Set a gate release timing. (2)
G1FS	FSCp	Set to 0. (2)
G1FE	IFEp	Set to 1. (2)
G1OER	EOCp	Set to 1. (2)
G1IOR1	IOp1 and IOp0	Set to 00b. (2)

j = 0 to 7; k = 6 and 7; p = k - 2

Notes:
1. This table does not describe a procedure.
2. Set when bits GT and GOC in the G1TMCRk register are 1.

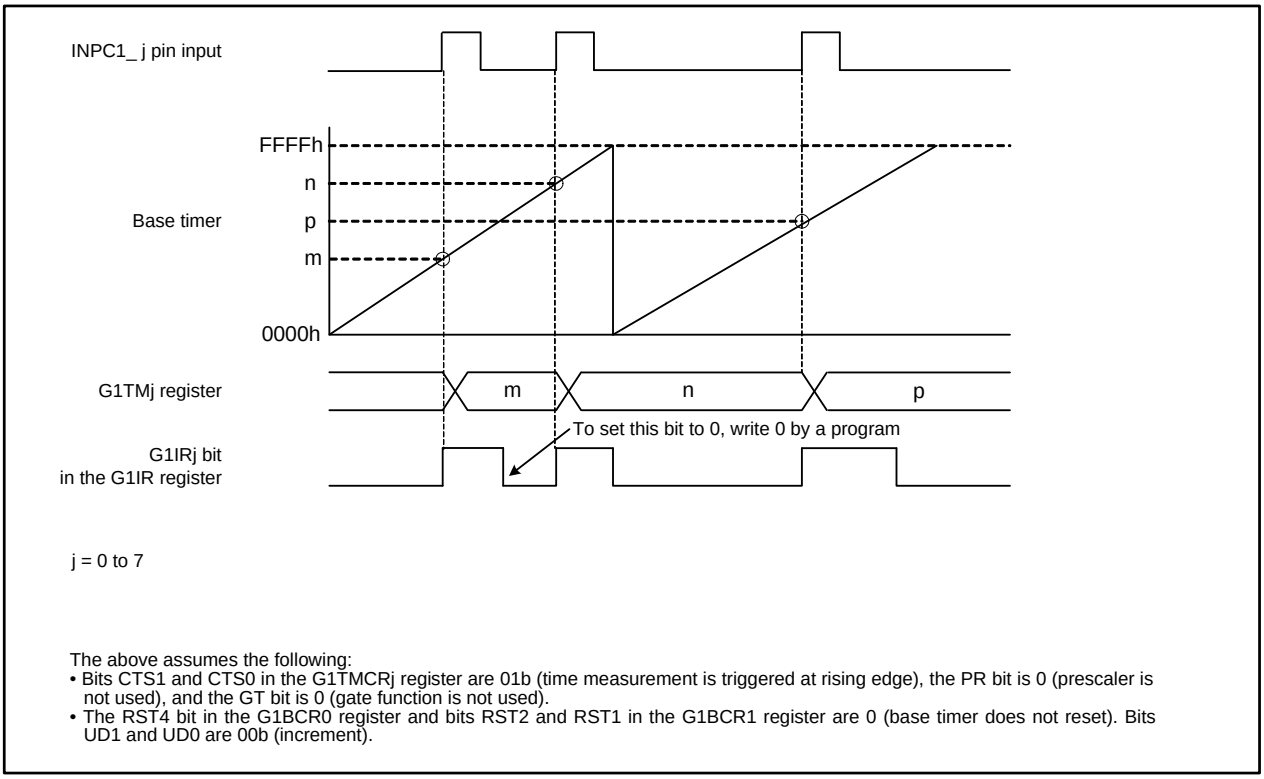
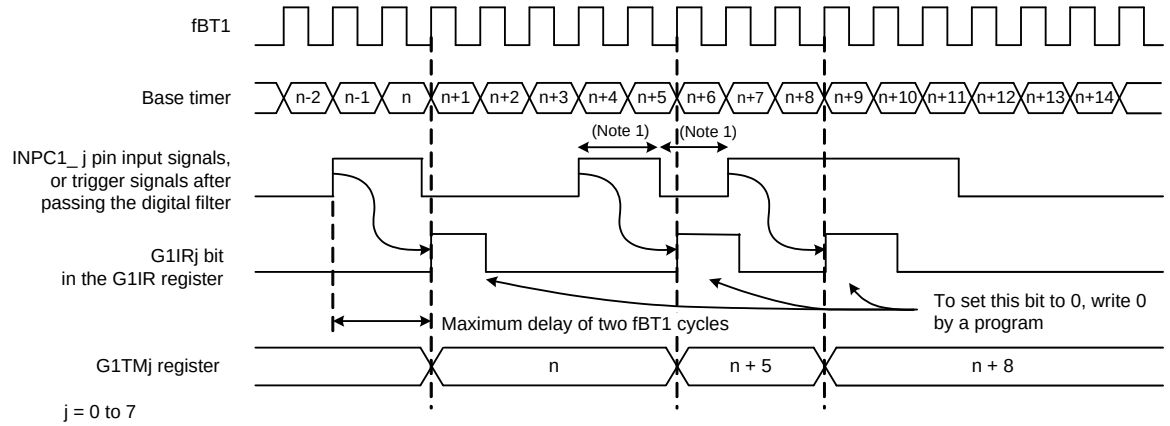


Figure 20.11 Time Measurement Function (1/2)

(1) The rising edge is selected as a time measurement trigger (bits CTS1 and CTS0 in the G1TMCRj register are 01b).

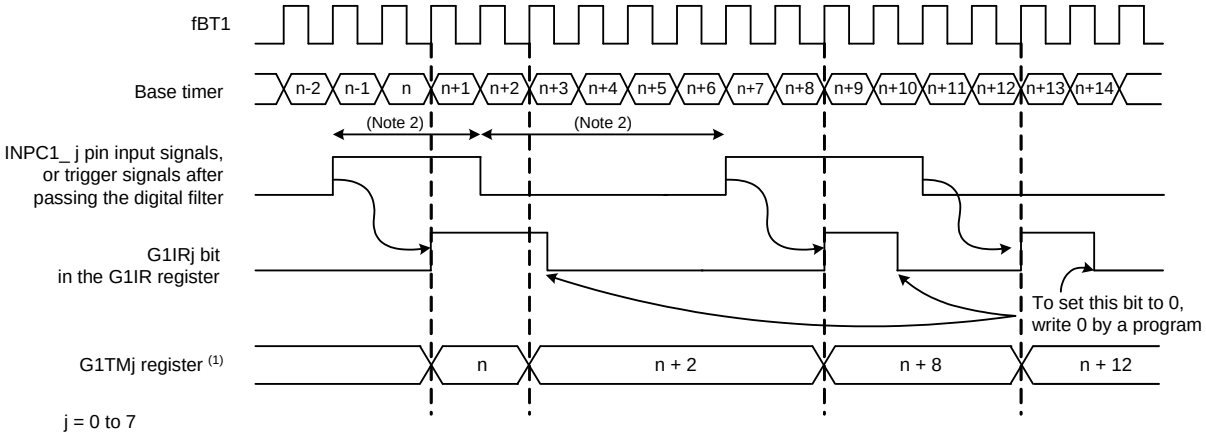


j = 0 to 7

Note:

1. Input pulse applied to the INPC1_ j pin requires at least 1.5 fBT1 cycles for both high and low widths.

(2) Both the rising and falling edges are selected as a time measurement trigger (bits CTS1 and CTS0 are 11b).

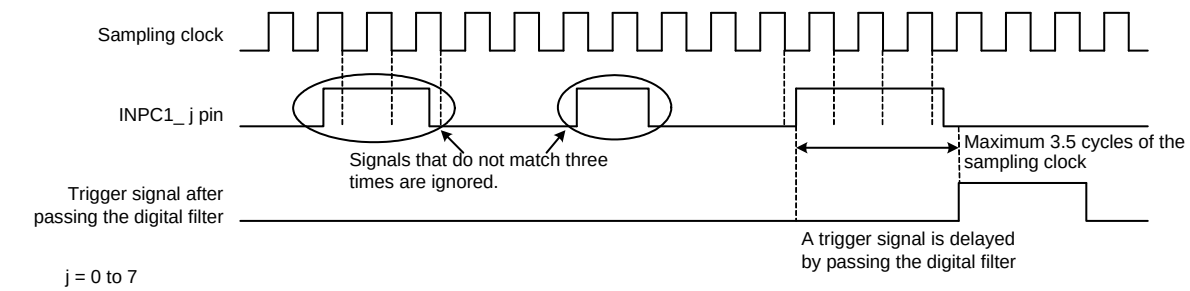


j = 0 to 7

Notes:

1. When the G1IRj bit is 1 and a trigger signal is generated, the IC/OC interrupt 0 and IC/OC interrupt 1 requests are not generated. However, values in the G1TMj register change.
2. Input pulse applied to the INPC1_j pin requires at least 2.5 fBT1 cycles for both the high and low widths.

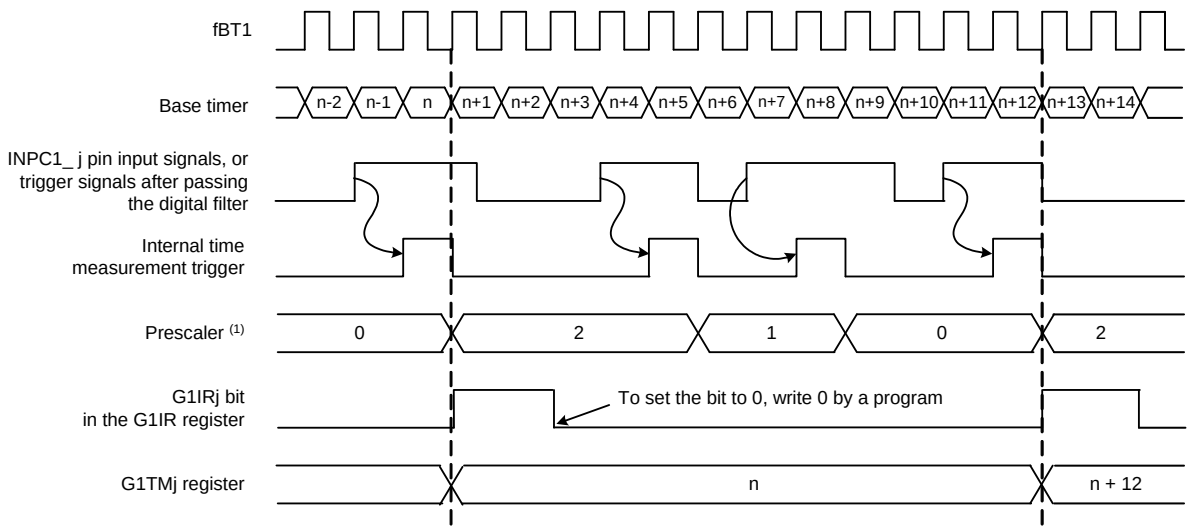
(3) Trigger signal when the digital filter function is used (bits DF1 and DF0 in the G1TMCRj register are 10b or 11b).



j = 0 to 7

Figure 20.12 Time Measurement Function (2/2)

(1) Example using the prescaler function (G1TPRj register is 02h and the PR bit in the G1TMCRj register is 1)

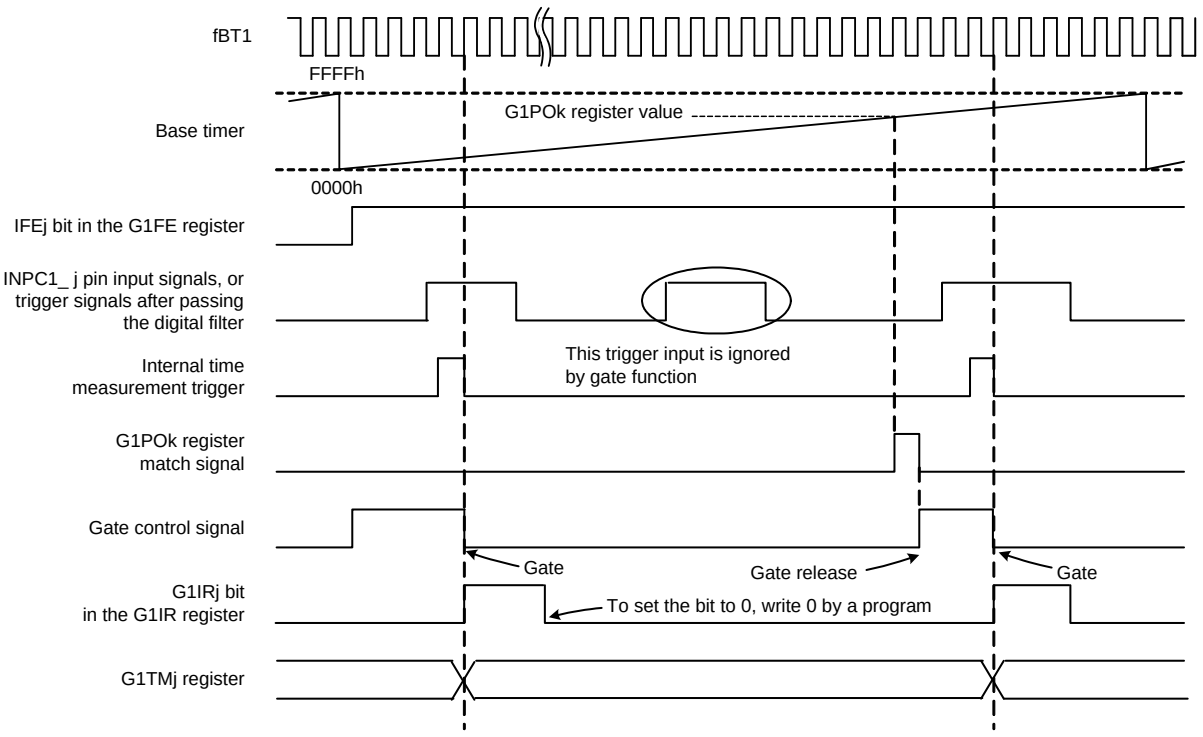


j = 6 and 7

Note:

1. This applies to the second or later prescaler cycle after the PR bit in the G1TMCRj register is set to 1 (prescaler function is used).

(2) Example using the gate function (bits GT and GOC in the G1TMCRj register are 1, and the gate function is disabled by matching with the G1POk register)



j = 6 and 7; k = j - 2

Figure 20.13 Prescaler and Gate Functions

20.3.2.1 Gate Function (Channel 6 and 7)

When the GT bit in the G1TMCRj register (j = 6 and 7) is 1 (gate function used), acceptance of trigger inputs is disabled after the time measurement by the first trigger input.

When 1 is written to the GSC bit in the G1TMCRj register, acceptance of trigger inputs becomes enabled again.

When the GOC bit in the G1TMCRj register is 1, acceptance of trigger inputs also becomes enabled again by matching the base timer with the G1POk register (k = j - 2).

"(2) Example using the gate function" in Figure 20.13 "Prescaler and Gate Functions" shows the operation example of this function.

20.3.3 Waveform Generation Function

A waveform is generated using the base timer value and the G1POj register value (j = 0 to 7). The waveform generation function has the following three modes:

- Single-phase waveform output mode
- Inverted waveform output mode
- Set/reset (SR) waveform output mode

In single-phase waveform output mode and inverted waveform output mode, compare match output is selectable.

In all three modes, each channel output can be temporarily disabled and used as a programmable I/O port when the waveform generation is in progress.

20.3.3.1 Single-Phase Waveform Output Mode

The OUTC1_j pin outputs high when the base timer value matches the G1POj register value (j = 0 to 7) and the INV bit in the G1POCRj register is 0 (output level is not inverted).
The OUTC1_j pin outputs low when the base timer reaches 0000h. When bits MOD1 and MOD0 in the G1POCRj register are 00b (single-phase waveform output mode), set bits UD1 and UD0 in the G1BCR register to 00b (increment). Table 20.12 lists the specifications of single-phase waveform output mode, Figure 20.14 to Figure 20.15 show operational examples in single-phase waveform output mode.

Table 20.12 Single-Phase Waveform Output Mode Specifications

Item	Specification
Output waveform	• Free-running operation (when bits RST2 and RST1 in the G1BCR1 register and the RST4 bit in the G1BCR0 register are all 0 (base timer is not reset)) Cycle: $\frac{65536}{fBT1}$ Initial output level width: $\frac{m}{fBT1}$ Inverted output level width: $\frac{65536 - m}{fBT1}$ • When the base timer matches either of following registers, the base timer is reset to 0000h. • G1PO0 register (when the RST1 bit is 1, and bits RST4 and RST2 are 0) • G1BTRR register (when the RST4 bit is 1, and bits RST2 and RST1 are 0) Cycle: $\frac{n + 2}{fBT1}$ Initial output level width: $\frac{m}{fBT1}$ Inverted output level width: $\frac{n + 2 - m}{fBT1}$ m: G1POj register setting value n: G1PO0 register or G1BTRR register setting value 0001h ≤ m < n ≤ FFFDh
Waveform output start condition	Set the IFEj bit in the G1FE register to 1 (channel j function enabled).
Waveform output stop condition	Set the IFEj bit to 0 (channel j function disabled).
Interrupt request occurrence timing	When the base timer value matches the G1POj register value.
OUTC1_ j pin	Pulse output or I/O port
Selectable functions	• Default value setting Select the starting waveform output level. • Output level inversion Output an inverted waveform from the OUTC1_j pin. • Compare match output When using the compare match output function, the output level is fixed to high or low from when the base timer value matches the G1POj register value. If the compare match output function is released, a single-phase waveform is output again when the base timer next matches the G1POj register. • Output disabled function When the EOCj bit in the G1OER register is 1 (output disabled), the OUTC1_j pin stops waveform output and becomes a programmable I/O port. When the EOCj bit is 0 (output enabled), the OUTC1_j pin outputs a single-phase waveform again.

j = 0 to 7

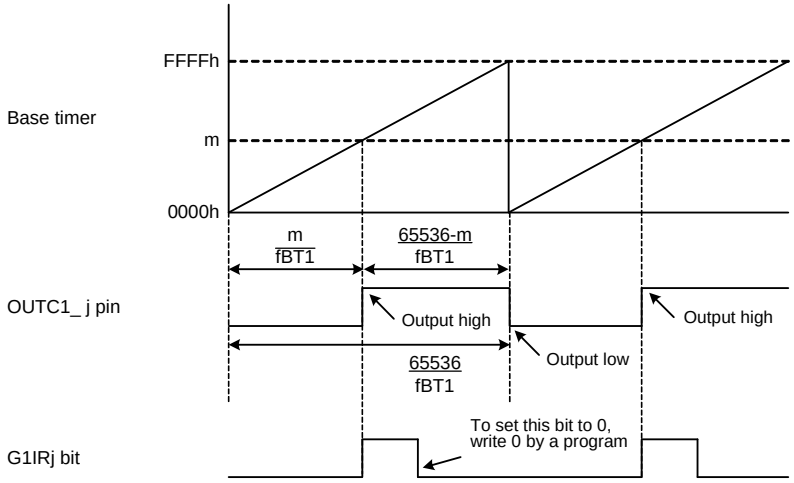
Table 20.13 Registers and Settings in Single-Phase Waveform Output Mode (1)

Register	Bit	Function
G1POj	—	Set the timing for an output level to become high. (2)
G1FS	FSCj	Set to 0 (waveform generation function selected).
G1FE	IFEj	Set to 1 (channel j function enabled).
G1POCRj	MOD1 and MOD0	Set to 00b.
	IVL	Select a default value of an output level.
	RLD	Select the reload timing for the G1POj register value.
	INV	Select whether an output level is inverted.
G1OER	EOCj	Set to 1 when the OUTC1_j output is disabled.
G1IOR0 G1IOR1	IOj1 and IOj0	Select an output level when compare results match.
G1BCR1	UD1 and UD0	Set to 00b.

j = 0 to 7, however, when the RST1 bit in the G1BCR1 register is 1 (the base timer is reset when the base timer and G1PO0 register values match), then j = 1 to 7.

Notes:
1. This table does not describe a procedure.
2. When the INV bit in the G1POCRj register is 0 (output level not inverted).

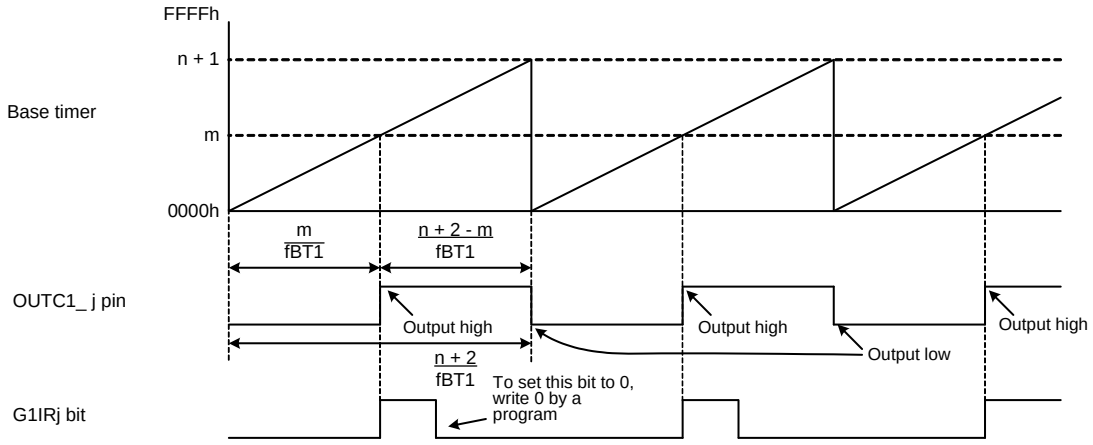
(1) Free-running operation (when bits RST2 and RST1 in the G1BCR1 register and the RST4 bit in the G1BCR0 register are all 0).



j = 0 to 7
m: G1POj register value
G1IRj: Bit in the G1IR register

The diagram above applies under the following conditions:
- The IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
- Bits IOj1 and IOj0 in registers G1IOR0 and G1IOR1 are 00b (outputs high or low depending on the mode selected by bits MOD1 and MOD0 in the G1POCRj register).
- The EOCj bit in the G1OER register is 0 (output enabled).

(2) When the base timer matches either of the following registers, the base timer is reset:
(a) G1PO0 register (when the RST1 bit is 1 and bits RST4 and RST2 are 0)
(b) G1BTRR register (when the RST4 bit is 1 and bits RST2 and RST1 are 0)

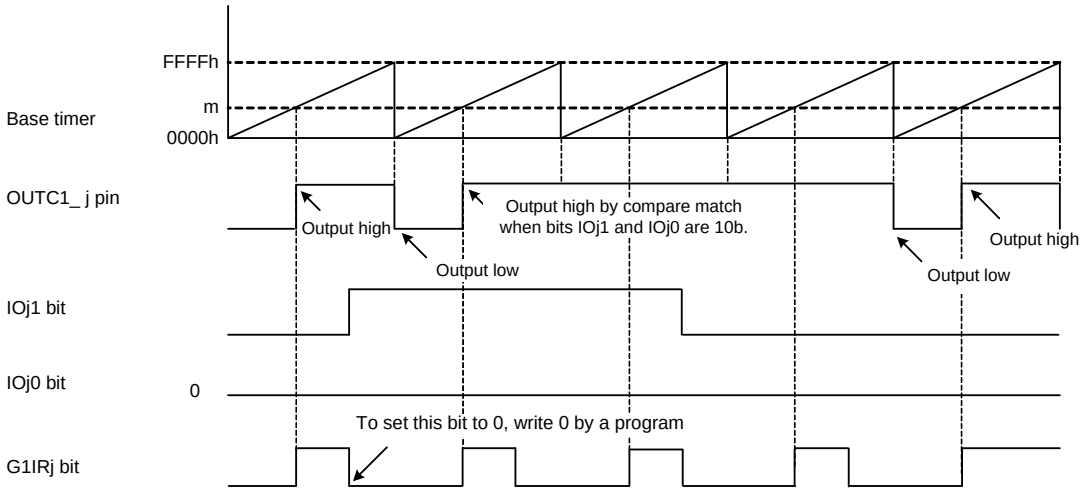


When (a), j = 1 to 7. When (b), j = 0 to 7.
m: G1POj register value
n: G1PO0 register or G1BTRR register setting value
G1IRj: Bit in the G1IR register

The above assumes the following:
- The IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
- Bits IOj1 and IOj0 in registers G1IOR0 and G1IOR1 are 00b (outputs high or low depending on the mode selected by bits MOD1 and MOD0 in the G1POCRj register).
- The EOCj bit in the G1OER register is 0 (output enabled).

Figure 20.14 Single-Phase Waveform Output Mode Operation (1/2)

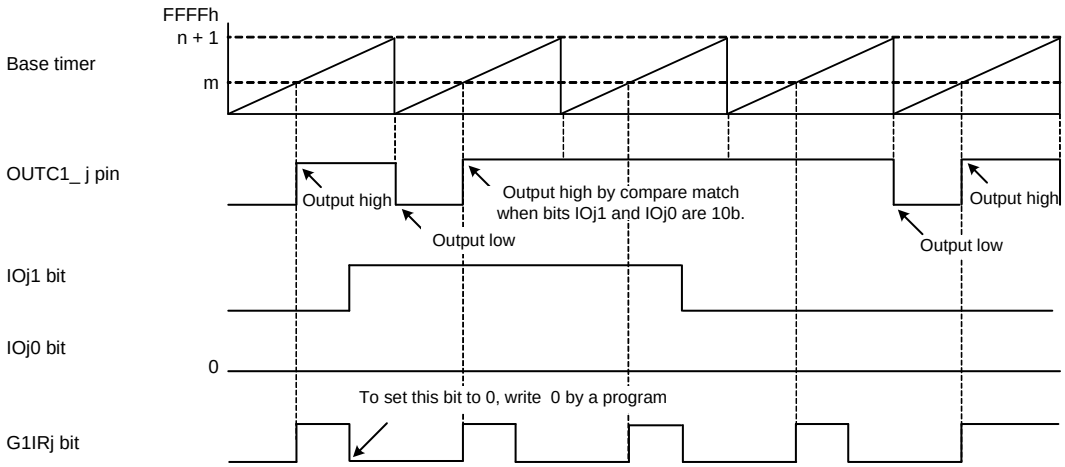
(3) Free-running operation (when bits RST2 and RST1 in the G1BCR1 register and the RST4 bit in the G1BCR0 register are all 0).



j = 0 to 7
m: G1POj register value
IOj1 and IOj0: Bits in registers G1IOR1 and G1IOR0
G1IRj: Bit in the G1IR register

The above assumes the following:
· IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
· EOCj bit in the G1OER register is 0 (output enabled).

(4) When the base timer matches either of following registers, the base timer is reset:
(a) G1PO0 register (when the RST1 bit is 1 and bits RST4 and RST2 are 0)
(b) G1BTRR register (when the RST4 bit is 1 and bits RST2 and RST1 are 0)



When (a), j = 1 to 7. When (b), j = 0 to 7.
m: G1POj register value
n: G1PO0 register or G1BTRR register setting value
G1IRj: Bit in the G1IR register

The above assumes the following:
· The IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
· The EOCj bit in the G1OER register is 0 (output enabled).

Figure 20.15 Single-Phase Waveform Output Mode Operation (2/2)

20.3.3.2 Inverted Waveform Output Mode

The output level at the OUTC1_j pin is inverted every time the base timer value matches the G1POj register value (j = 0 to 7). When bits MOD1 and MOD0 in the G1POCRj register are 10b (inverted waveform output mode), set bits UD1 and UD0 in the G1BCR1 register to 00b (increment) or 01b (increment/decrement).

Table 20.14 lists the specifications of inverted waveform output mode. Figure 20.16 and Figure 20.17 show the operational examples of inverted waveform output mode.

Table 20.14 Inverted Waveform Output Mode Specifications

Item	Specification
Output waveform	• Free-running operation (when bits RST2 and RST1 in the G1BCR1 register and the RST4 bit in the G1BCR0 register are all 0 (the base timer is not reset)) Cycle: $\frac{65536 \times 2}{fBT1}$ High or low width: $\frac{65536}{fBT1}$ • When the base timer matches either of the following registers, the base timer is set to 0000h: • G1PO0 register (when the RST1 bit is 1, and bits RST4 and RST2 are 0) • G1BTRR register (when the RST4 bit is 1, and bits RST2 and RST1 are 0) Cycle: $\frac{2(n+2)}{fBT1}$ High or low width: $\frac{n+2}{fBT1}$ m: G1POj register setting value n: G1PO0 register or G1BTRR register setting value 0000h ≤ m < n ≤ FFFDh
Waveform output start condition	Set the IFEj bit in the G1FE register to 1 (channel j function enabled).
Waveform output stop condition	Set the IFEj bit to 0 (channel j function disabled).
Interrupt request occurrence timing	When the base timer value matches the G1POj register value.
OUTC1_j pin	Pulse output or I/O port
Selectable functions	• Default value setting Select the starting waveform output level. • Output level inversion Select if the waveform level output from the OUTC1_j pin is inverted. • Compare match output function When the compare match output function is set, the output level is fixed to high or low from when the base timer value matches the G1POj register value. When the compare match output function is disabled, an inverted waveform is output again from the next compare match timing. • Output disabled function When the EOCj bit in the G1OER register is 1 (output disabled), the OUTC1_j pin stops waveform output and becomes a programmable I/O port. When the EOCj bit is 0 (output enabled), the OUTC1_j pin outputs inverted waveform again.

j = 0 to 7

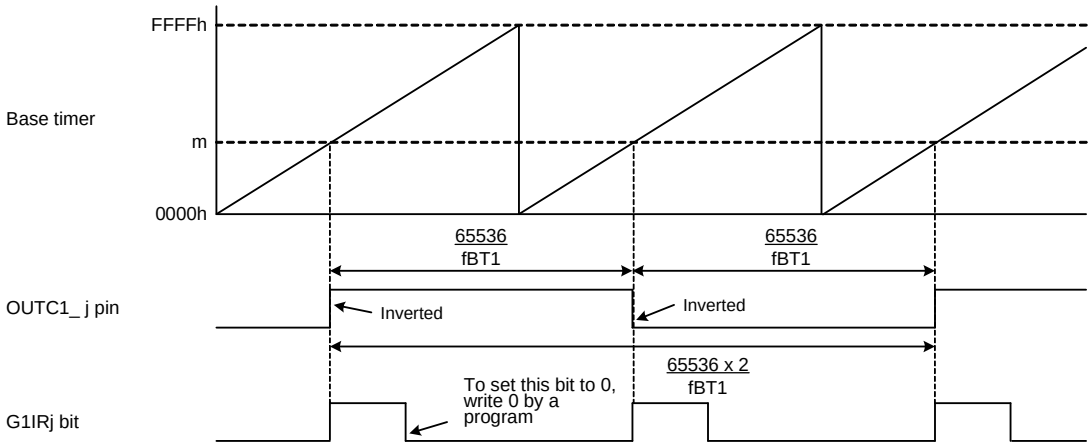
Table 20.15 Registers and Settings in Inverted Waveform Output Mode (1)

Register	Bit	Function
G1POj	—	Set the timing for the waveform to be inverted.
G1FS	FSCj	Set to 0 (waveform generation function selected).
G1FE	IFEj	Set to 1 (channel j function enabled).
G1POCRj	MOD1 and MOD0	Set to 10b.
	IVL	Select a default value of an output level.
	RLD	Select the reload timing for the G1POj register value.
	INV	Select whether an output level is inverted.
G1OER	EOCj	Set to 1 when the OUTC1_j output is disabled.
G1IOR0 G1IOR1	IOj1 and IOj0	Select an output level when compare results match.
G1BCR1	UD1 and UD0	Set to 00b or 01b.

j = 0 to 7, however, when the RST1 bit in the G1BCR1 register is 1 (the base timer is reset when the base timer and G1PO0 register values match), then j = 1 to 7.

Note:
1. This table does not describe a procedure.

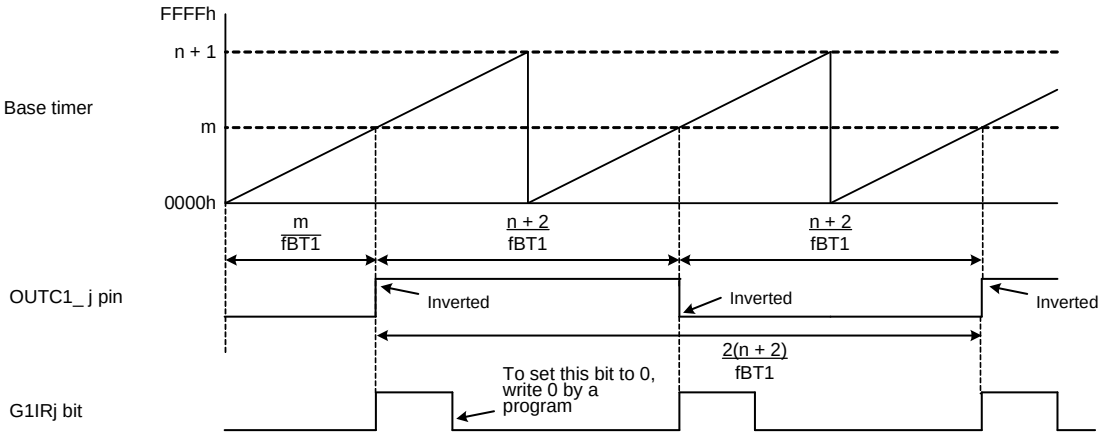
(1) Free-running operation (when bits RST2 and RST1 in the G1BCR1 register and the RST4 bit in the G1BCR0 register are all 0)



j = 0 to 7
m: G1POj register value
G1IRj: Bit in the G1IR register

The above assumes the following:
- The IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
- Bits UD1 and UD0 in the G1BCR1 register are 00b (increment).
- Bits IOj1 and IOj0 in registers G1IOR0 and G1IOR1 are 00b (outputs high or low depending on the mode selected by bits MOD1 and MOD0 in the G1POCRj register).
- The EOCj bit in the G1OER register is 0 (output enabled).

(2) When the base timer matches either of following registers, the base timer is reset:
(a) G1PO0 register (when the RST1 bit is 1 and bits RST4 and RST2 are 0)
(b) G1BTRR register (when the RST4 bit is 1 and bits RST2 and RST1 are 0)

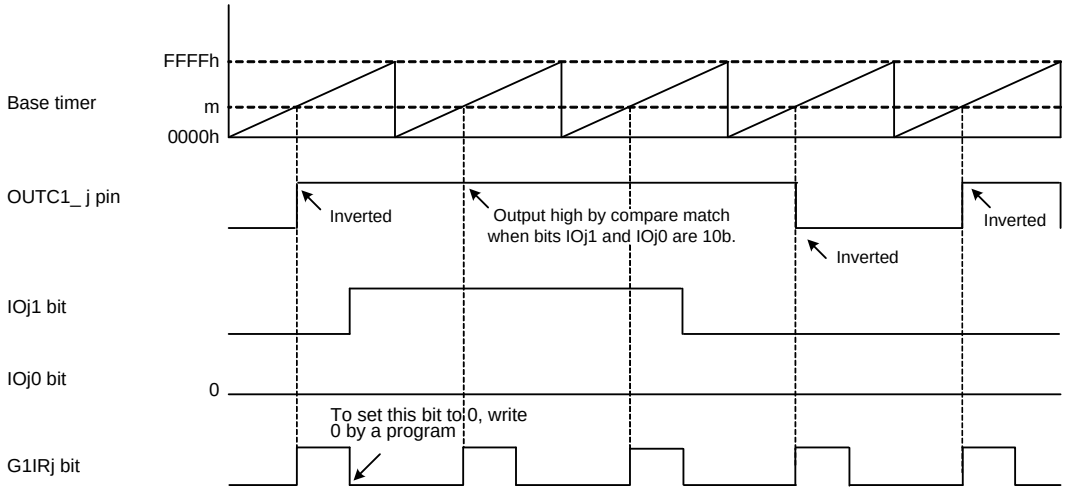


When (a), j = 1 to 7. When (b), j = 0 to 7.
m: G1POj register value
n: G1PO0 register or G1BTRR register value
G1IRj: Bit in the G1IR register

The above assumes the following:
- The IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
- Bits UD1 and UD0 in the G1BCR1 register are 00b (increment).
- Bits IOj1 and IOj0 in registers G1IOR0 and G1IOR1 are 00b (outputs high or low depending on the mode selected by bits MOD1 and MOD0 in the G1POCRj register).
- The EOCj bit in the G1OER register is 0 (output enabled).

Figure 20.16 Inverted Waveform Output Mode Operation (1/2)

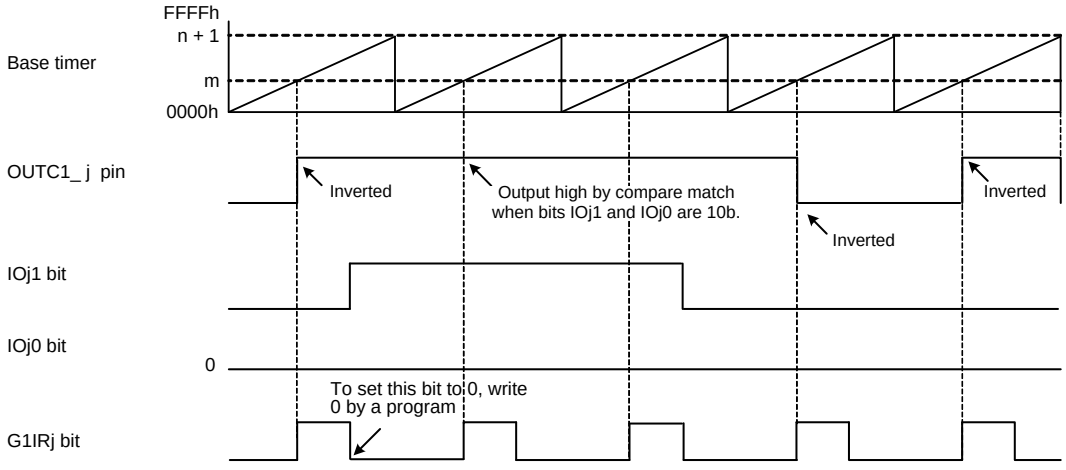
(3) Free-running operation (when bits RST2 and RST1 in the G1BCR1 register and the RST4 bit in the G1BCR0 register are all 0):



j = 0 to 7
m: G1POj register value
IOj1 and IOj0: Bits in registers G1IOR1 and G1IOR0
G1IRj: Bit in the G1IR register

The above assumes the following:
· The IVL bit in the G1POCRj register is 0 (Output low as default) and the INV bit is 0 (output is not inverted).
· Bits UD1 and UD0 in the G1BCR1 register are 00b (increment).
· The EOCj bit in the G1OER register is 0 (output enabled).

(4) When the base timer matches either of following registers, the base timer is reset:
(a) G1PO0 register (when the RST1 bit is 1 and bits RST4 and RST2 are 0)
(b) G1BTRR register (when the RST4 bit is 1 and bits RST2 and RST1 are 0)



When (a), j = 1 to 7. When (b), j = 0 to 7.
m: G1POj register value, n: G1PO0 register or G1BTRR register value
IOj1 and IOj0: Bits in registers G1IOR1 and G1IOR0
G1IRj: Bit in the G1IR register

The above assumes the following:
· The IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
· Bits UD1 and UD0 in the G1BCR1 register are 00b (increment).
· The EOCj bit in the G1OER register is 0 (output enabled).

Figure 20.17 Inverted Waveform Output Mode Operation (2/2)

20.3.3.3 Set/Reset Waveform Output Mode (SR Waveform Output Mode)

The OUTC1_j pin outputs high when the INV bit in the G1POCRj register (j = 0, 2, 4, 6) is 0 (output level is not inverted) and the base timer value matches the G1POj register value. When the base timer value matches the G1POk register value (k = j + 1), the OUTC1_j pin outputs low.

When bits MOD1 and MOD0 in registers G1POCRj and G1POCRk are 01b (SR waveform output mode), set bits UD1 and UD0 in the G1BCR register to 00b (increment).

Table 20.16 lists the specifications of SR waveform output mode and Figure 20.18 shows the operational example of SR waveform output mode.

Table 20.16 SR Waveform Output Mode Specifications

Item	Specification
Output waveform	• Free-running operation (when bits RST2 and RST1 in the G1BCR1 register and the RST4 bit in the G1BCR0 register are all 0 (the base timer is not reset)) Cycle: $\frac{65536}{fBT1}$ Inverted output level width: $\frac{n-m}{fBT1}$ • When the base timer matches either of following registers, the base timer is reset to 0000h: • G1PO0 register (when the RST1 bit is 1, and bits RST4 and RST2 are 0) (1) • G1BTRR register (when the RST4 bit is 1, and bits RST2 and RST1 are 0) Cycle: $\frac{p+2}{fBT1}$ Inverted output level width: $\frac{n-m}{fBT1}$ m: G1POj register setting value n: G1POk register setting value p: G1PO0 register or G1BTRR register value 0000h ≤ m < n < p ≤ FFFDh
Waveform output start condition	Set bits IFEj and IFEk in the G1FE register to 1 (channel j function enabled).
Waveform output stop condition	Set bits IFEj and IFEk to 0 (channel j function disabled).
Interrupt request occurrence timing	• Channel j When the base timer value matches the G1POj register value. • Channel k When the base timer value matches the G1POk register value.
OUTC1_ j pin	Pulse output or I/O port
Selectable functions	• Default value setting Select the starting waveform output level. • Output level inversion Select if the waveform level output from the OUTC1_j pin is inverted. • Output disabled When the EOCj bit in the G1OER register is 1 (output disabled), the OUTC1_j pin stops waveform output and becomes a programmable I/O port. When the EOCj bit is 0 (output enabled), the OUTC1_j pin outputs SR waveform again.

j = 0, 2, 4, 6; k = j + 1

Note:

1. When the RST1 bit in the G1BCR1 register is 1 (the base timer is reset by the G1PO0 register), SR waveform output mode is disabled for channels 0 and 1.

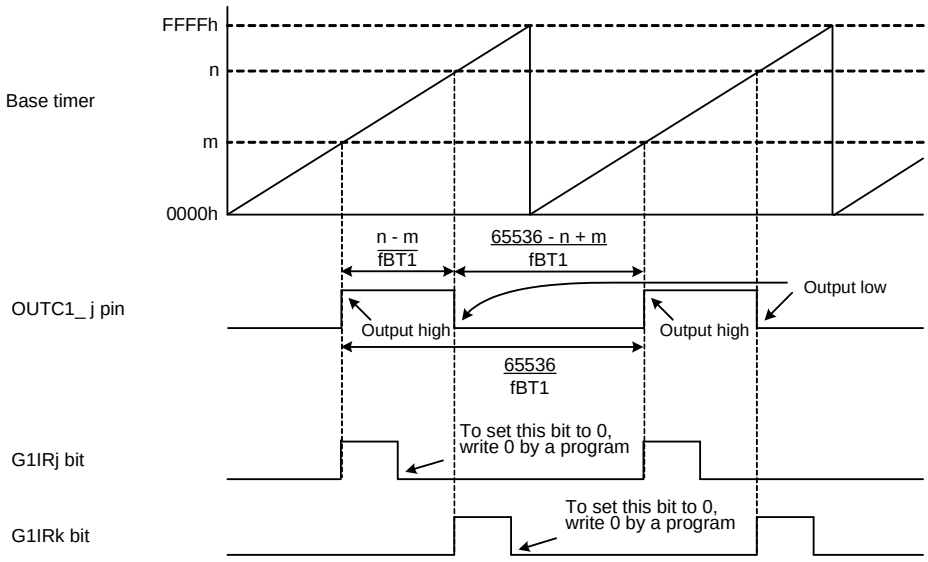
Table 20.17 Registers and Settings in SR Waveform Output Mode (1)

Register	Bit	Function	
		Even channel (channel j)	Odd channel (channel k)
G1POj	—	Set the timing for an output level to become high. (2)	Set the timing for an output level to become low. (2)
G1FS	FSCj	Set to 0 (waveform generation function selected).	Set to 0 (waveform generation function selected).
G1FE	IFEj	Set to 1 (channel j function enabled).	Set to 1 (channel k function enabled).
G1POCRj	MOD1 and MOD0	Set to 01b.	Set to 01b.
	IVL	Select a default value of an output level.	— (invalid)
	RLD	Select the reload timing for the G1POj register value.	Select the reload timing for the G1POk register value.
	INV	Select whether an output level is inverted.	— (invalid)
G1OER	EOCj	Set to 1 when the OUTC1_j is disabled.	Set to 1.
G1IOR0 G1IOR1	IOj1 and IOj0	Set to 00b.	Set to 00b.
G1BCR1	UD1 and UD0	Set to 00b.	

j = 0, 2, 4, 6; k = j + 1, however, when the RST1 bit in the G1BCR1 register is 1 (the base timer is reset when the base timer and G1PO0 register values match), then j = 2, 4, 6.

Notes:
1. This table does not describe a procedure.
2. When the INV bit in the G1POCRj register is 0 (output level not inverted).

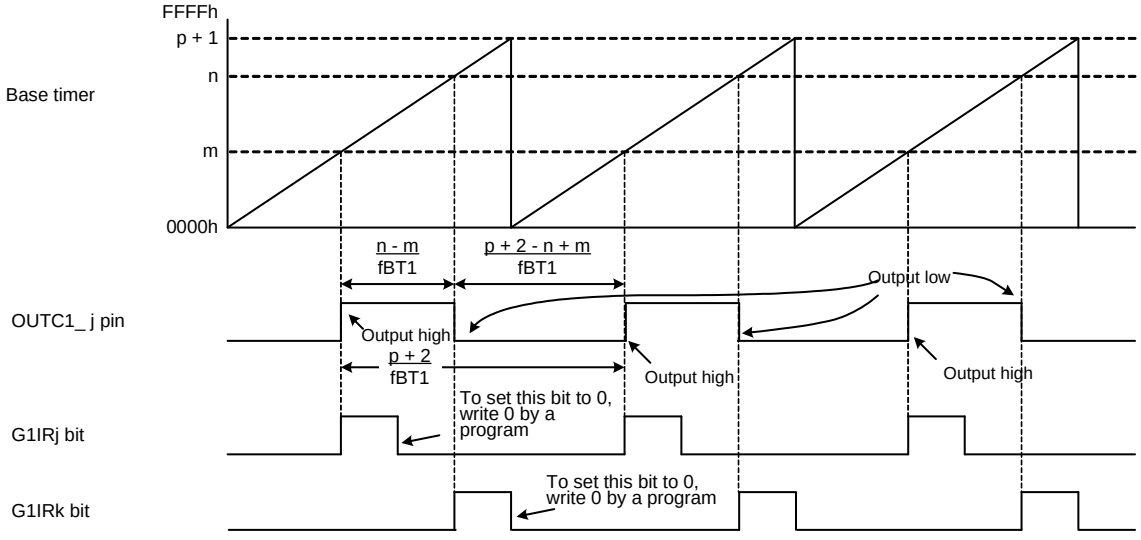
(1) Free-running operation (when bits RST2 and RST1 in the G1BCR1 register and the RST4 bit in the G1BCR0 register are all 0)



j = 0, 2, 4, 6; k = j + 1
m: G1POj register value
n: G1POk register value
G1IRj and G1IRk: Bits in the G1IR register

The above assumes the following:
· The IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
· The EOCj bit in the G1OER register is 0 (output enabled).

(2) When the base timer matches either of following registers, the base timer is reset:
(a) G1PO0 register (when the RST1 bit is 1 and bits RST4 and RST2 are 0)
(b) G1BTRR register (when the RST4 bit is 1 and bits RST2 and RST1 are 0)



When (a), j = 2, 4, 6. When (b), j = 0, 2, 4, 6.
k = j + 1
m: G1POj register value
p: Either G1PO0 or G1BTRR register value
G1IRj and G1IRk: Bits in the G1IR register

The above assumes the following:
· The IVL bit in the G1POCRj register is 0 (output low as default) and the INV bit is 0 (output is not inverted).
· The EOCj bit in the G1OER register is 0 (output enabled).

Figure 20.18 Operation Example in SR Waveform Output Mode

20.3.4 I/O Port Select Function

The I/O direction of IC/OC pins is determined by registers G1FE, G1FS, and G1OER.
In SR waveform output mode, an even channel and an odd channel are used for each output waveform, but a waveform is output only from the even channel. In this case, the corresponding pin for the odd channel can be used as an I/O port.

Table 20.18 Pin Settings for Time Measurement and Waveform Generation

Pin	Pin Settings				Pin Function
	IFE	FSC	MOD1 and MOD0	EOC	
P2_j/ INPC1_j/ OUTC1_j	0	—	—	—	P2_j used as I/O port
	1	1	—	—	INPC1_j (1)
	1	0	00b	0	Single-phase waveform output from OUTC1_j
	1	0	00b	1	P2_j used as I/O port
	1	0	01b	0	SR waveform output from OUTC1_j
	1	0	01b	1	P2_j used as I/O port
	1	0	10b	0	Inverted waveform output from OUTC1_j
	1	0	10b	1	P2_j used as I/O port

j = 0 to 7
—: 0 or 1
IFE: IFEj bit in the G1FE register
FSC: FSCj bit in the G1FS register
MOD1 and MOD0: Bits in the G1POCRj register
EOC: EOCj bit in the G1OER register

Note:
1. Set the port direction bits sharing pins to 0 (input mode).

20.4 Interrupts

Refer to each operation example for interrupt request occurrence timings.
Refer to 14.7 “Interrupt Control” for details on interrupt control. Table 20.19 lists Timer S Interrupt Associated Registers.

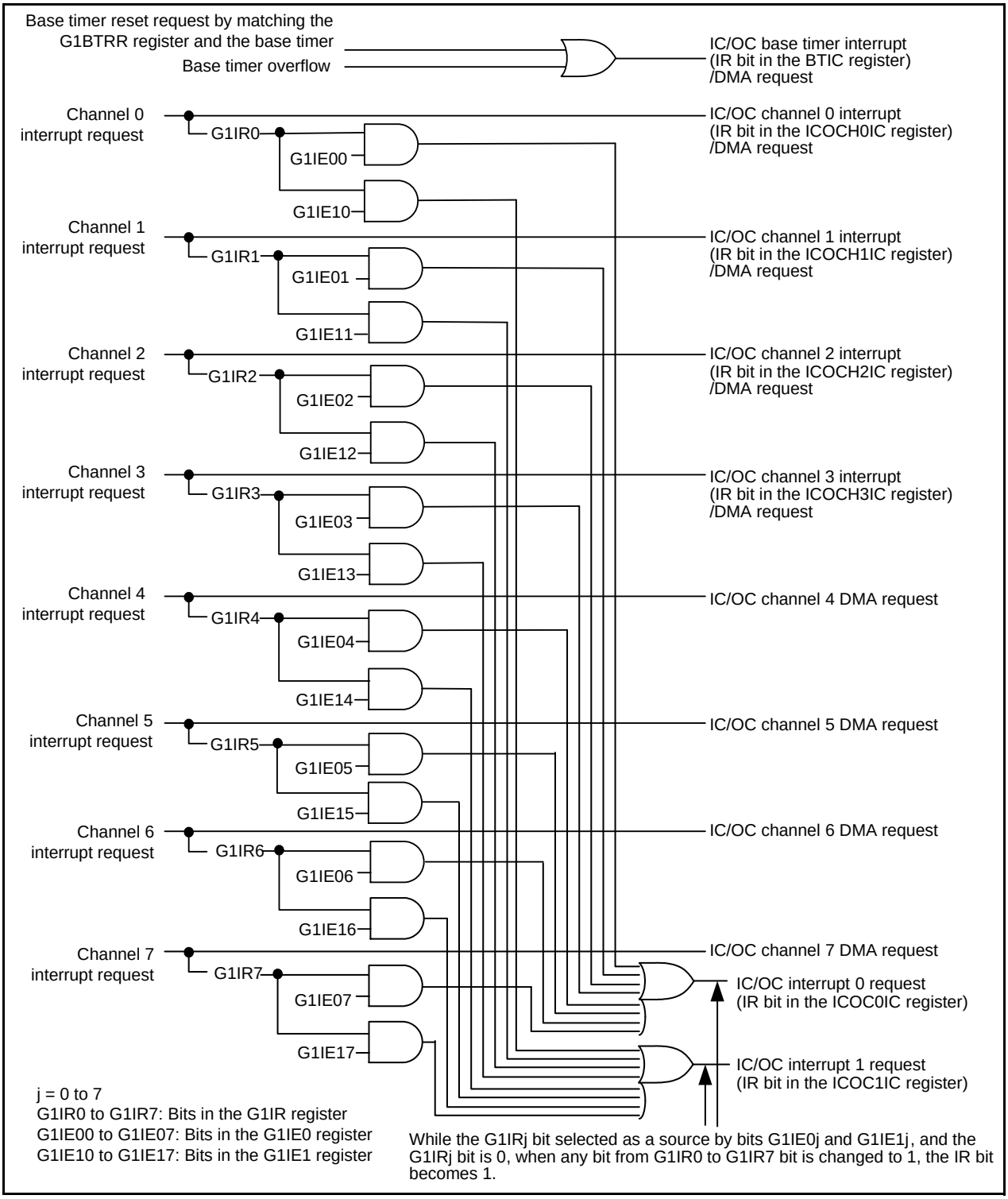


Figure 20.19 Timer S Interrupt and DMA Requests

Table 20.19 Timer S Interrupt Associated Registers

Address	Register	Symbol	Reset Value
0079h	IC/OC Interrupt 0 Control Register	ICOC0IC	XXXX X000b
007Ah	IC/OC Channel 0 Interrupt Control Register	ICOCH0IC	XXXX X000b
007Bh	IC/OC Interrupt 1 Control Register	ICOC1IC	XXXX X000b
007Ch	IC/OC Channel 1 Interrupt Control Register	ICOCH1IC	XXXX X000b
007Dh	IC/OC Channel 2 Interrupt Control Register	ICOCH2IC	XXXX X000b
007Eh	IC/OC Channel 3 Interrupt Control Register	ICOCH3IC	XXXX X000b
007Fh	IC/OC Base Timer Interrupt Control Register	BTIC	XXXX X000b

20.4.1 IC/OC Base Timer Interrupt

When the base timer reset request by matching the G1BTRR register and the base timer, or the base timer overflow is generated, the IR bit in the BTIC register becomes 1 (interrupt requested).

20.4.2 IC/OC Channel 0 Interrupt to IC/OC Channel 3 Interrupt

When interrupt requests for channels 0 to 3 are generated, the corresponding IR bit in registers ICOCH0IC to ICOCH3IC becomes 1 (interrupt requested).

20.4.3 IC/OC Interrupt 0 and IC/OC Interrupt 1

An interrupt request for IC/OC interrupt i (i = 0, 1) is generated in combination with the channel j interrupt request (j = 0 to 7). When the G1IEij bit in the G1IEi register is set to 1 (IC/OC interrupt i request enabled), the interrupt request for channel j becomes the IC/OC interrupt i source.

When the channel j interrupt request is generated, the G1IRj bit in the G1IR register becomes 1 (interrupt requested). While bits in the G1IR register corresponding to the channels selected as sources with the G1IEi register are all 0 (interrupt not requested), when any bit in the G1IR register becomes 1, the IR bit in the ICOCiIC register becomes 1 (interrupt requested).

The IR bit in the ICOCiIC register becomes 0 automatically when an interrupt request is received (interrupt not requested). However, the G1IRj bit does not become 0 automatically with an interrupt request reception. Thus, set the G1IRj bit to 0 by a program. If the G1IRj bit remains 1 when the IR bit is 0, the IR bit in the ICOCiIC register does not become 1 anymore. This means the IC/OC interrupt i request is no longer generated.

20.5 Notes on Timer S

20.5.1 Register Access

The explanation for some bits and registers states, “the value written to this register or this bit is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1)”. When writing these bits or registers, the written value is not reflected to the internal circuits immediately. After writing the value, prewrite operations are performed for up to one fBT1 cycle. When reading these bits or registers immediately after writing the value, the value before writing may be read.

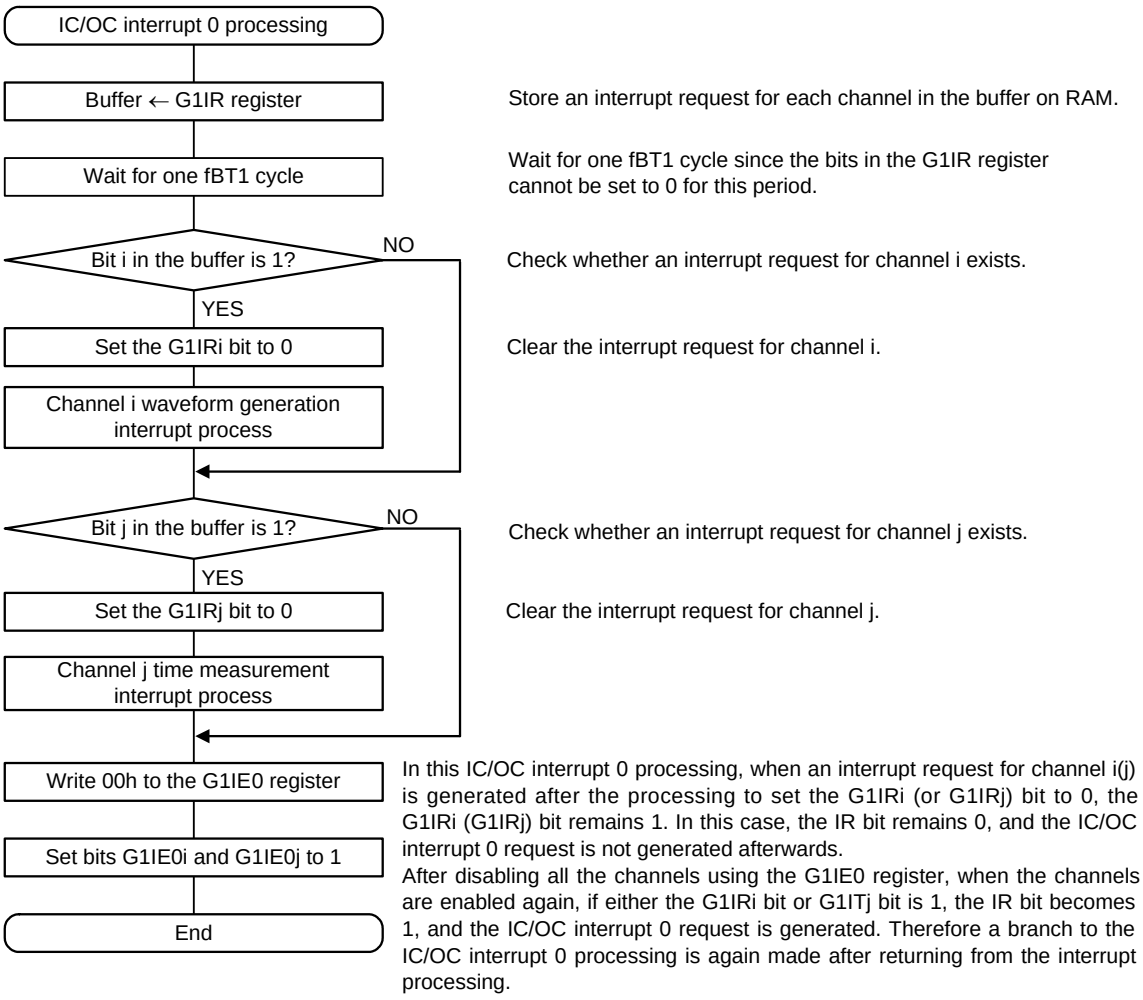
20.5.2 Changing the G1IR Register

Set the G1IRj bit in the G1IR register (j = 0 to 7) to 0 by a program since it does not become 0 automatically with an interrupt request reception.

However, the G1IRj bit cannot be set to 0 for one fBT1 cycle after this bit becomes 1. Wait for one or more fBT1 cycles after the G1IRj bit becomes 1, then set this bit to 0.

To write 0 to the G1IRj bit, use the AND and BCLR instructions to avoid deleting requests for other channels.

Figure 20.20 shows “IC/OC Interrupt 0 Operation Example”. As shown in the operation example, disable interrupt requests for all channels once at the last part of an interrupt process, then enable them again.



i = 0 to 7; j = 0 to 7 (however, j and i cannot be the same value)
G1IRi, G1IRj: Bits in the G1IR register
G1IE0i, G1IE0j: Bits in the G1IE0 register

The above assumes the following:
With IC/OC interrupt 0, a waveform generation interrupt is processed for channel i, and a time measurement interrupt for channel j.
Interrupt requests for the other channels are disabled with the G1IE0 register.

Figure 20.20 IC/OC Interrupt 0 Operation Example

20.5.3 Changing Registers ICOCiIC (i = 0, 1)

While the G1IEij bit in the G1IEi register is 1 (IC/OC interrupt 1 request enabled), use the AND, OR, BCLR, or BSET instruction to change bits ILVL2 to ILVL0 in the ICOCiIC register at the point where a channel j interrupt request may be generated (j = 0 to 7). The IR bit becomes 1 (interrupt requested) if a channel j interrupt is generated while executing these instructions.
If the MOV instruction is used to perform the above, when a channel j interrupt request is generated while executing the MOV instruction, the IR bit does not become 1, and the interrupt request is ignored. The G1IRj bit in the G1IR register becomes 1 (interrupt requested) at this timing. If the G1IRj remains 1, subsequent IC/OC interrupt i requests are not generated.

When timer S is initialized, change registers ICOCiIC after registers ICOCiIC and G1IR are both set to 00h.

20.5.4 Output Waveform During the Base Timer Reset with the BTS bit

When the BTS bit in the G1BCR1 register is set to 0 (base timer reset), the waveform output pin level remains as it is at that point. This output level is held until the base timer value matches the G1POj register value after the BTS bit is set to 1 (base timer starts counting).

20.5.5 OUTC1_0 Pin Output During the Base Timer Reset with the G1PO0 register

While the RST1 bit in the G1BCR1 register is set to 1 (the base timer is reset when the base timer matches the G1PO0 register), when the base timer matches the G1PO0 register, the base timer is reset after two fBT1 cycles. During the two fBT1 cycles from when the base timer value matches the G1PO0 register value to the base timer being reset, the OUTC1_0 pin is driven high. Thus set the EOC0 bit in the G1OER register to 1 (output disabled).

20.5.6 Interrupt Request When Selecting Time Measurement Function

When the FSCj bit (j = 0 to 7) in the G1FS register is set to 1, and the IFEj bit in the G1FE register is also set to 1, the G1IRj bit in the G1IR register, or the IR bits in registers ICOCiIC (i = 0, 1) or ICOCHjIC (j = 0 to 3) may become 1 (interrupt requested) after a maximum of two fBT1 cycles (1).
When using IC/OC interrupt i or IC/OC channel j interrupt, set bits FSCj and IFEj to 1, then perform the following:

(1) Wait for two or more fBT1 cycles (1).
(2) Set the IR bit in the ICOCiIC register and/or the ICOCHjIC register to 0.
(3) Wait for three or more fBT1 cycles (1) after the time measurement function is selected. Set the G1IR register to 00h (2) after setting the IR bit in the ICOCiIC register to 0.

Notes:
1. When using the digital filter, time required for the function also needs to be considered.
2. Verify the value in the G1IR register is 00h by reading. If the read value is not 00h, repeat writing 00h to the G1IR register.

21. Real-Time Clock

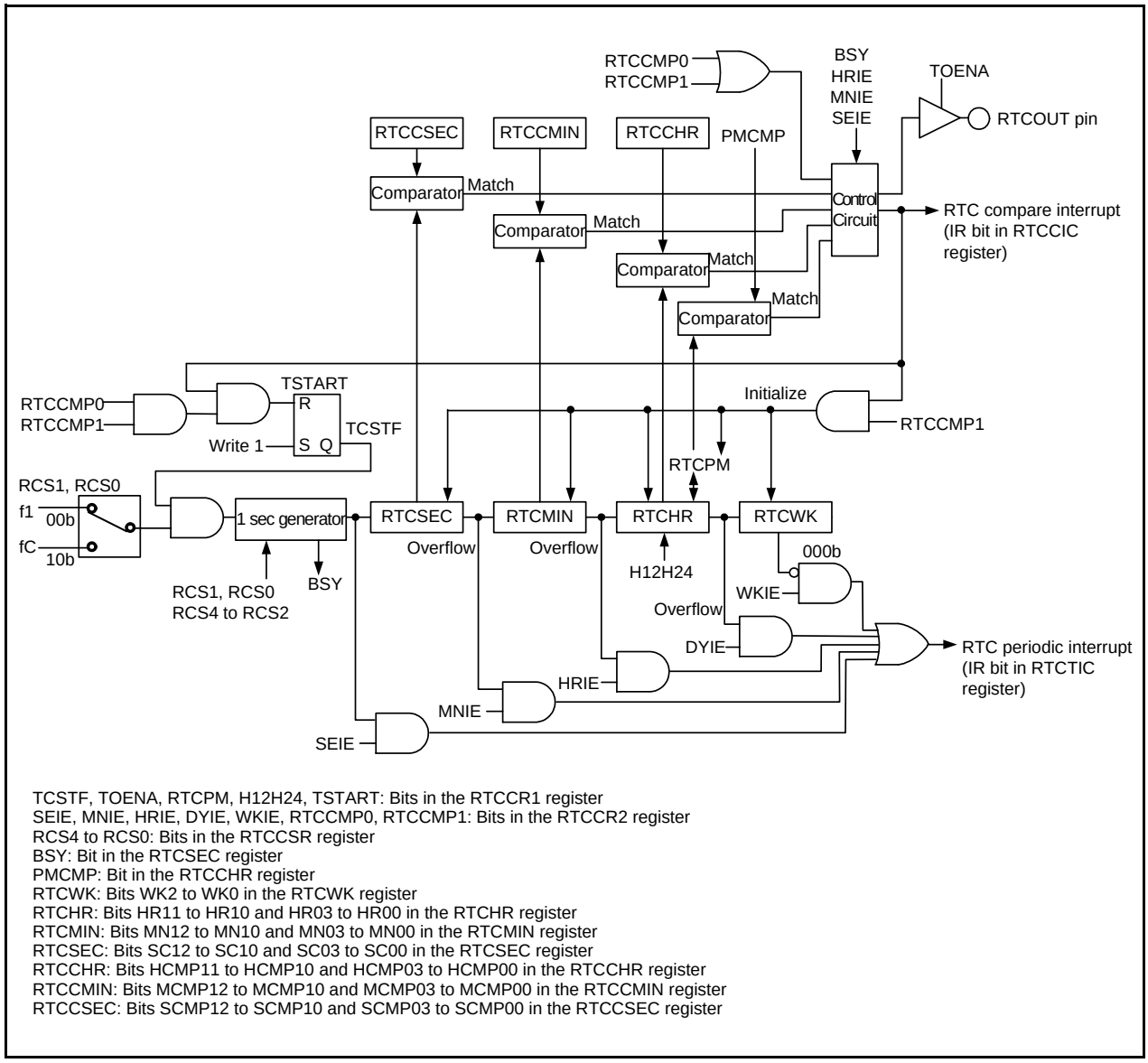
21.1 Introduction

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 21.1 lists Real-Time Clock Specifications, Figure 21.1 shows a Real-Time Clock Block Diagram, and Table 21.2 lists the I/O Port.

Table 21.1 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 21.2.4 “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 21.1 Real-Time Clock Block Diagram

Table 21.2 I/O Port

Pin Name	I/O	Function
RTCOUT	Output	Compare output

21.2 Registers

Table 21.3 Registers

Address	Register	Symbol	Reset Value
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

21.2.1 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).

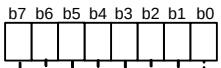
BSY (Real-time clock busy flag) (b7)

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

21.2.2 Real-Time Clock Minute Data Register (RTCMIN)

Real-Time Clock Minute Data Register



Symbol	Address	Reset Value
RTCMIN	0341h	X000 0000b

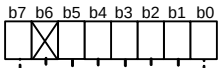
Bit Symbol	Bit Name	Function	Setting Range	RW
MN00	First digit of minute count bit	Count 0 to 9 every minute. When the digit increments, 1 is added to the 2nd digit of minute.	0 to 9	RW
MN01				RW
MN02				RW
MN03				RW
MN10	Second digit of minute count bit	When counting 0 to 5, 60 minutes are counted.	0 to 5	RW
MN11				RW
MN12				RW
$\overline{\text{(b7)}}$	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).

21.2.3 Real-Time Clock Hour Data Register (RTCHR)

Real-Time Clock Hour Data Register



Symbol	Address	Reset Value
RTCHR	0342h	XX00 0000b

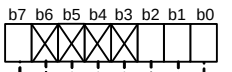
Bit Symbol	Bit Name	Function	Setting Range	RW
HR00	First digit of hour count bit	Count 0 to 9 every hour. When the digit increments, 1 is added to the 2nd digit of hour.	0 to 9	RW
HR01				RW
HR02				RW
HR03				RW
HR10	Second digit of hour count bit	Count 0 to 1 when the H12H24 bit is set to 0 (12-hour 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).

21.2.4 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).

21.2.5 Real-Time Clock Control Register 1 (RTCCR1)

Real-Time Clock Control Register 1

b7	b6	b5	b4	b3	b2	b1	b0
				0			0

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 21.2 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.

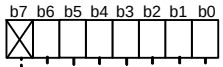
Figure 21.2 Time Representation

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).

21.2.6 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 21.4 lists Periodic Interrupt Sources.

Table 21.4 Periodic Interrupt Sources

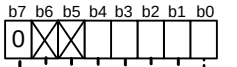
Factor	Interrupt Source	Interrupt Enable Bit
Periodic interrupt triggered every week	Value in RTCWK register is set to 000b (1-week period)	WKIE
Periodic interrupt triggered every day	RTCWK register is updated (1-day period)	DYIE
Periodic interrupt triggered every hour	RTCHR register is updated (1-hour 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.

21.2.7 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.

21.2.8 Real-Time Clock Second Compare Data Register (RTCCSEC)

Real-Time Clock Second Compare Data Register

b7 b6 b5 b4 b3 b2 b1 b0	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.			—

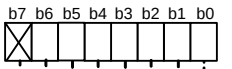
The RTCCSEC register is enabled when bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 01b, 10b, or 11b (any compare mode).

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).

21.2.9 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.			—

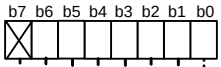
The RTCCMIN register is enabled when bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 01b, 10b, or 11b (any compare mode).

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).

21.2.10 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).

21.3 Operations

21.3.1 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 21.3 shows Real-Time Clock Basic Operating Example, Figure 21.4 shows Time and Day Change Procedure (No Compare Mode or Compare Mode 1), and Figure 21.5 shows Time and Day Change Procedure (Compare Mode 2 or Compare Mode 3).

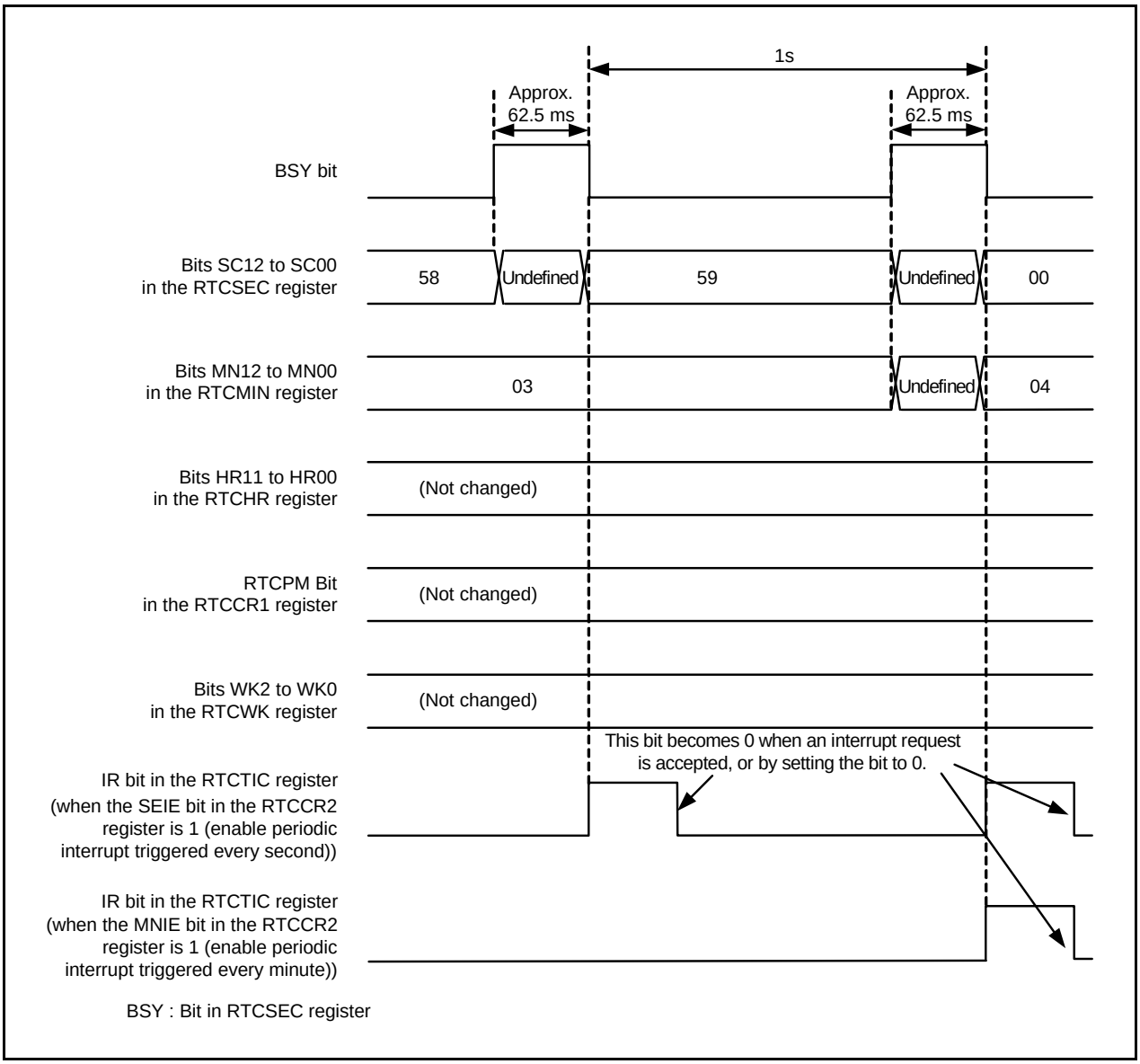


Figure 21.3 Real-Time Clock Basic Operating Example

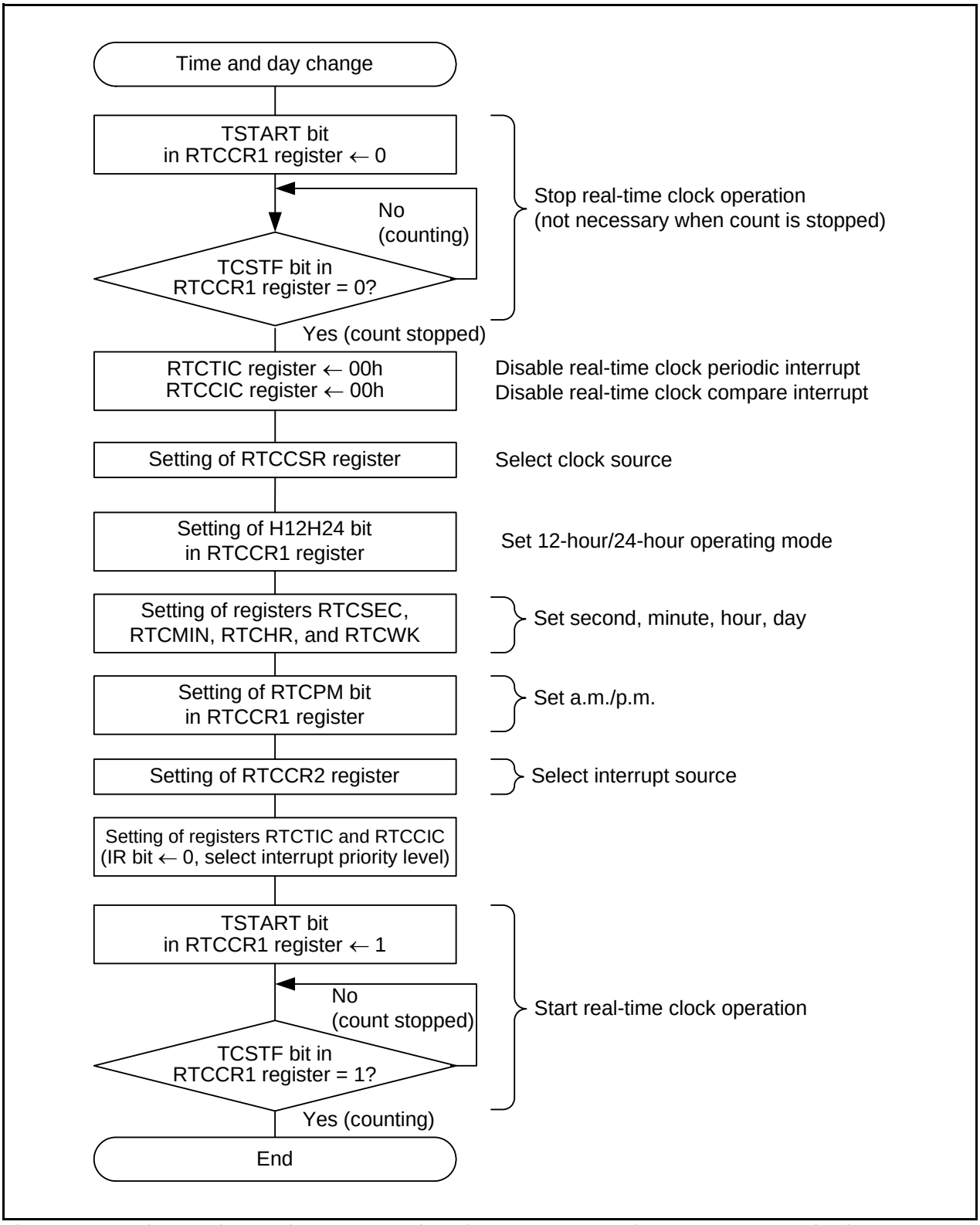
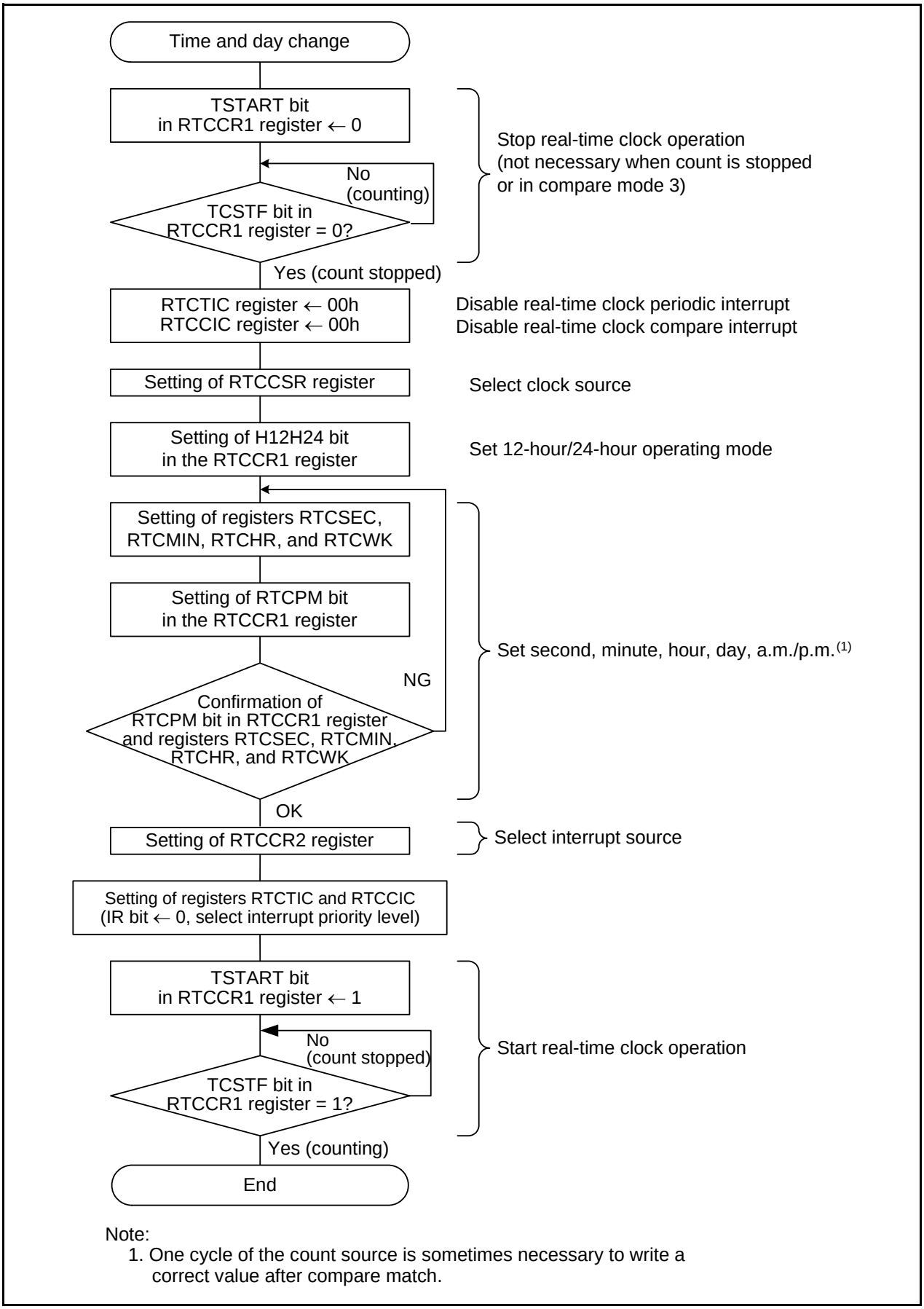


Figure 21.4 Time and Day Change Procedure (No Compare Mode or Compare Mode 1)



Note:
1. One cycle of the count source is sometimes necessary to write a correct value after compare match.

Figure 21.5 Time and Day Change Procedure (Compare Mode 2 or Compare Mode 3)

21.3.2 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 21.4 “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:

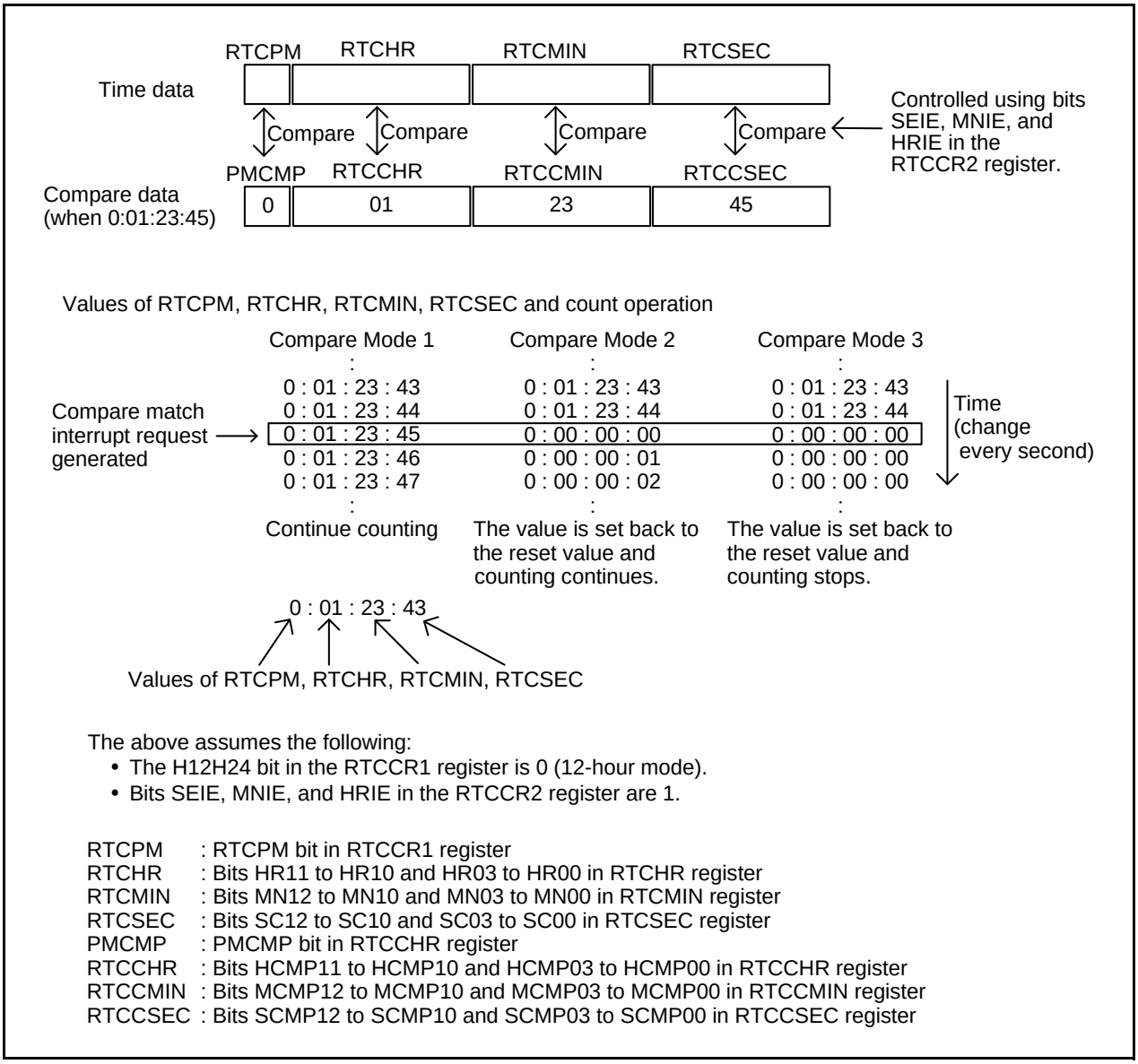
1. Bits for time data are as follows:
   Bits SC12 to SC10 and SC03 to SC00 in the RTCSEC register
   Bits MN12 to MN10 and MN03 to MN00 in the RTCMIN register
   Bits HR11 to HR10 and HR03 to HR00 in the RTCHR register
   The RTCPM bit in the RTCCR1 register

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 21.2.6 “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 21.6 shows Difference between Compare Modes, Figure 21.7 shows Count Start/Stop Operating Example, Figure 21.8 shows Compare Mode 1 Operating Example, Figure 21.9 shows Compare Mode 2 Operating Example, and Figure 21.10 shows Compare Mode 3 Operating Example.

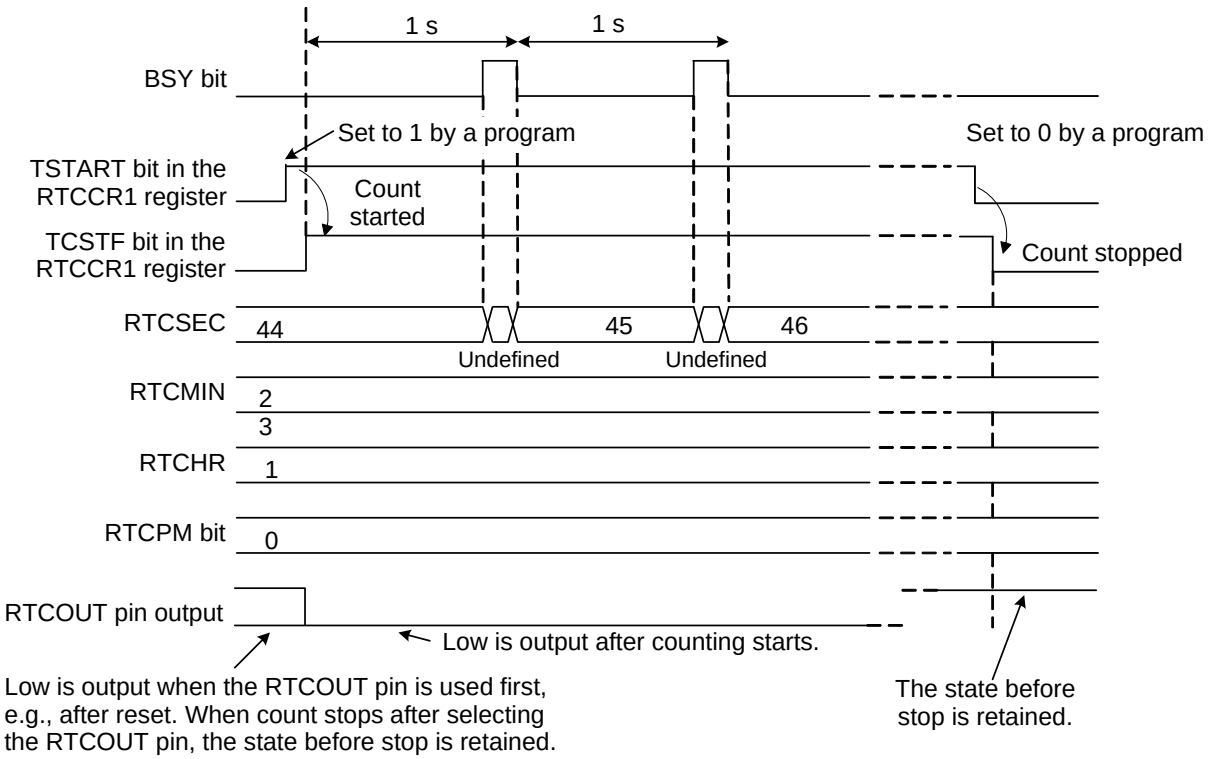


The above assumes the following:

- 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

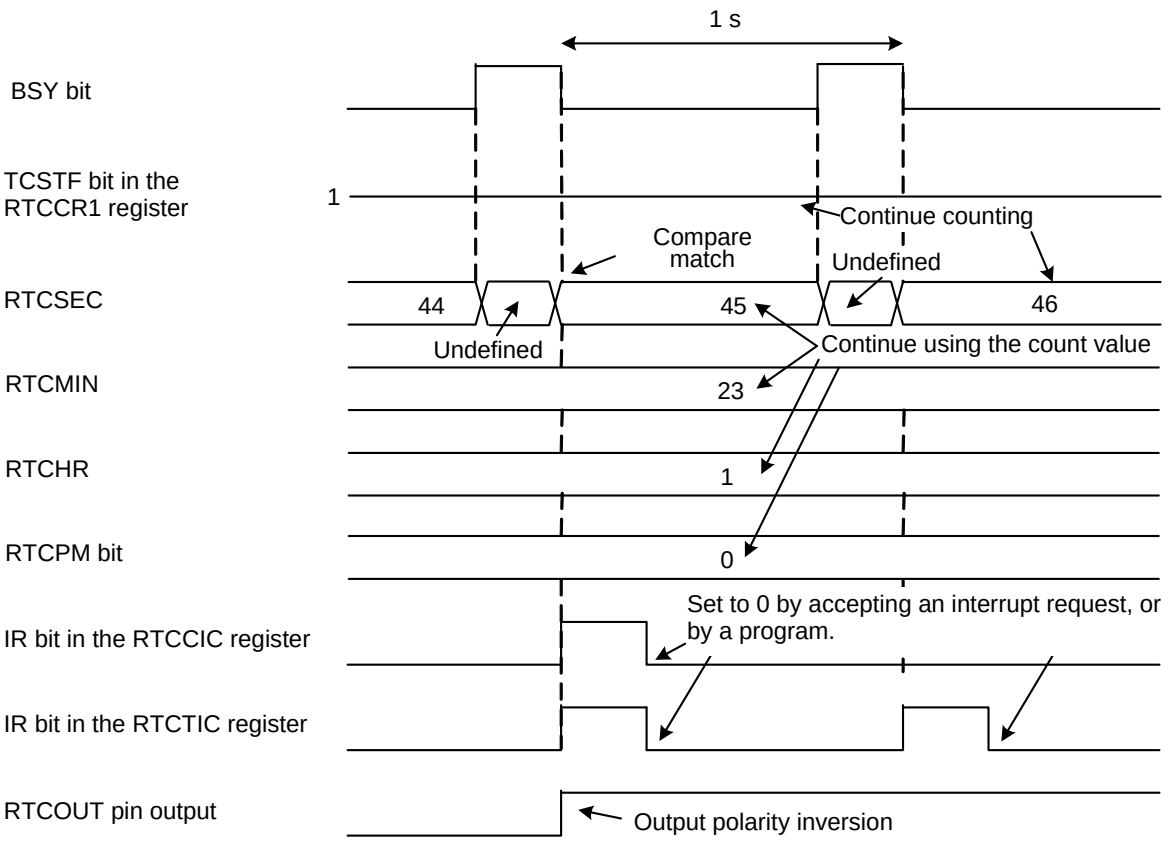
Figure 21.6 Difference between Compare Modes



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

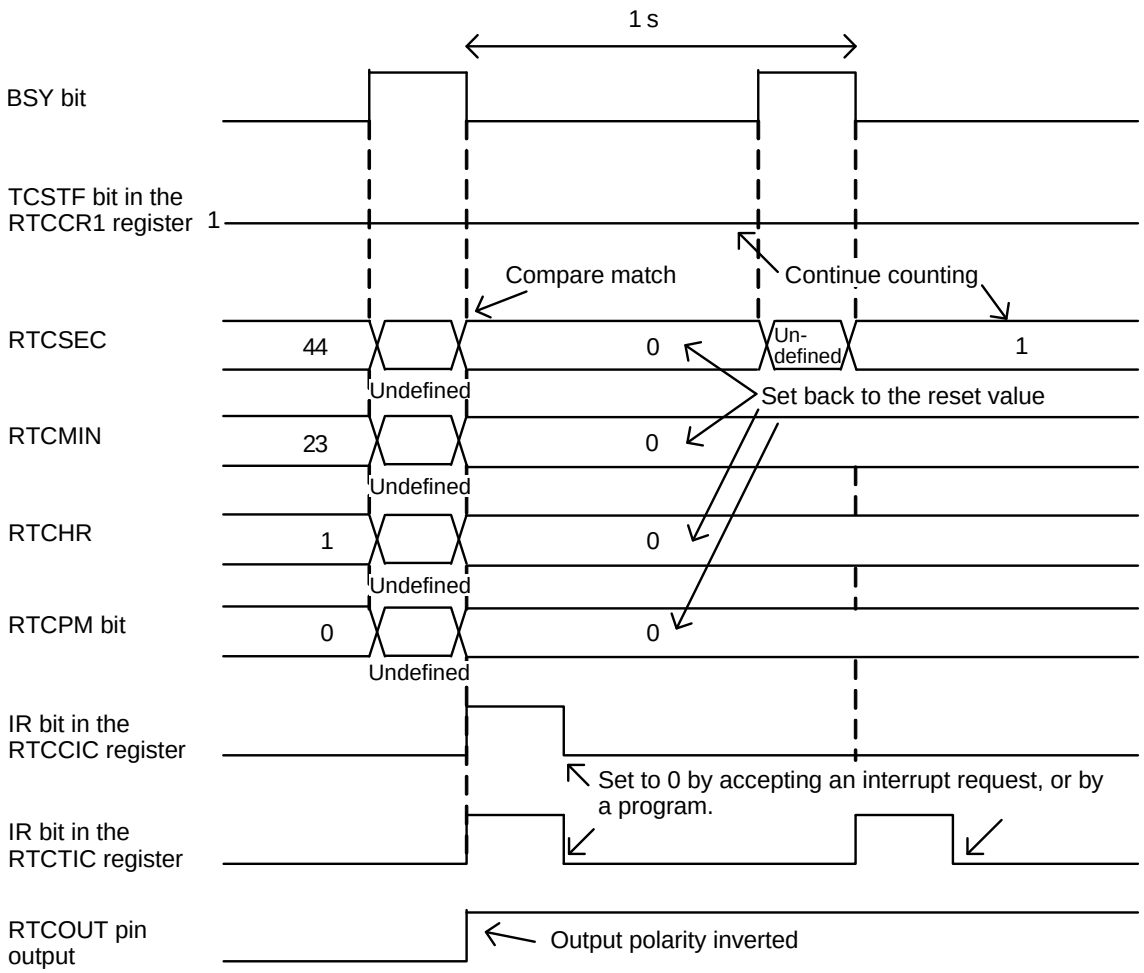
Figure 21.7 Count Start/Stop Operating Example



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 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 21.8 Compare Mode 1 Operating Example

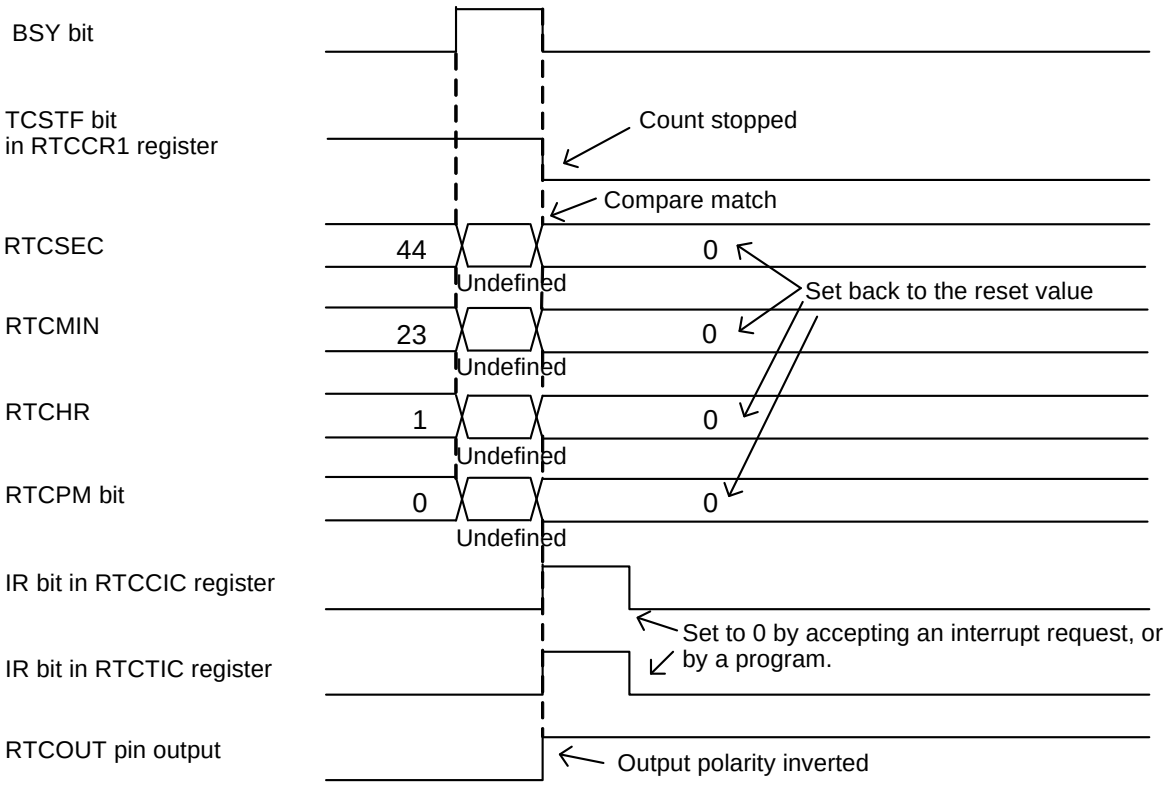


The above assumes the following:

- The TOENA bit in the RTCCR1 register is 1 (compare output enabled).
- Bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 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 21.9 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 21.10 Compare Mode 3 Operating Example

21.4 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 21.4 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 21.5 lists Real-Time Clock Interrupt-Associated Registers.

Table 21.5 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).

21.5 Notes on Real-Time Clock

21.5.1 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.

21.5.2 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 21.4 shows Time and Day Change Procedure (No Compare Mode or Compare Mode 1), and Figure 21.5 shows Time and Day Change Procedure (Compare Mode 2 or Compare Mode 3).

21.5.3 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

21.5.4 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 21.11 “Time Data Reading”.

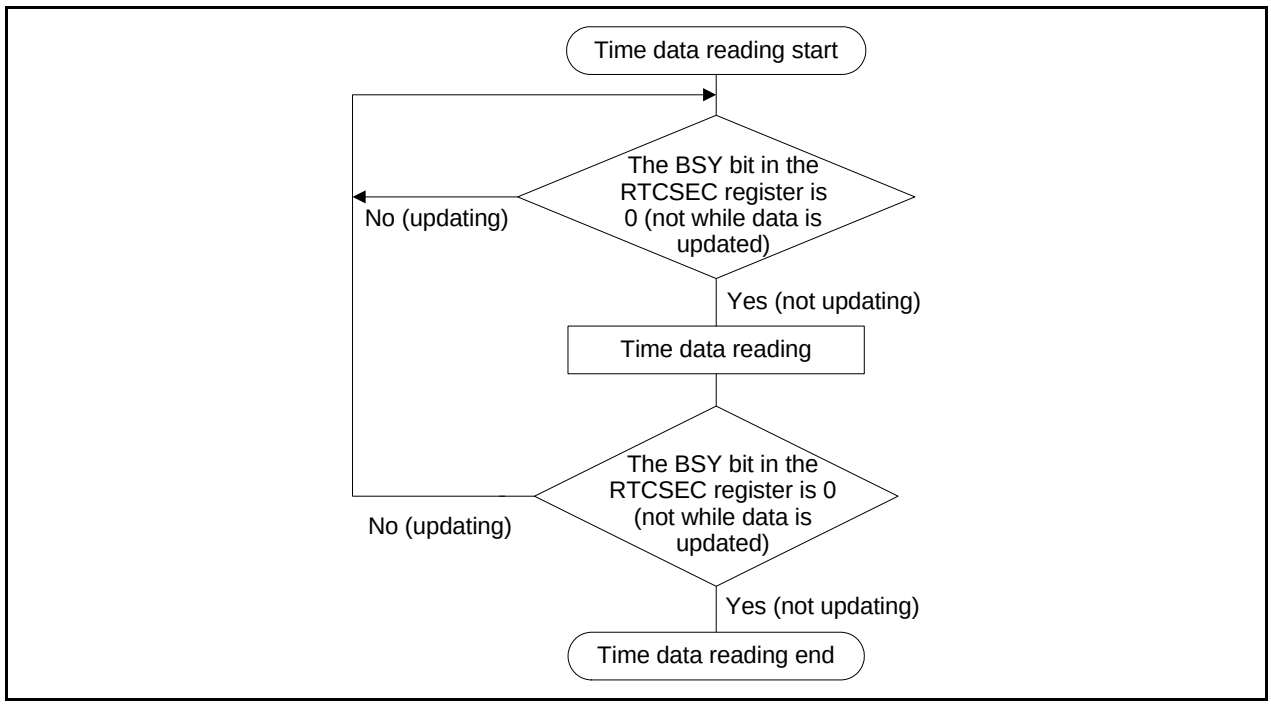


Figure 21.11 Time Data Reading

- 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

22. Serial Interface UARTi (i = 0 to 5)

22.1 Introduction

Each UART has a dedicated timer to generate a transmit/receive clock, and operates independently of the others.

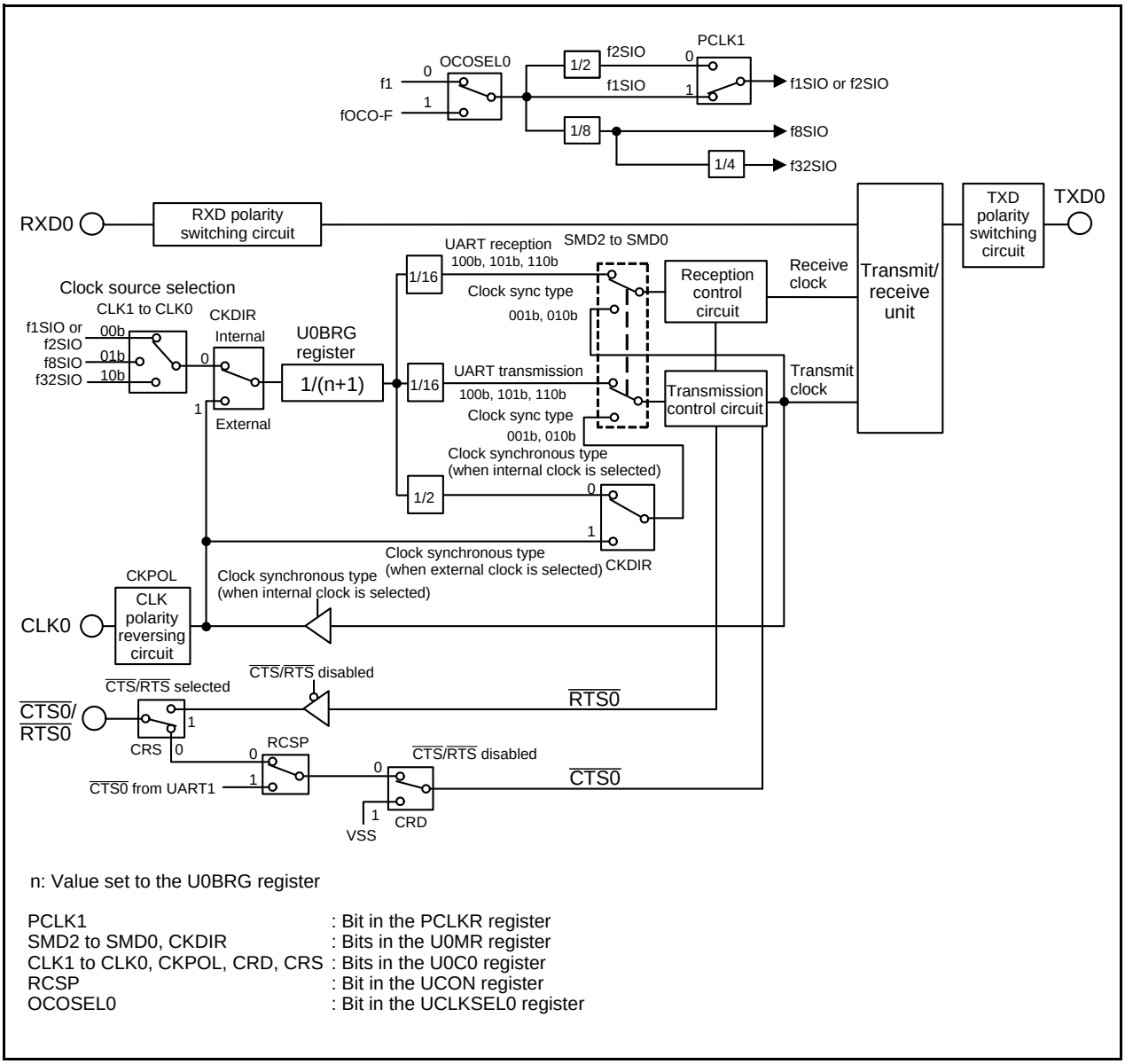
Table 22.1 lists UARTi Specifications (i = 0 to 5). Table 22.2 lists Specification Differences between UART0 to UART5. Figure 22.1 to Figure 22.3 show the block diagrams of UARTi. Figure 22.4 shows UARTi Transmit/Receive Unit Block Diagram.

Table 22.1 UARTi Specifications (i = 0 to 5)

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 22.2 Specification Differences between UART0 to UART5

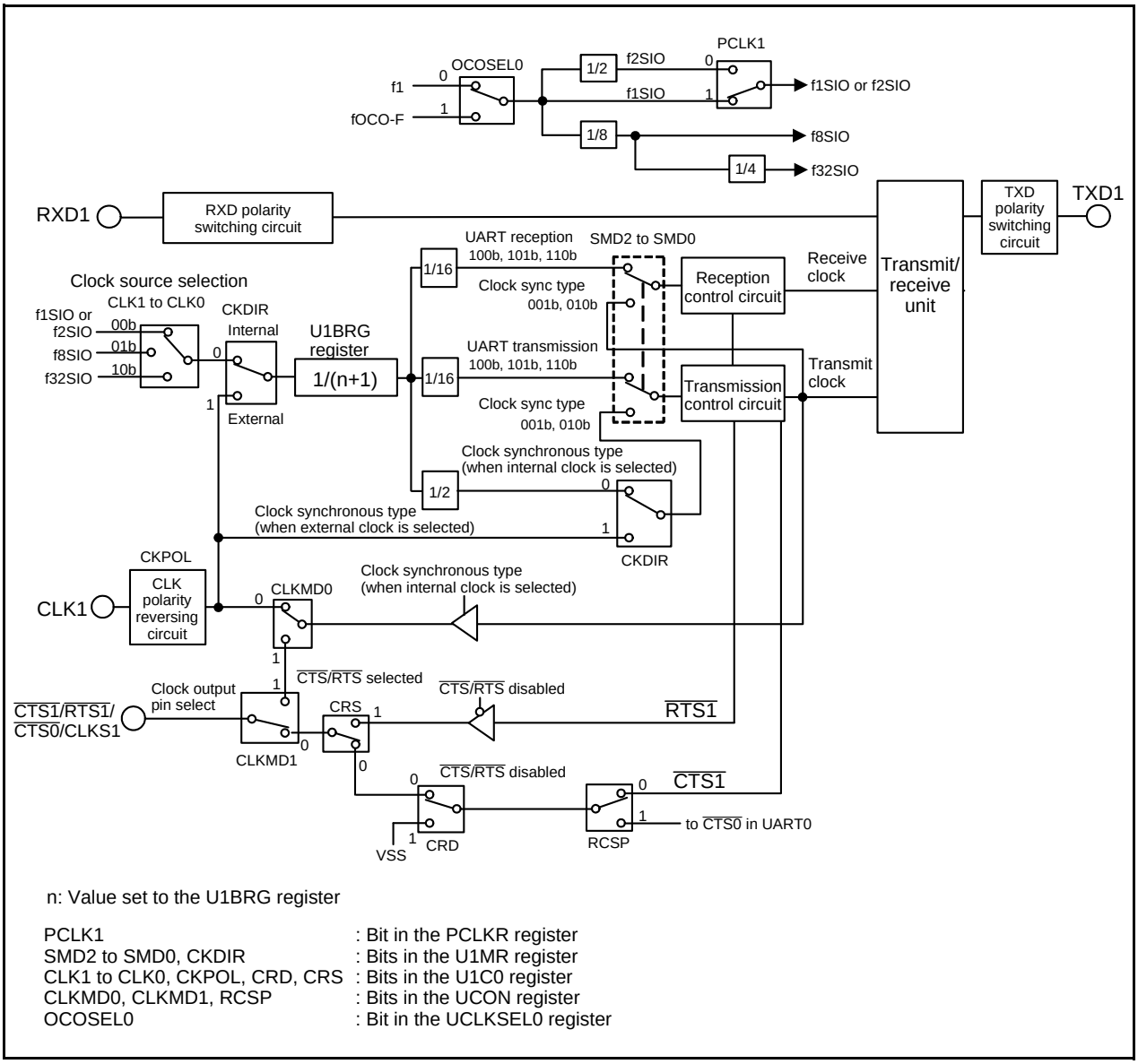
Mode	UART0	UART1	UART2	UART3	UART4	UART5
Clock synchronous serial I/O mode	Available		Available	Available		Available
Clock asynchronous serial I/O mode (UART mode)	Available		Available	Available		Available
Special mode 1 (I^2C mode)	Available		Available	Available		Available
Special mode 2	Available		Available	Available		Available
Special mode 3 (IE mode)	Available		Available	Available		Available
Special mode 4 (SIM mode)	Not available		Available	Not available		Not available



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

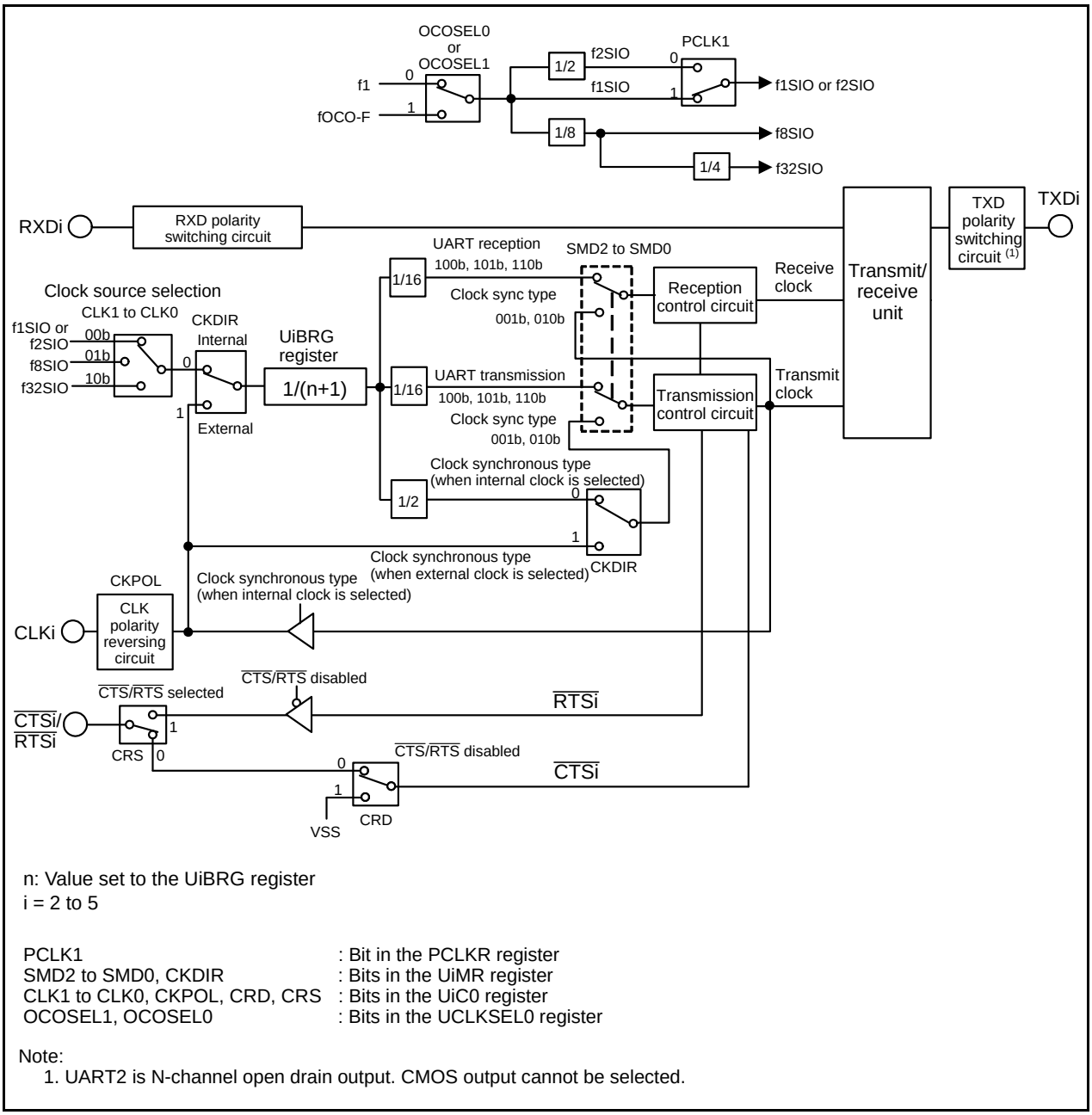
Figure 22.1 UART0 Block Diagram



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 22.2 UART1 Block Diagram

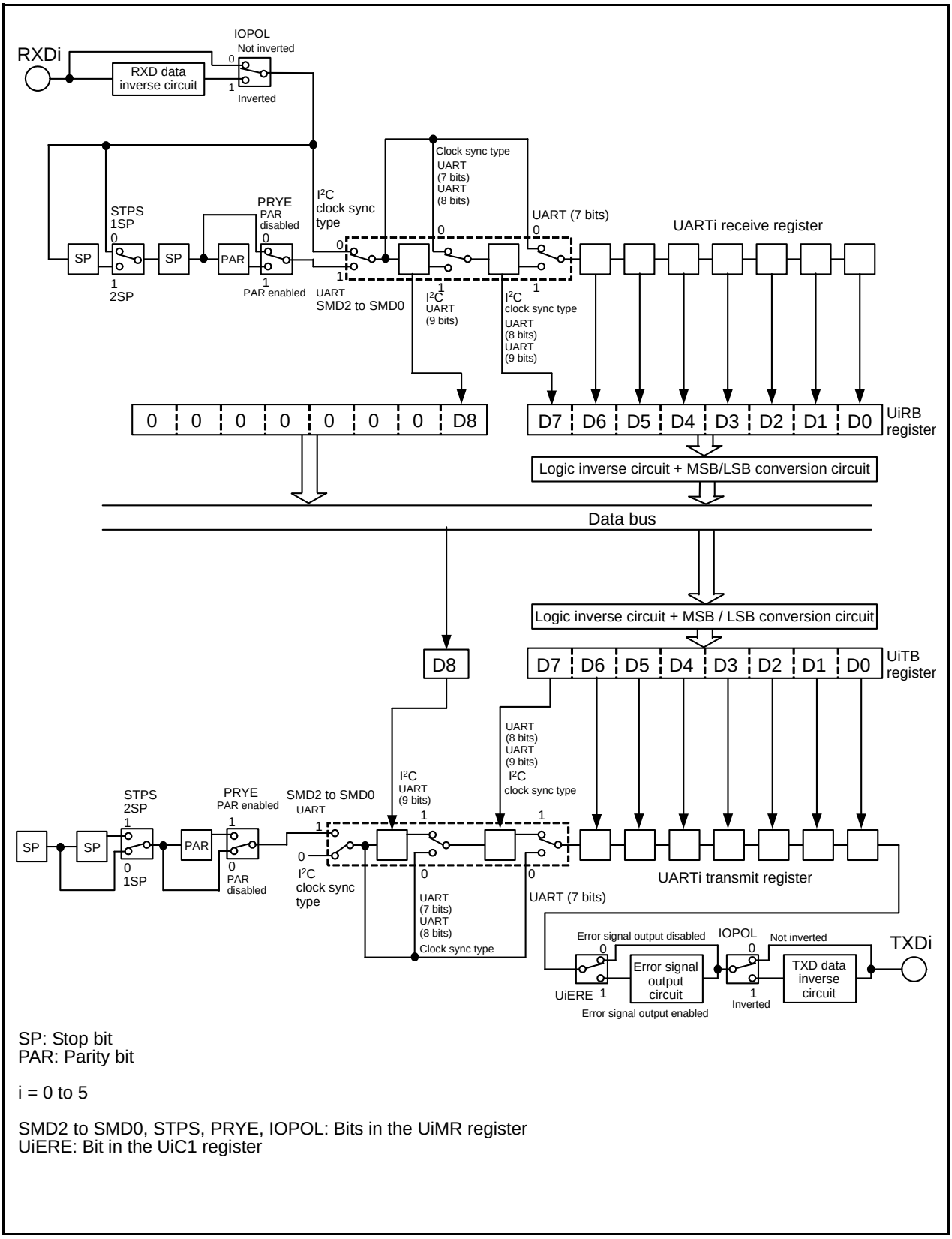


n: Value set to the UiBRG register
i = 2 to 5

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 22.3 Block Diagram of UART2 to UART5



SP: Stop bit
PAR: Parity bit

i = 0 to 5

SMD2 to SMD0, STPS, PRYE, IOPOL: Bits in the UiMR register
UiERE: Bit in the UiC1 register

Figure 22.4 UARTi Transmit/Receive Unit Block Diagram

22.2 Registers

Table 22.3 and Table 22.4 list registers associated with UART0 to UART5.
Set the OCOSEL0 or OCOSEL1 bit in the UCLKSEL0 register before setting other registers associated with UART0 to UART5. After changing the OCOSEL0 or OCOSEL1 bit, set other registers associated with UART0 to UART5 again.
Refer to “Registers Used and Settings” in each mode for the settings of registers and bits.

Table 22.3 Registers (1/2)

Address	Register	Symbol	Reset Value
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
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 22.4 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	UART4 Special Mode Register 4	U4SMR4	00h
0295h	UART4 Special Mode Register 3	U4SMR3	000X 0X0Xb
0296h	UART4 Special Mode Register 2	U4SMR2	X000 0000b
0297h	UART4 Special Mode Register	U4SMR	X000 0000b
0298h	UART4 Transmit/Receive Mode Register	U4MR	00h
0299h	UART4 Bit Rate Register	U4BRG	XXh
029Ah	UART4 Transmit Buffer Register	U4TB	XXh
029Bh			XXh
029Ch	UART4 Transmit/Receive Control Register 0	U4C0	0000 1000b
029Dh	UART4 Transmit/Receive Control Register 1	U4C1	0000 0010b
029Eh	UART4 Receive Buffer Register	U4RB	XXh
029Fh			XXh
02A4h	UART3 Special Mode Register 4	U3SMR4	00h
02A5h	UART3 Special Mode Register 3	U3SMR3	000X 0X0Xb
02A6h	UART3 Special Mode Register 2	U3SMR2	X000 0000b
02A7h	UART3 Special Mode Register	U3SMR	X000 0000b
02A8h	UART3 Transmit/Receive Mode Register	U3MR	00h
02A9h	UART3 Bit Rate Register	U3BRG	XXh
02AAh	UART3 Transmit Buffer Register	U3TB	XXh
02ABh			XXh
02ACh	UART3 Transmit/Receive Control Register 0	U3C0	0000 1000b
02ADh	UART3 Transmit/Receive Control Register 1	U3C1	0000 0010b
02AEh	UART3 Receive Buffer Register	U3RB	XXh
02AFh			XXh

22.2.1 UART Clock Select Register (UCLKSEL0)

UART Clock Select Register

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

Symbol: UCLKSEL0 — Address: 0252h — After Reset: 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	UART3 to UART5 clock prior to division select bit	0 : f1 1 : fOCO-F	RW
— (b7-b4)	No register bits. If necessary, set to 0. Read as undefined value		—

OCOSEL0 (UART0 to UART2 clock prior to division select bit) (b2)
OCOSEL1 (UART3 to UART5 clock prior to division select bit) (b3)

Set bits OCOSEL0 and OCOSEL1 while transmission/reception of UART0 to UART5 stops.
Set the OCOSEL0 or OCOSEL1 bit before setting other registers associated with UART0 to UART5. After changing the OCOSEL0 or OCOSEL1 bit, set other registers associated with UART0 to UART5 again.

22.2.2 Peripheral Clock Select Register (PCLKR)

Peripheral Clock Select Register

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

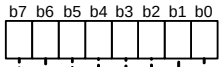
Symbol: PCLKR — Address: 0012h — Reset Value: 0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A, B and S clock select bit (clock source for timers A, B and S, the dead time timer, and multi-master I^2C-bus interface)	0: f2TIMAB/f2IIC/f2TIMS 1: f1TIMAB/f1IIC/f1TIMS	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART5)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function extension bit (valid in single-chip mode)	0: Selected by 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.

22.2.3 UARTi Transmit/Receive Mode Register (UiMR) (i = 0 to 5)

UARTi Transmit/Receive Mode Register (i = 0 to 5)



Symbol	Address	Reset Value
U0MR, U1MR, U2MR	0248h, 0258h, 0268h	00h
U5MR, U4MR, U3MR	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^2C 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

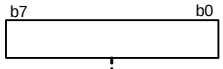
SMD2 to SMD0 (Serial I/O mode select bit) (b2 to b0)

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^2C mode, set the IICM bit in the UiSMR register to 1 (I^2C mode), then set bits SMD2 to SMD0 to 010b (I^2C mode).

22.2.4 UARTi Bit Rate Register (UiBRG) (i = 0 to 5)

UARTi Bit Rate Register (i = 0 to 5)



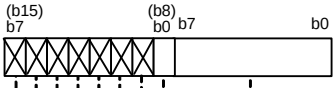
Symbol	Address	Reset Value
U0BRG, U1BRG, U2BRG	0249h, 0259h, 0269h	XXh
U5BRG, U4BRG, U3BRG	0289h, 0299h, 02A9h	XXh

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.

22.2.5 UARTi Transmit Buffer Register (UiTB) (i = 0 to 5)

UARTi Transmit Buffer Register (i = 0 to 5)



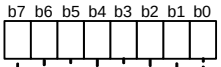
Symbol	Address	Reset Value
U0TB	024Bh to 024Ah	XXXXh
U1TB	025Bh to 025Ah	XXXXh
U2TB	026Bh to 026Ah	XXXXh
U5TB	028Bh to 028Ah	XXXXh
U4TB	029Bh to 029Ah	XXXXh
U3TB	02ABh to 02AAh	XXXXh

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.

22.2.6 UARTi Transmit/Receive Control Register 0 (UiC0) (i = 0 to 5)

UARTi Transmit/Receive Control Register 0 (i = 0 to 5)



Symbol	Address	Reset Value
U0C0, U1C0, U2C0	024Ch, 025Ch, 026Ch	0000 1000b
U5C0, U4C0, U3C0	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	$\overline{CTS}/\overline{RTS}$ function select bit	Enabled when CRD is 0 0 : $\overline{CTS}$ function selected 1 : $\overline{RTS}$ 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	$\overline{CTS}/\overline{RTS}$ disable bit	0 : $\overline{CTS}/\overline{RTS}$ function enabled 1 : $\overline{CTS}/\overline{RTS}$ 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 ($\overline{CTS}/\overline{RTS}$ function select bit) (b2)

$\overline{CTS1}/\overline{RTS1}$ 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 ($\overline{CTS0}/\overline{RTS0}$ not separated).

CRD ($\overline{CTS}/\overline{RTS}$ disable bit) (b4)

When the CRD bit is 1 ($\overline{CTS}/\overline{RTS}$ function disabled), the $\overline{CTSi}/\overline{RTSi}$ pin can be used as an I/O port.

NCH (Data output select bit) (b5)

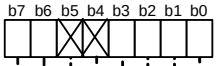
TXD2/SDA2 and SCL2 are N-channel open drain outputs. They cannot be set as CMOS outputs. Nothing is assigned to the NCH bit in the U2C0 register. If necessary, set this bit to 0.
This function is used to set the P-channel transistor of the CMOS output buffer always off, but not to change pins TXDi/SDAi 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).

22.2.7 UARTi Transmit/Receive Control Register 1 (UiC1) (i = 0 to 5)

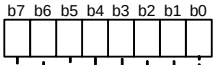
UARTi Transmit/Receive Control Register 1 (i = 0, 1)



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 to 5)



Symbol	Address	Reset Value
U2C1	026Dh	0000 0010b
U5C1, U4C1, U3C1	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

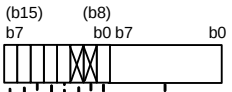
Bits UiIRS and UiRRM of UART0 and UART1 are bits in the UCON register.

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^2C mode) or 110b (UART mode, 9-bit character).

22.2.8 UARTi Receive Buffer Register (UiRB) (i = 0 to 5)

UARTi Receive Buffer Register (i = 0 to 5)



Symbol	Address	Reset Value
U0RB	024Fh to 024Eh	XXXXh
U1RB	025Fh to 025Eh	XXXXh
U2RB	026Fh to 026Eh	XXXXh
U5RB	028Fh to 028Eh	XXXXh
U4RB	029Fh to 029Eh	XXXXh
U3RB	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:

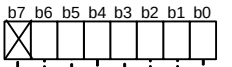
- Bits SMD2 to SMD0 in the UiMR register are 000b (serial interface disabled).
- The RE bit in the UiC1 register is 0 (reception disabled).
- Bits PER, FER and OER are all 0 (no error).

Condition to become 1:

- At least two bits out of PER, FER, or OER are 1 (error found).

22.2.9 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 $\overline{CTS}/\overline{RTS}$ bit	0 : $\overline{CTS}/\overline{RTS}$ shared pin 1 : $\overline{CTS}/\overline{RTS}$ separated	RW
— (b7)	No register bit. If necessary, set to 0. Read as undefined value		—

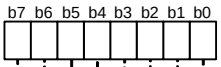
Bits UiIRS and UiRRM of UART2 to UART5 are bits in the UiC1 register.

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).

22.2.10 UARTi Special Mode Register 4 (UiSMR4) (i = 0 to 5)

UARTi Special Mode Register 4 (i = 0 to 2, 5 to 7)



Symbol	Address	Reset Value
U0SMR4, U1SMR4, U2SMR4	0244h, 0254h, 0264h	00h
U5SMR4, U4SMR4, U3SMR4	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)

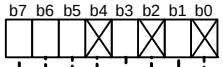
This bit is used in slave mode of I^2C mode. To set this bit to 1, preset the IICM bit in the UiSMR register to 1 (I^2C mode). Do not set this bit to 1 when the IICM bit is 0.

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.

22.2.11 UARTi Special Mode Register 3 (UiSMR3) (i = 0 to 5)

UARTi Special Mode Register 3 (i = 0 to 5)



Symbol	Address	Reset Value
U0SMR3, U1SMR3, U2SMR3 U5SMR3, U4SMR3, U3SMR3	0245h, 0255h, 0265h 0285h, 0295h, 02A5h	000X 0X0Xb 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)

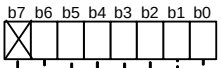
This function is used to set P-channel transistor of the CMOS output buffer always off, but not to change the CLKi pin to open drain output completely.
Refer to the electrical characteristics for the input voltage range.

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^2C mode. Except in I^2C 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.

22.2.12 UARTi Special Mode Register 2 (UiSMR2) (i = 0 to 5)

UARTi Special Mode Register 2 (i = 0 to 5)

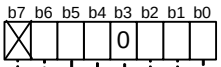


Symbol	Address	Reset Value
U0SMR2, U1SMR2, U2SMR2 U5SMR2, U4SMR2, U3SMR2	0246h, 0256h, 0266h 0286h, 0296h, 02A6h	X000 0000b X000 0000b

Bit Symbol	Bit Name	Function	RW
IICM2	I^2C 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.		—

22.2.13 UARTi Special Mode Register (UiSMR) (i = 0 to 5)

UARTi Special Mode Register (i = 0 to 5)



Symbol	Address	Reset Value
U0SMR, U1SMR, U2SMR	0247h, 0257h, 0267h	X000 0000b
U5SMR, U4SMR, U3SMR	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, UART4: Underflow signal of timer A3
UART1, UART3: 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).

22.3 Operations

22.3.1 Clock Synchronous Serial I/O Mode

The clock synchronous serial I/O mode uses a transmit/receive clock to transmit/receive data. Table 22.5 lists the Clock Synchronous Serial I/O Mode Specifications.

Table 22.5 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 $\overline{CTS}$, $\overline{RTS}$, or $\overline{CTS}$/$\overline{RTS}$ 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 $\overline{CTS}$ function is selected, input on the $\overline{CTS}$i 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 $\overline{CTS}$/$\overline{RTS}$ pins (UART0) $\overline{CTS0}$ and $\overline{RTS0}$ are input/output from separate pins.

i = 0 to 5

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 22.6 lists Pin Functions in Clock Synchronous Serial I/O Mode (Multiple Transmit/Receive Clock Output Pin Function Not Selected). Table 22.7 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 22.6 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.
$\overline{\text{CTS}}$i/$\overline{\text{RTS}}$i	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 5

Table 22.7 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 22.8 Registers Used and Settings in Clock Synchronous Serial I/O Mode (1)

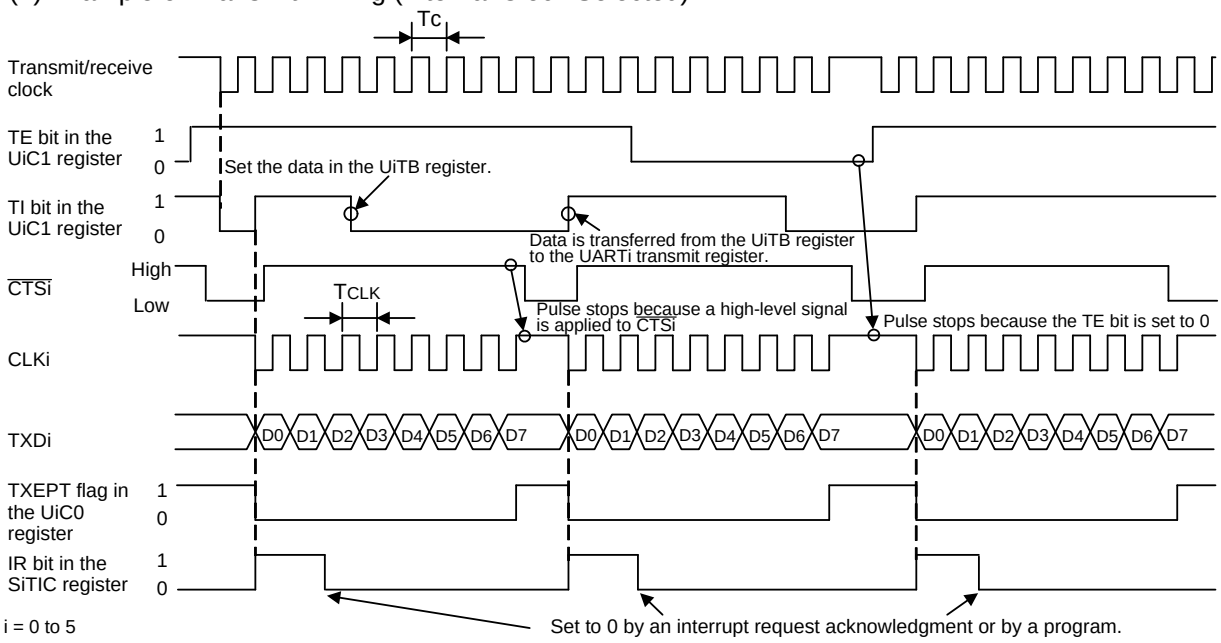
Register	Bits	Function
UCLKSEL0	OCOSEL0	Select clock prior to division for UART0 to UART2.
	OCOSEL1	Select clock prior to division for UART3 to UART5.
PCLKR	PCLK1	Select the count source for the UiBRG register.
UiTB	0 to 7	Set transmission data.
	8	- (does not need to be set) If necessary, set to 0.
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 $\overline{CTS}$ or $\overline{RTS}$ is used, select which function to use.
	TXEPT	Transmit register empty flag
	CRD	Enable or disable the $\overline{CTS}$ or $\overline{RTS}$ 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 $\overline{CTS0}$/$\overline{RTS}$ signal of UART0.
	7	Set to 0.

i = 0 to 5; j = 2 to 5

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)

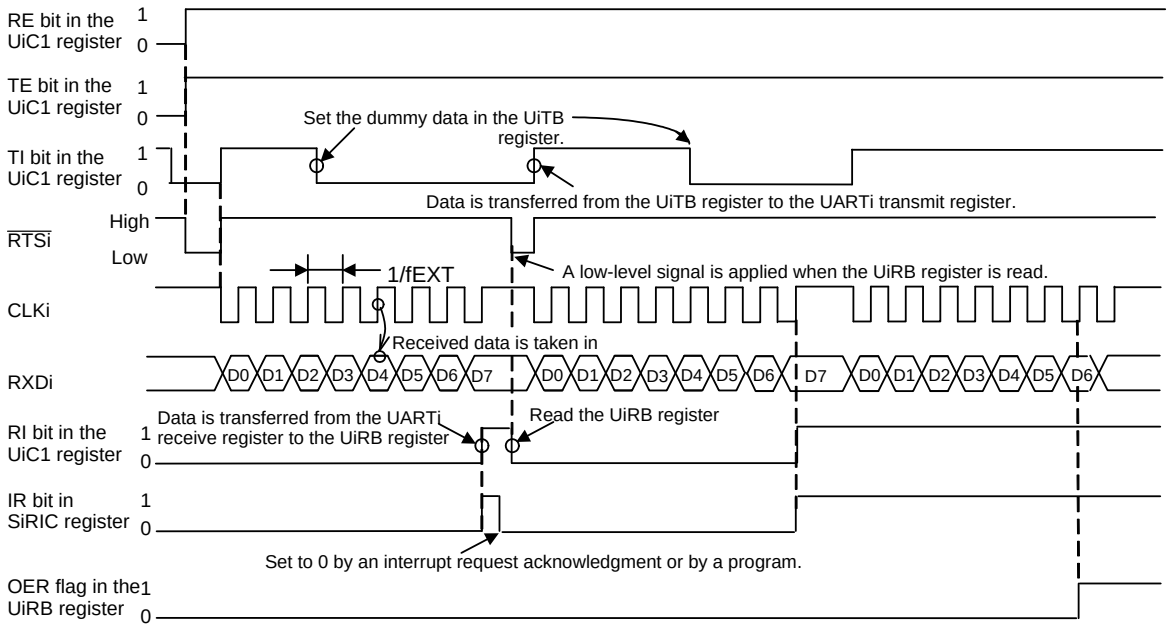


The above assumes the following:
- The CKDIR bit in the UiMR register is 0 (internal clock).
- The CRD bit in the UiC0 register is 0 ($\overline{CTS}/\overline{RTS}$ enabled), the CRS bit is 0 ($\overline{CTS}$ selected).
- The CKPOL bit in the UiC0 register is 0 (transmit data output at the falling 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).

$T_C = T_{CLK} = 2(n + 1)/fj$

fj: Frequency of UiBRG count source (f1SIO, f2SIO, f8SIO, f32SIO)
n: Value set to the UiBRG register

(2) Example of Receive Timing (External Clock Selected)



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 ($\overline{CTS}/\overline{RTS}$ enabled), the CRS bit is 1 ($\overline{RTS}$ 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 22.5 Transmit and Receive Operation during Clock Synchronous Serial I/O Mode

22.3.1.1 CLK Polarity Select Function

Use the CKPOL bit in the UiC0 register (i = 0 to 5) to select the transmit/receive clock polarity. Figure 22.6 shows the Transmit/Receive Clock Polarity.

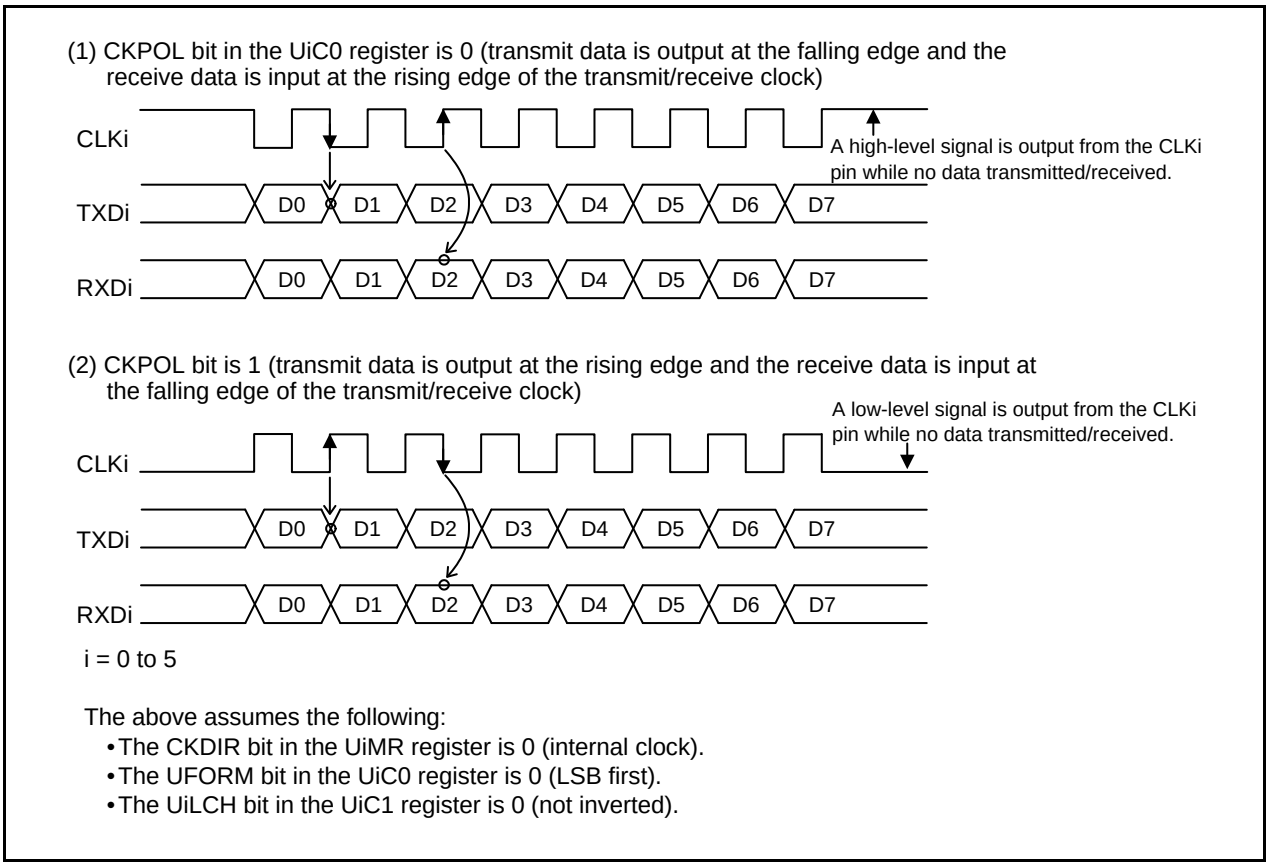
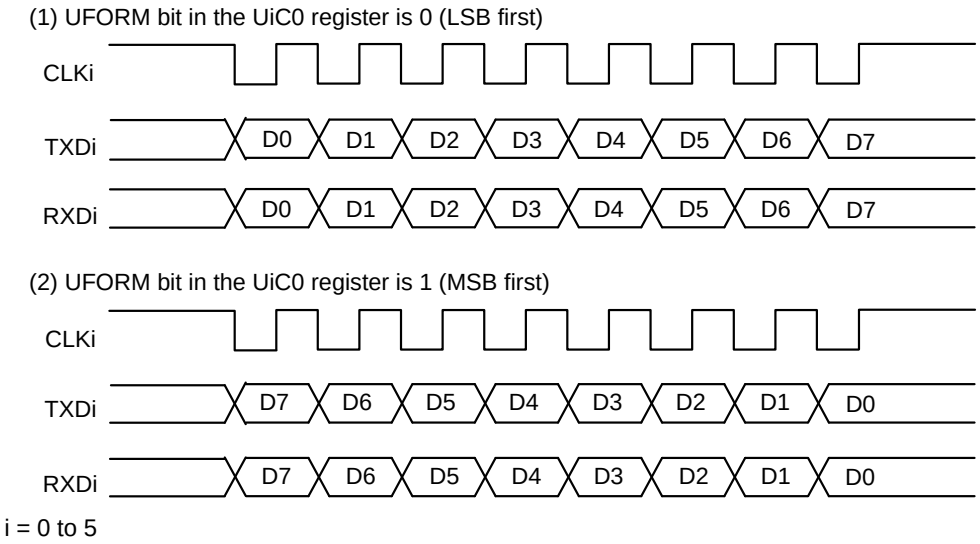


Figure 22.6 Transmit/Receive Clock Polarity

22.3.1.2 LSB First/MSB First Select Function

Use the UFORM bit in the UiC0 register (i = 0 to 5) to select the bit order. Figure 22.7 shows the Bit Order.



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 22.7 Bit Order

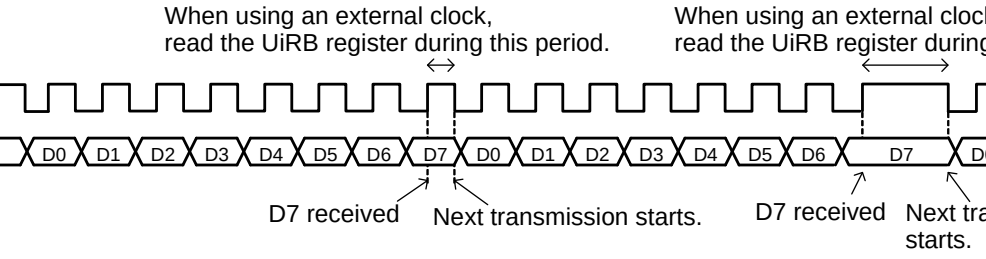
22.3.1.3 Continuous Receive Mode

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 5) 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 22.8 shows Operation Example in Continuous Receive Mode.



i = 0 to 5

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 22.8 Operation Example in Continuous Receive Mode

22.3.1.4 Serial Data Logic Switching Function

When the UiLCH bit in the UiC1 register (i = 0 to 5) 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 22.9 shows Serial Data Logic.

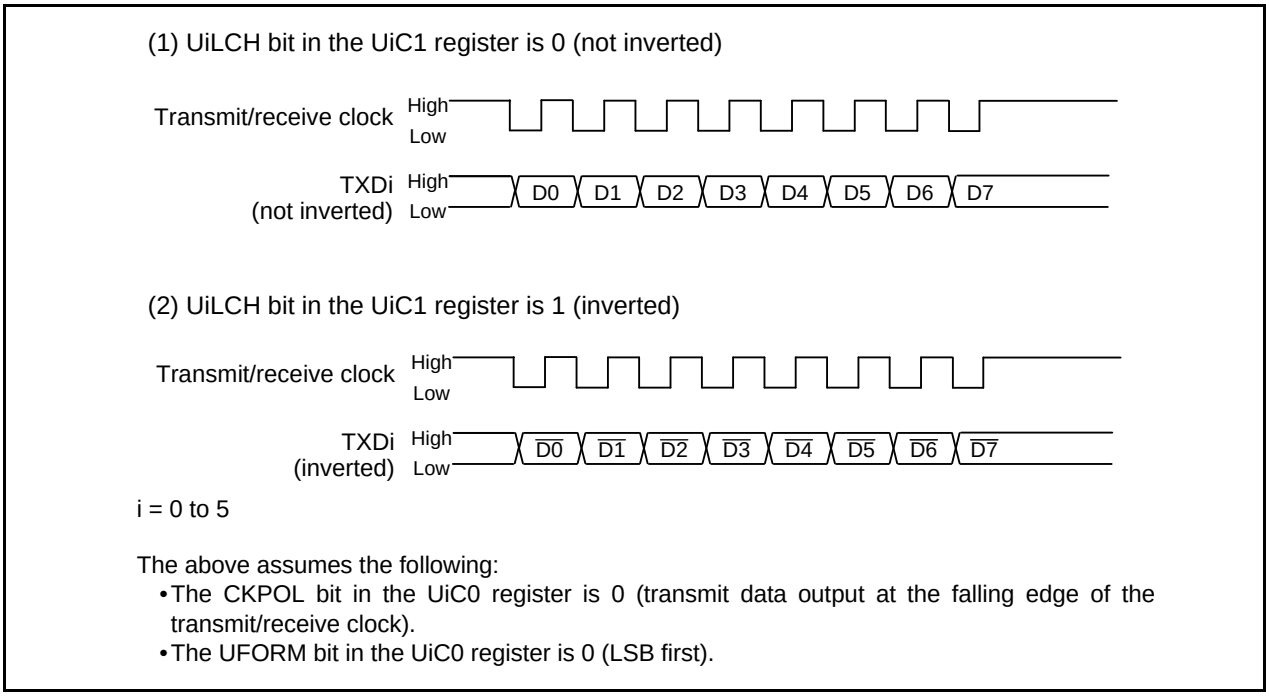


Figure 22.9 Serial Data Logic

22.3.1.5 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 22.10). This function can be used when the selected transmit/receive clock for UART1 is an internal clock.

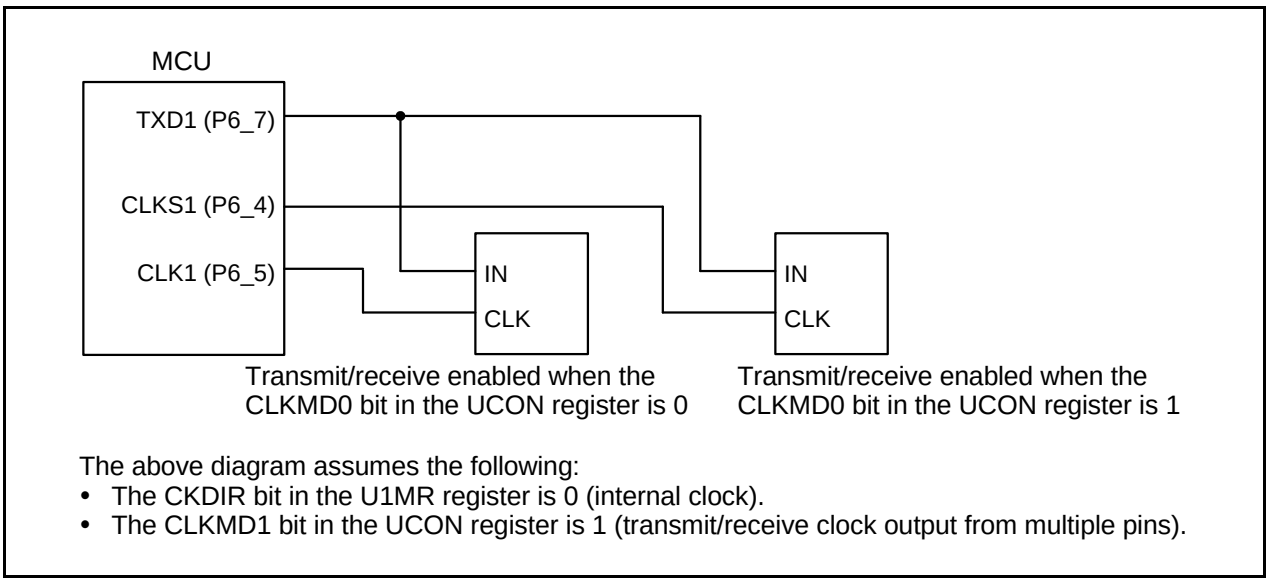


Figure 22.10 Transmit/Receive Clock Output from Multiple Pins

22.3.1.6 $\overline{CTS}/\overline{RTS}$ Function

The $\overline{CTS}$ function is used to start transmit/receive operation when a low signal is applied to the $\overline{CTSi}/\overline{RTSi}$ (i = 0 to 5) pin. Transmit/receive operation begins when input to the $\overline{CTSi}/\overline{RTSi}$ 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 $\overline{RTS}$ function, the $\overline{CTSi}/\overline{RTSi}$ 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 22.6 “Pin Functions in Clock Synchronous Serial I/O Mode (Multiple Transmit/Receive Clock Output Pin Function Not Selected)”.

22.3.1.7 $\overline{CTS}/\overline{RTS}$ Separate Function (UART0)

This function separates $\overline{CTS0}/\overline{RTS0}$, outputs $\overline{RTS0}$ from the P6_0 pin, and inputs $\overline{CTS0}$ 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 $\overline{CTS}/\overline{RTS}$ of UART0)
- The CRS bit in the U0C0 register is 1 (output $\overline{RTS}$ of UART0)
- The CRD bit in the U1C0 register is 0 (enable $\overline{CTS}/\overline{RTS}$ of UART1)
- The CRS bit in the U1C0 register is 0 (input $\overline{CTS}$ of UART1)
- The RCSP bit in the UCON register is 1 (inputs $\overline{CTS0}$ from the P6_4 pin)
- The CLKMD1 bit in the UCON register is 0 (CLKS1 not used)

Note that when using the $\overline{CTS}/\overline{RTS}$ separate function, $\overline{CTS}/\overline{RTS}$ of UART1 function cannot be used.

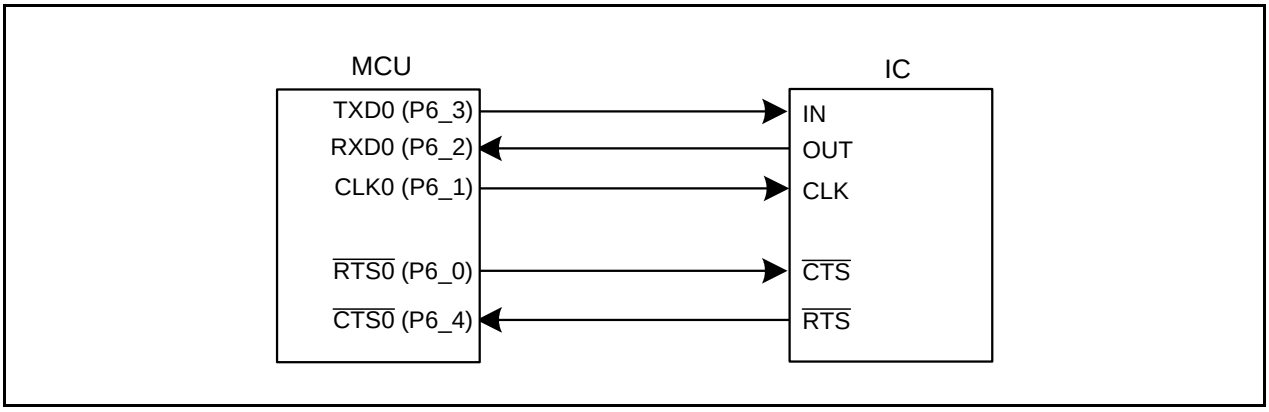


Figure 22.11 $\overline{CTS}/\overline{RTS}$ Separate Function

22.3.1.8 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 5) 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).

22.3.2 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 22.9 lists the UART Mode Specifications.

Table 22.9 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 $\overline{CTS}$, $\overline{RTS}$, or $\overline{CTS}/\overline{RTS}$ 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 $\overline{CTS}$ function is selected, input on the $\overline{CTSi}$ 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 $\overline{CTS}/\overline{RTS}$ pins (UART0) $\overline{CTS0}$ and $\overline{RTS0}$ are input/output from separate pins.

i = 0 to 5

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 22.10 lists I/O Pin Functions in UART Mode. Table 22.11 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 22.10 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 5

Table 22.11 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 22.12 Registers Used and Settings in UART Mode (1)

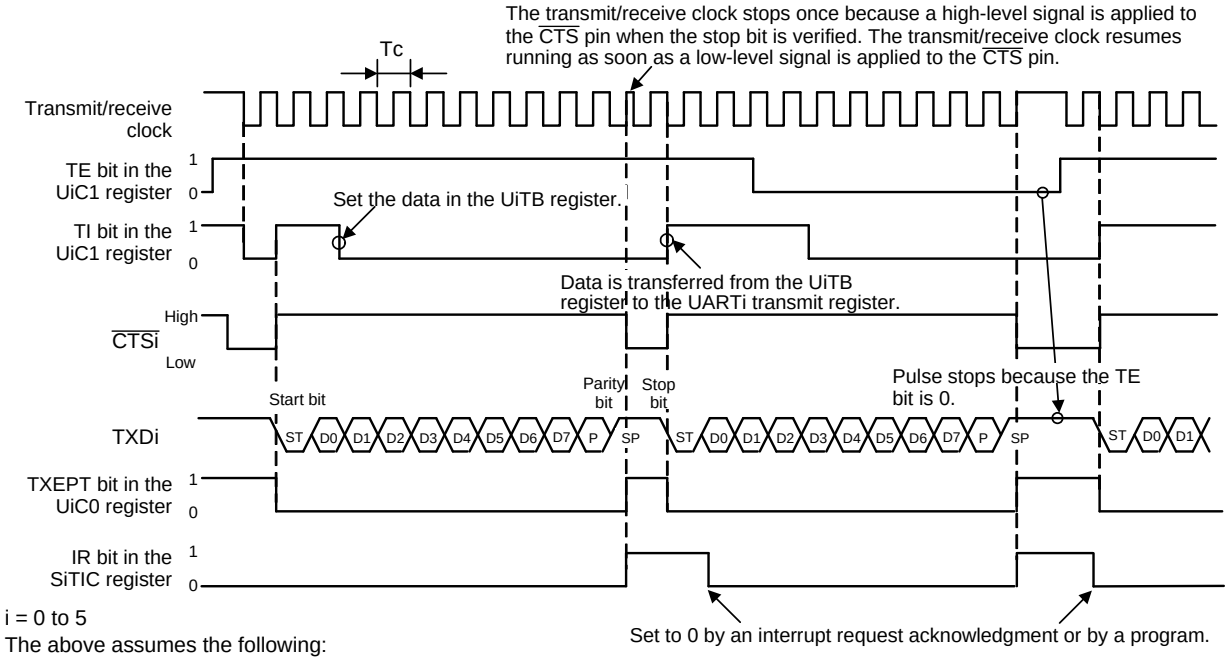
Register	Bits	Function
UCLKSEL0	OCOSEL0	Select clock prior to division for UART0 to UART2.
	OCOSEL1	Select clock prior to division for UART3 to UART5.
PCLKR	PCLK1	Select the count source for the UiBRG register.
UiTB	0 to 8	Set transmission data. (2)
UiRB	0 to 8	Reception data can be read. (2, 4)
	OER, 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 $\overline{CTS}$ or $\overline{RTS}$ is used, select which function to use.
	TXEPT	Transmit register empty flag
	CRD	Enable or disable the $\overline{CTS}$ or $\overline{RTS}$ 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 $\overline{CTS0}$ signal of UART0 from the P6_4 pin.
	7	Set to 0.

i = 0 to 5; j = 2 to 5

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)



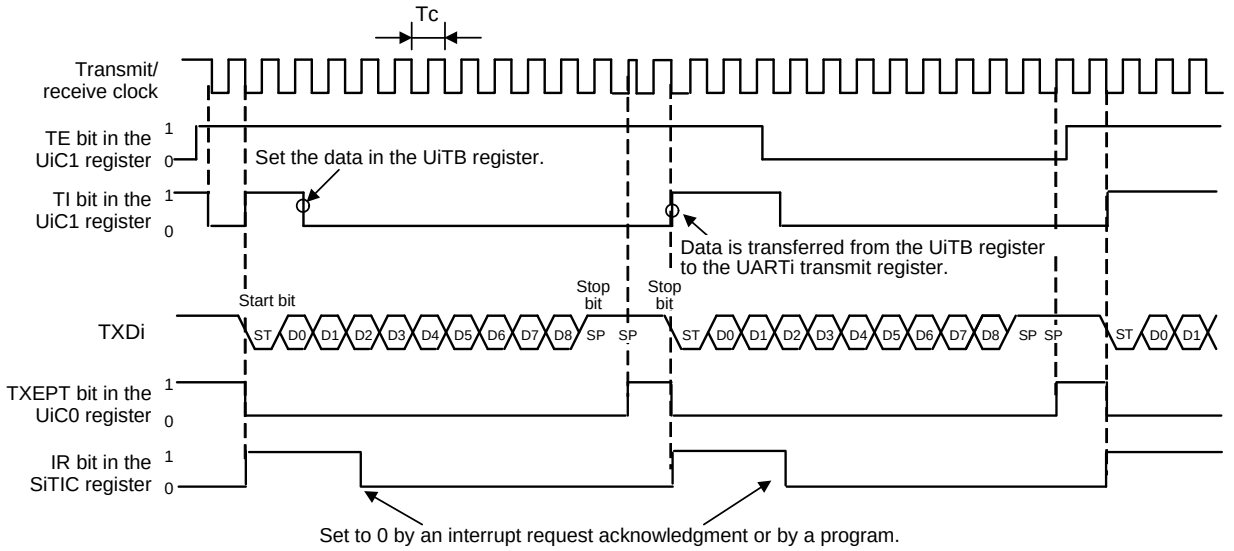
i = 0 to 5

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)



i = 0 to 5

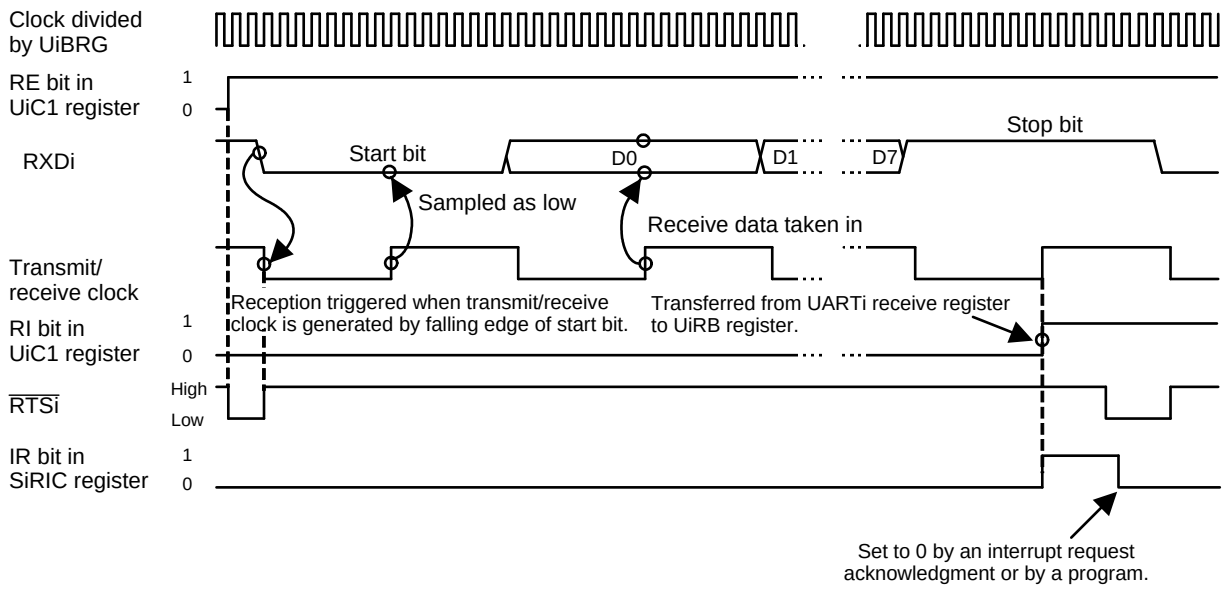
The above assumes the following:

- 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 22.12 Transmit Timing in UART Mode

Example of Receive Timing When Character Bit Length is 8 Bits
(Parity Disabled, 1 Stop Bit)



i = 0 to 5

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 22.13 Receive Timing in UART Mode

22.3.2.1 Bit Rate

In UART mode, the frequency set by the UiBRG register (i = 0 to 5) divided by 16 becomes a bit rate.

The setting value (n) of the UiBRG register is calculated by the following formula:

$$n = \frac{fj}{bitrate(bps) \times 16} - 1$$

fj = f1SIO, f2SIO, f8SIO, f32SIO

n = 00h to FFh

Table 22.13 lists Example Bit Rates and Settings.

Table 22.13 Example of Bit Rates and Settings (1)

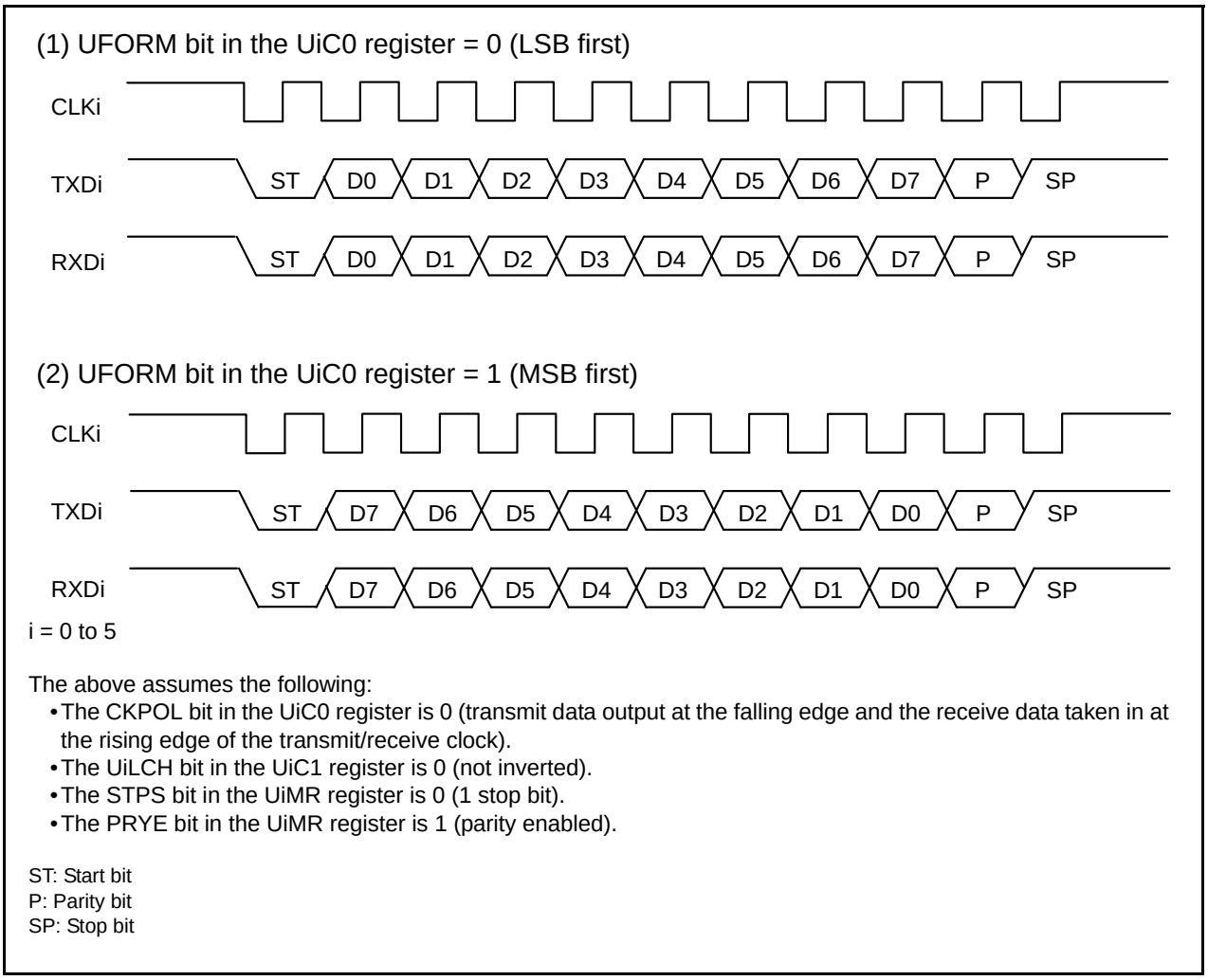
Bit Rate (bps)	Count Source of UiBRG	Peripheral Function Clock f1: 16 MHz		Peripheral Function Clock f1: 24 MHz	
		Set Value of UiBRG: n	Bit Rate (bps)	Set value of UiBRG: n	Bit Rate (bps)
1200	f8SIO	103 (67h)	1202	155 (9Bh)	1202
2400	f8SIO	51 (33h)	2404	77 (4Dh)	2404
4800	f8SIO	25 (19h)	4808	38 (26h)	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).

22.3.2.2 LSB First/MSB First Select Function

As shown in Figure 22.14, 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.



i = 0 to 5

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 22.14 Bit Order

22.3.2.3 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.

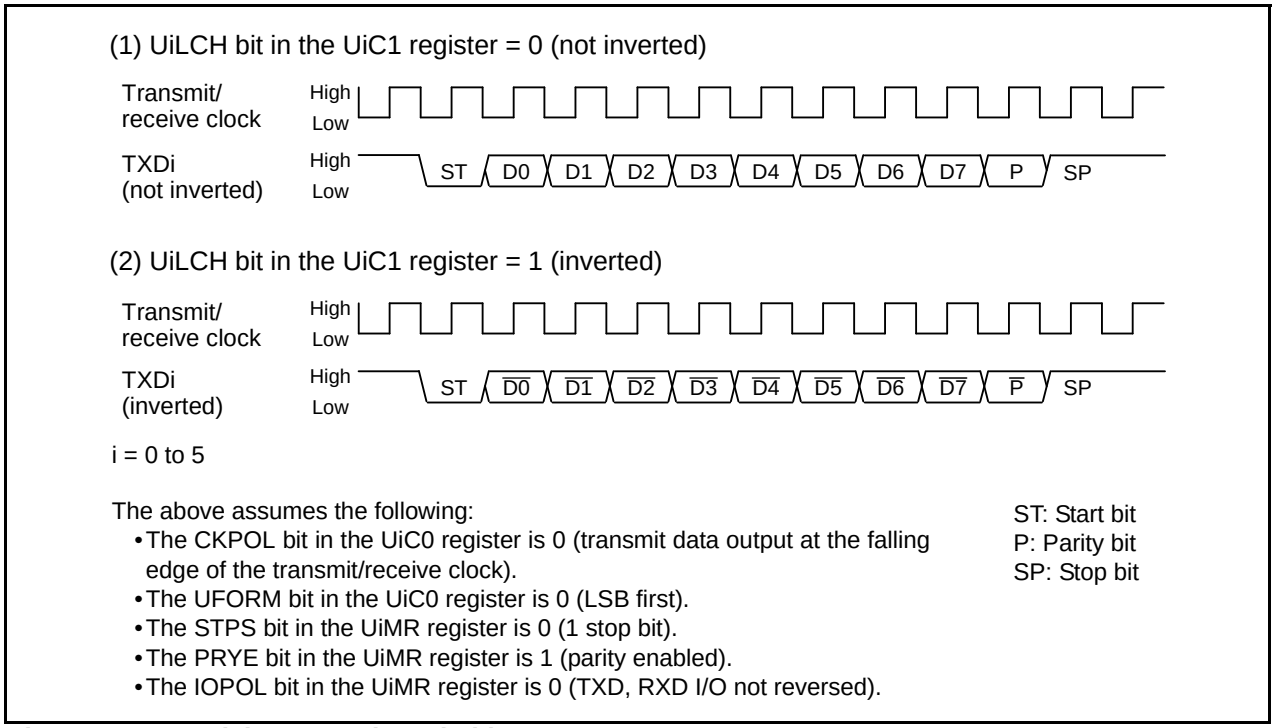


Figure 22.15 Serial Data Logic Switching

22.3.2.4 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.

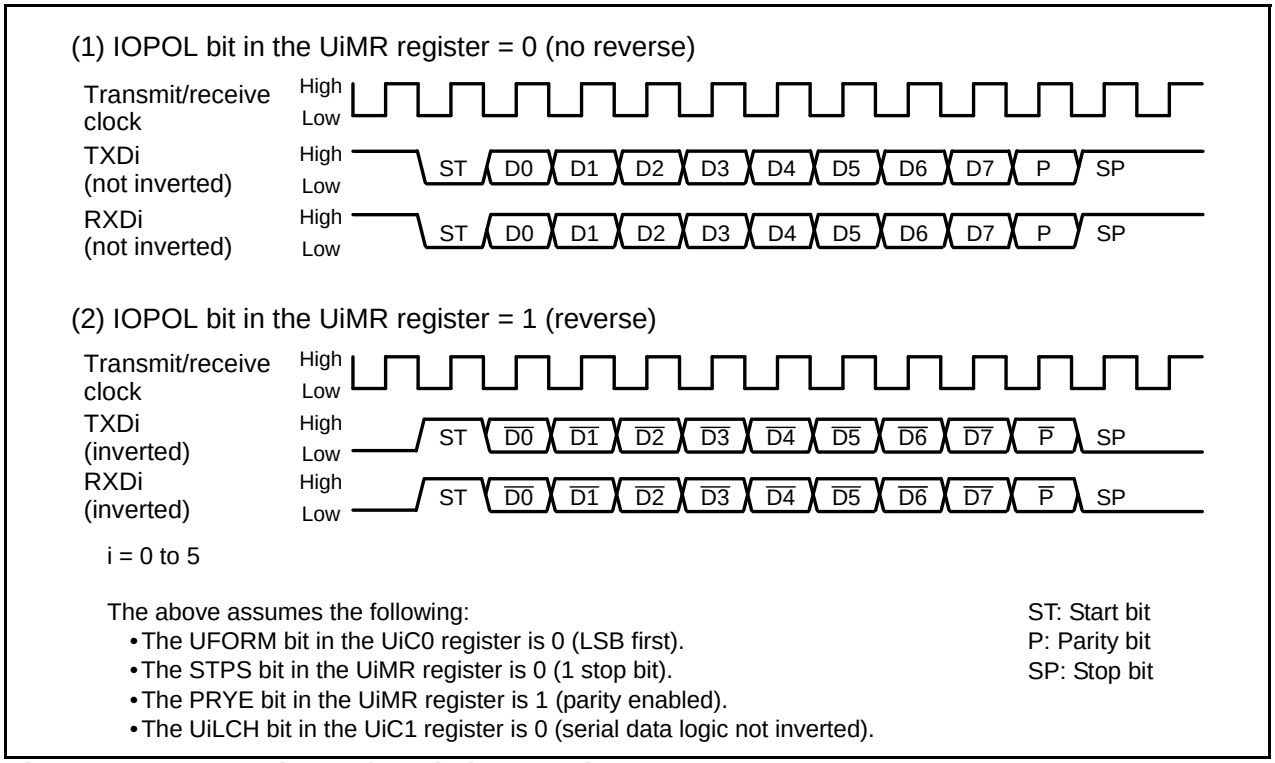


Figure 22.16 TXD and RXD I/O Polarity Inversion

22.3.2.5 $\overline{CTS}/\overline{RTS}$ Function

The $\overline{CTS}$ function is used to start transmit operation when a low signal is applied to the $\overline{CTSi}/\overline{RTSi}$ (i = 0 to 5) pin. Transmit operation begins when input to the $\overline{CTSi}/\overline{RTSi}$ 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 $\overline{RTS}$ function is selected, the $\overline{CTSi}/\overline{RTSi}$ 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 22.10 “I/O Pin Functions in UART Mode”.

22.3.2.6 $\overline{CTS}/\overline{RTS}$ Separate Function (UART0)

This function separates $\overline{CTS0}$ and $\overline{RTS0}$, outputs $\overline{RTS0}$ from the P6_0 pin, and inputs $\overline{CTS0}$ 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 $\overline{CTS}/\overline{RTS}$ of UART0)
- The CRS bit in the U0C0 register is 1 (output $\overline{RTS}$ of UART0)
- The CRD bit in the U1C0 register is 0 (enable $\overline{CTS}/\overline{RTS}$ of UART1)
- The CRS bit in the U1C0 register is 0 (input $\overline{CTS}$ of UART1)
- The RCSP bit in the UCON register is 1 (inputs $\overline{CTS0}$ from the P6_4 pin)
- The CLKMD1 bit in the UCON register is 0 (CLKS1 not used)

Note that when using the $\overline{CTS}/\overline{RTS}$ separate function, $\overline{CTS}/\overline{RTS}$ function of UART1 cannot be used.

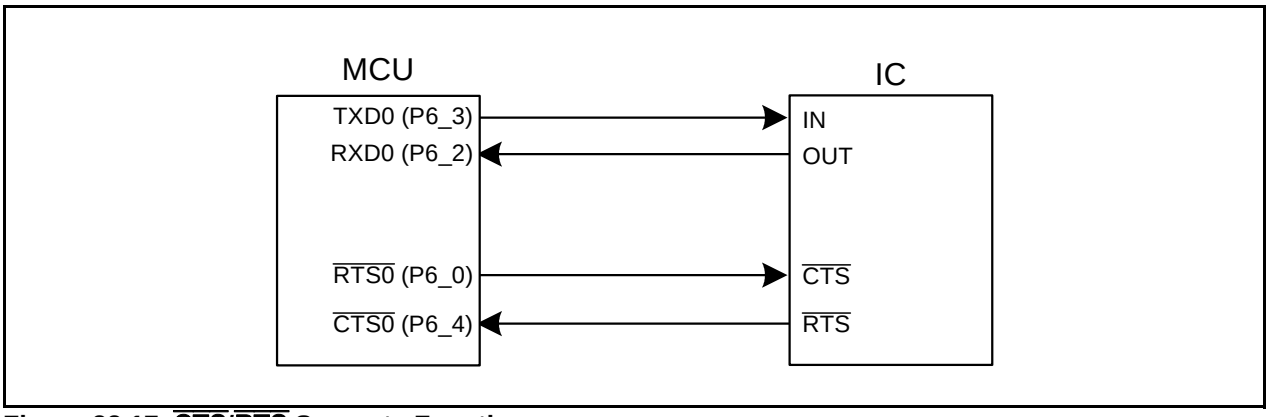


Figure 22.17 $\overline{CTS}/\overline{RTS}$ Separate Function

22.3.2.7 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 5) 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).

22.3.3 Special Mode 1 (I^2C Mode)

I^2C mode is compatible with the simplified I^2C interface. Table 22.14 lists the I^2C Mode Specifications. Table 22.16 and Table 22.17 list the Registers Used and Settings in I^2C Mode. Table 22.18 lists the I^2C Mode Functions. Figure 22.18 shows the I^2C Mode Block Diagram.

As shown in Table 22.18, 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.

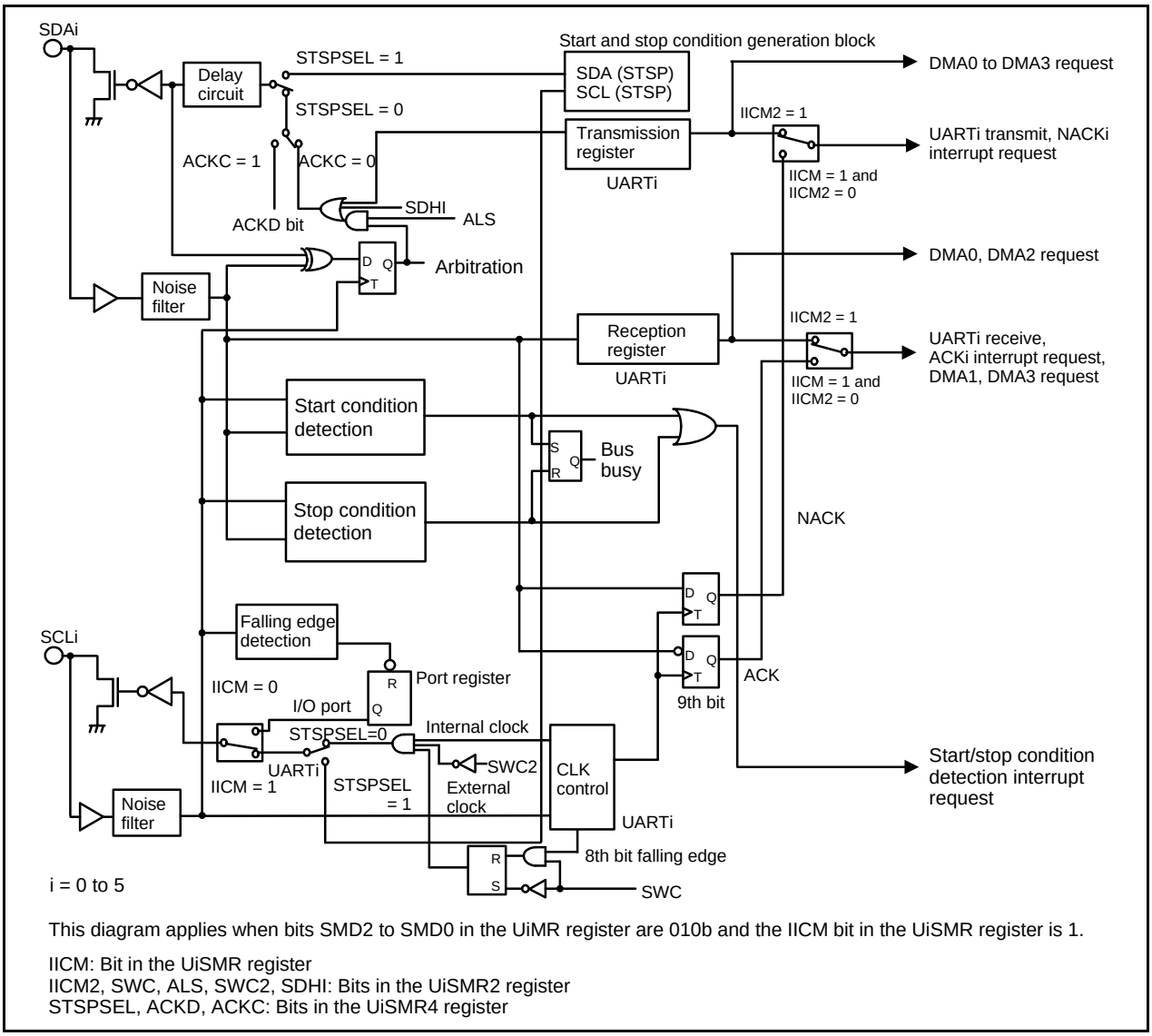
Table 22.14 I^2C Mode Specifications

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 5

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 22.18 I²C Mode Block Diagram

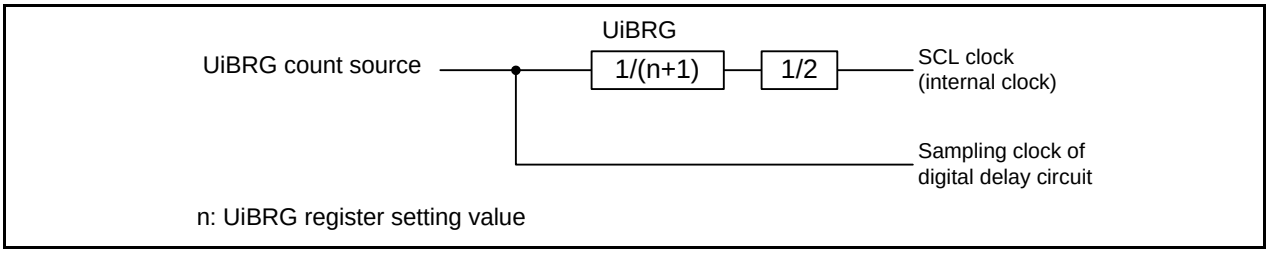


Figure 22.19 Internal Clock Configuration

Table 22.15 I/O Pin Functions in I²C 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 $\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$ are not used (they can be used as I/O ports).

Table 22.16 Registers Used and Settings in I²C 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 UART3 to UART5.	Select clock prior to division for UART3 to UART5.
PCLKR	PCLK1	Select the count source for the UiBRG register.	Select the count source for the UiBRG register.
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 5; j = 2 to 5

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 I²C mode, to enable the $\overline{CTS}/\overline{RTS}$ separate function of UART0, set the CRD bit in the U1C0 register to 0 ($\overline{CTS}/\overline{RTS}$ enabled) and the CRS bit to 0 ($\overline{CTS}$ input).

Table 22.17 Registers Used and Settings in I²C Mode (2/2) (1)

Register	Bits	Function	
		Master	Slave
UiSMR2	IICM2	See Table 22.18 "I²C Mode Functions".	See Table 22.18 "I²C 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 5

Note:

1. This table does not describe a procedure.

In I²C mode, functions and timings vary depending on the IICM2 bit setting in the UiSMR2 register. Figure 22.20 shows Transfer to UiRB Register and Interrupt Timing. See Figure 22.20 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 22.18 lists a comparison of other functions in clock synchronous serial I/O mode with I²C mode.

Table 22.18 I²C Mode Functions

Function	Clock Synchronous Serial I/O Mode (SMD2 to SMD0 = 001b, IICM = 0)	I²C 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 22.22 “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 I²C mode (1)	The value set in the port register before setting I²C 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 22.20 “Transfer to UiRB Register and Interrupt Timing”.

i = 0 to 5
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 22.20 “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.

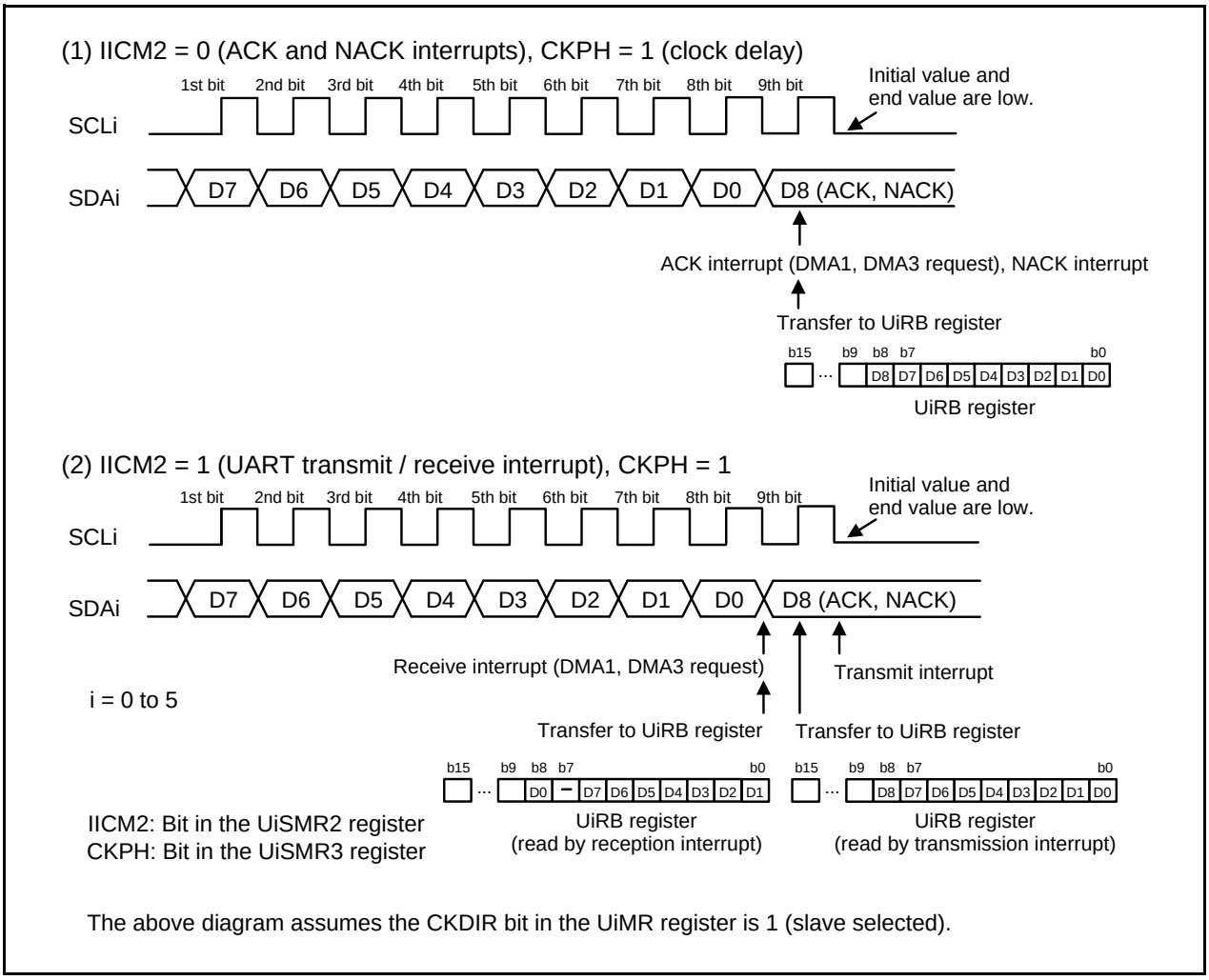


Figure 22.20 Transfer to UiRB Register and Interrupt Timing

22.3.3.1 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 22.21. To meet the condition for the Fast-mode specification, the BRGi count source must be at least 10 MHz.

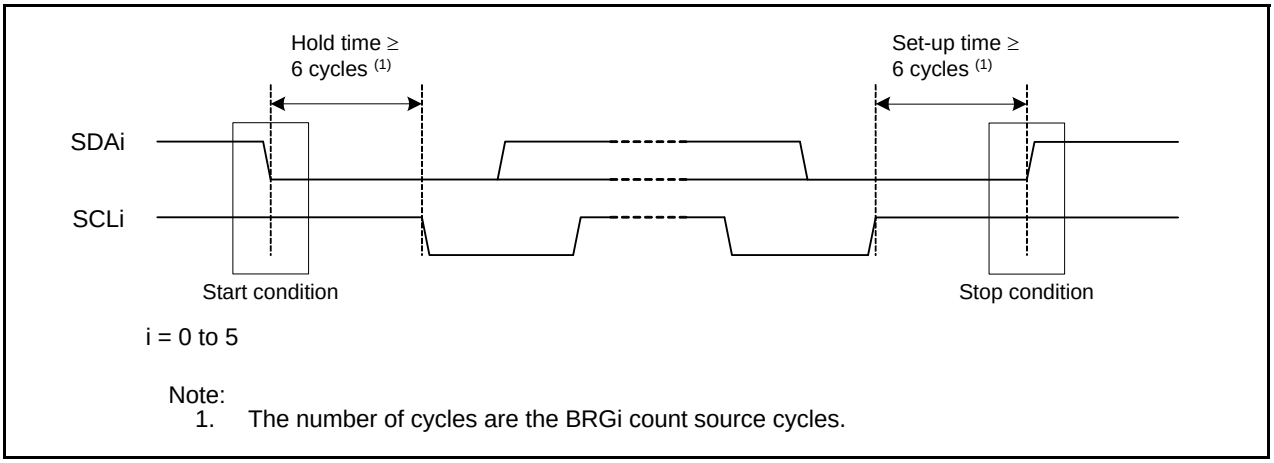


Figure 22.21 Detecting Start and Stop Conditions

22.3.3.2 Generating Start and Stop Conditions

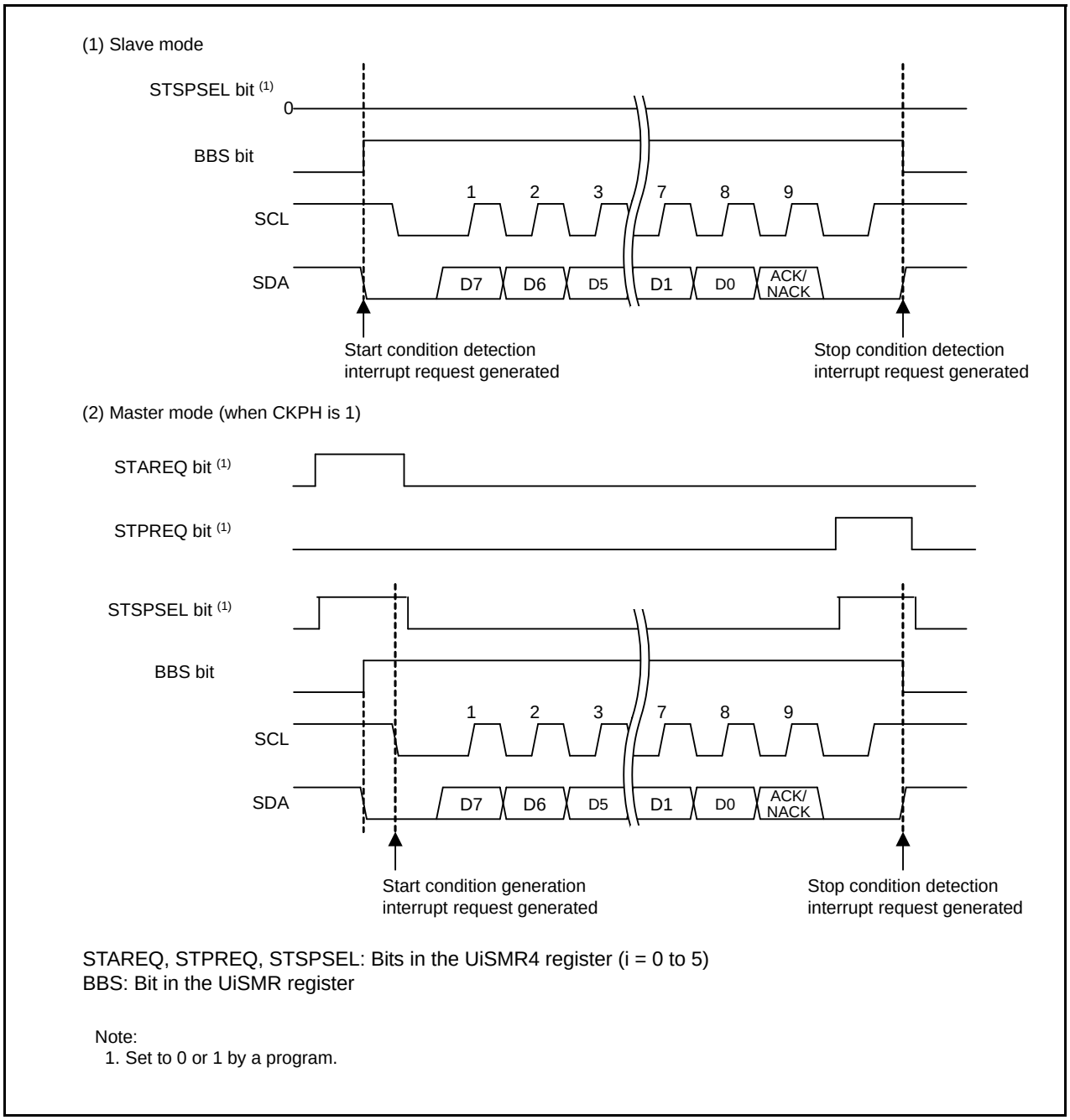
A start condition is generated by setting the STAREQ bit in the UiSMR4 register (i = 0 to 5) to 1 (start).
A restart condition is generated by setting the RSTAREQ bit in the UiSMR4 register to 1 (start).
A stop condition is generated by setting the STPREQ bit in the UiSMR4 register to 1 (start).
The 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 22.19 and Figure 22.22.

Table 22.19 STSPSEL Bit Functions

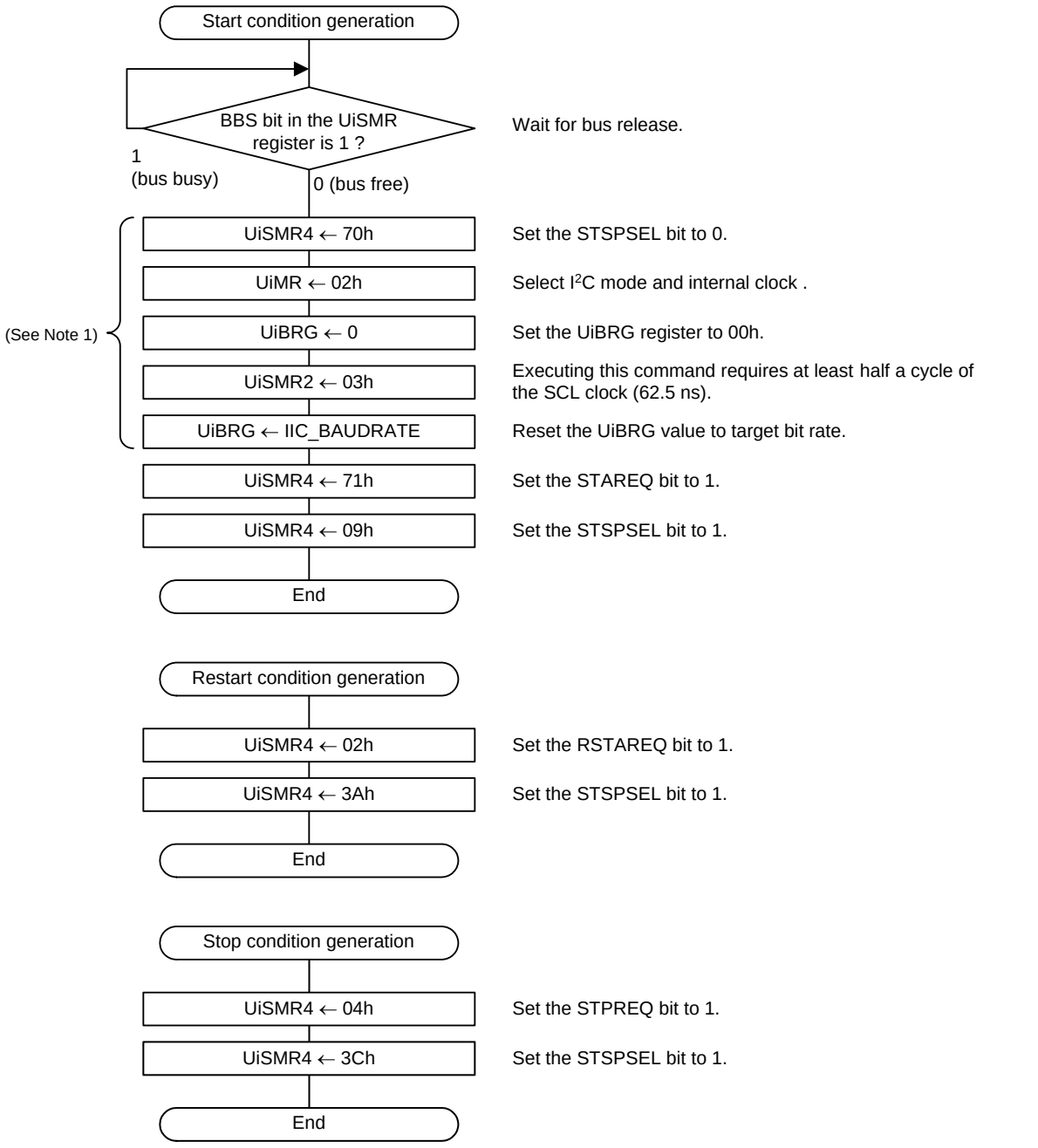
Function	STSPSEL = 0	STSPSEL = 1
Output of pins SCLi and SDAi	Output of transmit/receive clock and data Output of start/stop condition is accomplished by a program using ports (not automatically generated in hardware)	Output of a start/stop condition according to bits STAREQ, RSTAREQ, and STPREQ
Start/stop condition Interrupt request generation timing	Detection of start/stop condition	Completion of generating start/stop condition



STAREQ, STPREQ, STSPSEL: Bits in the UiSMR4 register (i = 0 to 5)
BBS: Bit in the UiSMR register

Note:
1. Set to 0 or 1 by a program.

Figure 22.22 STSPSEL Bit Functions



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 22.23 Register Setting Procedures for Condition Generation

22.3.3.3 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 5) 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.

22.3.3.4 SCL Control and Clock Synchronization

Data transmission/reception in I^2C mode uses the transmit/receive clock as shown in Figure 22.20 “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^2C 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 5) 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.

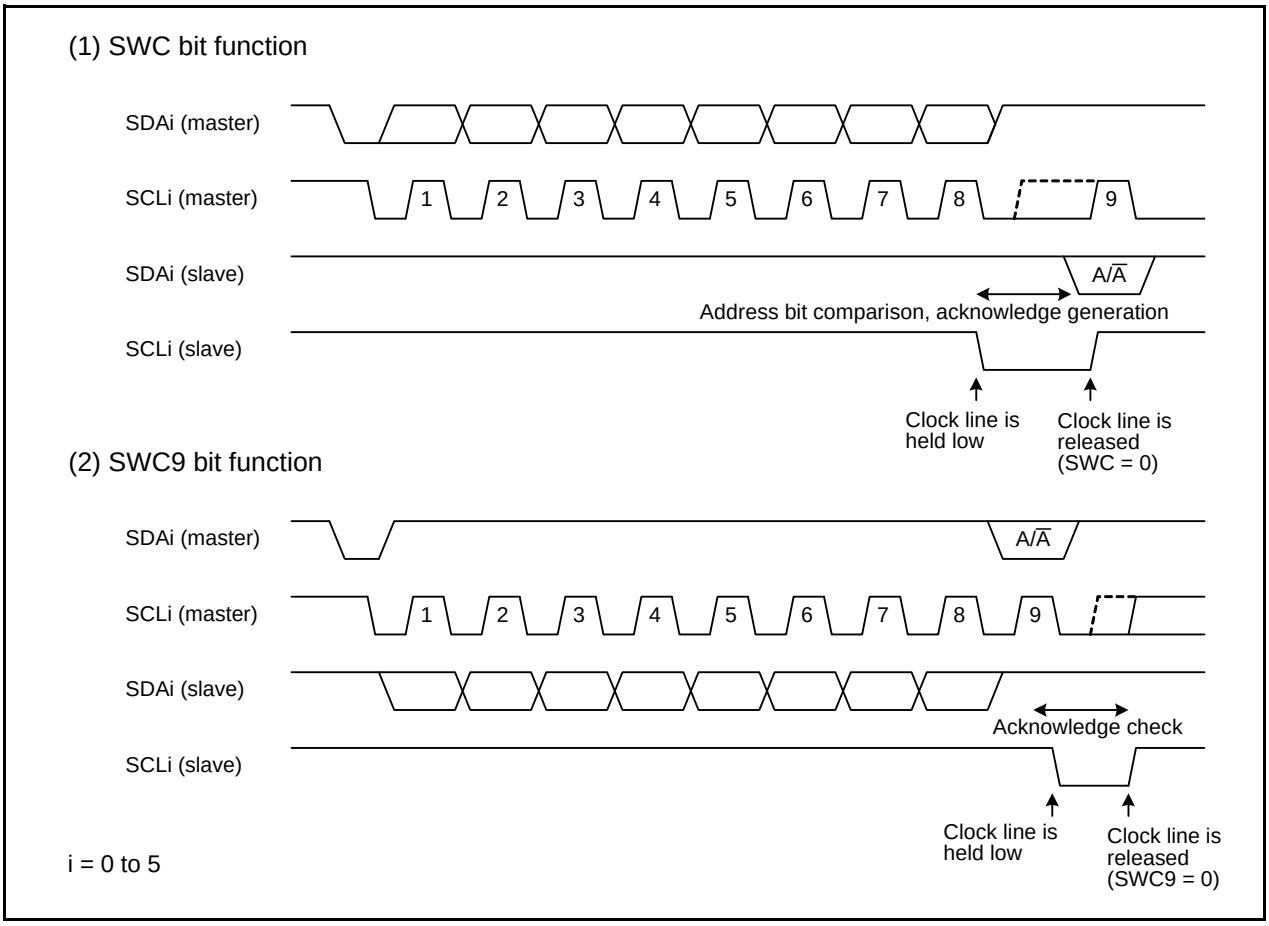


Figure 22.24 Inserting Wait-States Using Bits SWC and SWC9

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.

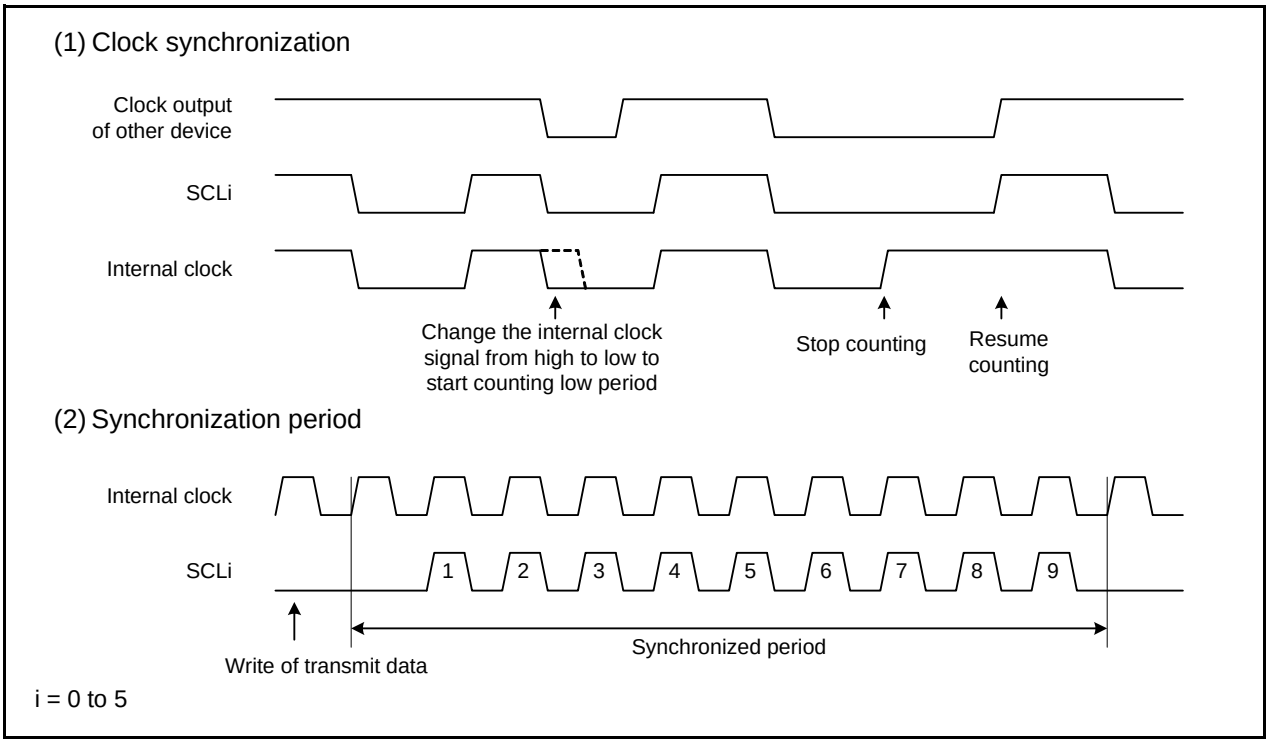


Figure 22.25 Clock Synchronization

22.3.3.5 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 22.25 “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.

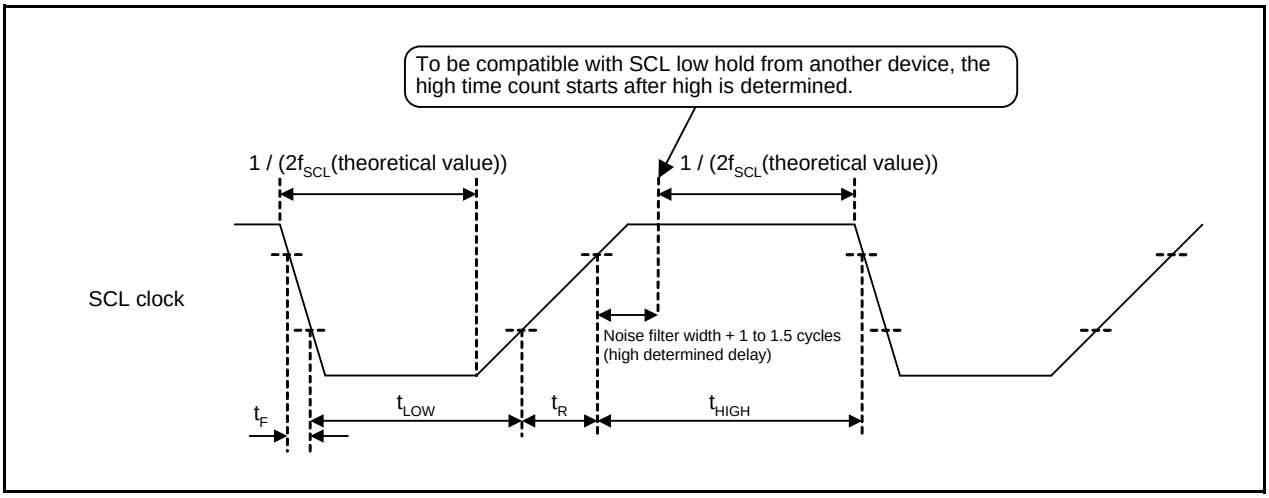


Figure 22.26 SCL Clock

22.3.3.6 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^2C 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.

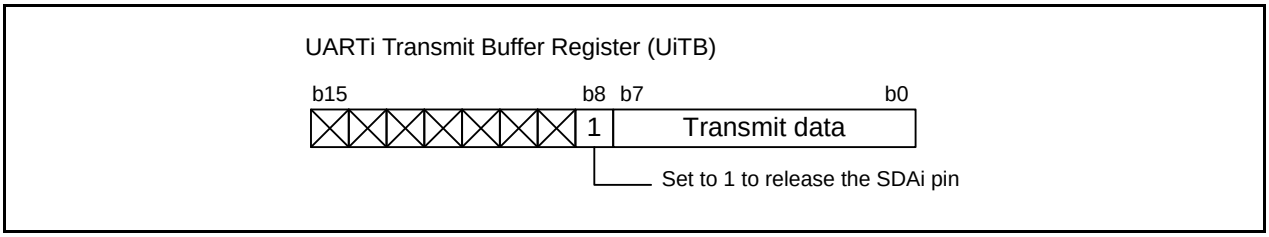


Figure 22.27 UiTB Register Setting (SDA Output)

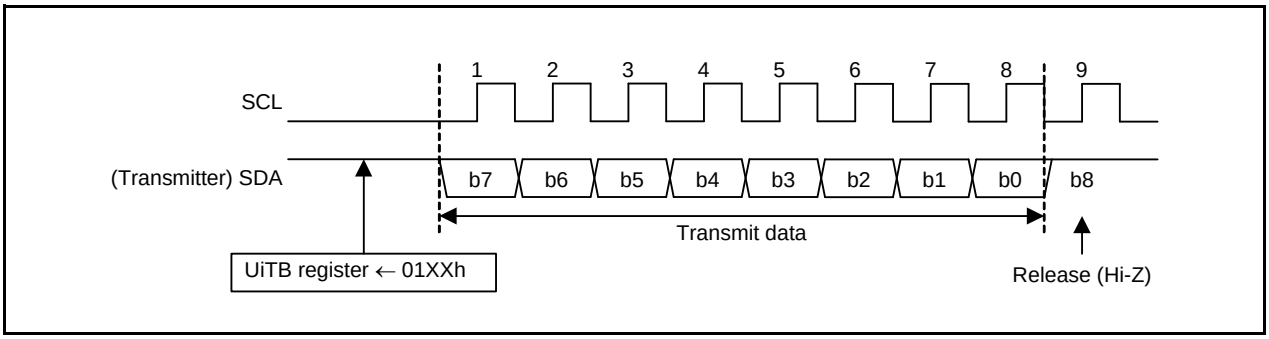


Figure 22.28 Byte Data Transmission

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).

22.3.3.7 SDA Digital Delay

When transferring data with the I2C-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 22.5.3.4 “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.

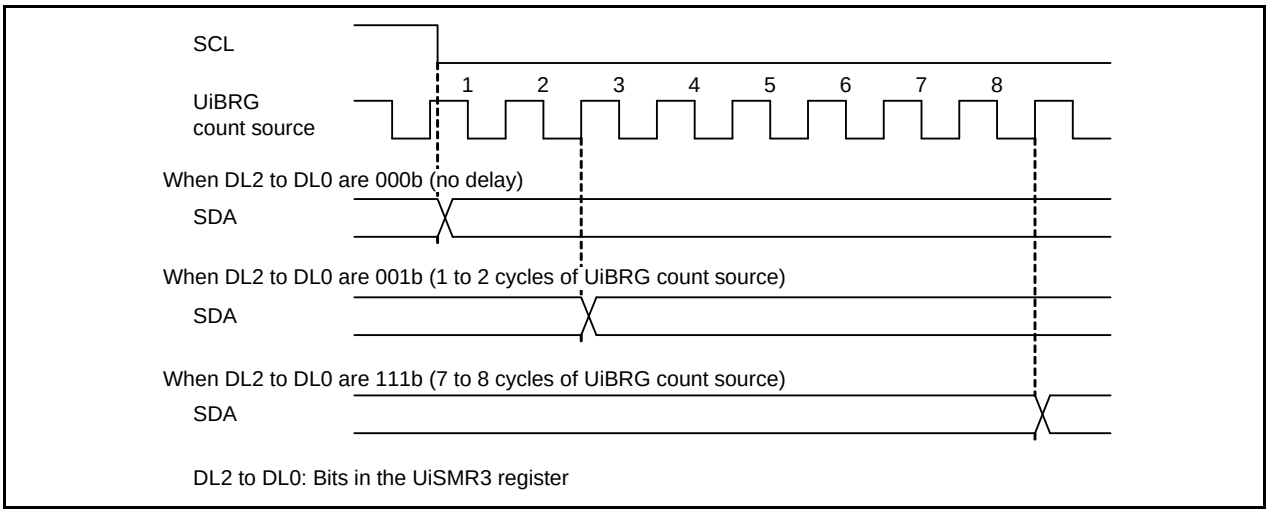


Figure 22.29 SDA Output Selection by Setting Bits DL2 to DL0

22.3.3.8 SDA Input

When the IICM2 bit in the UiSMR2 register (i = 0 to 5) 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 I2C 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 22.20 “Transfer to UiRB Register and Interrupt Timing” for details.

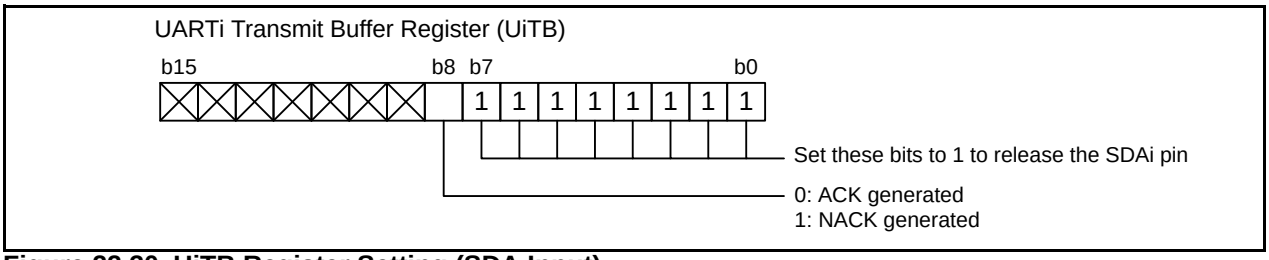


Figure 22.30 UiTB Register Setting (SDA Input)

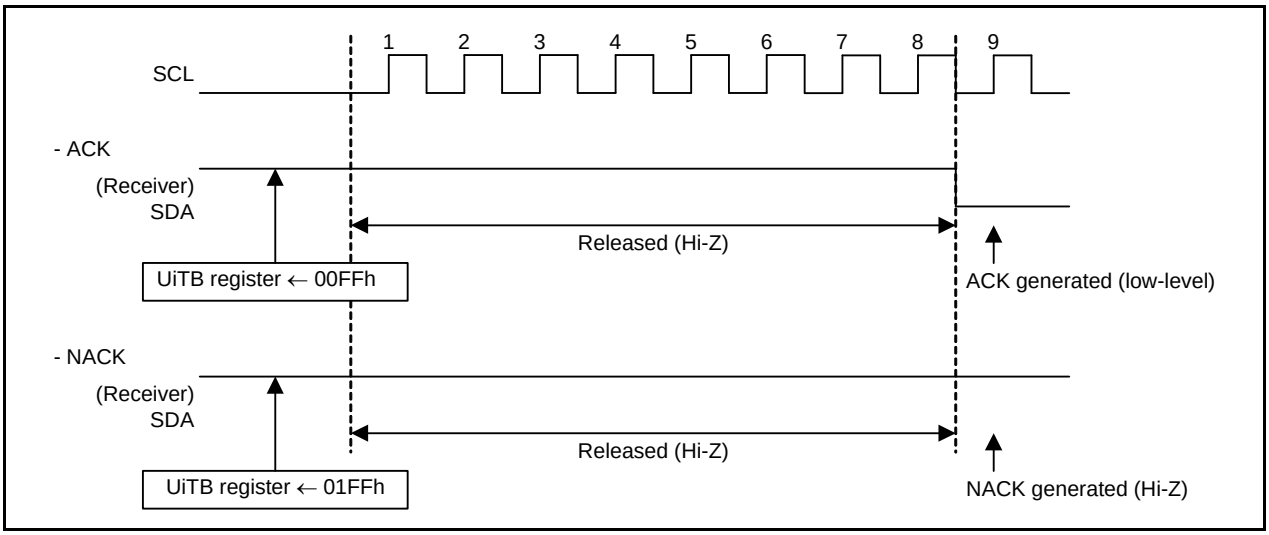


Figure 22.31 Byte Data Reception

22.3.3.9 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 5) 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.

22.3.3.10 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.

22.3.4 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 22.20 lists Special Mode 2 Specifications.

Table 22.20 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 5

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.

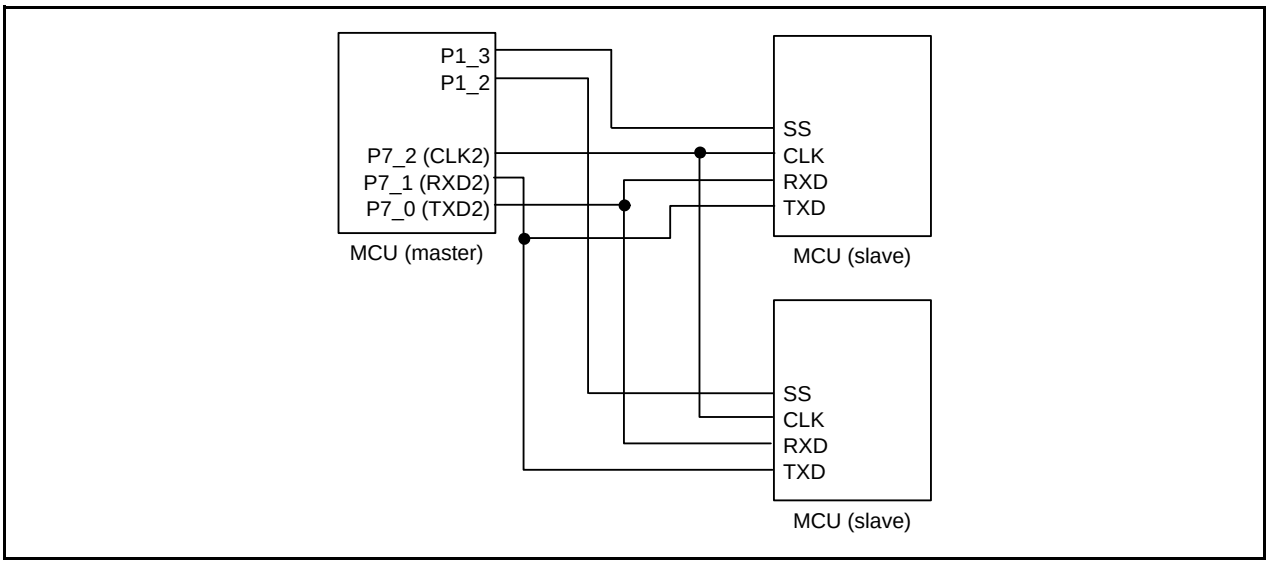


Figure 22.32 Serial Bus Communication Control Example in Special Mode 2 (UART2)

Table 22.21 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 5
Pins $\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$ are not used. (They can be used as I/O ports.)

Table 22.22 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 UART3 to UART5.
PCLKR	PCLK1	Select the count source for the UiBRG register.
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 5; j = 2 to 5

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.

22.3.4.1 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 22.33 shows the Transmit and Receive Timing in Master Mode (Internal Clock).

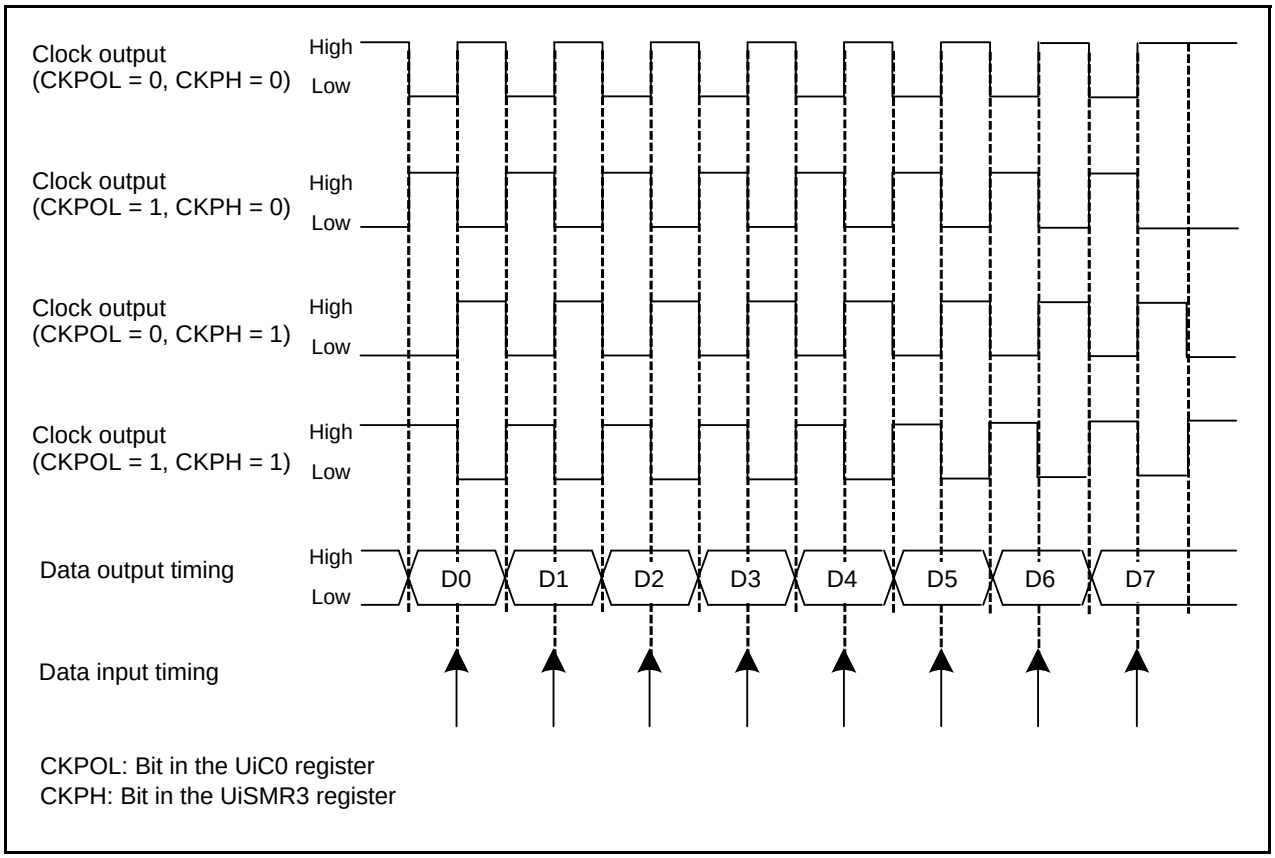


Figure 22.33 Transmit and Receive Timing in Master Mode (Internal Clock)

22.3.5 Special Mode 3 (IE Mode)

In this mode, 1 bit of IEBus is approximated by 1 byte of UART mode waveform.
Table 22.23 lists the Registers Used and Settings in IE Mode. Figure 22.34 shows the Bus Collision Detect Function-Related Bits.
If the TXDi pin (i = 0 to 5) 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 22.23 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.

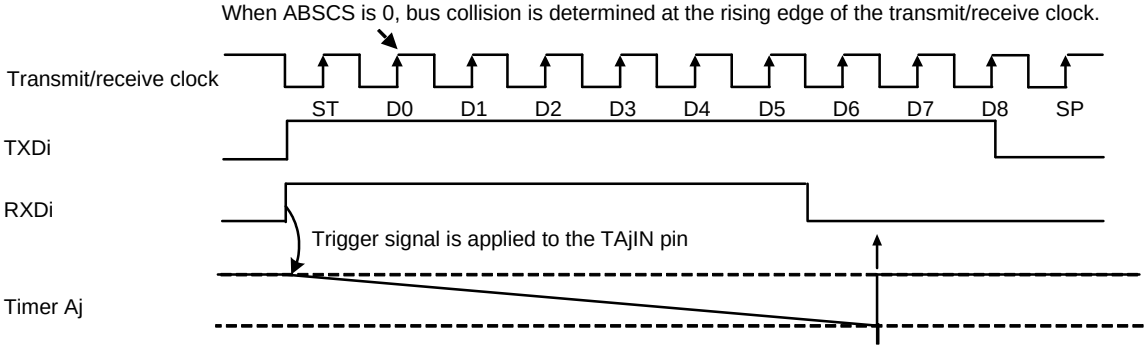
i = 0 to 5; j = 2 to 5

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 5)

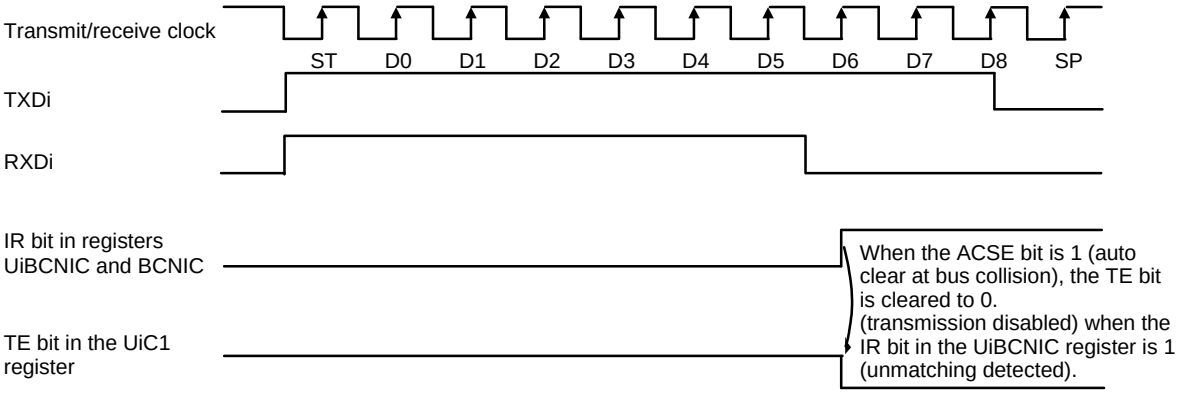
When ABSCS is 0, bus collision is determined at the rising edge of the transmit/receive clock.



When ABSCS is 1, bus collision is determined when timer Aj (one-shot timer mode) underflows.

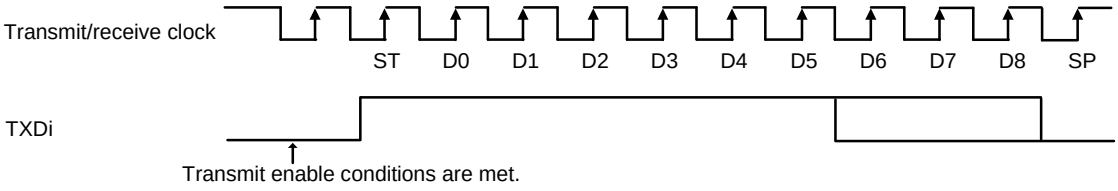
Timer Aj: Timer A3 in UART0; timer A4 in UART1; timer A0 in UART2
timer A0 in UART5; timer A3 in UART4; timer A4 in UART3

(2) ACSE bit in UiSMR register (transmit enable bit automatically cleared)

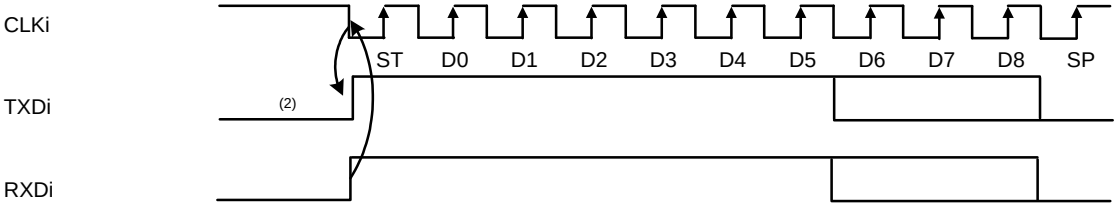


(3) SSS bit in the UiSMR register (transmit start condition select)

When the SSS bit is 0, the serial interface starts sending data one transmit/receive clock cycle after the transmission start condition is met.



When the SSS bit is 1, the serial interface starts sending data at the rising edge of RXDi. (1)



i = 0 to 5

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 22.34 Bus Collision Detect Function-Related Bits

22.3.6 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 22.24 lists the specifications of SIM mode. Table 22.25 lists the related registers and their settings.

Table 22.24 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 22.25 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.

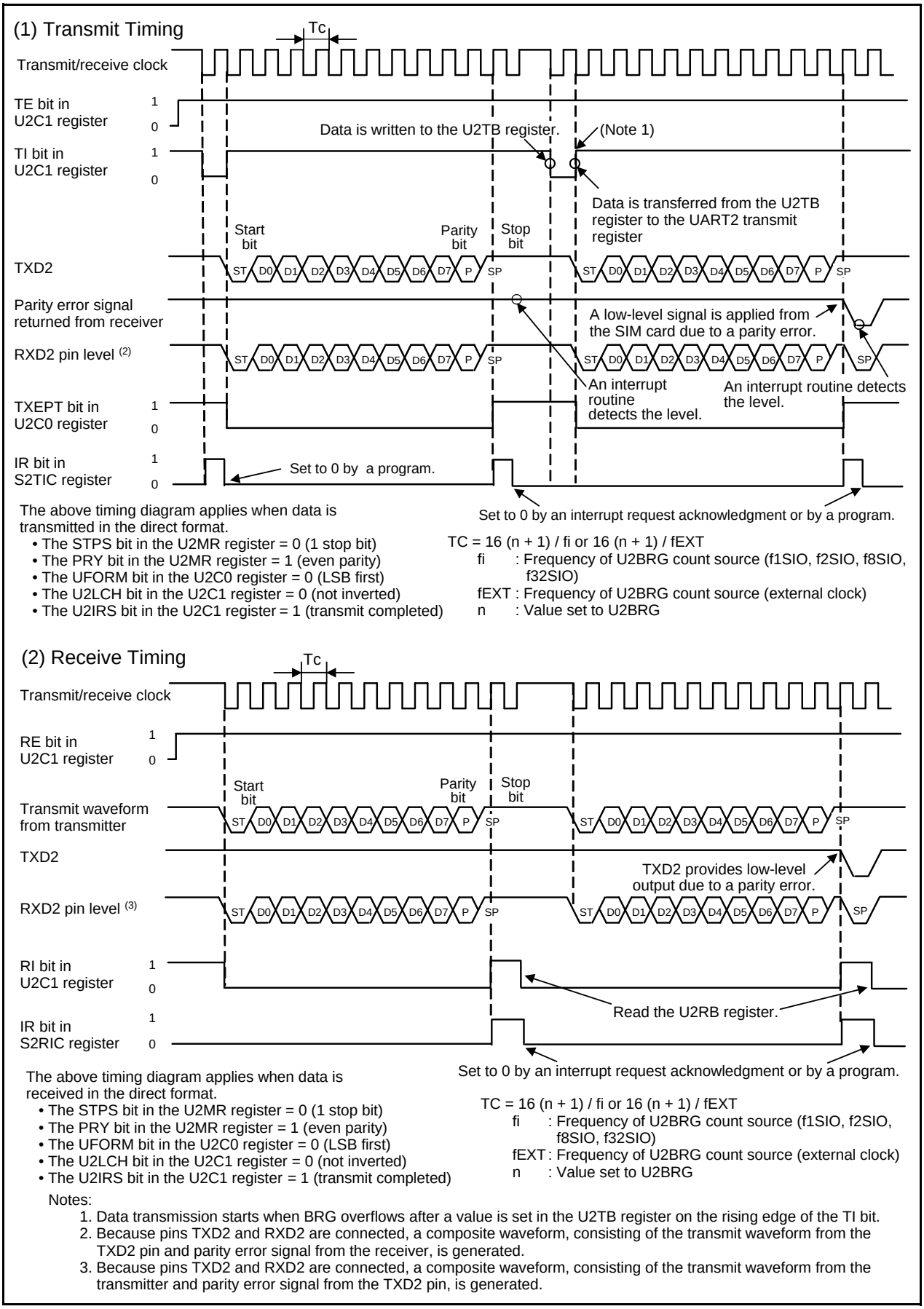


Figure 22.35 Transmit/Receive Timing in SIM Mode

Figure 22.36 shows the Example of SIM Interface Connection. Connect pins TXD2 and RXD2, and then place a pull-up resistance.

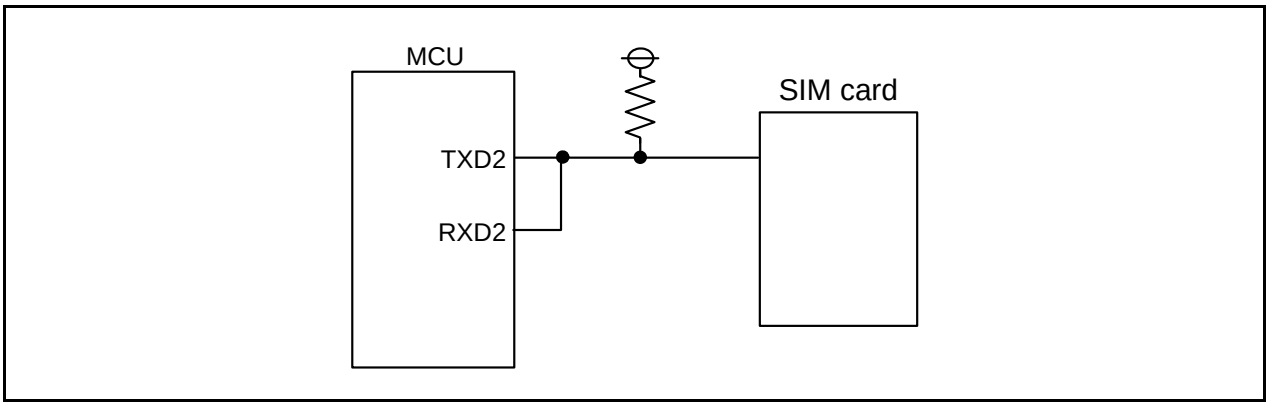


Figure 22.36 Example of SIM Interface Connection

22.3.6.1 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 22.37. 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.

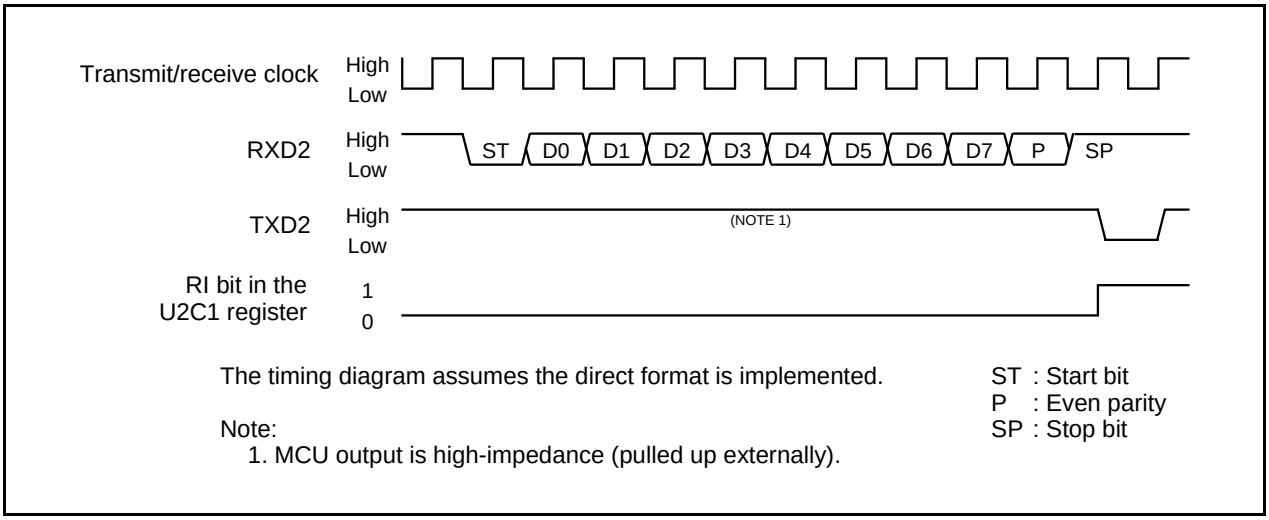


Figure 22.37 Parity Error Signal Output Timing

22.3.6.2 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 22.38 shows the SIM Interface Format.

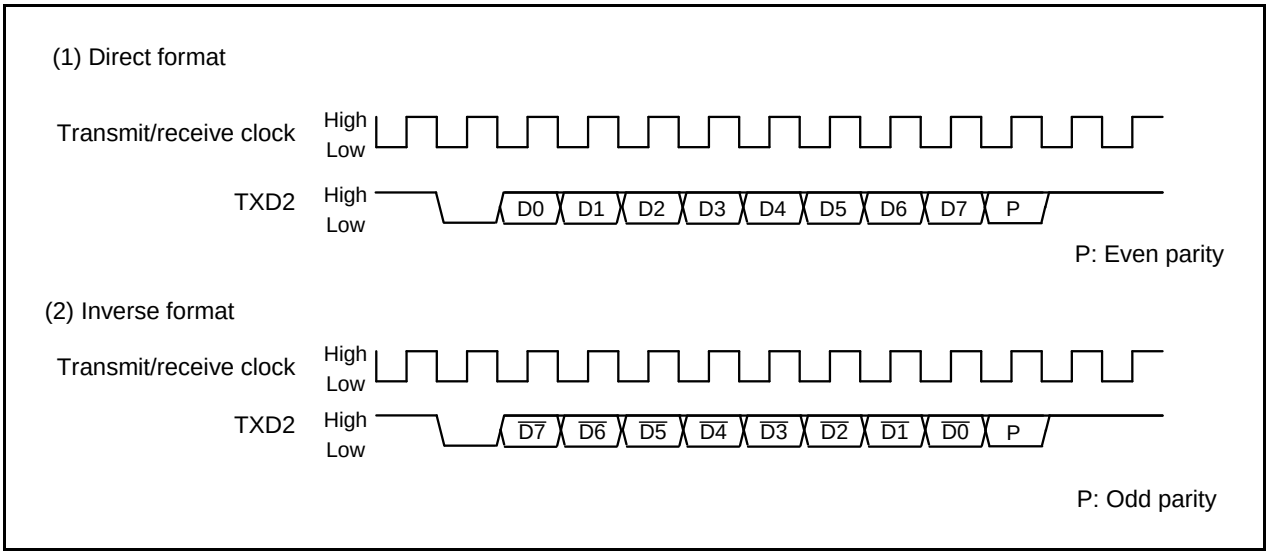


Figure 22.38 SIM Interface Format

22.4 Interrupts

UART0 to UART5 include interrupts by transmission, reception, ACK, NACK, start/stop condition detection, and bus collision detection.

22.4.1 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 22.26 lists UART0 to UART5 Interrupt Related Registers.

Table 22.26 UART0 to UART5 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	UART4 Bus Collision Detection Interrupt Control Register	U4BCNIC	XXXX X000b
006Fh	UART4 Transmit Interrupt Control Register	S4TIC	XXXX X000b
0070h	UART4 Receive Interrupt Control Register	S4RIC	XXXX X000b
0071h	UART3 Bus Collision Detection Interrupt Control Register	U3BCNIC	XXXX X000b
0072h	UART3 Transmit Interrupt Control Register	S3TIC	XXXX X000b
0073h	UART3 Receive Interrupt Control Register	S3RIC	XXXX X000b
0205h	Interrupt Source Select Register 3	IFSR3A	00h
0206h	Interrupt Source Select Register 2	IFSR2A	00h

Some interrupts of UART0 to UART5 share interrupt vectors and interrupt control registers with other peripheral functions. When using these interrupts, select them by interrupt source select registers. Table 22.27 lists Interrupt Selection in UART0 to UART5.

Table 22.27 Interrupt Selection in UART0 to UART5

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
UART4 start/stop condition detection, bus collision detection	IFSR3A	IFSR35	0
UART4 transmission, NACK	IFSR3A	IFSR36	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.

22.4.2 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.

22.5 Notes on Serial Interface UARTi (i = 0 to 5)

22.5.1 Common Notes on Multiple Modes

22.5.1.1 Influence of $\overline{SD}$

When a low-level signal is applied to the $\overline{SD}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{SD}$ pin enabled), the following pins become high-impedance: P7_2/CLK2/TA1OUT/V, P7_3/$\overline{CTS2}$/$\overline{RTS2}$/TA1IN/$\overline{V}$, P7_4/TA2OUT/W, P7_5/TA2IN/$\overline{W}$, P8_0/TA4OUT/RXD5/SCL5/U/TSUDA, P8_1/TA4IN/$\overline{CTS5}$/$\overline{RTS5}$/$\overline{U}$/TSUDB

22.5.1.2 Register Setting

Set the OCOSEL0 or OCOSEL1 bit in the UCLKSEL0 register before setting other registers associated with UART0 to UART5. After changing the OCOSEL0 or OCOSEL1 bit, set other registers associated with UART0 to UART5 again.

22.5.1.3 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.

22.5.2 Clock Synchronous Serial I/O Mode

22.5.2.1 Transmission/Reception

When the $\overline{RTS}$ function is used with an external clock, the $\overline{RTSi}$ pin (i = 0 to 5) outputs a low-level signal, which informs the transmitting side that the MCU is ready for a receive operation. The $\overline{RTSi}$ pin outputs a high-level signal when a receive operation starts. Therefore, transmit timing and receive timing can be synchronized by connecting the $\overline{RTSi}$ pin to the $\overline{CTSi}$ pin on the transmitting side. The $\overline{RTS}$ function is disabled when an internal clock is selected.

22.5.2.2 Transmission

If the transmission is started while an external clock is selected and the TXEPT bit in the UiC0 register (i = 0 to 5) 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 $\overline{CTS}$ function is selected, input on the $\overline{CTSi}$ pin is low.

22.5.2.3 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 5) 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).

22.5.3 Special Mode 1 (I^2C Mode)

22.5.3.1 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 5) 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.

22.5.3.2 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

22.5.3.3 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 I²C-bus specification.
Refer to the recommended operating conditions for I/O ports which share the pins with SCL and SDA.

I²C-bus specification
High level input voltage (V_{IH}) = min. 0.7 V_{CC}
Low level input voltage (V_{IL}) = max. 0.3 V_{CC}

22.5.3.4 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 22.3.3.7 “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

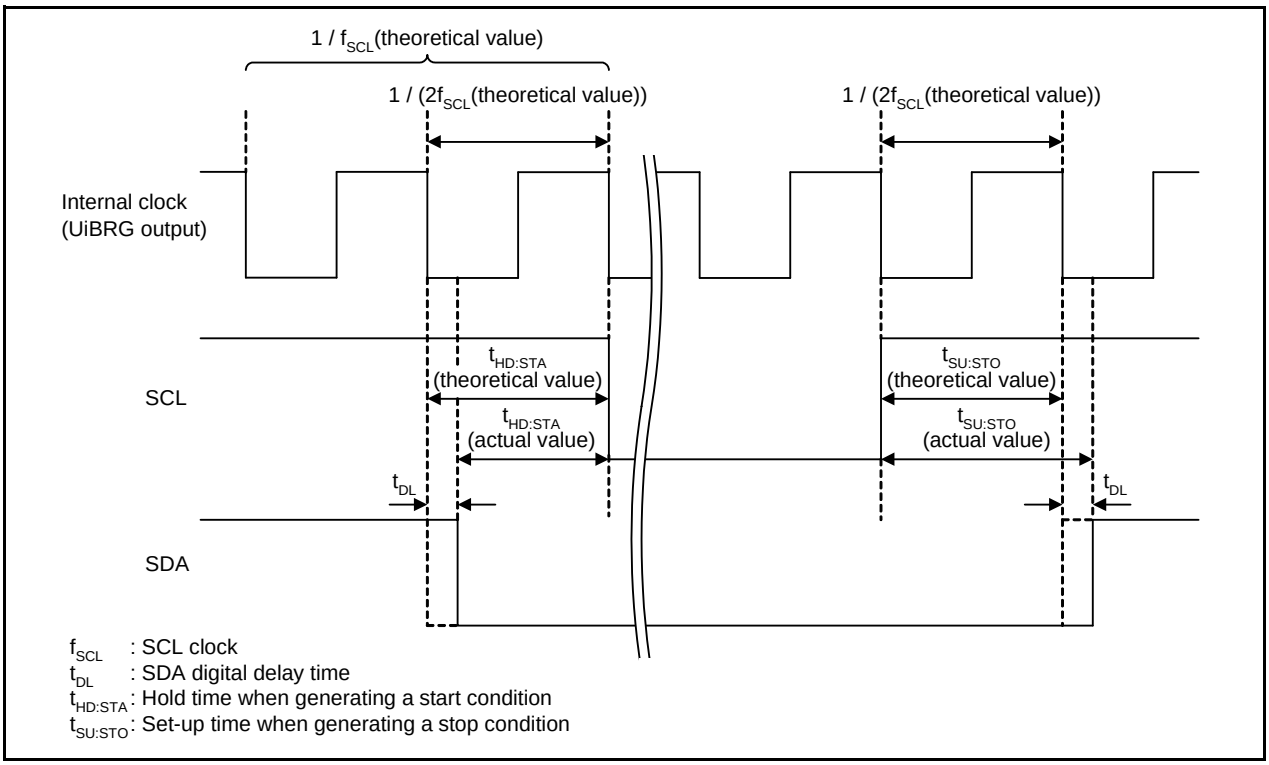


Figure 22.39 Setup and Hold Times When Generating Start and Stop Conditions

22.5.3.5 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.

22.5.3.6 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.

22.5.3.7 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).

22.5.4 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.

23. Multi-master I2C-bus Interface

23.1 Introduction

The multi-master I2C-bus interface (I2C interface) is a serial communication circuit based on the I2C-bus data transmit/receive format, and is equipped with arbitration lost detect and clock synchronous functions. Table 23.1 lists the Multi-master I2C-bus Interface Specifications, Table 23.2 lists the I2C Interface Detection Function, Figure 23.1 shows the Multi-master I2C-bus Interface Block Diagram, and Table 23.3 lists the I/O Ports.

Table 23.1 Multi-master I2C-bus Interface Specifications

Item	Function
Formats	Based on I2C-bus standard: 7-bit addressing format Fast-mode Standard clock mode
Communication modes	Based on I2C-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	• I2C-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	• I2C-bus interface pin input level select Selectable input level with I2C-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: I2C-bus system clock

Table 23.2 I2C 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.

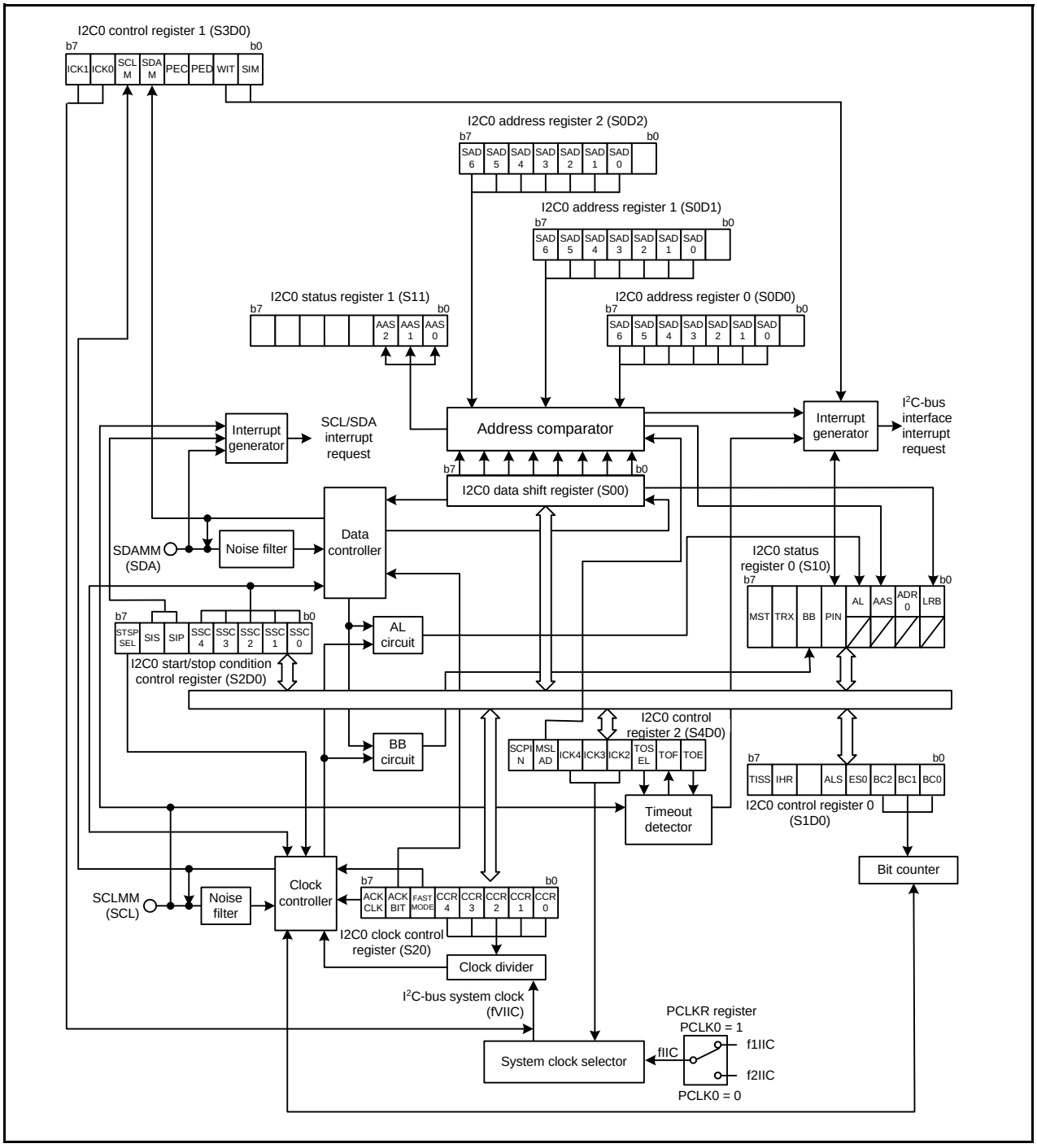


Figure 23.1 Multi-master I2C-bus Interface Block Diagram

Table 23.3 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)

23.2 Registers Descriptions

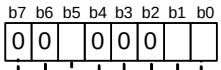
Table 23.4 lists registers associated with multi-master I2C-bus interface. When the CM07 bit in the CM0 register is set to 1 (sub clock is CPU clock), registers listed in Table 23.4 should not be accessed. Set them after the CM07 bit is set to 0 (main clock, PLL clock, or on-chip oscillator clock).

Table 23.4 Registers

Address	Register	Symbol	Reset Value
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
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

23.2.1 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, B and S clock select bit (clock source for timers A, B and S, the dead time timer, and multi-master I2C-bus interface)	0: f2TIMAB/f2IIC/f2TIMS 1: f1TIMAB/f1IIC/f1TIMS	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART5)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function extension bit (valid in single-chip mode)	0: Selected by 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).

23.2.2 I2C0 Data Shift Register (S00)

I2C0 Data Shift Register

b7 b0	Symbol	Address	Reset Value
	S00	02B0h	XXh

Function	RW
Transmit/receive data is stored.	RW

When the I2C interface is a transmitter, write transmit data to the S00 register. When the I2C 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 23.3.2 “Generating a Start Condition” and 23.3.3 “Generating a Stop Condition”.)

Write to the S00 register when the ES0 bit in the S1D0 register is 1 (I2C interface enabled).

Do not write to the S00 register when transmitting/receiving data.

When the I2C 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 I2C 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 23.2 shows Timing to Store Received Data to the S00 Register.

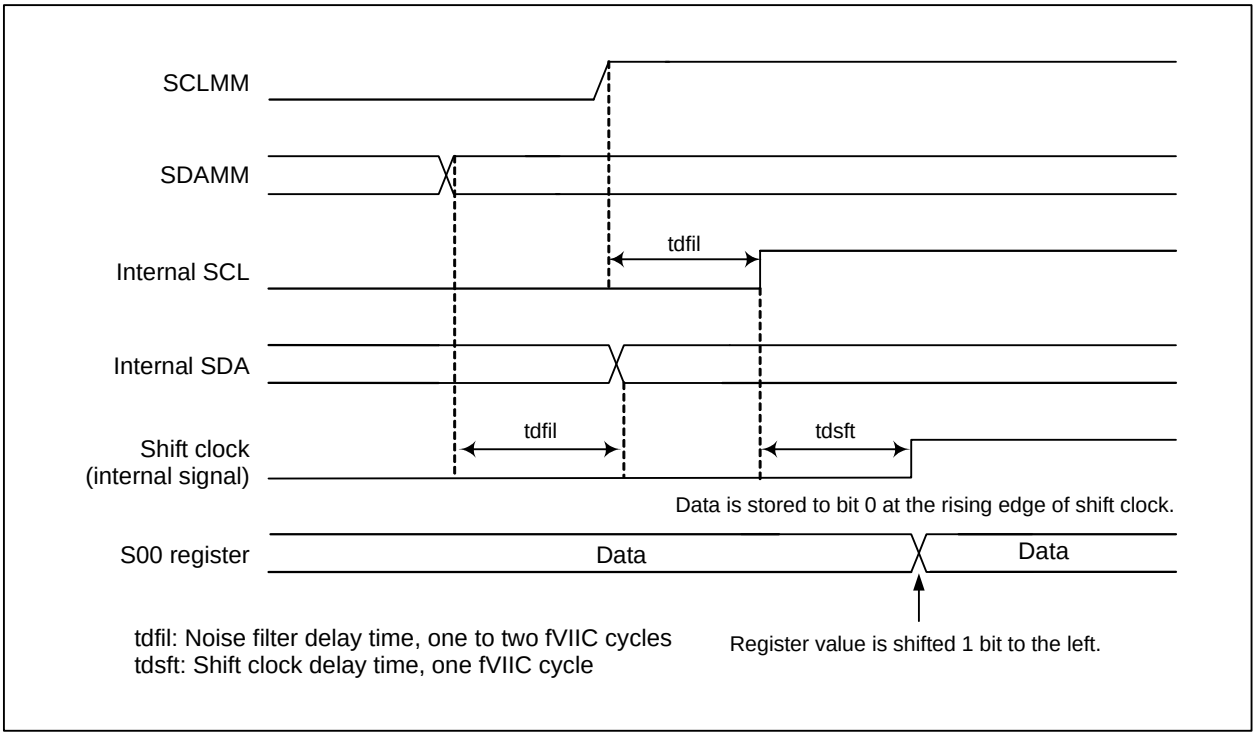
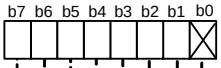


Figure 23.2 Timing to Store Received Data to the S00 Register

23.2.3 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.

23.2.4 I2C0 Control Register 0 (S1D0)

I2C0 Control Register 0

b7	b6	b5	b4	b3	b2	b1	b0
		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 23.3 shows the I2C Interface Reset Timing.

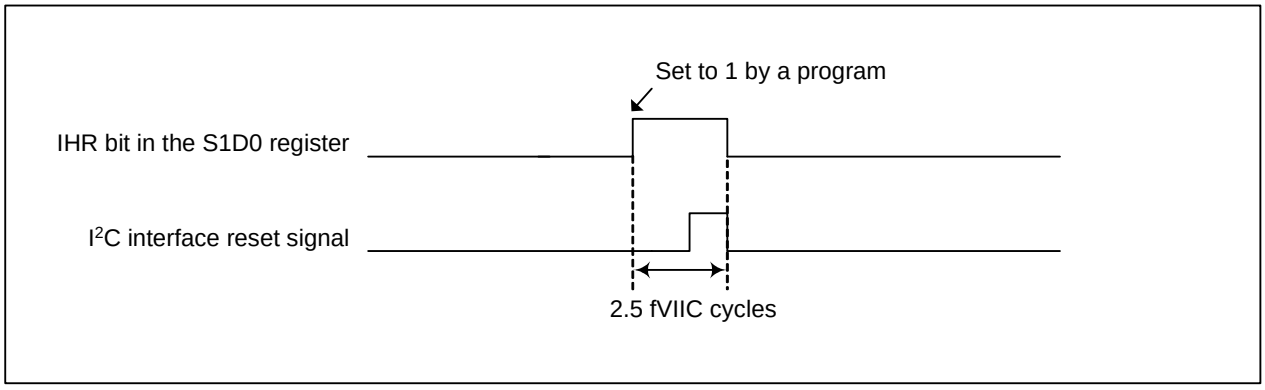


Figure 23.3 I2C Interface Reset Timing

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.

23.2.5 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 23.3.1.2 “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 I2C-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 23.5 lists the SDAMM Pin Level during the ACK Clock Pulse.

Table 23.5 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.

23.2.6 I2C0 Start/Stop Condition Control Register (S2D0)

I2C0 Start/Stop Condition Control Register

b7 b6 b5 b4 b3 b2 b1 b0	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 23.3.7 “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 I2C interface detects the edge selected by the SIP bit for the pin signal selected by the SIS bit. Refer to 23.4 “Interrupts”.

STSPSEL (Start/stop condition generation select bit) (b7)

See Table 23.13 “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).

23.2.7 I2C0 Control Register 1 (S3D0)

I2C0 Control Register 1

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	After Reset
								S3D0	02B6h	0011 0000b

Bit Symbol	Bit Name	Function	RW
SIM	Stop condition detect interrupt enable bit	0: I2C-bus interrupt by stop condition detection is disabled 1: I2C-bus interrupt by stop condition detection is enabled	RW
WIT	Data receive interrupt enable bit	When write, 0: I2C-bus interrupt at 8th clock is disabled 1: I2C-bus interrupt is enabled at 8th clock When read, internal WAIT bit monitor 0: I2C-bus interrupt by falling edge of ACK clock 1: I2C-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	I2C-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 (I2C-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 23.6 lists interrupt request generation timing and the conditions to restart transmission/reception when receiving data. Figure 23.4 shows Interrupt Request Generation Timing in Receive Mode.

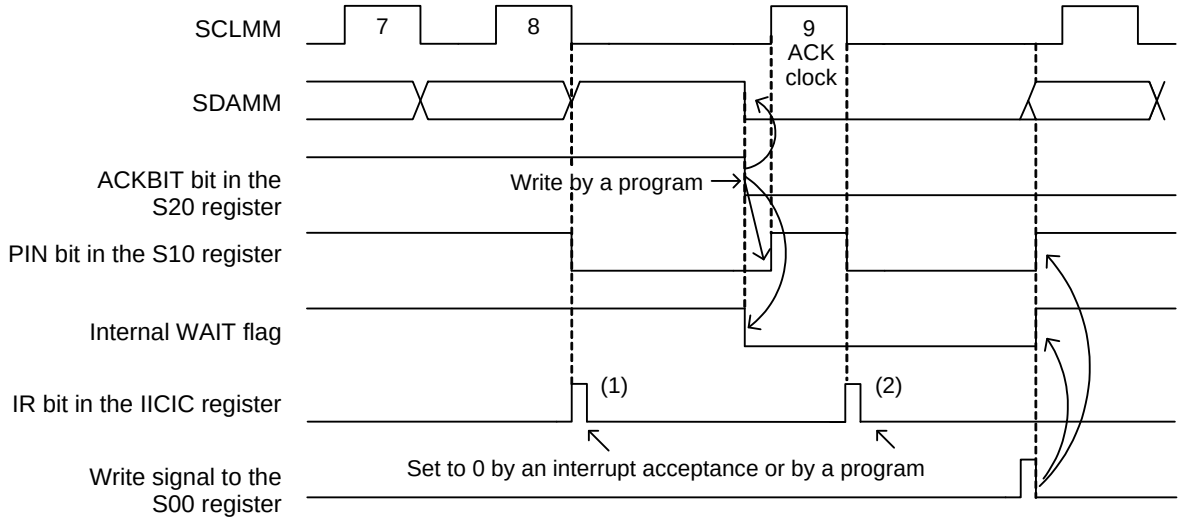
Table 23.6 Generating an Interrupt Request and Restarting Transmission/Reception When Receiving Data

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 23.4.
2. See the timing of (2) on the IR bit in the IICIC register in Figure 23.4.
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:
(I2C-bus interrupt is enabled at eighth clock)



When setting the WIT bit to 0 in receive mode, and the ACK clock is present:
(I2C-bus interrupt is disabled at eighth clock)

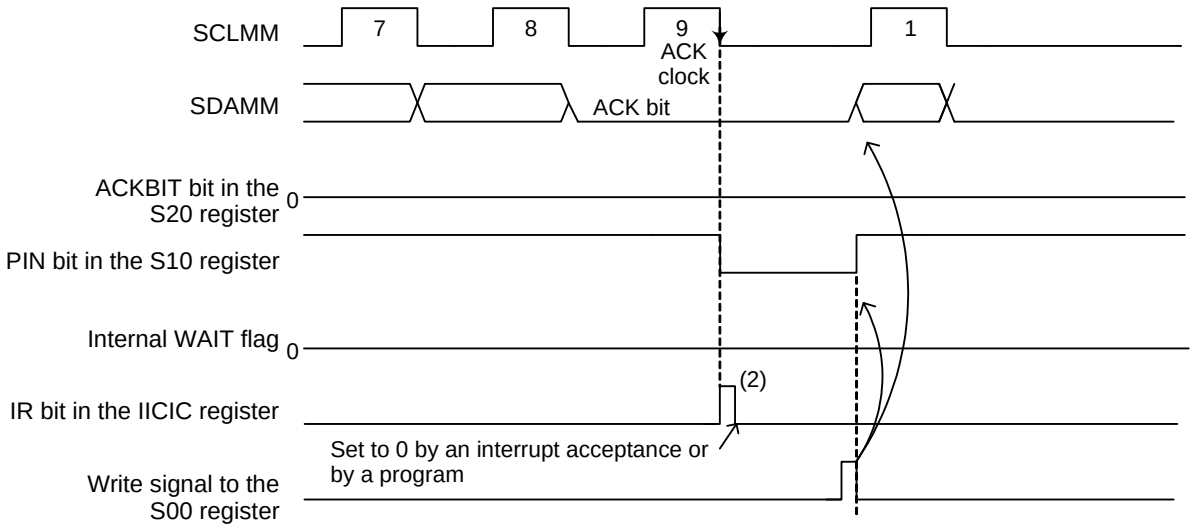


Figure 23.4 Interrupt Request Generation Timing in Receive Mode

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 23.7 lists SCLMM and SDAMM Pin Functions.

Table 23.7 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 23.3.1.2 “Bit Rate and Duty Cycle”.

Table 23.8 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.

23.2.8 I2C0 Control Register 2 (S4D0)

I2C0 Control Register 2

b7	b6	b5	b4	b3	b2	b1	b0

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 23.3.9 “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)

$$65536 \times \frac{1}{fVIIC}$$

When the TOSEL bit is set to 1 (short time)

$$16384 \times \frac{1}{fVIIC}$$

Table 23.9 lists Timeout Detect Time.

Table 23.9 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 23.8 “I2C-bus System Clock Select Bits” and 23.3.1.2 “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.)

23.2.9 I2C0 Status Register 0 (S10)

I2C0 Status Register 0

b7	b6	b5	b4	b3	b2	b1	b0	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 23.10 “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 23.10 “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 23.10 “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 23.10 “Functions Enabled by Writing to the S10 Register”	RW
PIN	I2C-bus interface interrupt request bit	When read, 0: Interrupt requested 1: Interrupt not requested When write, see Table 23.10 “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 23.10 “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 I2C 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 23.10 lists Functions Enabled by Writing to the S10 Register. Only set the values listed in Table 23.10. If the values listed in Table 23.10 are written to the S10 register, the 6 lower bits in the S10 register will not be changed.

Table 23.10 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 23.3.2 “Generating a Start Condition” and 23.3.3 “Generating a Stop Condition” for start/stop conditions.

LRB (Last receive bit) (b0)

When read, the LRB bit functions as described below. See Table 23.10 “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 23.10 “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 23.10 “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 23.10 “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 (I2C-bus interface interrupt request bit) (b4)

The PIN bit function in read access is described below. See Table 23.10 “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 (I2C-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 (I2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I2C interface reset).

The IR bit in the IICIC register becomes 1 (interrupt requested) as soon as the PIN bit becomes 0 (I2C-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 23.10 “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 (I2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I2C 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:

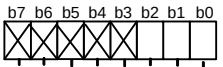
- The MST bit is set to 0 by a program.
- The 1-byte data that lost arbitration is completed transmitting/receiving when arbitration lost is detected.
- Stop condition is detected.
- Start condition overlap protect function is enabled.
- The ES0 bit in the S1D0 register is 0 (I2C interface disabled).
- 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.

23.2.10 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)

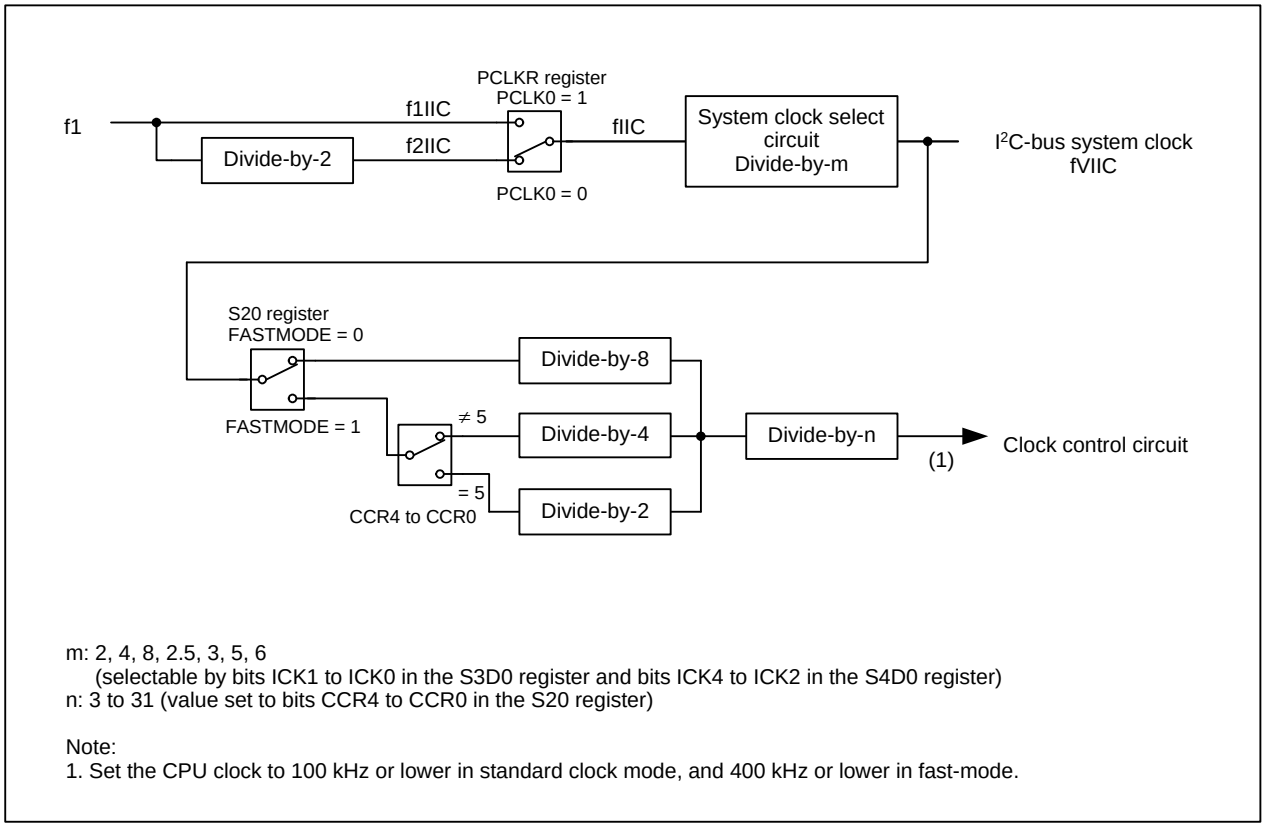
When the ALS bit in the S1D0 register is 0 (addressing format), any slave address stored in bits SAD6 to SAD0 in the S0Di register (i = 0 to 2) is compared with the received slave address. The compare result is shown in the AASi bit. The AASi bit becomes 1 when there is an address match or when a general 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.

23.3 Operations

23.3.1 Clock

Figure 23.5 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 23.5 I2C-bus Interface Clock

23.3.1.1 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 23.8 “I2C-bus System Clock Select Bits” for details.

23.3.1.2 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 23.11 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 23.11 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)	$\frac{fVIIC}{8 \times CCR\ value}$	$\frac{fVIIC}{4 \times CCR\ value}$	$\frac{fVIIC}{2 \times CCRvalue} = \frac{fVIIC}{10}$
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:

$$\frac{fVIIC}{2 \times CCR\ value} = \frac{fVIIC}{10}$$

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 23.12 lists the Bit Setting for Bits CCR4 to CCR0 and Bit Rate (fVIIC = 4 MHz).

Table 23.12 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.

23.3.1.3 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.

23.3.2 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 23.6 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).

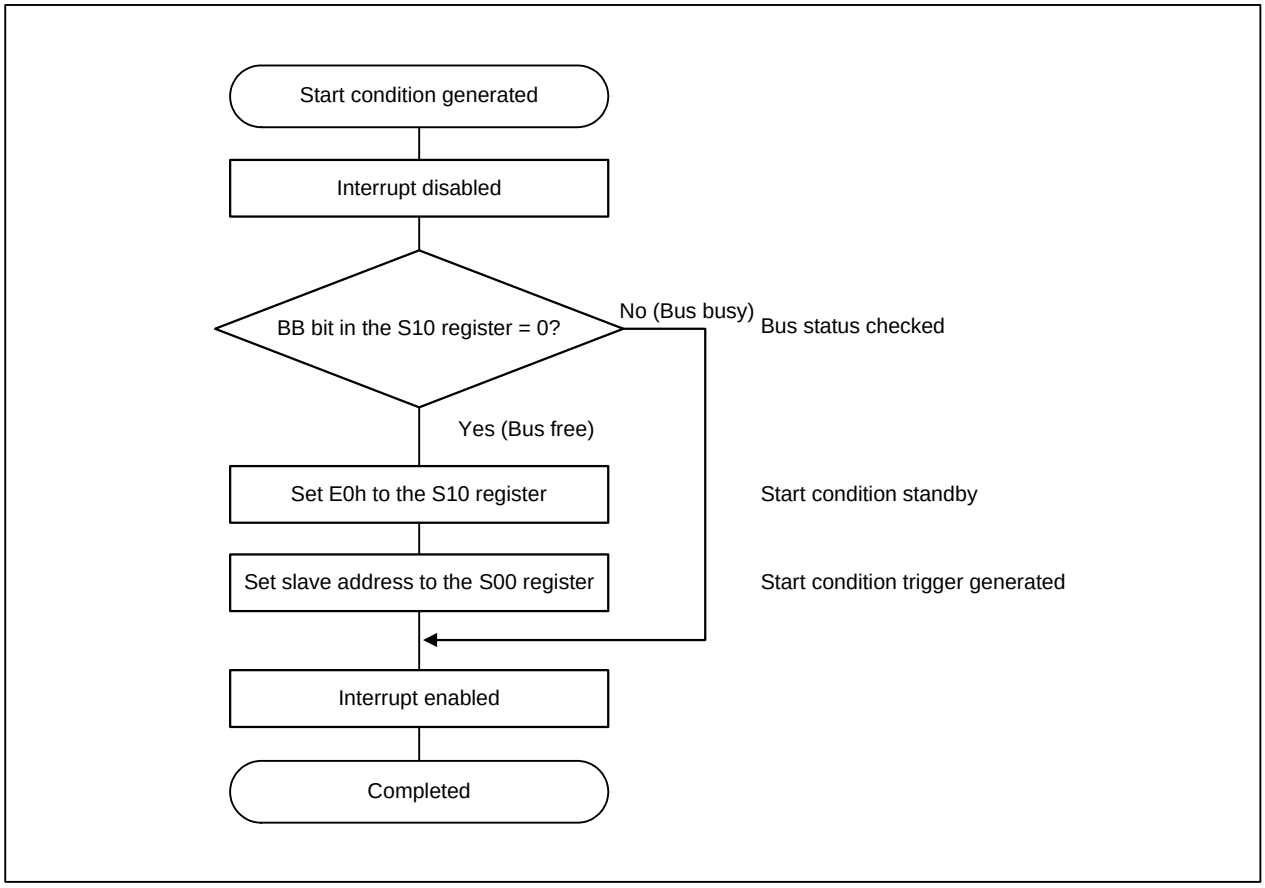


Figure 23.6 Procedure to Generate a Start Condition

The start condition generation timing depends on the modes - standard clock mode or fast-mode. Figure 23.7 shows the Start Condition Generation Timing.
Table 23.13 lists the Setup/Hold Time for Generating a Start/Stop Condition.

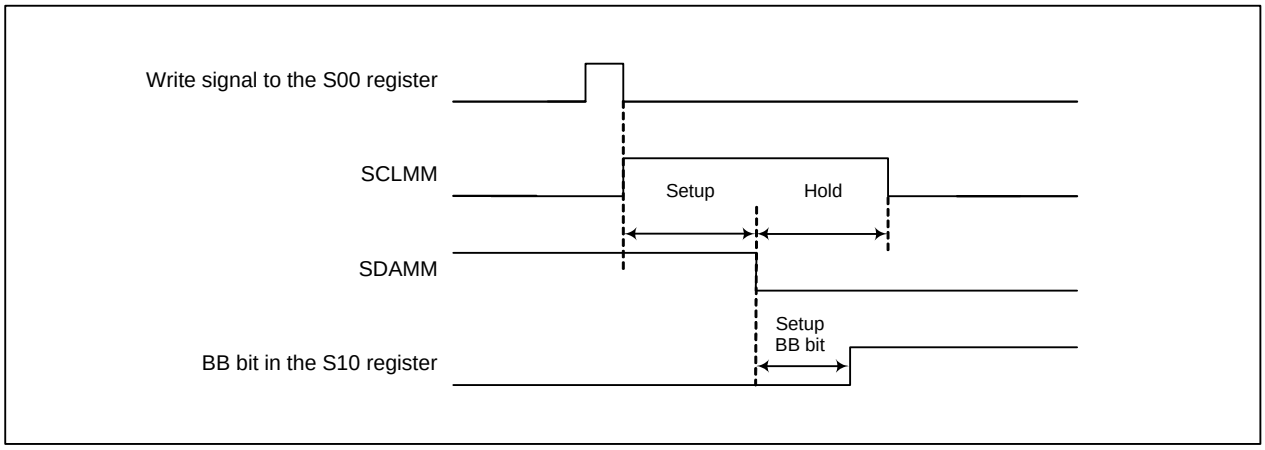


Figure 23.7 Start Condition Generation Timing

Table 23.13 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.

23.3.3 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 23.8 shows the Stop Condition Generation Timing. See Table 23.13 “Setup/Hold Time for Generating a Start/Stop Condition” for setup/hold time.

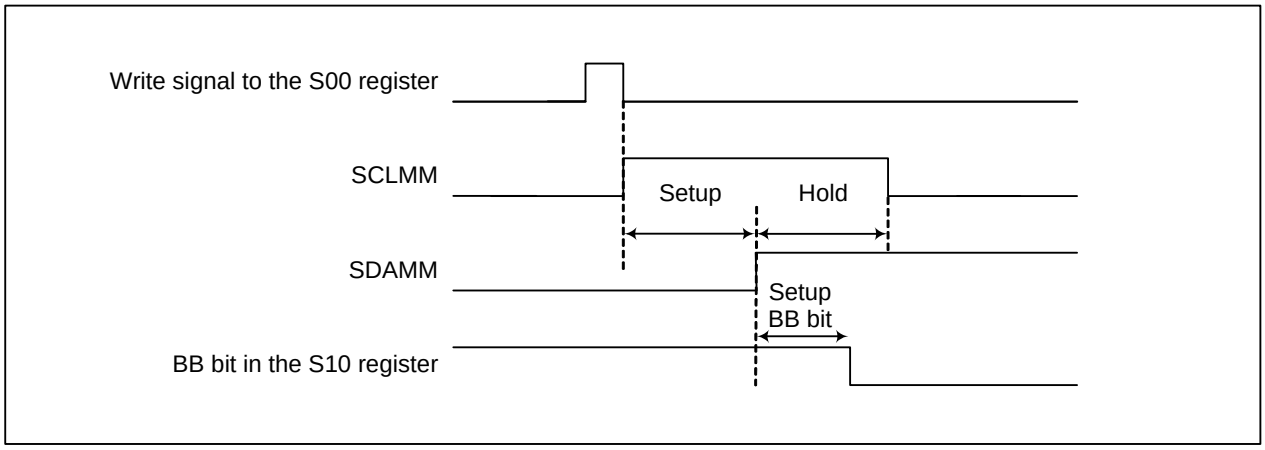


Figure 23.8 Stop Condition Generation Timing

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).

23.3.4 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 23.9 shows the Restart Condition Generation Timing.

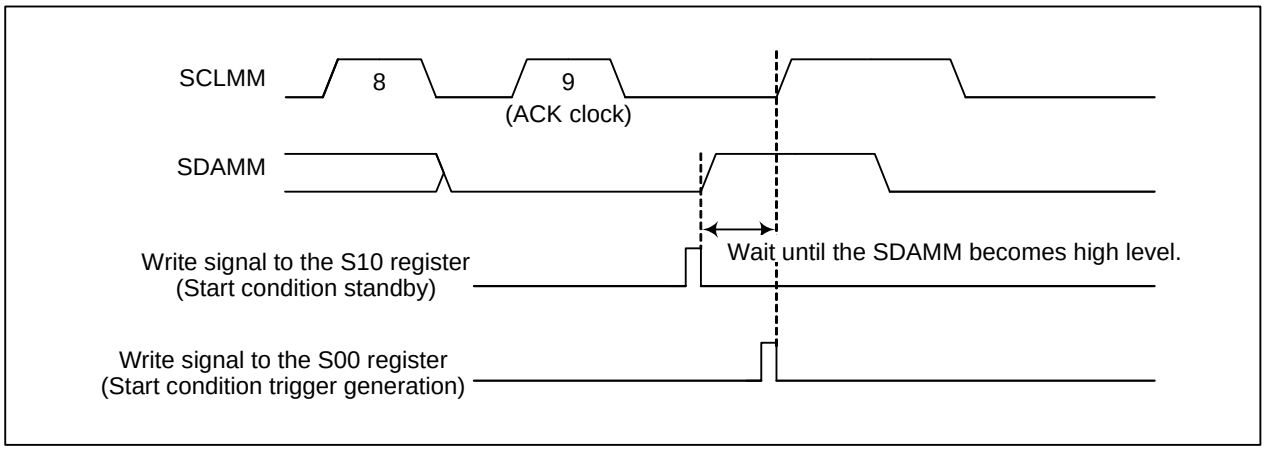


Figure 23.9 Restart Condition Generation Timing

23.3.5 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 23.10 shows the Start Condition Overlap Protect Operation.

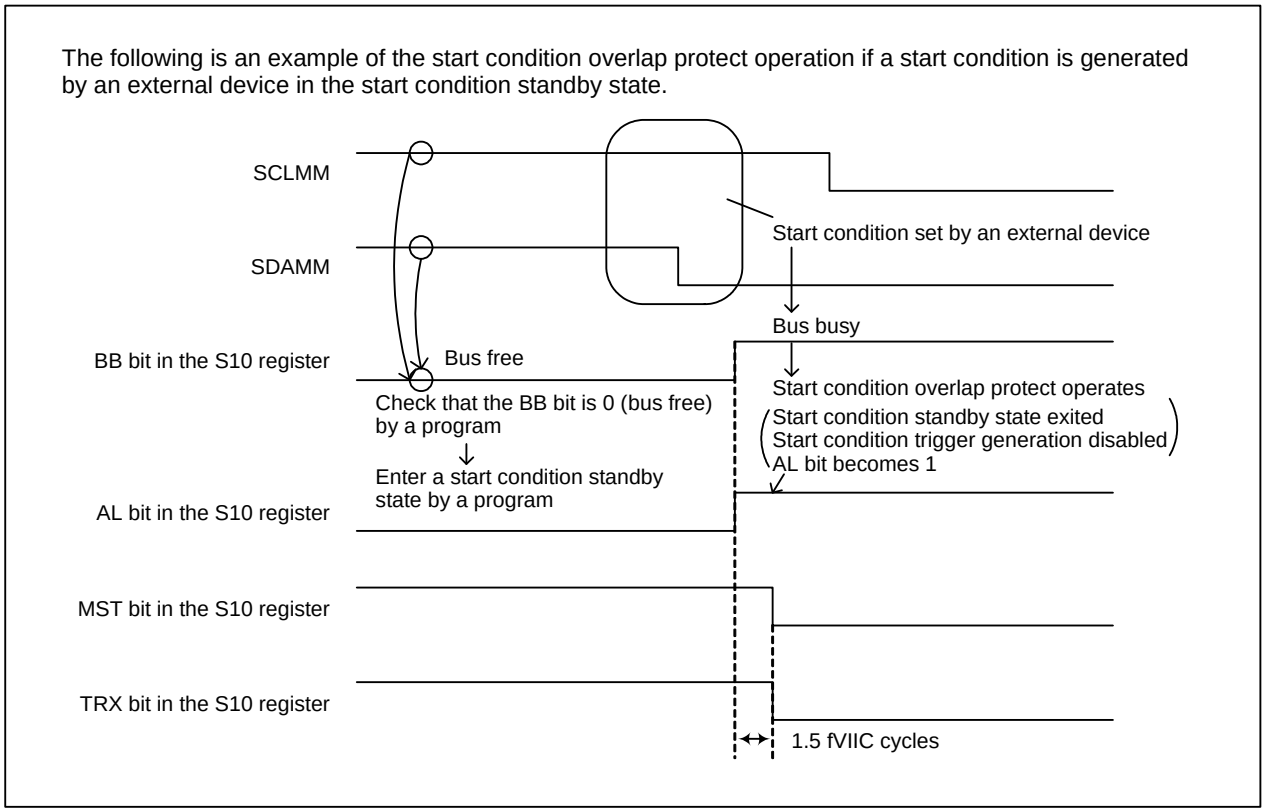


Figure 23.10 Start Condition Overlap Protect Operation

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 23.11 shows the Start Condition Overlap Protect Function Enable Period.

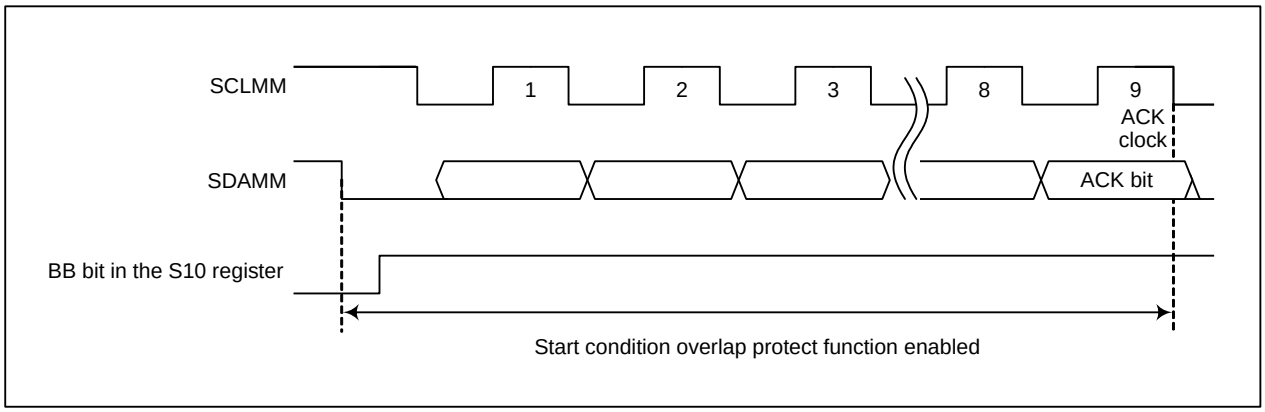


Figure 23.11 Start Condition Overlap Protect Function Enable Period

23.3.6 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 23.12 shows Operation Example When Arbitration Lost is Detected.

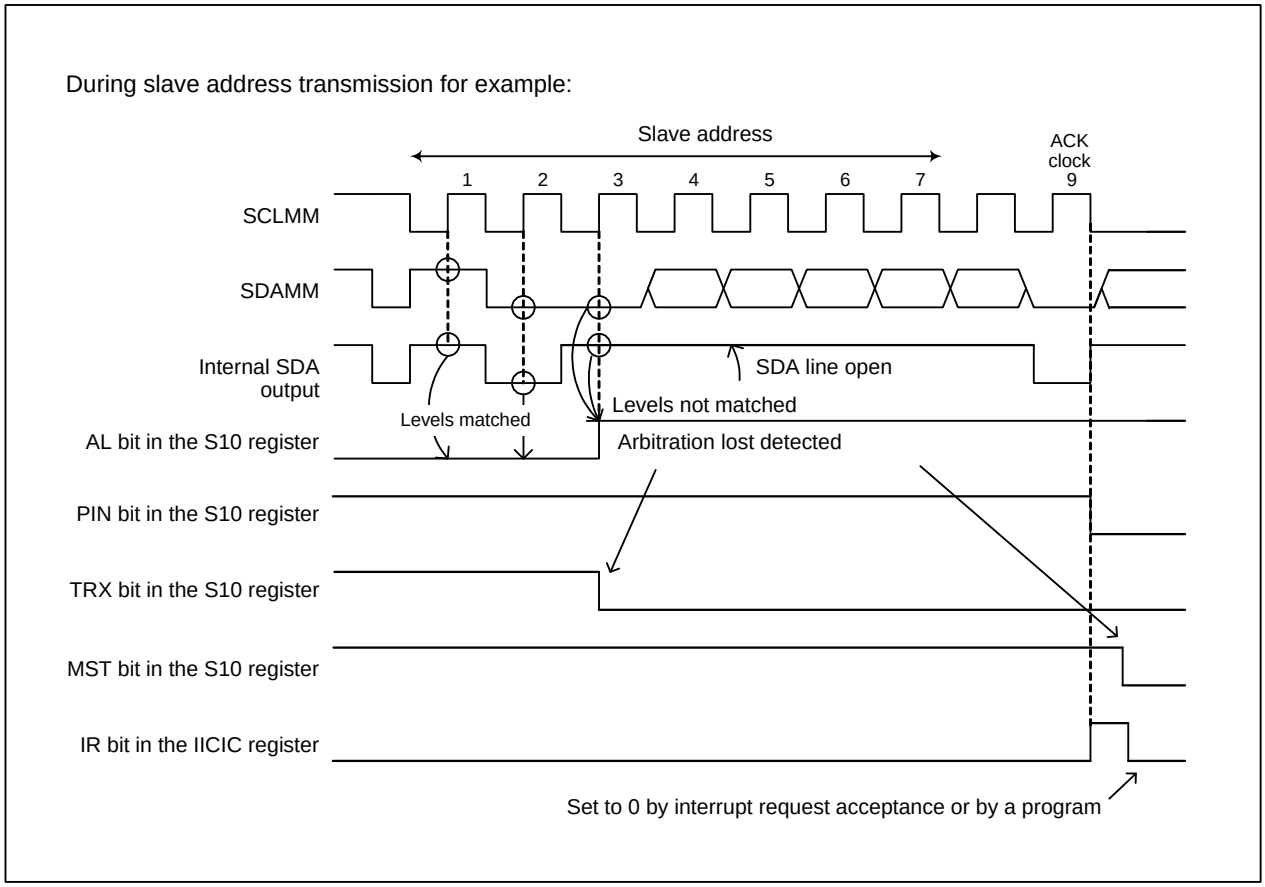


Figure 23.12 Operation Example When Arbitration Lost is Detected

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.

23.3.7 Detecting Start/Stop Conditions

Figure 23.13 shows Start Condition Detection, Figure 23.14 shows Stop Condition Detection, and Table 23.14 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 23.14.

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 23.15.

Table 23.15 lists the Recommended Values of Bits SSC4 to SSC0 in Standard Clock Mode.

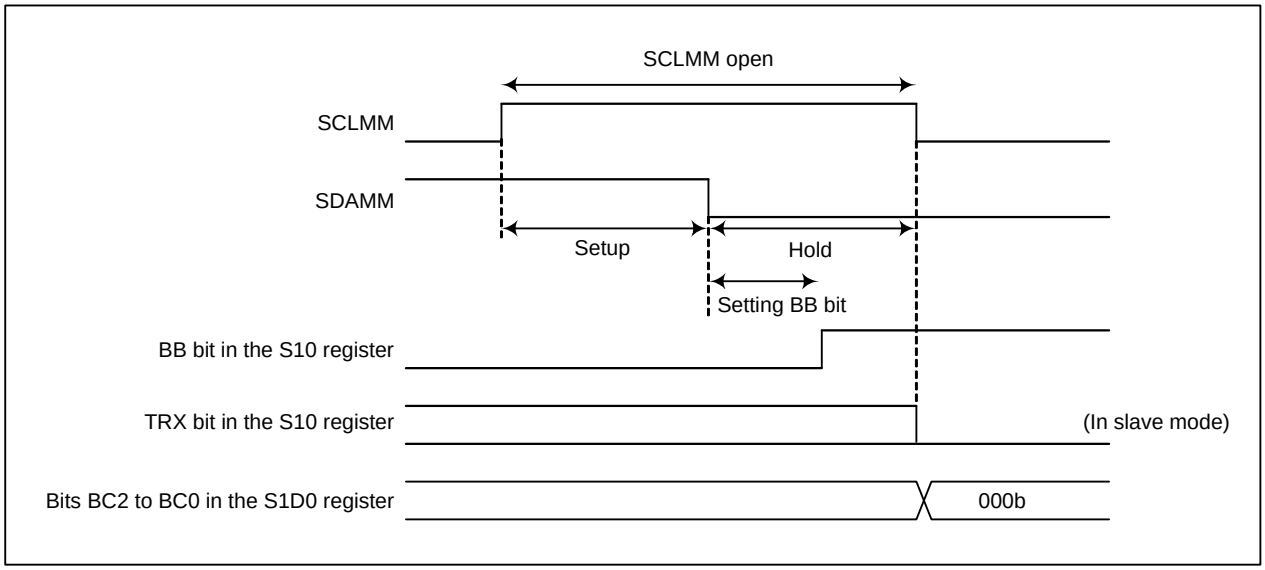


Figure 23.13 Start Condition Detection

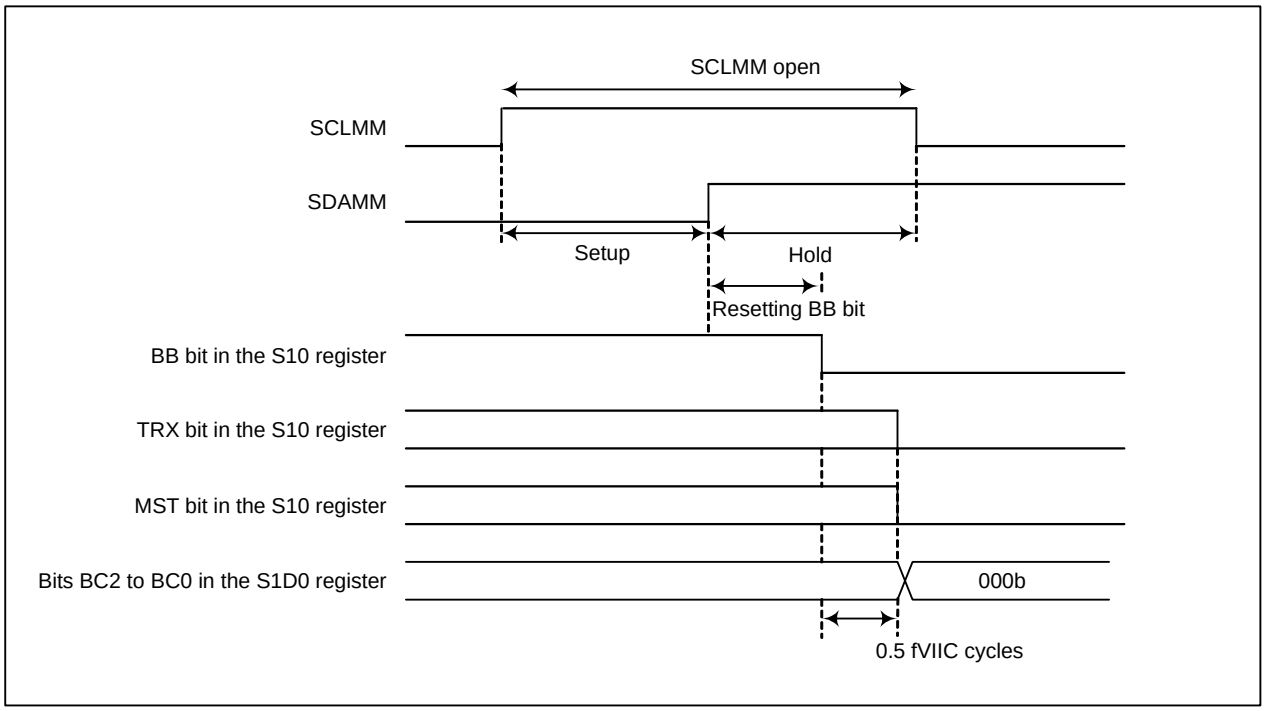


Figure 23.14 Stop Condition Detection

Table 23.14 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 23.15 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

23.3.8 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 23.15 shows Operation When Transmitted/Received a Slave Address or Data.

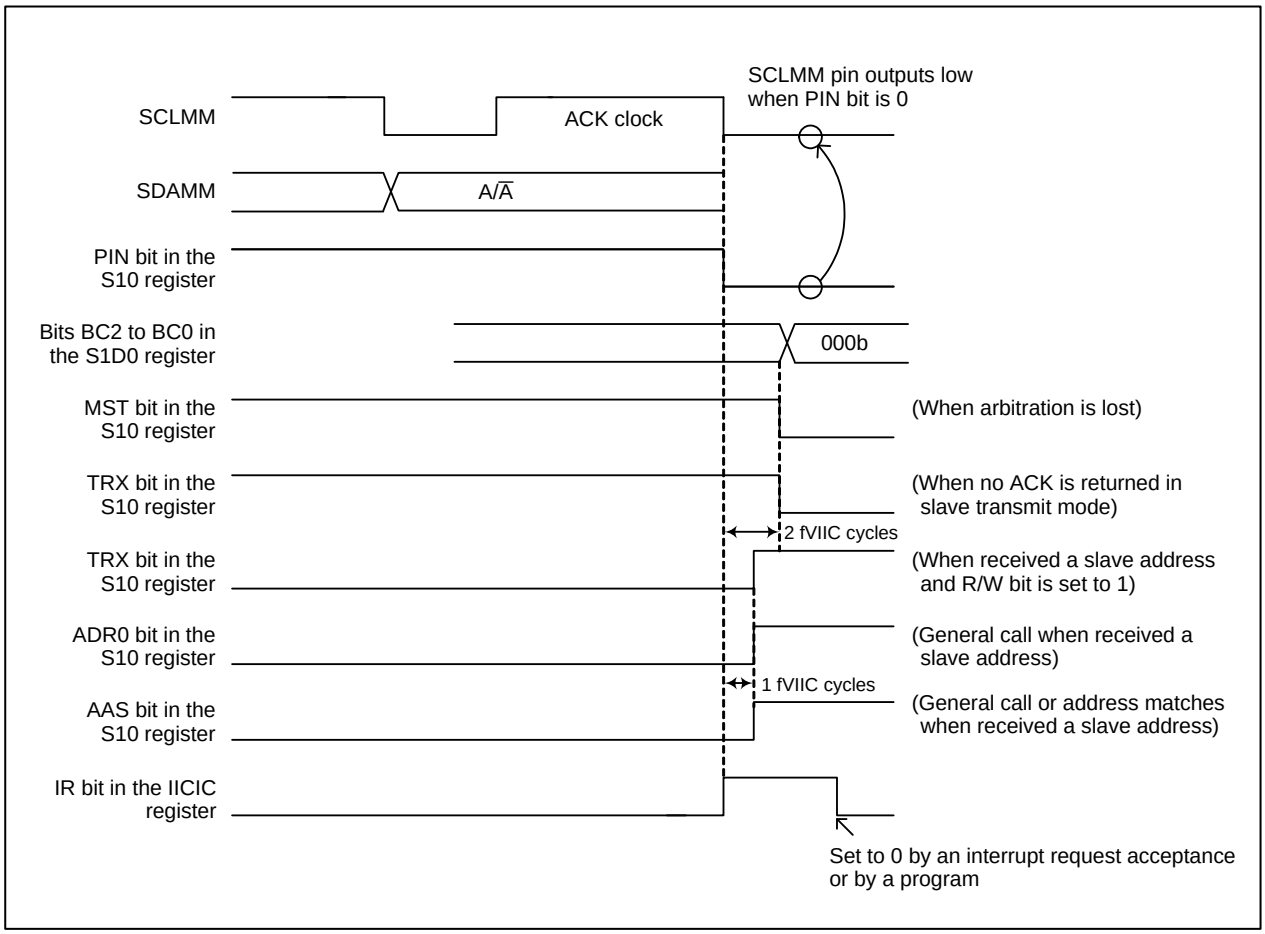


Figure 23.15 Operation When Transmitted/Received a Slave Address or Data

23.3.9 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 23.16 shows the Timeout Detection Timing. Refer to “TOSEL (Timeout Detection Period Select Bit) (b2)” in 23.2.8 “I2C0 Control Register 2 (S4D0)” for the timeout detection period.

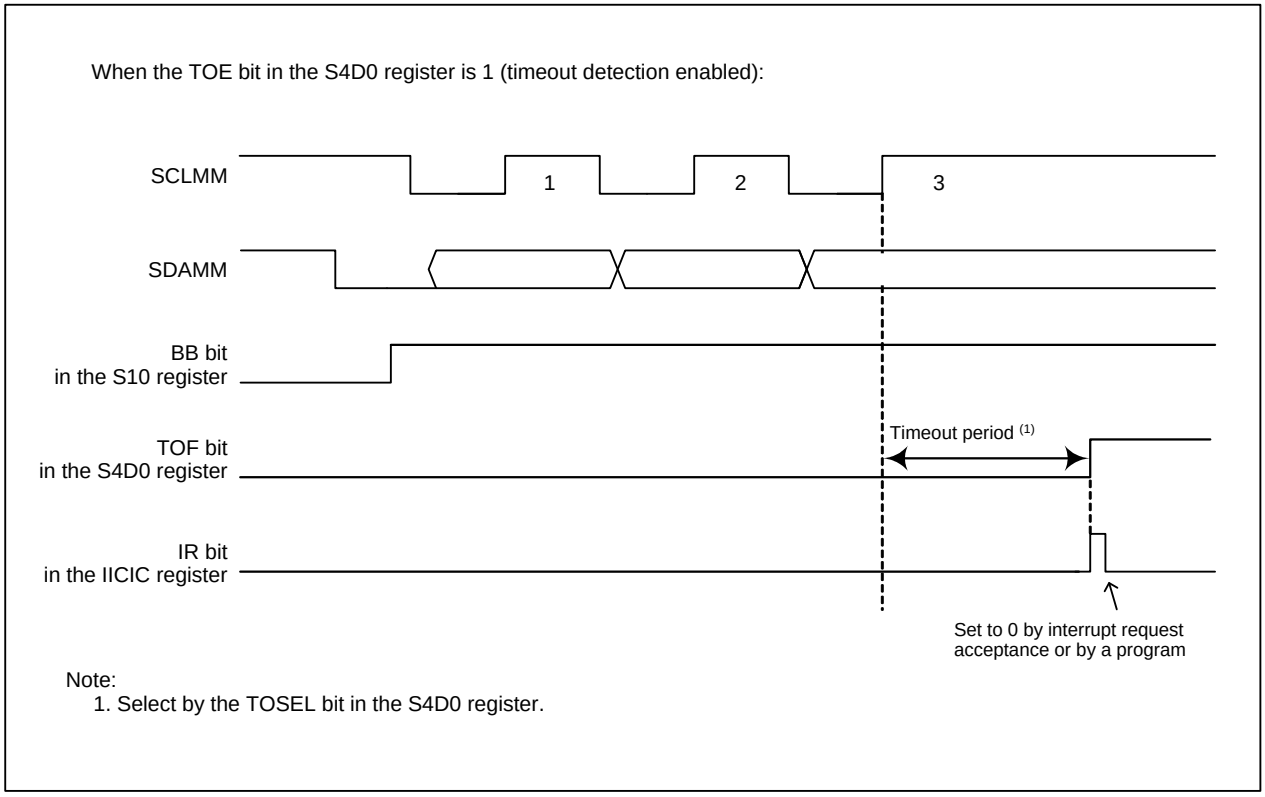


Figure 23.16 Timeout Detection Timing

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).

23.3.10 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, I2C-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 I2C-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.

23.3.10.1 Initial Settings

Follow the initial setting procedures below for 23.3.10.2 to 23.3.10.5.

(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 I2C-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, I2C interface enabled, addressing format, input level: I2C-bus input).

If the MCU uses a single-master system and it is a master, start the initial setting procedures from step (2).

23.3.10.2 Master Transmission

Master transmission is described in this section. The initial settings described in 23.3.10.1 “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 23.17, respectively.

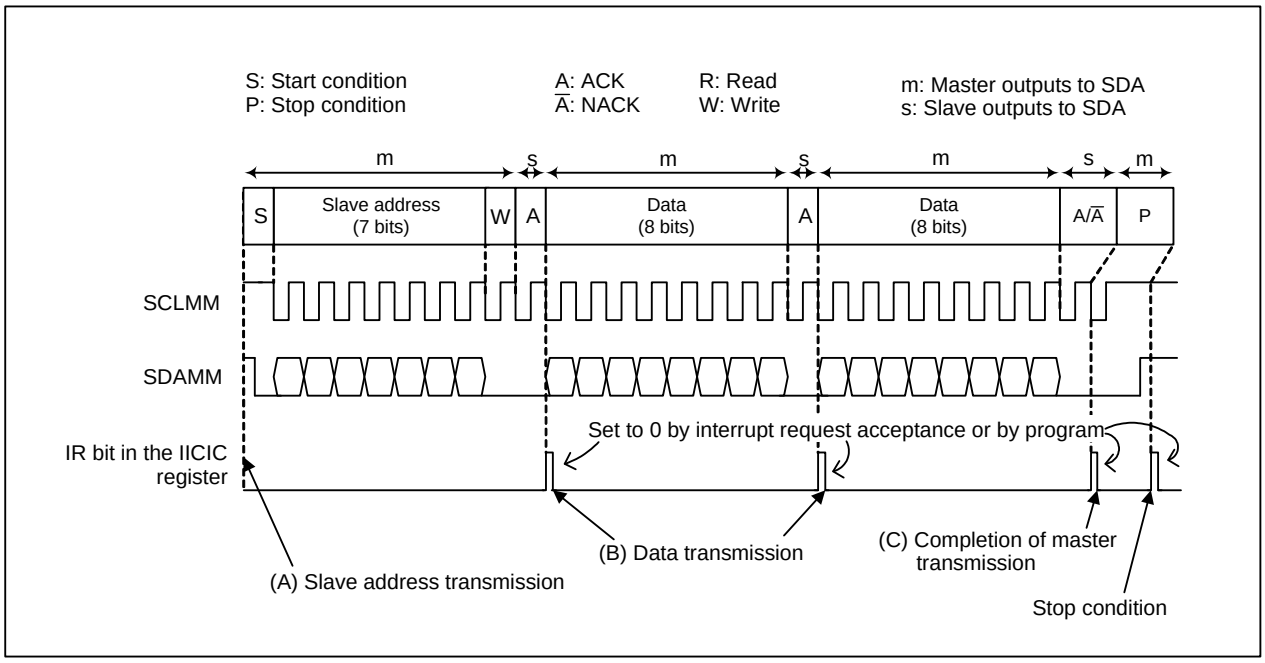


Figure 23.17 Example of Master Transmission

(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.

23.3.10.3 Master Reception

Master reception is described in this section. The initial settings described in 23.3.10.1 “Initial Settings” are assumed to be completed. Figure 23.18 shows the operation example of master reception. The following programs (A) to (D) are executed at (A) to (D) in Figure 23.18, respectively.

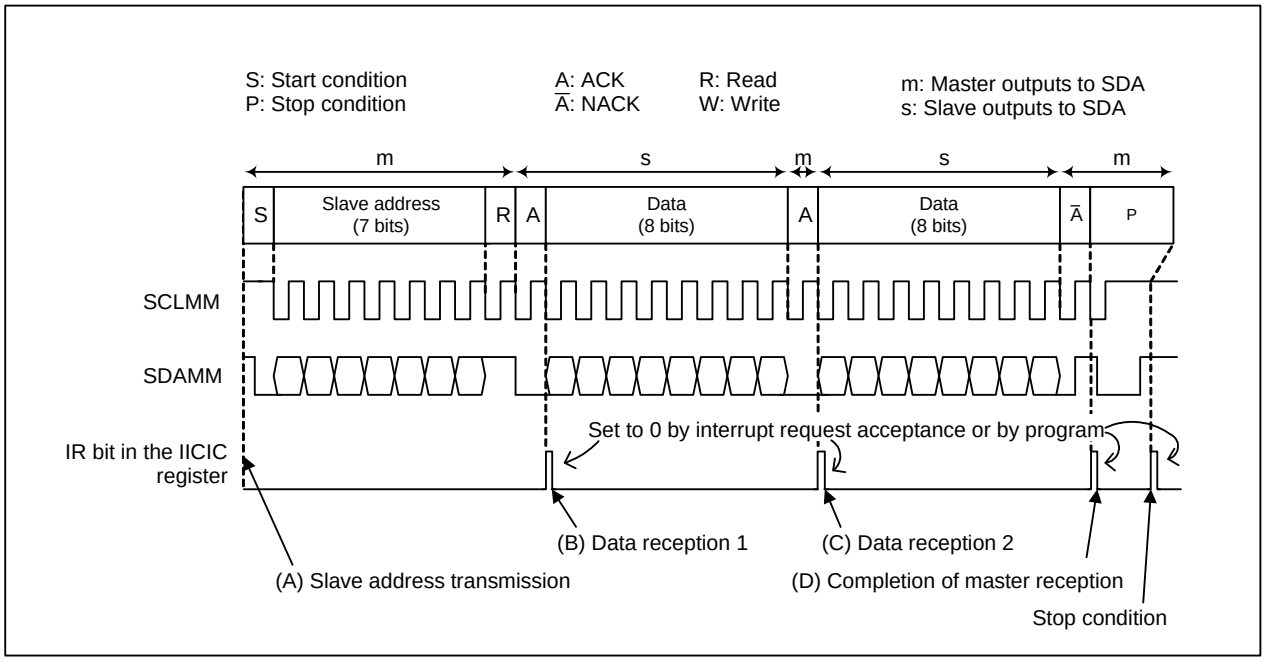


Figure 23.18 Example of Master Reception

(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).

23.3.10.4 Slave Reception

The slave reception is described in this section. The initial settings described in 223.3.10.1 “Initial Settings” are assumed to be completed. Figure 23.19 shows the example of slave reception. The following programs (A) to (C) are executed at (A) to (C) in Figure 23.19, respectively.

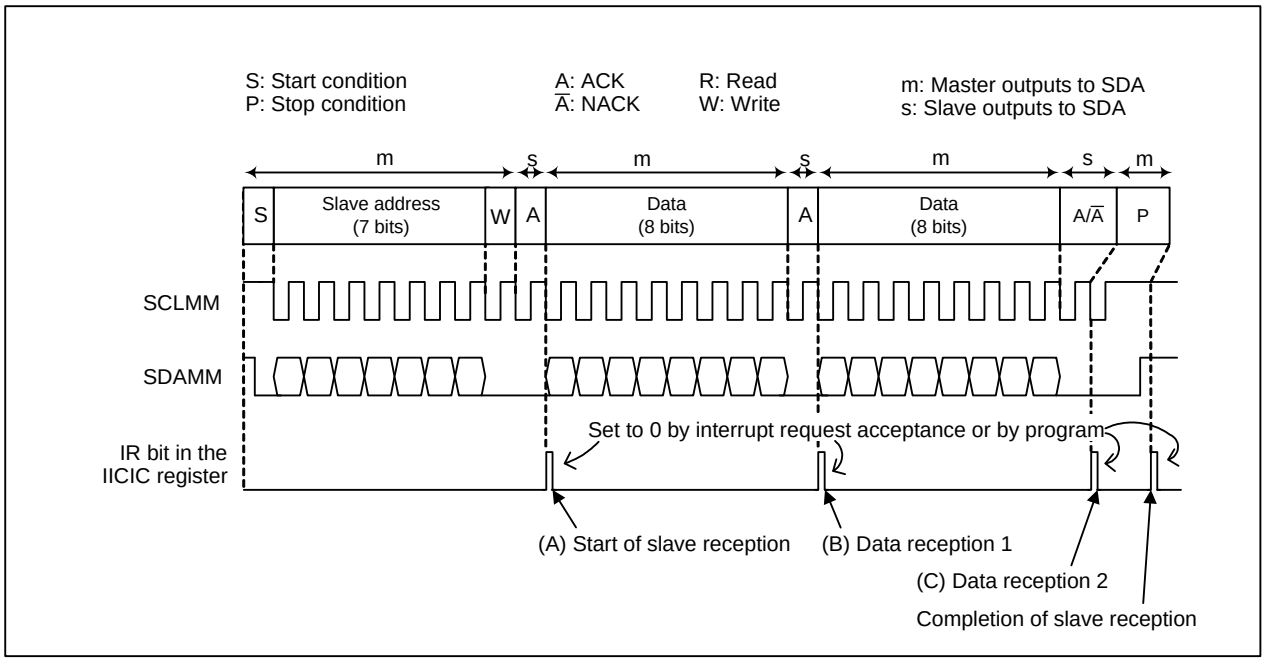


Figure 23.19 Example of Slave Reception

(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.

23.3.10.5 Slave Transmission

Slave transmission is described in this section. The initial settings described in 23.3.10.1 “Initial Settings” are assumed to be completed. Figure 23.20 shows the example of slave transmission. The following programs (A) to (B) are executed at (A) and (B) in Figure 23.20, 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.

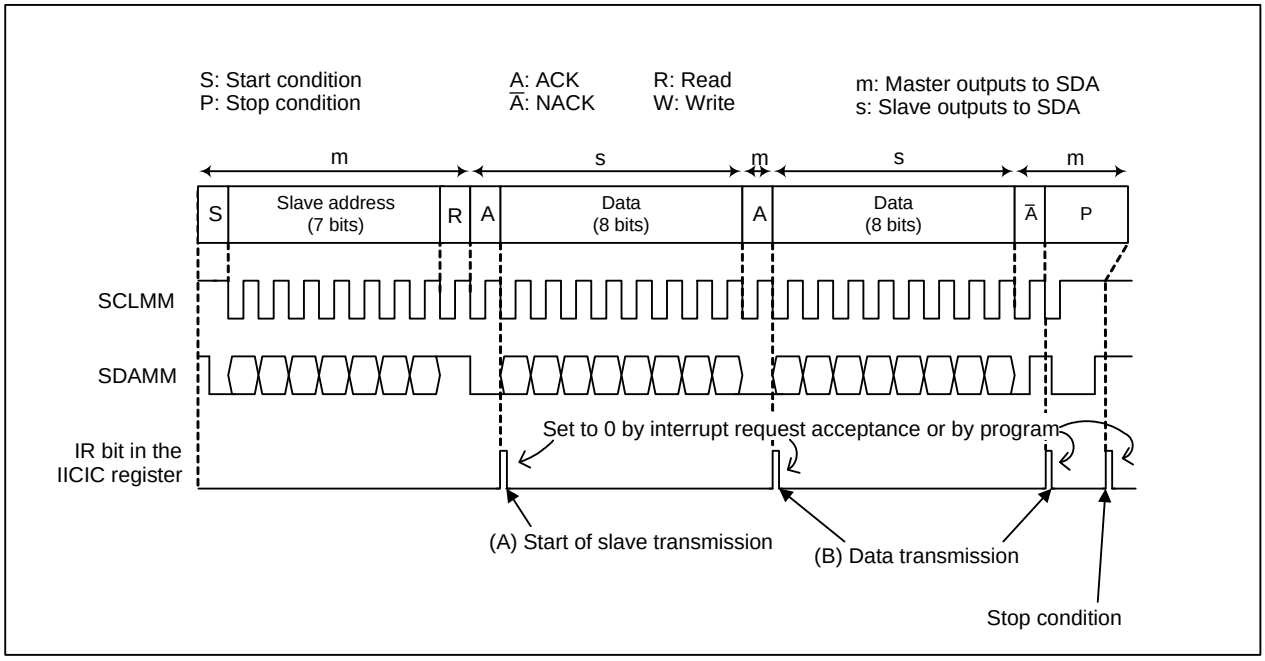


Figure 23.20 Example of Slave Transmission

(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.

23.4 Interrupts

The I2C interface generates interrupt requests. Figure 23.21 shows I2C Interface Interrupts, and Table 23.16 lists I2C-bus Interrupts.

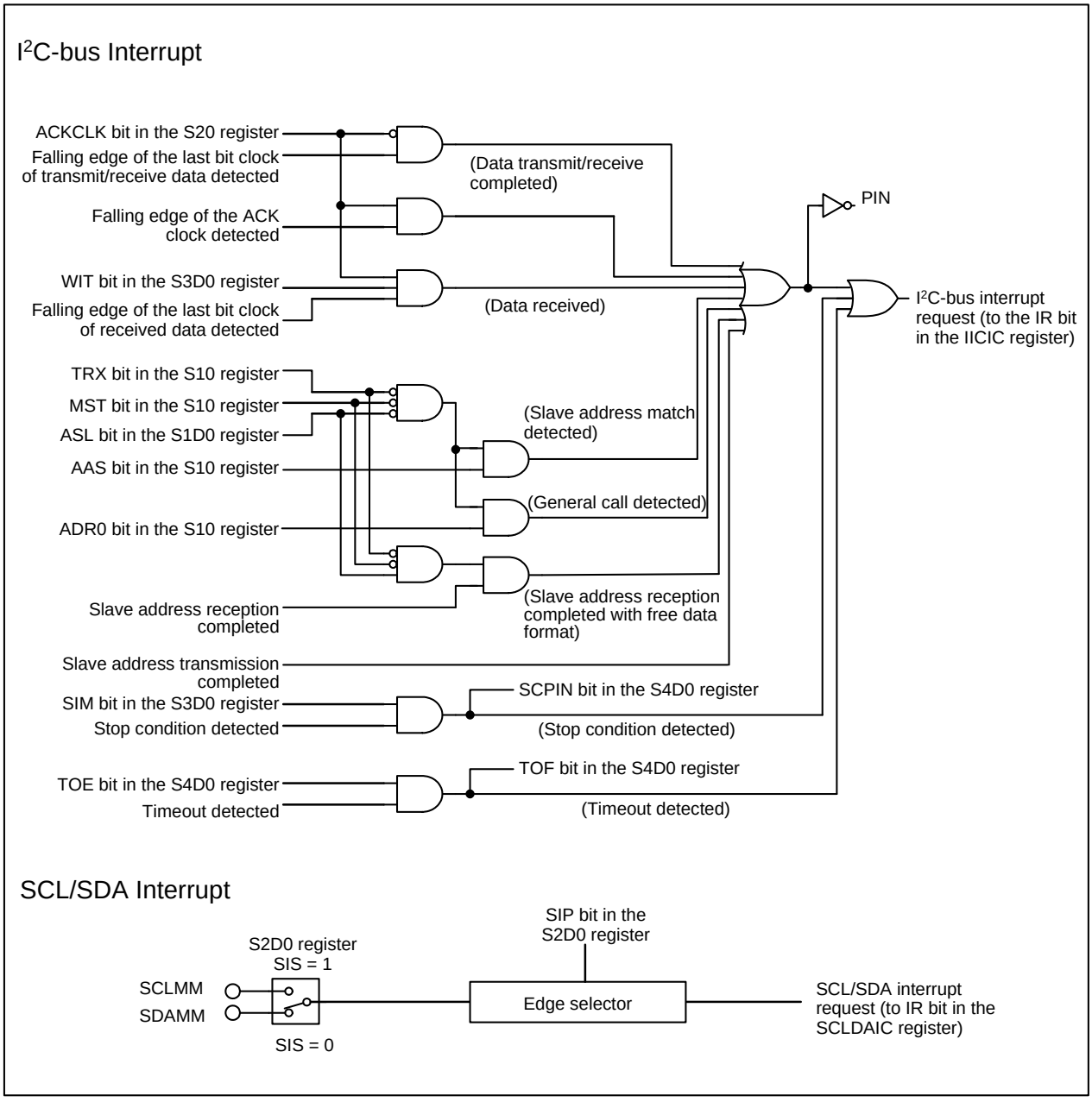


Figure 23.21 I2C Interface Interrupts

Table 23.16 I2C-bus Interrupts

Interrupt	Interrupt Source	Associated Bits (Register)		Interrupt Control Register
		Interrupt enabled	Interrupt request	
I2C-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 23.17 lists Registers Associated with I2C Interface Interrupts.

Table 23.17 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).

23.5 Notes on Multi-master I2C-bus Interface

23.5.1 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 23.4 “Registers”. Set the CM07 bit to 0 (main clock, PLL clock, or on-chip oscillator clock) to access these registers.

23.5.2 Register Access

Refer to the notes below when accessing the I2C 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.

23.5.2.1 S00 Register

Do not write to the S00 register during transmission/reception.

23.5.2.2 S1D0 Register

Do not change bits other than the IHR bit in the S1D0 register during transmission/reception.

23.5.2.3 S20 Register

Do not change bits other than the ACKBIT bit in the S20 register during transmission/reception.

23.5.2.4 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 (I2C interface disabled).

23.5.2.5 S4D0 Register

Rewrite bits ICK4 to ICK2 when the ES0 bit in the S1D0 register is 0 (I2C interface disabled).

23.5.2.6 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 23.3 “Operations” for bits MST and TRX change.

23.5.3 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 I2C-bus specification.
Refer to the recommended operating conditions for I/O ports which share the pins with SCL and SDA.

I2C-bus specification

High level input voltage (V_{IH}) = min. 0.7 V_{CC}

Low level input voltage (V_{IL}) = max. 0.3 V_{CC}

24. USB Function

24.1 Introduction

The universal serial bus (USB) module transmits/receives data based on the universal serial bus specification Rev. 2.0. It can be used when VCC1 ≥ 3.0 V. Table 24.1 lists USB Specifications, Table 24.2 lists Endpoint Configuration, Figure 24.1 shows USB Block Diagram, and Table 24.3 lists I/O Pins.

Table 24.1 USB Specifications

Item	Specification
USB specification	USB 2.0 compliant Full speed (12 Mbps)
Endpoint	7 (control IN/OUT, bulk IN × 2, bulk OUT × 2, interrupt IN × 2)
Transfer mode	3 (control transfer, bulk transfer, interrupt transfer)
FIFO buffer	584 bytes (see Table 24.2 “Endpoint Configuration”.)
Interrupt request generation request source	• USB bus reset detection • Completion of endpoint information setting (loading complete) • Suspend or resume detection • Detection of Set Configuration command • Detection of Set Interface command • Detection of USB bus connection or disconnection • SOF packet detection • Completion of setup command reception • Endpoint 0 Completion of data reception, data transfer request, or completion of data transmission • Endpoint 1 Receive FIFO buffer full • Endpoint 2 At least one layer is empty in transmit FIFO buffer, both layers are empty in transmit FIFO buffer, or data transfer request to the transmit FIFO buffer • Endpoint 3 Completion of data transmission, or data transfer request to the transmit FIFO buffer • Endpoint 4 Receive FIFO buffer full • Endpoint 5 At least one layer is empty in the transmit FIFO buffer, both layers are empty in the transmit FIFO buffer, or data transfer request to the transmit FIFO buffer • Endpoint 6 Transmission completion, or data transfer request to the transmit FIFO buffer
DMA transfer	• Endpoint 1, endpoint 4 DMA request is generated when data is in the receive FIFO buffer. • Endpoint 2, endpoint 5 DMA request is generated when at least one layer of the transmit FIFO buffer is empty.
Selectable function	• Self-power mode or bus-power mode selectable

Table 24.2 Endpoint Configuration

Endpoint	Transfer Type	Maximum Packet Size (bytes)	FIFO Buffer Capacity (bytes)	DMA Transfer
Endpoint 0	Setup	8	8	—
	Control IN	16	16	—
	Control OUT	16	16	—
Endpoint 1	Bulk OUT	64	64 × 2	Available
Endpoint 2	Bulk IN	64	64 × 2	Available
Endpoint 3	Interrupt IN	16	16	—
Endpoint 4	Bulk OUT	64	64 × 2	Available
Endpoint 5	Bulk IN	64	64 × 2	Available
Endpoint 6	Interrupt IN	16	16	—

Note:
1. For endpoints 1 to 6, 0 to 1 can be selected as Configuration and 0 to 3 can be selected as Interface. Set Alternate to 0.

Table 24.3 I/O Pins

Pin Name	I/O	Function
ATTACH	Output (1)	Output used for D+ 1.5 kΩ pull-up (external)
VbusDTCT	Input (1)	Input the power supply signal from the host
UVCC	I/O (2)	Input power supply for pins ATTACH, D+, and D-
D+	I/O (1)	USB D+ I/O
D-	I/O (1)	USB D- I/O

Notes:
1. Set 0 (input mode) to the direction register corresponding to the selected pin.
2. Apply 3.3 V to the pin when using the USB module without using internal power for the USB module.

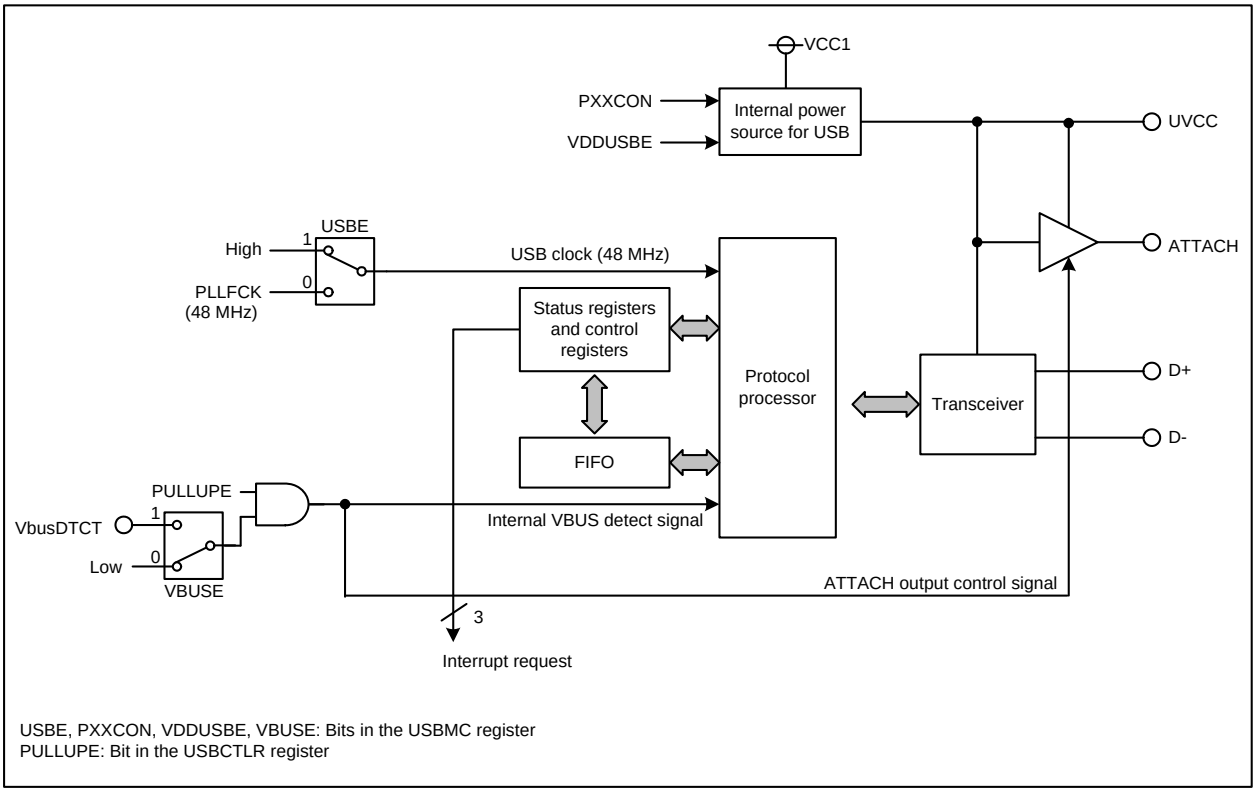


Figure 24.1 USB Block Diagram

24.2 Registers

Access the registers in Table 24.4 in 8-bit units - do not access these registers in 16-bit units. Registers other than the USBMC register can be accessed successfully when the USBE bit in the USBMC register is set to 0 (USB clock supplied) and the USBSTS bit in the USBMC register is set to 0 (USB module enabled).

Table 24.4 Registers

Address	Register	Symbol	Reset Value
D100h	USB Interrupt Flag Register 0	USBIFR0	00h
D101h	USB Interrupt Flag Register 1	USBIFR1	XXX0 0000b
D102h	USB Interrupt Flag Register 2	USBIFR2	XX00 0110b
D103h	USB Interrupt Flag Register 3	USBIFR3	XX00 0110b
D108h	USB Interrupt Enable Register 0	USBIER0	0000 00X0b
D109h	USB Interrupt Enable Register 1	USBIER1	XXX0 0000b
D10Ah	USB Interrupt Enable Register 2	USBIER2	XX00 0000b
D10Bh	USB Interrupt Enable Register 3	USBIER3	XX00 0000b
D110h	USB Interrupt Select Register 0	USBISR0	00X0 00X0b
D111h	USB Interrupt Select Register 1	USBISR1	XXX0 0000b
D112h	USB Interrupt Select Register 2	USBISR2	XX00 0000b
D113h	USB Interrupt Select Register 3	USBISR3	XX00 0000b
D120h	USB Endpoint 0 IN Data Register	USBEPDR0I	XXh
D124h	USB Endpoint 0 OUT Data Register	USBEPDR0O	00h
D128h	USB Endpoint 0 S Data Register	USBEPDR0S	00h
D130h	USB Endpoint 1 Data Register	USBEPDR1	00h
D134h	USB Endpoint 2 Data Register	USBEPDR2	XXh
D138h	USB Endpoint 3 Data Register	USBEPDR3	XXh
D140h	USB Endpoint 4 Data Register	USBEPDR4	00h
D144h	USB Endpoint 5 Data Register	USBEPDR5	XXh
D148h	USB Endpoint 6 Data Register	USBEPDR6	XXh
D180h	USB Endpoint 0 OUT Receive Data Size Register	USBEPSZ0O	000X XXXXb
D181h	USB Endpoint 1 Receive Data Size Register	USBEPSZ1	0XXX XXXXb
D182h	USB Endpoint 4 Receive Data Size Register	USBEPSZ4	0XXX XXXXb
D188h	USB Data Status Register 0	USBDASTS0	XXXX XXX0b
D189h	USB Data Status Register 1	USBDASTS1	XXXX X00Xb
D18Ah	USB Data Status Register 2	USBDASTS2	XXXX X00Xb
D190h	USB Trigger Register 0	USBTRG0	XXh
D191h	USB Trigger Register 1	USBTRG1	XXh
D192h	USB Trigger Register 2	USBTRG2	XXh
D198h	USB FIFO Clear Register 0	USBFCLR0	XXh
D199h	USB FIFO Clear Register 1	USBFCLR1	XXh
D19Ah	USB FIFO Clear Register 2	USBFCLR2	XXh
D1A0h	USB Endpoint Stall Register 0	USBEPSTL0	XXXX XXX0b
D1A1h	USB Endpoint Stall Register 1	USBEPSTL1	XXXX X000b
D1A2h	USB Endpoint Stall Register 2	USBEPSTL2	XXXX X000b
D1A9h	USB Stall Status Register 1	USBSTLSR1	X000 X000b
D1AAh	USB Stall Status Register 2	USBSTLSR2	X000 X000b
D1B0h	USB DMA Transfer Setting Register	USBDMAR	XXX0 0X00b
D1B4h	USB Configuration Value Register	USBCVR	0000 X000b
D1B8h	USB Control Register	USBCTLR	0XX0 0001b
D1C0h	USB Endpoint Information Register	USBEPIR	XXh
D1CCh	USB Module Control Register	USBMC	11X1 0000b

24.2.1 USB Interrupt Flag Register 0 (USBIFR0)

USB Interrupt Flag Register 0 (USBIFR0)

b7	b6	b5	b4	b3	b2	b1	b0

Symbol	Address	Reset Value
USBIFR0	D100h	00h

Bit Symbol	Bit Name	Function	RW
VBUSF	USB bus connection/ disconnection detect flag	0: Not detected 1: Detected	RW
VBUSMN	Internal VBUS signal monitor flag	0: Internal VBUS signal is 0 1: Internal VBUS signal is 1	RO
SETI	Set Interface command detect flag	0: Not detected 1: Detected	RW
SETC	Set Configuration command detect flag	0: Not detected 1: Detected	RW
SURSF	Suspend/resume detect flag	0: Not detected 1: Detected	RW
SURSS	Suspend/resume status flag	0: USB bus in other than suspend state 1: USB bus in the suspend state	RO
CFDN	Endpoint information loading complete flag	0: Not detected 1: Detected	RW
BRST	USB bus reset detect flag	0: Not detected 1: Detected	RW

Access the USBIFR0 register in 8-bit units.
Use the MOV instruction when writing to this register. Any bits that are not set to 0 should be set to 1.

VBUSF (USB bus connection/disconnection detect flag) (b0)

The VBUSF bit monitors the internal VBUS detect signal.
An interrupt request is generated when the VBUSF bit becomes 1.
Condition to become 0:

- Write 0 to the VBUSF bit.

Conditions to become 1:

- The USB bus enters the connected state from a disconnected state.
- The USB bus enters the disconnected state from the connected state.

(Writing 1 has no effect.)

VBUSMN (Internal VBUS signal monitor flag) (b1)

The VBUSMN bit monitors the internal VBUS detect signal level. No interrupt request is generated.

SETI (Set Interface command detect flag) (b2)

An interrupt request is generated when the SETI bit becomes 1.
Condition to become 0:
- Write 0 to the SETI bit.

Condition to become 1:
- The Set Interface command is detected.

(Writing 1 has no effect.)

SETC (Set Configuration command detect flag) (b3)

When the SETC bit becomes 1, an interrupt request is generated.
Condition to become 0:
- Write 0 to the SETC bit.

Condition to become 1:
- The Set Configuration command is detected.

(Writing 1 has no effect.)

SURSF (Suspend/resume detect flag) (b4)

When the SURSF bit becomes 1, an interrupt request is generated.
Condition to become 0:
- Write 0 to the SURSF bit.

Conditions to become 1:
- The USB bus enters the suspend state.
- The USB bus enters the non-suspend state (resume).

(Writing 1 has no effect.)

SURSS (Suspend/resume status flag) (b5)

The SURSS bit indicates the USB bus status. An interrupt request is not generated.

CFDN (Endpoint information loading complete flag) (b6)

An interrupt request is generated when the CFDN bit becomes 1.
Condition to become 0:
- Write 0 to the CFDN bit.

Condition to become 1:
- VBUSMN bit in the USBIFR0 register is 1 and load of the data that is written to the USBEPIR register is completed inside the USB module.

(Writing 1 has no effect.)

BRST (USB bus reset detect flag) (b7)

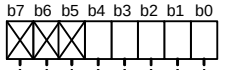
An interrupt request is generated when the BRST bit becomes 1.
Condition to become 0:
- Write 0 to the BRST bit.

Condition to become 1:
- A bus reset signal is detected on the USB bus.

(Writing 1 has no effect.)

24.2.2 USB Interrupt Flag Register 1 (USBIFR1)

USB Interrupt Flag Register 1 (USBIFR1)



Symbol	Address	Reset Value
USBIFR1	D101h	XXX0 0000b

Bit Symbol	Bit Name	Function	RW
EP0ITS	Endpoint 0 IN transmit complete flag	0: Not detected 1: Detected	RW
EP0ITR	Endpoint 0 IN transfer request flag	0: Not detected 1: Detected	RW
EP0OTS	Endpoint 0 OUT receive complete flag	0: Not detected 1: Detected	RW
SETUPTS	Setup command receive complete flag	0: Not detected 1: Detected	RW
SOF	Start of frame (SOF) packet detect flag	0: Not detected 1: Detected	RW
— (b7-b5)	No register bits. Should be written with 0 and read as undefined value.		—

Access the USBIFR1 register in 8-bit units.
Use the MOV instruction when writing to this register. Any bits that are not set to 0 should be set to 1.

EP0ITS (Endpoint 0 IN transmit complete flag) (b0)

When the EP0ITS bit becomes 1, an interrupt request is generated.
Condition to become 0:

- Write 0 to the EP0ITS bit.

Condition to become 1:

- An ACK is returned from the host after data is transmitted from endpoint 0 to the host.

(Writing 1 has no effect.)

EP0ITR (Endpoint 0 IN transfer request flag) (b1)

When the EP0ITR bit becomes 1, an interrupt request is generated.
Condition to become 0:

- Write 0 to the EP0ITR bit.

Condition to become 1:

- No valid transmit data is detected in the endpoint 0 transmit buffer when an IN token for endpoint 0 is received.

(Writing 1 has no effect.)

EP0OTS (Endpoint 0 OUT receive complete flag) (b2)

When the EP0OTS bit becomes 1, an interrupt request is generated.
Condition to become 0:
- Write 0 to the EP0OTS bit.

Condition to become 1:
- An ACK is returned to the host after endpoint 0 successfully receives data from the host and stores it to the endpoint 0 receive FIFO buffer.

(Writing 1 has no effect.)

SETUPTS (Setup command receive complete flag) (b3)

When the SETUPTS bit becomes 1, an interrupt request is generated.
Condition to become 0:
- Write 0 to the SETUPTS bit.

Condition to become 1:
- An ACK is returned to the host after endpoint 0 receives the setup command and stores it to the endpoint 0 setup command FIFO buffer.

(Writing 1 has no effect.)

SOF (Start of frame (SOF) packet detect flag) (b4)

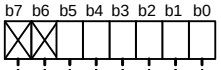
When the SOF bit becomes 1, an interrupt request is generated.
Condition to become 0:
- Write 0 to the SOF bit.

Condition to become 1:
- The SOF packet is detected.

(Writing 1 has no effect.)

24.2.3 USB Interrupt Flag Register 2 (USBIFR2)

USB Interrupt Flag Register 2 (USBIFR2)



Symbol	Address	Reset Value
USBIFR2	D102h	XX00 0110b

Bit Symbol	Bit Name	Function	RW
EP1FULL	Endpoint 1 FIFO full status flag	0: No receive data present 1: Receive data present	RO
EP2ALLEMP	Endpoint 2 FIFO all empty status flag	Endpoint 2 transmit FIFO buffer: 0: Between one and two layers are full (transmit data present) 1: Both layers are empty (no transmit data present)	RO
EP2EMPTY	Endpoint 2 FIFO empty status flag	Endpoint 2 transmit FIFO buffer: 0: Both layers are full 1: Between one and two layers are empty	RO
EP2TR	Endpoint 2 transfer request flag	0: Not detected 1: Detected	RW
EP3TS	Endpoint 3 transmit complete flag	0: Not detected 1: Detected	RW
EP3TR	Endpoint 3 transfer request flag	0: Not detected 1: Detected	RW
— (b7-b6)	No register bits. Should be written with 0 and read as undefined value		—

Access the USBIFR2 register in 8-bit units.
Use the MOV instruction when writing to this register. Any bits that are not set to 0 should be set to 1.

EP1FULL (Endpoint 1 FIFO full status flag) (b0)

The EP1FULL bit becomes 1 when endpoint 1 receives one packet of data from the host. This bit remains 1 as long as the endpoint 1 receive FIFO buffer contains valid data.
Condition to become 0:

- Both layers of the endpoint 1 receive FIFO buffer are empty.

Condition to become 1:

- Between one and two layers of endpoint 1 receive FIFO buffer are full.

EP2TR (Endpoint 2 transfer request flag) (b3)

When the EP2TR bit becomes 1, an interrupt request is generated.
Condition to become 0:

- Write 0 to the EP2TR bit.

Condition to become 1:

- No valid transmit data is detected in the endpoint 2 transmit FIFO buffer when an IN token for endpoint 2 is received.

(Writing 1 has no effect.)

EP3TS (Endpoint 3 transmit complete flag) (b4)

When the EP3TS bit becomes 1, an interrupt request is generated.
Condition to become 0:

- Write 0 to the EP3TS bit.

Condition to become 1:

- An ACK is returned from the host after data is transmitted to the host from endpoint 3.

(Writing 1 has no effect.)

EP3TR (Endpoint 3 transfer request flag) (b5)

When the EP3TR bit becomes 1, an interrupt request is generated.
Condition to become 0:

- Write 0 to the EP3TR bit.

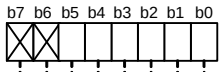
Condition to become 1:

- No valid transmit data is detected in the endpoint 3 transmit FIFO buffer when an IN token for endpoint 3 is received.

(Writing 1 has no effect.)

24.2.4 USB Interrupt Flag Register 3 (USBIFR3)

USB Interrupt Flag Register 3 (USBIFR3)



Symbol	Address	Reset Value
USBIFR3	D103h	XX00 0110b

Bit Symbol	Bit Name	Function	RW
EP4FULL	Endpoint 4 FIFO full status flag	0: No receive data present 1: Receive data present	RO
EP5ALLEMP	Endpoint 5 FIFO all empty status flag	Endpoint 5 FIFO buffer for transmission: 0: Between one and two layers are full (transmit data present) 1: Both layers are empty (no transmit data present)	RO
EP5EMPTY	Endpoint 5 FIFO empty status flag	Endpoint 5 FIFO buffer for transmission: 0: Both layers are full 1: Between one and two layers are empty	RO
EP5TR	Endpoint 5 transfer request flag	0: Not detected 1: Detected	RW
EP6TS	Endpoint 6 transmit complete flag	0: Not detected 1: Detected	RW
EP6TR	Endpoint 6 transfer request flag	0: Not detected 1: Detected	RW
— (b7-b6)	No register bits. Should be written with 0 and read as undefined value		—

Access the USBIFR3 register in 8-bit units.
Use the MOV instruction when writing to this register. Any bits that are not set to 0 should be set to 1.

EP4FULL (Endpoint 4 FIFO full status flag) (b0)

The EP4FULL bit becomes 1 when endpoint 4 receives one packet of data from the host and remains 1 as long as the endpoint 4 receive FIFO buffer has valid data.
Condition to become 0:

- Both layers in the endpoint 4 receive FIFO buffer are empty.

Condition to become 1:

- Between one and two layers in the endpoint 4 receive FIFO buffer are full.

EP5TR (Endpoint 5 transfer request flag) (b3)

When the EP5TR bit becomes 1, an interrupt request is generated.
Condition to become 0:

- Write 0 to the EP5TR bit.

Condition to become 1:

- No valid transmit data is detected in the endpoint 5 transmit FIFO buffer when an IN token for endpoint 5 is received.

(Writing 1 has no effect.)

EP6TS (Endpoint 6 transmit complete flag) (b4)

When the EP6TS bit becomes 1, an interrupt request is generated.
Condition to become 0:

- Write 0 to the EP6TS bit.

Condition to become 1:

- Transmit data from endpoint 6 to the host and receive an ACK.

(Writing 1 has no effect.)

EP6TR (Endpoint 6 transfer request flag) (b5)

When the EP6TR bit becomes 1, an interrupt request is generated.
Condition to become 0:

- Write 0 to the EP6TR bit.

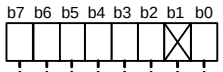
Condition to become 1:

- No valid data is detected in the endpoint 6 transmit FIFO buffer when an IN token for endpoint 6 is received.

(Writing 1 has no effect.)

24.2.5 USB Interrupt Enable Register 0 (USBIER0)

USB Interrupt Enable Register 0 (USBIER0)



Symbol	Address	Reset Value
USBIER0	D108h	0000 00X0b

Bit Symbol	Bit Name	Function	RW
VBUSFE	USB bus connection/ disconnection detect interrupt enable bit	0: Disabled 1: Enabled	RW
— (b1)	No register bits. Should be written with 0 and read as undefined value.		—
SETIE	Set Interface command detect interrupt enable bit	0: Disabled 1: Enabled	RW
SETCE	Set Configuration command detect interrupt enable bit	0: Disabled 1: Enabled	RW
SURSFE	Suspend/resume detect interrupt enable bit	0: Disabled 1: Enabled	RW
SSRSME	Standby-clear resume detect interrupt enable bit	0: USB RESUME interrupt disabled 1: USB RESUME interrupt enabled	RW
CFDNE	Endpoint information loading complete interrupt enable bit	0: Disabled 1: Enabled	RW
BRSTE	USB bus reset detect interrupt enable bit	0: Disabled 1: Enabled	RW

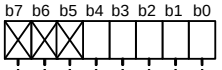
Access the USBIER0 register in 8-bits units. Do not access this register in 16-bit units.

SSRSME (Standby-clear resume detect interrupt enable bit) (b5)

Set the SSRSME bit to 1 (USB RESUME interrupt enabled) before entering the suspend state. When exiting the suspend state, set this bit to 0 (USB RESUME interrupt disabled).

24.2.6 USB Interrupt Enable Register 1 (USBIER1)

USB Interrupt Enable Register 1 (USBIER1)



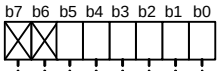
Symbol	Address	Reset Value
USBIER1	D109h	XXX0 0000b

Bit Symbol	Bit Name	Function	RW
EP0ITSE	Endpoint 0 IN transmit complete interrupt enable bit	0: Disabled 1: Enabled	RW
EP0ITRE	Endpoint 0 IN transfer request interrupt enable bit	0: Disabled 1: Enabled	RW
EP0OTSE	Endpoint 0 OUT receive complete interrupt enable bit	0: Disabled 1: Enabled	RW
SETUPTSE	Setup command receive complete interrupt enable bit	0: Disabled 1: Enabled	RW
SOFE	Start of Frame (SOF) packet detect interrupt enable bit	0: Disabled 1: Enabled	RW
— (b7-b5)	No register bits. Should be written with 0 and read as undefined value.		—

Access the USBIER1 register in 8-bits units. Do not access this register in16-bit units.

24.2.7 USB Interrupt Enable Register 2 (USBIER2)

USB Interrupt Enable Register 2(USBIER2)



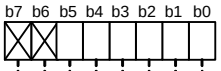
Symbol	Address	Reset Value
USBIER2	D10Ah	XX00 0000b

Bit Symbol	Bit Name	Function	RW
EP1FULLE	Endpoint 1 FIFO full status interrupt enable bit	0: Disabled 1: Enabled	RW
EP2ALLEMPE	Endpoint 2 FIFO all empty interrupt enable bit	0: Disabled 1: Enabled	RW
EP2EMPTYE	Endpoint 2 FIFO empty interrupt enable bit	0: Disabled 1: Enabled	RW
EP2TRE	Endpoint 2 transfer request interrupt enable bit	0: Disabled 1: Enabled	RW
EP3TSE	Endpoint 3 transmit complete interrupt enable bit	0: Disabled 1: Enabled	RW
EP3TRE	Endpoint 3 transfer request interrupt enable bit	0: Disabled 1: Enabled	RW
— (b7-b6)	No register bits. Should be written with 0 and read as undefined value.		—

Access the USBIER2 register in 8-bits units. Do not access this register in 16-bit units.

24.2.8 USB Interrupt Enable Register 3 (USBIER3)

USB Interrupt Enable Register 3 (USBIER3)



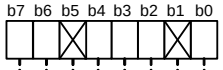
Symbol	Address	Reset Value
USBIER3	D10Bh	XX00 0000b

Bit Symbol	Bit Name	Function	RW
EP4FULLE	Endpoint 4 FIFO full status interrupt enable bit	0: Disabled 1: Enabled	RW
EP5ALLEMPE	Endpoint 5 FIFO all empty interrupt enable bit	0: Disabled 1: Enabled	RW
EP5EMPTYE	Endpoint 5 FIFO empty interrupt enable bit	0: Disabled 1: Enabled	RW
EP5TRE	Endpoint 5 transfer request interrupt enable bit	0: Disabled 1: Enabled	RW
EP6TSE	Endpoint 6 transmit complete interrupt enable bit	0: Disabled 1: Enabled	RW
EP6TRE	Endpoint 6 transfer request interrupt enable bit	0: Disabled 1: Enabled	RW
— (b7-b6)	No register bits. Should be written with 0 and read as undefined value.		—

Access the USBIER3 register in 8-bits units. Do not access this register in 16-bit units.

24.2.9 USB Interrupt Select Register 0 (USBISR0)

USB Interrupt Select Register 0 (USBISR0)



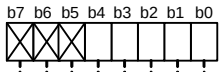
Symbol	Address	Reset Value
USBISR0	D110h	00X0 00X0b

Bit Symbol	Bit Name	Function	RW
VBUSFS	USB bus connection/ disconnection detect interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
— (b1)	No register bits. Should be written with 0 and read as undefined value.		—
SETIS	Set Interface command detect interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
SETCS	Set Configuration command detect interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
SURSFS	Suspend/resume detect interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
— (b5)	No register bits. Should be written with 0 and read as undefined value.		—
CFDNS	Endpoint information loading complete interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
BRSTS	USB bus reset detect interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW

Access the USBISR0 register in 8-bits units. Do not access this register in 16-bit units.

24.2.10 USB Interrupt Select Register 1 (USBISR1)

USB Interrupt Select Register 1 (USBISR1)



Symbol	Address	Reset Value
USBISR1	D111h	XXX0 0000b

Bit Symbol	Bit Name	Function	RW
EP0ITSS	Endpoint 0 IN transmit complete interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP0ITRS	Endpoint 0 IN transfer request interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP0OTSS	Endpoint 0 OUT receive complete interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
SETUPTSS	Setup command receive complete interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
SOFS	Start of Frame (SOF) packet detect interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
— (b7-b5)	No register bits. Should be written with 0 and read as undefined value.		—

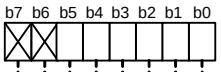
Access the USBISR1 register in 8-bits units. Do not access this register in 16-bit units.

EP0ITSS (Endpoint 0 IN transmit complete interrupt select bit) (b0)
EP0ITRS (Endpoint 0 IN transfer request interrupt select bit) (b1)
EP0OTSS (Endpoint 0 OUT receive complete interrupt select bit) (b2)

To enable multiple interrupts from the endpoint 0 OUT receive complete, endpoint 0 IN transfer request, and endpoint 0 IN transmit complete interrupts, set the same value to bits EP0OTSS, EP0ITRS, and EP0ITSS in the USBISR1 register. That is to say, select either USB interrupt 0 or USB interrupt 1 for all three interrupt requests.

24.2.11 USB Interrupt Select Register 2 (USBISR2)

USB Interrupt Select Register 2 (USBISR2)



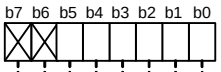
Symbol	Address	Reset Value
USBISR2	D112h	XX00 0000b

Bit Symbol	Bit Name	Function	RW
EP1FULLS	Endpoint 1 FIFO full status interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP2ALLEMPS	Endpoint 2 FIFO all empty interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP2EMPTYS	Endpoint 2 FIFO empty interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP2TRS	Endpoint 2 transfer request interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP3TSS	Endpoint 3 transmit complete interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP3TRS	Endpoint 3 transfer request interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
— (b7-b6)	No register bits. Should be written with 0 and read as undefined value.		—

Access the USBISR2 register in 8-bit units. Do not access this register in 16-bit units.

24.2.12 USB Interrupt Select Register 3 (USBISR3)

USB Interrupt Select Register 3 (USBISR3)



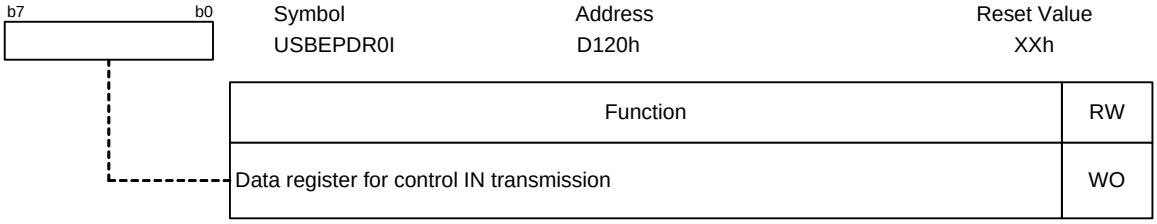
Symbol	Address	Reset Value
USBISR3	D113h	XX00 0000b

Bit Symbol	Bit Name	Function	RW
EP4FULLS	Endpoint 4 FIFO full status interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP5ALLEMPS	Endpoint 5 FIFO all empty interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP5EMPTYS	Endpoint 5 FIFO empty interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP5TRS	Endpoint 5 transfer request interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP6TSS	Endpoint 6 transmit complete interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
EP6TRS	Endpoint 6 transfer request interrupt select bit	0: USB interrupt 0 1: USB interrupt 1	RW
— (b7-b6)	No register bits. Should be written with 0 and read as undefined value.		—

Access the USBISR3 register in 8-bit units. Do not access this register in 16-bit units.

24.2.13 USB Endpoint 0 IN Data Register (USBEPDR0I)

USB Endpoint 0 IN Data Register (USBEPDR0I)



Symbol	Address	Reset Value
USBEPDR0I	D120h	XXh

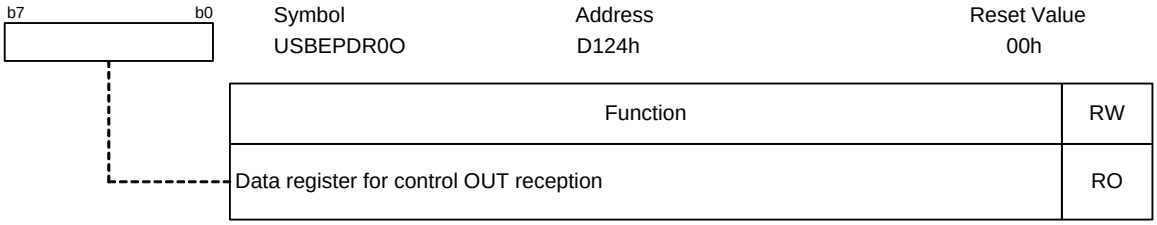
Function	RW
Data register for control IN transmission	WO

Access the USBEPDR0I register in 8-bit units. Use the MOV instruction to access this register.

The USBEPDR0I register writes data to the endpoint 0 transmit FIFO buffer.
The endpoint 0 transmit FIFO buffer consists of 16 bytes. Do not write more than 16 bytes of data to the USBEPDR0I register. The endpoint 0 transmit FIFO buffer is cleared by setting the EP0ICLR bit in the USBFCLR0 register to 1.

24.2.14 USB Endpoint 0 OUT Data Register (USBEPDR0O)

USB Endpoint 0 OUT Data Register (USBEPDR0O)



Symbol	Address	Reset Value
USBEPDR0O	D124h	00h

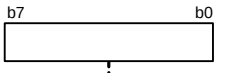
Function	RW
Data register for control OUT reception	RO

Access the USBEPDR0O register in 8-bit units. Do not access this register in 16-bit units.

The USBEPDR0O register reads data from the endpoint 0 receive FIFO buffer.
The endpoint 0 receive FIFO buffer consists of 16 bytes. Do not read more than 16 bytes of data from the USBEPDR0O register. The endpoint 0 receive FIFO buffer can be cleared by setting the EP0OCLR bit in the USBFCLR0 register to 1.

24.2.15 USB Endpoint 0 S Data Register (USBEPDR0S)

USB Endpoint 0 S Data Register (USBEPDR0S)



Symbol	Address	Reset Value
USBEPDR0S	D128h	00h

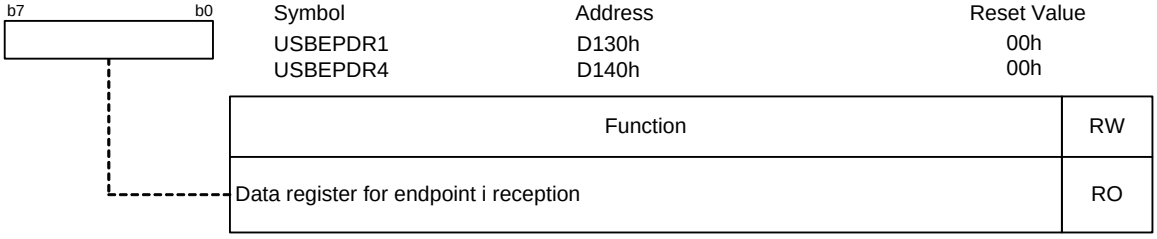
Function	RW
Data register to store the setup command when receiving the control OUT	RO

Access the USBEPDR0S register in 8-bit units. Do not access this register in 16-bit units.

The USBEPDR0S register reads setup commands from the endpoint 0 setup command FIFO buffer. The setup command receive operation always has the highest priority. Even when data not read exists in the endpoint 0 setup command FIFO buffer, when a setup command receive operation is started, the newly received setup command is written to the endpoint 0 setup command FIFO buffer.
Therefore, when starting to receive the setup command while reading the USBEPDR0S register, the read operation becomes disabled, and an undefined value is read.
The endpoint 0 setup command FIFO buffer consists of 8 bytes. Read 8 bytes from the USBEPDR0S register. If the read is aborted, the command cannot be read successfully when the next setup command is received. Do not read more than 8 bytes from the USBEPDR0S register.
The endpoint 0 setup command FIFO buffer stores only the setup command which needs to be decoded by a program.
Refer to 24.3.11 “Processing Standard USB Commands and Class/Vendor Commands”.

24.2.16 USB Endpoint i Data Register (USBEPDRi) (i = 1, 4)

USB Endpoint i Data Register (USBEPDRi) (i = 1, 4)



Symbol	Address	Reset Value
USBEPDR1	D130h	00h
USBEPDR4	D140h	00h

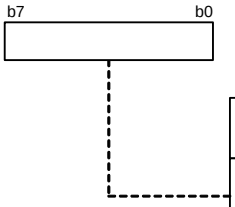
Function	RW
Data register for endpoint i reception	RO

Access the USBEPDRi register in 8-bit units. Do not access this register in 16-bit units.

The USBEPDRi register reads data from the endpoint i receive FIFO buffer (i = 1, 4).
The endpoint i receive FIFO buffer consists of two 64-byte layers (128 bytes total).
When the EPiRDFN bit in the USBTRG1 or USBTRG2 register is set to 1 after the USBEPDRi register reads one packet of data from one layer of the endpoint i receive FIFO buffer, that layer can then receive data. At the same time, the other layer can be read through the USBEPDRi register. Do not read more than 64 bytes of data per layer.
The endpoint i receive FIFO buffer can be cleared by setting the EPiCLR bit in the USBFCLR1 or USBFCLR2 register to 1.
Data in the endpoint i receive FIFO buffer can be transferred using the DMAC. Refer to 24.5 “DMA Transfer”.

24.2.17 USB Endpoint i Data Register (USBEPDRi) (i = 2, 5)

USB Endpoint i Data Register (USBEPDRi) (i = 2, 5)



Symbol	Address	Reset Value
USBEPDR2	D134h	XXh
USBEPDR5	D144h	XXh

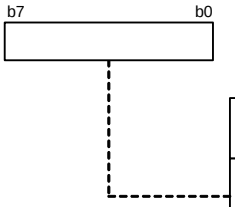
Function	RW
Data register for endpoint i transmission	WO

Access the USBEPDRi register in 8-bit units. Use the MOV instruction to access this register.

The USBEPDRi register writes data to the endpoint i transmit FIFO buffer (i = 2, 5).
The endpoint i transmit FIFO buffer consists of two 64-byte layers (128 bytes total).
When the EPiPKTE bit in the USBTRG1 or USBTRG2 register is set to 1 after data is written to the USBEPDRi register, the data in the layer is determined as one packet of data. At the same time, the other layer becomes writable.
Do not write more than 64 bytes of data per layer.
The endpoint i transmit FIFO buffer can be cleared by setting the EPiCLR bit in the USBFCLR1 or USBFCLR2 register to 1.
Data in the endpoint i transmit FIFO buffer can be transferred using the DMAC. Refer to 24.5 “DMA Transfer”.

24.2.18 USB Endpoint i Data Register (USBEPDRi) (i = 3, 6)

USB Endpoint i Data Register (USBEPDRi) (i = 3, 6)



Symbol	Address	Reset Value
USBEPDR3	D138h	XXh
USBEPDR6	D148h	XXh

Function	RW
Data register for endpoint i transmission	WO

Access the USBEPDRi register in 8-bit units. Use the MOV instruction to access this register.

The USBEPDRi register writes data to the endpoint i transmit FIFO buffer (i = 3, 6).

The endpoint i transmit FIFO buffer consists of 16 bytes. When writing data to the USBEPDRi register, and setting the EPiPKTE bit in the USBTRG1or USBTRG2 register to 1, one packet of data is determined. Do not write more than 16 bytes of data to the USBEPDRi register.
The endpoint i transmit FIFO buffer is cleared by setting the EPiCLR bit in the USBFCLR1 or USBFCLR2 register to 1.

24.2.19 USB Endpoint 0 OUT Receive Data Size Register (USBEPSZ0O)

USB Endpoint 0 OUT Receive Data Size Register (USBEPSZ0O)

b7	b6	b5	b4	b3	b2	b1	b0

Symbol	Address	Reset Value
USBEPSZ0O	D180h	000X XXXXb

Function		RW
Number of endpoint 0 OUT receive bytes		RO
Reserved bits	When read, the content is 0.	RO

Access the USBEPSZ0O register in 8-bit units. Do not access this register in 16-bit units.

24.2.20 USB Endpoint i Receive Data Size Register (USBEPSZi) (i = 1, 4)

USB Endpoint i Receive Data Size Register (USBEPSZi) (i = 1, 4)

b7	b6	b5	b4	b3	b2	b1	b0

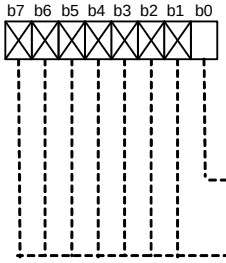
Symbol	Address	Reset Value
USBEPSZ1	D181h	0XXX XXXXb
USBEPSZ4	D182h	0XXX XXXXb

Function		RW
Number of endpoint i receive bytes		RO
Reserved bit	When read, the content is 0.	RO

Access the USBEPSZi register in 8-bit units. Do not access this register in 16-bit units.
The USBEPSZi register indicates the number of bytes for received data in the selected layer (which is readable by the USBEPDRi register) of the endpoint i receive FIFO buffer.

24.2.21 USB Data Status Register j (USBDASTSj) (j = 0 to 2)

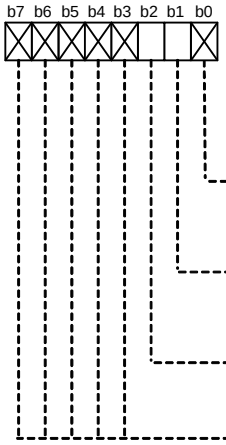
USB Data Status Register 0 (USBDASTS0)



Symbol	Address	Reset Value
USBDASTS0	D188h	XXXX XXX0b

Bit Symbol	Bit Name	Function	RW
EP0IDE	Endpoint 0 IN data status flag	Endpoint 0 transmit FIFO buffer: 0: No valid data present (transmission completed) 1: Valid data present	RO
— (b7-b1)	No register bits. Should be written with 0 and read as undefined values.		—

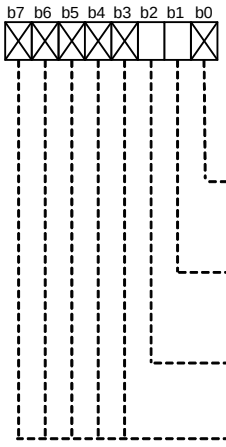
USB Data Status Register 1 (USBDASTS1)



Symbol	Address	Reset Value
USBDASTS1	D189h	XXXX X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. Should be written with 0 and read as undefined value.		—
EP2DE	Endpoint 2 data status flag	Endpoint 2 transmit FIFO buffer: 0: No valid data present in both layers (transmission completed) 1: Valid data present	RO
EP3DE	Endpoint 3 data status flag	Endpoint 3 transmit FIFO buffer: 0: No valid data present (transmission completed) 1: Valid data present	RO
— (b7-b3)	No register bits. Should be written with 0 and read as undefined values.		—

USB Data Status Register 2 (USBDASTS2)



Symbol	Address	Reset Value
USBDASTS2	D18Ah	XXXX X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. Should be written with 0 and read as undefined value.		—
EP5DE	Endpoint 5 data status flag	Endpoint 5 transmit FIFO buffer: 0: No valid data present in both layers (transmission completed) 1: Valid data present	RO
EP6DE	Endpoint 6 data status flag	Endpoint 6 transmit FIFO buffer: 0: No valid data present (transmission completed) 1: Valid data present	RO
— (b7-b3)	No register bits. Should be written with 0 and read as undefined values.		—

Access the USBDASTSj register (j = 0 to 2) in 8-bit units. Do not access this register in 16-bit units.

Condition to become 0:

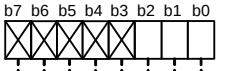
- Transmit all data in the endpoint i (i = 0, 2, 3, 5, 6) transmit FIFO buffer.

Condition to become 1:

- Set data to the endpoint i transmit FIFO buffer and write 1 (transmit data determined) to the EPiIPKTE bit in the USBTRGj register.

24.2.22 USB Trigger Register 0 (USBTRG0)

USB Trigger Register 0 (USBTRG0)



Symbol	Address	Reset Value
USBTRG0	D190h	XXh

Bit Symbol	Bit Name	Function	RW
EP0IPKTE	Endpoint 0 IN packet enable trigger bit	When this bit is set to 1, the endpoint 0 IN transmit data is determined.	WO
EP0ORDFN	Endpoint 0 OUT read complete trigger bit	When this bit is set to 1, the endpoint 0 OUT receive FIFO buffer is initialized and the next packet can be received.	WO
EP0SRDFN	Endpoint 0 S read complete trigger bit	When reading the setup command from the endpoint 0 S receive FIFO buffer, and setting this bit to 1, the host advances to the data stage and the data becomes transmittable/receivable.	WO
— (b7-b3)	No register bits. Should be written with 0 and read as undefined value.		—

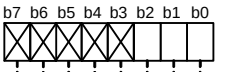
Access the USBTRG0 register in 8-bit units. Use the MOV instruction to access this register.

EP0SRDFN (Endpoint 0 S read complete trigger bit) (b2)

After the setup command is read from the endpoint 0 S reception FIFO buffer, set the EP0SRDFN bit to 1. If the USB module receives the data-stage transmit/receive request before the EP0SRDFN bit is set to 1, a NACK is returned. Values in registers USBEPDR0I and USBEPDR0O can be transmitted/ received when setting this bit to 1 after the setup command is received. The endpoint 0 S reception FIFO buffer can receive data regardless of the EP0SRDFN bit value.

24.2.23 USB Trigger Register j (USBTRGj) (j = 1, 2)

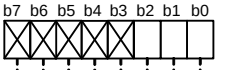
USB Trigger Register 1 (USBTRG1)



Symbol	Address	Reset Value
USBTRG1	D191h	XXh

Bit Symbol	Bit Name	Function	RW
EP1RDFN	Endpoint 1 read complete trigger bit	When reading one packet of data from one layer of the endpoint 1 receive FIFO buffer, and setting this bit to 1, the layer becomes data receivable again.	WO
EP2PKTE	Endpoint 2 packet enable trigger bit	When writing one packet of data to the endpoint 2 transmit FIFO buffer, and setting this bit to 1, the endpoint 2 transmit data is determined.	WO
EP3PKTE	Endpoint 3 packet enable trigger bit	When writing one packet of data to the endpoint 3 transmit FIFO buffer, and setting this bit to 1, the endpoint 3 transmit data is determined.	WO
— (b7-b3)	No register bits. Should be written with 0 and read as undefined value.		—

USB Trigger Register 2 (USBTRG2)



Symbol	Address	Reset Value
USBTRG2	D192h	XXh

Bit Symbol	Bit Name	Function	RW
EP4RDFN	Endpoint 4 read complete trigger bit	When reading one packet of data from one layer of the endpoint 4 receive FIFO buffer, and setting this bit to 1, the layer becomes data receivable again.	WO
EP5PKTE	Endpoint 5 packet enable trigger bit	When writing one packet of data to the endpoint 5 transmit FIFO buffer, and setting this bit to 1, the endpoint 5 transmit data is determined.	WO
EP6PKTE	Endpoint 6 packet enable trigger bit	When writing one packet of data to the endpoint 6 transmit FIFO buffer, and setting this bit to 1, the endpoint 6 transmit data is determined.	WO
— (b7-b3)	No register bit. Should be written with 0 and read as undefined value.		—

Access the USBTRGj register in 8-bit units. Use the MOV instruction to access this register.

EPiRDFN (Endpoint i read complete trigger bit) (b0) (i = 1, 4)

When the EPiRDFN bit is set to 1, the endpoint i receive FIFO buffer becomes as follows:

- The layer whose data is read becomes data receivable.
- The content of the other layer can be read from the USBEPDRi register.

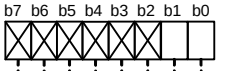
EPiPKTE (Endpoint i packet enable trigger bit) (b1) (i = 2, 5)

When the EPiPKTE bit is set to 1, the endpoint i transmit FIFO buffer becomes as follows:

- The data in the written layer is determined to be transmit data.
- When writing to the USBEPDRi register, the other layer becomes data writable.

24.2.24 USB FIFO Clear Register 0 (USBFCLR0)

USB FIFO Clear Register 0 (USBFCLR0)



Symbol	Address	Reset Value
USBFCLR0	D198h	XXh

Bit Symbol	Bit Name	Function	RW
EP0ICLR	Endpoint 0 IN FIFO buffer clear bit	When this bit is set to 1, the endpoint 0 IN transmit FIFO buffer is cleared.	WO
EP0OCLR	Endpoint 0 OUT FIFO buffer clear bit	When this bit is set to 1, the endpoint 0 OUT receive FIFO buffer is cleared.	WO
— (b7-b2)	No register bits. Should be written with 0 and read as undefined value.		—

Access the USBFCLR0 register in 8-bit units. Use the MOV instruction to access this register.

EP0ICLR (Endpoint 0 IN FIFO buffer clear bit) (b0)

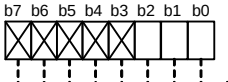
Do not write 1 to the EP0ICLR bit in the control IN transmit operation for endpoint 0.

EP0OCLR (Endpoint 0 OUT FIFO buffer clear bit) (b1)

Do not write 1 to the EP0OCLR bit in the control OUT receive operation for endpoint 0.

24.2.25 USB FIFO Clear Register j (USBFCLRj) (j = 1, 2)

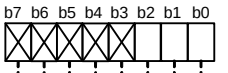
USB FIFO Clear Register 1 (USBFCLR1)



Symbol	Address	Reset Value
USBFCLR1	D199h	XXh

Bit Symbol	Bit Name	Function	RW
EP1CLR	Endpoint 1 FIFO buffer clear bit	When this bit is set to 1, both layers of the endpoint 1 receive FIFO buffer are cleared.	WO
EP2CLR	Endpoint 2 FIFO buffer clear bit	When this bit is set to 1, both layers of the endpoint 2 transmit FIFO buffer are cleared.	WO
EP3CLR	Endpoint 3 FIFO buffer clear bit	When this bit is set to 1, the endpoint 3 transmit FIFO buffer is cleared.	WO
— (b7-b3)	No register bits. Should be written with 0 and read as undefined.		—

USB FIFO Clear Register 2 (USBFCLR2)



Symbol	Address	Reset Value
USBFCLR2	D19Ah	XXh

Bit Symbol	Bit Name	Function	RW
EP4CLR	Endpoint 4 FIFO buffer clear bit	When this bit is set to 1, both layers of the endpoint 4 receive FIFO buffer are cleared.	WO
EP5CLR	Endpoint 5 FIFO buffer clear bit	When this bit is set to 1, both layers of the endpoint 5 transmit FIFO buffer are cleared.	WO
EP6CLR	Endpoint 6 FIFO buffer clear bit	When this bit is set to 1, the endpoint 6 transmit FIFO buffer is cleared.	WO
— (b7-b3)	No register bits. Should be written with 0 and read as undefined values.		—

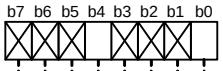
Access the USBFCLRj register in 8-bit units. Use the MOV instruction to access this register.

EPiCLR (Endpoint i FIFO buffer clear bit) (b2-b0) (i = 1 to 6)

Do not write 1 to the EPiCLR bit when endpoint i transmitting or receiving.

24.2.26 USB Endpoint Stall Register 0 (USBEPSTL0)

USB Endpoint Stall Register 0 (USBEPSTL0)



Symbol	Address	Reset Value
USBEPSTL0	D1A0h	XXXX XXX0b

Bit Symbol	Bit Name	Function	RW
EP0STLS	Endpoint 0 stall setting bit	0: Default 1: Stall	RW
— (b3-b1)	No register bits. Should be written with 0 and read as undefined values.		—
EP0STLC	Endpoint 0 stall clear bit	When this bit is set to 1, the EP0STLS bit becomes 0 (default).	WO
— (b7-b5)	No register bits. Should be written with 0 and read as undefined values.		—

Access the USBEPSTL0 register in 8-bit units.
Use the MOV instruction when writing to this register. Any bits that are not set to 1 should be set to 0.

EP0STLS (Endpoint 0 stall setting bit) (b0)

To set the USB bus line to the stall state by a program, set the EP0STLS bit to 1 (stall). Writing 0 has no effect.
Conditions to become 0:

- Write 1 to the EP0STLC bit.
- Receive the 8-byte setup command to decode by a program (refer to Table 24.13 “Processing Commands When Received”).
- The EP0ASCE bit in the USBCTLR register is 1 (stall auto-clear enabled), and STALL is returned in response to a transaction from the host.

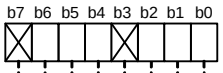
Do not set bits EP0STLS and EP0STLC to 1 simultaneously (by one instruction).
When the SETUPTS bit in the USBIFR1 register is set to 1 (receive completion of setup command), the bus line is not stalled even if the EP0STLS bit is set to 1.

EP0STLC (Endpoint 0 stall clear bit) (b4)

Do not set bits EP0STLS and EP0STLC to 1 simultaneously (by one instruction).

24.2.27 USB Endpoint Stall Register j (USBEPSTLj) (j = 1, 2)

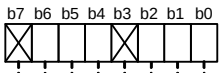
USB Endpoint Stall Register 1 (USBEPSTL1)



Symbol	Address	Reset Value
USBEPSTL1	D1A1h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
EP1STLS	Endpoint 1 stall setting bit	0: Default 1: Stall	RW
EP2STLS	Endpoint 2 stall setting bit	0: Default 1: Stall	RW
EP3STLS	Endpoint 3 stall setting bit	0: Default 1: Stall	RW
— (b3)	No register bit. Should be written with 0 and read as undefined value.		—
EP1STLC	Endpoint 1 stall clear bit	When this bit is set to 1, the EP1STLS bit becomes 0 (default).	WO
EP2STLC	Endpoint 2 stall clear bit	When this bit is set to 1, the EP2STLS bit becomes 0 (default).	WO
EP3STLC	Endpoint 3 stall clear bit	When this bit is set to 1, the EP3STLS bit becomes 0 (default).	WO
— (b7)	No register bit. Should be written with 0 and read as undefined value.		—

USB Endpoint Stall Register 2 (USBEPSTL2)



Symbol	Address	Reset Value
USBEPSTL2	D1A2h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
EP4STLS	Endpoint 4 stall setting bit	0: Default 1: Stall	RW
EP5STLS	Endpoint 5 stall setting bit	0: Default 1: Stall	RW
EP6STLS	Endpoint 6 stall setting bit	0: Default 1: Stall	RW
— (b3)	No register bit. Should be written with 0 and read as undefined value.		—
EP4STLC	Endpoint 4 stall clear bit	When this bit is set to 1, the EP4STLS bit becomes 0 (default).	WO
EP5STLC	Endpoint 5 stall clear bit	When this bit is set to 1, the EP5STLS bit becomes 0 (default).	WO
EP6STLC	Endpoint 6 stall clear bit	When this bit is set to 1, the EP6STLS bit becomes 0 (default).	WO
— (b7)	No register bit. Should be written with 0 and read as undefined value.		—

Access the USBEPSTLj (j = 1, 2) register in 8-bit units.
Use the MOV instruction when writing to this register. Any bits that are not set to 1 should be set to 0.

EPiSTLS (Endpoint i stall setting bit) (b2-b0) (i = 1 to 6)

To set the USB bus line to the stall state by a program, set the EPiSTLS bit to 1 (stall). Writing 0 has no effect. Refer to Figure 24.8 “STALL and Exit From STALL (When STALL Source Is Used During Communication with the Host)” and Figure 24.9 “STALL and Exit From STALL (When Setting STALL Source by a Program)”.
Conditions to become 0:

- Write 1 to the EPiSTLC bit.
- The EPiASCE bit in the USBSTLSRj register is 1 (STALL auto-clear enabled), and STALL is returned in response to a transaction from the host.

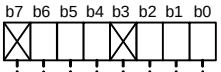
Do not set bits EPiSTLS and EPiSTLC to 1 simultaneously (by one instruction).

EPiSTLC (Endpoint i stall clear bit) (b6-b4)

Do not set bits EPiSTLS and EPiSTLC to 1 simultaneously (by one instruction).

24.2.28 USB Stall Status Register j (USBSTLSRj) (j = 1, 2)

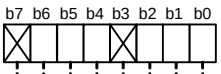
USB Stall Status Register 1 (USBSTLSR1)



Symbol	Address	Reset Value
USBSTLSR1	D1A9h	X000 X000b

Bit Symbol	Bit Name	Function	RW
EP1STLST	Endpoint 1 internal stall status flag	0: Other than STALL state 1: STALL state	RO
EP2STLST	Endpoint 2 internal stall status flag	0: Other than STALL state 1: STALL state	RO
EP3STLST	Endpoint 3 internal stall status flag	0: Other than STALL state 1: STALL state	RO
— (b3)	No register bit. Should be written with 0 and read as undefined value.		—
EP1ASCE	Endpoint 1 automatic stall clear enable bit	0: Auto-clear disabled 1: Auto-clear enabled	RW
EP2ASCE	Endpoint 2 automatic stall clear enable bit	0: Auto-clear disabled 1: Auto-clear enabled	RW
EP3ASCE	Endpoint 3 automatic stall clear enable bit	0: Auto-clear disabled 1: Auto-clear enabled	RW
— (b7)	No register bit. Should be written with 0 and read as undefined value.		—

USB Stall Status Register 2 (USBSTLSR2)



Symbol	Address	Reset Value
USBSTLSR2	D1AAh	X000 X000b

Bit Symbol	Bit Name	Function	RW
EP4STLST	Endpoint 4 internal stall status flag	0: Other than STALL state 1: STALL state	RO
EP5STLST	Endpoint 5 internal stall status flag	0: Other than STALL state 1: STALL state	RO
EP6STLST	Endpoint 6 internal stall status flag	0: Other than STALL state 1: STALL state	RO
— (b3)	No register bit. Should be written with 0 and read as undefined value.		—
EP4ASCE	Endpoint 4 automatic stall clear enable bit	0: Auto-clear disabled 1: Auto-clear enabled	RW
EP5ASCE	Endpoint 5 automatic stall clear enable bit	0: Auto-clear disabled 1: Auto-clear enabled	RW
EP6ASCE	Endpoint 6 automatic stall clear enable bit	0: Auto-clear disabled 1: Auto-clear enabled	RW
— (b7)	No register bit. Should be written with 0 and read as undefined value.		—

Access the USBSTLSRj (j = 1, 2) register in 8-bit units. Do not access this register in 16-bit units.

EPiSTLST (Endpoint i internal stall status flag) (b2-b0) (i = 1 to 6)

Condition to become 0:

- The EPiSTLS bit in the USBEPSTL1 or USBEPSTL2 register is 0 (default) and the Clear Feature command is detected (refer to Figure 24.8 “STALL and Exit From STALL (When STALL Source Is Used During Communication with the Host)” and Figure 24.9 “STALL and Exit From STALL (When Setting STALL Source by a Program)”).

Conditions to become 1:

- The EPiSTLS bit in the USBEPSTL1 or USBEPSTL2 register is 1 (stall), and a transaction from the host is received.
- A STALL source is detected.

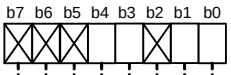
EPiASCE (Endpoint i automatic stall clear enable bit) (b6 to b4)

When the EPiASCE bit is 1 (auto-clear enabled), and returning a STALL handshake to the host, the EPiSTLS bit in the USBEPSTL1 or USBEPSTL2 register becomes 0 (default). Refer to Figure 24.8 “STALL and Exit From STALL (When STALL Source Is Used During Communication with the Host)” and Figure 24.9 “STALL and Exit From STALL (When Setting STALL Source by a Program)”.

To set the EPiASCE bit to 1, write 1 to the EPiASCE bit when the EPiSTLS bit in the USBEPSTLj register is 0.

24.2.29 USB DMA Transfer Setting Register (USBDMAR)

USB DMA Transfer Setting Register (USBDMAR)



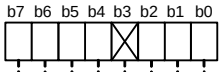
Symbol	Address	Reset Value
USBDMAR	D1B0h	XXX0 0X00b

Bit Symbol	Bit Name	Function	RW
EP1DMAE	Endpoint 1 DMA transfer enable bit	0: DMA request disabled 1: DMA request enabled	RW
EP2DMAE	Endpoint 2 DMA transfer enable bit	0: DMA request disabled 1: DMA request enabled	RW
— (b2)	No register bit. Should be written with 0 and read as undefined value.		—
EP4DMAE	Endpoint 4 DMA transfer enable bit	0: DMA request disabled 1: DMA request enabled	RW
EP5DMAE	Endpoint 5 DMA transfer enable bit	0: DMA request disabled 1: DMA request enabled	RW
— (b7-b5)	No register bits. Should be written with 0 and read as undefined value.		—

Access the USBDMAR register in 8-bit units. Do not access this register in 16-bit units.

24.2.30 USB Configuration Value Register (USBCVR)

USB Configuration Value Register (USBCVR)



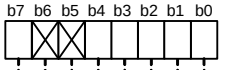
Symbol	Address	Reset Value
USBCVR	D1B4h	0000 X000b

Bit Symbol	Bit Name	Function	RW
ALTV0	Alternate setting store bit	Store the alternate setting value when the Set Interface command is accepted.	RO
ALTV1			RO
ALTV2			RO
— (b3)	No register bit. Should be written with 0 and read as undefined value.		—
INTV0	Interface setting store bit	Store the interface setting value when the Set Interface command is accepted.	RO
INTV1			RO
CNFV0	Configuration setting store bit	Configuration setting value is stored when the Set Configuration command is accepted.	RO
CNFV1			RO

Access the USBCVR register in 8-bit units. Do not access this register in 16-bit units.

24.2.31 USB Control Register (USBCTLR)

USB Control Register (USBCTLR)



Symbol	Address	Reset Value
USBCTLR	D1B8h	0XX0 0001b

Bit Symbol	Bit Name	Function	RW
PRTRST	Protocol processor reset bit	0: Protocol processing unit operating state 1: Protocol processing unit reset state	RW
EP0ASCE	Endpoint 0 automatic stall clear enable bit	0: Auto-clear disabled 1: Auto-clear enabled	RW
PWMD	Power mode setting bit	0: Self-powered mode 1: Bus powered mode	RW
RSME	Resume request bit	0: Resume not requested 1: Resume requested	RW
RWUPS	Remote wakeup status flag	0: Remote wakeup disabled 1: Remote wakeup enabled	RO
— (b6-b5)	No register bits. Should be written with 0 and read as undefined value.		—
PULLUPE	Pull-up enable bit	0: ATTACH output OFF (D+ not pulled up) 1: ATTACH output ON (D+ pulled up)	RW

Access the USBCTLR register in 8-bit units. Do not access this register in 16-bit units.

EP0ASCE (Endpoint 0 automatic stall clear enable bit) (b1)

When the EP0ASCE bit is 1 (auto-clear enabled), set the EP0STLS bit to 0 (default) after a STALL handshake is returned. See Figure 24.8 “STALL and Exit From STALL (When STALL Source Is Used During Communication with the Host)” and Figure 24.9 “STALL and Exit From STALL (When Setting STALL Source by a Program)”.

To set the EP0ASCE bit to 1, write 1 to the EP0ASCE bit when the EP0STLS bit in the USBEPSTL0 register is 0.

RSME (Resume request bit) (b3)

The RSME bit wakes up the USB bus from the suspend state (execute remote wake-up).

Follow the procedure below to exit the suspend state:

(1) Set the RSME bit to 1 (resume requested).
(2) Wait for four USB clock cycles.
(3) Set the RSME bit to 0.

RWUPS (Remote wake-up status flag) (b4)

The RWUPS flag indicates whether the remote wake-up from the host is disabled or enabled.

When the Device_Remote_Wakeup of the Set Feature command or Clear Feature command is received, the value of the RWUPS bit changes according to the content.

PULLUPE (Pull-up enable bit) (b7)

When the PULLUPE bit is 0 (ATTACH output OFF), the internal VBUS signal becomes 0 regardless of the input level to the VbusDTCT pin.

When the PULLUPE bit is 1 (ATTACH output ON), the VbusDTCT pin input becomes the internal VBUS signal to send to the protocol processors.

24.2.32 USB Endpoint Information Register (USBEPIR)

USB Endpoint Information Register (USBEPIR)

b7 ... b0	Symbol	Address	Reset Value
	USBEPIR	D1C0h	XXh

Function	RW
Set the endpoint information	WO

Access the USBEPIR register in 8-bit units. Use the MOV instruction to access this register.
The USBEPIR register sets information for individual endpoints. Endpoint information is 5 bytes per endpoint. Table 24.5 lists Write Order and Meanings of the Endpoint Information.

Table 24.5 Write Order and Meanings of the Endpoint Information

Write Order	Bit Content							
	b7	b6	b5	b4	b3	b2	b1	b0
1	Endpoint number used by the host [0 to 6]				Configuration number [0, 1]		Interface number [0 to 3]	
2	Alternate setting [0]		Transfer type 00b: Control 01b: Do not set 10b: Bulk 11b: Interrupt		Transfer direction 0: OUT 1: IN	000b (reserved)		
3	Maximum packet size for endpoint [0 to 64]							0 (reserved)
4	00h (reserved)							
5	Endpoint FIFO number (USB module endpoint number for this MCU) [0 to 6]							

Numbers in brackets [ ] represent settable values.

Write data in order, from endpoint 0 to endpoint 6 of the endpoint FIFO number (see order step number 5 in the table above).
Write 00h for 5 bytes to an unused endpoint. Therefore, write 00h for 35 bytes to the USBEPIR register, but no more than 35 bytes. Do not rewrite a value once it has been set. Table 24.6 to Table 24.12 list the values to set to individual endpoints.
Data written to the USBEPIR register is loaded to the USB module. When loading is completed, the CFDN bit in the USBIFR0 register becomes 1 (endpoint information loading complete detected). Each endpoint can be used after the CFDN bit becomes 1.
Do not set the same value to both the endpoint number used by the host (refer to b7 to b4 in step 1 of the write order in Table 24.5) and another endpoint number.

Table 24.6 Write Value for Endpoint 0

Write Order	Bit Content							
	b7	b6	b5	b4	b3	b2	b1	b0
1	00h (reserved)							
2	00h (reserved)							
3	0010000b: 16 bytes							0 (reserved)
4	00h (reserved)							
5	00h: Endpoint 0							

Table 24.7 Write Value for Endpoint 1

Write Order	Bit Content							
	b7	b6	b5	b4	b3	b2	b1	b0
1	Endpoint number used by the host [0 to 6]				Configuration number [0, 1]		Interface number [0 to 3]	
2	Alternate number [0]		10b: Bulk		0: OUT	000b (reserved)		
3	1000000b: 64 bytes							0 (reserved)
4	00h (reserved)							
5	01h: Endpoint 1							

Numbers in brackets [ ] represent settable values. Write 00h for 5 bytes when not using endpoint 1.

Table 24.8 Write Value for Endpoint 2

Write Order	Bit Content							
	b7	b6	b5	b4	b3	b2	b1	b0
1	Endpoint number used by the host [0 to 6]				Configuration number [0, 1]		Interface number [0 to 3]	
2	Alternate number [0]		10b: Bulk		1: IN	000b (reserved)		
3	1000000b: 64 bytes							0 (reserved)
4	00h (reserved)							
5	02h: Endpoint 2							

Numbers in brackets [ ] represent settable values. Write 00h for 5 bytes when not using endpoint 2.

Table 24.9 Write Value for Endpoint 3

Write Order	Bit Content							
	b7	b6	b5	b4	b3	b2	b1	b0
1	Endpoint number used by the host [0 to 6]				Configuration number [0, 1]		Interface number [0 to 3]	
2	Alternate number [0]		11b: Interrupt		1: IN	000b (reserved)		
3	0010000b: 16 bytes							0 (reserved)
4	00h (reserved)							
5	03h: Endpoint 3							

Numbers in brackets [ ] represent settable values. Write 00h for 5 bytes when not using endpoint 3.

Table 24.10 Write Value for Endpoint 4

Write Order	Bit Content							
	b7	b6	b5	b4	b3	b2	b1	b0
1	Endpoint number used by the host [0 to 6]				Configuration number [0, 1]		Interface number [0 to 3]	
2	Alternate number [0]		10b: Bulk		0: OUT	000b (reserved)		
3	1000000b: 64 bytes							0 (reserved)
4	00h (reserved)							
5	04h: Endpoint 4							

Numbers in brackets [ ] represent settable values. Write 00h for 5 bytes when not using endpoint 4.

Table 24.11 Write Value for Endpoint 5

Write Order	Bit Content							
	b7	b6	b5	b4	b3	b2	b1	b0
1	Endpoint number used by the host [0 to 6]				Configuration number [0, 1]		Interface number [0 to 3]	
2	Alternate number [0]		10b: Bulk		1: IN	000b (reserved)		
3	1000000b: 64 bytes							0 (reserved)
4	00h (reserved)							
5	05h: Endpoint 5							

Numbers in brackets [ ] represent settable values. Write 00h for 5 bytes when not using endpoint 5.

Table 24.12 Write Value for Endpoint 6

Write Order	Bit Content							
	b7	b6	b5	b4	b3	b2	b1	b0
1	Endpoint number used by the host [0 to 6]				Configuration number [0, 1]		Interface number [0 to 3]	
2	Alternate number [0]		11b: Interrupt		1: IN	000b (reserved)		
3	0010000b: 16 bytes							0 (reserved)
4	00h (reserved)							
5	06h: Endpoint 6							

Numbers in brackets [ ] represent settable values. Write 00h for 5 bytes when not using endpoint 6.

24.2.33 USB Module Control Register (USBMC)

USB Module Control Register (USBMC)

b7	b6	b5	b4	b3	b2	b1	b0
		X			0	0	

Symbol	Address	Reset Value
USBMC	D1CCh	11X1 0000b

Bit Symbol	Bit Name	Function	RW
VBUSE	VbusDTCT input enable bit	0: VbusDTCT input disabled 1: VbusDTCT input enabled	RW
— (b2-b1)	Reserved bits	Set to 0.	RW
VDDUSBE	USB internal power supply control bit 0	0: USB internal power supply stopped, UVCC pin input enabled 1: 3.3 V USB internal power source supplied	RW
PXXCON	USB internal power supply control bit 1	0: VDDUSBE bit disabled 1: VDDUSBE bit enabled	RW
— (b5)	No register bits. Should be written with 0 and read as undefined values.		—
USBSTS	USB module status flag	0: USB module enabled 1: USB module disabled	RO
USBE	USB module enable bit	0: USB clock supplied (USB starts operating) 1: USB clock stopped (USB stops operating)	RW

Access the USBMC register in 8-bit units. Do not access this register in 16-bit units.

VDDUSBE (USB internal power supply control bit 0) (b3)

This bit is enabled when the PXXCON bit is 1 (VDDUSBE bit enabled).
When the VDDUSBE bit is 0 (UVCC pin input enabled), pins ATTACH, D+, and D- operates referring the external voltage level input from UVCC pin as high level.
When the VDDUSBE bit is 1 (3.3 V USB internal power source supplied), pins ATTACH, D+, and D- operates referring the USB internal voltage level of 3.3 V as high level. The UVCC pin outputs 3.3 V.

PXXCON (USB internal power supply control bit 1) (b4)

In order to use the USB module, set the PXXCON bit to 1 (VDDUSBE bit enabled). Select the UVCC pin function using the VDDUSBE bit. When not using the USB module, set the PXXCON bit to 0 (VDDUSBE bit disabled). The UVCC pin outputs the VCC1 level. Refer to 13.5 “Unassigned Pin Handling”.

USBSTS (USB module status flag) (b6)

When the USB module is enabled after setting the USBE bit to 0 (USB clock supplied), the USBSTS bit becomes 0 (USB module enabled). Access USB associated registers other than the USBMC register when the USBE bit is 0 and the USBSTS bit is 0 (USB module enabled).
Once the USBSTS bit becomes 0, then it remains 0 even if the USBE bit is set to 1.

USBE (USB module enable bit) (b7)

To use the USB module, set the USBE bit to 0 (USB clock supplied).

24.3 Operations

24.3.1 USB Clock

PLLFCK becomes the USB clock (operating clock for the USB module). Set PLLFCK to 48 MHz. Refer to 8. “Clock Generator” when setting the clock.

When using the USB module, first set the USBE bit in the USBMC register to 0 (USB clock supplied). When the USB module is enabled, the USBSTS bit in the USBMC register becomes 0 (USB module enabled). When the USBSTS bit is 0, USB related registers (except for the USBMC register) can be successfully accessed. Refer to Table 24.4 for USB register configuration.

24.3.2 Internal Power for the USB Module and UVCC Pin

The USB module has an internal power source which outputs 3.3 V for USB communication.
Internal power for the USB module can be used when 4.0 V ≤ VCC1 ≤ 5.5 V. The output of the internal power source for the USB module is connected to the UVCC pin. To use the internal power source for the USB module, connect a 0.33 μF capacitor to the UVCC pin.
In order for the internal power source to output 3.3 V, set the PXXCON bit in the USBMC register to 1 (VDDUSBE bit enabled), and the VDDUSBE bit in the USBMC register to 1 (3.3 V USB internal power source supplied).
When outputting 3.3 V from the internal power source for the USB module, set the 125 kHz on-chip oscillator to the operating state (set the CM14 bit in the CM1 register to 0). Set the VDDUSBE bit to 1, and wait a minimum of 1 ms for the 3.3 V internal power source for the USB module to stabilize. Generate the wait time by a program. The 125 kHz on-chip oscillator can be stopped after the 3.3 V output stabilizes (after 1 ms passes).
Apply 3.3 V to the UVCC pin when using the USB module while 3.0 V ≤ VCC1 ≤ 4.0 V, or when using the USB module without using the USB internal power source even while 4.0 V ≤ VCC1 ≤ 5.5 V. When the PXXCON bit in the USBMC register is 1 (VDDUSBE bit enabled) and the VDDUSBE bit is 0 (USB internal power stopped), UVCC pin input is enabled.
When not using the USB module, set the PXXCON bit in the USBMC register to 0 (VDDUSBE bit disabled) and connect the UVCC pin to VCC1.

24.3.3 Self-Powered Mode Circuit (3.3 V)

Figure 24.2 shows Self-Powered Mode Circuit (3.3 V).

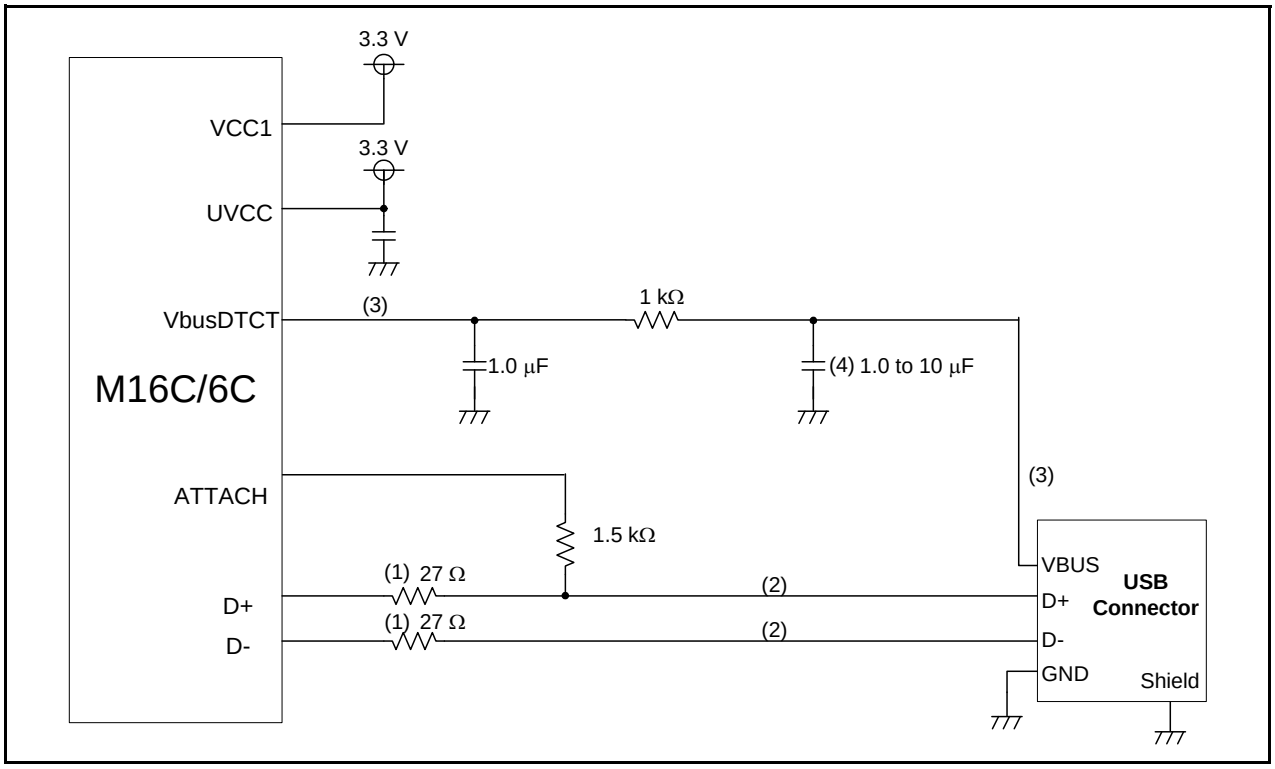


Figure 24.2 Self-Powered Mode Circuit (3.3 V)

Set the following when using this example circuit:

- Set the PXXCON bit in the USBMC register to 1 (VDDUSBE bit enabled)
- Set the VDDUSBE bit in the USBMC register to 0 (UVCC pin input enabled)
- Set the PWMD bit in the USBCTLR register to 0 (self-powered mode)

Note the items below when using the self-powered mode circuit (3.3 V). Numbers (1) to (4) below correspond to (1) to (4) in Figure 24.2.

(1) Series resistors on the D+/D- lines
Connect 27 Ω resistors in series on the D+/D- lines. Also, connect them as close to the MCU as possible.

(2) Wiring of the D+/D- lines
Wire the D+/D- lines so the differential impedance becomes the recommended value of 90 Ω. When it is difficult to achieve the same impedance between the D+/D- lines, put the two lines closer using wires as close to the same length as possible.

(3) Wiring of the VBUS line
When the VbusDTCT pin becomes low, the USB module is reset to the Powered state. Therefore, pay attention to the layout of the wiring to prevent noise.

(4) Capacitor on VBUS line
Connect a 1 to 10 µF capacitor. Attach a filter circuit on the VBUS line because overshoot may occur when connecting a USB cable.

24.3.4 Self-Powered Mode Circuit (5.0 V)

Figure 24.3 shows Self-Powered Mode Circuit (5.0 V)

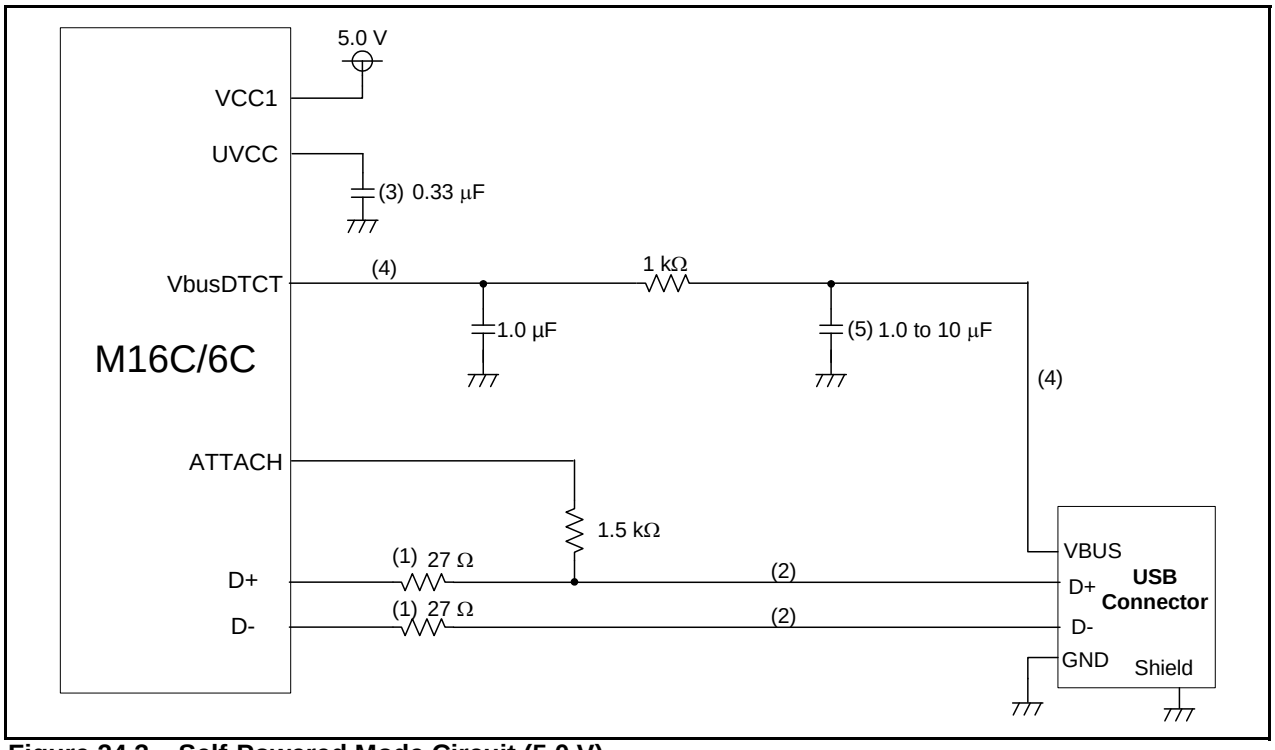


Figure 24.3 Self-Powered Mode Circuit (5.0 V)

Set the following when using this example circuit:

- Set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on)
- Set the PXXCON bit in the USBMC register to 1 (VDDUSBE bit enabled)
- Set the VDDUSBE bit in the USBMC register to 1 (supplying 3.3 V USB internal power supply)
- Set the PWMD bit in the USBCTLR register to 0 (self-powered mode)

Note the items below when using self-powered mode circuit (5.0 V). Numbers (1) to (5) below correspond to (1) to (5) in Figure 24.2.

(1) Series resistors on the D+/D- lines
Connect 27 Ω resistors in series on the D+/D- lines. Also, connect them as close to the MCU as possible.

(2) Wiring of the D+/D- lines
Wire the D+/D- lines so the differential impedance becomes the recommended value of 90 Ω. When it is difficult to achieve the same impedance between the D+/D- lines, put the two lines closer using wires as close to the same length as possible.

(3) Bypass capacitor of the UVCC pin
When using the internal power supply for USB, connect a 0.33 µF capacitor between the UVCC pin and VSS with the shortest and thickest possible wiring.

(4) Wiring of the VBUS line
When the VbusDTCT pin becomes low, the USB module is reset to the Powered state. Therefore, pay attention to the layout of the wiring to prevent noise.

(5) Capacitor on the VBUS line
Connect a 1 to 10 µF capacitor. The VBUS line may overshoot when connecting a USB cable. Therefore, embed a filter circuit.

24.3.5 Bus-Powered Mode (3.3 V)

Figure 24.4 shows Bus-Powered Mode Circuit (3.3 V).

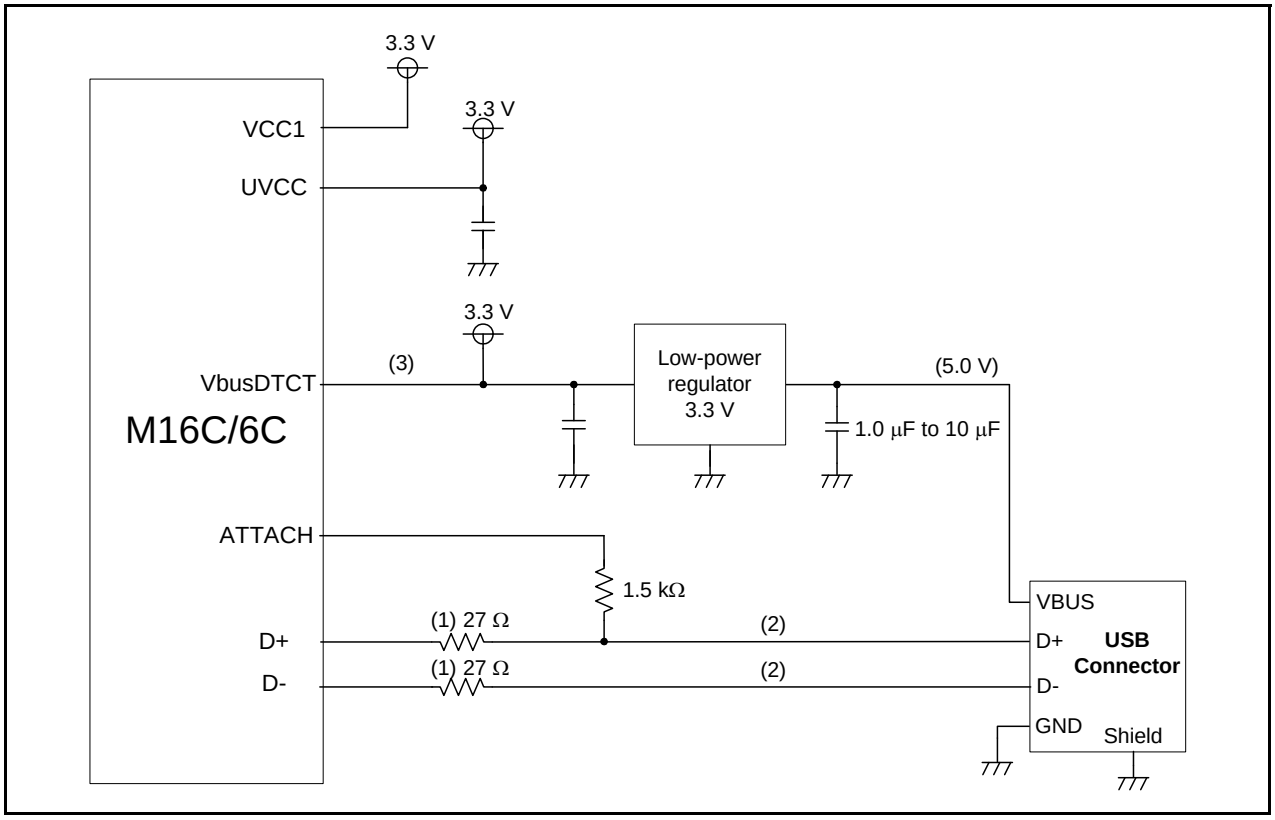


Figure 24.4 Bus-Powered Mode Circuit (3.3 V)

Set the following when using this example circuit:

- Set the PXXCON bit in the USBMC register to 1 (VDDUSBE bit enabled).
- Set the VDDUSBE bit in the USBMC register to 0 (UVCC pin input enabled).
- Set the PWMD bit in the USBCTLR register to 1 (bus-powered mode).

Note the items below when using bus-powered mode circuit (3.3 V). Numbers (1) to (3) listed below correspond to (1) to (3) in Figure 24.2.

(1) Series resistors on the D+/D- lines
Connect 27 Ω resistors in series on the D+/D- lines. Also, connect them as close to the MCU as possible.

(2) Wiring of the D+/D- lines
Wire the D+/D- lines so the differential impedance becomes the recommended value of 90 Ω. When it is difficult to achieve the same impedance between the D+/D- lines, put the two lines closer using wires as close to the same length as possible.

(3) Wiring of the VBUS line
When the VbusDTCT pin becomes low, the USB module is reset to the Powered state. Therefore, pay attention to the layout of the wiring to prevent noise.
If noise cannot be removed, take a measures such as applying the RC circuit or filter.

24.3.6 Bus-Powered Mode (5.0 V)

Figure 24.5 shows Bus-Powered Mode Circuit (5.0 V).

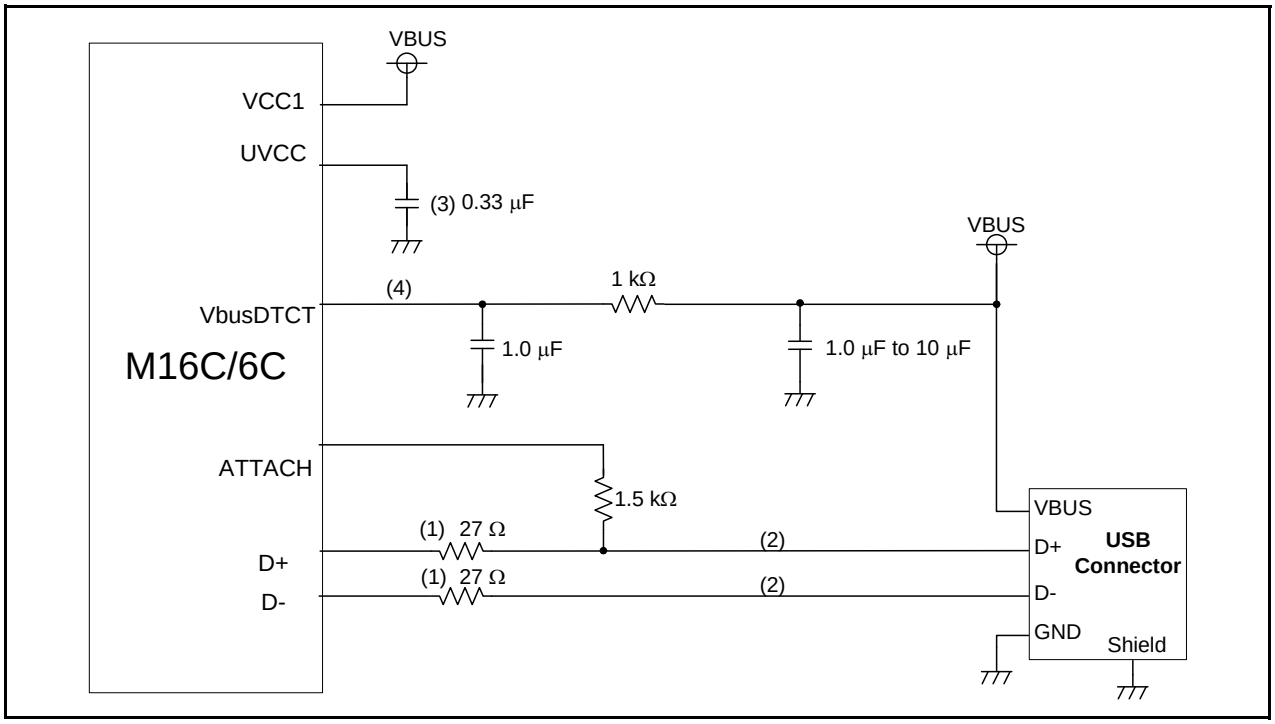


Figure 24.5 Bus-Powered Mode Circuit (5.0 V)

Set the following when using this example circuit:

- Set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on)
- Set the PXXCON bit in the USBMC register to 1 (VDDUSBE bit enabled).
- Set the VDDUSBE bit in the USBMC register to 1 (supplying 3.3 V USB internal power supply)
- Set the PWMD bit in the USBCTLR register to 1 (bus-powered mode).

Note the items below when using bus-powered mode circuit (5.0 V). Numbers (1) to (4) listed below correspond to (1) to (4) in Figure 24.2.

(1) Series resistors on the D+/D- lines
Connect 27 Ω resistors in series on the D+/D- lines. Also, connect them as close to the MCU as possible.

(2) Wiring of the D+/D- lines
Wire the D+/D- lines so the differential impedance becomes the recommended value of 90 Ω. When it is difficult to achieve the same impedance between the D+/D- lines, put the two lines closer using wires as close to the same length as possible.

(3) Bypass capacitor of the UVCC pin
When using the internal power supply for USB, connect a 0.33 µF capacitor between the UVCC pin and VSS with the shortest and thickest possible wiring.

(4) Wiring of the VBUS line
When the VbusDTCT pin becomes low, the USB module is reset to the Powered state. Therefore, pay attention to the layout of the wiring to prevent the noise.

24.3.7 USB Initial Setting

Figure 24.6 shows the USB Module Initial Setting and Figure 24.7 shows the Setting when Connecting the Cable.

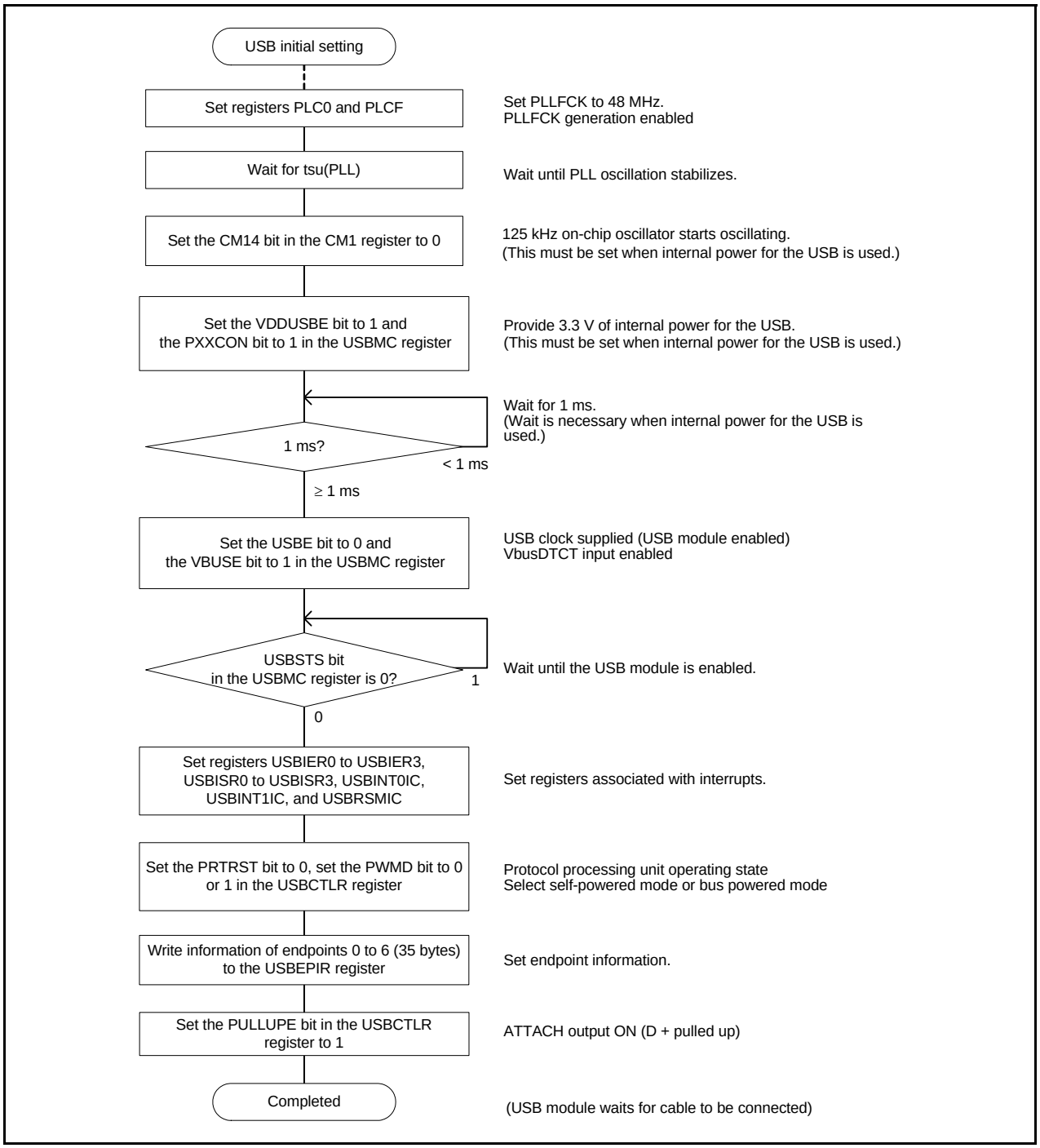


Figure 24.6 USB Module Initial Setting

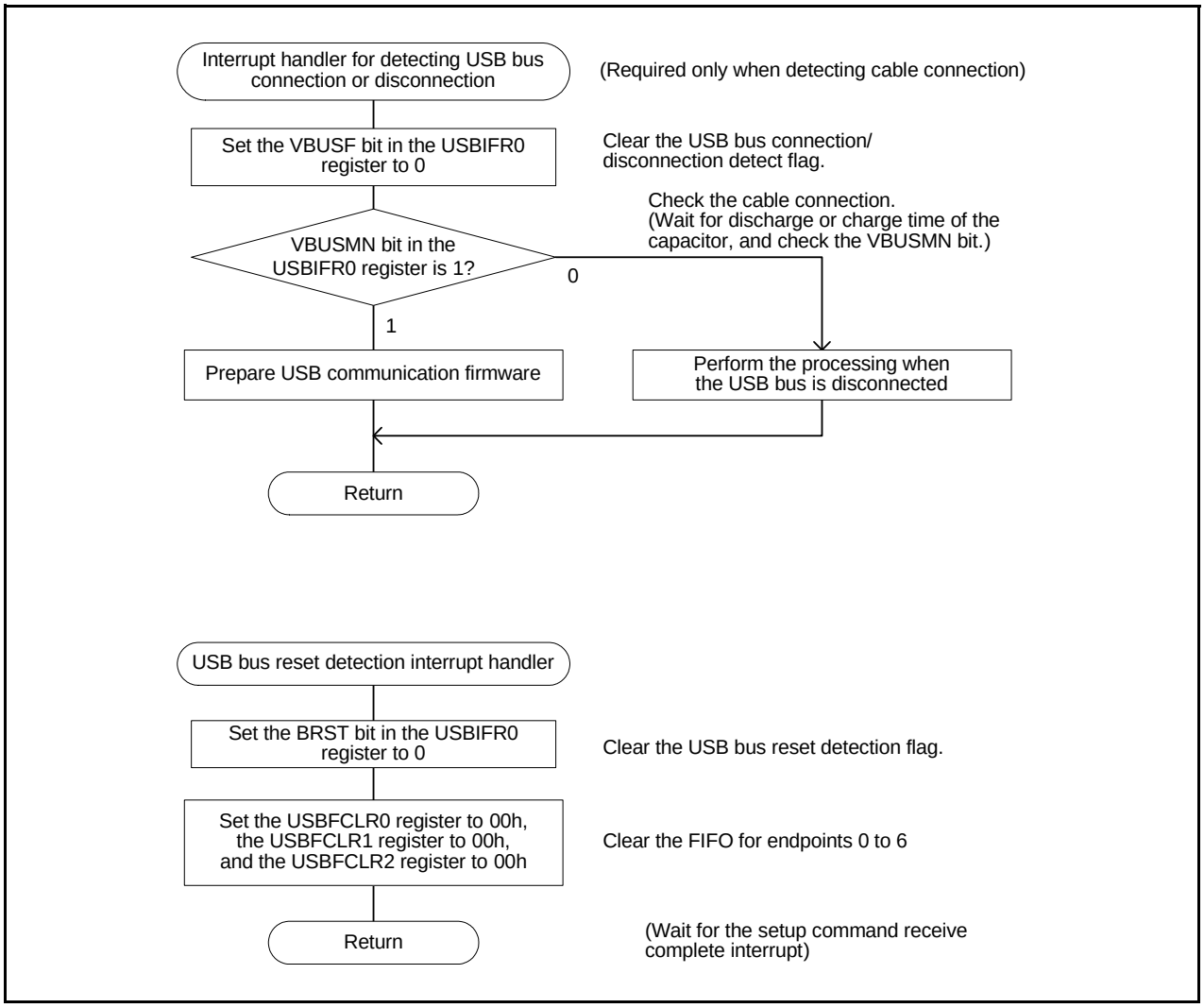


Figure 24.7 Setting when Connecting the Cable

24.3.8 STALL

When there is a STALL source during communication with the host, STALL is returned in response to a transaction. A stall state can also be set internally by a program and STALL is returned in response to a transaction.

Use the EPiSTLST bit to read the endpoint i (i = 0 to 6) internal stall state. The EPiSTLS bit is used to set the internal STALL state by a program, the EPiSTLC bit is used to exit the internal STALL state by a program, and the EPiASCE bit is used to automatically exit the internal stall state after STALL is returned.

The following operations occur when a transaction is received from the host:

- A transaction is received when both the EPiSTLST and EPiSTLS bits are 0.
- STALL is returned when the EPiSTLST bit is 1.
- When the EPiSTLS bit is 1, the EPiSTLST bit is set to 1 and STALL is returned.
- When the Clear Feature command is received, the EPiSTLST bit becomes 0 to exit the stall state.

Figures 24.8 and 24.9 show STALL and Exit From STALL.

The internal stall state for endpoint 0 cannot be read by a program. However, there is an internal bit that acts as the EPiSTLST bit and operates the same as endpoints 1 to 6.

Note:
EPiSTLC, EPiSTLS: Bits in the registers USBEPSTL0, USBEPSTL1, and USBEPSTL2
EPiSTLST: Bit in registers USBSTLSR1 and USBSTLSR2
EPiASCE: Bit in registers USBCTLR, USBSTLSR1, and USBSTLSR2

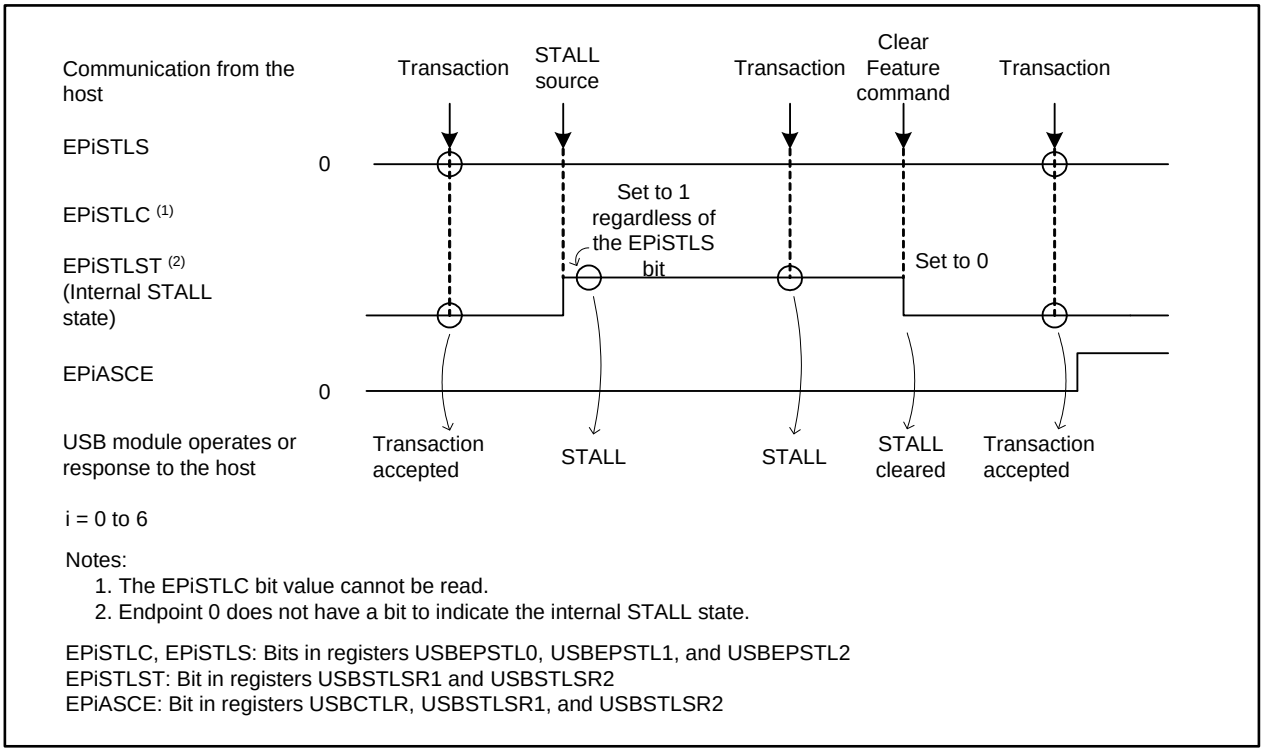
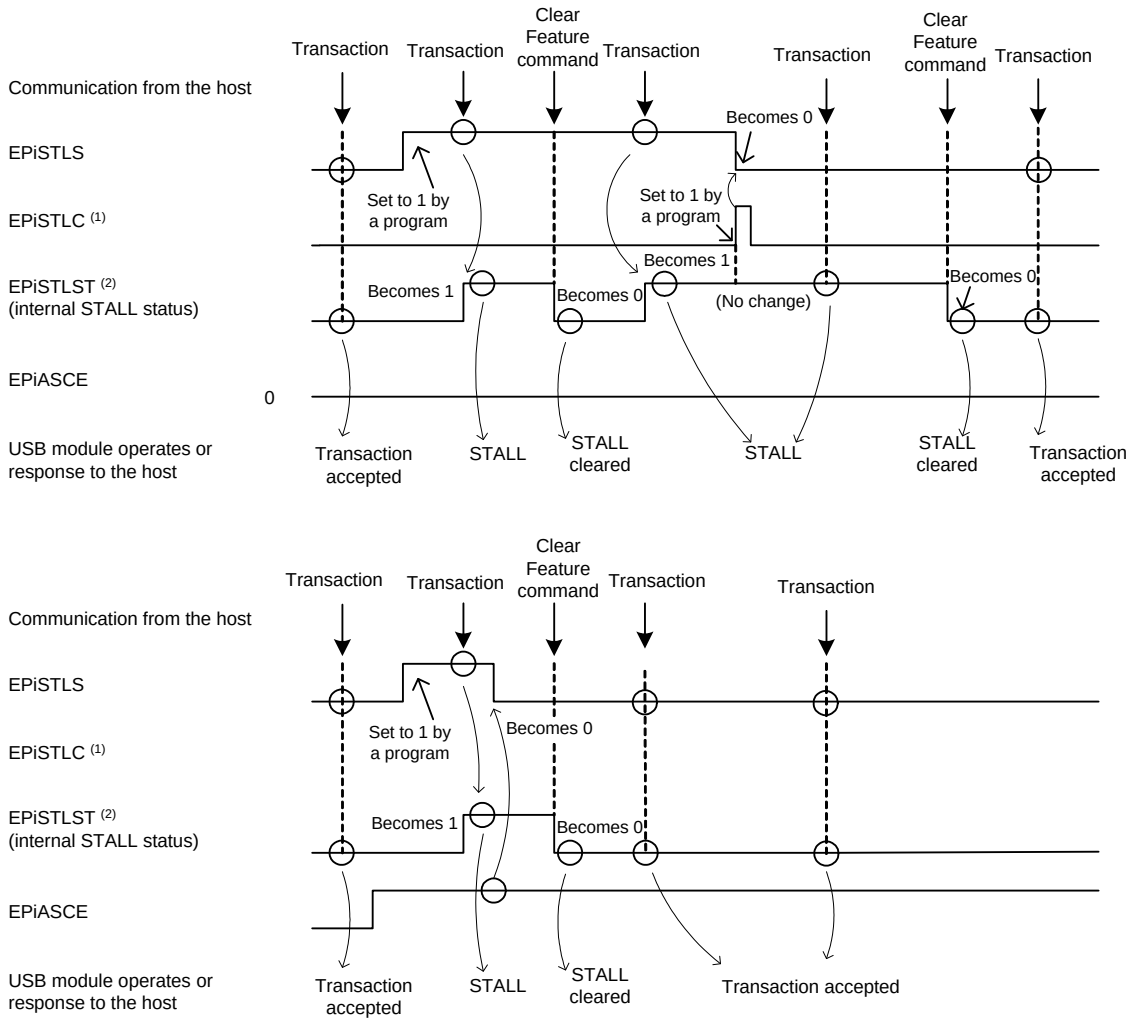


Figure 24.8 STALL and Exit From STALL (When STALL Source Is Used During Communication with the Host)



i = 0 to 6
Notes:
1. The EPiSTLC bit value cannot be read.
2. Endpoint 0 does not have a bit to indicate the internal stall status.

EPiSTLC, EPiSTLS: Bits in registers USBEPSTL0, USBEPSTL1, and USBEPSTL2
EPiSTLST: Bit in registers USBSTLSR1 and USBSTLSR2
EPiASCE: Bit in registers USBCTLR, USBSTLSR1, and USBSTLSR2

Figure 24.9 STALL and Exit From STALL (When Setting STALL Source by a Program)

24.3.9 VBUS Detection

This function detects the presence or absence of voltage being supplied from the host to the USB bus. Set the VBUSE bit in the USBMC register to 1 (VbusDTCT input enabled) and the PULLUPE bit in the USBCTLR register to 1 to monitor the VbusDTCT pin level.

When the VBUSE bit or PULLUPE bit is 0, the internal VBUS detect signal is low regardless of the VbusDTCT pin level. That is to say, the MCU recognizes the USB bus is disconnected even if a USB cable is connected.

If there is a change in the internal VBUS detect signal, the VBUSF bit in the USBIFR0 register becomes 1 (USB bus connect/disconnect detected).

24.3.10 ATTACH Output Function

The ATTACH pin is a P-channel open drain output pin and used as an output pin to pull up the D+ level by 1.5 kΩ. Pullup a 1.5 kΩ resistor between the ATTACH pin and the D+ pin.

To enable the ATTACH output, set the VBUSE bit in the USBMC register to 1 (VbusDTCT input enabled) and the PULLUPE bit in the USBCTLR register to 1 (ATTACH output ON). When the VBUSE bit and PULLUPE bit are 1, and a high level signal is applied to the VbusDTCT pin, the ATTACH pin outputs high and the D+ pin is pulled up. When either the VBUSE bit or PULLUPE bit is 0, the ATTACH pin becomes high-impedance.

24.3.11 Processing Standard USB Commands and Class/Vendor Commands

When receiving standard USB commands, some of the command decode and other operations are automatically performed by the USB module and some must be processed by the user. The user must process class or vendor commands when received. Table 24.13 shows how commands are processed when received.

Table 24.13 Processing Commands When Received

Command	USB Module Operation	User Processed
Get Configuration Get Interface Get Status Set Address Set Feature Clear Feature	(1) Automatically performs command decode, data stage, and status stage processing.	Unnecessary
Set Interface	In addition to (1) above, the SETI bit in the USBIFR0 register becomes 1 (interrupt request generated).	
Set Configuration	In addition to (1) above, the SETC bit in the USBIFR0 register becomes 1 (interrupt request generated)	
Get Descriptor Set Descriptor Sync Frame	Save the command to the endpoint 0 setup command FIFO buffer. After a successful reception, the SETUPTS bit in the USBIFR1 register becomes 1 (interrupt request generated).	(1) Use the USBEPDR0S register to read the endpoint 0 setup command FIFO buffer command. (2) Decode (3) Data stage and status stage processing
Class Vendor		

24.4 Interrupts

The USB module generates interrupt requests from 24 interrupt sources. There are three types of interrupts:

- USB RESUME interrupt
- USB interrupt 0
- USB interrupt 1

Refer to individual mode specifications and operations for information on interrupt request generation timing. Refer to 14.7 “Interrupt Control” for details regarding interrupt control.

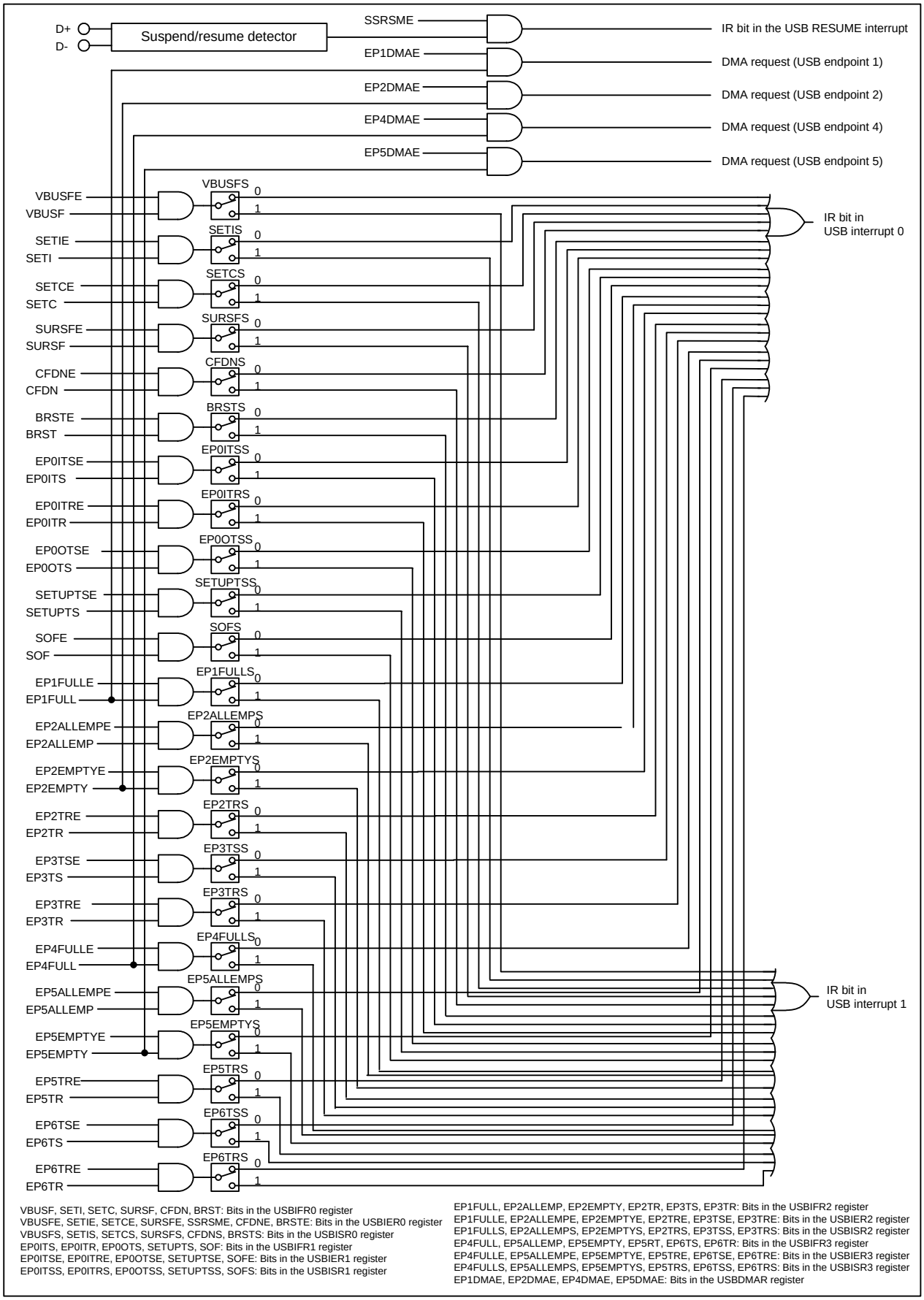


Figure 24.10 USB Module Interrupts

Table 24.14 USB Interrupt Sources and Control (1/4)

Interrupt Source	Associated Registers and Bits			Interrupt
	Flag	Enable	Select	
	Bit in the USBIFR0 register	Bit in the USBIER0 register	Bit in the USBISR0 register	
USB bus connect/disconnect	VBUSF	VBUSFE	VBUSFS	USB0 or USB1
Set Interface command detect	SETI	SETIE	SETIS	USB0 or USB1
Set Configuration command detect	SETC	SETCE	SETCS	USB0 or USB1
Suspend/resume detect	SURSF	SURSFE	SURSFS	USB0 or USB1
Standby clear resume detect	—	SSRSME	—	USB RESUME
Endpoint information loading complete	CFDN	CFDNE	CFDNS	USB0 or USB1
USB bus reset detect	BRST	BRSTE	BRSTS	USB0 or USB1

Table 24.15 USB Interrupt Sources and Control (2/4)

Interrupt Source	Associated Registers and Bits			Interrupt
	Flag	Enable	Select	
	Bit in the USBIFR1 register	Bit in the USBIER1 register	Bit in the USBISR1 register	
Endpoint 0 IN transmit complete	EP0ITS	EP0ITSE	EP0ITSS	USB0 or USB1
Endpoint 0 IN transfer request	EP0ITR	EP0ITRE	EP0ITRS	USB0 or USB1
Endpoint 0 OUT receive complete	EP0OTS	EP0OTSE	EP0OTSS	USB0 or USB1
Setup command receive complete	SETUPTS	SETUPTSE	SETUPTSS	USB0 or USB1
SOF packet detect	SOF	SOFE	SOFS	USB0 or USB1

Table 24.16 USB Interrupt Sources and Control (3/4)

Interrupt Source	Associated Registers and Bits			Interrupt
	Flag	Enable	Select	
	Bit in the USBIFR2 register	Bit in the USBIER2 register	Bit in the USBISR2 register	
Endpoint 1 FIFO full	EP1FULL	EP1FULLE	EP1FULLS	USB0 or USB1
Endpoint 2 FIFO all empty	EP2ALLEMP	EP2ALLEMPE	EP2ALLEMPS	USB0 or USB1
Endpoint 2 FIFO empty	EP2EMPTY	EP2EMPTYE	EP2EMPTYS	USB0 or USB1
Endpoint 2 transfer request	EP2TR	EP2TRE	EP2TRS	USB0 or USB1
Endpoint 3 transmit complete	EP3TS	EP3TSE	EP3TSS	USB0 or USB1
Endpoint 3 transfer request	EP3TR	EP3TRE	EP3TRS	USB0 or USB1

Table 24.17 USB Interrupt Sources and Control (4/4)

Interrupt Source	Associated Registers and Bits			Interrupt
	Flag	Enable	Select	
	Bit in the USBIFR3 register	Bit in the USBIER3 register	Bit in the USBISR3 register	
Endpoint 4 FIFO full	EP4FULL	EP4FULLE	EP4FULLS	USB0 or USB1
Endpoint 5 FIFO all empty	EP5ALLEMP	EP5ALLEMPE	EP5ALLEMPS	USB0 or USB1
Endpoint 5 FIFO empty	EP5EMPTY	EP5EMPTYE	EP5EMPTYS	USB0 or USB1
Endpoint 5 transfer request	EP5TR	EP5TRE	EP5TRS	USB0 or USB1
Endpoint 6 transmit complete	EP6TS	EP6TSE	EP6TSS	USB0 or USB1
Endpoint 6 transfer request	EP6TR	EP6TRE	EP6TRS	USB0 or USB1

Table 24.18 USB Interrupt Associated Registers

Address	Register Name	Register Symbol	After Reset
0076h	USB Interrupt 0 Control Register	USBINT0IC	XXXX X000b
0077h	USB Interrupt 1 Control Register	USBINT1IC	XXXX X000b
0078h	USB RESUME Interrupt Control Register	USBRSMIC	XXXX X000b

24.4.1 USB RESUME Interrupt

When the SSRSME bit in the USBIER0 register is 1 (interrupt enabled), and the USB bus resume is detected, a USB RESUME interrupt is generated. To use the USB RESUME interrupt, detect a suspend state on the USB bus, and set the SSRSME bit to 1. After the resume is detected, set the SSRSME bit to 0 to disable the USB RESUME interrupt.

The USB RESUME interrupt can be used to exit from wait or stop mode. When using this interrupt to exit from wait or stop mode, detect a suspend state on the USB bus first, and enable this interrupt to enter wait mode or stop mode. After exit wait mode or stop mode using this interrupt, disable this interrupt.

24.4.2 USB Interrupt 0, USB Interrupt 1

When a bit in the USBIERj (j = 0 to 3) register is 1 (interrupt enabled) for an interrupt request source, and the corresponding bit in the USBIFRj register is 1, an interrupt request for that request source is generated. At this point, if the corresponding bit in the USBISRj register is 0, a USB interrupt 0 request is generated. However, if the bit is 1, then a USB interrupt 1 request is generated.

Differences in the IR bit in the USBINT0IC and USBINT1IC registers and other IR bits are listed below.

- When a bit in the USBIFRj register is 1, and the corresponding bit in the USBIERj register is 1 (interrupt enabled), the IR bit in the interrupt control register becomes 1 (interrupt requested).
- If either or both a bit in the USBIFRj register and the corresponding bit in the USBIERj register becomes 0, the IR bit becomes 0 (interrupt not requested). That is to say, even if the IR bit becomes 1 and an interrupt is not accepted, the interrupt request is not held. The IR bit cannot be set to 0 by a program.
- Even if an interrupt is accepted, each bit in the USBIFRj register does not automatically become 0. Consequently, the IR bit does not automatically become 0 when an interrupt is accepted. Set each bit in the USBIFRj register to 0 in the interrupt routine.
- When setting multiple bits in the USBIERj register to 1, after the IR bit becomes 1, if a separate interrupt request source is generated, the IR bit remains 1.

To enable multiple interrupts from endpoint 0 OUT receive complete, endpoint 0 IN transfer request, and endpoint 0 IN transmit complete interrupts, set the same value to bits EP0OTSS, EP0ITRS, and EP0ITSS in the USBISR1 register. That is to say, select either USB interrupt 0 or USB interrupt 1 for all three interrupt requests.

24.5 DMA Transfer

The DMA transfer source is generated when both the interrupt flag as the DMA request source is 1 and a DMA transfer enable bit is 1. Table 24.19 lists DMA Requests for USB Module.
For more information on DMA, refer to 16. “DMAC”.
When using the DMAC to access the USB associated registers, set the transfer unit to 8 bits.

Table 24.19 DMA Requests for USB Module

DMA Request	DMA Request Source	DMA Transfer Enable Bit
USB endpoint 1	The EP1FULL bit in the USBIFR2 register is 1 (receive data present).	EP1DMAE bit in the USBDMAR register
USB endpoint 2	The EP2EMPTY bit in the USBIFR2 register is 1 (between one and two layers are empty in the endpoint 2 transmit FIFO buffer).	EP2DMAE bit in the USBDMAR register
USB endpoint 4	The EP4FULL bit in the USBIFR3 register is 1 (receive data present).	EP4DMAE bit in the USBDMAR register
USB endpoint 5	The EP5EMPTY bit in the USBIFR3 register is 1 (between one and two layers are empty in the endpoint 5 transmit FIFO buffer).	EP5DMAE bit in the USBDMAR register

24.5.1 Endpoint 1 and Endpoint 4

When using the DMAC to read all the data of the accessible layer of the endpoint i receive FIFO buffer from the USBEPDRi register (i = 1 and 4), the layers automatically switch. Therefore, when reading the endpoint i receive FIFO buffer with the DMA transfer, do not set the EPiRDFN bit in the USBTRG1 register or USBTRG2 register to 1 by a program. Figure 24.11 shows Using DMAC to Read the Endpoint 1 and Endpoint 4 Receive FIFO Buffers.

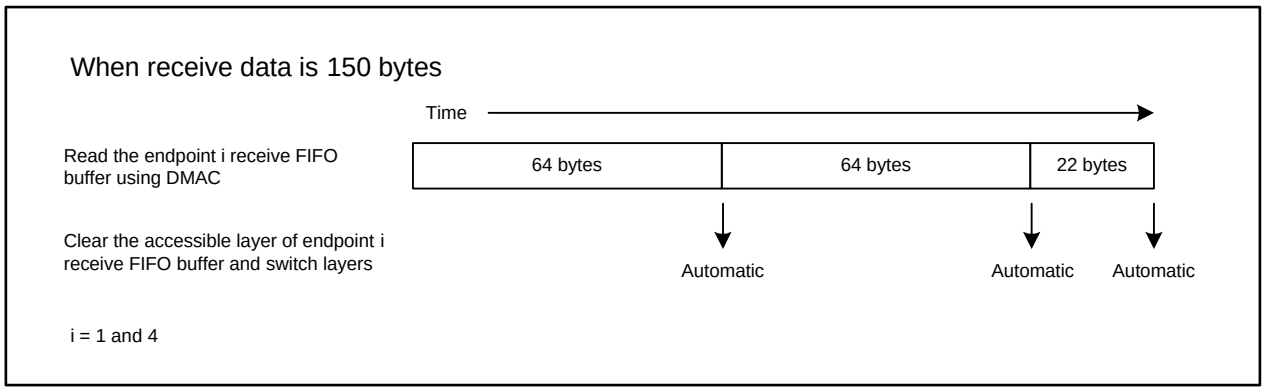


Figure 24.11 Using DMAC to Read the Endpoint 1 and Endpoint 4 Receive FIFO Buffers

The endpoint 1 receive FIFO buffer cannot be cleared when the EP1DMAE bit in the USBDMAR register is 1 (DMA request enabled). After setting the EP1DMAE bit to 0 (DMA request disabled), write 1 (clear) to the EP1CLR bit in the USBFCLR1 register.
Similarly, for the endpoint 4 receive FIFO buffer, after setting the EP4DMAE bit in the USBDMAR register to 0 (DMA request disabled), set the EP4CLR bit in the USBFCLR2 register to 1 (clear).

24.5.2 Endpoint 2 and Endpoint 5

Data for the accessible layer of the endpoint i transmit FIFO buffer is written to the USBEPDRi register (i = 2 and 5) using the DMAC. After writing the maximum 64 bytes, the data is automatically determined, and the layers are switched. Therefore, when writing 64 bytes of data to the endpoint i transmit FIFO buffer with the DMA transfer, do not set the EPiPKTE bit in the USBTRG1 register or USBTRG2 register to 1.
Conversely, when writing less than 64 bytes, after the data is written, set the EPiPKTE bit to 1.
Figure 24.12 shows Using DMAC to Write to the Endpoint 2 and Endpoint 5 Transmit FIFO Buffers.

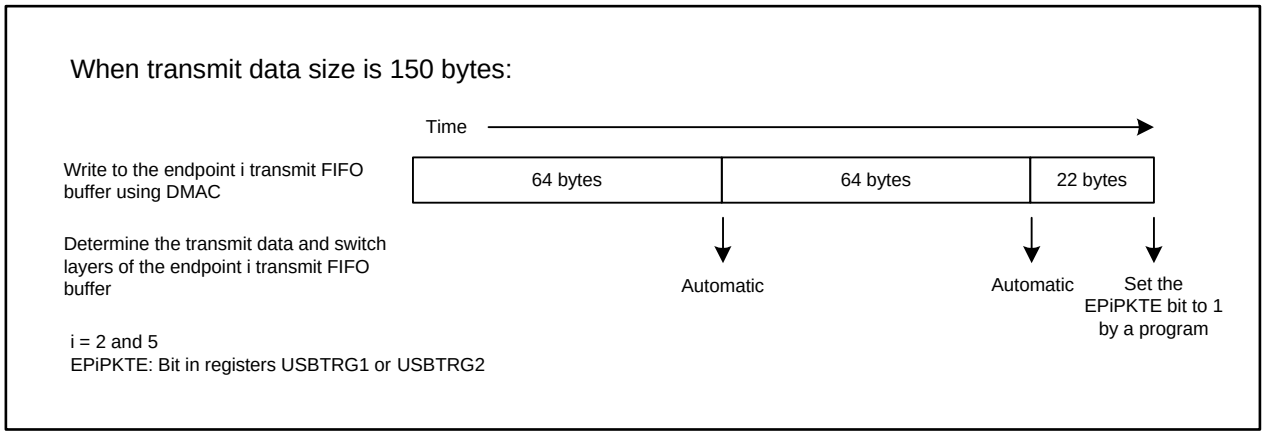


Figure 24.12 Using DMAC to Write to the Endpoint 2 and Endpoint 5 Transmit FIFO Buffers

24.6 Notes on USB Module

24.6.1 Accessing USB Associated Registers

Access USB associated registers in 8-bit units only. Do not access these registers in 16-bit units. Registers other than the USBMC register can be accessed successfully when the USBE bit in the USBMC register is 0 (USB clock supplied) and the USBSTS bit in the USBMC register is 0 (USB function enabled).
When using the DMAC to access the USB associated registers, set the transfer unit to 8 bits.

24.6.2 USB Interrupt Flag Registers

Perform the following when writing to registers USBIFR0, USBIFR1, USBIFR2, and USBIFR3.

- Use the MOV instruction and write to the registers in 8-bit units.
- Those bits that are not set to 0 should be set to 1.

Example 1: When setting the BRST bit (bit 7) in the USBIFR0 register to 0

```
MOV.B #7Fh, USBIFR0
```

Example 2: When setting bits BRST and CFDN (bits 7 and 6) in the USBIFR0 register to 0

```
MOV.B #3Fh, USBIFR0
```

24.6.3 USB Endpoint Stall Registers

Follow the instructions below when writing to registers USBEPSTL0, USBEPSTL1, and USBEPSTL2.

- Use the MOV instruction and write to the registers in 8-bit units.
- Those bits that are not set to 0 should be set to 1.

24.6.4 Detecting a Transmit FIFO Buffer Transfer Request

The following precautions need to be observed when detecting a transfer request of the endpoint i (i = 0, 2, 3, 5 and 6) transmit FIFO buffer. Endpoint 0 is used as an example.

When an IN token is received for endpoint 0, and if there is no valid data in the endpoint 0 transmit FIFO buffer, the USB module returns a NACK to the host and then the EP0ITR bit in the USBIFR1 register becomes 1 (endpoint 0 IN transfer request detected). The USB module repeats this process for every IN token received until the EP0IPKTE bit in the USBTRG0 register is set to 1 (transmit data determined) by a program.
Therefore, when setting the transmit data using the following procedure, and an IN token is received after step (1) until the EP0IPKTE bit becomes 1 in step (3), the EP0ITR bit becomes 1 again.

(1) Set the EP0ITR bit to 0 (endpoint 0 IN transfer request not detected).
(2) Write data to the endpoint 0 transmit FIFO buffer.
(3) Set the EP0IPKTE bit to 1 (transmit data determined).

24.6.5 Internal Power for USB Module and UVCC Pin

Internal power for the USB module can be used when 4.0 V ≤ VCC1 ≤ 5.5 V. When VCC1 is less than 4.0 V, internal power for the USB module cannot be used. The output of the internal power for the USB module is connected to the UVCC pin. When using internal power for the USB module, connect a 0.33 μF capacitor between the UVCC pin and VSS.
When outputting 3.3 V from the internal power for the USB module, start the 125 kHz on-chip oscillator (set the CM14 bit in the CM1 register to 0). Set the VDDUSBE bit in the USBMC register to 1, and wait a minimum of 1 ms for the 3.3 V internal power for the USB to stabilize. Generate the wait time in the program. The 125 kHz on-chip oscillator can be stopped after the 3.3 V output stabilizes (after 1 ms has passed).
Apply 3.3 V to the UVCC pin when using the USB module while 3.0 V ≤ VCC1 ≤ 4.0 V or when using the USB module without using the USB internal power even while 4.0 V ≤ VCC1 ≤ 5.5 V. When the PXXCON bit in the USBMC register is 1 (VDDUSBE bit enabled) and the VDDUSBE bit is 0 (USB internal power stopped), the UVCC pin input is enabled.

24.6.6 Settings When Not Using the USB Module

When not using the USB module, set the PXXCON bit in the USBMC register to 0 (VDDUSBE bit disabled) and connect the UVCC pin to VCC1.

24.6.7 CPU Clock When Using the USB Module

When using the USB module, set the CPU clock to a minimum of 16 MHz.

24.6.8 Entering Wait mode or Stop Mode

(Technical update number: TN-16C-A189A/E)
To enter wait mode or stop mode while using the USB module in memory expansion mode, follow the procedure below.

While using the USB module after setting the VDDUSBE bit in the USBMC register to 1 (3.3 V USB internal power source supplied), when turning off the USB internal power supply to enter wait mode or stop mode, enter single-chip mode before entering wait mode or stop mode.

(1) Set bits PM01 and PM00 in the PM0 register to 00b (single-chip mode).
(2) Set the VDDUSBE bit in the USBMC register to 0 (USB internal power supply stopped).
(3) Enter wait mode or stop mode.

Use the following procedure to rewrite bits PM01 and PM00 after exiting wait mode or stop mode:

(1) Set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on).
(2) Set the VDDUSBE bit in the USBMC register to 1.
(3) Wait for 1 ms.
(4) Rewrite bits PM01 and PM00 in the PM0 register.

Entering wait mode or stop mode while in memory expansion mode or microprocessor mode is possible if the power supply to the USB device continues even in wait mode or stop mode.

24.6.9 Low Supply Voltage

(Technical update number: TN-16C-A189A/E)
When using memory expansion mode or microprocessor mode, the UVCC level becomes undefined if either of the conditions below is met. When this occurs, problems such as an external device not being read correctly or port P1 outputting an unexpected level may occur.

- When the VDDUSBE bit in the USBMC register is 1 (3.3 V USB internal power source supplied), VCC1 < 4.0 V.
- When the VDDUSBE bit is 0 (USB internal power stopped), UVCC < 3.0 V.

When this issue causes a problem, connect a reset IC to prevent the MCU from operating at or under the levels specified above.

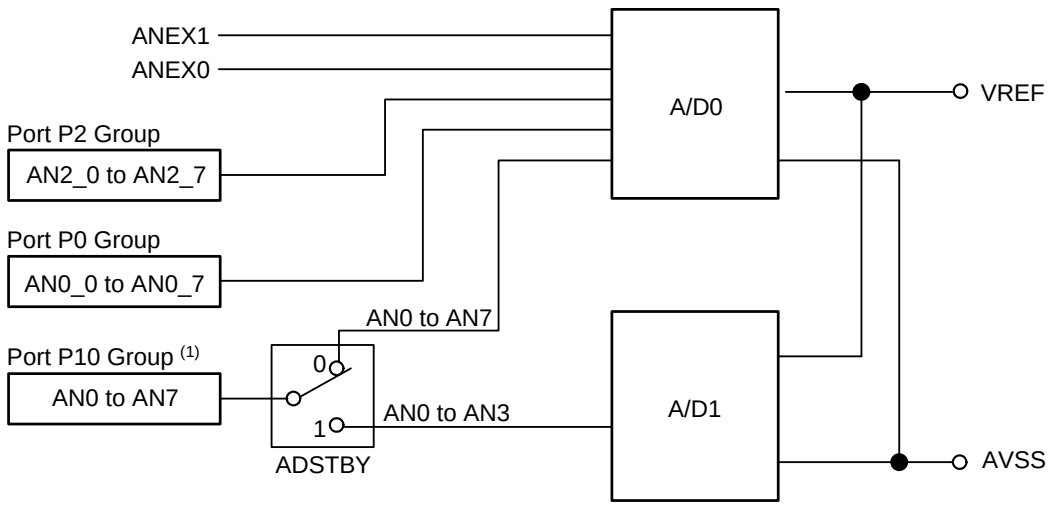
25. A/D Converter

25.1 Introduction

A/D converter consists of two 10-bit successive approximation A/D converters (A/D0, A/D1).
Figure 25.1 shows A/D Converter Block Diagram (A/D0, A/D1), Figure 25.2 shows A/D Converter Block Diagram (A/D0) and Figure 25.3 shows Block Diagram (A/D1).

Table 25.1 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
Analog input pins	A/D0: 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/D1: 4 pins (AN0 to AN3)
A/D conversion start conditions	• Software trigger The ADST bit in the AD0CON0 or the AD1CON0 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). • Timer trigger Timer B0 interrupt request, Timer B1 interrupt request or Timer B2 interrupt request (Timer B2 underflow or ICTB2 register underflow)
Conversion rate per pin	Minimum 43 ϕAD cycles



ADSTBY: Bit in the AD1CON1 register

Note:

1. When the A/D1 operation is enabled (the ADSTBY bit in the AD1CON1 register is set to 1), do not use pins AN0 to AN7 with the A/D0.

Figure 25.1 A/D Converter Block Diagram (A/D0, A/D1)

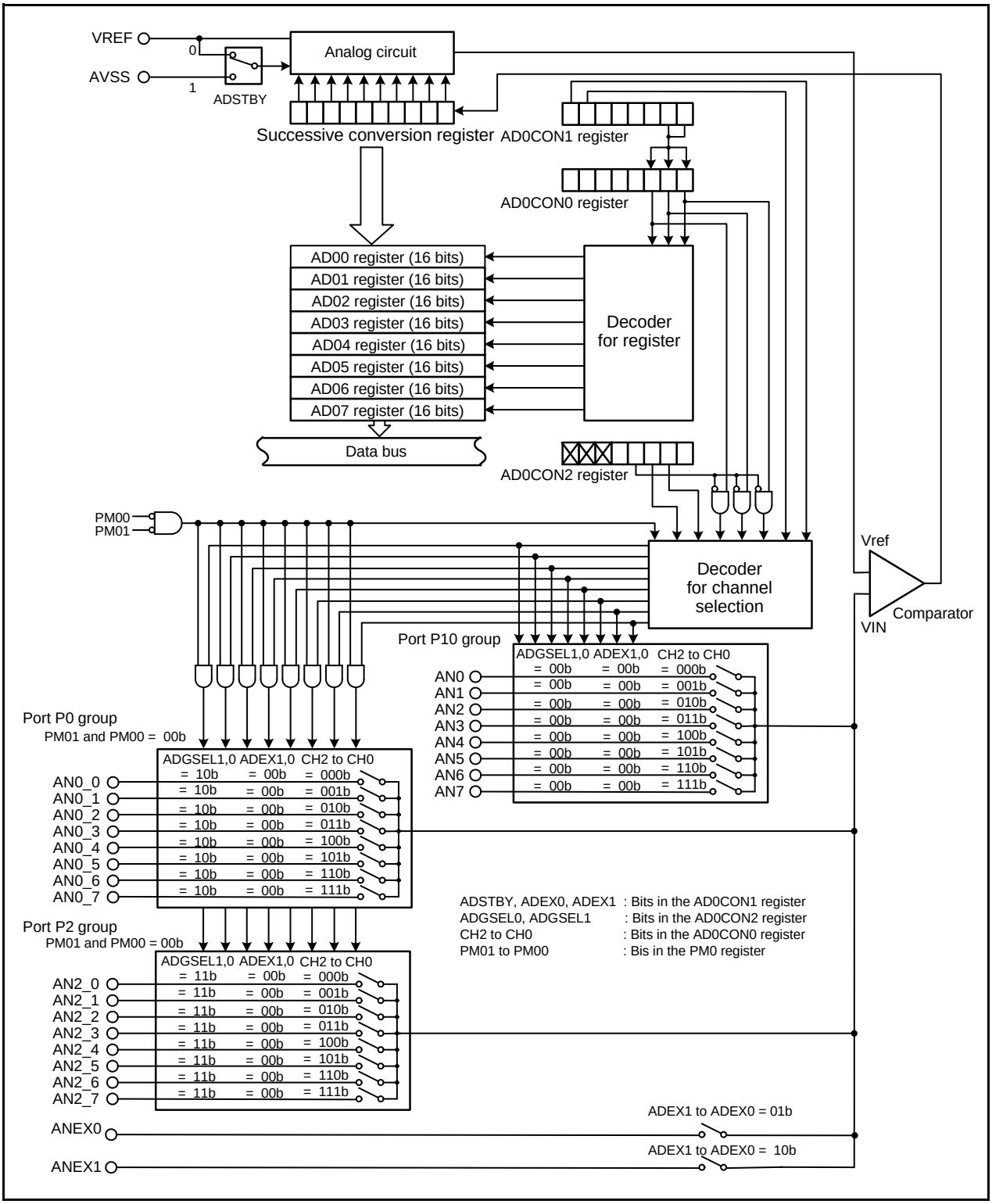


Figure 25.2 A/D Converter Block Diagram (A/D0)

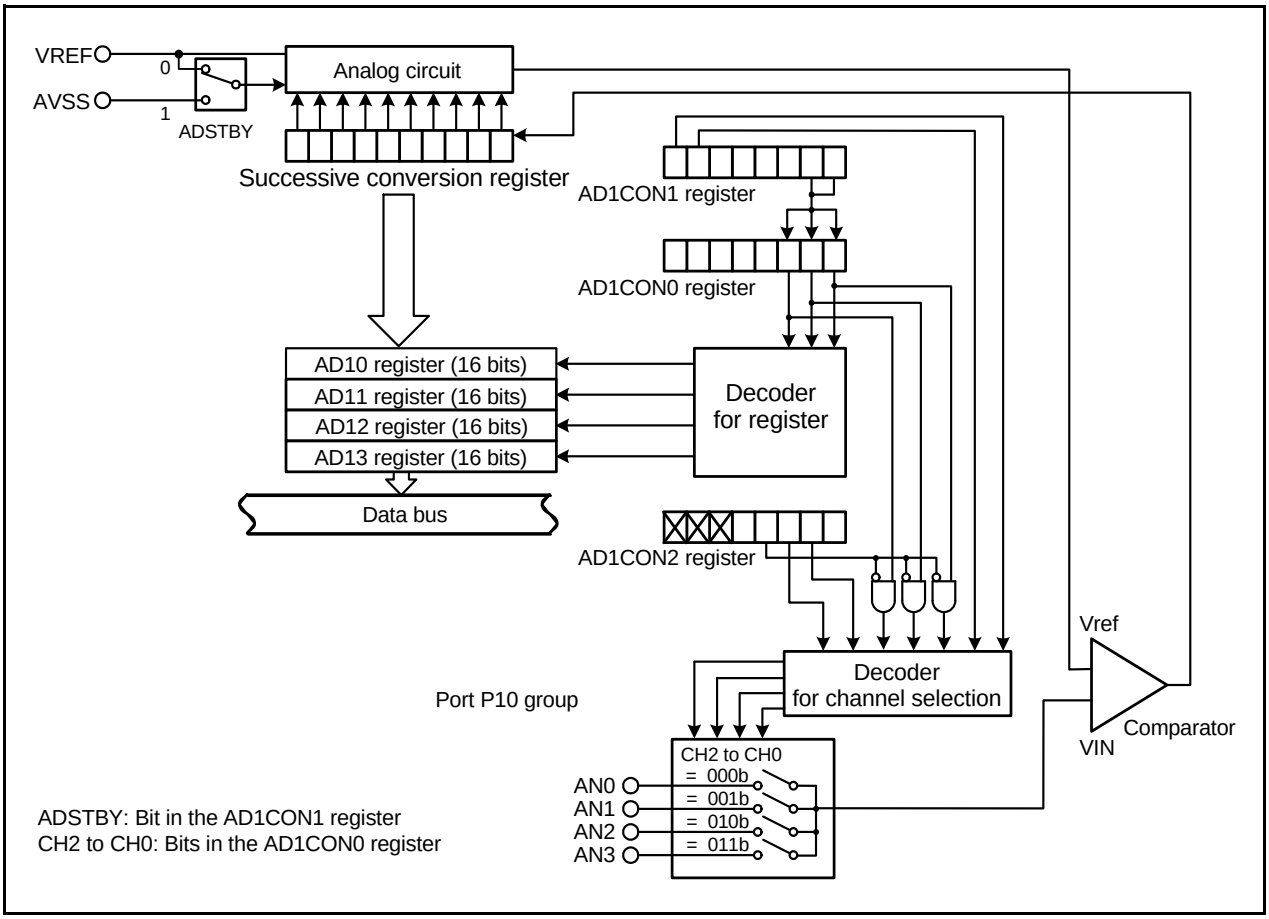


Figure 25.3 Block Diagram (A/D1)

Table 25.2 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).

25.2 Registers

Table 25.3 lists registers associated with A/D converters both for A/D0 and A/D1.
Table 25.4 lists registers associated with A/D converter (A/D0). Set the CKS3 bit in the AD0CON2 register before setting other registers associated with A/D converter (A/D0) excluding the PCR register. However, bits in the AD0CON2 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 25.5 lists registers associated with A/D converter (A/D1). Set the CKS3 bit in the AD1CON2 register before setting other registers associated with A/D converter (A/D1). However, bits in the AD1CON2 register and the CKS3 bit can be set simultaneously. After changing the CKS3 bit, set the registers in the same way again.

Table 25.3 Register Structure (A/D0, A/D1)

Address	Register Name	Register Symbol	After Reset
030Dh	Timer B2 Interrupt Generation Frequency Set Counter	ICTB2	XXh
033Eh	Timer B2 Special Mode Register	TB2SC	X000 0000b

Table 25.4 Register Structure (A/D0)

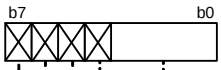
Address	Register	Symbol	Reset Value
0366h	Port Control Register	PCR	0000 0XX0b
03C0h 03C1h	A/D0 Register 0	AD00	XXXX XXXXb 0000 00XXb
03C2h 03C3h	A/D0 Register 1	AD01	XXXX XXXXb 0000 00XXb
03C4h 03C5h	A/D0 Register 2	AD02	XXXX XXXXb 0000 00XXb
03C6h 03C7h	A/D0 Register 3	AD03	XXXX XXXXb 0000 00XXb
03C8h 03C9h	A/D0 Register 4	AD04	XXXX XXXXb 0000 00XXb
03CAh 03CBh	A/D0 Register 5	AD05	XXXX XXXXb 0000 00XXb
03CCh 03CDh	A/D0 Register 6	AD06	XXXX XXXXb 0000 00XXb
03CEh 03CFh	A/D0 Register 7	AD07	XXXX XXXXb 0000 00XXb
03D2h	A/D0 Trigger Control Register	AD0TRGCON	XXXX 00XXb
03D4h	A/D0 Control Register 2	AD0CON2	0000 X00Xb
03D6h	A/D0 Control Register 0	AD0CON0	0000 0XXXb
03D7h	A/D0 Control Register 1	AD0CON1	0000 X000b

Table 25.5 Register Structure (A/D1)

Address	Register Name	Register Symbol	After Reset
0140h 0141h	A/D1 Register 0	AD10	XXXX XXXXb 0000 00XXb
0142h 0143h	A/D1 Register 1	AD11	XXXX XXXXb 0000 00XXb
0144h 0145h	A/D1 Register 2	AD12	XXXX XXXXb 0000 00XXb
0146h 0147h	A/D1 Register 3	AD13	XXXX XXXXb 0000 00XXb
0152h	A/D1 Trigger Control Register	AD1TRGCON	XXXX 00XXb
0154h	A/D1 Control Register 2	AD1CON2	0000 X00Xb
0156h	A/D1 Control Register 0	AD1CON0	0000 0XXXb
0157h	A/D1 Control Register 1	AD1CON1	0000 X000b

25.2.1 Timer B2 Interrupt Generation Frequency Set Counter (ICTB2)

Timer B2 Interrupt Generation Frequency Set Counter



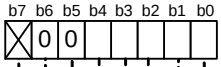
Symbol	Address	Reset Value
ICTB2	030Dh	Undefined

Function	Setting Range	RW
When a setting value is n, timer B2 interrupt is generated every n times Timer B2 underflows.	1 to 15	WO
No register bits. If necessary, set to 0		—

Use the MOV instruction to set the ICTB2 register.
Set this register when the TB2S bit in the TABSR register is 0 (timer B2 counter stop) and the ADST bits in registers AD0CON0 and AD1CON0 are set to 0 (A/D conversion stop).
ICTB2 register is enabled when the INV02 bit in the INVC0 register is 1 (three-phase motor control timer function used) and when the TB2SEL bit in the TB2SC register is 1 (ICTB2 register underflow is the A/D trigger) for the A/D converter.

25.2.2 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
TB0EN	Timer B0 operation mode select bit	0 : Other than A/D trigger mode 1 : A/D trigger mode	RW
TB1EN	Timer B1 operation mode select bit	0 : Other than A/D trigger mode 1 : A/D trigger mode	RW
TB2SEL	Trigger select bit	0 : Timer B2 underflow 1 : ICTB2 register underflow	RW
— (b6-b5)	Reserved bits	Set to 0	RW
— (b7)	No register bit. If necessary, set to 0. The read value is undefined.		—

Write to this register after the PRC1 bit in the PRCR register is set to 1 (write enabled).

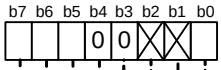
TB2SEL (Trigger select bit) (b4)

When the TB2SEL bit is set to 0, A/D trigger and Timer B2 interrupt request occur with Timer B2 underflow.

When the TB2SEL bit is set to 1, and a value set in the ICTB2 register is n, every n times Timer B2 underflows A/D trigger and Timer B2 interrupt request occur.

25.2.3 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
— (b4)	Reserved bit	Set to 0.	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)

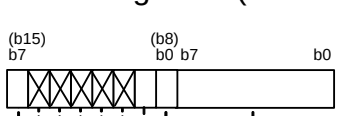
Set the PCR6 bit to 1 ($\overline{\text{INT7}}$ input disabled) when using AN2_5 pin for analog input.

PCR7 (Key input enable bit) (b7)

Set the PCR7 bit to 1 (key input disabled) when using pins AN4 to AN7 for analog input.

25.2.4 AD0 Register i (AD0i) (i = 0 to 7)

A/D0 Register i (i = 0 to 7)



Symbol	Address	Reset Value
AD00	03C1h to 03C0h	0000 00XX XXXX XXXXb
AD01	03C3h to 03C2h	0000 00XX XXXX XXXXb
AD02	03C5h to 03C4h	0000 00XX XXXX XXXXb
AD03	03C7h to 03C6h	0000 00XX XXXX XXXXb
AD04	03C9h to 03C8h	0000 00XX XXXX XXXXb
AD05	03CBh to 03CAh	0000 00XX XXXX XXXXb
AD06	03CDh to 03CCh	0000 00XX XXXX XXXXb
AD07	03CFh to 03CEh	0000 00XX XXXX XXXXb

Function		RW
8 low-order bits of A/D conversion result		RO
2 high-order bits of A/D conversion result		RO
No register bits. If necessary, set to 0. Read as 0		—
Reserved bit	Read as 0	RO

The A/D conversion result is stored in the AD0i register corresponding to pins ANi, ANEXi, AN0_i, and AN2_i. Read the AD0i register in 16-bit units. Table 25.6 lists Analog Pin and A/D Conversion Result Storing Register (A/D0).

Table 25.6 Analog Pin and A/D Conversion Result Storing Register (A/D0)

Analog Pin				A/D Conversion Result Storing Register
AN0	ANEX0	AN0_0	AN2_0	AD00 register
AN1	ANEX1	AN0_1	AN2_1	AD01 register
AN2	-	AN0_2	AN2_2	AD02 register
AN3	-	AN0_3	AN2_3	AD03 register
AN4	-	AN0_4	AN2_4	AD04 register
AN5	-	AN0_5	AN2_5	AD05 register
AN6	-	AN0_6	AN2_6	AD06 register
AN7	-	AN0_7	AN2_7	AD07 register

25.2.5 A/D0 Trigger Control Register (AD0TRGCON)

A/D0 Trigger Control Register

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	Reset Value
0	0	0	0			0	0	AD0TRGCON	03D2h	XXXX 00XXb

Bit Symbol	Bit Name	Function	RW
— (b1-b0)	Reserved bit	Set to 0	RW
HDTRG0	A/D Trigger select bit	b3 b2 0 0 : $\overline{\text{ADTRG}}$ 0 1 : Timer B0 interrupt request 1 0 : Timer B1 interrupt request 1 1 : Timer B2 interrupt request (Timer B2 underflow or ICTB2 register underflow)	RW
HDTRG1			RW
— (b7-b4)	Reserved bit	Set to 0	RW

HDTRG1-HDTRG0 (A/D trigger select bit) (b3-b2)

These bits are enabled when the TRG bit in the AD0CON0 register is set to 1 ($\overline{\text{ADTRG}}$ or timer trigger). The source selected by bits HDTRG1 to HDTRG0 becomes A/D conversion start condition (trigger).
When bits HDTRG1 to HDTRG0 are 00b, a trigger occurs at the falling edge of $\overline{\text{ADTRG}}$ signal.
When bits HDTRG1 to HDTRG0 are 01b, 10b or 11b, a trigger occurs when Timer Bk (k = 0 to 2) interrupt request occurs (When a value of the IR bit in the Timer Bk interrupt control register, if the current value is 0, turns to 1). Trigger still can occur when interrupt is disabled.

25.2.6 A/D0 Control Register 2 (AD0CON2)

A/D0 Control Register 2

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

Symbol	Address	Reset Value
AD0CON2	03D4h	0000 X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. Read as undefined value		—
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. Read as undefined value		—
CKS2	Frequency select bit 2	Refer to the CKS0 bit in the AD0CON0 register.	RW
— (b6-b5)	Reserved bits	Set to 0	RW
CKS3	fAD select bit	0: f1 1: fOCO40M	RW

When the AD0CON2 register is rewritten during A/D conversion, the conversion result is undefined.

ADGSEL1-ADGSEL0 (A/D input group select bit) (b2-b1)

AN0_0 to AN0_7 are used as analog input pins even if bits PM01 to PM00 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 stops.
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 AD0CON2 register and the CKS3 bit can be set simultaneously.

25.2.7 A/D0 Control Register 0 (AD0CON0)

A/D0 Control Register 0

b7	b6	b5	b4	b3	b2	b1	b0

Symbol	Address	Reset Value
AD0CON0	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	RW
MD1			RW
TRG	Trigger select bit	0 : Software trigger 1 : ADTRG or timer 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 CKS0 on the next page.	RW

When the AD0CON0 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, AN0_0 to AN0_7 and AN2_0 to AN2_7 can be used in the same way as AN0 to AN7. Use bits ADGSEL1 to ADGSEL0 in the AD0CON2 register to select the desired group. These bits are disabled in single sweep mode and repeat sweep mode 0.

CKS0 (Frequency select bit) (b7)

ϕAD frequency is selected by a combination of the CKS0 bit in the AD0CON0 register, the CKS1 bit in the AD0CON1 register, and bits CKS3 and CKS2 in the AD0CON2 register. Select bits CKS2 to CKS0 after setting the CKS3 bit. Note that bits CKS3 and CKS2 can be set simultaneously. Table 25.7 lists ϕ A/D Frequency.

Table 25.7 ϕ A/D Frequency

CKS3	CKS2	CKS1	CKS0	ϕA/D
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	

Note:
1. Do not set bit combinations not listed above.

25.2.8 A/D0 Control Register 1 (AD0CON1)

A/D0 Control Register 1

b7	b6	b5	b4	b3	b2	b1	b0
				X	0		

Symbol	Address	Reset Value
AD0CON1	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)	RW
SCAN1			RW
— (b2)	Reserved bit	Set to 0.	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 AD0CON0 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: Do not use ANEX0 and ANEX1 0 1: ANEX0 input to be A/D converted 1 0: ANEX1 input to be A/D converted 1 1: Do not set	RW
ADEX1			RW

When the AD0CON1 register is rewritten during A/D conversion, the conversion result is undefined.

SCAN1-SCAN0 (A/D sweep pin select bit) (b1-b0)

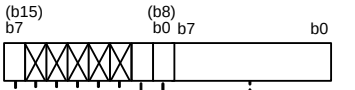
These bits are disabled in one-shot and repeat modes.
In single sweep mode and repeat sweep mode 0, AN0_0 to AN0_7 and AN2_0 to AN2_7 can be used in the same way as AN0 to AN7. Use bits ADGSEL1 to ADGSEL0 in the AD0CON2 register to select the desired group.

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 1 ϕA/D 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 the power consumption to be reduced.

25.2.9 A/D1 Register i (A/D1i) (i = 0 to 3)

A/D1 Register i (i = 0 to 3)



Symbol	Address	Reset Value
AD10	0141h to 0140h	0000 00XX XXXX XXXXb
AD11	0143h to 0142h	0000 00XX XXXX XXXXb
AD12	0145h to 0144h	0000 00XX XXXX XXXXb
AD13	0147h to 0146h	0000 00XX XXXX XXXXb

Function		RW
8 low-order bits of A/D conversion result		RO
2 high-order bits of A/D conversion result		RO
No register bit(s). 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 AD1i register corresponding to ANi pin. Read the AD1i register in 16-bit units. Table 25.8 lists Analog Pin and A/D Conversion Result Storing Register (A/D1).

Table 25.8 Analog Pin and A/D Conversion Result Storing Register (A/D1)

Analog Pin	A/D Conversion Result Storing Register
AN0	AD10 register
AN1	AD11 register
AN2	AD12 register
AN3	AD13 register

25.2.10 A/D1 Trigger Control Register (AD1TRGCON)

A/D1 Trigger Control Register

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

Symbol: AD1TRGCON
Address: 0152h
Reset Value: XXXX 00XXb

Bit Symbol	Bit Name	Function	RW
— (b1-b0)	Reserved bit	Set to 0	RW
HDTRG0	A/D Trigger select bit	b3 b2 0 0 : $\overline{\text{ADTRG}}$ 0 1 : Timer B0 interrupt request 1 0 : Timer B1 interrupt request 1 1 : Timer B2 interrupt request (Timer B2 underflow or ICTB2 register underflow)	RW
HDTRG1			RW
— (b7-b4)	Reserved bit	Set to 0	RW

HDTRG1-HDTRG0 (A/D trigger select bit) (b3-b2)

These bits are enabled when the TRG bit in the AD1CON0 register is set to 1 ($\overline{\text{ADTRG}}$ or timer trigger). The source selected by bits HDTRG1 to HDTRG0 becomes A/D conversion start condition (trigger).
When bits HDTRG1 to HDTRG0 are 00b, a trigger occurs at the falling edge of $\overline{\text{ADTRG}}$ signal.
When bits HDTRG1 to HDTRG0 are 01b, 10b or 11b, a trigger occurs when Timer Bk (k = 0 to 2) interrupt request occurs (When a value of the IR bit in the Timer Bk interrupt control register, if the current value is 0, turns to 1). Trigger still can occur when interrupt is disabled.

25.2.11 A/D1 Control Register 2 (AD1CON2)

A/D1 Control Register 2

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

Symbol	Address	Reset Value
AD1CON2	0154h	0000 X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. Read as undefined value		—
ADGSEL0	A/D input group select bit	b2 b1 0 0 : AN0 to AN3 0 1 : Do not set 1 0 : Do not set 1 1 : Do not set	RW
ADGSEL1			RW
— (b3)	No register bit. If necessary, set to 0. Read as undefined value		—
CKS2	Frequency select bit 2	Refer to the CKS0 bit in the AD1CON0 register.	RW
— (b6-b5)	Reserved bits	Set to 0	RW
CKS3	fAD select bit	0: f1 1: fOCO40M	RW

When the AD1CON2 register is rewritten during A/D conversion, the conversion result is undefined.

CKS3 (fAD select bit) (b7)

Set the CKS3 bit while A/D conversion stops.

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 AD1CON2 register and the CKS3 bit can be set simultaneously.

25.2.12 A/D1 Control Register 0 (AD1CON0)

A/D1 Control Register 0

b7	b6	b5	b4	b3	b2	b1	b0

Symbol	Address	Reset Value
AD1CON0	0156h	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 : Do not set 1 0 1 : Do not set 1 1 0 : Do not set 1 1 1 : Do not set	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	RW
MD1			RW
TRG	Trigger select bit	0 : Software trigger 1 : ADTRG or Timer 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 CKS0 on the next page.	RW

When the AD1CON0 register is rewritten during A/D conversion, the conversion result is undefined.

CH2-CH0 (Analog input pin select bit) (b2-b0)

These bits are disabled in single sweep mode and repeat sweep mode 0.

CKS0 (Frequency select bit) (b7)

ϕAD frequency is selected by a combination of the CKS0 bit in the AD1CON0 register, the CKS1 bit in the AD1CON1 register, and bits CKS3 and CKS2 in the AD1CON2 register. Select bits CKS2 to CKS0 after setting the CKS3 bit. Note that bits CKS3 and CKS2 can be set simultaneously. Table 25.9 lists ϕ A/D Frequency.

Table 25.9 ϕ A/D Frequency

CKS3	CKS2	CKS1	CKS0	ϕA/D
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	

Note:
1. Do not set bit combinations not listed above.

25.2.13 A/D1 Control Register 1 (AD1CON1)

A/D1 Control Register 1

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

Symbol	Address	Reset Value
AD1CON1	0157h	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: Do not set 1 1: Do not set	RW
SCAN1			RW
— (b2)	Reserved bit	Set to 0.	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 AD1CON0 register	RW
ADSTBY	A/D standby bit	0 : A/D operation stopped (standby) 1 : A/D operation enabled	RW
— (b6)	Reserved bit	Set to 0.	RW
— (b7)	Reserved bit	Set to 0.	RW

If the AD1CON1 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.

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 1 ϕA/D 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 the power consumption to be reduced.

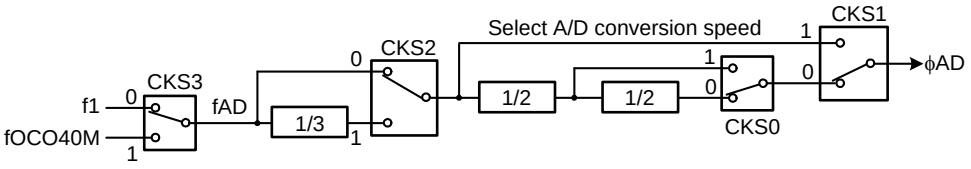
25.3 Operations

25.3.1 A/D Conversion Cycle

A/D conversion cycle is based on fAD and ϕAD. Figure 25.4 shows fAD and ϕAD. fAD and ϕAD are set for A/D0 and A/D1 separately.

When the CKS3 bit in the AD0CON2 register is 1 (fOCO40M is fAD), do not set the CKS2 bit in the AD0CON2 register to 0 and the CKS1 bit in the AD0CON1 register to 1 (fAD = ϕAD). Set registers associated with A/D converter after setting the CKS3 bit.

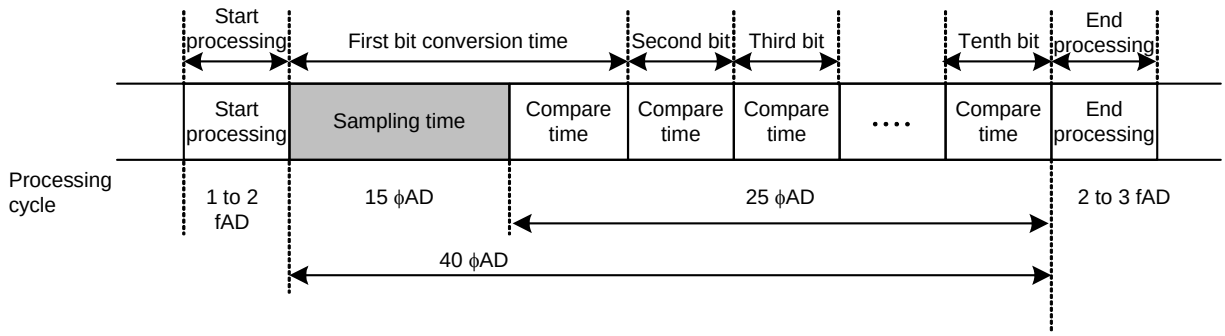
Also, when the CKS3 bit in the AD1CON2 register is 1 (fOCO40M is fAD), do not set the CKS2 bit in the AD1CON2 register to 0 and the CKS1 bit in the AD1CON1 register to 1 (fAD = ϕAD). Set registers associated with A/D converter after setting the CKS3 bit.



CKS0: Bit in registers AD0CON0 and AD1CON0
CKS1: Bit in registers AD0CON1 and AD1CON1
CKS2, CKS3: Bits in registers AD0CON2 and AD1CON2

Figure 25.4 fAD and ϕAD

Figure 25.5 shows A/D Conversion Timing.



The above figure applies under the following conditions:
- One-shot mode
- ϕAD = fAD

Figure 25.5 A/D Conversion Timing

Table 25.10 lists Cycles of A/D Conversion Item. A/D conversion period is as follows.
Start processing time varies depends on which ϕAD is selected.

For A/D0, A/D conversion starts after the start processing time elapses by setting the ADST bit in the AD0CON0 register to 1 (A/D conversion start). When reading the ADST bit in the AD0CON0 register before A/D0 starts 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 in the AD0CON0 register becomes 0 at the end processing time and the last A/D conversion result is stored in the AD0i register (i = 0 to 7).

For A/D1, A/D conversion starts after the start processing time elapses by setting the ADST bit in the AD1CON0 register to 1 (A/D conversion start). When reading the ADST bit in the AD1CON0 register before A/D1 starts 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 in the AD1CON0 register becomes 0 at the end processing time and the last A/D conversion result is stored in the AD1j register (j = 0 to 3).

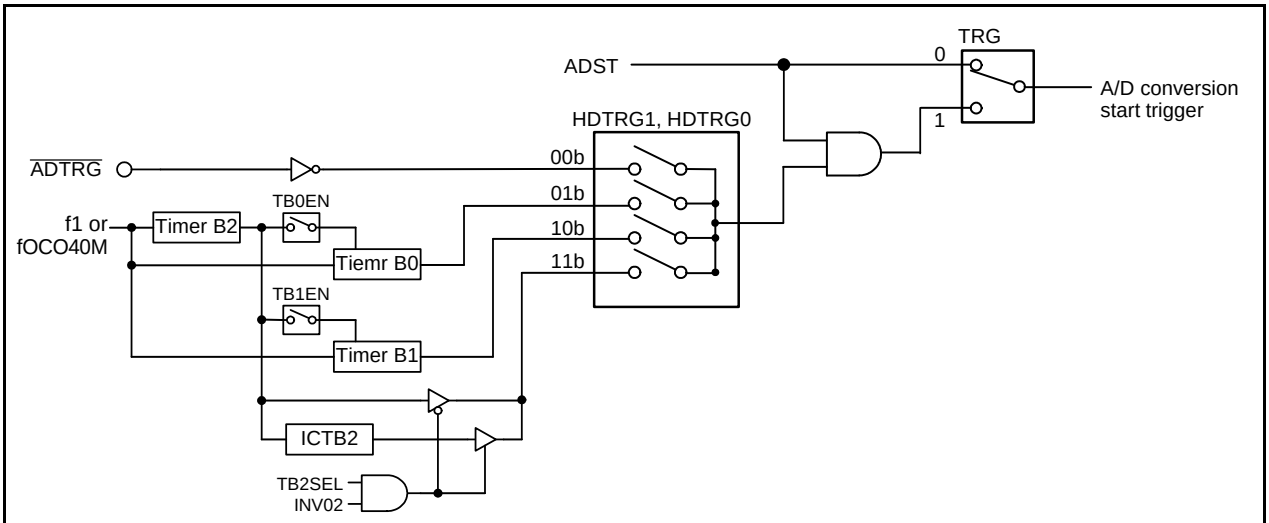
One-shot mode:
Start processing time + A/D conversion execution time + end processing time
Two pins are selected in single sweep mode:
Start processing time + (A/D conversion execution time + inter execution processing time + A/D conversion execution time) + end processing time

Table 25.10 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		40 cycles of ϕAD
Inter execution processing time		1 cycle of ϕAD
End processing time		2 to 3 cycles of fAD

25.3.2 A/D Conversion Start Conditions

An A/D conversion start trigger has a software trigger, timer trigger and an external trigger. Figure 25.6 shows A/D Conversion Start Trigger.



ADST, TRG: Bits in registers AD0CON0 and AD1CON0
HDTRG1, HDTRG0: Bits in registers AD0TRGCON and AD1TRGCON
TB2SEL, TB1EN, TB0EN: Bits in the TB2SC register.
INV02: Bit in the INVC0 register.

Figure 25.6 A/D Conversion Start Trigger

25.3.2.1 Software Trigger

For A/D0, when the TRG bit in the AD0CON0 register is 0 (software trigger), A/D conversion starts by setting the ADST bit in the AD0CON0 register to 1 (A/D conversion start).
For A/D1, when the TRG bit in the AD1CON0 register is 0 (software trigger), A/D conversion starts by setting the ADST bit in the AD1CON0 register to 1 (A/D conversion start).

25.3.2.2 External Trigger

For A/D0, when the TRG bit in the AD0CON0 register is 1 and bits HDTRG1 to HDTRG1 are 00b ($\overline{\text{ADTRG}}$ trigger) is the case.
To use this function with A/D0, set as follows.

- The direction bit of the port sharing a pin with $\overline{\text{ADTRG}}$ is set to 0 (input mode)
- The TRG bit in the AD0CON0 register is set to 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON register are 00b ($\overline{\text{ADTRG}}$ trigger)
- The ADST bit in the AD0CON0 register is set to 1 (A/D conversion start)

For A/D1, when the TRG bit in the AD1CON0 register is 1 and bits HDTRG1 to HDTRG0 are 00b ($\overline{\text{ADTRG}}$ trigger) is the case.
To use this function with A/D1, set as follows.

- The direction bit of the port sharing a pin with $\overline{\text{ADTRG}}$ is set to 0 (input mode)
- The TRG bit in the AD1CON0 register is set to 1 and bits HDTRG1 to HDTRG0 in the AD1TRGCON register are 00b ($\overline{\text{ADTRG}}$ trigger)
- The ADST bit in the AD1CON0 register is set to 1 (A/D conversion start)

Under the above conditions, when input to the $\overline{\text{ADTRG}}$ pin is changed from high to low, the 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.

25.3.2.3 Timer trigger

For A/D0, timer trigger is enabled when the TRG bit in the AD0CON0 register is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON and bits TB2SEL, TB1EN and TB0EN in the TB2SC register are the combination of values shown in Table 25.11.

For A/D1, timer trigger is enabled when the TRG bit in the AD1CON0 register is 1 and bits HDTRG1 to HDTRG0 in the AD1TRGCON and bits TB2SEL, TB1EN and TB0EN in the TB2SC register are the combination of values shown in Table 25.11.

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Table 25.11 Timer trigger

AD0CON0 register AD1CON0 register		TB2SC register			Trigger
HDTRG1 bit	HDTRG0 bit	TB2SEL bit	TB1EN bit	TB0EN bit	
0	1	-	-	1	Timer B0 interrupt request
1	0	-	1	-	Timer B1 interrupt request
1	1	0	-	-	Timer B2 interrupt request (Timer B2 underflow)
1	1	1	-	-	Timer B2 interrupt request (ICTB2 register underflow)

For A/D0, when the ADST bit in the AD0CON0 register is set to 1 (A/D conversion start), A/D conversion starts with selected trigger. For the timer count source that generates the A/D trigger, select the f1 clock and set the periods more than twice as long as that of the fAD. Use the f1 clock in the PLL clock or the main clock.

For A/D1, when the ADST bit in the AD1CON0 register is set to 1 (A/D conversion start), A/D conversion starts with selected trigger. For the timer count source that generates the A/D trigger, select the f1 clock and set the periods more than twice as long as that of the fAD. Use the f1 clock in the PLL clock or the main clock.

When selecting Timer B0 as a trigger, set Timer B0 to timer mode. When the TB0S bit in the TABSR register is set to 1 (start counting), Timer B0 counting is started by Timer B2 underflow signal. When Timer B0 underflows, A/D trigger and Timer B0 interrupt request occur and Timer B0 stops. Refer to 18. “Timer B” for setting timer mode.

When selecting Timer B1 as a trigger, set Timer B1 to timer mode. When the TB1S bit in the TABSR register is set to 1 (start counting), Timer B1 counting is started by Timer B2 underflow signal. When Timer B1 underflows, A/D trigger and Timer B1 interrupt request occur and Timer B1 stops. Refer to 18. “Timer B” for setting timer mode.

When selecting Timer B2 as a trigger, and the TB2SEL bit in the TB2SC register is set to 0 (Timer B2 underflow), Timer B2 underflow causes A/D trigger and Timer B2 interrupt request. When the TB2SEL bit in the TB2SC register is set to 1 (ICTB2 register underflow), and a value set in the ICTB2 register is n, every n times Timer B2 underflows, A/D trigger and Timer B2 interrupt request occur.

25.3.3 A/D Conversion Result (A/D0)

When reading the AD0i register before A/D conversion is completed, an undefined value is read. Read the AD0i 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 the completion of A/D conversion. Ensure that the IR bit becomes 1 to read the AD0i register.
  When not using A/D (A/D0) interrupt, set the IR bit to 0 (interrupt not requested) by a program after reading the AD0i register.

- In repeat mode and repeat sweep mode 0:
  The IR bit remains unchanged (no interrupt requests generated). At first, read the AD0i register after one A/D conversion period elapses (refer to 25.3.1 “A/D Conversion Cycle”). After that, whenever the AD0i register is read, the conversion result which has been obtained before reading is read.
  The AD0i register is overwritten in every A/D conversion. Read the value before the AD0i register is overwritten as required.

25.3.4 A/D Conversion Result (A/D1)

When reading the AD1j register before A/D conversion is completed, an undefined value is read. Read the AD1j 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 ADEIC register becomes 1 (interrupt requested) at the completion of A/D conversion. Ensure that the IR bit becomes 1 to read the AD1j register.
  When not using A/D (A/D1) interrupt, set the IR bit to 0 (interrupt not requested) by a program after reading the AD1j register.

- In repeat mode and repeat sweep mode 0:
  The IR bit remains unchanged (no interrupt requests generated). At first, read the AD1j register after one A/D conversion period elapses (refer to 25.3.1 “A/D Conversion Cycle”). After that, whenever the AD1j register is read, the conversion result which has been obtained before reading is read.
  The AD1j register is overwritten in every A/D conversion. Read the value before the AD1j register is overwritten as required.

25.3.5 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 AD0CON1 register.
The A/D conversion result of pins ANEX0 and ANEX1 are stored in registers AD00 and AD01, respectively. ANEX0 and ANEX1 cannot be used with A/D1.

25.3.6 Current Consumption Reduce Function

When the A/D converter (A/D0) is not in use, the power consumption can be reduced by setting the ADSTBY bit in the AD0CON1 register to 0 (A/D operation stopped: standby) to shut off any analog circuit current flow. Also, same thing can say for A/D1 by setting the ADSTBY bit in the AD1CON1 register to 0 (A/D operation stopped: standby).
To use the A/D converter, set the ADSTBY bit to 1 (A/D operation enabled) and wait for 1 ϕAD cycle or more before setting the ADST bit to 1 (A/D conversion start) in registers AD0CON0 and AD1CON0 for A/D0 and A/D1, respectively. Do not set bits ADST and ADSTBY to 1 simultaneously.
Also, do not set the ADSTBY bit to 0 (A/D operation stopped: standby) during A/D conversion.

25.4 Operational Modes

25.4.1 One-Shot Mode

In one-shot mode, the analog voltage applied to a selected pin is converted to a digital code once. Table 25.12 and Table 25.13 show One-Shot Mode Specifications.

Table 25.12 One-Shot Mode Specifications (A/D0)

Item	Specification
Function	Bits CH2 to CH0 in the AD0CON0 register and bits ADGSEL1 to ADGSEL0 in the AD0CON2 register, or bits ADEX1 to ADEX0 in the AD0CON1 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 AD0CON0 register is 0 (software trigger): The ADST bit in the AD0CON0 register is set to 1 (A/D conversion start). • When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON are 00b ($\overline{\text{ADTRG}}$ trigger): 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). • When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON are 01b, 10b or 11b (timer trigger): Selected trigger (Timer B0, Timer B1 or Timer B2 interrupt request) occurs.
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	• When A/D1 operation stopped (standby) (the ADSTBY bit in the AD1CON1 register is 0): Select one pin from AN0 to AN7, AN0_0 to AN0_7, AN2_0 to AN2_7 and ANEX0 to ANNEX1 • When A/D1 operation enabled (the ADSTBY bit in the AD1CON1 register is 1): Select one pin from AN0_0 to AN0_7, AN2_0 to AN2_7 and ANEX0 to ANNEX1. AN0 to AN7 are not available.
Reading of A/D conversion result	Read the register among AD00 to AD07 that corresponds to the selected pin.

Table 25.13 One-Shot Mode Specifications (A/D1)

Item	Specification
Function	Bits CH2 to CH0 in the AD1CON0 register and bits ADGSEL1 to ADGSEL0 in the AD1CON2 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 AD1CON0 register is 0 (software trigger): The ADST bit in the AD1CON0 register is set to 1 (A/D conversion start). • When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD1TRGCON are 00b ($\overline{\text{ADTRG}}$ trigger): 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). • When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD1TRGCON are 01b, 10b or 11b (timer trigger): Selected trigger (Timer B0, Timer B1 or Timer B2 interrupt request) occurs.
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 AN3
Reading of A/D conversion result	Read the register among AD10 to AD13 that corresponds to the selected pin.

Table 25.14 Registers and Settings in One-Shot Mode (A/D0) (1)

Register	Bit	Setting
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.
AD0TRGCON	HDTRG1, HDTRG0	Select a trigger.
AD00 to AD07	b9 to b0	A/D conversion result can be read.
AD0CON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕA/D frequency.
	CKS3	Select fAD.
AD0CON0	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.
AD0CON1	SCAN1, SCAN0	Disabled
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when executing A/D conversion.
	ADEX1, ADEX0	Select whether ANEX0 and ANEX1 are used or not.

Note:
1. This table does not describe a procedure.

Table 25.15 Registers and Settings in One-Shot Mode (A/D1) (1)

Register	Bit	Setting
AD1TRGCON	HDTRG1, HDTRG0	Select a trigger.
AD10 to AD13	b9 to b0	A/D conversion result can be read.
AD1CON2	ADGSEL1, ADGSEL0	Set to 00b.
	CKS2	Select ϕA/D frequency.
	CKS3	Select fAD.
AD1CON0	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.
AD1CON1	SCAN1, SCAN0	Disabled
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when operating A/D conversion.

Note:
1. This table does not describe a procedure.

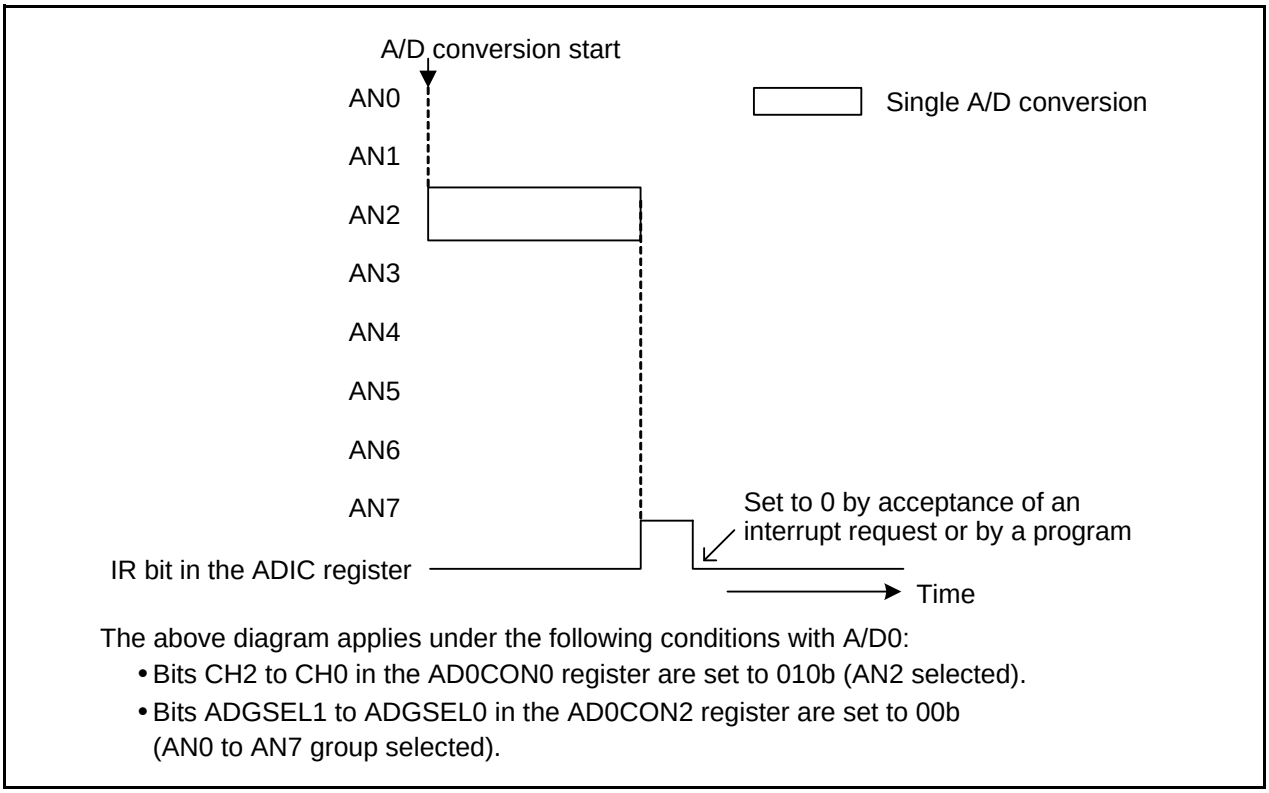


Figure 25.7 Operation Example in One-Shot Mode

25.4.2 Repeat Mode

In repeat mode, the analog voltage applied to a selected pin is repeatedly converted to a digital code. Table 25.16 and Table 25.17 show Repeat Mode Specifications.

Table 25.16 Repeat Mode Specifications (A/D0)

Item	Specification
Function	Bits CH2 to CH0 in the AD0CON0 register and bits ADGSEL1 to ADGSEL0 in the AD0CON2 register, or bits ADEX1 to ADEX0 in the AD0CON1 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 AD0CON0 register is 0 (software trigger): The ADST bit in the AD0CON0 register is set to 1 (A/D conversion start). When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON are 00b ($\overline{\text{ADTRG}}$ trigger): 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). When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON are 01b, 10b or 11b (timer trigger): Selected trigger (Timer B0, Timer B1 or Timer B2 interrupt request) occurs.
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	When A/D1 operation stopped (standby) (the ADSTBY bit in the AD1CON1 register is 0): Select one pin from AN0 to AN7, AN0_0 to AN0_7, AN2_0 to AN2_7 and ANEX0 to ANNEX1 When A/D1 operation enabled (the ADSTBY bit in the AD1CON1 register is 1): Select one pin from AN0_0 to AN0_7, AN2_0 to AN2_7 and ANEX0 to ANEX1. AN0 to AN7 are not available.
Reading of A/D conversion result	Read the register among AD00 to AD07 that corresponds to the selected pin.

Table 25.17 Repeat Mode Specifications (A/D1)

Item	Specification
Function	Bits CH2 to CH0 in the AD1CON0 register and bits ADGSEL1 to ADGSEL0 in the AD1CON2 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 AD1CON0 register is 0 (software trigger): The ADST bit in the AD1CON0 register is set to 1 (A/D conversion start). When the TRG bit is 1 and bits HDTRG1 and HDTRG0 in the AD1TRGCON are 00b ($\overline{\text{ADTRG}}$ trigger): 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). When the TRG bit is 1 and bits HDTRG1 and HDTRG0 in the AD1TRGCON are 01b, 10b or 11b (timer trigger): Selected trigger (Timer B0, Timer B1 or Timer B2 interrupt request) occurs.
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 AN0 to AN3
Reading of A/D conversion result	Read the register among AD10 to AD13 that corresponds to the selected pin.

Table 25.18 Registers and Settings in Repeat Mode (A/D0) (1)

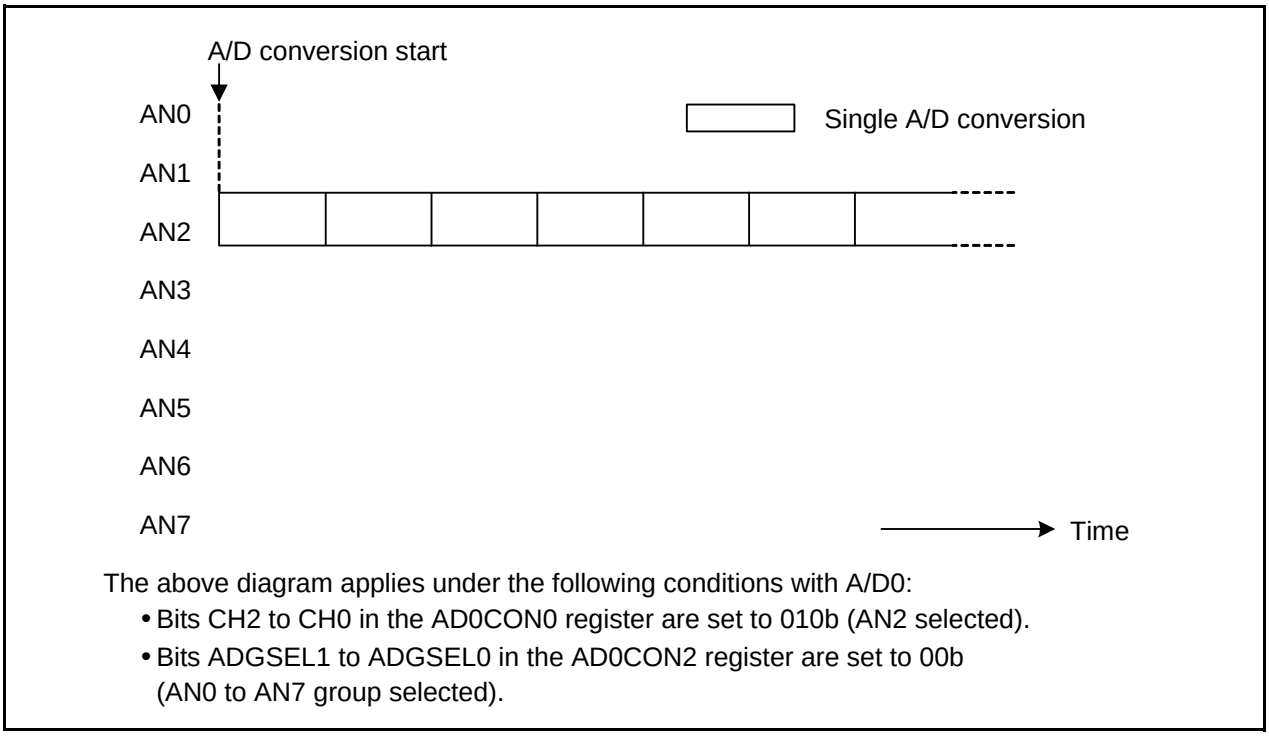
Register	Bit	Setting
PCR	PCR5	Set to 1 ($\overline{INT6}$ input disabled) when using the AN2_4 pin for analog input.
	PCR6	Set to 1 ($\overline{INT7}$ input disabled) when using the AN2_5 pin for analog input.
	PCR7	Set to 1 (key input disabled) when using pins AN4 to AN7 for analog input.
AD0TRGCON	HDTRG1, HDTRG0	Select a trigger.
AD00 to AD07	b9 to b0	A/D conversion result can be read.
AD0CON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕA/D frequency.
	CKS3	Select fAD.
AD0CON0	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
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when operating A/D conversion.
	ADEX1, ADEX0	Select whether ANEX0 and ANEX1 are used or not

Note:
1. This table does not describe a procedure.

Table 25.19 Registers and Settings in Repeat Mode (A/D1) (1)

Register	Bit	Setting
AD1TRGCON	HDTRG1, HDTRG0	Select a trigger.
AD10 to AD13	b9 to b0	A/D conversion result can be read.
AD1CON2	ADGSEL1, ADGSEL0	Set to 00b.
	CKS2	Select ϕA/D frequency.
	CKS3	Select fAD.
AD1CON0	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.
AD1CON1	SCAN1, SCAN0	Disabled
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 in A/D conversion.

Note:
1. This table does not describe a procedure.



The above diagram applies under the following conditions with A/D0:

- Bits CH2 to CH0 in the AD0CON0 register are set to 010b (AN2 selected).
- Bits ADGSEL1 to ADGSEL0 in the AD0CON2 register are set to 00b (AN0 to AN7 group selected).

Figure 25.8 Operation Example in Repeat Mode

25.4.3 Single Sweep Mode

In single sweep mode, the analog voltage applied to selected pins is converted one-by-one to a digital code. Table 25.20 and Table 25.21 shows the Single Sweep Mode Specifications.

Table 25.20 Single Sweep Mode Specifications (A/D0)

Item	Specification
Function	Bits SCAN1 to SCAN0 in the AD0CON1 register and bits ADGSEL1 to ADGSEL0 in the AD0CON2 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 AD0CON0 register is 0 (software trigger): The ADST bit in the AD0CON0 register is set to 1 (A/D conversion start). When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON register are 00b ($\overline{\text{ADTRG}}$ trigger): 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). When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON register are 01b, 10b or 11b (timer trigger): Selected trigger (Timer B0, Timer B1 or Timer B2 interrupt request) occurs.
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	When A/D1 operation stopped (standby) (the ADSTBY bit in the AD1CON1 register is 0): Select from AN0 to AN1 (2 pins), AN0 to AN3 (4 pins), AN0 to AN5 (6 pins) and AN0 to AN7 (8 pins). AN0_0 to AN0_7 and AN2_0 to AN2_7 can be selected in the same way. When A/D1 operation enabled (the ADSTBY bit in the AD1CON1 register is 1): Select from AN0_0 to AN0_1 (2 pins), AN0_0 to AN0_3 (4 pins), AN0_0 to AN0_5 (6 pins) and AN0_0 to AN0_7 (8 pins). AN2_0 to AN2_7 can be selected in the same way. AN0 to AN7 are not available.
Reading of A/D conversion result	Read the registers among AD00 to AD07 that corresponds to the selected pin.

Table 25.21 Single Sweep Mode Specifications (A/D1)

Item	Specification
Function	Bits SCAN1 to SCAN0 in the AD1CON1 register and bits ADGSEL1 to ADGSEL0 in the AD1CON2 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 AD1CON0 register is 0 (software trigger): The ADST bit in the AD1CON0 register is set to 1 (A/D conversion start). When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD1TRGCON register are 00b ($\overline{\text{ADTRG}}$ trigger): 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). When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD1TRGCON register are 01b, 10b or 11b (timer trigger): Selected trigger (Timer B0, Timer B1 or Timer B2 interrupt request) occurs.
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 from AN0 to AN1 (2 pins) and AN0 to AN3 (4 pins).
Reading of A/D conversion result	Read the registers among AD10 to AD13 that corresponds to the selected pin.

Table 25.22 Registers and Settings in Single Sweep Mode (A/D0) (1)

Register	Bit	Setting
PCR	PCR5	Set to 1 ($\overline{INT6}$ input disabled) when using the AN2_4 pin for analog input.
	PCR6	Set to 1 ($\overline{INT7}$ 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.
AD0TRGCON	HDTRG1, HDTRG0	Select a trigger.
AD00 to AD07	b9 to b0	A/D conversion result can be read.
AD0CON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕA/D frequency.
	CKS3	Select fAD.
AD0CON0	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.
AD0CON1	SCAN1, SCAN0	Select analog input pin.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when operating A/D conversion.
	ADEX1, ADEX0	Set to 00b.

Note:
1. This table does not describe a procedure.

Table 25.23 Registers and Settings in Single Sweep Mode (A/D1) (1)

Register	Bit	Setting
AD1TRGCON	HDTRG1, HDTRG0	Select a trigger.
AD10 to AD13	b9 to b0	A/D conversion result can be read.
AD1CON2	ADGSEL1, ADGSEL0	Set to 00b.
	CKS2	Select ϕA/D frequency.
	CKS3	Select fAD.
AD1CON0	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.
AD1CON1	SCAN1, SCAN0	Select analog input pin.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 in A/D conversion.

Note:
1. This table does not describe a procedure.

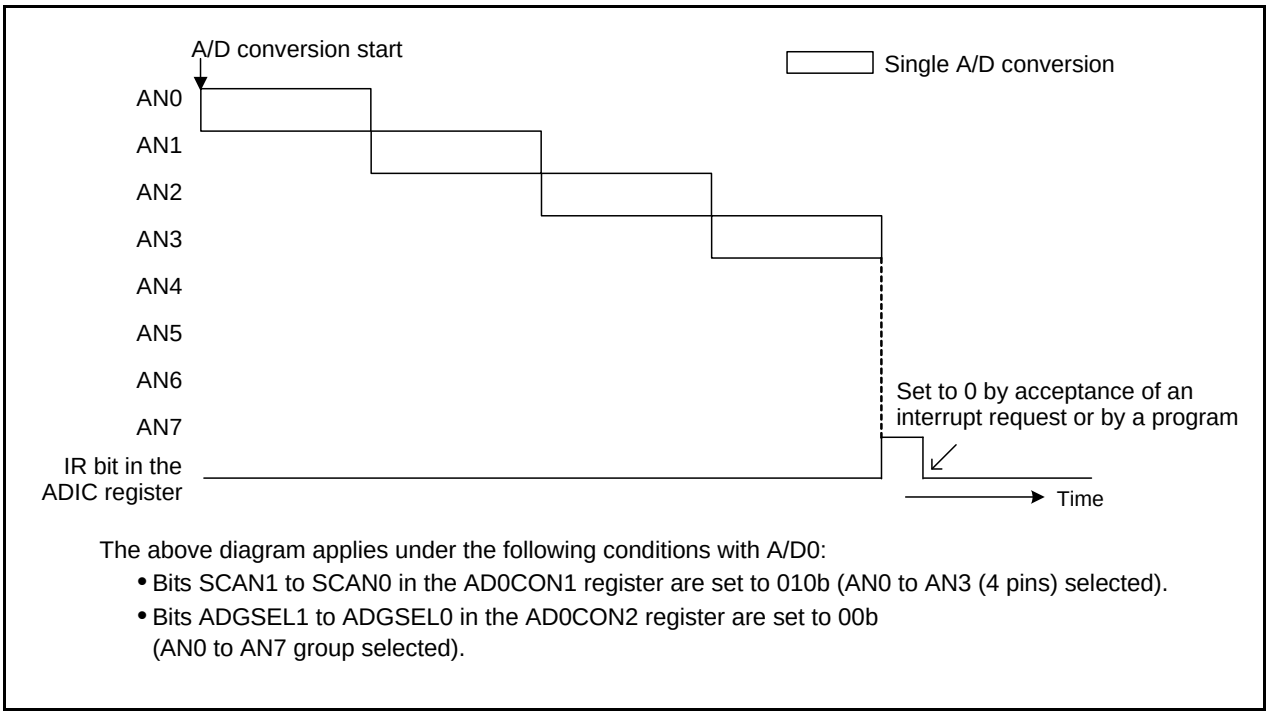


Figure 25.9 Operation Example in Single Sweep Mode

25.4.4 Repeat Sweep Mode 0

In repeat sweep mode 0, the analog voltage applied to selected pins is repeatedly converted to a digital code. Table 25.24 and Table 25.25 show the Repeat Sweep Mode 0 Specifications.

Table 25.24 Repeat Sweep Mode 0 Specifications (A/D0)

Item	Specification
Function	Bits SCAN1 to SCAN0 in the AD0CON1 register and bits ADGSEL1 to ADGSEL0 in the AD0CON2 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 AD0CON0 register is 0 (software trigger): The ADST bit in the AD0CON0 register is set to 1 (A/D conversion start). When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON register are 00b ($\overline{\text{ADTRG}}$ trigger): 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). When the TRG bit is 1 and bits HDTRG1 to HDTRG0 in the AD0TRGCON register are 01b, 10b or 11b (timer trigger): Selected trigger (Timer B0, Timer B1 or Timer B2 interrupt request) occurs.
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	When A/D1 operation stopped (standby) (the ADSTBY bit in the AD1CON1 register is 0): Select from AN0 to AN1 (2 pins), AN0 to AN3 (4 pins), AN0 to AN5 (6 pins) and AN0 to AN7 (8 pins) AN0_0 to AN0_7 and AN2_0 to AN2_7 can be selected in the same way. When A/D1 operation enabled (the ADSTBY bit in the AD1CON1 register is 1): Select from AN0_0 to AN0_1 (2 pins), AN0_0 to AN._3 (4 pins), AN0_0 to AN0_5 (6 pins) and AN0_0 to AN0_7 (8 pins). AN2_0 to AN2_7 can be selected in the same way. AN0 to AN7 are not available.
Reading of A/D conversion result	Read the registers among AD00 to AD07 that corresponds to the selected pins.

Table 25.25 Repeat Sweep Mode 0 Specifications (A/D1)

Item	Specification
Function	Bits SCAN1 to SCAN0 in the AD1CON1 register and bits ADGSEL1 to ADGSEL0 in the AD1CON2 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 AD1CON0 register is 0 (software trigger): The ADST bit in the AD1CON0 register is set to 1 (A/D conversion start). When the TRG bit is 1 and bits HDTRG1 and HDTRG0 in the AD1TRGCON register are 00b ($\overline{\text{ADTRG}}$ trigger): 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). When the TRG bit is 1 and bits HDTRG1 and HDTRG0 in the AD1TRGCON register are 01b, 10b or 11b (timer trigger): Selected trigger (Timer B0, Timer B1 or Timer B2 interrupt request) occurs.
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 from AN0 to AN1 (2 pins), AN0 to AN3 (4 pins)
Reading of A/D conversion result	Read the registers among AD10 to AD13 that corresponds to the selected pins.

Table 25.26 Registers and Settings in Repeat Sweep Mode 0 (A/D0) (1)

Register	Bit	Setting
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.
AD0TRGCON	HDTRG1, HDTRG0	Select a trigger.
AD00 to AD07	b9 to b0	A/D conversion result can be read.
AD0CON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕA/D frequency.
	CKS3	Select fAD.
AD0CON0	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.
AD0CON1	SCAN1, SCAN0	Select analog input pin.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when operating A/D conversion.
	ADEX1, ADEX0	Set to 00b.

Note:
1. This table does not describe a procedure.

Table 25.27 Registers and Settings in Repeat Sweep Mode 0 (A/D1) (1)

Register	Bit	Setting
AD1TRGCON	HDTRG1, HDTRG0	Select a trigger.
AD10 to AD13	b9 to b0	A/D conversion result can be read.
AD1CON2	ADGSEL1, ADGSEL0	Set to 00b.
	CKS2	Select ϕA/D frequency.
	CKS3	Select fAD.
AD1CON0	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.
AD1CON1	SCAN1, SCAN0	Select analog input pin.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when operating A/D conversion.

Note:
1. This table does not describe a procedure.

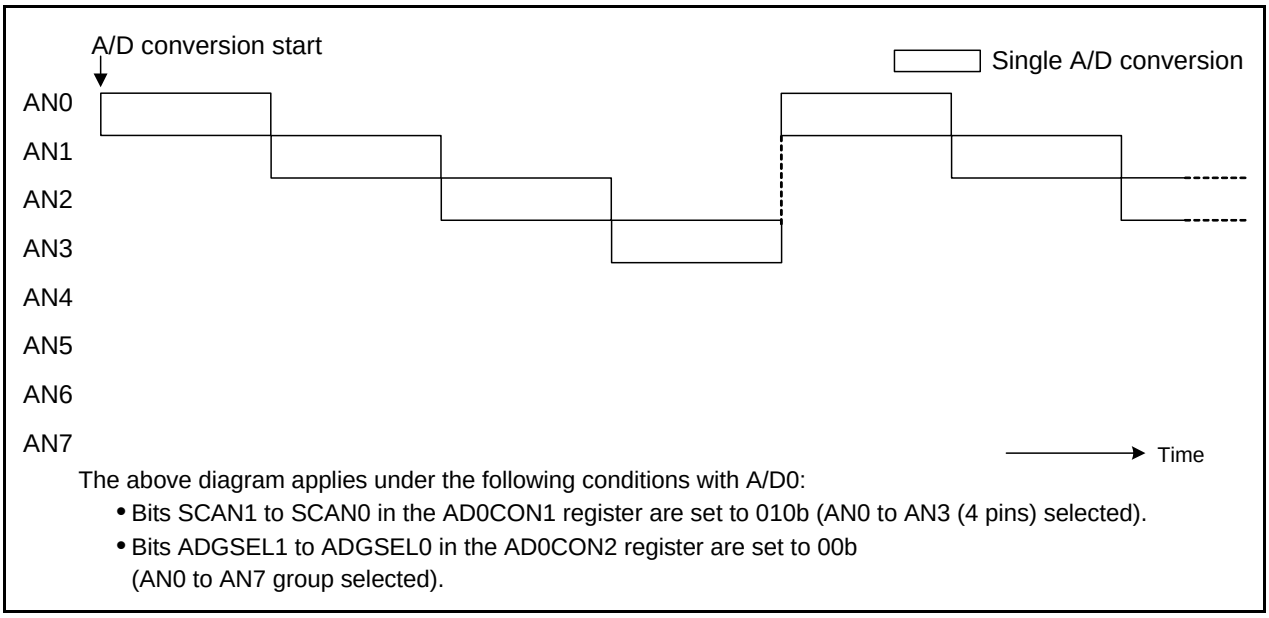


Figure 25.10 Operation Example in Repeat Sweep Mode 0

25.5 External Sensor

To perform A/D conversion accurately, charging the internal capacitor C shown in Figure 25.11 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, $R0 = -\frac{T}{C \bullet \ln\frac{X}{Y}} - R$

Figure 25.11 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. Actual error however 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 the 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.

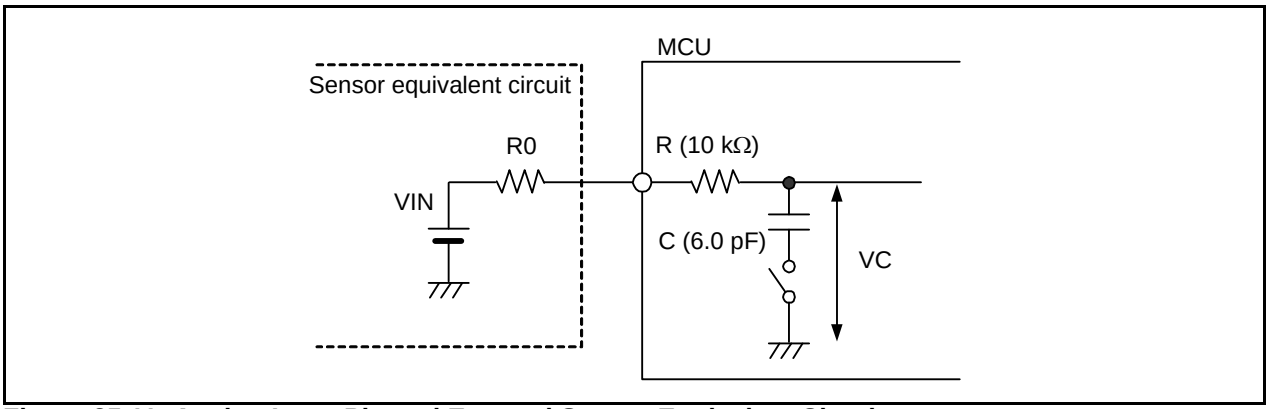


Figure 25.11 Analog Input Pin and External Sensor Equivalent Circuit

25.6 Interrupt

Refer to the operation examples for timing of generating interrupt requests.
Also, refer to 14.7 “Interrupt Control” for details. Table 25.28 lists Registers Associated with A/D Converter Interrupt.

Table 25.28 Registers Associated with A/D Converter Interrupt

Address	Register	Symbol	Reset Value
004Eh	A/D Conversion (A/D0) Interrupt Control Register	ADIC	XXXX X000b
004Dh	Key Input Interrupt Control Register A/D Conversion (A/D1) Interrupt Control Register	KUPIC ADEIC	XXXX X000b
0206h	Interrupt Source Select Register 2	IFSR2A	00h

Note:
1. Interrupt source of key input and A/D conversion (A/D1) is selected by the IFSR21 bit in the IFSR2A register.

25.7 Notes on A/D Converter

25.7.1 Analog Input Voltage

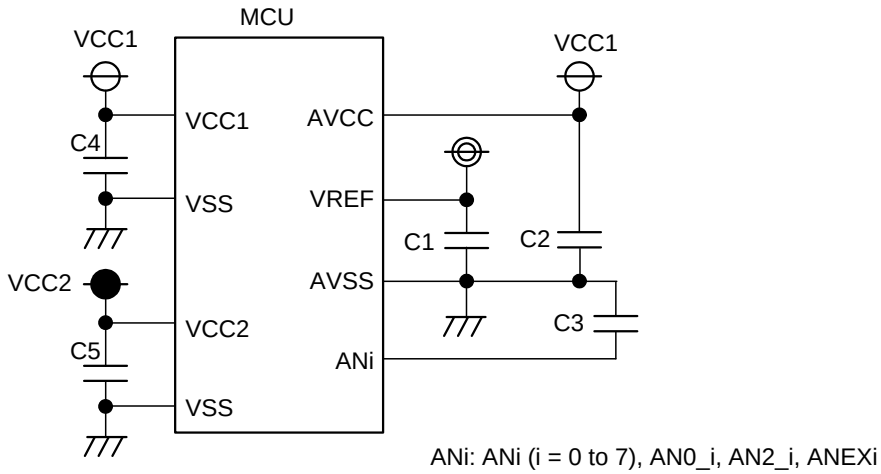
Use when AVCC = VCC1 = VCC2.
Do not use A/D converter when VCC1 > VCC2.

25.7.2 Analog Input Pin

When A/D1 operation is enabled (the ADSTBY bit in the AD1CON1 register is set to 1), AN0 to AN7 pins are not available for A/D0. Select any pins of AN0_0 to AN0_7, AN2_0 to AN2_7, ANEX0 or ANEX1. When A/D0 selects pins AN0 to AN7 and operates A/D conversion with A/D1 operation enabled, the conversion result becomes undefined. To select pins AN0 to AN7 with A/D0, set A/D1 operation to stop (set the ADSTBY bit in the AD1CON1 register to 0).
Do not use any pin from AN4 to AN7 as analog input pin if any pin from $\overline{KI0}$ to $\overline{KI3}$ is used as a key input interrupt.
Do not convert an analog signal in A/D0 and A/D1 simultaneously. When converting an analog signal in both A/D0 and A/D1, make sure to finish one A/D conversion and start another A/D conversion. Take the average of the both of the conversion.

25.7.3 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), AN0_i, and AN2_i and ANEXj (j = 0 to 1)). 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 25.12 Example of Pin Configuration

25.7.4 Register Access (A/D0 related registers)

Set registers associated with A/D converter (A/D0) after setting the CKS3 bit in the AD0CON2 register. However the other bits in the AD0CON2 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 AD0CON0 (excluding the ADST bit), AD0CON1, and AD0CON2 when A/D conversion stops (before a trigger is generated).
After A/D conversion stops, set the ADSTBY bit in the AD0CON1 register from 1 to 0.

25.7.5 Register Access (A/D1 related registers)

Set registers associated with A/D converter (A/D1) after setting the CKS3 bit in the AD1CON2 register. However the other bits in the AD1CON2 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 AD1CON0 (excluding the ADST bit), AD1CON1 and AD1CON2 when A/D conversion stops (before a trigger is generated).
After A/D conversion stops, set the ADSTBY bit in the AD1CON1 register from 1 to 0.

25.7.6 A/D Conversion Start

For A/D0, when rewriting the ADSTBY bit in the AD0CON1 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 (A/D0).
For A/D1, when rewriting the ADSTBY bit in the AD1CON1 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 (A/D1).

25.7.7 A/D Operation Mode Change

When the A/D operation mode for A/D0 has been changed, reselect analog input pins by using bits CH2 to CH0 in the AD0CON0 register or bits SCAN1 to SCAN0 in the AD0CON1 register.
When the A/D operation mode for A/D1 has been changed, re-select analog input pins by using bits CH2 to CH0 in the AD1CON0 register or bits SCAN1 to SCAN0 in the AD1CON1 register.

25.7.8 State When Forcibly Terminated (A/D0)

If A/D conversion (A/D0) in progress is halted by setting the ADST bit in the AD0CON0 register to 0 (A/D conversion stopped), the conversion result is undefined. In addition, the unconverted AD0i register (i = 0 to 7) may also become undefined. Do not use any value in AD0i registers when setting the ADST bit to 0 by a program during A/D conversion.

25.7.9 State When Forcibly Terminated (A/D1)

If A/D conversion (A/D1) in progress is halted by setting the ADST bit in the AD1CON0 register to 0 (A/D conversion stopped), the conversion result is undefined. In addition, the unconverted AD1j register (j = 0 to 3) may also become undefined. Do not use any value in AD1j registers when setting the ADST bit to 0 by a program during A/D conversion.

25.7.10 Detecting Completion of A/D Conversion (A/D0)

In one-shot mode and single sweep mode, use the IR bit in the ADIC register to detect completion of A/D conversion (A/D0). 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 AD0CON0 register, the ADST bit becomes 1 (A/D conversion start) after start processing time elapses (see Table 25.10 “Cycles of A/D Conversion Item”). Therefore when reading the ADST bit immediately after writing 1, 0 (A/D conversion stop) may be read.

25.7.11 Detecting Completion of A/D Conversion (A/D1)

In one-shot mode and single sweep mode, use the IR bit in the ADEIC register to detect completion of A/D conversion (A/D1). When not using interrupt, set the IR bit to 0 by a program after the detection.
When 1 is written to the ADST bit in the AD1CON0 register, the ADST bit becomes 1 (A/D conversion start) after start processing time elapses (see Table 25.10 “Cycles of A/D Conversion Item”). Therefore when reading the ADST bit immediately after writing 1, 0 (A/D conversion stop) may be read.

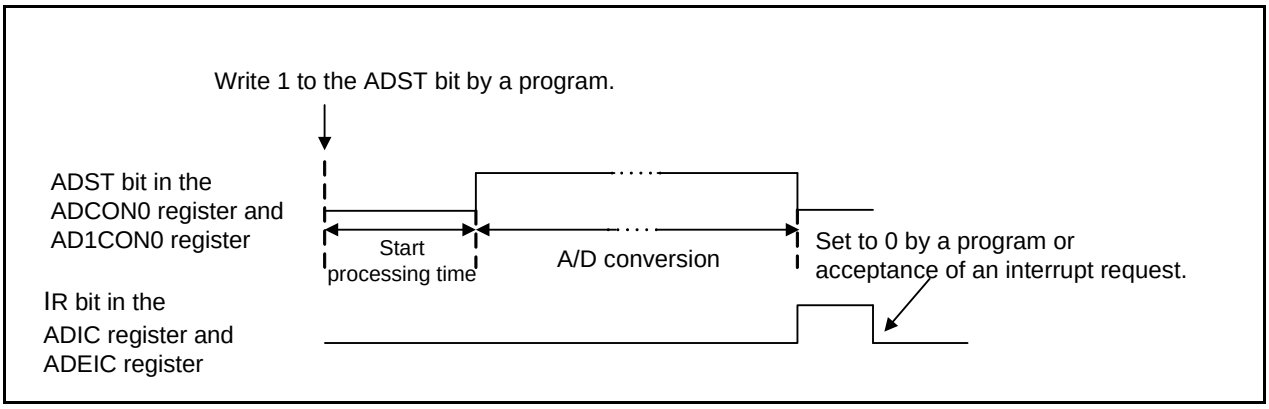


Figure 25.13 ADST Bit Operation

25.7.12 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).

26. D/A Converter

26.1 Introduction

The D/A converter is an 8-bit, R-2R type converter. There are two independent D/A converters.
Table 26.1 lists the D/A Converter Specifications and Figure 26.1 shows the D/A Converter Block Diagram.

Table 26.1 D/A Converter Specifications

Item	Specification
D/A conversion method	R-2R
Resolution	8 bits

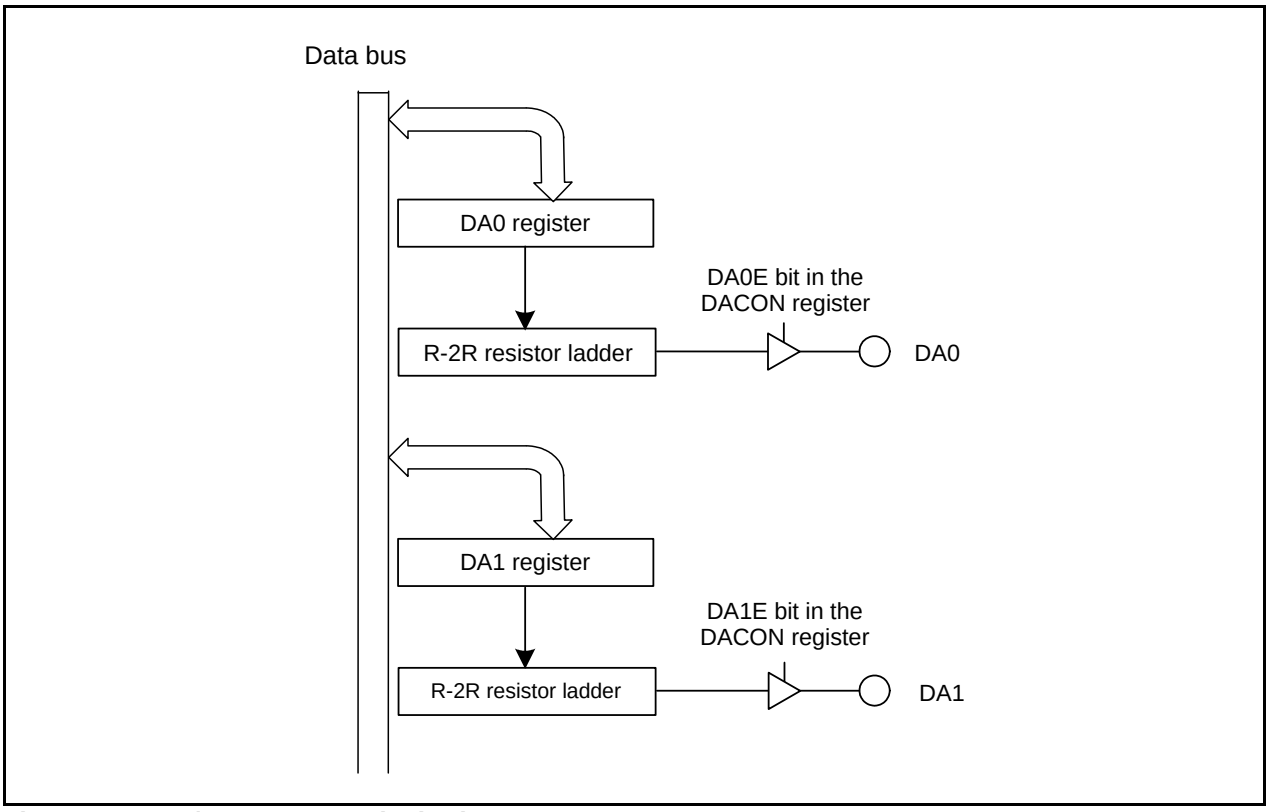


Figure 26.1 D/A Converter Block Diagram

Table 26.2 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.

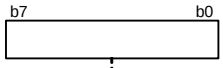
26.2 Registers

Table 26.3 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

26.2.1 D/Ai Register (DAi) (i = 0, 1)

D/Ai Register (i = 0, 1)

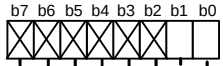


Symbol	Address	Reset Value
DA0	03D8h	00h
DA1	03DAh	00h

Function	Setting Range	RW
Output value of D/A conversion	00h to FFh	RW

26.2.2 D/A Control Register (DACON)

D/A Control Register



Symbol	Address	Reset Value
DACON	03DCh	00h

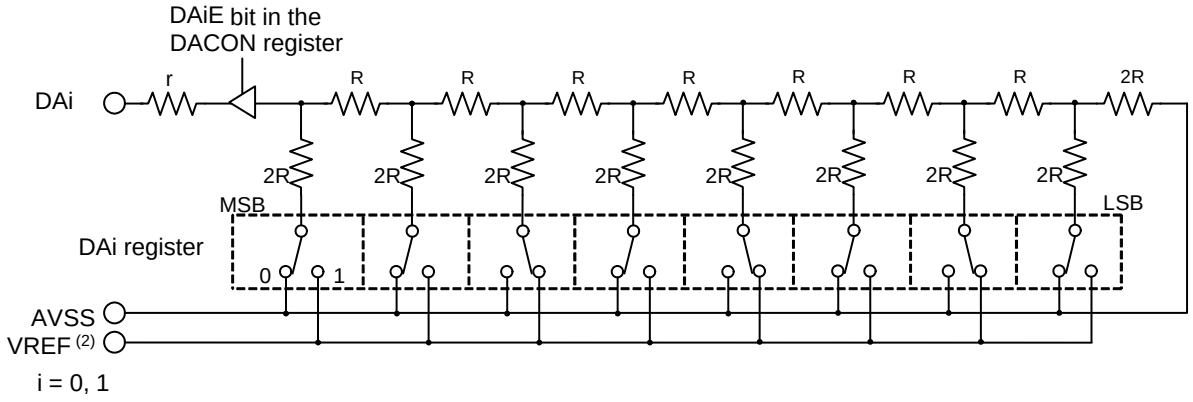
Bit Symbol	Bit Name	Function	RW
DA0E	D/A0 output enable bit	0 : Output disabled 1 : Output enabled	RW
DA1E	D/A1 output enable bit	0 : Output disabled 1 : Output enabled	RW
— (b7-b2)	No register bits. If necessary, set to 0. The read values are undefined.		—

26.3 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 26.2 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 26.2 D/A Converter Equivalent Circuit

26.4 Notes on D/A Converter

26.4.1 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.

27. CRC Calculator

27.1 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 27.1 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

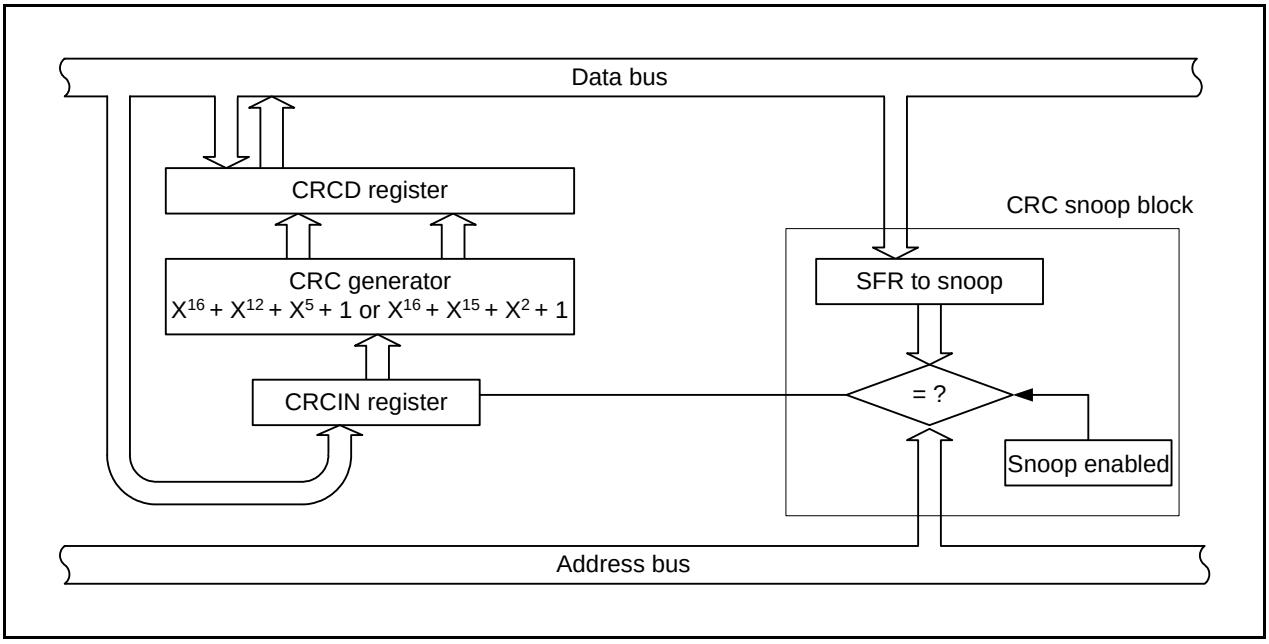


Figure 27.1 CRC Calculator Block Diagram

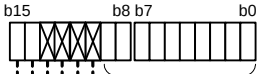
27.2 Registers

Table 27.2 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

27.2.1 SFR Snoop Address Register (CRCSAR)

SFR Snoop Address Register



Symbol: CRCSAR
Address: 03B5h to 03B4h
Reset Value: 00XX XXXX XXXX XXXXb

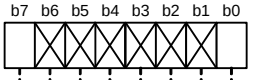
Bit Symbol	Bit Name	Function	RW
CRCSAR9 to CRCSAR0	SFR snoop address bit	Set the SFR address to snoop	RW
— (b13-b10)	No register bits. If necessary, set to 0. The read value is undefined.		—
CRCSR	Snoop-on-read enable bit	0: Disabled 1: Enabled	RW
CRCSW	Snoop-on-write enable bit	0: Disabled 1: Enabled	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.

27.2.2 CRC Mode Register (CRCMR)

CRC Mode Register

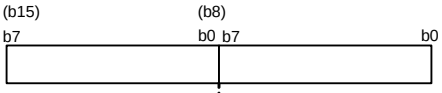


Symbol	Address	Reset Value
CRCMR	03B6h	0XXX XXX0b

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

27.2.3 CRC Data Register (CRCD)

CRC Data Register



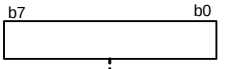
Symbol	Address	Reset Value
CRCD	03BDh to 03BCh	Undefined

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 27.2 “CRC Calculation When Using CRC-CCITT” and Figure 27.3 “CRC Calculation When Using CRC-16”.

27.2.4 CRC Input Register (CRCIN)

CRC Input Register



Symbol	Address	Reset Value
CRCIN	03BEh	Undefined

Function	Setting Range	RW
Data input	00h to FFh	RW

27.3 Operations

27.3.1 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.

27.3.2 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.

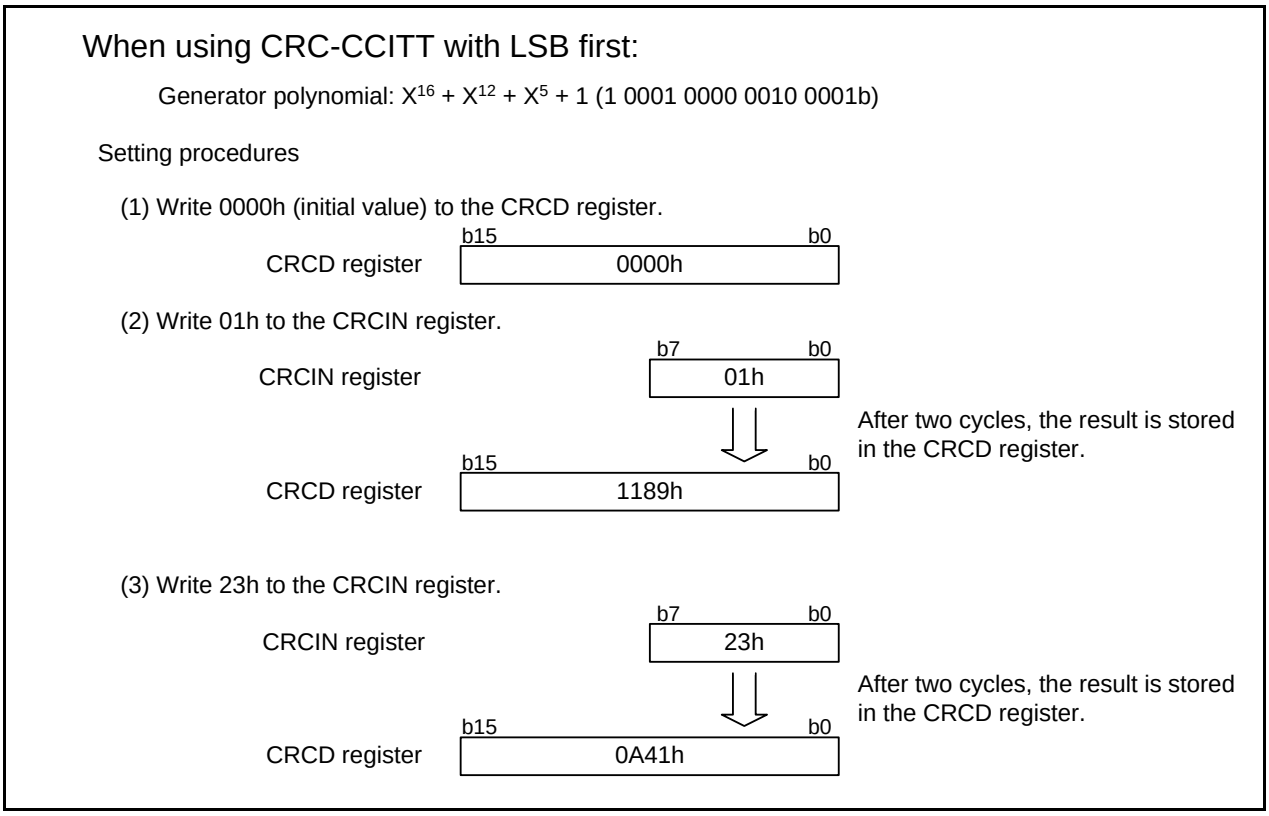


Figure 27.2 CRC Calculation When Using CRC-CCITT

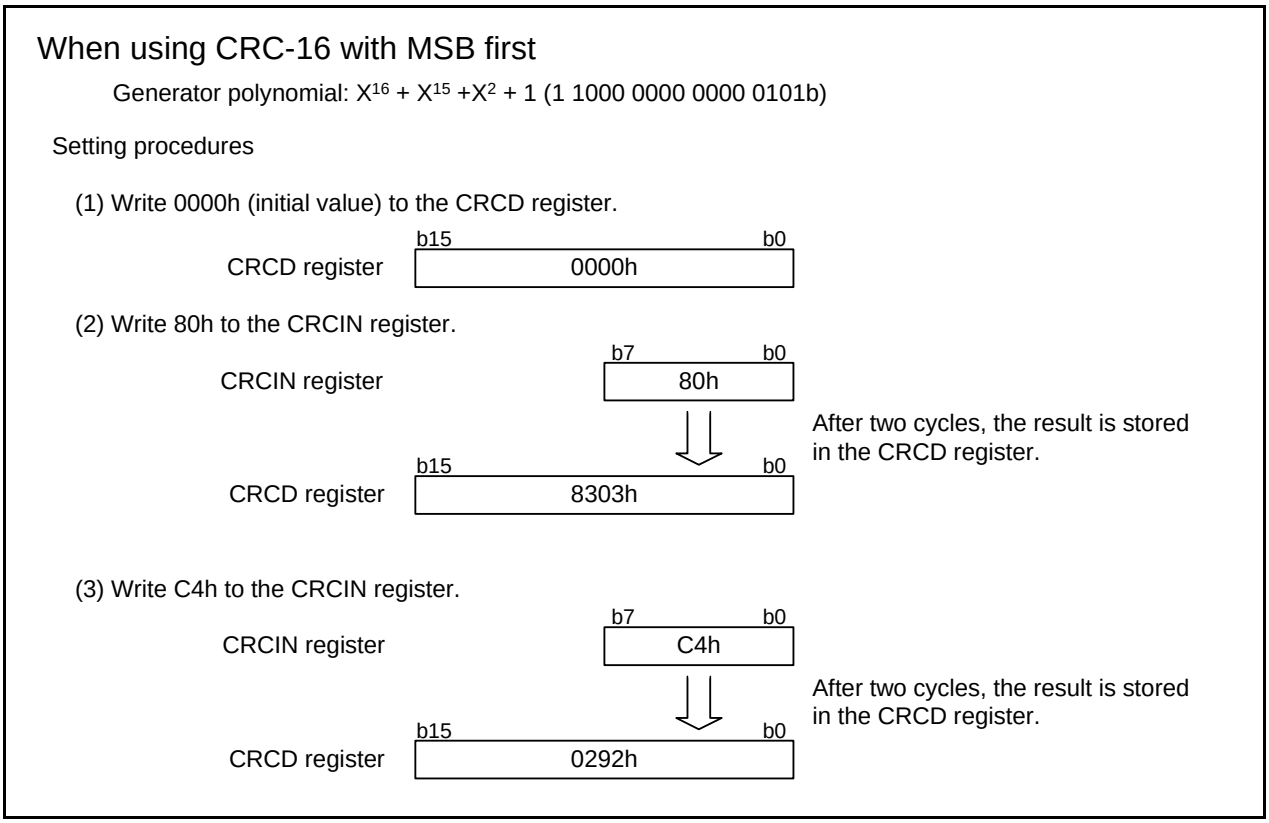


Figure 27.3 CRC Calculation When Using CRC-16

28. Flash Memory

28.1 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 28.1 lists Flash Memory Specifications (see Table 1.1 to Table 1.2 “Specifications” for the items not listed in Table 28.1).

Table 28.1 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 28.1 “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
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 28.2 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

28.2 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 28.1 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). Program ROM 2 includes a user boot code area.

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 28.3 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 28.3 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

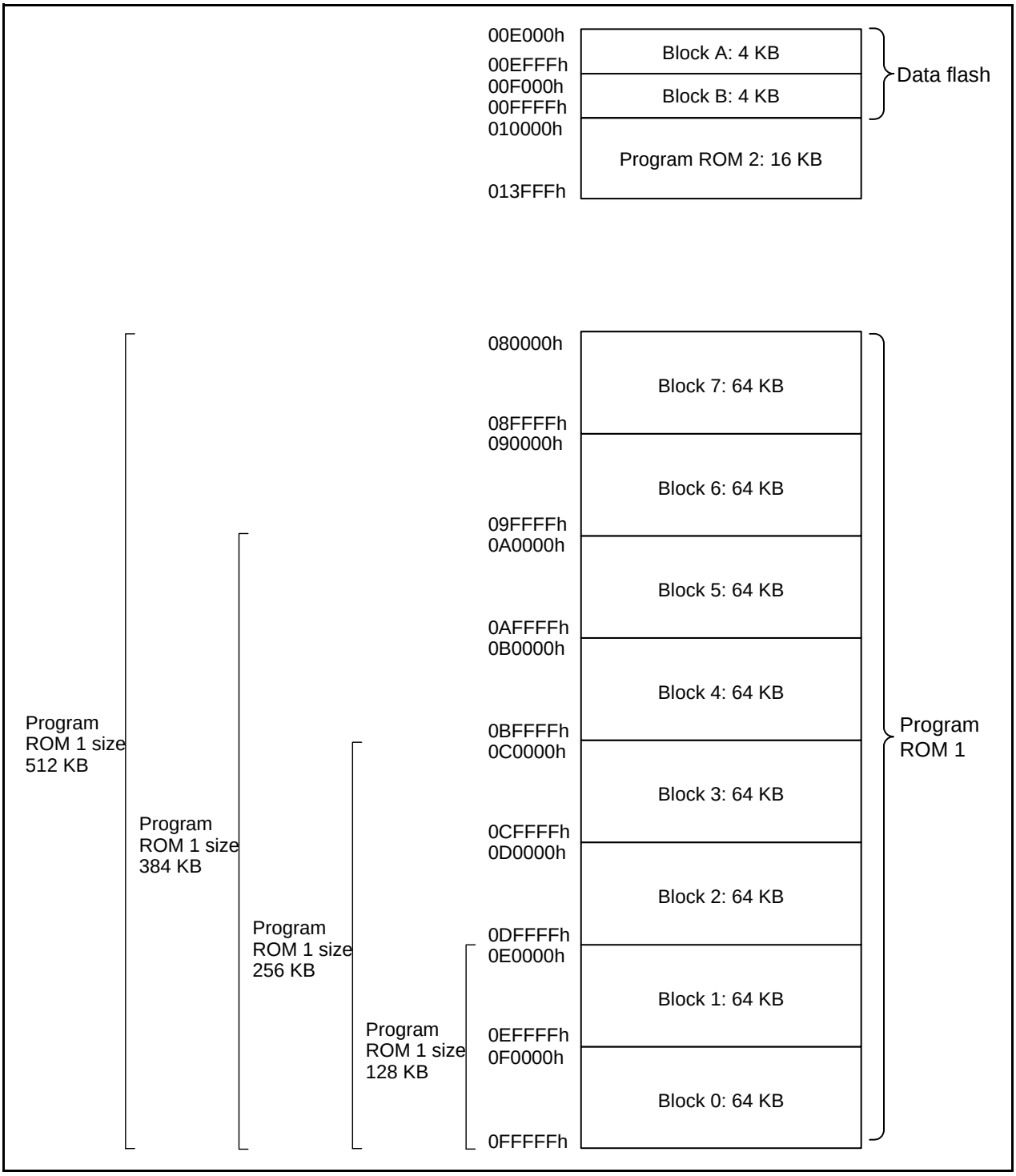


Figure 28.1 Flash Memory Block Diagram

28.3 Registers

Table 28.4 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
0230h	Flash Memory Control Register 6	FMR6	XX0X XX00b

28.3.1 Flash Memory Control Register 0 (FMR0)

Flash Memory Control Register 0

b7	b6	b5	b4	b3	b2	b1	b0
			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/$\overline{BY}$ 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/$\overline{BY}$ 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 28.8.4 “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 or erasing.

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 28.8.6.1 “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)

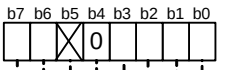
This bit indicates the auto-erase operation state.
Condition to become 0:
- Execute the clear status command

Condition to become 1:
- Refer to 28.8.6.1 “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.

28.3.2 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)

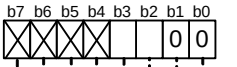
This bit indicates the execution result of the read lock bit status command.

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.

28.3.3 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”.

28.3.4 Flash Memory Control Register 6 (FMR6)

Flash Memory Control Register 6

b7	b6	b5	b4	b3	b2	b1	b0
		0				1	

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.

28.4 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.

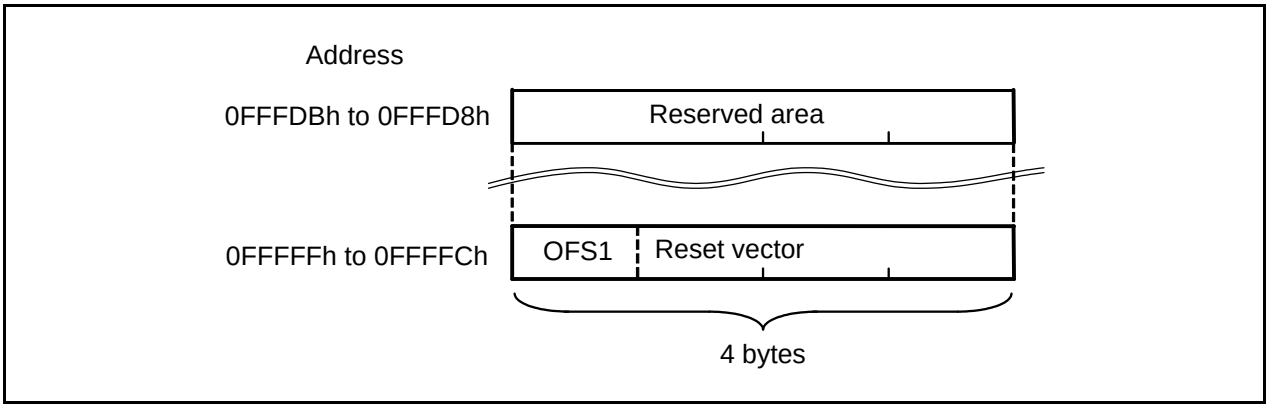


Figure 28.2 Option Function Select Area

28.4.1 Optional Function Select Address 1 (OFS1)

Optional Function Select Address 1

b7	b6	b5	b4	b3	b2	b1	b0
			1			1	

Symbol: OFS1 — Address: FFFFFFh

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 28.5 ROM Code Protect

Bit Setting		ROM Code Protect
ROMCR bit	ROMCP1 bit	
0	0	Disabled
0	1	
1	0	Enabled
1	1	Disabled

28.5 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

28.6 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 28.9 “Standard Serial I/O Mode” for details.

The MCU does not enter boot mode in power-on reset and voltage monitor 0 reset.

28.7 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.

28.7.1 User Boot Function

User boot mode can be selected by the status of a port when the MCU starts in boot mode. Table 28.6 lists the User Boot Function Specifications.

Table 28.6 User Boot Function Specifications

Item	Specification
Entry pin	None or select a port from P0 to P10
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 28.3 shows the User Boot Code Area, Table 28.7 lists Start Mode (When Port Pi_j is Selected for Entry), Table 28.8 lists “UserBoot” in ASCII Code, and Table 28.9 lists Addresses of Selectable Ports for Entry.

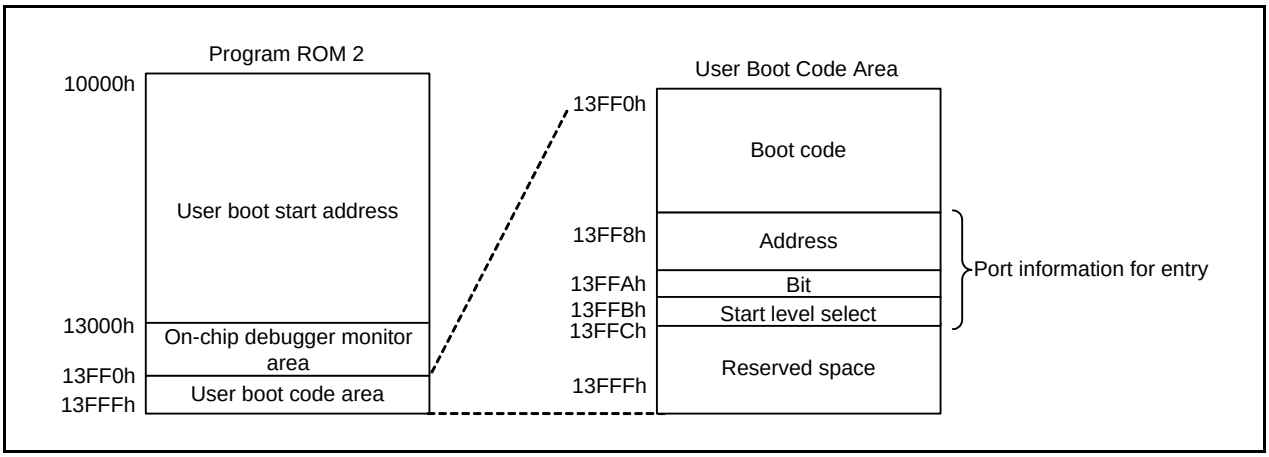


Figure 28.3 User Boot Code Area

Table 28.7 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 10; j = 0 to 7

Notes:
1. Only use the values listed in Table 28.7.
2. See Table 28.8 "UserBoot" in ASCII Code.
3. See Table 28.9 "Addresses of Selectable Ports for Entry".

Table 28.8 "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 28.9 Addresses of Selectable Ports for Entry

Port	Address	
	13FF9h	13FF8h
P0	03h	E0h
P1	03h	E1h
P2	03h	E4h
P3	03h	E5h
P6	03h	ECh
P7	03h	EDh
P8	03h	F0h
P9	03h	F1h
P10	03h	F4h

Table 28.10 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

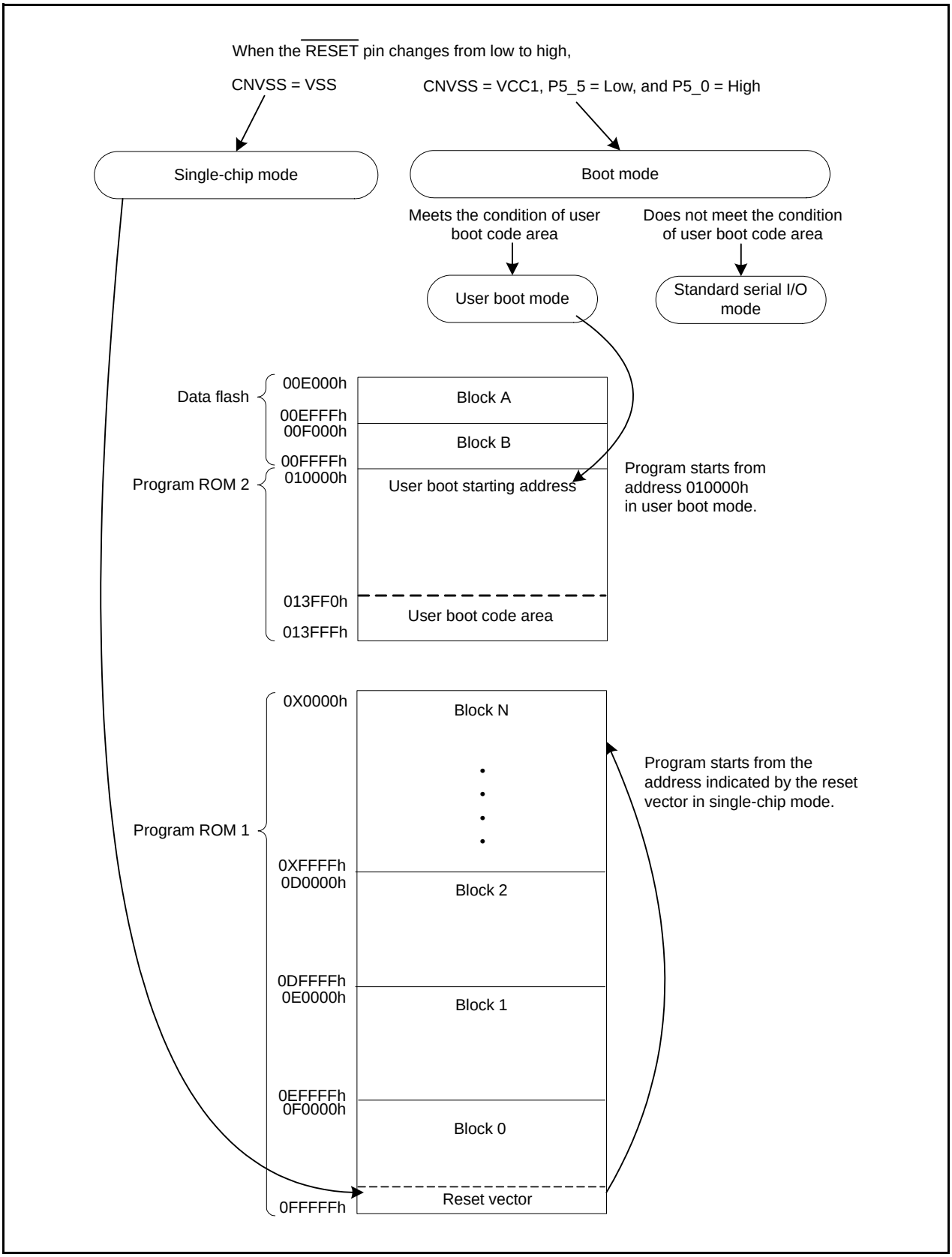


Figure 28.4 Program Starting Address in User Boot Mode

28.8 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.
EW0 mode and EW1 mode are available in CPU rewrite mode. Table 28.11 lists the differences between EW0 mode and EW1 mode.
Refer to 28.8.1 “EW0 Mode” and 28.8.2 “EW1 Mode” for details.

Table 28.11 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	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 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 by a program.

Note:
1. Refer to 11.3.1.2 “Bus Hold” for detail about the bus hold.

28.8.1 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 28.5 shows Setting and Resetting of EW0 Mode

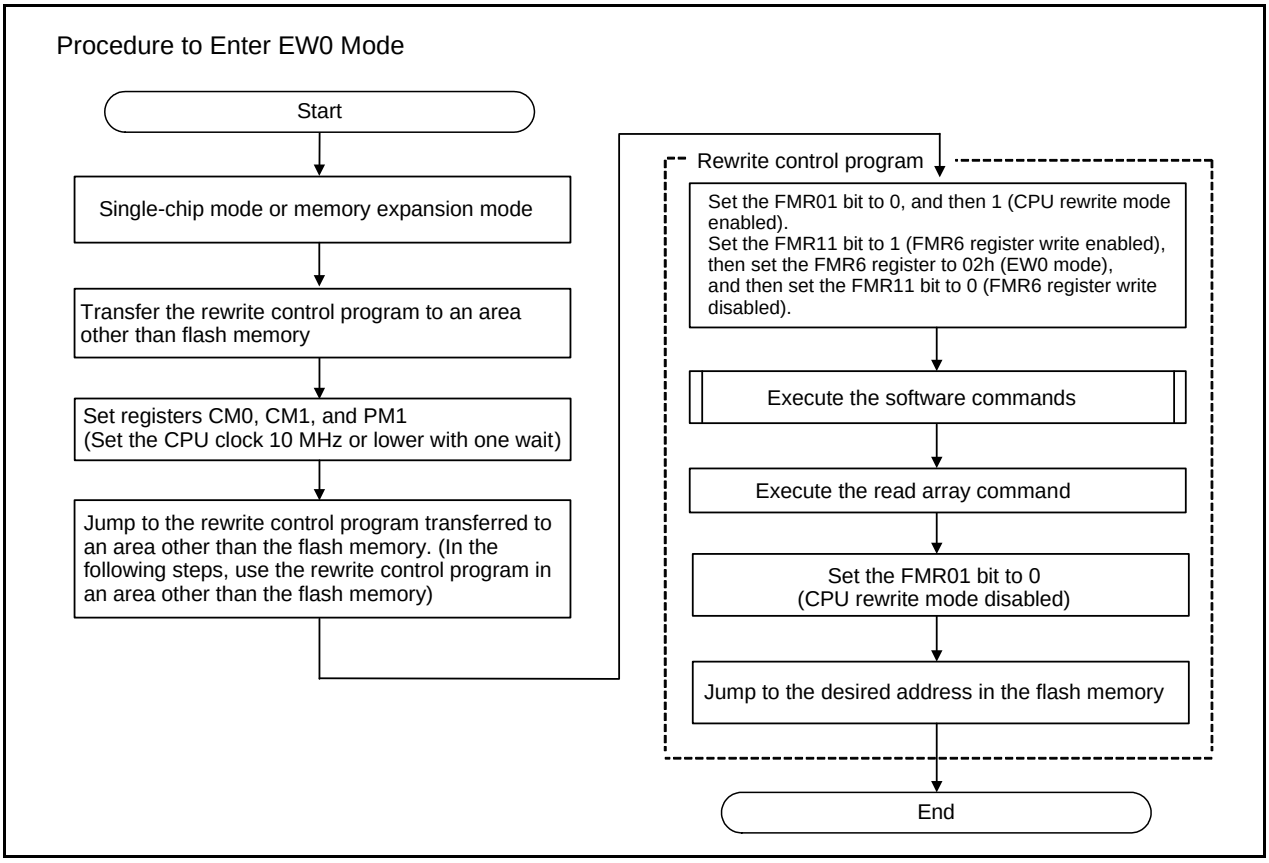


Figure 28.5 Setting and Resetting of EW0 Mode

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
  To use the interrupt, allocate a variable vector table in an area other than the flash memory.
- $\overline{\text{NMI}}$, 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 28.12 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.

28.8.2 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 28.6 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.

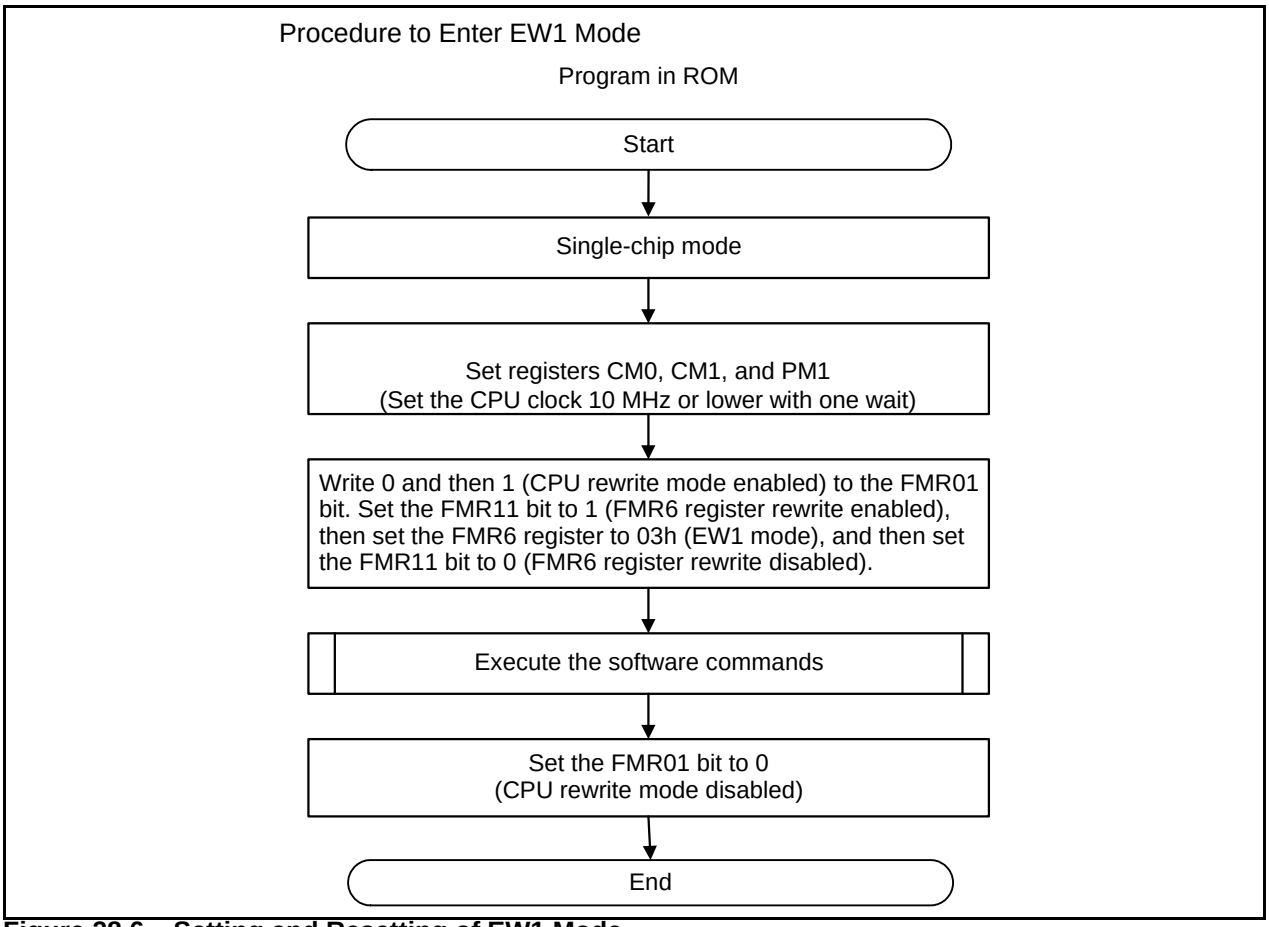


Figure 28.6 Setting and Resetting of EW1 Mode

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
  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.

Table 28.13 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	

28.8.3 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).

28.8.4 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 28.14 lists Lock Bit and Block State.

Table 28.14 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 28.8.5 “Software Commands”, for details on each command.

28.8.5 Software Commands

Table 28.15 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 28.15 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 28.15.

28.8.5.1 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.

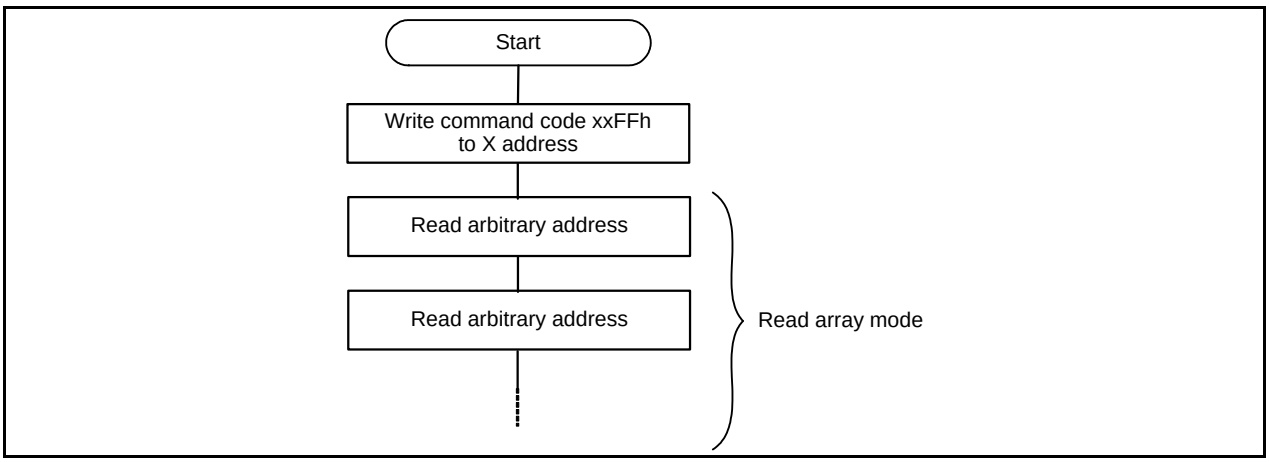


Figure 28.7 Read Array Command

28.8.5.2 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 28.8.6 “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.

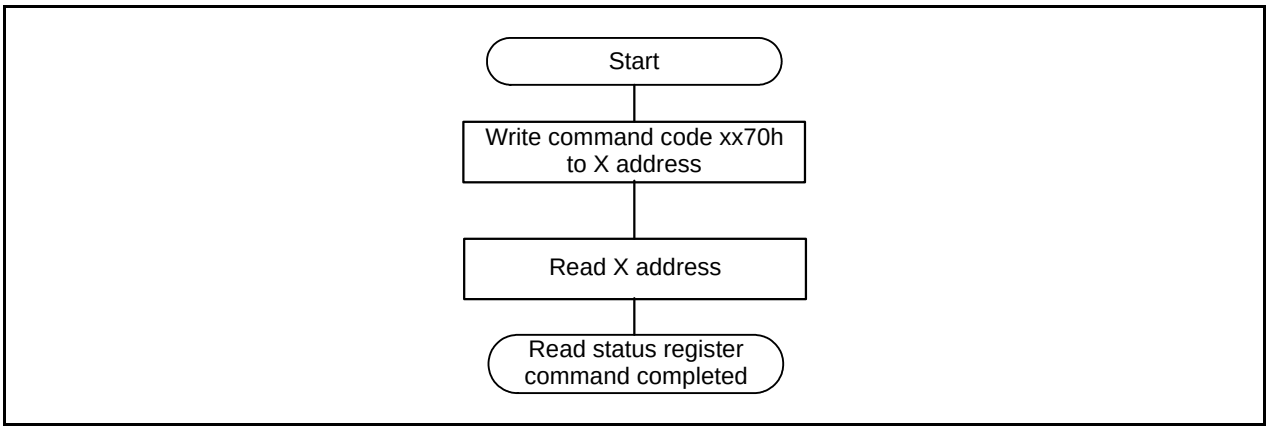


Figure 28.8 Read Status Register Command

28.8.5.3 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.

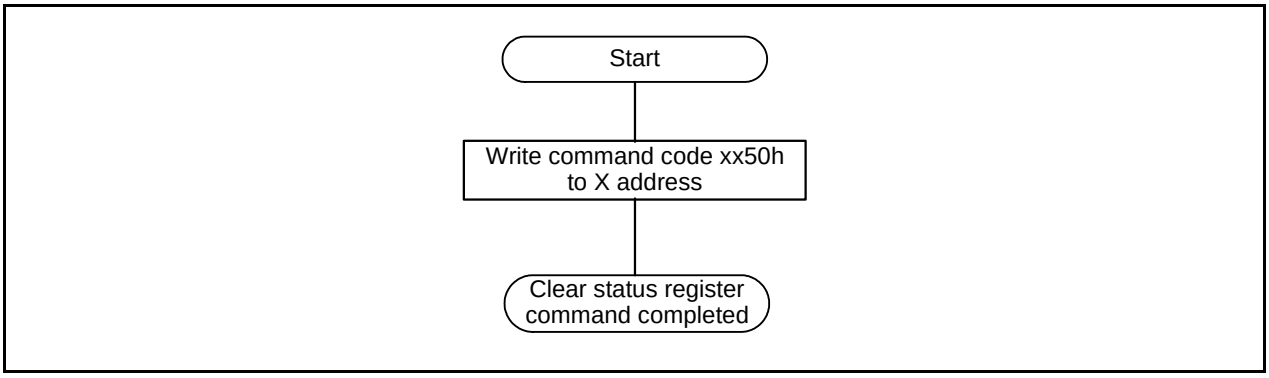


Figure 28.9 Clear Status Register Command

28.8.5.4 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 28.8.6.1 “Full Status Check”).
Do not rewrite the addresses already programmed. Figure 28.10 shows a flowchart of the Program Command.
The lock bit protects individual blocks from being programmed inadvertently. (Refer to 28.8.4 “Data Protect Function”.)

In EW1 mode, do not execute this command on a block to which the rewrite control program is allocated.

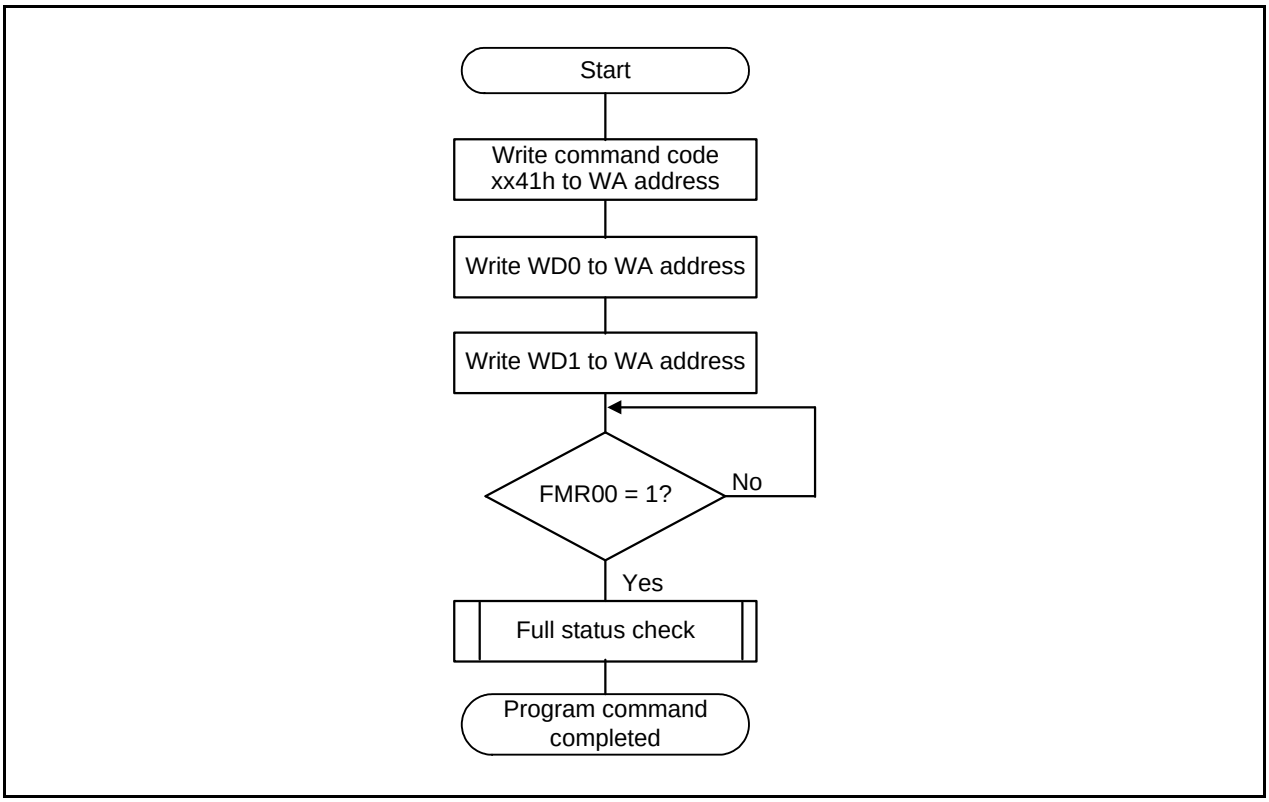


Figure 28.10 Program Command

28.8.5.5 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 28.8.6.1 “Full Status Check”).
Figure 28.11 shows a flowchart of the Block Erase Command.
The lock bit protects individual blocks from being erased inadvertently. (Refer to 28.8.4 “Data Protect Function”.)
In EW1 mode, do not execute this command on the block to which the rewrite control program is allocated.

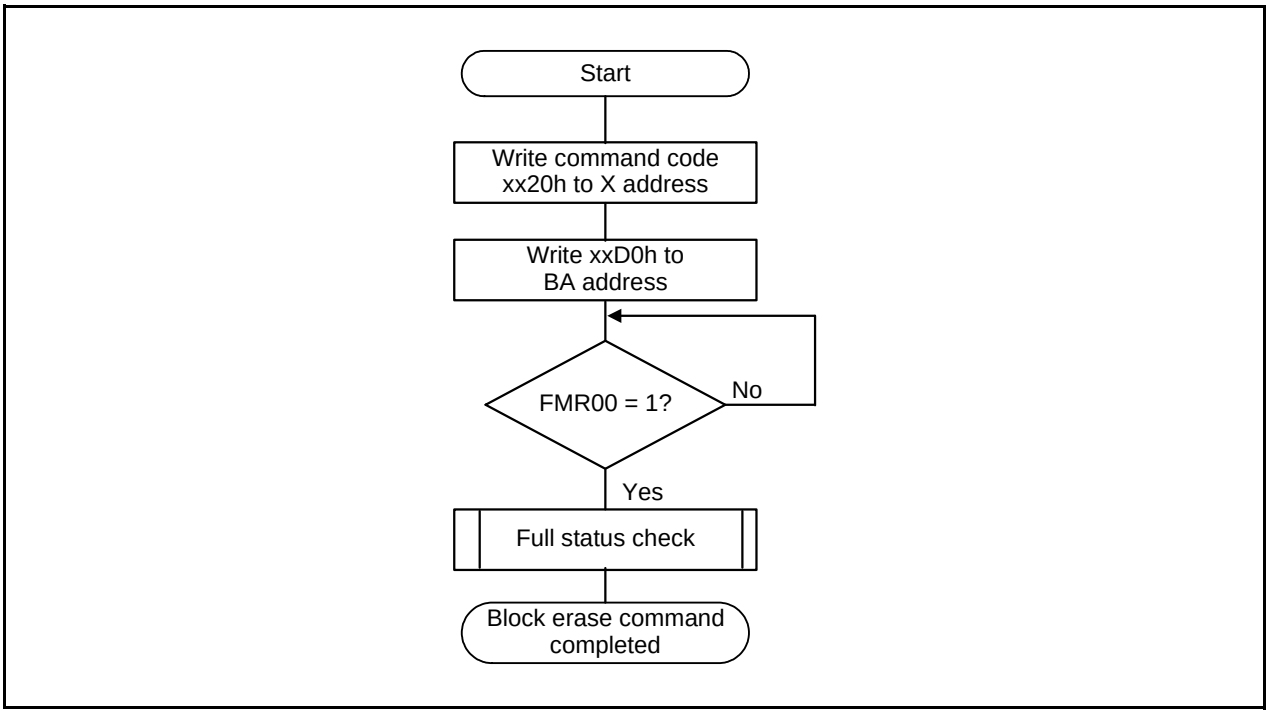


Figure 28.11 Block Erase Command

28.8.5.6 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 28.12 shows a flowchart of the Lock Bit Program Command. 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 28.8.4 “Data Protect Function”, for details on lock bit functions and how to set it to 1 (unlocked).

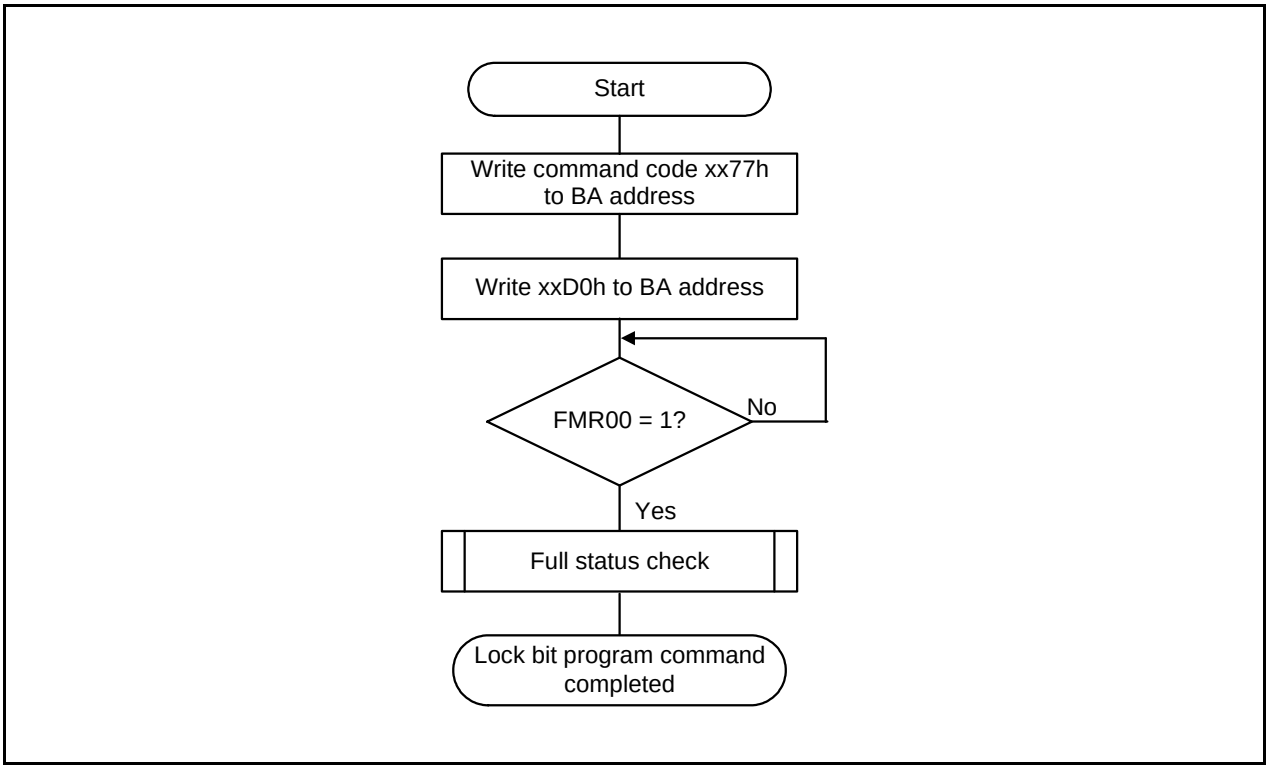


Figure 28.12 Lock Bit Program Command

28.8.5.7 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 28.13 shows a flowchart of the Read Lock Bit Status Command.

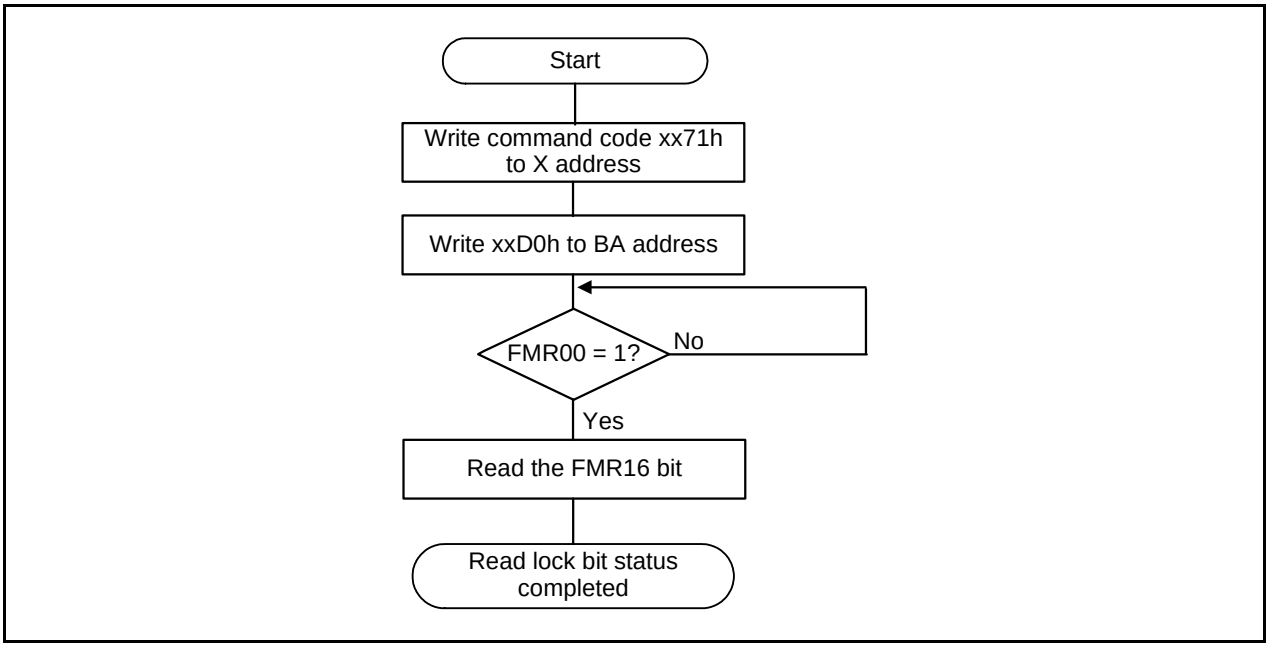


Figure 28.13 Read Lock Bit Status Command

28.8.5.8 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 28.14 shows a flowchart of the Block Blank Check Command.

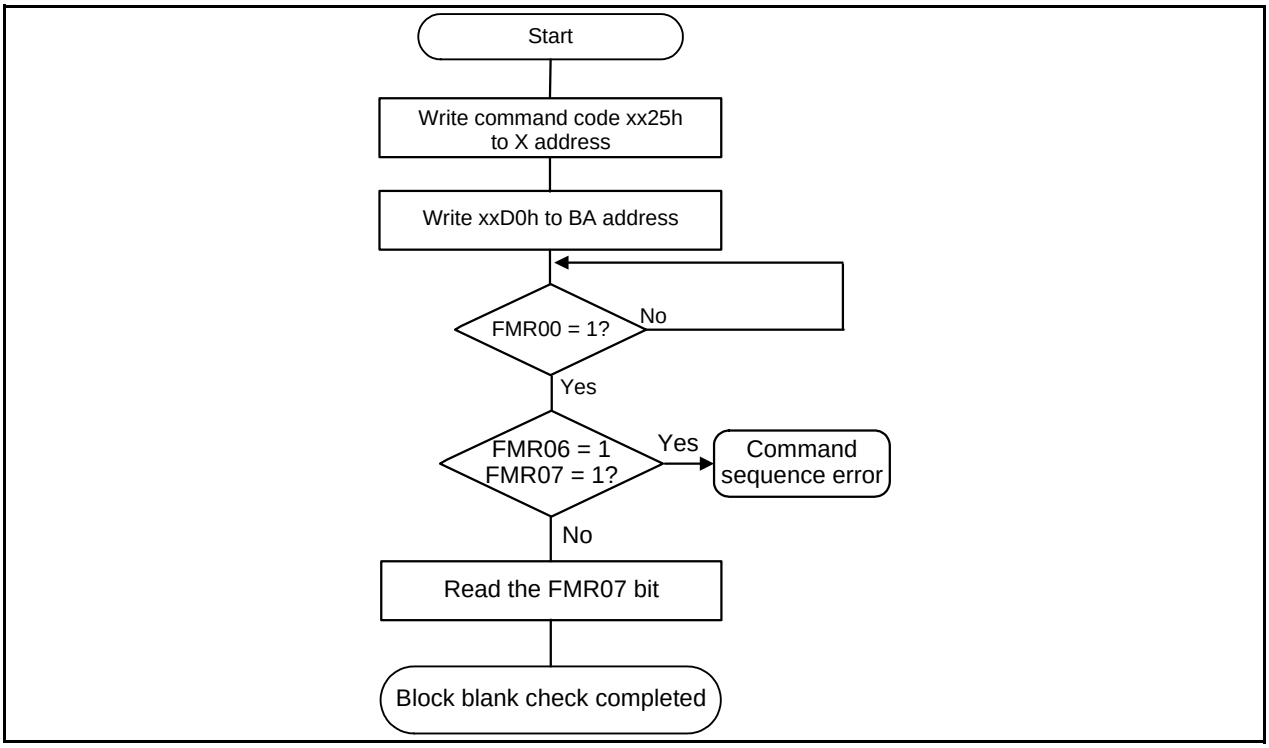


Figure 28.14 Block Blank Check Command

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.

28.8.6 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 28.3.1 “Flash Memory Control Register 0 (FMR0)” for a description of each bit.

Table 28.16 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 28.17 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.

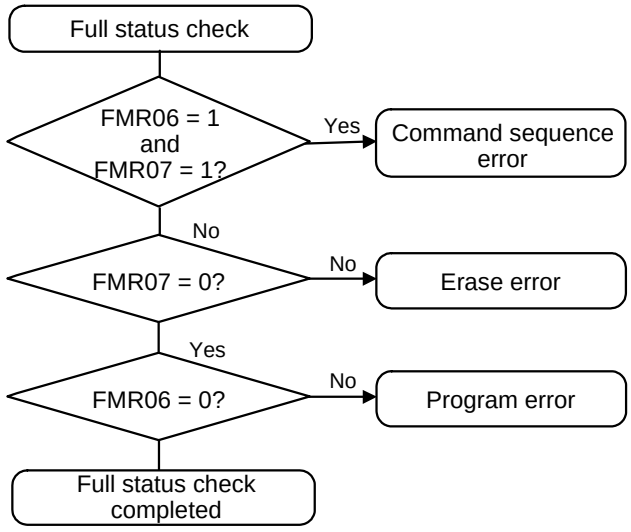
28.8.6.1 Full Status Check

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 28.18 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.



FMR07, FMR06: Bits in the FMR0 register

Figure 28.15 Full Status Check

28.8.6.2 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.

28.9 Standard Serial I/O Mode

In standard serial I/O mode, a serial programmer supporting the M16C/6C 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.

28.9.1 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 28.16 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 28.19 lists Reserved Word of ID Code. All ID code storage addresses and data must match the combinations listed in Table 28.19. When the forced erase function or standard serial I/O mode disable function is not used, use another combination of ID codes.

Table 28.19 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 28.19.

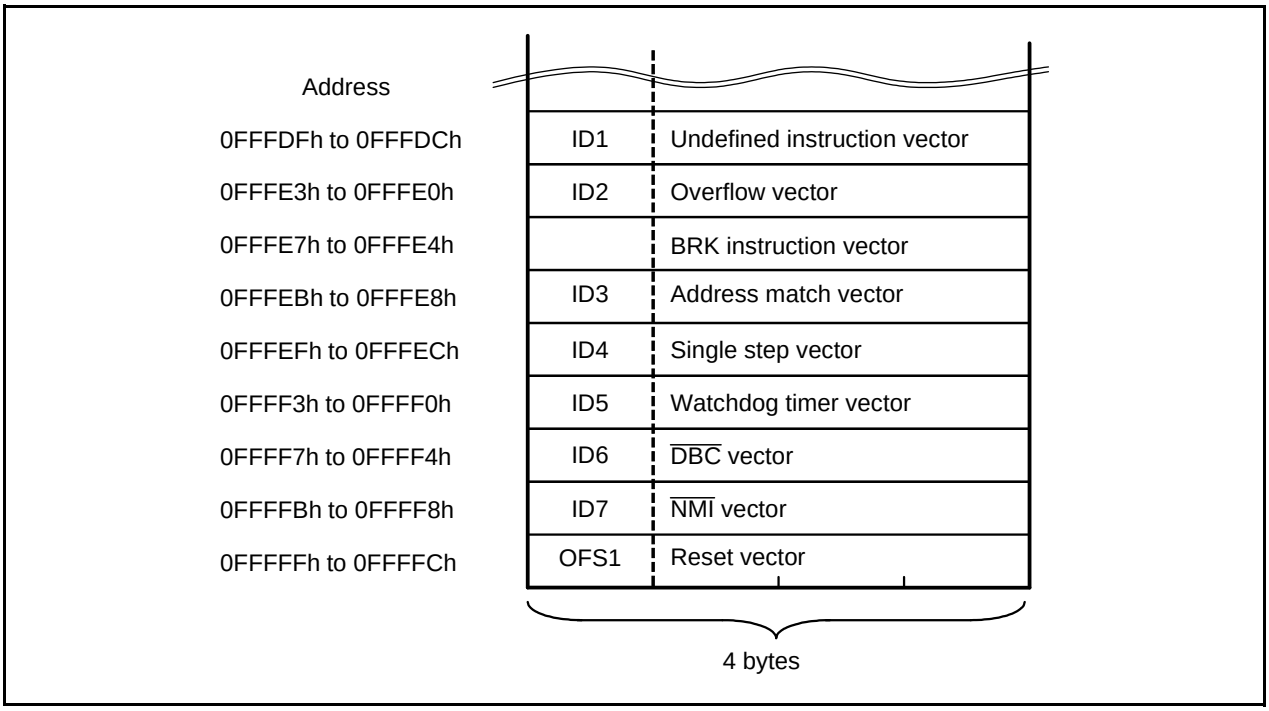


Figure 28.16 ID Code Storage Addresses

28.9.2 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 28.19), 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 28.20 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 28.20 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 28.9.3 “Standard Serial I/O Mode Disable Function”.

28.9.3 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 28.19 “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.

28.9.4 Standard Serial I/O Mode 1

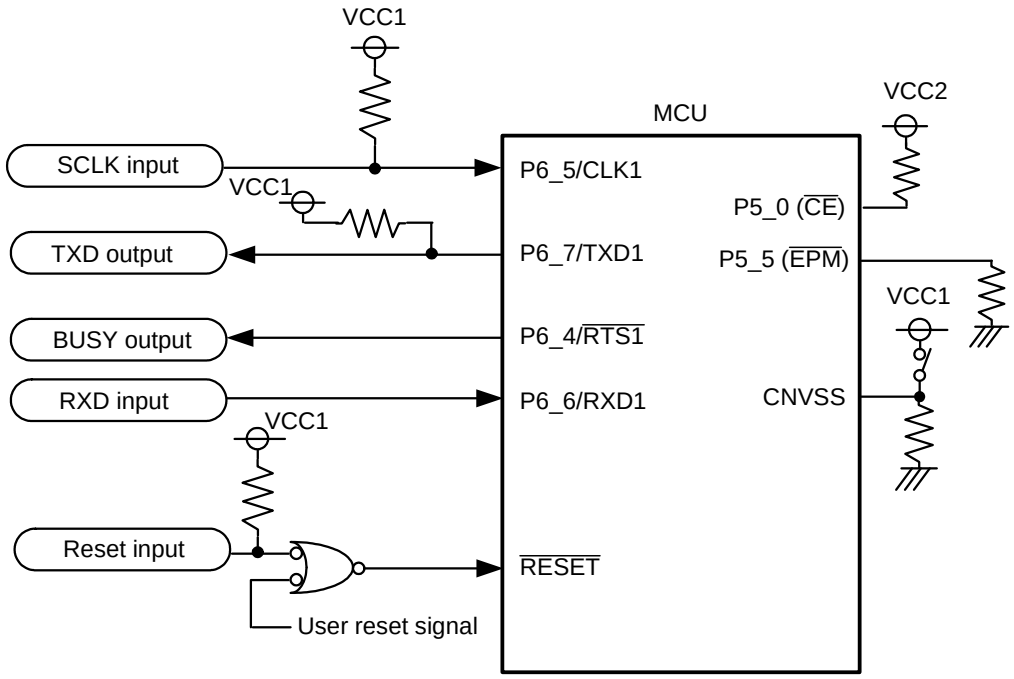
In standard serial I/O mode 1, a serial programmer is connected to the MCU using clock synchronous serial I/O.

Table 28.21 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		
UVCC	USB power supply input	I/O		Power supply pin for ATTACH, D+ and D-.
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.

Table 28.22 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 28.17 Circuit Application in Standard Serial I/O Mode 1

28.9.5 Standard Serial I/O Mode 2

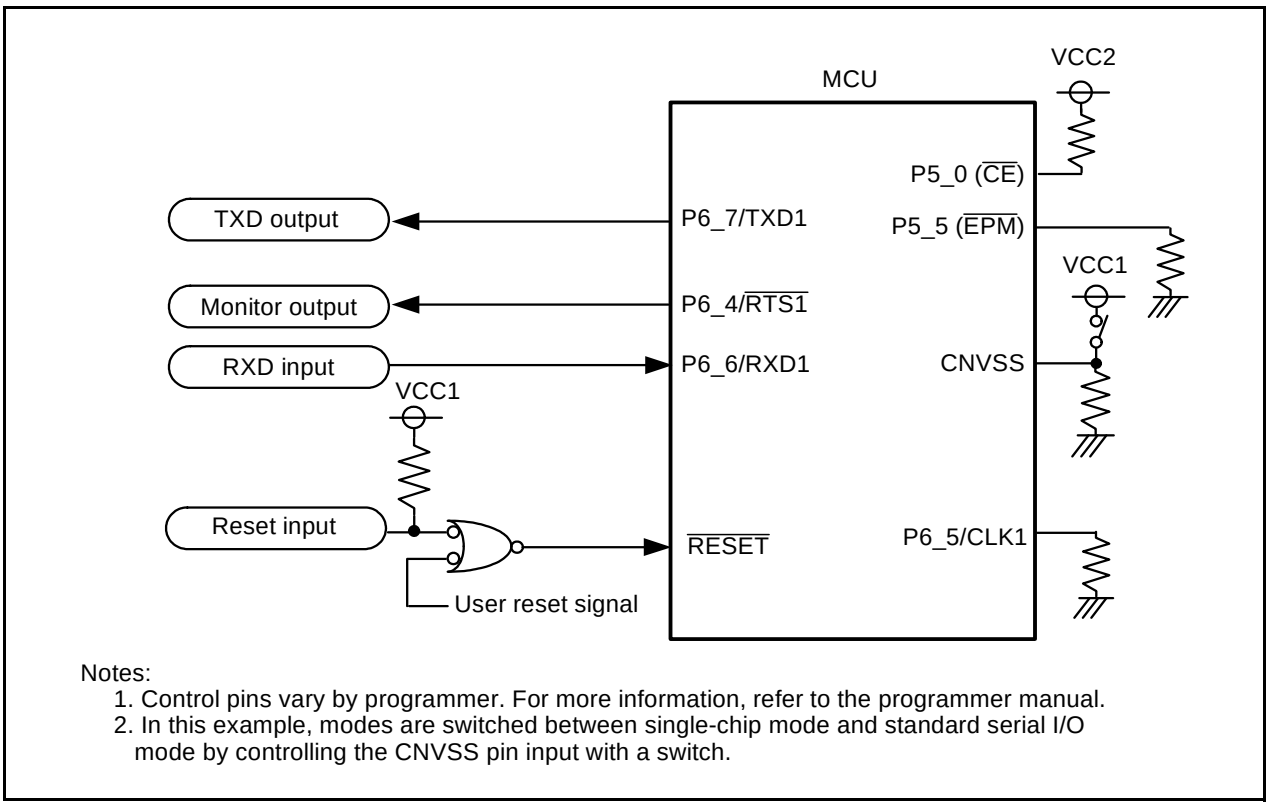
In standard serial I/O mode 2, a serial programmer is connected to the MCU by using 2-wire clock asynchronous serial I/O. The main clock is used.

Table 28.23 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	
UVCC	USB power supply input	I/O		Power supply pin for ATTACH, D+ and D-.
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.

Table 28.24 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 28.18 Circuit Application in Standard Serial I/O Mode 2

28.10 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/6C Group. Contact the parallel programmer manufacturer for more information. Refer to the user's manual included with your parallel programmer for instructions.

28.10.1 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 28.4.1 "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.

28.11 Notes on Flash Memory

28.11.1 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.)

28.11.2 Reading Data Flash

When 2.7 V ≤ VCC1 ≤ 3.0 V and f(BCLK) ≥ 16 MHz, or 3.0 V < VCC1 ≤ 5.5 V and f(BCLK) ≥ 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.

28.11.3 CPU Rewrite Mode

28.11.3.1 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).

28.11.3.2 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).

28.11.3.3 Prohibited Instructions

Do not use the following instructions in EW0 mode:
UND instruction, INTO instruction, JMPS instruction, JSRS instruction, and BRK instruction.

28.11.3.4 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.

28.11.3.5 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.

28.11.3.6 Rewrite (EW1 Mode)

Do not rewrite any blocks in which the rewrite control program is stored.

28.11.3.7 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).

28.11.3.8 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.

28.11.3.9 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).

28.11.3.10 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).

28.11.3.11 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.

28.11.3.12 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.

28.11.3.13 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.

28.11.3.14 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.

28.11.4 User Boot

28.11.4.1 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.

29. Electrical Characteristics

29.1 Electrical Characteristics (Common to 3 V and 5 V)

29.1.1 Absolute Maximum Rating

Table 29.1 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	$\overline{RESET}$, CNVSS, 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 XIN, UVCC		–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		–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 XOUT, UVCC		–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		–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} ≤ 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	0 to 60	
T_{stg}	Storage temperature			–65 to 150	°C

Note:
1. Maximum value is 6.5 V.

29.1.2 Recommended Operating Conditions

Table 29.2 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 ($V_{CC1} \geq V_{CC2}$)		USB function is used	3.0	5.0	5.5	V
			USB function is not used	2.7	5.0	5.5	V
AV_{CC}	Analog supply voltage				V_{CC1}		V
UVCC	USB Supply Voltage (When UVCC pin is input)	USB function is used	V_{CC1} = 3.6 to 5.5V	3.0	3.3	3.6	V
			V_{CC1} = 3.0 to 3.6V	3.0	-	V_{CC1}	V
		USB function is not used	V_{CC1} = 2.7 to 5.5V	-	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		$0.8V_{CC2}$		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, 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 XIN, $\overline{RESET}$, CNVSS		$0.8V_{CC1}$		V_{CC1}	V
		P7_0, P7_1, P8_5		$0.8V_{CC1}$		6.5	V
V_{IL}	Low input voltage	P3_1 to P3_7, P4_0 to P4_7, P5_0 to P5_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, 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 XIN, $\overline{RESET}$, CNVSS		0		$0.2V_{CC1}$	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				-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				-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				–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				–5.0	mA

Note:
1. The average output current is the mean value within 100 ms.

Table 29.3 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			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			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			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			5.0	mA
$f_{(XIN)}$	Main clock input oscillation frequency	V_{CC1} = 2.7 V to 5.5 V	2		16	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		fOCO-S divided by 16		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 29.4 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.

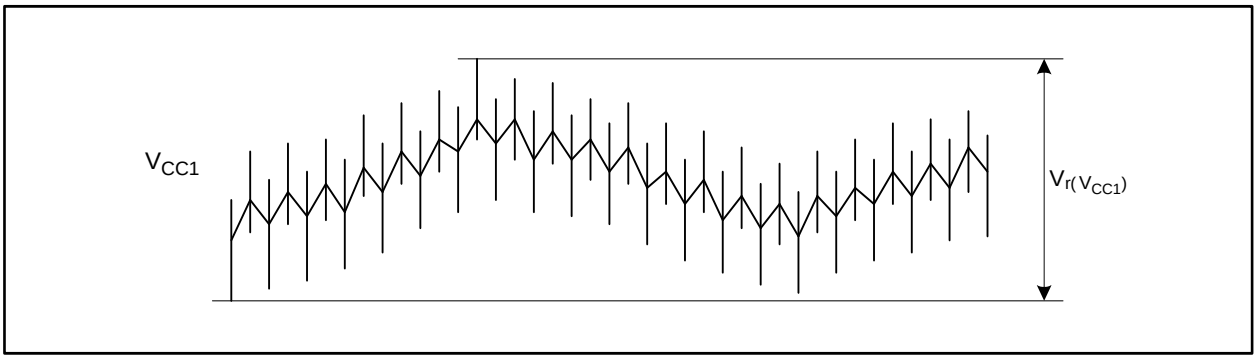


Figure 29.1 Ripple Waveform

29.1.3 A/D Conversion Characteristics

Table 29.5 A/D Conversion Characteristics (1/2) (1, 2)

$AV_{CC} = V_{CC1} = V_{CC2} = V_{REF}$ = 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		$AV_{CC} = V_{CC1} = V_{CC2} = V_{REF}$				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 3)			±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 3)			±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 3)			±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 3)			±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 3)			±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 3)			±3	LSB

Notes:
1. This applies when using one A/D converter, with the ADSTBY bit for the unused A/D converter set to 0 (A/D operation stopped (standby).
2. Use when $AV_{CC} = V_{CC1} = V_{CC2}$.
3. 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 29.2 “A/D Accuracy Measure Circuit”.

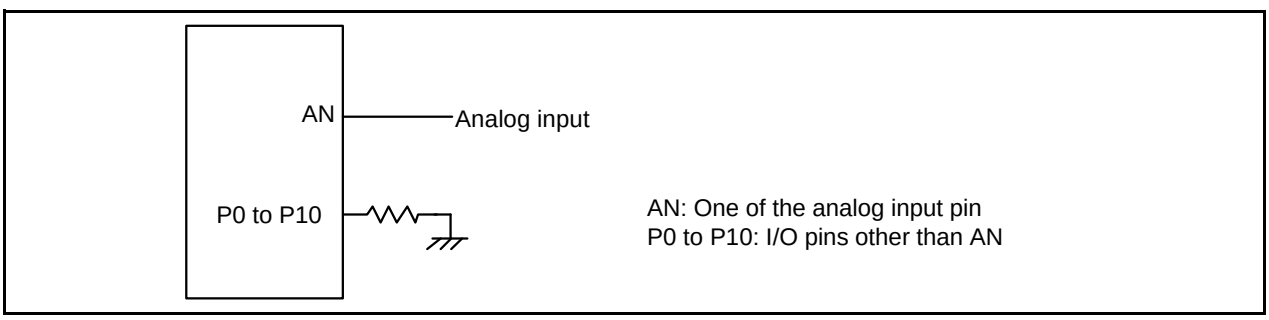


Figure 29.2 A/D Accuracy Measure Circuit

Table 29.6 A/D Conversion Characteristics (2/2) (1, 2)

$AV_{CC} = V_{CC1} = V_{CC2} = V_{REF} = 3.0$ 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.	
ϕAD	A/D operating clock frequency	4.0 V ≤ V_{REF} ≤ AV_{CC} ≤ 5.5 V	2		25	MHz
		3.2 V ≤ V_{REF} ≤ AV_{CC} ≤ 5.5 V	2		16	MHz
		3.0 V ≤ V_{REF} ≤ AV_{CC} ≤ 5.5 V	2		10	MHz
-	Tolerance level impedance			3		kΩ
D_{NL}	Differential non-linearity error	(5)			±1	LSB
-	Offset error	(5)			±3	LSB
-	Gain error	(5)			±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		AV_{CC}	V
V_{IA}	Analog input voltage (3), (4)		0		V_{REF}	V

Notes:
1. This applies when using one A/D converter, with the ADSTBY bit for the unused A/D converter set to 0 (A/D operation stopped (standby).
2. Use when $AV_{CC} = V_{CC1} = V_{CC2}$.
3. Do not use A/D converter when $V_{CC1} > V_{CC2}$.
4. When analog input voltage is over reference voltage, the result of A/D conversion is 3FFh.
5. 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 29.2 “A/D Accuracy Measure Circuit”.

29.1.4 D/A Conversion Characteristics

Table 29.7 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)).

29.1.5 USB Characteristics

Table 29.8 USB Characteristics

V_{CC1} = 3.0 to 5.5 V, UVCC = 3.0 to 3.6 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.	
V_{IH}	Input Characteristics	High Input Voltage	Figure 29.3, Figure 29.4	2.0	-	-	V
V_{IL}		Low Input Voltage		-	-	0.8	V
V_{DI}		Differential Input Sensitivity		0.2	-	-	V
V_{CM}		Differential Common Mode Range		0.8	-	2.5	V
V_{OH}	Output Characteristics	High Output Voltage	Figure 29.3, Figure 29.4 I_{OH} = 200 µA	2.8	-	-	V
V_{OL}		Low Output Voltage	Figure 29.3, Figure 29.4 I_{OL} = 2 mA	-	-	0.3	V
V_{CRS}		Crossover Voltage	Figure 29.3, Figure 29.4	1.3	-	2.0	V
t_R		Rise Time	Figure 29.3, Figure 29.4	4.0	-	20.0	ns
t_F		Fall Time	Figure 29.3, Figure 29.4	4.0	-	20.0	ns
t_{RFM}		Rise Time / Fall Time Matching	Figure 29.3, Figure 29.4 (t_R/t_F)	90.0	-	111.1	%
Z_{DRV}		Output Resistance	Figure 29.3, Figure 29.4 Includes R_S = 27 Ω	28.0	-	44.0	W
UV_{CC}	UVCC Output Voltage	V_{CC1} = 4.0 to 5.5V, PXXCON = VDDUSBE = 1		3.0	3.3	3.6	V
		PXXCON = 0		-	V_{CC1}	-	V
I_{susp}	Consumption current of the Internal Power Supply for USB		V_{CC1} = 4.0 to 5.5 V UV_{CC} to V_{SS} 0.33 µF V_{CC1} to V_{SS} 0.1 µF		50		µA

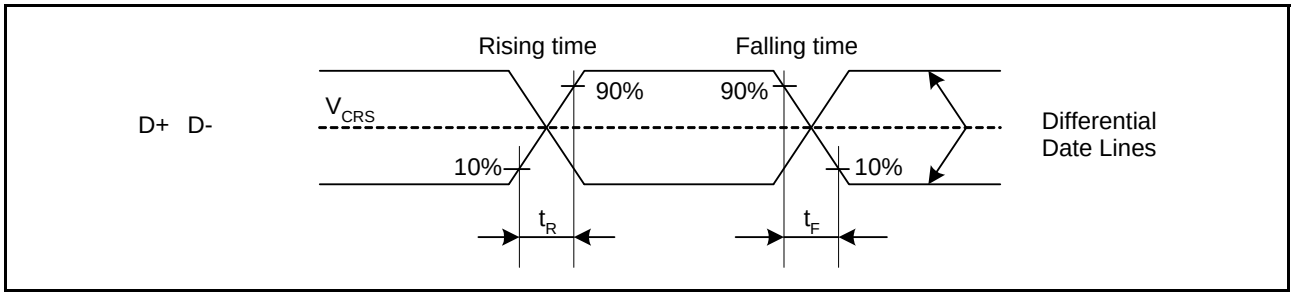


Figure 29.3 Data Signal Timing Diagram

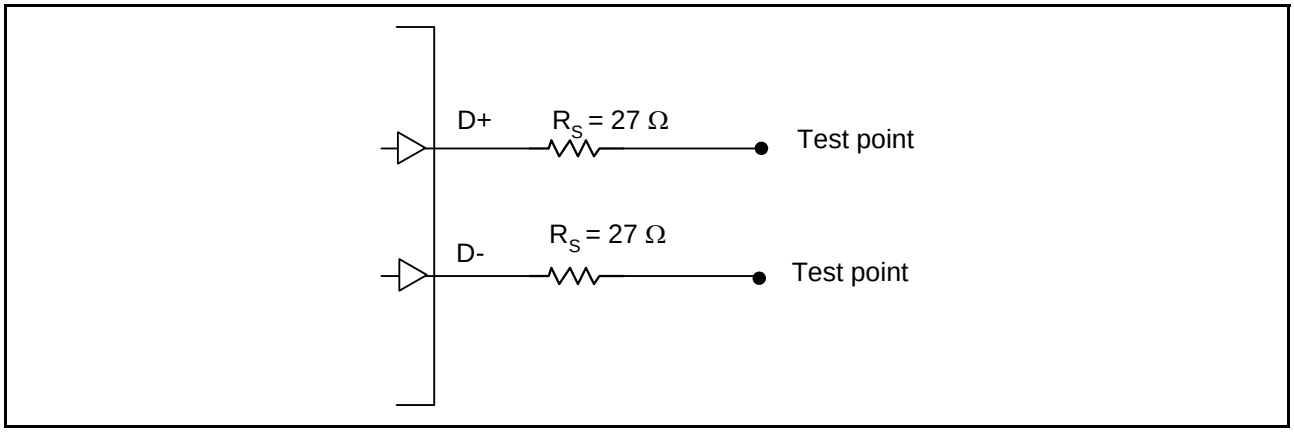


Figure 29.4 Load Condition

29.1.6 Flash Memory Electrical Characteristics

Table 29.9 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 29.10 Flash Memory (Program ROM 1, 2) Electrical Characteristics

V_{CC1} = 2.7 to 5.5 V at T_{opr} = 0°C to 60°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
-	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.

Table 29.11 Flash Memory (Data Flash) Electrical Characteristics

V_{CC1} = 2.7 to 5.5 V at T_{opr} = 0 to 60°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
-	Program, erase voltage		2.7		5.5	V
-	Read voltage		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 = 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.

29.1.7 Voltage Detector and Power Supply Circuit Electrical Characteristics

Table 29.12 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.	1.60	1.90	2.20	V
	Voltage detection level Vdet0_2 (1)	When V_{CC1} is falling.	2.70	2.85	3.15	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 29.13 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	When V_{CC} is falling	2.95	3.25	3.55	V
-	Hysteresis width when V_{CC1} of voltage detector 1 is rising			0.15		V
-	Voltage detector 1 response time (2)	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 (1)				100	µs

Notes:
1. Necessary time until the voltage detector operates when setting to 1 again after setting the VC26 bit in the VCR2 register to 0.
2. Time from when passing the V_{det1} until when a voltage monitor 1 reset is generated.

Table 29.14 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

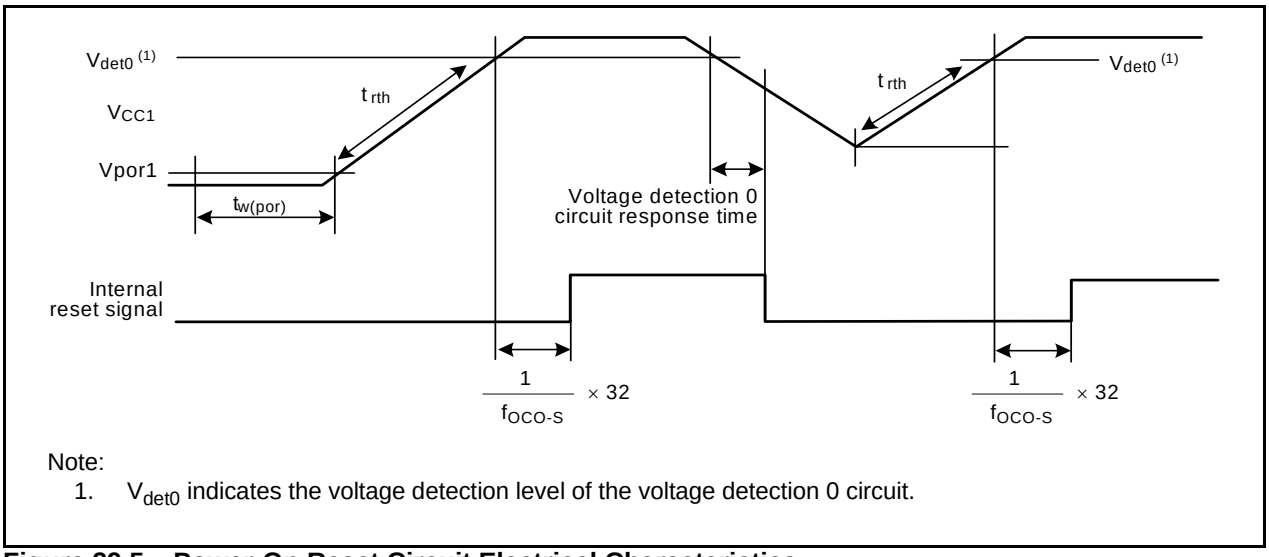
Notes:
1. Necessary time until the voltage detector operates after setting to 1 again after setting the VC27 bit in the VCR2 register to 0.
2. Time from when passing the V_{det2} until when a voltage monitor 2 reset is generated.

Table 29.15 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 29.5 Power-On Reset Circuit Electrical Characteristics

Table 29.16 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.

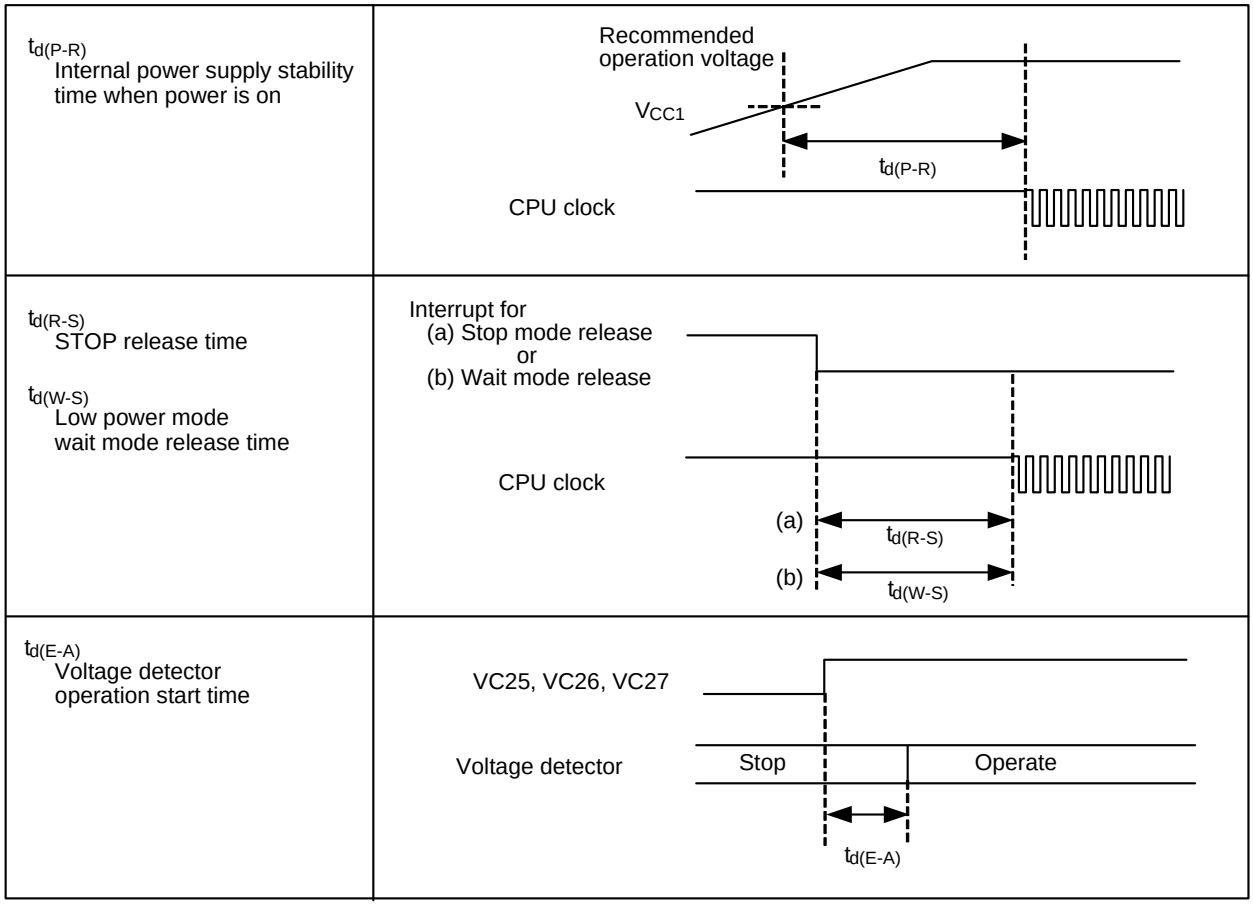


Figure 29.6 Power Supply Circuit Timing Diagram

29.1.8 Oscillator Electrical Characteristics

Table 29.17 40 MHz 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_{OCO40M}	40 MHz on-chip oscillator frequency	Average frequency in a 10 ms period	36	40	44	MHz
tsu(f_{OCO40M})	Wait time until 40 MHz on-chip oscillator stabilizes				2	ms

Table 29.18 125 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

29.2 Electrical Characteristics (V_{CC1} = V_{CC2} = 5 V)

29.2.1 Electrical Characteristics

V_{CC1} = V_{CC2} = 5 V

Table 29.19 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		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		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		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		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		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		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		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		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 29.20 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	$\overline{HOLD}$, $\overline{RDY}$, TA0IN to TA4IN, TB0IN to TB5IN, $\overline{INT0}$ to $\overline{INT7}$, $\overline{NMI}$, $\overline{ADTRG}$, $\overline{CTS0}$ to $\overline{CTS5}$, SCL0 to SCL5, SDA0 to SDA5, CLK0 to CLK5, TA0OUT to TA4OUT, $\overline{KI0}$ to $\overline{KI3}$, RXD0 to RXD5, $\overline{SD}$, SCLMM, SDAMM, ZP, IDU, IDV, IDW		0.5		2.0	V
$V_{T+} - V_{T-}$	Hysteresis	$\overline{RESET}$		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 XIN, $\overline{RESET}$, CNVSS	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 XIN, $\overline{RESET}$, CNVSS	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	V_I = 0 V	30	50	100	kΩ
R_{fXIN}	Feedback resistance XIN				1.5		MΩ
R_{fXCIN}	Feedback resistance XCIN				8		MΩ
V_{RAM}	RAM retention voltage		In stop mode	1.8			V

Note:
1. When $V_{CC1} \neq V_{CC2}$, refer to 5 Vor 3 V standard depending on the voltage.

$V_{CC1} = V_{CC2} = 5\ V$

Table 29.21 Electrical Characteristics (3)

$V_{CC1} = V_{CC2} = 4.2$ 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.	
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		27.0		mA
			$f_{(BCLK)}$ =32 MHz, A/D conversion (2) XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		27.7		mA
			$f_{(BCLK)}$ = 16 MHz XIN = 16 MHz (square wave) 125 kHz on-chip oscillator stopped		13.0		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		21.0		µA
			$f_{(XCIN)}$ = 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
			$f_{(XCIN)}$ = 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
		Stop mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock stopped T_{opr} = 25°C		2.2		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

Notes:
1. This indicates the memory in which the program to be executed exists.
2. This applies when using one A/D converter (fAD = 25MHz), with the ADSTBY bit for the unused A/D converter set to 0 (A/D operation stopped (standby).

$V_{CC1} = V_{CC2} = 5\ V$

29.2.2 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)

29.2.2.1 Reset Input ($\overline{\text{RESET}}$ Input)

Table 29.22 Reset Input ($\overline{\text{RESET}}$ Input)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(RSTL)}$	$\overline{\text{RESET}}$ input low pulse width	10		µs

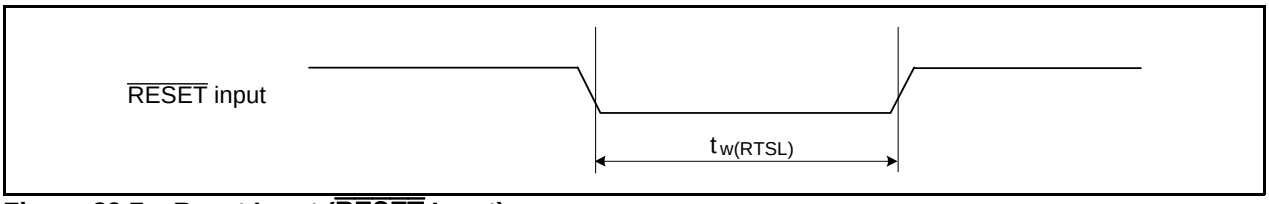


Figure 29.7 Reset Input ($\overline{\text{RESET}}$ Input)

29.2.2.2 External Clock Input

Table 29.23 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.

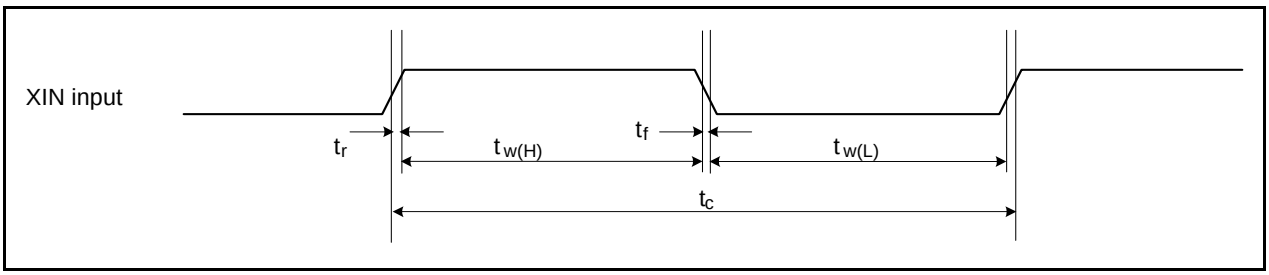


Figure 29.8 External Clock Input (XIN Input)

$V_{CC1} = V_{CC2} = 5\ V$

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)

29.2.2.3 Timer A Input

Table 29.24 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 29.25 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 29.26 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 29.27 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

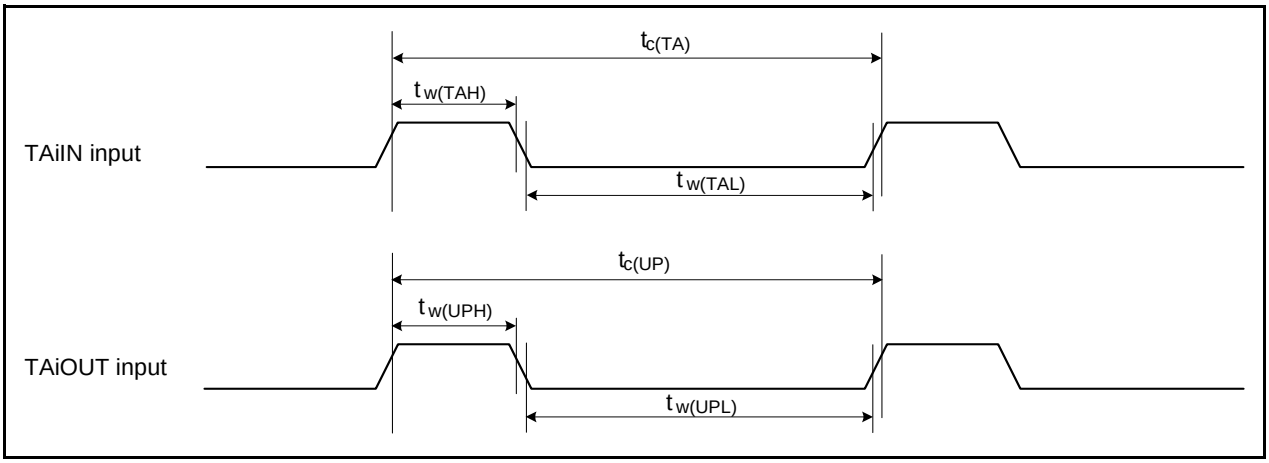


Figure 29.9 Timer A Input

$V_{CC1} = V_{CC2} = 5\ V$

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 29.28 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

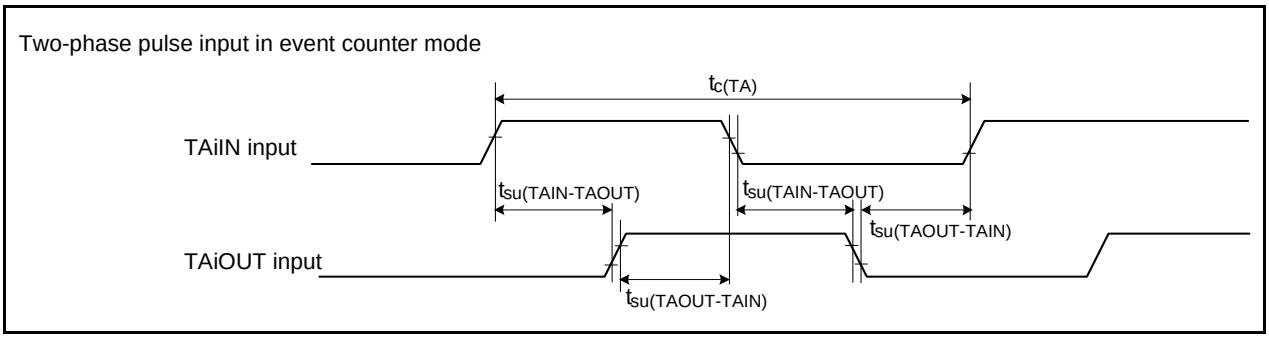


Figure 29.10 Timer A Input (Two-Phase Pulse Input in Event Counter Mode)

$V_{CC1} = V_{CC2} = 5\ V$

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)

29.2.2.4 Timer B Input

Table 29.29 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 29.30 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 29.31 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

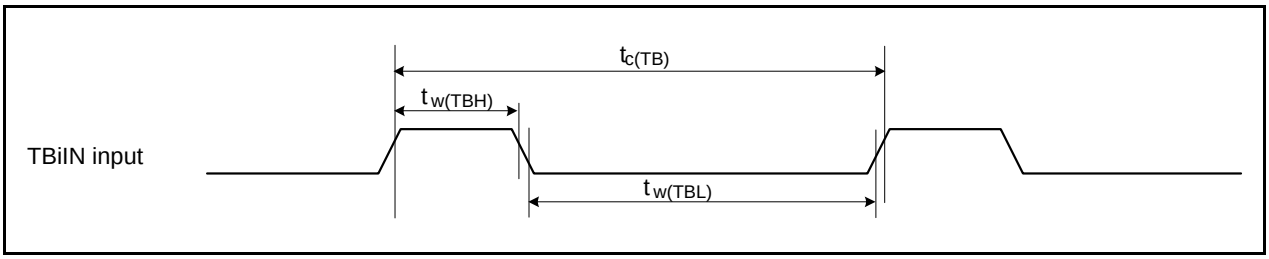


Figure 29.11 Timer B Input

$V_{CC1} = V_{CC2} = 5\ V$

Timing Requirements

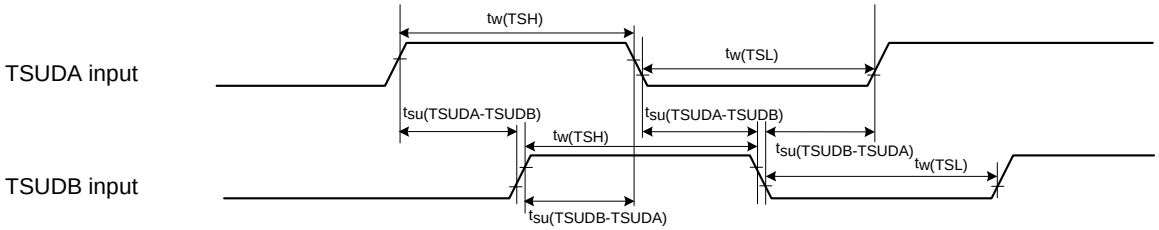
($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

29.2.2.5 Timer S Input

Table 29.32 Timer S Input (Two-Phase Pulse Input in Two-Phase Pulse Signal Processing Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(TSH)}$	TSUDA, TSUDB input high pulse width	2		µs
$t_{w(TSL)}$	TSUDA, TSUDB input low pulse width	2		µs
$t_{su(TSUDA-TSUDB)}$	TSUDB input setup time	1		µs
$t_{su(TSUDB-TSUDA)}$	TSUDA input setup time	1		µs

Two-phase pulse input in two-phase pulse signal processing mode



Note:

1. When the TSUDA and TSUDB phases are interchanged, $t_{su(TSUDA-TSUDB)}$ and $t_{su(TSUDB-TSUDA)}$ are also interchanged.

Figure 29.12 Timer S Input (Two-Phase Pulse Input in Two-Phase Pulse Signal Processing 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)

29.2.2.6 Serial Interface

Table 29.33 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

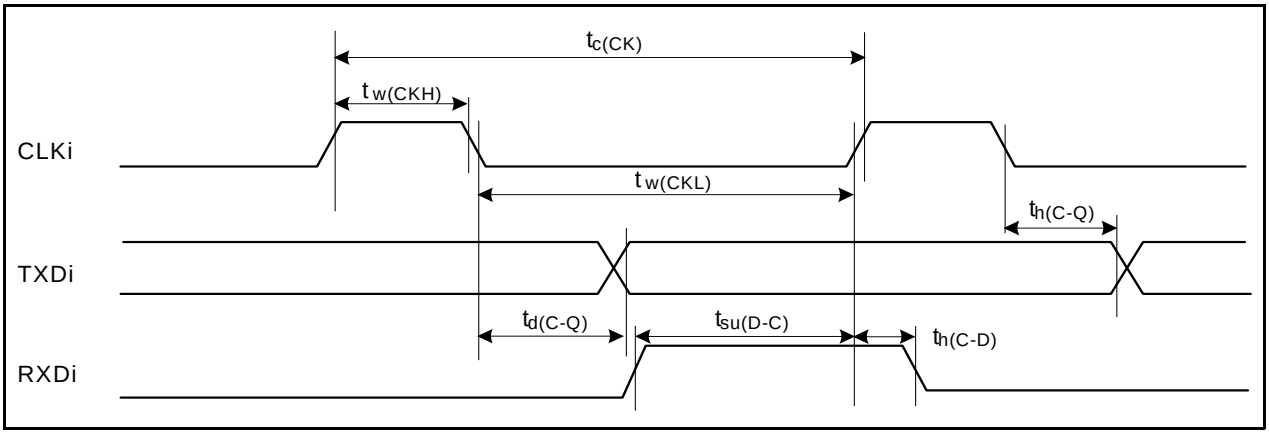


Figure 29.13 Serial Interface

29.2.2.7 External Interrupt $\overline{INTi}$ Input

Table 29.34 External Interrupt $\overline{INTi}$ Input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(INH)}$	$\overline{INTi}$ input high pulse width	250		ns
$t_{w(INL)}$	$\overline{INTi}$ input low pulse width	250		ns

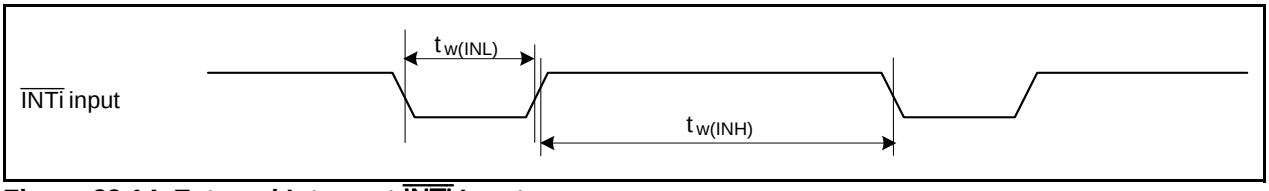


Figure 29.14 External Interrupt $\overline{INTi}$ Input

$V_{CC1} = V_{CC2} = 5\ V$

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)

29.2.2.8 Multi-master I²C-bus

Table 29.35 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

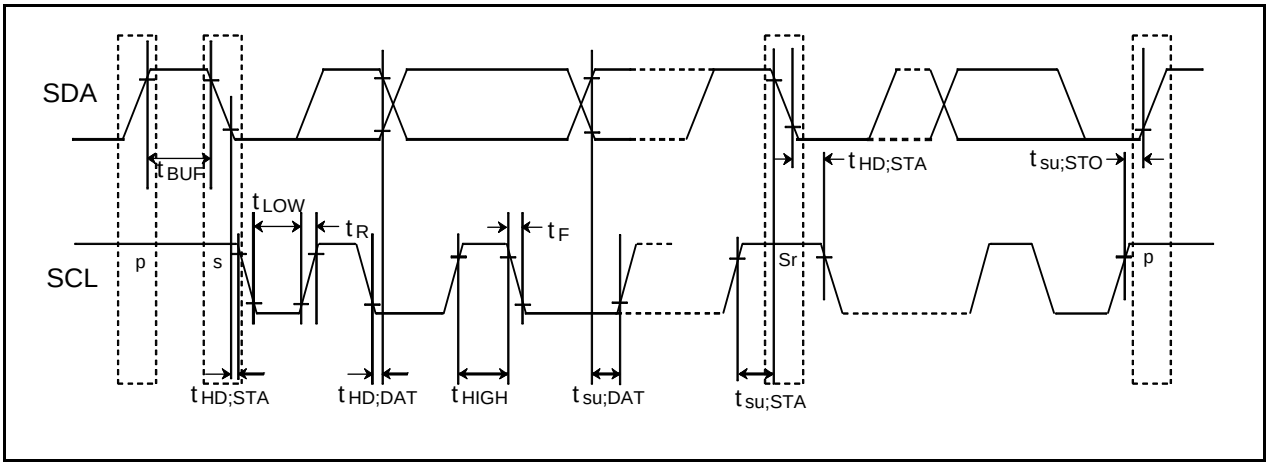


Figure 29.15 Multi-master I²C-bus

$V_{CC1} = V_{CC2} = 5\ V$

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)

29.2.3 Timing Requirements (Memory Expansion Mode and Microprocessor Mode)

Table 29.36 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
$t_{su(DB-RD)}$	Data input setup time	40		ns
$t_{su(RDY-BCLK)}$	$\overline{RDY}$ input setup time	80		ns
$t_{h(RD-DB)}$	Data input hold time	0		ns
$t_{h(BCLK-RDY)}$	$\overline{RDY}$ 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.

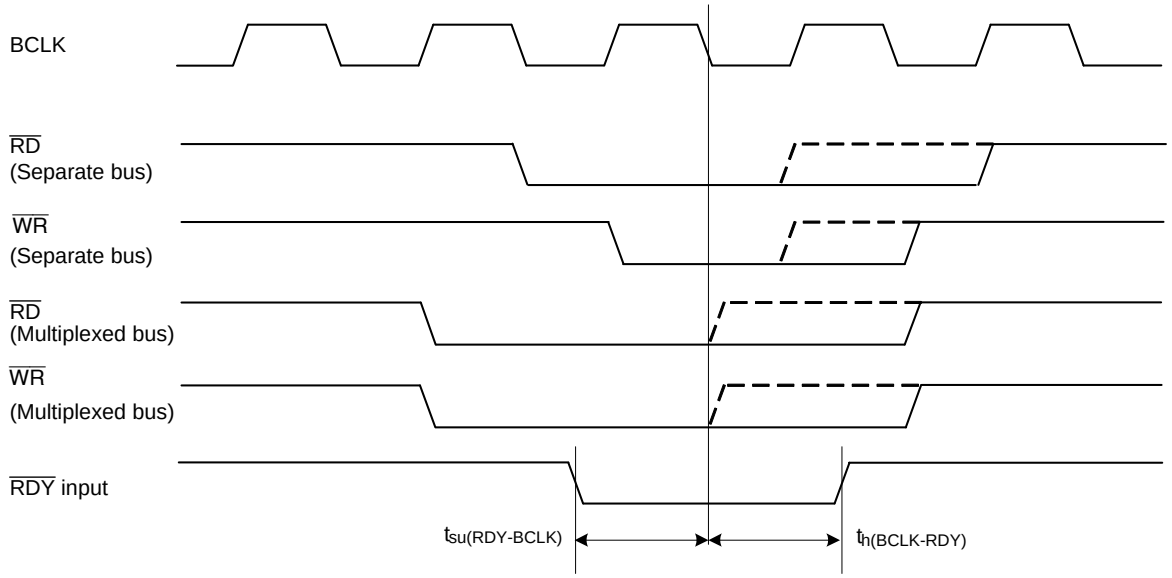
3. Calculated according to the BCLK frequency as follows:

$$\frac{(n - 0.5) \times 10^9}{f_{(BCLK)}} - 45[ns]$$ n is 2 for 2 waits setting, and 3 for 3 waits setting.

Memory Expansion Mode and Microprocessor Mode

$V_{CC1} = V_{CC2} = 5\ V$

(Effective in wait state setting**)**



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 29.16 Timing Diagram

$V_{CC1} = V_{CC2} = 5\ V$

29.2.4 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)

29.2.4.1 In No Wait State Setting

Table 29.37 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 29.17		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
$t_{h(BCLK-DB)}$	Data output hold time (in relation to BCLK) (3)		0		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 2)		ns

Notes:

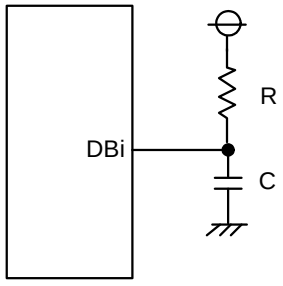
1. Calculated according to the BCLK frequency as follows:

   $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 40[ns]$ $f_{(BCLK)}$ 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
   $t = -30\ pF \times 1\ k\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
   = 6.7 ns.



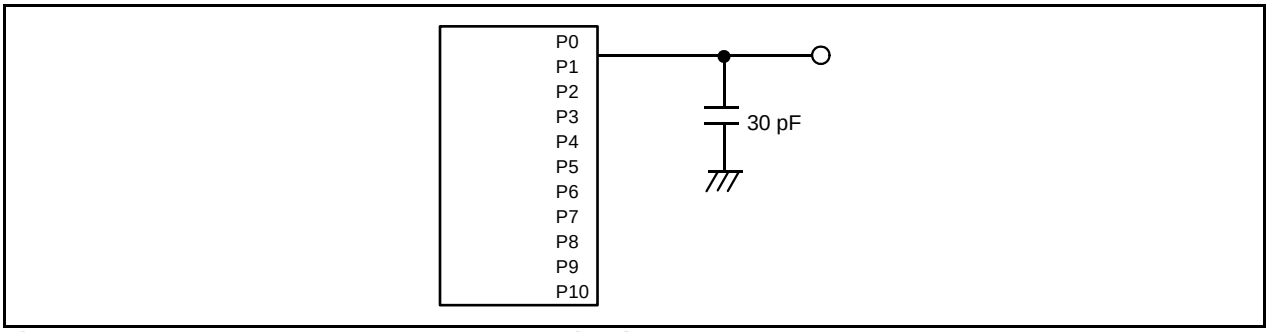
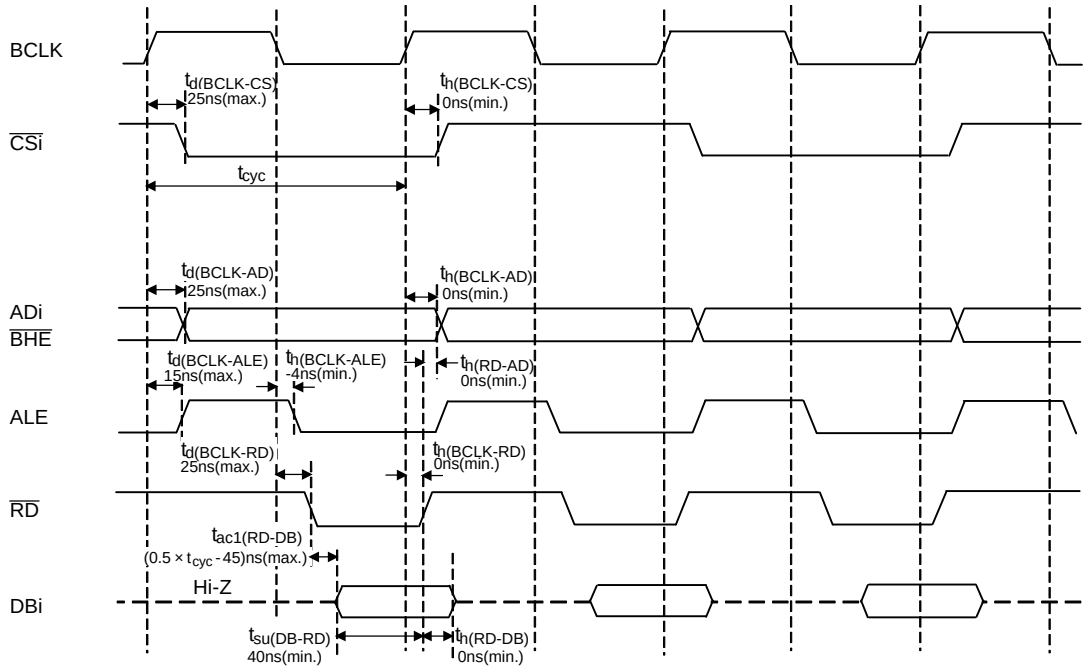


Figure 29.17 Ports P0 to P10 Measurement Circuit

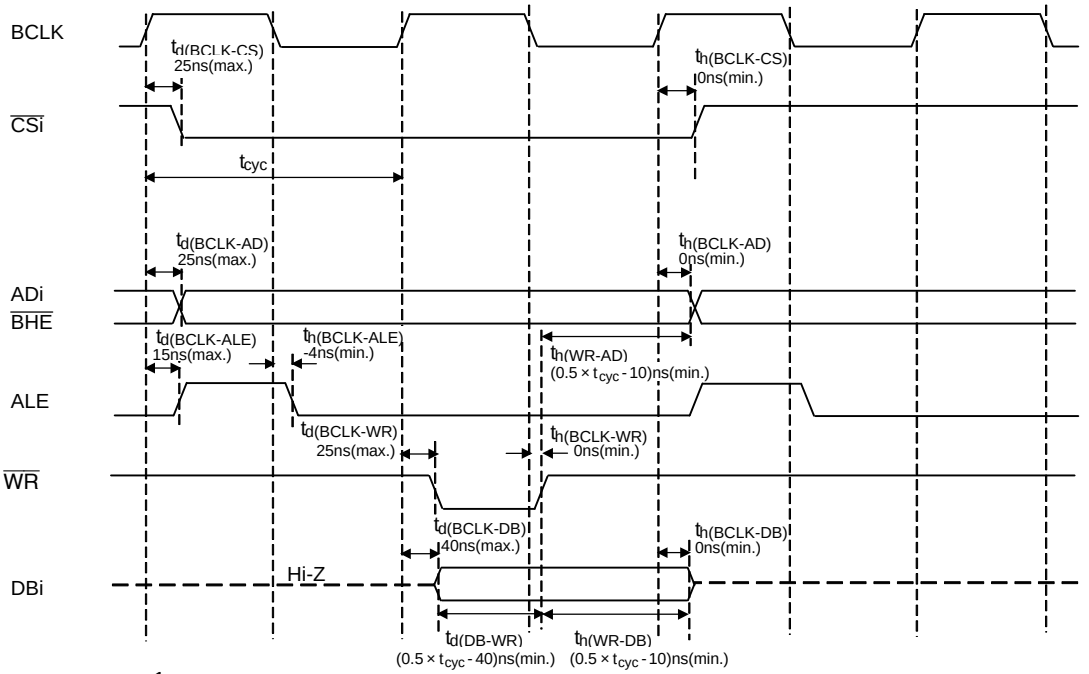
Memory Expansion Mode and Microprocessor Mode
(in no wait state setting)

$V_{CC1} = V_{CC2} = 5V$

Read timing



Write timing



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

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 29.18 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)

29.2.4.2 In 1 to 3 Waits Setting and When Accessing External Area

Table 29.38 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 29.17		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
$t_{h(BCLK-DB)}$	Data output hold time (in relation to BCLK) (3)		0		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 2)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

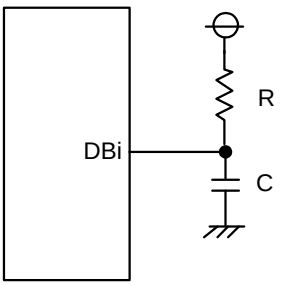
$$\frac{(n-0.5)\times 10^9}{f_{(BCLK)}} - 40[ns]$$

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:

$$\frac{0.5\times 10^9}{f_{(BCLK)}} - 10[ns]$$

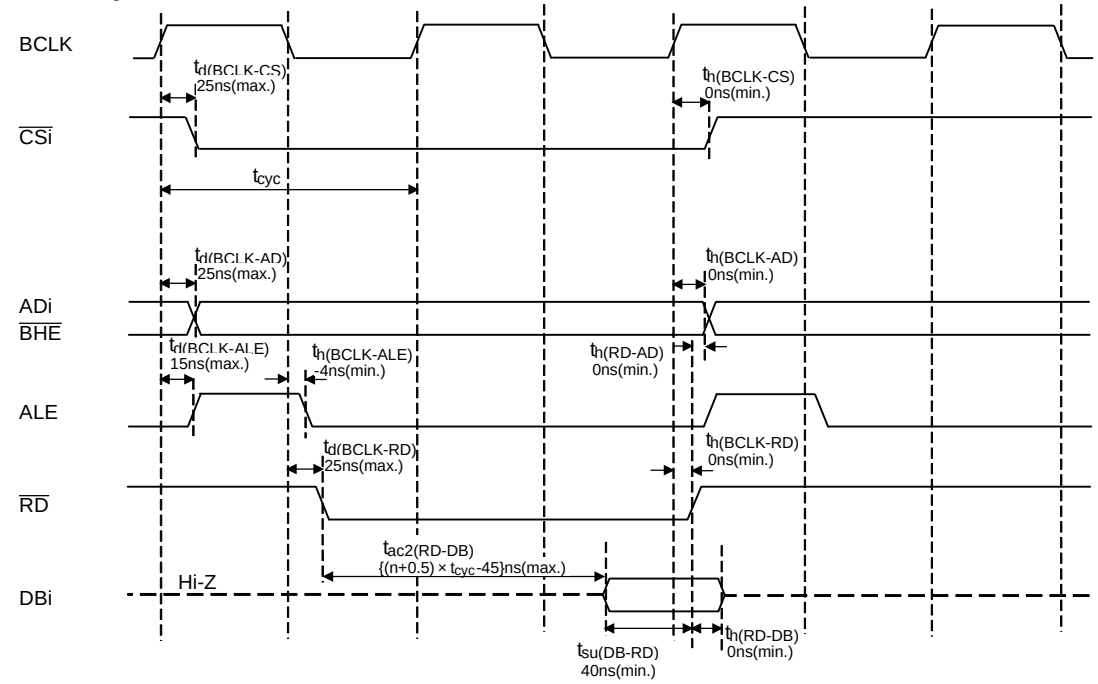
3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1 - V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30\ pF \times 1\ k\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
= 6.7 ns.



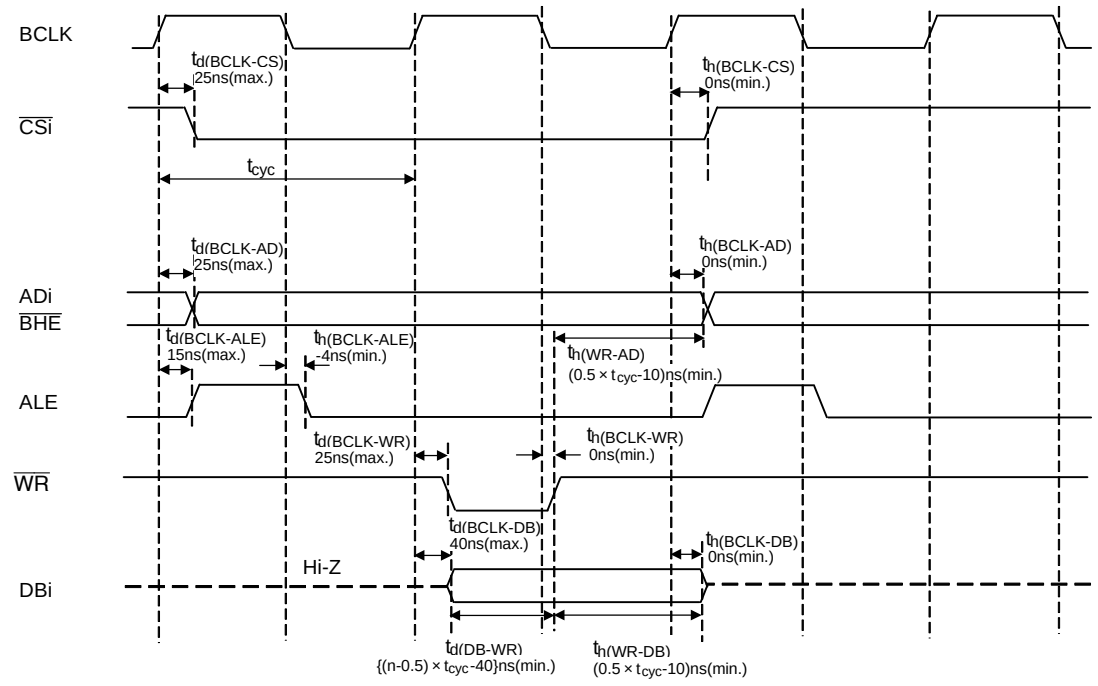
Memory Expansion Mode and Microprocessor Mode
(in 1 to 3 waits setting and when accessing external area)

$V_{CC1} = V_{CC2} = 5V$

Read timing



Write timing



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

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 29.19 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)

29.2.4.3 In 2 or 3 Waits Setting, and When Accessing External Area and Using Multiplexed Bus

Table 29.39 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 29.17		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
$t_{h(BCLK-DB)}$	Data output hold time (in relation to BCLK)		0		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 1)		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:

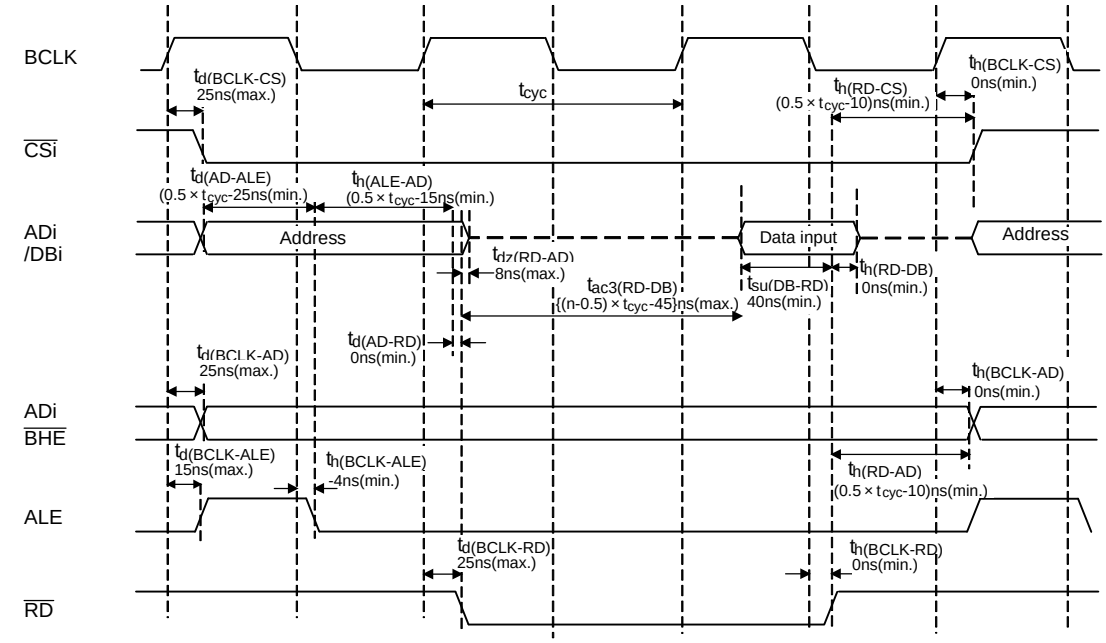
$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 15[ns]$$

5. When using multiplex bus, set $f_{(BCLK)}$ 12.5 MHz or less.

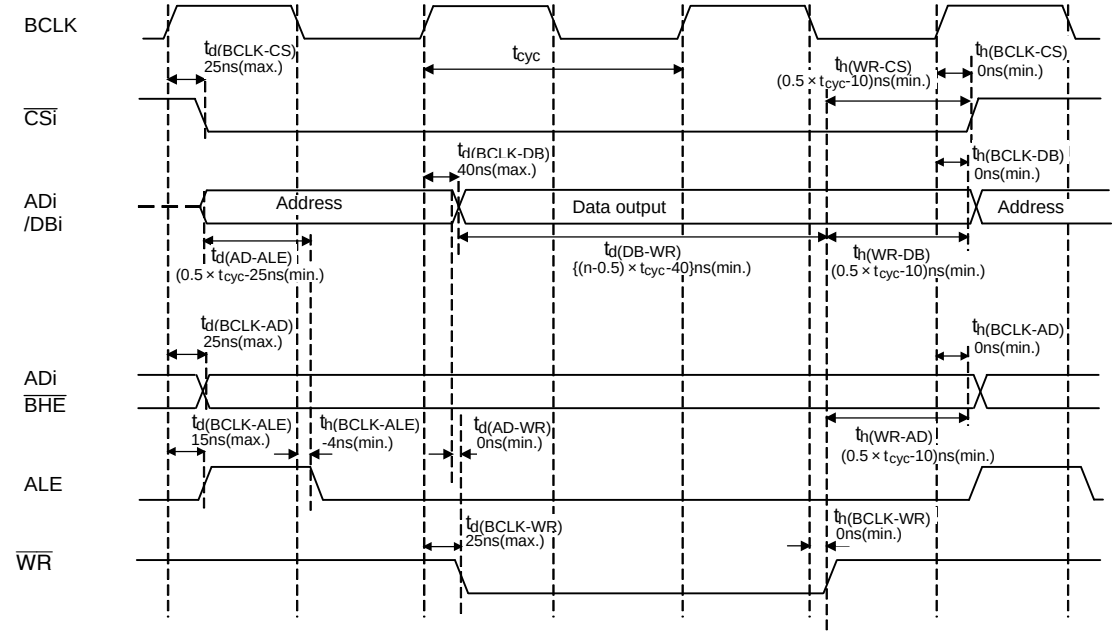
Memory Expansion Mode and Microprocessor Mode
(in 2 or 3 waits setting, and when accessing external area and using multiplexed bus)

$V_{CC1} = V_{CC2} = 5V$

Read timing



Write timing



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 29.20 Timing Diagram

29.3 Electrical Characteristics (V_{CC1} = V_{CC2} = 3 V)

29.3.1 Electrical Characteristics

VCC1 = VCC2 = 3 V

Table 29.40 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		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		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		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		I_{OL} = 1 mA			0.5	
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	$\overline{HOLD}$, $\overline{RDY}$, TA0IN to TA4IN, TB0IN to TB5IN, $\overline{INT0}$ to $\overline{INT7}$, $\overline{NMI}$, $\overline{ADTRG}$, $\overline{CTS0}$ to $\overline{CTS5}$, SCL0 to SCL5, SDA0 to SDA5, CLK0 to CLK5, TA0OUT to TA4OUT, $\overline{KI0}$ to $\overline{KI3}$, RXD0 to RXD5, $\overline{SD}$, SCLMM, SDAMM, ZP, IDU, IDV, IDW			0.2		1.0	V
		$\overline{RESET}$			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 XIN, $\overline{RESET}$, CNVSS		V_I = 3 V			4.0	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 XIN, $\overline{RESET}$, CNVSS		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		V_I = 0 V	50	80	150	kΩ
R_{fXIN}	Feedback resistance XIN					3.0		MΩ
R_{fXCIN}	Feedback resistance XCIN					16		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.

$V_{CC1} = V_{CC2} = 3$ V

Table 29.41 Electrical Characteristics (2)

$V_{CC1} = V_{CC2} = 2.7$ 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}	High-speed mode	$f_{(BCLK)}$ = 32 MHz XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		27.0		mA
			$f_{(BCLK)}$ = 32 MHz (2) XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		27.7		mA
			$f_{(BCLK)}$ = 16 MHz XIN = 16 MHz (square wave) 125 kHz on-chip oscillator stopped		13.0		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
			$f_{(XCIN)}$ = 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
			$f_{(XCIN)}$ = 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
		Stop mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock stopped T_{opr} = 25°C		2.0		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

Notes:
1. This indicates the memory in which the program to be executed exists.
2. This applies when using one A/D converter (fAD = 25MHz), with the ADSTBY bit for the unused A/D converter set to 0 (A/D operation stopped (standby).

$V_{CC1} = V_{CC2} = 3\ V$

29.3.2 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)

29.3.2.1 Reset Input ($\overline{\text{RESET}}$ Input)

Table 29.42 Reset Input ($\overline{\text{RESET}}$ Input)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(RSTL)}$	$\overline{\text{RESET}}$ input low pulse width	10		µs

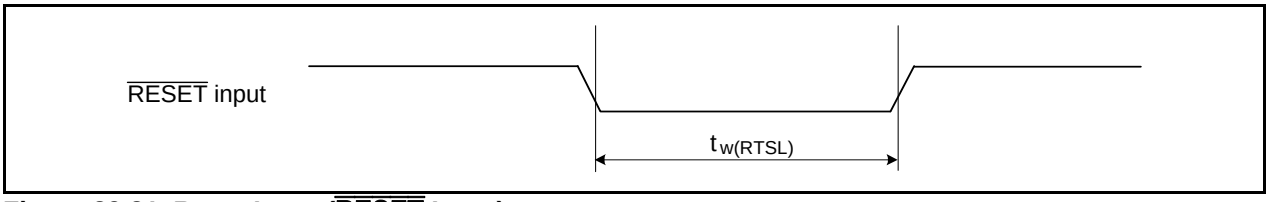


Figure 29.21 Reset Input ($\overline{\text{RESET}}$ Input)

29.3.2.2 External Clock Input

Table 29.43 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.

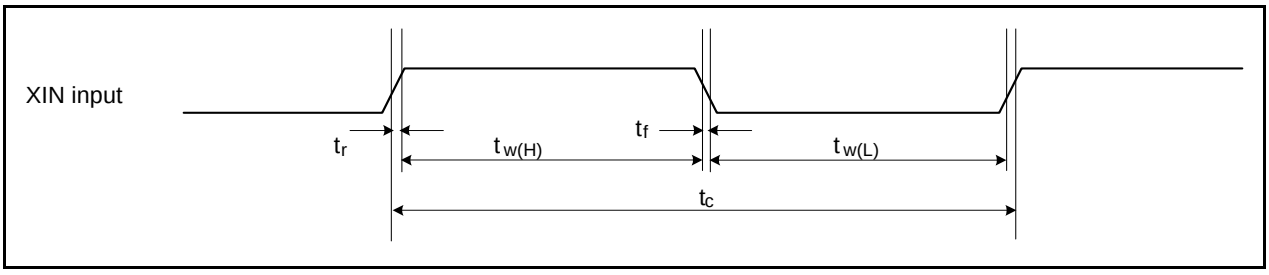


Figure 29.22 External Clock Input (XIN Input)

$V_{CC1} = V_{CC2} = 3\ V$

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)

29.3.2.3 Timer A Input

Table 29.44 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 29.45 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 29.46 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 29.47 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

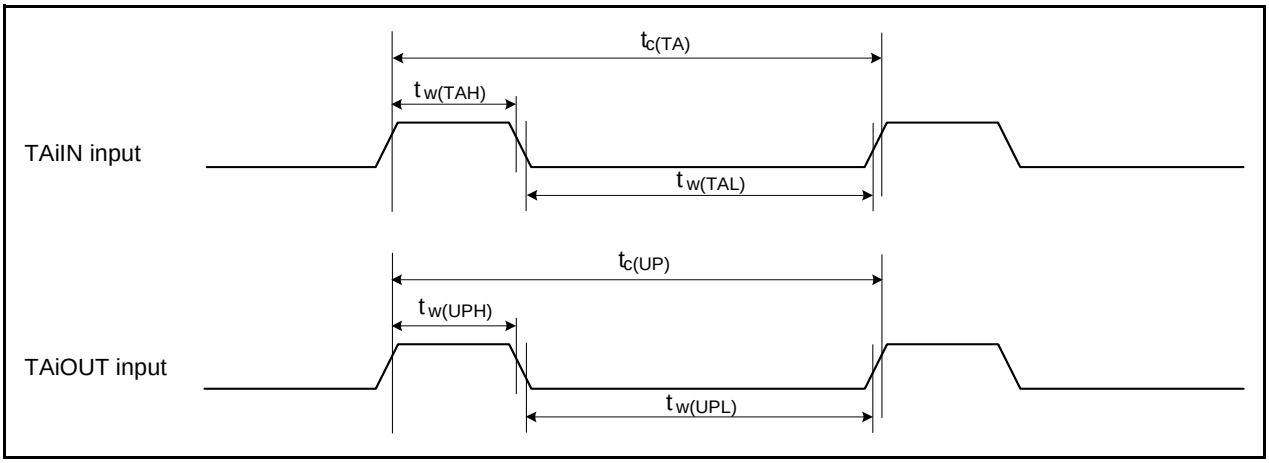


Figure 29.23 Timer A Input

$V_{CC1} = V_{CC2} = 3\ V$

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 29.48 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

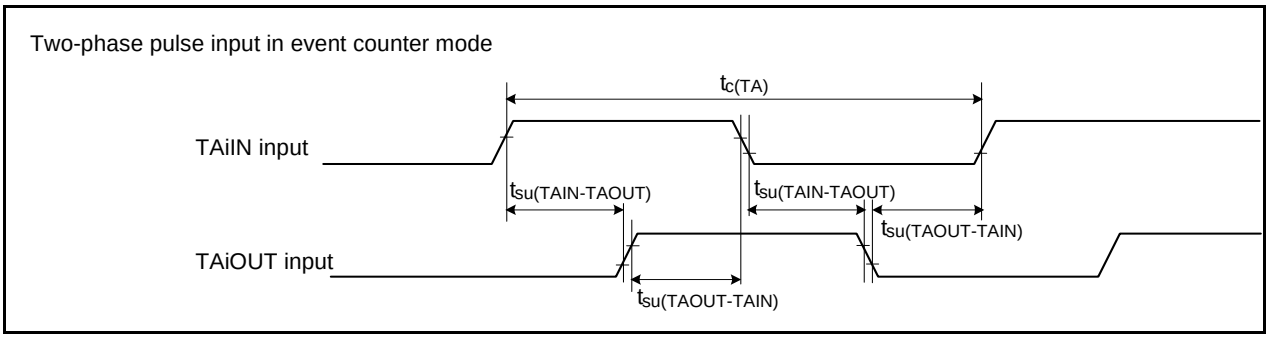


Figure 29.24 Timer A Input (Two-Phase Pulse Input in Event Counter Mode)

$V_{CC1} = V_{CC2} = 3\ V$

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)

29.3.2.4 Timer B Input

Table 29.49 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 29.50 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 29.51 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

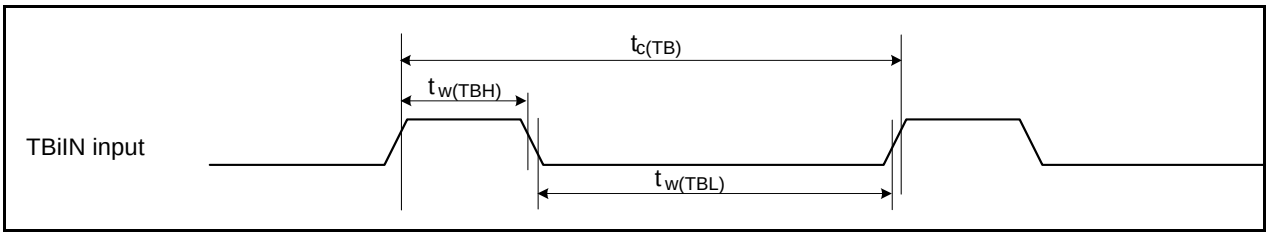


Figure 29.25 Timer B Input

$V_{CC1} = V_{CC2} = 3\ V$

Timing Requirements

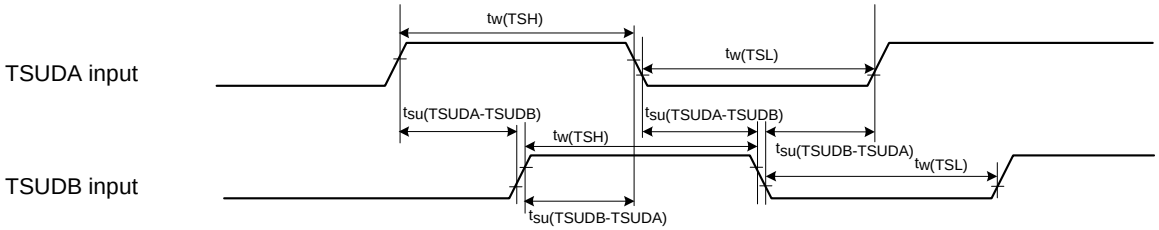
($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

29.3.2.5 Timer S Input

Table 29.52 Timer S Input (Two-Phase Pulse Input in Two-Phase Pulse Signal Processing Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(TSH)}$	TSUDA, TSUDB input high pulse width	2		µs
$t_{w(TSL)}$	TSUDA, TSUDB input low pulse width	2		µs
$t_{su(TSUDA-TSUDB)}$	TSUDB input setup time	1		µs
$t_{su(TSUDB-TSUDA)}$	TSUDA input setup time	1		µs

Two-phase pulse input in two-phase pulse signal processing mode



Note:

1. When the TSUDA and TSUDB phases are interchanged, $t_{su(TSUDA-TSUDB)}$ and $t_{su(TSUDB-TSUDA)}$ are also interchanged.

Timer S Input (Two-Phase Pulse Input in Two-Phase Pulse Signal Processing 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)

29.3.2.6 Serial Interface

Table 29.53 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

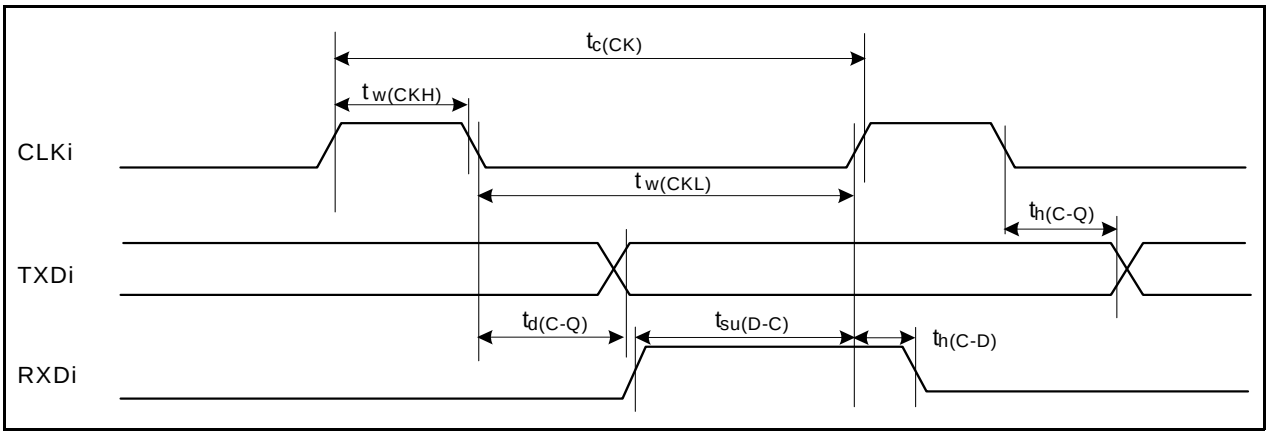


Figure 29.26 Serial Interface

29.3.2.7 External Interrupt $\overline{INTi}$ Input

Table 29.54 External Interrupt $\overline{INTi}$ Input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(INH)}$	$\overline{INTi}$ input high pulse width	380		ns
$t_{w(INL)}$	$\overline{INTi}$ input low pulse width	380		ns

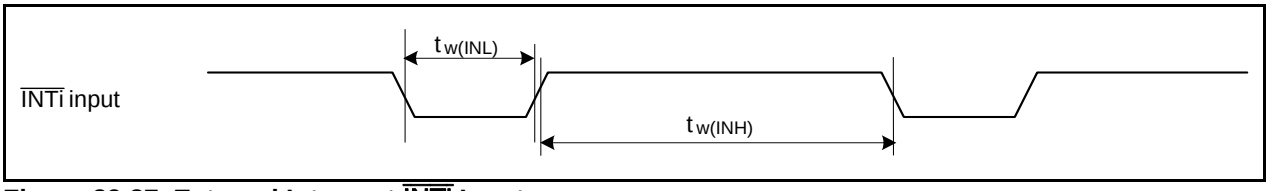


Figure 29.27 External Interrupt $\overline{INTi}$ Input

$V_{CC1} = V_{CC2} = 3\ V$

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)

29.3.2.8 Multi-master I²C-bus

Table 29.55 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

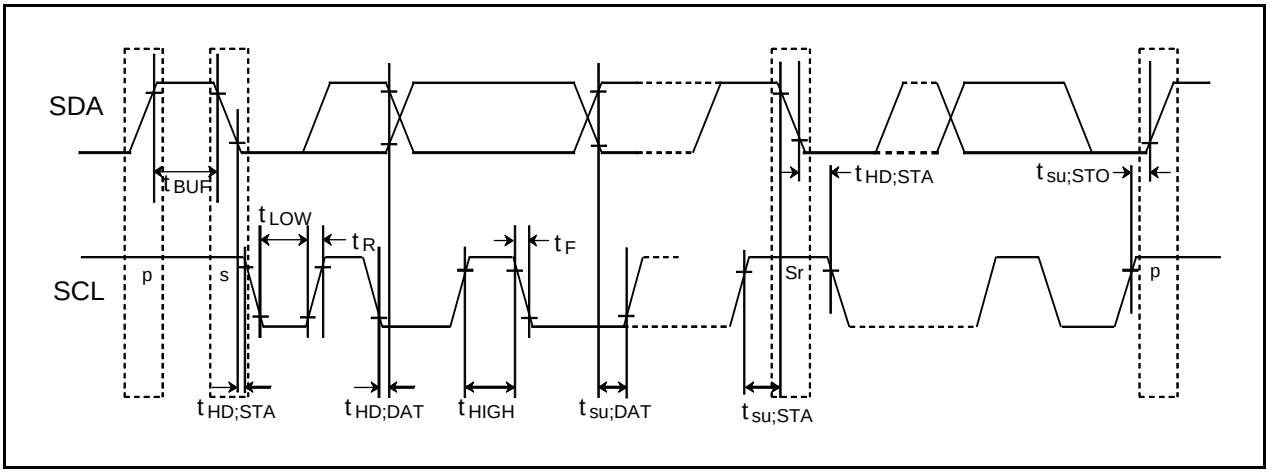


Figure 29.28 Multi-master I²C-bus

$V_{CC1} = V_{CC2} = 3\ V$

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)

29.3.3 Timing Requirements (Memory Expansion Mode and Microprocessor Mode)

Table 29.56 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
$t_{su(DB-RD)}$	Data input setup time	50		ns
$t_{su(RDY-BCLK)}$	$\overline{RDY}$ input setup time	85		ns
$t_{h(RD-DB)}$	Data input hold time	0		ns
$t_{h(BCLK-RDY)}$	$\overline{RDY}$ 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.

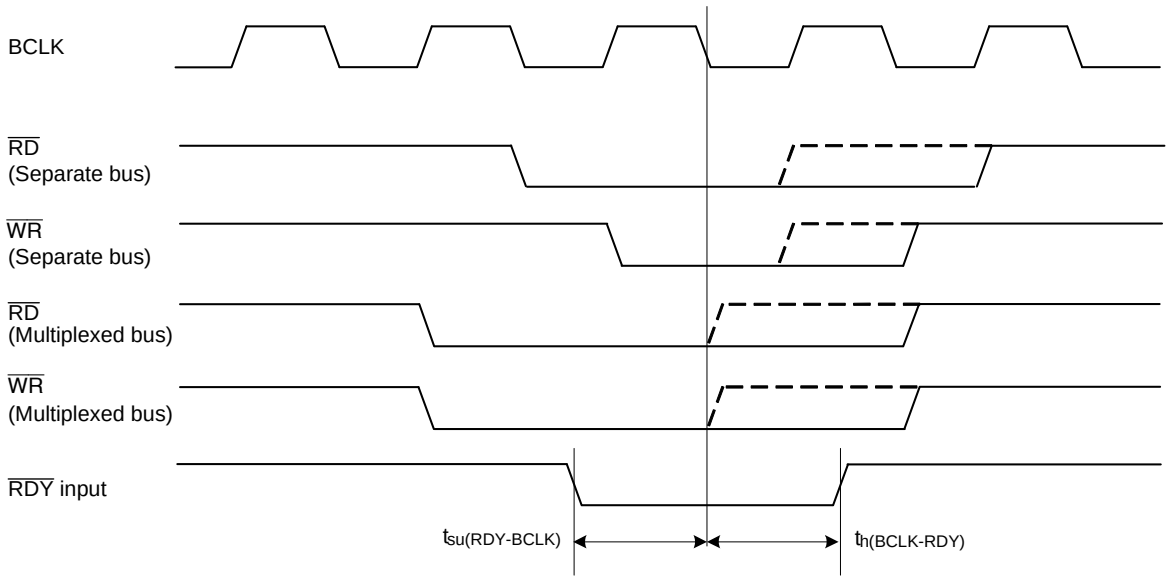
3. Calculated according to the BCLK frequency as follows:

$$\frac{(n - 0.5) \times 10^9}{f_{(BCLK)}} - 60[ns]$$ n is 2 for 2 waits setting, 3 for 3 waits setting.

Memory Expansion Mode and Microprocessor Mode

$V_{CC1} = V_{CC2} = 3$ V

(Effective in wait state setting**)**



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 29.29 Timing Diagram

$V_{CC1} = V_{CC2} = 3\ V$

29.3.4 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)

29.3.4.1 In No Wait State Setting

Table 29.57 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 29.30		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
$t_{h(BCLK-DB)}$	Data output hold time (in relation to BCLK) (3)		0		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 2)		ns

Notes:

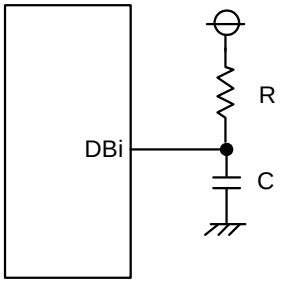
1. Calculated according to the BCLK frequency as follows:

   $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 40[ns]$ $f_{(BCLK)}$ 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
   $t = -30\ pF \times 1\ k\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
   = 6.7 ns.



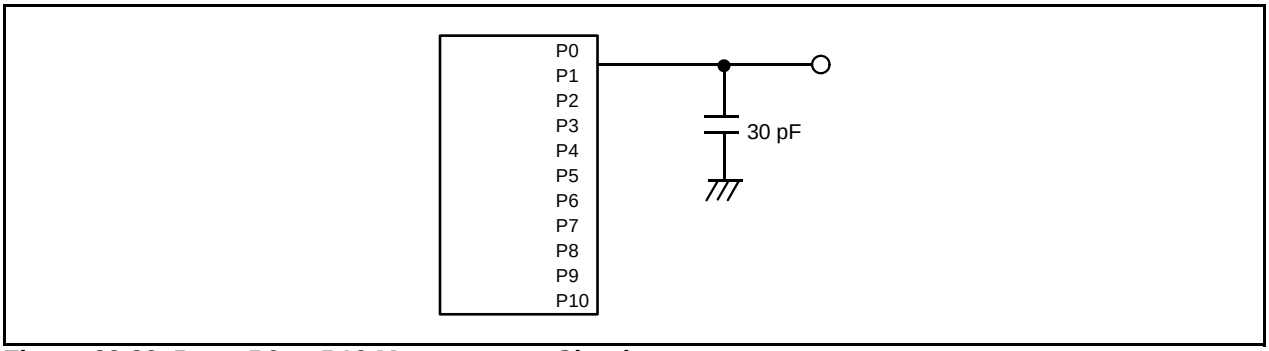
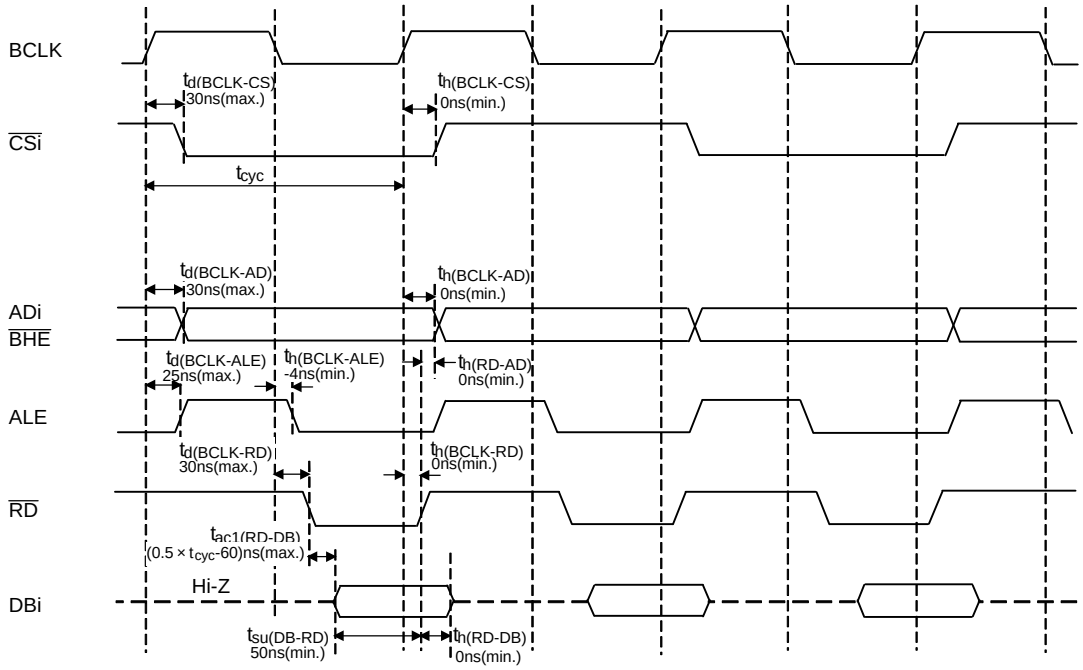


Figure 29.30 Ports P0 to P10 Measurement Circuit

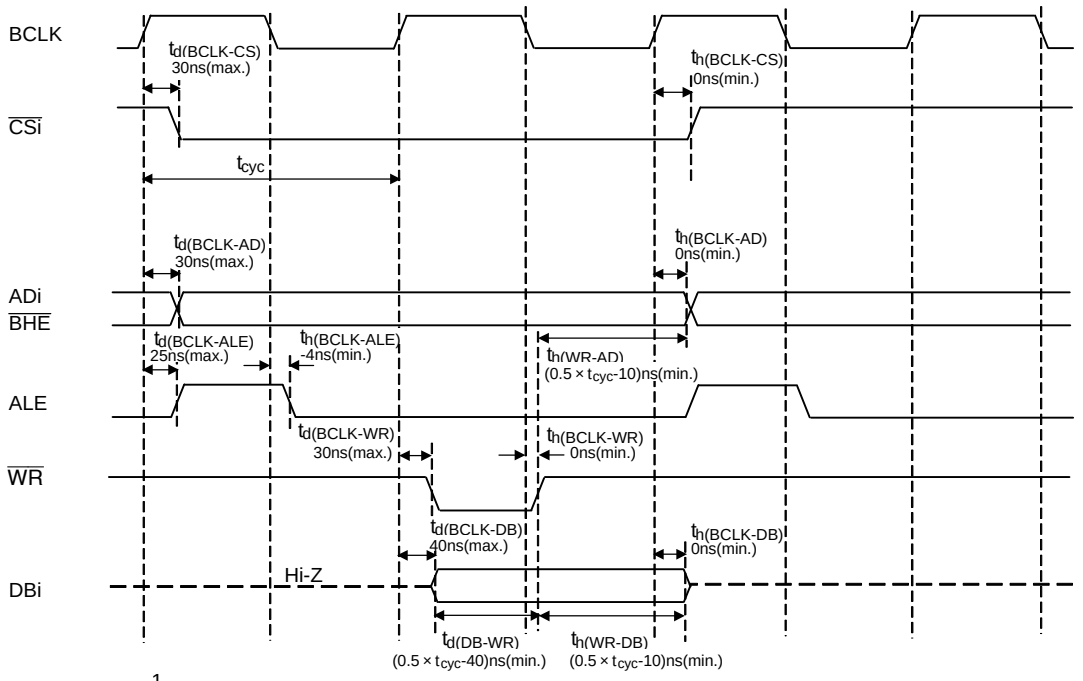
Memory Expansion Mode and Microprocessor Mode
(in no wait state setting)

$V_{CC1} = V_{CC2} = 3V$

Read timing



Write timing



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

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 29.31 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)

29.3.4.2 In 1 to 3 Waits Setting and When Accessing External Area

Table 29.58 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 29.30		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
$t_{h(BCLK-DB)}$	Data output hold time (in relation to BCLK) (3)		0		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 2)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

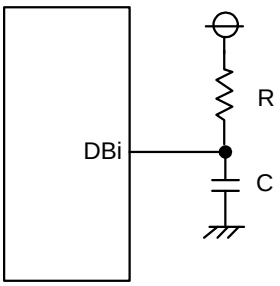
$$\frac{(n-0.5)\times 10^9}{f_{(BCLK)}} - 40[ns]$$

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:

$$\frac{0.5\times 10^9}{f_{(BCLK)}} - 10[ns]$$

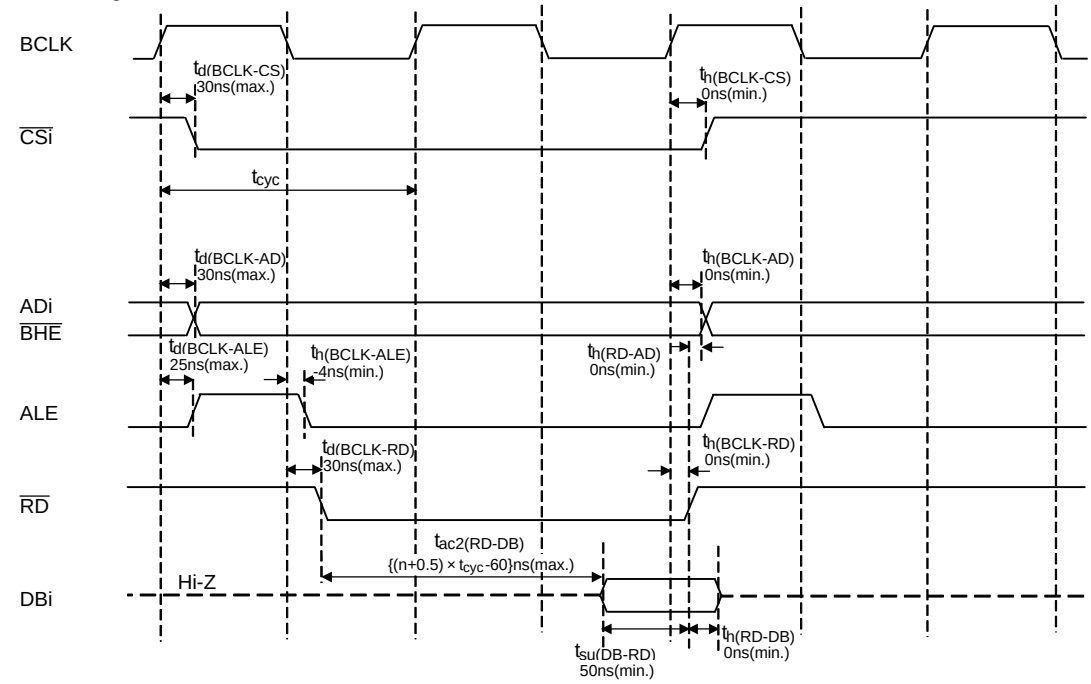
3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1 - V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30\ pF \times 1\ k\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
= 6.7 ns.



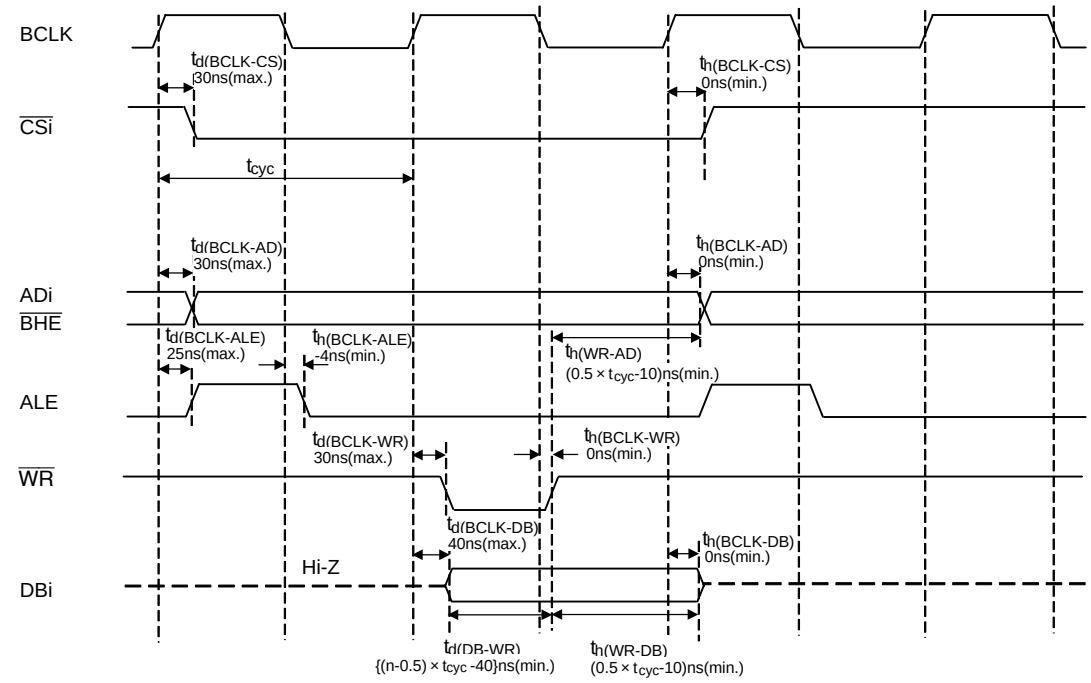
Memory Expansion Mode and Microprocessor Mode
(in 1 to 3 waits setting and when accessing external area)

$V_{CC1} = V_{CC2} = 3V$

Read timing



Write timing



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

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 29.32 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)

29.3.4.3 In 2 or 3 Waits Setting, and When Accessing External Area and Using Multiplexed Bus

Table 29.59 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 29.30		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 1)		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
$t_{h(BCLK-DB)}$	Data output hold time (in relation to BCLK)		0		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 1)		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

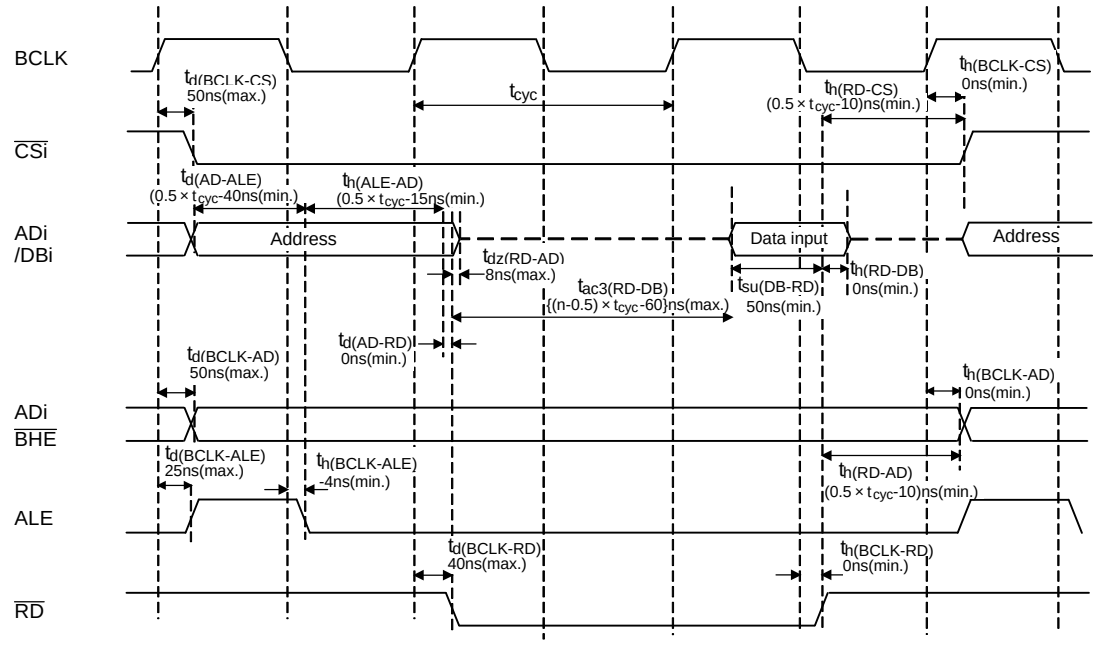
Notes:

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.

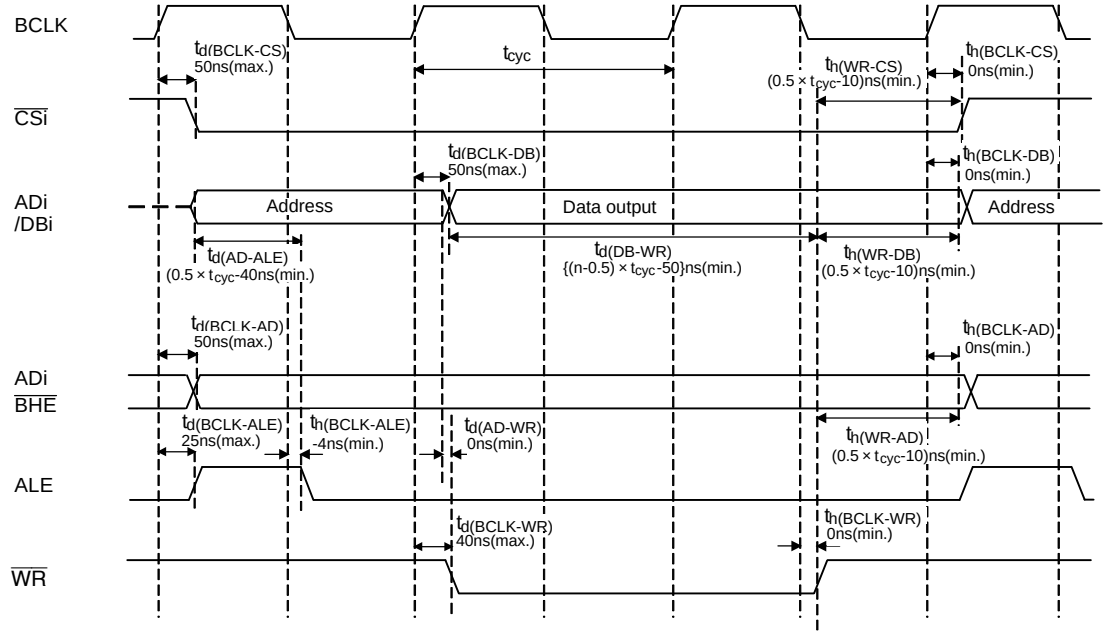
Memory Expansion Mode and Microprocessor Mode
(in 2 or 3 waits setting, and when accessing external area and using multiplexed bus)

$V_{CC1} = V_{CC2} = 3V$

Read timing



Write timing



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

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 29.33 Timing Diagram

30. Usage Notes

30.1 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 30.1 shows the Bypass Capacitor Connection.

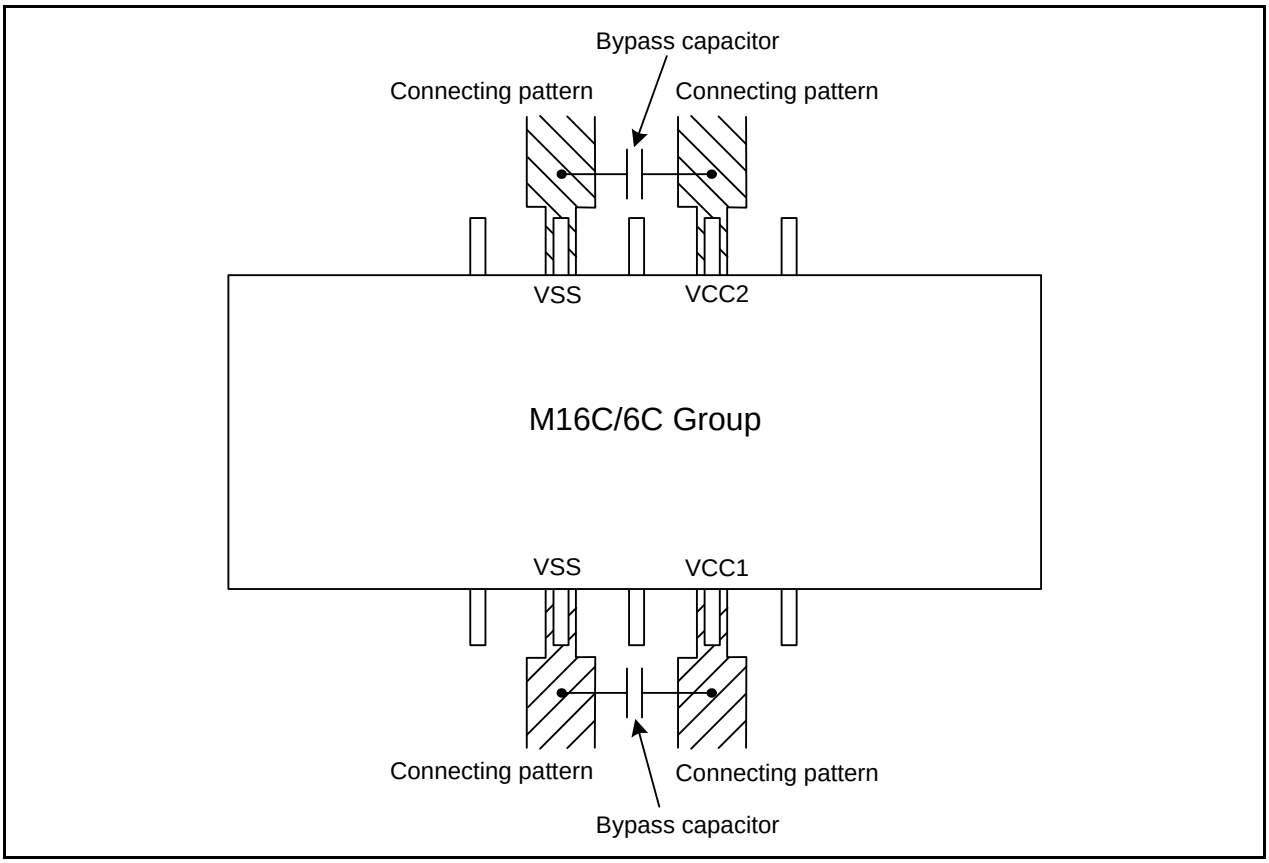


Figure 30.1 Bypass Capacitor Connection

30.2 Notes on SFRs

30.2.1 Register Settings

Table 30.1 lists Registers with Write-Only Bits (1/2) 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 30.1 Registers with Write-Only Bits (1/2)

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
0289h	UART5 Bit Rate Register	U5BRG
028Bh to 028Ah	UART5 Transmit Buffer Register	U5TB
0299h	UART4 Bit Rate Register	U4BRG
029Bh to 029Ah	UART4 Transmit Buffer Register	U4TB
02A9h	UART3 Bit Rate Register	U3BRG
02ABh to 02AAh	UART3 Transmit Buffer Register	U3TB
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 30.2 Registers with Write-Only Bits (2/2)

Address	Register	Symbol
D120h	USB Endpoint 0 IN Data Register	USBEPDR0I
D134h	USB Endpoint 2 Data Register	USBEPDR2
D138h	USB Endpoint 3 Data Register	USBEPDR3
D144h	USB Endpoint 5 Data Register	USBEPDR5
D148h	USB Endpoint 6 Data Register	USBEPDR6
D190h	USB Trigger Register 0	USBTRG0
D191h	USB Trigger Register 1	USBTRG1
D192h	USB Trigger Register 2	USBTRG2
D198h	USB FIFO Clear Register 0	USBFCLR0
D199h	USB FIFO Clear Register 1	USBFCLR1
D19Ah	USB FIFO Clear Register 2	USBFCLR2
D1A0h	USB Endpoint Stall Register 0	USBEPSTL0
D1A1h	USB Endpoint Stall Register 1	USBEPSTL1
D1A2h	USB Endpoint Stall Register 2	USBEPSTL2
D1C0h	USB Endpoint Information Register	USBEPIR

Table 30.3 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

30.3 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.

30.4 Notes on Resets

30.4.1 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

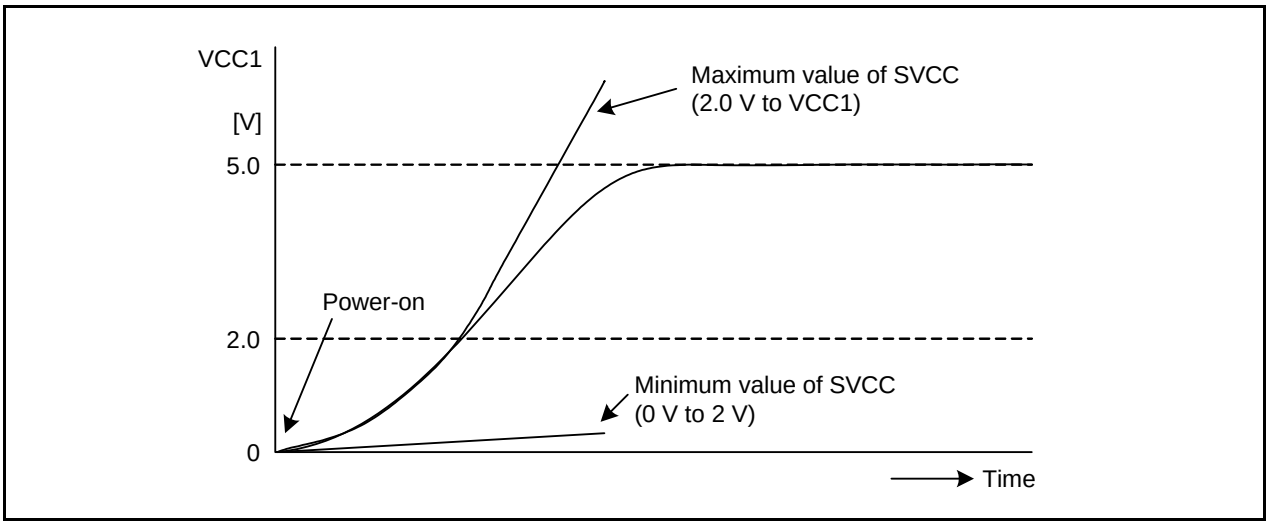


Figure 30.2 SVCC Timing (3.6 V < VCC1)

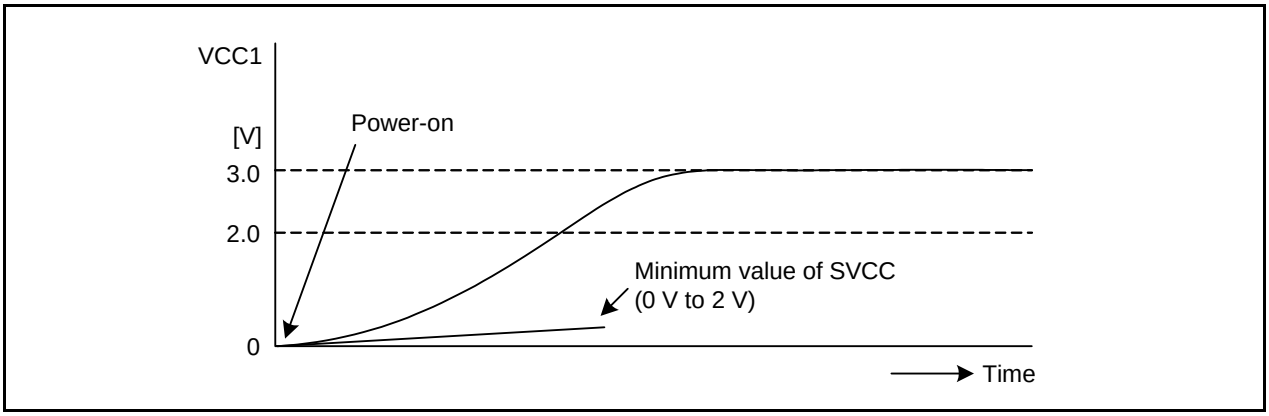


Figure 30.3 SVCC Timing (VCC1 ≤ 3.6 V)

30.4.2 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.

30.4.3 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.

30.5 Notes on Clock Generator

30.5.1 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/6C 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 30.4 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).

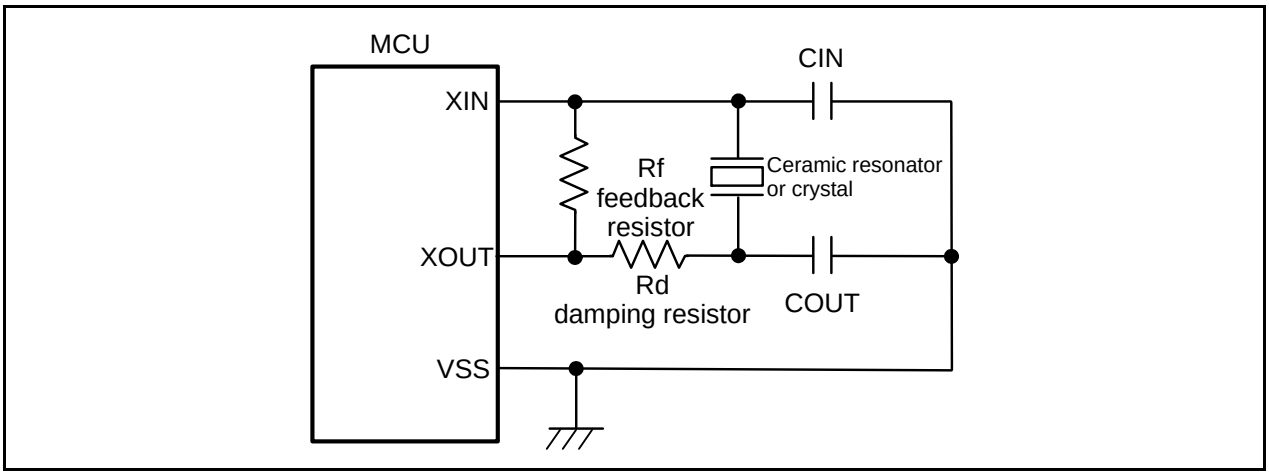


Figure 30.4 Oscillator Example

30.5.2 Noise Countermeasure

30.5.2.1 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).

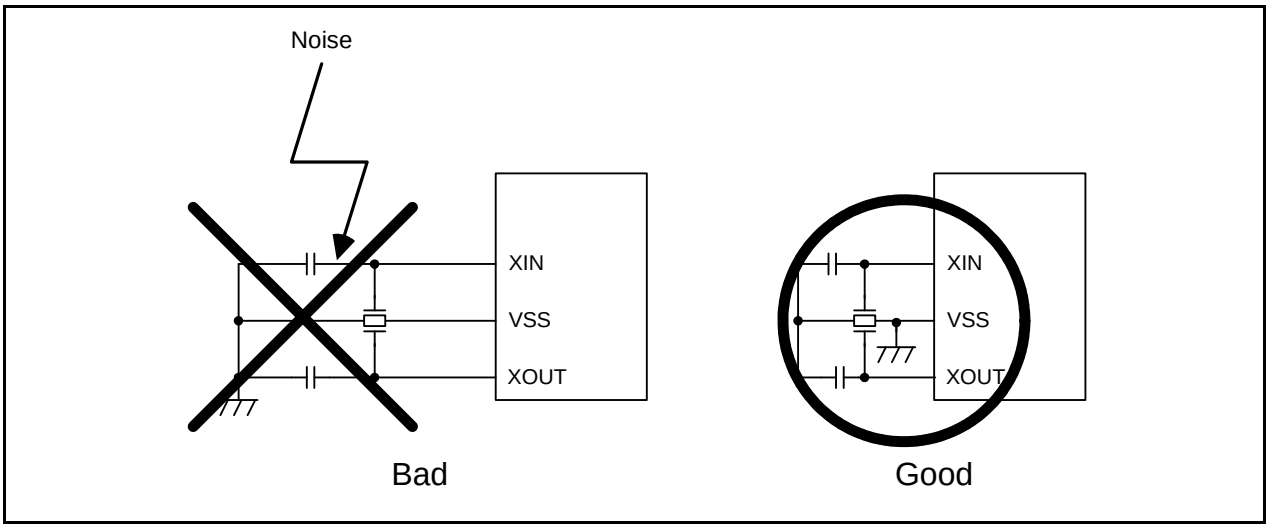


Figure 30.5 Clock I/O Pin Wiring

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.

30.5.2.2 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.

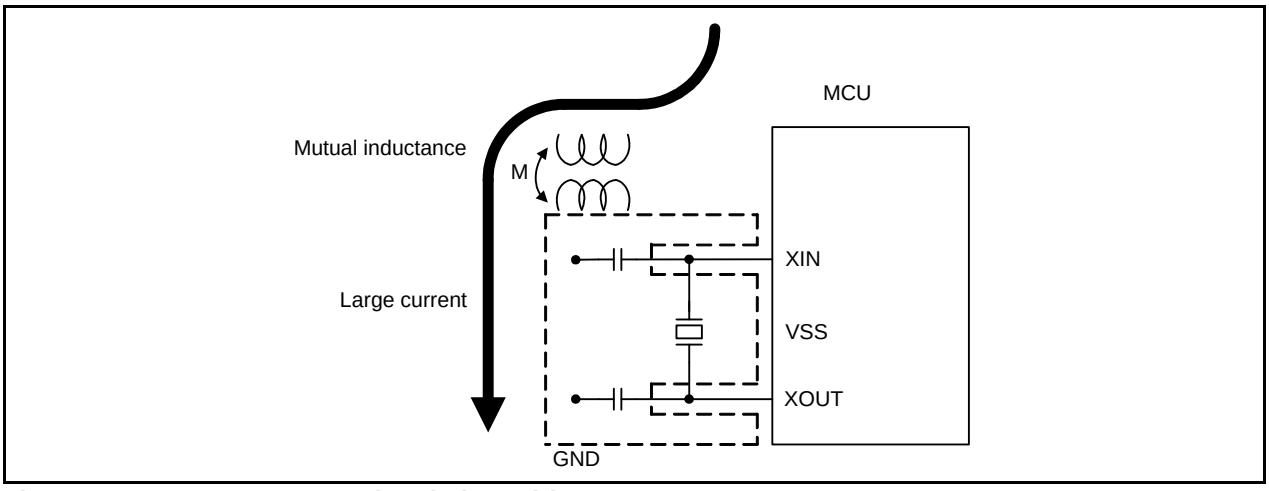


Figure 30.6 Large Current Signal Line Wiring

30.5.2.3 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.

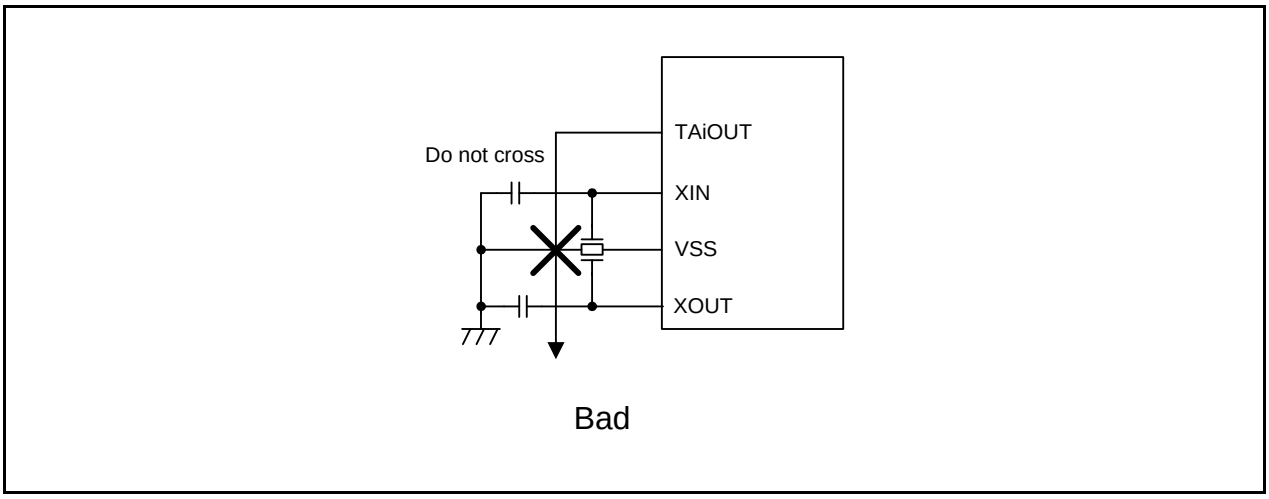


Figure 30.7 Wiring of Signal Line Whose Level Changes at High-Speed

30.5.3 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.

30.5.4 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.)

30.5.5 PLL Frequency Synthesizer

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

Table 30.5 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

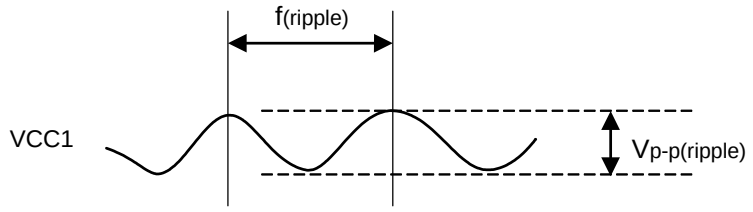


Figure 30.8 Voltage Fluctuation Timing

30.6 Notes on Power Control

30.6.1 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.

30.6.2 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.

30.6.3 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).

30.6.4 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).

30.6.5 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).

30.7 Notes on Bus

30.7.1 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.

30.7.2 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.

30.7.3 $\overline{\text{HOLD}}$

$\overline{\text{HOLD}}$ input is unavailable. Connect the $\overline{\text{HOLD}}$ pin to VCC2 via a resistor (pull-up).

30.8 Notes on Programmable I/O Ports

30.8.1 Influence of $\overline{SD}$

When a low-level signal is applied to the $\overline{SD}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{SD}$ pin enabled), the following pins become high-impedance: P7_2/CLK2/TA1OUT/V, P7_3/$\overline{CTS2}$/$\overline{RTS2}$/TA1IN/$\overline{V}$, P7_4/TA2OUT/W, P7_5/TA2IN/$\overline{W}$, P8_0/TA4OUT/RXD5/SCL5/U/TSUDA, P8_1/TA4IN/$\overline{CTS5}$/$\overline{RTS5}$/$\overline{U}$/TSUDB

30.9 Notes on Interrupts

30.9.1 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.

30.9.2 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.

30.9.3 $\overline{\text{NMI}}$ Interrupt

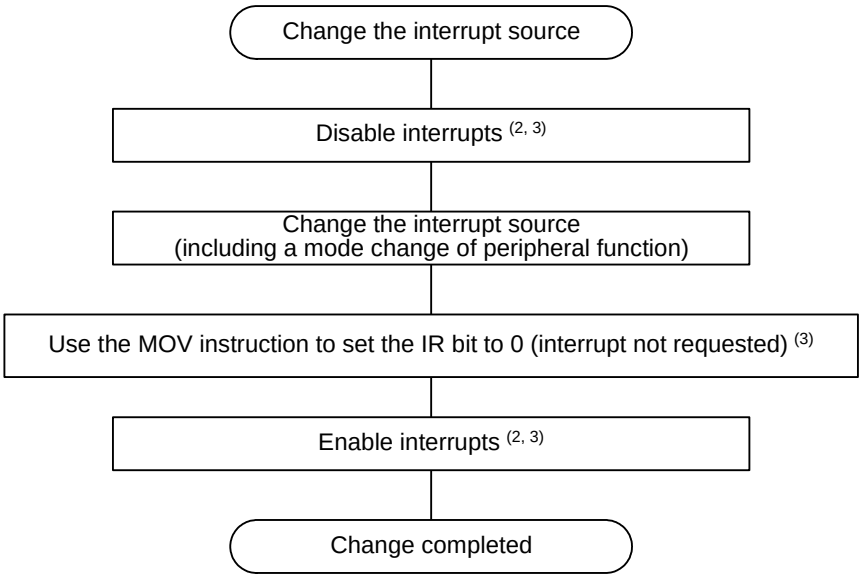
- When not using the $\overline{\text{NMI}}$ interrupt, set the PM24 bit in the PM2 register to 0 ($\overline{\text{NMI}}$ interrupt disabled).
- The $\overline{\text{NMI}}$ interrupt is disabled after reset. The $\overline{\text{NMI}}$ interrupt is enabled by setting the PM24 bit in the PM2 register 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.

30.9.4 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 30.9 shows the Procedure for Changing the Interrupt Generate Source.



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 $\overline{\text{INT}}$i interrupt (i = 0 to 7).
   For the interrupts from peripheral functions other than the $\overline{\text{INT}}$i 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 30.9.5 “Rewriting the Interrupt Control Register” for details about the instructions to be used and the notes to be taken for instruction execution.

Figure 30.9 Procedure for Changing the Interrupt Generate Source

30.9.5 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 30.9.6 “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.
```

30.9.6 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.

30.9.7 $\overline{\text{INT}}$ 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.

30.9.8 IR bits in the USBINT0IC, USBINT1IC and USBRSMIC registers

The IR bit behavior differs with the interrupts used in the USB function and the behavior discussed in 14.7.1.2 “IR Bit”. Refer to 24.4.2 “USB Interrupt 0, USB Interrupt 1”.

30.10 Notes on the Watchdog Timer

After the watchdog timer interrupt is generated, use the WDTR register to refresh the watchdog timer counter.

30.11 Notes on DMAC

30.11.1 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.

30.11.2 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.

30.12 Notes on Timer A

30.12.1 Common Notes on Multiple Modes

30.12.1.1 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.

30.12.1.2 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.

30.12.1.3 Influence of $\overline{SD}$

When a low-level signal is applied to the $\overline{SD}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{SD}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{CTS2}$/$\overline{RTS2}$/TA1IN/$\overline{V}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{W}$, P8_0/TA4OUT/RXD5/SCL5/U/TSUDA, P8_1/TA4IN/$\overline{CTS5}$/$\overline{RTS5}$/$\overline{U}$/TSUDB

30.12.2 Timer A (Timer Mode)

30.12.2.1 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.

30.12.3 Timer A (Event Counter Mode)

30.12.3.1 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.

30.12.4 Timer A (One-Shot Timer Mode)

30.12.4.1 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).

30.12.4.2 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.

30.12.4.3 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.

30.12.4.4 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.

30.12.5 Timer A (Pulse Width Modulation Mode)

30.12.5.1 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.

30.12.5.2 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.

30.12.6 Timer A (Programmable Output Mode)

30.12.6.1 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.

30.12.6.2 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.

30.13 Notes on Timer B

30.13.1 Common Notes on Multiple Modes

30.13.1.1 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.

30.13.2 Timer B (Timer Mode)

30.13.2.1 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.

30.13.3 Timer B (Event Counter Mode)

30.13.3.1 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.

30.13.3.2 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.

30.13.4 Timer B (Pulse Period/Pulse Width Measurement Modes)

30.13.4.1 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.

30.13.4.2 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.

30.13.4.3 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.

30.13.4.4 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.

30.13.4.5 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.

30.13.4.6 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.

30.14 Notes on Three-Phase Motor Control Timer Function

30.14.1 Timer A and Timer B

Refer to 17.5 “Notes on Timer A” and 18.5 “Notes on Timer B”.

30.14.2 Influence of $\overline{SD}$

When a low-level signal is applied to the $\overline{SD}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{SD}$ pin enabled), the following pins become high-impedance: P7_2/CLK2/TA1OUT/V, P7_3/$\overline{CTS2}$/$\overline{RTS2}$/TA1IN/$\overline{V}$, P7_4/TA2OUT/W, P7_5/TA2IN/$\overline{W}$, P8_0/TA4OUT/RXD5/SCL5/U/TSUDA, P8_1/TA4IN/$\overline{CTS5}$/$\overline{RTS5}$/$\overline{U}$/TSUDB

30.15 Notes on Timer S

30.15.1 Register Access

The explanation for some bits and registers states, “the value written to this register or this bit is reflected to the internal circuit when the clock is synchronized with the base timer count source (fBT1)”. When writing these bits or registers, the written value is not reflected to the internal circuits immediately. After writing the value, prewrite operations are performed for up to one fBT1 cycle. When reading these bits or registers immediately after writing the value, the value before writing may be read.

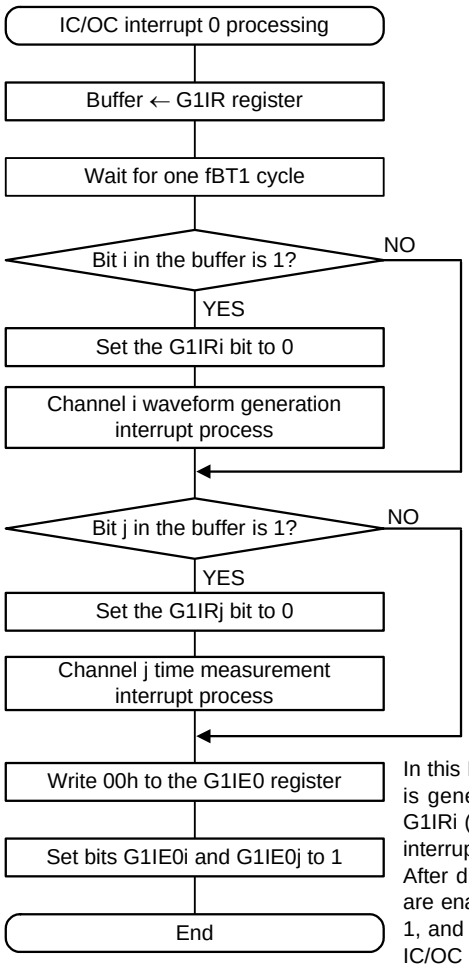
30.15.2 Changing the G1IR Register

Set the G1IRj bit in the G1IR register (j = 0 to 7) to 0 by a program since it does not become 0 automatically with an interrupt request reception.

However, the G1IRj bit cannot be set to 0 for one fBT1 cycle after this bit becomes 1. Wait for one or more fBT1 cycles after the G1IRj bit becomes 1, then set this bit to 0.

To write 0 to the G1IRj bit, use the AND and BCLR instructions to avoid deleting requests for other channels.

Figure 30.10 shows “IC/OC Interrupt 0 Operation Example”. As shown in the operation example, disable interrupt requests for all channels once at the last part of an interrupt process, then enable them again.



Store an interrupt request for each channel in the buffer on RAM.

Wait for one fBT1 cycle since the bits in the G1IR register cannot be set to 0 for this period.

Check whether an interrupt request for channel i exists.

Clear the interrupt request for channel i.

Check whether an interrupt request for channel j exists.

Clear the interrupt request for channel j.

In this IC/OC interrupt 0 processing, when an interrupt request for channel i(j) is generated after the processing to set the G1IRi (or G1IRj) bit to 0, the G1IRi (G1IRj) bit remains 1. In this case, the IR bit remains 0, and the IC/OC interrupt 0 request is not generated afterwards.
After disabling all the channels using the G1IE0 register, when the channels are enabled again, if either the G1IRi bit or G1ITj bit is 1, the IR bit becomes 1, and the IC/OC interrupt 0 request is generated. Therefore a branch to the IC/OC interrupt 0 processing is again made after returning from the interrupt processing.

i = 0 to 7; j = 0 to 7 (however, j and i cannot be the same value)
G1IRi, G1IRj: Bits in the G1IR register
G1IE0i, G1IE0j: Bits in the G1IE0 register

The above assumes the following:
With IC/OC interrupt 0, a waveform generation interrupt is processed for channel i, and a time measurement interrupt for channel j. Interrupt requests for the other channels are disabled with the G1IE0 register.

Figure 30.10 IC/OC Interrupt 0 Operation Example

30.15.3 Changing Registers ICOCiIC (i = 0, 1)

While the G1IEij bit in the G1IEi register is 1 (IC/OC interrupt 1 request enabled), use the AND, OR, BCLR, or BSET instruction to change bits ILVL2 to ILVL0 in the ICOCiIC register at the point where a channel j interrupt request may be generated (j = 0 to 7). The IR bit becomes 1 (interrupt requested) if a channel j interrupt is generated while executing these instructions.
If the MOV instruction is used to perform the above, when a channel j interrupt request is generated while executing the MOV instruction, the IR bit does not become 1, and the interrupt request is ignored. The G1IRj bit in the G1IR register becomes 1 (interrupt requested) at this timing. If the G1IRj remains 1, subsequent IC/OC interrupt i requests are not generated.

When timer S is initialized, change registers ICOCiIC after registers ICOCiIC and G1IR are both set to 00h.

30.15.4 Output Waveform During the Base Timer Reset with the BTS bit

When the BTS bit in the G1BCR1 register is set to 0 (base timer reset), the waveform output pin level remains as it is at that point. This output level is held until the base timer value matches the G1POj register value after the BTS bit is set to 1 (base timer starts counting).

30.15.5 OUTC1_0 Pin Output During the Base Timer Reset with the G1PO0 register

While the RST1 bit in the G1BCR1 register is set to 1 (the base timer is reset when the base timer matches the G1PO0 register), when the base timer matches the G1PO0 register, the base timer is reset after two fBT1 cycles. During the two fBT1 cycles from when the base timer value matches the G1PO0 register value to the base timer being reset, the OUTC1_0 pin is driven high. Thus set the EOC0 bit in the G1OER register to 1 (output disabled).

30.15.6 Interrupt Request When Selecting Time Measurement Function

When the FSCj bit (j = 0 to 7) in the G1FS register is set to 1, and the IFEj bit in the G1FE register is also set to 1, the G1IRj bit in the G1IR register, or the IR bits in registers ICOCiIC (i = 0, 1) or ICOCHjIC (j = 0 to 3) may become 1 (interrupt requested) after a maximum of two fBT1 cycles (1).
When using IC/OC interrupt i or IC/OC channel j interrupt, set bits FSCj and IFEj to 1, then perform the following:

(1) Wait for two or more fBT1 cycles (1).
(2) Set the IR bit in the ICOCiIC register and/or the ICOCHjIC register to 0.
(3) Wait for three or more fBT1 cycles (1) after the time measurement function is selected. Set the G1IR register to 00h (2) after setting the IR bit in the ICOCiIC register to 0.

Notes:
1. When using the digital filter, time required for the function also needs to be considered.
2. Verify the value in the G1IR register is 00h by reading. If the read value is not 00h, repeat writing 00h to the G1IR register.

30.16 Notes on Real-Time Clock

30.16.1 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.

30.16.2 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 21.4 shows Time and Day Change Procedure (No Compare Mode or Compare Mode 1), and Figure 21.5 shows Time and Day Change Procedure (Compare Mode 2 or Compare Mode 3).

30.16.3 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

30.16.4 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 30.11 “Time Data Reading”.

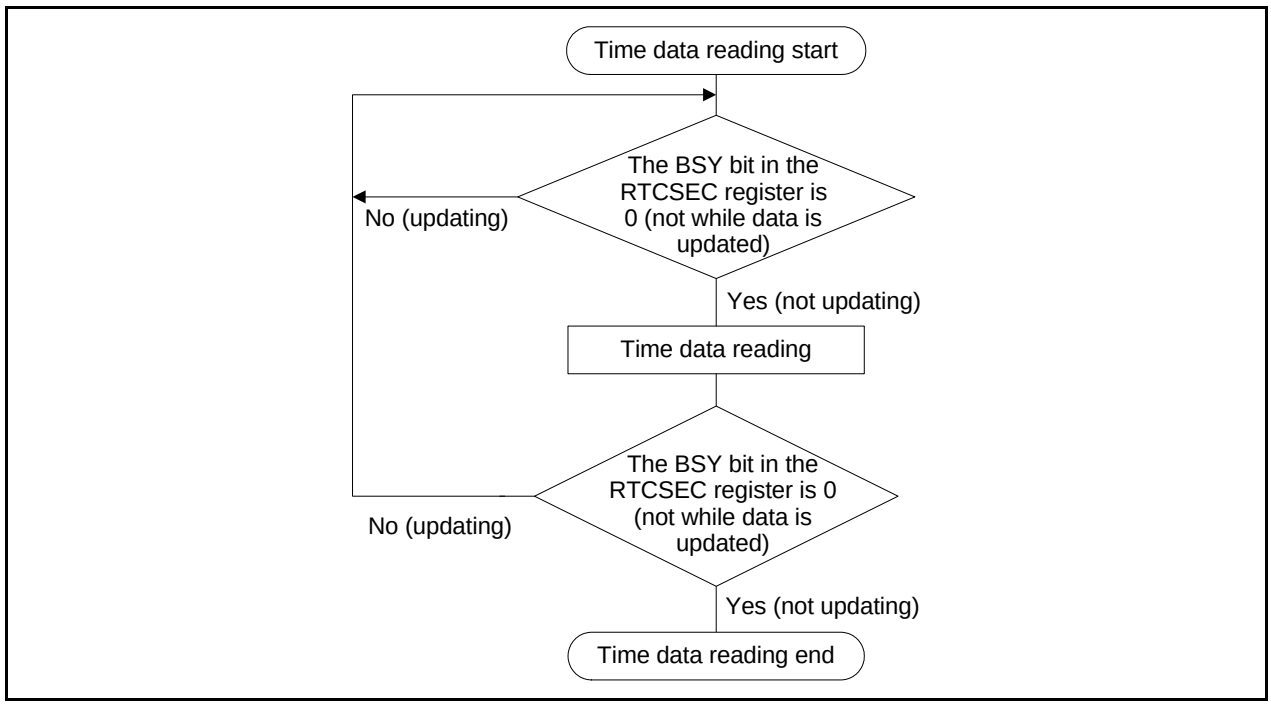


Figure 30.11 Time Data Reading

- 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

30.17 Notes on Serial Interface UARTi (i = 0 to 5)

30.17.1 Common Notes on Multiple Modes

30.17.1.1 Influence of $\overline{SD}$

When a low-level signal is applied to the $\overline{SD}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{SD}$ pin enabled), the following pins become high-impedance: P7_2/CLK2/TA1OUT/V, P7_3/$\overline{CTS2}$/$\overline{RTS2}$/TA1IN/$\overline{V}$, P7_4/TA2OUT/W, P7_5/TA2IN/$\overline{W}$, P8_0/TA4OUT/RXD5/SCL5/U/TSUDA, P8_1/TA4IN/$\overline{CTS5}$/$\overline{RTS5}$/$\overline{U}$/TSUDB

30.17.1.2 Register Setting

Set the OCOSEL0 or OCOSEL1 bit in the UCLKSEL0 register before setting other registers associated with UART0 to UART5. After changing the OCOSEL0 or OCOSEL1 bit, set other registers associated with UART0 to UART5 again.

30.17.1.3 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.

30.17.2 Clock Synchronous Serial I/O Mode

30.17.2.1 Transmission/Reception

When the $\overline{RTS}$ function is used with an external clock, the $\overline{RTSi}$ pin (i = 0 to 5) outputs a low-level signal, which informs the transmitting side that the MCU is ready for a receive operation. The $\overline{RTSi}$ pin outputs a high-level signal when a receive operation starts. Therefore, transmit timing and receive timing can be synchronized by connecting the $\overline{RTSi}$ pin to the $\overline{CTSi}$ pin on the transmitting side. The $\overline{RTS}$ function is disabled when an internal clock is selected.

30.17.2.2 Transmission

If the transmission is started while an external clock is selected and the TXEPT bit in the UiC0 register (i = 0 to 5) 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 $\overline{CTS}$ function is selected, input on the $\overline{CTSi}$ pin is low.

30.17.2.3 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 5) 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).

30.17.3 Special Mode 1 (I^2C Mode)

30.17.3.1 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 5) 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.

30.17.3.2 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

30.17.3.3 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 I2C-bus specification.
Refer to the recommended operating conditions for I/O ports which share the pins with SCL and SDA.

I2C-bus specification
High level input voltage (V_{IH}) = min. 0.7 V_{CC}
Low level input voltage (V_{IL}) = max. 0.3 V_{CC}

30.17.3.4 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 22.3.3.7 “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

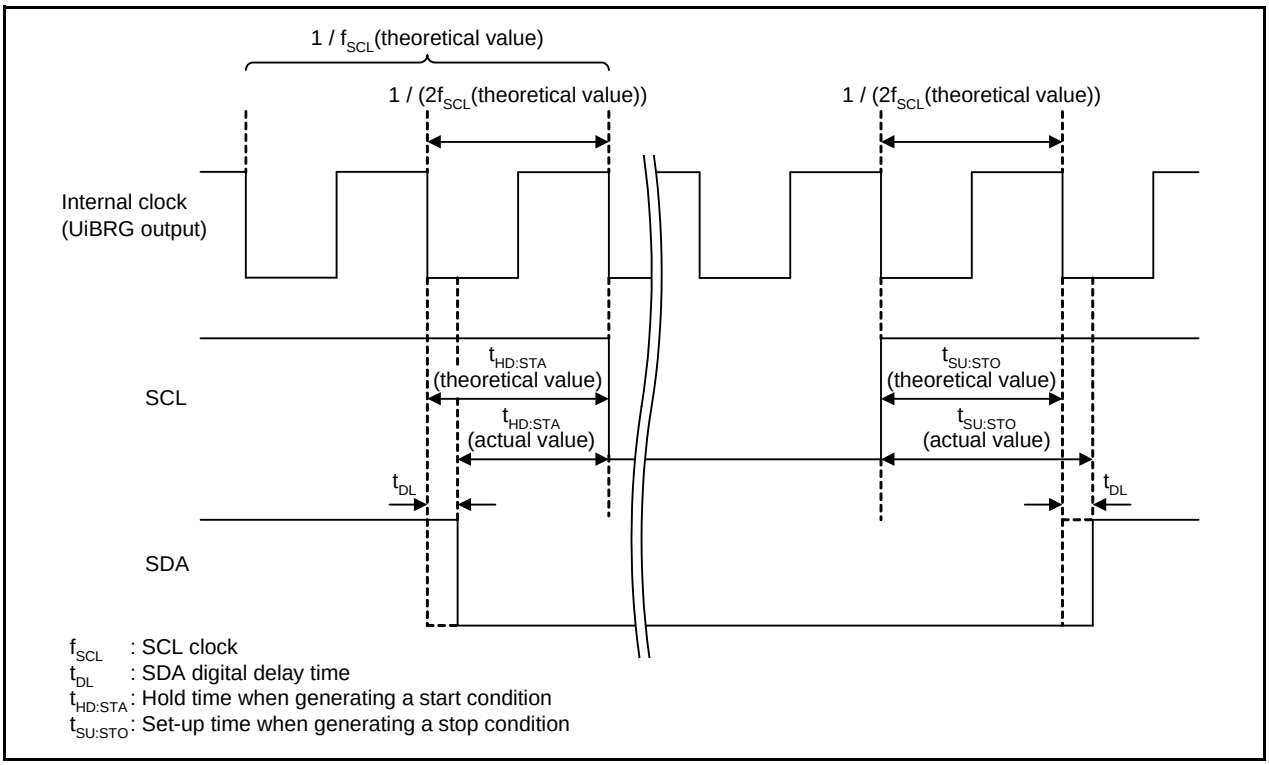


Figure 30.12 Setup and Hold Times When Generating Start and Stop Conditions

30.17.3.5 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.

30.17.3.6 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.

30.17.3.7 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).

30.17.4 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.

30.18 Notes on Multi-master I2C-bus Interface

30.18.1 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 23.4 “Registers”. Set the CM07 bit to 0 (main clock, PLL clock, or on-chip oscillator clock) to access these registers.

30.18.2 Register Access

Refer to the notes below when accessing the I2C 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.

30.18.2.1 S00 Register

Do not write to the S00 register during transmission/reception.

30.18.2.2 S1D0 Register

Do not change bits other than the IHR bit in the S1D0 register during transmission/reception.

30.18.2.3 S20 Register

Do not change bits other than the ACKBIT bit in the S20 register during transmission/reception.

30.18.2.4 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 (I2C interface disabled).

30.18.2.5 S4D0 Register

Rewrite bits ICK4 to ICK2 when the ES0 bit in the S1D0 register is 0 (I2C interface disabled).

30.18.2.6 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 23.3 “Operations” for bits MST and TRX change.

30.18.3 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 I2C-bus specification.
Refer to the recommended operating conditions for I/O ports which share the pins with SCL and SDA.

I2C-bus specification

High level input voltage (V_{IH}) = min. 0.7 V_{CC}

Low level input voltage (V_{IL}) = max. 0.3 V_{CC}

30.19 Notes on USB Module

30.19.1 Accessing USB Associated Registers

Access USB associated registers in 8-bit units only. Do not access these registers in 16-bit units. Registers other than the USBMC register can be accessed successfully when the USBE bit in the USBMC register is 0 (USB clock supplied) and the USBSTS bit in the USBMC register is 0 (USB function enabled).
When using the DMAC to access the USB associated registers, set the transfer unit to 8 bits.

30.19.2 USB Interrupt Flag Registers

Perform the following when writing to registers USBIFR0, USBIFR1, USBIFR2, and USBIFR3.

- Use the MOV instruction and write to the registers in 8-bit units.
- Those bits that are not set to 0 should be set to 1.

Example 1: When setting the BRST bit (bit 7) in the USBIFR0 register to 0

```
MOV.B #7Fh, USBIFR0
```

Example 2: When setting bits BRST and CFDN (bits 7 and 6) in the USBIFR0 register to 0

```
MOV.B #3Fh, USBIFR0
```

30.19.3 USB Endpoint Stall Registers

Follow the instructions below when writing to registers USBEPSTL0, USBEPSTL1, and USBEPSTL2.

- Use the MOV instruction and write to the registers in 8-bit units.
- Those bits that are not set to 0 should be set to 1.

30.19.4 Detecting a Transmit FIFO Buffer Transfer Request

The following precautions need to be observed when detecting a transfer request of the endpoint i (i = 0, 2, 3, 5 and 6) transmit FIFO buffer. Endpoint 0 is used as an example.

When an IN token is received for endpoint 0, and if there is no valid data in the endpoint 0 transmit FIFO buffer, the USB module returns a NACK to the host and then the EP0ITR bit in the USBIFR1 register becomes 1 (endpoint 0 IN transfer request detected). The USB module repeats this process for every IN token received until the EP0IPKTE bit in the USBTRG0 register is set to 1 (transmit data determined) by a program.
Therefore, when setting the transmit data using the following procedure, and an IN token is received after step (1) until the EP0IPKTE bit becomes 1 in step (3), the EP0ITR bit becomes 1 again.

(1) Set the EP0ITR bit to 0 (endpoint 0 IN transfer request not detected).
(2) Write data to the endpoint 0 transmit FIFO buffer.
(3) Set the EP0IPKTE bit to 1 (transmit data determined).

30.19.5 Internal Power for USB Module and UVCC Pin

Internal power for the USB module can be used when 4.0 V ≤ VCC1 ≤ 5.5 V. When VCC1 is less than 4.0 V, internal power for the USB module cannot be used. The output of the internal power for the USB module is connected to the UVCC pin. When using internal power for the USB module, connect a 0.33 μF capacitor between the UVCC pin and VSS.
When outputting 3.3 V from the internal power for the USB module, start the 125 kHz on-chip oscillator (set the CM14 bit in the CM1 register to 0). Set the VDDUSBE bit in the USBMC register to 1, and wait a minimum of 1 ms for the 3.3 V internal power for the USB to stabilize. Generate the wait time in the program. The 125 kHz on-chip oscillator can be stopped after the 3.3 V output stabilizes (after 1 ms has passed).
Apply 3.3 V to the UVCC pin when using the USB module while 3.0 V ≤ VCC1 ≤ 4.0 V or when using the USB module without using the USB internal power even while 4.0 V ≤ VCC1 ≤ 5.5 V. When the PXXCON bit in the USBMC register is 1 (VDDUSBE bit enabled) and the VDDUSBE bit is 0 (USB internal power stopped), the UVCC pin input is enabled.

30.19.6 Settings When Not Using the USB Module

When not using the USB module, set the PXXCON bit in the USBMC register to 0 (VDDUSBE bit disabled) and connect the UVCC pin to VCC1.

30.19.7 CPU Clock When Using the USB Module

When using the USB module, set the CPU clock to a minimum of 16 MHz.

30.19.8 Entering Wait mode or Stop Mode

(Technical update number: TN-16C-A189A/E)
To enter wait mode or stop mode while using the USB module in memory expansion mode, follow the procedure below.

While using the USB module after setting the VDDUSBE bit in the USBMC register to 1 (3.3 V USB internal power source supplied), when turning off the USB internal power supply to enter wait mode or stop mode, enter single-chip mode before entering wait mode or stop mode.

(1) Set bits PM01 and PM00 in the PM0 register to 00b (single-chip mode).
(2) Set the VDDUSBE bit in the USBMC register to 0 (USB internal power supply stopped).
(3) Enter wait mode or stop mode.

Use the following procedure to rewrite bits PM01 and PM00 after exiting wait mode or stop mode:

(1) Set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on).
(2) Set the VDDUSBE bit in the USBMC register to 1.
(3) Wait for 1 ms.
(4) Rewrite bits PM01 and PM00 in the PM0 register.

Entering wait mode or stop mode while in memory expansion mode or microprocessor mode is possible if the power supply to the USB device continues even in wait mode or stop mode.

30.19.9 Low Supply Voltage

(Technical update number: TN-16C-A189A/E)
When using memory expansion mode or microprocessor mode, the UVCC level becomes undefined if either of the conditions below is met. When this occurs, problems such as an external device not being read correctly or port P1 outputting an unexpected level may occur.

- When the VDDUSBE bit in the USBMC register is 1 (3.3 V USB internal power source supplied), VCC1 < 4.0 V.
- When the VDDUSBE bit is 0 (USB internal power stopped), UVCC < 3.0 V.

When this issue causes a problem, connect a reset IC to prevent the MCU from operating at or under the levels specified above.

30.20 Notes on A/D Converter

30.20.1 Analog Input Voltage

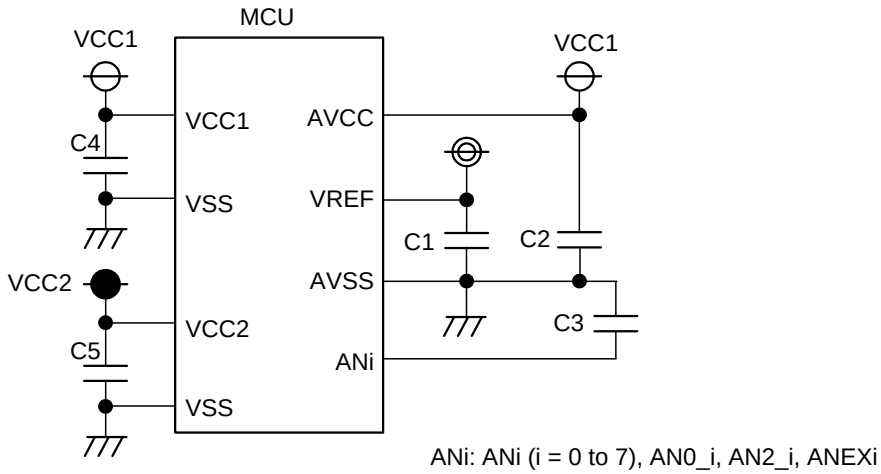
Use when AVCC = VCC1 = VCC2.
Do not use A/D converter when VCC1 > VCC2.

30.20.2 Analog Input Pin

When A/D1 operation is enabled (the ADSTBY bit in the AD1CON1 register is set to 1), AN0 to AN7 pins are not available for A/D0. Select any pins of AN0_0 to AN0_7, AN2_0 to AN2_7, ANEX0 or ANEX1. When A/D0 selects pins AN0 to AN7 and operates A/D conversion with A/D1 operation enabled, the conversion result becomes undefined. To select pins AN0 to AN7 with A/D0, set A/D1 operation to stop (set the ADSTBY bit in the AD1CON1 register to 0).
Do not use any pin from AN4 to AN7 as analog input pin if any pin from $\overline{KI0}$ to $\overline{KI3}$ is used as a key input interrupt.
Do not convert an analog signal in A/D0 and A/D1 simultaneously. When converting an analog signal in both A/D0 and A/D1, make sure to finish one A/D conversion and start another A/D conversion. Take the average of the both of the conversion.

30.20.3 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), AN0_i, and AN2_i and ANEXj (j = 0 to 1)). 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 30.13 Example of Pin Configuration

30.20.4 Register Access (A/D0 related registers)

Set registers associated with A/D converter (A/D0) after setting the CKS3 bit in the AD0CON2 register. However the other bits in the AD0CON2 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 AD0CON0 (excluding the ADST bit), AD0CON1, and AD0CON2 when A/D conversion stops (before a trigger is generated).
After A/D conversion stops, set the ADSTBY bit in the AD0CON1 register from 1 to 0.

30.20.5 Register Access (A/D1 related registers)

Set registers associated with A/D converter (A/D1) after setting the CKS3 bit in the AD1CON2 register. However the other bits in the AD1CON2 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 AD1CON0 (excluding the ADST bit), AD1CON1 and AD1CON2 when A/D conversion stops (before a trigger is generated).
After A/D conversion stops, set the ADSTBY bit in the AD1CON1 register from 1 to 0.

30.20.6 A/D Conversion Start

For A/D0, when rewriting the ADSTBY bit in the AD0CON1 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 (A/D0).
For A/D1, when rewriting the ADSTBY bit in the AD1CON1 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 (A/D1).

30.20.7 A/D Operation Mode Change

When the A/D operation mode for A/D0 has been changed, reselect analog input pins by using bits CH2 to CH0 in the AD0CON0 register or bits SCAN1 to SCAN0 in the AD0CON1 register.
When the A/D operation mode for A/D1 has been changed, re-select analog input pins by using bits CH2 to CH0 in the AD1CON0 register or bits SCAN1 to SCAN0 in the AD1CON1 register.

30.20.8 State When Forcibly Terminated (A/D0)

If A/D conversion (A/D0) in progress is halted by setting the ADST bit in the AD0CON0 register to 0 (A/D conversion stopped), the conversion result is undefined. In addition, the unconverted AD0i register (i = 0 to 7) may also become undefined. Do not use any value in AD0i registers when setting the ADST bit to 0 by a program during A/D conversion.

30.20.9 State When Forcibly Terminated (A/D1)

If A/D conversion (A/D1) in progress is halted by setting the ADST bit in the AD1CON0 register to 0 (A/D conversion stopped), the conversion result is undefined. In addition, the unconverted AD1j register (j = 0 to 3) may also become undefined. Do not use any value in AD1j registers when setting the ADST bit to 0 by a program during A/D conversion.

30.20.10 Detecting Completion of A/D Conversion (A/D0)

In one-shot mode and single sweep mode, use the IR bit in the ADIC register to detect completion of A/D conversion (A/D0). 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 AD0CON0 register, the ADST bit becomes 1 (A/D conversion start) after start processing time elapses (see Table 25.10 “Cycles of A/D Conversion Item”). Therefore when reading the ADST bit immediately after writing 1, 0 (A/D conversion stop) may be read.

30.20.11 Detecting Completion of A/D Conversion (A/D1)

In one-shot mode and single sweep mode, use the IR bit in the ADEIC register to detect completion of A/D conversion (A/D1). When not using interrupt, set the IR bit to 0 by a program after the detection.
When 1 is written to the ADST bit in the AD1CON0 register, the ADST bit becomes 1 (A/D conversion start) after start processing time elapses (see Table 25.10 “Cycles of A/D Conversion Item”). Therefore when reading the ADST bit immediately after writing 1, 0 (A/D conversion stop) may be read.

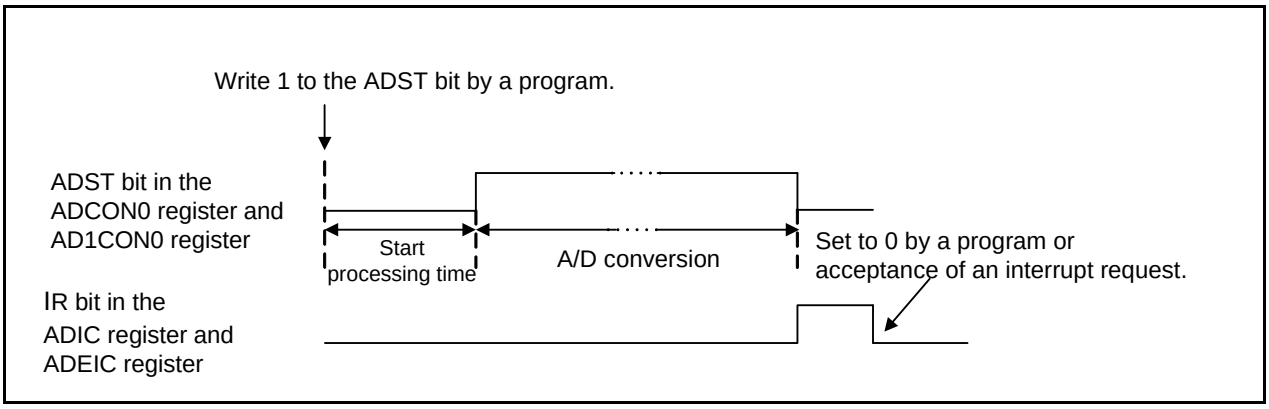


Figure 30.14 ADST Bit Operation

30.20.12 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).

30.21 Notes on D/A Converter

30.21.1 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.

30.22 Notes on Flash Memory

30.22.1 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.)

30.22.2 Reading Data Flash

When 2.7 V ≤ VCC1 ≤ 3.0 V and f(BCLK) ≥ 16 MHz, or 3.0 V < VCC1 ≤ 5.5 V and f(BCLK) ≥ 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.

30.22.3 CPU Rewrite Mode

30.22.3.1 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).

30.22.3.2 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).

30.22.3.3 Prohibited Instructions

Do not use the following instructions in EW0 mode:
UND instruction, INTO instruction, JMPS instruction, JSRS instruction, and BRK instruction.

30.22.3.4 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.

30.22.3.5 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.

30.22.3.6 Rewrite (EW1 Mode)

Do not rewrite any blocks in which the rewrite control program is stored.

30.22.3.7 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).

30.22.3.8 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.

30.22.3.9 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).

30.22.3.10 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).

30.22.3.11 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.

30.22.3.12 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.

30.22.3.13 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.

30.22.3.14 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.

30.22.4 User Boot

30.22.4.1 User Boot Mode Program

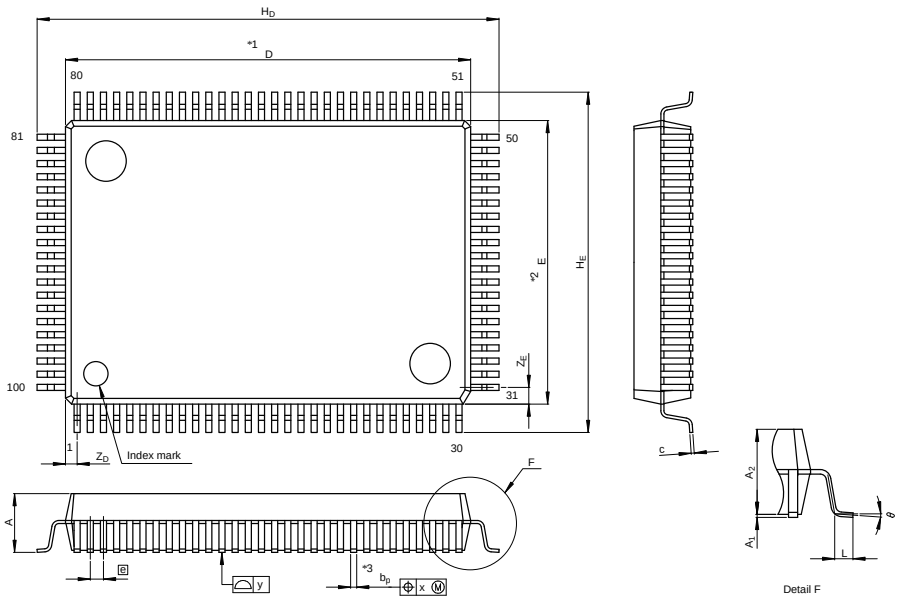
Note the following when using user boot mode:

- 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.

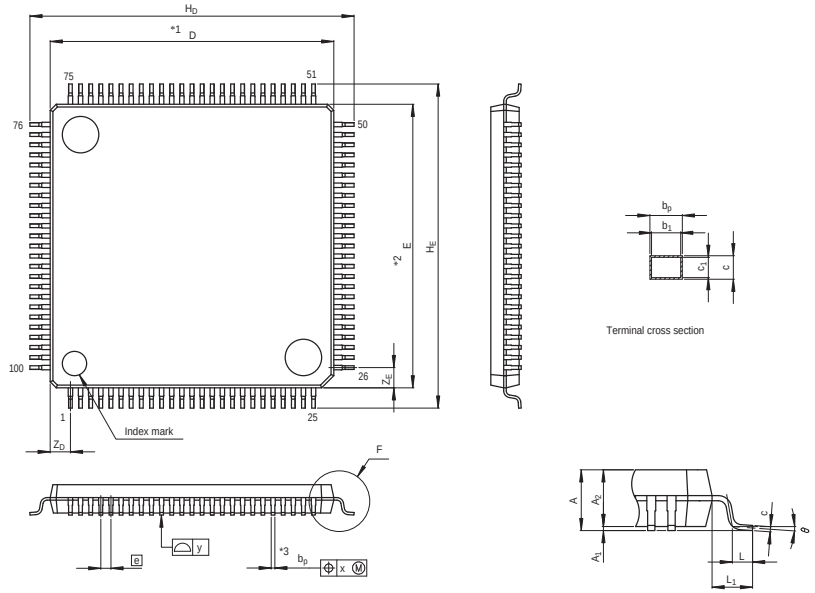
JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-QFP100-14x20-0.65	PRQP0100JD-B	100P6F-A	1.8g



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°
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	—

REGISTER INDEX

N

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1. Items revised or added in this version

REVISION HISTORY	M16C/6C Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
2.10	Jul 31, 2012	**Resets**	
		52	6.2.1 Processor Mode Register 0 (PM0): Added the description regarding PM04 to PM07 to the register explanation.
		60	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.
		60	Figure 6.5 Power-On Reset Circuit and Operation Example: Changed tw(por1) to tw(por).
		Clock Generator	
		89	Figure 8.1 System Clock Generator: Changed a part of the configuration in the PLL frequency synthesizer.
		91	8.2.1 Processor Mode Register 0 (PM0): Added the description regarding PM04 to PM07 to the register explanation.
		107	8.3.6 Sub Clock (fC): Deleted P8_5 in the parenthesis in step (1).
		Processor Mode	
		141	10.2.1 Processor Mode Register 0 (PM0): Added the description regarding PM04 to PM07 to the register explanation.
		142	10.2.2 Processor Mode Register 1 (PM1): Added the description regarding PM11, PM14 and PM15 to the register explanation.
		Bus	
		157	Table 11.7 Pin Functions for Each Processor Mode: Changed the Memory Expansion Mode column for P3_0.
		Programmable I/O Ports	
		171, 172	Figure 13.5 I/O Ports (N-channel Open Drain Output): Partially modified.
		162	11.6.2 Influence of SD: Added TSUDA and TSUDB to the pins.
		Timer A	
		298	17.5.1.3 Influence of $\overline{SD}$: Added TSUDA and TSUDB to the pins.
		Three-Phase Motor Control Timer Function	
		330, 350, 355	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.
		368	19.5.2 Influence of $\overline{SD}$: Added TSUDA and TSUDB to the pins.
		Timer S	
		Chap. 20.	Changed terminologies in this chapter are as follows: • “phase-delayed waveform” to “inverted waveform” • Remove the term “mode” from increment, increment/decrement, and two-phase pulse signal processing. • “channel interrupt” to “IC/OC channel interrupt” • “base timer interrupt” to “IC/OC base timer interrupt” • Appropriate explanations/names are provided for base timer reset depending on its condition. • “fBT1 clock cycles” to “fBT1 cycles”
		Chap. 20.	Added legends where i, j, or k is used to indicate its value.
		370, 371	Figure 20.1 IC/OC Block Diagram (1/2) and Figure 20.2 IC/OC Block Diagram (2/2): Added details.
		372	Table 20.2 I/O Pins: Added note 1 and note 2.
		376	20.2.2 Waveform Generation Register j (G1POj) (j = 0 to 7): Added details.
		377	20.2.3 Waveform Generation Control Register j (G1POCRj) (j = 0 to 7): Changed the explanation of bits MOD1 and MOD0.
		379	20.2.4 Time Measurement Control Register j (G1TMCRj) (j = 0 to 7): • Added some descriptions to the Function columns of bits DFS1 and DFS0, and the GOC bit. • Changed the register explanation. • Added some explanations to bits DFS1 and DFS0, and the GSC bit.
		381	20.2.5 Base Timer Register (G1BT): • Changed the Function column in the register diagram. • Changed the explanation since the write operation to this register is disabled.
		382	20.2.6 Base Timer Control Register 0 (G1BCR0): • Rewrote the first and second paragraphs in the explanation for bits BCK1 and BCK0. • Added the IT bit explanation.

Rev.	Date	Description	
		Page	Summary
2.10	Jul 31, 2012	383	20.2.7 Base Timer Control Register 1 (G1BCR1); Changed the following in the RST1 bit explanation: • Changed the reference target. • Deleted the explanation regarding the G1POj register and moved it to 20.2.2.
		384	20.2.8 Time Measurement Prescaler Register j (G1TPRj) (j = 6 and 7): Added the Set Value column.
		393	Table 20.5 Base Timer Specifications: • Added a condition regarding the BTS bit to the Base timer reset conditions. • Deleted “while the base timer is counting” from “Base timer reset value while the base timer is counting”. • Deleted the Write to base timer row. • Deleted the Selectable functions row and moved the contents to 20.3.1.2 and 20.3.1.3.
		394	Figure 20.3 Base Timer Block Diagram: • Added registers G1DV and G1BT. • Added detailed description of two-phase pulse clock.
		394	Table 20.6 Base Timer Associated Register Settings: Added details.
		395, 396, 397	20.3.1.1 Increment, 20.3.1.2 Increment/Decrement and 20.3.1.3 Two-Phase Pulse Signal Processing: • Added titles and explanations. • Changed descriptions of interrupt requests in figures for each operation.
		398	Figure 20.7 Two-Phase Pulse Signal Processing (When Using the Base Timer Reset): • Deleted the values to indicate timings, and moved the information to the Electrical Characteristics chapter. • Added a condition for the G1DV register.
		399	Figure 20.8 Base Timer Reset with the G1BTRR Register: • Deleted the description of the base timer overflow request. • Added a condition.
		399	Figure 20.9 Base Timer Reset with the G1PO0 Register: Added a condition.
		400	Figure 20.10 Base Timer Reset with $\overline{\text{INT1}}$ Pin Input: Added a condition.
		401, 405	20.3.2 Time Measurement Function and 20.3.3 Waveform Generation Function: Moved under 20.3 Operations.
		401	Table 20.10 Time Measurement Function Specifications: • Changed the Interrupt request to the Interrupt request occurrence timing in the Item column and its specification accordingly. • The explanations for the Gate function in the Selectable functions is simplified.
		402	Table 20.11 Time Measurement Function Associated Registers: • Changed. • Added settings when the gate function is used.
		402	Figure 20.11 Time Measurement Function (1/2): Deleted the description for when the base timer and the G1PO0 register match.
		403	Figure 20.12 Time Measurement Function (2/2): Modified timings.
		404	Figure 20.13 Prescaler and Gate Functions: Modified the timing of the G1IR bit.
		405	20.3.2.1 Gate Function (Channel 6 and 7): Added
		406	Table 20.12 Single-Phase Waveform Output Mode Specifications: • Changed the range of values for m and n. • Changed the Interrupt request to the Interrupt request occurrence timing in the Item column and its specification accordingly. • Added “or I/O port” to the Specification of the OUTC1_ j pin. • Simplified the explanation for the Compare match output in the Selectable functions
		407	Table 20.13 Registers and Settings in Single-Phase Waveform Output Mode: Added.
		409	Figure 20.15 Single-Phase Waveform Output Mode Operation (2/2): • Added “when bits IOj1 and IOj0 are 10b” to the description “Output high by compare match”. • Added a condition regarding the EOCj bit in the G1OER register.
		410	Table 20.14 Inverted Waveform Output Mode Specifications: • Changed the range of values for m and n. • Changed the Interrupt request to the Interrupt request occurrence timing in the Item column and its specification accordingly. • Added “or I/O port” to the Specification of the OUTC1_ j pin.
		411	Table 20.15 Registers and Settings in Inverted Waveform Output Mode: Added.
		413	Figure 20.17 Inverted Waveform Output Mode Operation (2/2): Added “when bits IOj1 and IOj0 are 10b” to the description “Output high by compare match”.

Rev.	Date	Description	
		Page	Summary
2.10	Jul 31, 2012	414	Table 20.16 SR Waveform Output Mode Specifications: • Changed the range of values for m, n and p. • Changed the Interrupt request to the Interrupt request occurrence timing in the Item column and its specification accordingly. • Added “or I/O port” to the Specification of the OUTC1_ j pin.
		415	Table 20.17 Registers and Settings in SR Waveform Output Mode: Added.
		417	Table 20.18 Pin Settings for Time Measurement and Waveform Generation: Simplified.
		418	20.4 Interrupts: Changed.
		420	20.5.2 Changing the G1IR Register: Changed.
		421	Figure 20.20 IC/OC Interrupt 0 Operation Example: Changed from “IC/OC Interrupt 0 and 1 Operation”.
		422	20.5.3 Changing Registers ICOCiIC (i = 0, 1): Changed from “Registers ICOCiIC and ICOCHjIC”.
		422	20.5.4 Output Waveform During the Base Timer Reset with the BTS bit and 20.5.5 OUTC1_0 Pin Output During the Base Timer Reset with the G1PO0 register: Changed from “Waveform Generation Function”.
		422	20.5.6 Interrupt Request When Selecting Time Measurement Function: Added.
		Serial Interface UARTi (i = 0 to 2, 5 to 7)	
		458	22.2.3 UARTi Transmit/Receive Mode Register (UiMR) (i = 0 to 5): Added the description regarding I^2C mode.
		459, 463	22.2.5 UARTi Transmit Buffer Register (UiTB) (i = 0 to 5), 22.2.8 UARTi Receive Buffer Register (UiRB) (i = 0 to 5): Modified the Reset Value.
		489	Table 22.15 “I/O Pin Functions in I^2C Mode”: Added note 1.
		516	22.5.1.1 Influence of $\overline{SD}$: Added TSUDA and TSUDB to the pins.
		Multi-master I^2C-bus Interface	
		567	23.5.3 “Low/High-level Input Voltage and Low-level Output Voltage”: Added.
		USB Function	
		609	24.2.33 USB Module Control Register (USBMC): Changed the USBSTS bit explanation.
		610	24.3.1 USB Clock: Changed “When the USB clock is stable” to “When the USB module is enabled” in the second line.
		615	Figure 24.6 USB Module Initial Setting: Changed.
		616	Figure 24.7 Setting when Connecting the Cable: Added.
		A/D Converter	
		631, 632	Figure 25.2 A/D Converter Block Diagram (A/D0) and Figure 25.3 Block Diagram (A/D1): Unified upper data bus and lower data bus with a single data bus.
		671	25.7.2 Analog Input Pin: Modified the last line of the first paragraph.
		CRC Calculator	
		680	27.2.3 CRC Data Register (CRCD): Added the explanation.
		682	Figure 27.2 CRC Calculation When Using CRC-CCITT and Figure 27.3 CRC Calculation When Using CRC-16: Changed.
		Flash Memory	
		687	28.3.1 Flash Memory Control Register 0 (FMR0): Changed the description of steps in the FMSTP bit explanation.
		Electrical Characteristics	
		Vcc = 5 V	
		741	Table 29.21 Electrical Characteristics (3): Changed the Measuring Condition column of 40 MHz on-chip oscillator for the 40 MHz on-chip oscillator mode in the I_{CC}.
		Vcc = 3 V	
		759	Table 29.41 Electrical Characteristics (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	
		790	30.8.1 Influence of $\overline{SD}$: Added TSUDA and TSUDB to the pins.
		797	30.12.1.3 Influence of $\overline{SD}$: Added TSUDA and TSUDB to the pins.
		803	30.14.2 Influence of $\overline{SD}$: Added TSUDA and TSUDB to the pins.
		804	30.15.2 Changing the G1IR Register: Changed.
		805	Figure 30.10 IC/OC Interrupt 0 Operation Example: Changed from “IC/OC Interrupt 0 and 1 Operation”.
		806	30.15.3 Changing Registers ICOCiIC (i = 0, 1): Changed from “Registers ICOCiIC and ICOCHjIC”.

REVISION HISTORY	M16C/6C Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
2.10	Jul 31, 2012	806	30.15.4 Output Waveform During the Base Timer Reset with the BTS bit and 30.15.5 OUTC1_0 Pin Output During the Base Timer Reset with the G1PO0 register: Changed from “Waveform Generation Function”.
		806	30.15.6 Interrupt Request When Selecting Time Measurement Function: Added.
		809	30.17.1.1 Influence of $\overline{SD}$: Added TSUDA and TSUDB to the pins.
		813	30.18.3 Low/High-level Input Voltage and Low-level Output Voltage: Added
		816	30.20.2 Analog Input Pin: Modified the last line of the first paragraph.

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/6C Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
0.10	Apr 22, 2009	-	First Edition issued.
1.00	Jul 15, 2009	55	Figure 6.3 “Reset Sequence” partially modified
		56	6.4.2 “Hardware Reset” partially modified
		513	22.5.1.3 “CLKi Output” newly added
		615	Figure 24.4 “USB Initial Setting” notes revised
		626	24.6.2 “USB Interrupt Flag Register” newly added
		626	24.6.3 “USB Endpoint Stall Register” newly added
		628	25. “A/D Converter” revised in full scale
		715	28.9.4 “Standard Serial I/O Mode 1” partially modified
		717	28.9.5 “Standard Serial I/O Mode 2” partially modified
		722	29. “Electrical Characteristics” newly added
		795	30.18.1.3 “CLKi Output” newly added
		801	30.21 “Notes on A/D Converter” revised in full scale
2.00	Feb 07, 2011	Overall	0004h Processor Mode Register 0: Combined differing reset values into one.
		Overall	0019h Voltage Detector 2 Flag Register: Changed the reset value from “0000 X000b”.
		Overall	001Ah Voltage Detector Operation Enable Register: Changed reset value from “000X 0000b”.
		Overall	002Ah Voltage Monitor 0 Control Register: Changed reset value from “1100 XX10b”.
		Overall	002Bh Voltage Monitor 1 Control Register: Changed reset value from “1000 1X10b”.
		Overall	02B9h I2C0 Status Register 1: Changed reset value from “00h”.
		Overall	0324h Increment/Decrement Flag: Changed name from Up/Down Flag.
		Overall	03DCh D/A Control Register: Changed reset value from “XXXX XX00b”.
		Overall	Changed the UVCC pin from “Input” to “I/O”.
		Overall	Changed “high-speed clock mode” to “fast-mode”.
		Overview	
		Chap. 1.	Changed from “INPC10 to INPC17” to “INPC1_0 to INPC1_7” and from “OUTC10 to OUTC17” to “OUTC1_0 to OUTC1_7”.
		1	1.1.1 Applications: Added the note.
		3	Table 1.2 Specifications (2/2): • Changed the value in the Current Consumption row to “Described in Electrical Characteristics”. • Deleted note 1.
		4	Table 1.3 Product List: Changed the development status.
		5	Figure 1.2 Marking Diagram (Top View): Added the detail explanations for the 7-digit date code.
		7, 8	Figure 1.4 Pin Assignment and Figure 1.5 Pin Assignment: Added “/TSUDA” to P8_0 and “/TSUDB” to P8_1.
		9	Table 1.4 Pin Names (1/2): Added “/TSUDB” to P8_1 and “/TSUDA” to P8_0.
		11	Table 1.6 Pin Functions (1/3): • Changed the description of CNVSS pin. • Changed the description of $\overline{\text{HOLD}}$ pin.
		12	Table 1.7 Pin Functions (2/3): Added “TSUDA, TSUDB” to the pin name of Timer S.
		13	Table 1.8 Pin Functions (3/3): Deleted notes 1 and 2.
		Address Space	
		18	Figure 3.2 Memory Map: Added note 1 and 3 to the reserved areas.
		Special Function Registers (SFRs)	
		20	Table 4.1 SFR Information (1): • Deleted “the VCR1 register, the VCR2 register” from note 2. • Deleted notes 5 to 6 and added note 5.
		21	Table 4.2 SFR Information (2): Deleted notes 2 to 6 and added note 2.
		35	Table 4.16 SFR Information (16): Deleted “00000010b” from values after hardware reset in note 2.
		43	4.2.1 Register Settings: Added the description regarding read-modify-write instructions.
		44	Table 4.26 Read-Modify-Write Instructions: Added.
		Protection	
		45	5.2.1 Protect Register (PRCR): Deleted “VD1LS” from the Function column of the PRC3 bit.

Revision History	M16C/6C Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	**Resets**	
		Chap. 6.	6.5.4 Hardware Reset When VCC1 < Vdet0: Deleted.
		48	Table 6.1 Types of Resets: Added the "Registers and Bits Not to Reset" column.
		48	Figure 6.1 Reset Circuit Block Diagram: • Deleted register/bit names included in each group of SFRs. • Added the NOR gate next to SFR (A).
		49	Table 6.2 Classification of SFRs Which are Reset: Added.
		50	Table 6.4 Registers: Changed note 1 and the reset value of the RSTFR register.
		51	6.2.2 Reset Source Determine Register (RSTFR): Changed the CWR and OSDR bit explanations.
		52	6.3 Optional Function Select Area: Added the descriptions for the OFS1 address when shipped.
		52	6.3.1 Optional Function Select Address 1 (OFS1): • Deleted the Factory Setting value and RW column. • Changed the Function column of the VDSEL1 bit.
		54	Table 6.7 Pin Status When $\overline{\text{RESET}}$ Pin Level is Low: • Deleted the Microprocessor Mode (CNVSS = VCC1, P5_5 = high) column. • Changed note 1.
		56	Figure 6.3 Reset Sequence: Deleted the lines for $\overline{\text{RD}}$, $\overline{\text{WR}}$, $\overline{\text{CS0}}$, and Address in Single-chip mode.
		58	6.4.3 Power-On Reset Function: • Added line 1. • Added the “the VDSEL1 bit to 0 (Vdet0_2)” to the setting for the power-on reset. • Moved lines 3 to 4 in the previous version to the last line and changed “at 0.8 VCC1 or more” to “in the range of VIH.”
		58	Figure 6.5 Power-On Reset Circuit and Operation Example: Revised.
		59	6.4.5 Voltage Monitor 1 Reset and 6.4.6 Voltage Monitor 2 Reset: Clarified the set mount of time before executing the program.
		61	6.4.10 Cold/Warm Start Discrimination: Added line 2 of the second bullet.
		61	Figure 6.6 Cold/Warm Start Discrimination Example: • Changed “Voltage monitor 0 reset” to “Internal reset signal”. • Changed the timing of the internal reset signal.
		62	6.5.1 Power Supply Rising Gradient: Deleted “VCC1 ≤ 3.6 V” from the table.
		62	Figure 6.7 SVCC Timing (3.6 V < VCC1), Figure 6.8 SVCC Timing (VCC1 ≤ 3.6 V): Revised from Figure 6.7 SVCC Timing.
		62	6.5.2 Power-On Reset: Added the "the VDSEL1 bit to 0 (Vdet0_2)" to the power-on reset setting.
		Voltage Detector	
		64	Table 7.1 Voltage Detector Specifications: • Added the Voltage to the detect field. • Clarified the time in both Voltage Detector 1 and 2 columns of the Reset. • Changed the Voltage Detector 0 column in the Digital filter row.
		65	Figure 7.1 Voltage Detector Block Diagram: Revised.
		66	7.2 Registers: Added the explanations above the table.
		66	Table 7.2 Registers: • Deleted the reset value after a reset other than hardware reset. • Deleted notes 1 to 3.
		68	7.2.2 Voltage Detector Operation Enable Register (VCR2): Changed b4.
		69	7.2.3 Voltage Monitor Function Select Register (VWCE): Changed name and function of b4 from “voltage detectors” to “voltage monitors”.
		70	7.2.4 Voltage Monitor 0 Control Register (VW0C): • Changed b1 from Voltage monitor 0 digital filter disable mode select bit to Reserved bit. • Changed b5 and b4 from Sampling clock select bit to Reserved bit. • Added the explanation of Bit 6.
		71	7.2.5 Voltage Monitor 1 Control Register (VW1C): • Added the lines 2 to 3 below the register diagram. • Added the last 2 lines to the VW1C3 bit explanation.
		73	7.2.6 Voltage Monitor 2 Control Register (VW2C): • Changed the explanation below the register diagram. • Changed “VCC2 reaches Vdet1” in the bit VW2C7 explanation to “VCC1 reaches Vdet2”.
		52	7.3 Optional Function Select Area: Added the descriptions for the OFS1 address when shipped.

Revision History	M16C/6C Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	52	7.3.1 Optional Function Select Address 1 (OFS1): • Deleted the Factory Setting value and RW column. • Changed the Function column of the VDSEL1 bit. • Added the last line to the VDSEL1 bit explanation. • Added line 1 to the LVDAS bit explanation.
		77	Figure 7.3 Voltage Monitor 0 Reset Generator Block Diagram: Revised.
		78	7.4.2.1 Voltage Monitor 0 Reset: • Added lines 2 to 5. • Deleted 2 lines below Table 7.5.
		78	Table 7.5 Procedure for Setting Voltage Monitor 0 Reset Related Bits: Deleted steps 1, 2, 5, and 6.
		78	Figure 7.4 Voltage Monitor 0 Reset Operation Example: Revised.
		79, 82	Figure 7.5 Voltage Monitor 1 Interrupt/Reset Generator and Figure 7.7 Voltage Monitor 2 Interrupt/Reset Generator: • Added a level converter in voltage detector 1 and 2. • Changed the VW1C1/VW2C1 gate from 0 to 1.
		80, 83	Table 7.6 Procedures for Setting Voltage Monitor 1 Interrupt/Reset Related Bits and Table 7.7 Procedure for Setting Voltage Monitor 2 Interrupt/Reset Related Bits: • Changed the sequence of the steps. • Added note 3.
		81, 84	Figure 7.6 Voltage Monitor 1 Interrupt/Reset Operation Example and Figure 7.8 Voltage Monitor 2 Interrupt/Reset Operation Example: • Added the period that internal reset signal is low to the bottom of diagram. • Changed note 1 from “VCC1 ≥ 2.7 V” to “recommended operation condition VCC1”.
		82	7.4.4.1 Monitoring Vdet2: Corrected typo from “VCA13 bit in the VCA1” to “VC13 bit in the VCR1”.
		Clock Generator	
		86	Table 8.1 Clock Generator Specifications: Rewrote the values in the Clock frequency row to symbols.
		87	Figure 8.1 System Clock Generator: • Changed the setting of the CM21 selector. • Changed the logic symbol connected to $\overline{\text{NMI}}$ and PM24. • Changed a part of the main clock.
		88	Table 8.3 Registers: Corrected typo in the 001Ch row from 0X01 X010b to 0001 X010b.
		90	8.2.2 System Clock Control Register 0 (CM0): Changed “CM07 bit is 1” to “CM21 bit in the CM2 register is 0” in the explanation about the CM06 bit.
		92	8.2.3 System Clock Control Register 1 (CM1): • Changed the CM10 bit explanation. • Changed the explanation about the CM15 bit.
		100	8.2.8 Processor Mode Register 2 (PM2): Added the last line in the PM21 bit explanation.
		103	8.3.2 PLL Clock: Changed lines 4 to 5.
		103	Table 8.6 Example Settings for PLL Clock Frequencies (When the PLC06 Bit in the PLC0 Register is 0 (PLLFCK Disabled)): Added the 16 MHz and 8 MHz rows.
		103	Table 8.7 Example Settings for PLL Clock Frequencies (When the PLC06 Bit in the PLC0 Register is 1 (PLLFCK Enabled)): Deleted the rows which contents are 12 MHz in the PLL Clock column.
		104	8.3.3 fOCO40M: Changed “td (OCOF)” to “tsu(fOCO40M)” in step (2).
		104	8.3.4 fOCO-F: Deleted the description for starting/stopping the 40 MHz on-chip oscillator clock.
		104	8.3.5 125 kHz On-Chip Oscillator Clock (fOCO-S): Changed “td(OCOS)” to “tsu(fOCO-S)” in step (2).
		106	8.4.1 CPU Clock and BCLK: • Added lines 6 to 7. • Deleted “Set the CPU clock more than 16 MHz when USB functions are used.”. • Changed the sixth line up from the bottom.
		106	8.4.2 Peripheral Function Clocks (f1, fOCO40M, fOCO-F, fOCO-S, fC32, fC, PLLFCK): Deleted “fC is used for the watchdog timer.” in the seventh line up from the bottom.
		114	8.9.3 CPU Clock: Added the technical update number.
		115	8.9.5 PLL Frequency Synthesizer: Added.
		Power Control	
		117	9.2.1 Flash Memory Control Register 0 (FMR0): Changed the FMR01 and FMSTP bit explanations.
		118	9.2.2 Flash Memory Control Register 2 (FMR2): Changed the FMR23 bit explanation.
		120	9.3.1.2 PLL Operating Mode: Deleted “high-speed mode” from the last 3 lines.

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	121	9.3.1.7 Low Power Mode: Deleted the last 3 lines in the previous version.
		122	Table 9.2 Clocks in Normal Operating Mode: Deleted notes 2 to 6 in the previous version and newly added note 2.
		124	9.3.2 Clock Mode Transition Procedure: • Changed the arrow “i” to “e” in the Figure 9.1. • Divided high-speed mode and medium-speed mode in Figure 9.2. • Deleted “g”, “h”, and “i” from 125 kHz on-chip oscillator mode in Figure 9.2. • Added” 40 MHz on-chip oscillator mode” to the explanation of “e”. • Deleted the explanation of “i”.
		128	9.3.3 Wait Mode: Changed the last line.
		128	9.3.3.1 Peripheral Function Clock Stop Function: Added “fOCO40M” to line 3.
		128	9.3.3.2 Entering Wait Mode: Added line 5 and below.
		129	9.3.3.4 Exiting Wait Mode: Deleted the 2 paragraphs below the table.
		129	Table 9.7 Resets and Interrupts to Exit Wait Mode and Conditions for Use: • Changed the conditions for use in the Voltage monitor 1, Voltage monitor 2 row. • Divided the Voltage monitor 1 reset, Voltage monitor 2 reset row from the Voltage monitor 0 reset row and changed the conditions for use.
		130	9.3.4.1 Entering Stop Mode: Added line 8 and below.
		130	Table 9.8 Pin Status in Stop Mode: Combine the FC selected row and the f1, f8, f32 selected row.
		131	9.3.4.3 Exiting Stop Mode: Deleted the second paragraph in the previous version.
		131	Table 9.9 Resets and Interrupts to Exit Stop Mode and Conditions for Use: Changed the conditions for use in the Voltage monitor 0 reset row.
		131	Table 9.10 CPU Clock After Exiting Stop Mode: Deleted “FOCO-F divided by 1” in the fourth row.
		132	Figure 9.3 Stop and Restart of the Flash Memory: • Changed the ranges of Stop Procedure and Restart Procedure. •Deleted note 4.
		133	9.4.2.1 Slow Read Mode: Added lines 3 and 4.
		133, 134	Figure 9.4 Setting and Canceling Slow Read Mode and Figure 9.5 Setting and Canceling Low Current Consumption Read Mode: Deleted “Restore the CPU clock” from the canceling procedure.
		135	9.5.2 A/D Converter: Deleted the explanation for when A/D conversion is performed.
		136	9.6.1 CPU Clock: Added line 2.
		136	9.6.2 Wait Mode: • Added lines 4 and 5 to the first bullet. • Deleted second bullet in the previous version and added the second to fifth bullets.
		136	9.6.3 Stop Mode: • Changed “until main clock oscillation is stabilized” in line 1 to “for 20 fOCO-S cycles or more”. • Added lines 6 to 8 to the third bullet. • Deleted fourth bullet in the previous version and added fourth to eighth bullets.
		137	9.6.4 Low Current Consumption Read Mode: Added the third bullet.
		137	9.6.5 Slow Read Mode: Added.
		Processor Mode	
		Chap. 10.	Table 10.2 I/O Pins: Deleted.
		139	10.2.1 Processor Mode Register 0 (PM0): Added the technical update number to the explanation of bits PM01 to PM00.
		143	10.3.1 Processor Mode Settings: • Deleted the descriptions for CNVSS pin input level. • Deleted Table 10.8 Processor Mode after Hardware Reset, Power-On Reset, or Voltage Monitor 0 Reset.
		Bus	
		Chap. 11.	11.3.5.7 $\overline{\text{HOLD}}$ Signal: Deleted.
		Chap. 11.	11.4.2 External Bus: Deleted.
		145	Table 11.1 Bus Specifications: • Changed the number of software waits in the Internal Bus row from “0 to 2” to “0 or 1”. • Deleted “$\overline{\text{HOLD}}$, $\overline{\text{HDLA}}$ available” in the External Bus row.
		146	11.2.1 Chip Select Control Register (CSR): Added the modes to the third bullet in the CSiW bit explanation.

Revision History	M16C/6C Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	148	11.3.1.2 Bus Hold: • Deleted the second condition to enter hold state “Inputting a low-level signal to the $\overline{\text{HOLD}}$ pin....”. • Added the fourth bullet to the explanations when the bus is in hold state.
		155	Table 11.7 Pin Functions for Each Processor Mode: Deleted note 1.
		157	Table 11.9 Bits and Bus Cycles Related to Software Wait States (External Area): Added note 5.
		158	Figure 11.6 Typical Bus Timings Using Software Wait States (1/2): Corrected the typo in figure (1) from “Bus cycle = 2ϕ" to “Bus cycle = 1ϕ".
		160	11.4.3 $\overline{\text{HOLD}}$: Added.
		Programmable I/O Ports	
		165	13.2 I/O Ports and Pins: Changed the style and layout.
		176	Table 13.9 Registers: Deleted “00000010b” from values after hardware reset in note 1.
		178	13.3.2 Pull-Up Control Register 1 (PUR1): Deleted “00000010b” from values after hardware reset.
		179	13.3.3 Pull-Up Control Register 2 (PUR2): Changed the PU21 bit from “P8_4 to P8_7 pull-up” to “P8_4, P8_6, P8_7 pull-up”.
		184	13.4.2 Priority Level of Peripheral Function I/O: Deleted the last bullet and the Table 13.5 Priority Level of Peripheral Function Output.
		186, 187	Table 13.11 Unassigned Pin Handling in Single-Chip Mode and Table 13.12 Unassigned Pin Handling in Memory Expansion Mode and Microprocessor Mode: Changed “Open” in the UVCC row to “Connect to VCC1”.
		186, 187	Figure 13.14 Unassigned Pin Handling in Single-Chip Mode and Figure 13.15 Unassigned Pin Handling in Memory Expansion Mode and Microprocessor Mode: Changed "OPEN" connected with the UVCC to "VCC1".
		Interrupts	
		193, 194	14.2.2 Interrupt Control Register 1 and 14.2.3 Interrupt Control Register 2: • Moved the description for symbols and addresses to tables below the register diagram. • Changed the IR bit explanations.
		195	14.2.4 “Interrupt Control Register 3: Modified the IR bit explanation.
		198	14.2.7 Interrupt Source Select Register (IFSR): Changed the explanation for 0 in the Function columns of bits IFSR6 and IFSR7.
		202	14.2.12 $\overline{\text{NMI}}$/SD Digital Filter Register (NMIDF): Added the explanation below the register diagram.
		204	14.4.4 INT Instruction Interrupt: Changed the software interrupt numbers in line 2 from “59, and 60” to “54 to 63”.
		207	14.6.2 Relocatable Vector Tables: Added note (6) to the INT instruction interrupt row.
		209	14.7.1.2 IR Bit: Rewritten.
		219	14.13.2 SP Setting: Deleted the descriptions regarding the $\overline{\text{NMI}}$ interrupt.
		219	14.13.3 $\overline{\text{NMI}}$ Interrupt: Added the second bullet.
		221	14.13.5 Rewriting the Interrupt Control Register and 14.13.6 Instruction to Rewrite the Interrupt Control Register: Rewritten from 14.13.5 Rewriting the Interrupt Control Register in the previous version.
		222	14.13.8 IR bits in the USBINT0IC, USBINT1IC and USBRSMIC registers: Rewritten.
		Watchdog Timer	
		224	15.2.1 Voltage Monitor 2 Control Register (VW2C): Changed the explanation below the diagram.
		225	15.2.2 Count Source Protection Mode Register (CSPR): Changed the content of b6 to b0.
		228	15.3 Optional Function Select Area: Added the descriptions for the OFS1 address when shipped.
		228	15.3.1 Optional Function Select Address 1 (OFS1): • Deleted the Factory Setting value and RW column. • Changed the Function column of the VDSEL1 bit. • Deleted the explanation below the diagram.
		DMAC	
		243	16.3.3 Transfer Cycles: Changed “one cycle” to “one bus cycle” in line 5.
		242	Table 16.7 Timing at Which the DMAS Bit Value Changes: Changed “bits DSEL4 to DSEL0” in the External factor row to “bits DSEL4 to DSEL0 and DMS”.
		250	16.5.1 Write to the DMAE Bit in the DMiCON Register (i = 0 to 3): Added the technical update number.
		Timer A	
		252	Figure 17.2 Timer A Configuration: Deleted “programmable output mode” from 11b of timer A0 and timer A3.

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	253	Figure 17.3 Timer A Block Diagram: Moved POFSi to right of MR0.
		253	Table 17.3 I/O Ports: Added “programmable output” in the TAiIN row.
		257	17.2.4 Timer A Count Source Select Register 2: Corrected the typo in the Function column of TCS3 bit.
		270, 283, 287, 292	Table 17.7, Table 17.13, Table 17.15, and Table 17.17 Registers and Settings: Changed the Bit column of the TAi1 and TAi from “7 to 0”.
		273, 277	Table 17.8 and Table 17.10 Event Counter Mode Specifications: Added “When selecting reload type:” in the Number of counts row.
		274	Table 17.9 Registers and Settings in Event Counter Mode (When Not Using Two-Phase Pulse Signal Processing): • Changed the Setting column in the PCLKR, TCKDIVC0, and TACS0 to TACS2 rows. • Changed the Bit column of the TAi1 and TAi from “7 to 0”.
		278	Table 17.11 Registers and Settings in Event Counter Mode (When Processing Two-Phase Pulse Signal): • Changed the Setting column in the PCLKR, TCKDIVC0, TACS0 to TACS2, and ONSF rows. • Changed the Bit column of the TAi1 and TAi from “7 to 0”.
		291	17.3.7 Programmable Output Mode (Timers A1, A2, and A4): Added “when the MR2 bit is 1” to the MR1 bit explanation of the Programmable Output Mode Timer Ai Mode Register (i = 1, 2, 4).
		296	17.5.1.2 Event or Trigger: Added.
		296	17.5.1.3 Influence of $\overline{SD}$: Added.
		Timer B	
		308	18.2.6 Timer B Count Source Select Register 0, Timer B Count Source Select Register 2: Corrected the typo in the Function column of the TCS7 bit.
		314, 320	Table 18.6 and Table 18.10 Registers and Settings: Changed the Bit column of the TBi1 and TBi from “7 to 0”.
		316	Table 18.8 Registers and Settings in Event Counter Mode: • Changed the Setting column in the PCLKR, TCKDIVC0, and TBCS0 to TBCS2 rows. • Changed the Bit column of the TBi1 and TBi from “7 to 0”.
		316	Timer Bi Mode Register (i = 0 to 5) in 18.3.3 Event Counter Mode: • Changed the Function column of the TCK1 bit. • Added the TCK1 bit explanation.
		319	Table 18.9 Specifications of Pulse Period/Pulse Width Measurement Modes: • Deleted the specification ”when counting” in the Write to timer row. • Changed note 3.
		325	18.5.3.2 Event: Added.
		326	18.5.4.3 Event or Trigger: Added.
		Three-Phase Motor Control Timer	
		328	Table 19.1 Three-Phase Motor Control Timer Function Specifications: Added “fOCO-F” to the Carrier wave cycle and Three-phase PWM output width rows.
		346	19.3.1.8 Three-Phase Output Forced Cutoff Function: Added step (2).
		347	Figure 19.5 Position-Data-Retain Function (U-Phase) Operation: Added the second bullet.
		349, 354, 361	Table 19.9, Table 19.12, and Table 19.16 Registers Used and Settings: • Added the TB0EN, TB1EN, TB2SEL fields in the TB2SC row. • Changed “b7 to b2” in the TB2SC row to “b7 to b5”.
		351, 356, 363	Figure 19.6, Figure 19.7, and Figure 19.9 Usage Example: Modified the descriptions below the diagram.
		353	Table 19.11 Three-Phase Mode 1 Specifications: Changed the second and third bullets in the Timer B2 interrupt row.
		365	19.4.1 Timer B2 Interrupt: Modified the interrupt request timings.
		366	19.5.2 Influence of $\overline{SD}$: Changed the section title and descriptions.
		Timer S	
		Chap. 18	Changed “P8_0” and “P8_1” to ”TSUDA” and “TSUDB”, respectively.
		369	Table 20.2 I/O Pins: Added pins TSUDA, TSUDB, and $\overline{INT1}$
		372	20.2.2 Waveform Generation Register j (G1POj) (j = 0 to 7): Changed the description in lines 1 and 2 below the register diagram.

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	373	20.2.3 Waveform Generation Control Register j (G1POCRj) (j = 0 to 7): • Changed the RW column of the b6. • Changed the last sentence of the explanation of bits MOD1 and MOD0.
		375	20.2.4 Time Measurement Control Register j (G1TMCRj) (j = 0 to 7): Added “internal circuit” to the last sentence of the explanation of bits GT, GOC, and GSC.
		376	20.2.5 Base Timer Register (G1BT): Added “the state is released” to third line up from the bottom.
		377	20.2.6 Base Timer Control Register 0 (G1BCR0): Changed lines 1 to 4 in the explanation of bits BCK1 and BCK0.
		378	20.2.7 Base Timer Control Register 1 (G1BCR1): • Added “while the RST1 bit is 1” to line 3 in the RST1 bit explanation. • Changed the BTS bit explanation.
		379, 379	20.2.8 Time Measurement Prescaler Register j (G1TPRj) (j = 6 and 7) and 20.2.9 Function Enable Register (G1FE): Changed the first sentence of the description below the register diagram.
		381	20.2.11 Base Timer Reset Register (G1BTRR): Changed the description in lines 1 and 2 below the register diagram.
		382	20.2.13 Waveform Output Master Enable Register (G1OER): Changed “set the EOCj bit to 0” to “set the EOCj bit to 1” in line 4 below the register diagram.
		383, 384	20.2.14 and 20.2.15 Timer S I/O Control Register 0 and 1 (G1IOR0, G1IOR1): Changed the first sentence of the description below the register diagram.
		385	20.2.16 Interrupt Request Register (G1IR): Changed the description below the register diagram.
		388	Table 20.5 Base Timer Specifications: • Changed the second bullet in the Specification column of the Read from base timer. • Changed the Specification column of the Write to base timer. • Deleted the last 4 lines of the second bullet in the Specification column of the Selectable functions.
		394	Figure 20.8 Base Timer Reset with $\overline{\text{INT1}}$ Pin Input: Changed note 2.
		395	20.4 Time Measurement Function: Changed line 1.
		395	Table 20.10 Time Measurement Function Specifications: Deleted “the interrupt request is generated” from the Specification column of Interrupt request.
		397	Figure 20.10 Time Measurement Function (2/2): Added “However, values in the G1TMj register change.” to note 2 in (2).
		399	20.5 Waveform Generation Function: Changed line 1.
		399	Table 20.12 Waveform Generation Associated Registers and Settings: Changed the Function column of G1OER.
		397	Figure 20.12 Single-Phase Waveform Output Mode Operation (1/2): Corrected the typo in figure (1) from “fBTi” to “fBT1”.
		406	Table 20.15 SR Waveform Output Mode Specifications: Added the third bullet to the Specifications column of the Selectable functions row.
		412	20.8.1 Register Access: Added.
		412	20.8.2 Changing the G1IR Register: Changed the title and description.
		Real-Time Clock	
		419, 420, 421	21.2.2 Real-Time Clock Minute Data Register (RTCMIN), 21.2.3 Real-Time Clock Hour Data Register (RTCHR), and 21.2.4 Real-Time Clock Day Data Register (RTCWK): Added “When the digit increments from the register, 1 is added.” to the bit explanations.
		422	21.2.5 Real-Time Clock Control Register 1 (RTCCR1): Added “RTCCSEC, RTCCMIN, and RTCCHR” to note 1.
		441	21.5.4 Time Reading Procedure in Real-Time Clock Mode: Rewrite the step for “Monitoring by a program 2” as Figure 21.11 Time Data Reading
		Serial Interface UARTi	
		Chap. 22.	Changed the sequence of the register diagrams.
		Chap. 22.	22.3.1.1 and 22.3.2.2 Transmit/Receive Circuit Initialization: Deleted.
		Chap. 22.	22.3.3.4 Transmit/Receive Clock: Deleted.
		Chap. 22.	Figure 22.24 and Figure 22.25 Transmission and Reception Timing: Deleted.
		Chap. 22.	22.5.3 UART (Clock Asynchronous Serial I/O) Mode: Deleted.
		442	Table 22.1 UARTi Specifications (i = 0 to 5): Changed the descriptions for special mode 1 and 2.

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	442	Table 22.2 Specification Differences between UART0 to UART5: Deleted the Memory expansion mode or microprocessor mode row.
		443 to 445	Figure 22.1 to Figure 22.3 UARTi Block Diagram: Changed the values of SMD2 to SMD0.
		450	22.2.3 UARTi Transmit/Receive Mode Register (UiMR) (i = 0 to 5): Added the explanation of bits SMD2 to SMD0.
		451	22.2.4 UARTi Bit Rate Register (UiBRG) (i = 0 to 5): Added the setting range in I^2C mode.
		451	22.2.5 UARTi Transmit Buffer Register (UiTB) (i = 0 to 5): Added “or I^2C mode" after “When character length is 9 bits long,”.
		458	22.2.10 UARTi Special Mode Register 4 (UiSMR4) (i = 0 to 5): • Changed the bit names of bits SCLHI and SWC9. • Changed the functions of bits STSPSEL, SCLHI, and SWC9. • Changed and added all the bit explanations.
		461	22.2.12 UARTi Special Mode Register 2 (UiSMR2) (i = 0 to 5): • Changed the bit names of bits SWC, ALS, and STAC. • Changed the functions of bits other than b7.
		463	Table 22.5 Clock Synchronous Serial I/O Mode Specifications: Changed note 1.
		470	22.3.1.8, 22.3.2.7 Processing When Terminating Communication or When an Error Occurs: Added.
		475	Figure 22.13 Receive Timing in UART Mode: Changed “UiBRG countsource” to “Clock divided by UiBRG”.
		480	Table 22.14 I^2C Mode Specifications: • Changed “00h to FFh” to “03h to FFh” in the Transmit/receive clock row. • Changed the Interrupt request generation timing row. • Changed note 1.
		481	Figure 22.18 I^2C Mode Block Diagram: Changed “9th bit falling edge” to “8th bit falling edge” below the CLK control.
		481	Figure 22.19 Internal Clock Configuration: Added.
		482	Table 22.16 Registers Used and Settings in I^2C Mode (1/2): Changed the function of the UiTB register.
		483	Table 22.17 Registers Used and Settings in I^2C Mode (2/2): Changed the function of the SWC bit and CKPH bit.
		484	Table 22.18 I^2C Mode Functions: • Deleted the description that the I^2C mode functions vary depending on the CKPH bit in the UiSMR3 register. • Deleted “CKPH = 0” fields. • Changed the IICM2 = 1 column in the Transmission, NACK interrupt and Timing for transferring data from UART reception shift register to UiRB register rows. • Deleted the Noise filter width row. • Changed the IICM2 = 1 column in the Read received data row. • Added note 3.
		485	Figure 22.20 Transfer to UiRB Register and Interrupt Timing: Deleted “(1) IICM2 = 0 (ACK and NACK interrupts), CKPH = 0 (no clock delay)” and “(3) IICM2 = 1 (UART transmit/receive interrupt), CKPH = 0”.
		486	22.3.3.1 Detecting Start and Stop Conditions: • Changed lines 1 and 2. • Added the last 3 lines.
		486	Figure 22.21 Detecting Start and Stop Conditions: Rewritten.
		486	22.3.3.2 Generating Start and Stop Conditions: Changed the title.
		487	Figure 22.22 STSPSEL Bit Functions: Rewritten.
		488	Figure 22.23 Register Setting Procedures for Condition Generation: Added.
		489	22.3.3.3 Arbitration: Rewritten.
		489	22.3.3.4 SCL Control and Clock Synchronization: Added, including Figure 22.24 and Figure 22.25.
		491	22.3.3.5 SCL Clock Frequency: Added, including Figure 22.26.
		492	22.3.3.6 SDA Output Control: Rewritten and added Figure 22.27 and Figure 22.28.
		493	22.3.3.7 SDA Digital Delay: Added, including Figure 22.28.
		493	22.3.3.8 SDA Input: Rewritten and added Figure 22.30 and Figure 22.31.
		494	22.3.3.9 ACK and NACK: Rewritten.
		494	22.3.3.10 Initialization of Transmission/Reception: Added the last 2 lines.

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	495	Table 22.20 Special Mode 2 Specifications: • Deleted the description for slave mode in the Transmit/receive clock row. • Deleted note 1.
		496	Figure 22.32 Serial Bus Communication Control Example in Special Mode 2 (UART2): Changed the pin names in the MCU (slave).
		496	Table 22.21 I/O Pin Functions in Special Mode 2: Deleted Input field in the CLKi row.
		497	Table 22.22 Registers Used and Settings in Special Mode 2: Deleted "in master mode or 1 in slave mode" in the CKDIR bit row.
		501	Table 22.24 SIM Mode Specifications: Changed note 2.
		503	Figure 22.35 Transmit/Receive Timing in SIM Mode: Added the timing when the IR bit in the S2TIC register becomes 1.
		506	22.4.1 Interrupt Related Registers: Changed the description about Special mode 4 (SIM mode).
		508, 509	22.5.2.2 Transmission and 22.5.2.3 Reception: Changed the explanations about the external clock level into bullet lists.
		509	22.5.3.1 Generating Start and Stop Conditions: Added the technical update number.
		510 to 511	22.5.3.3 Low/High-level Input Voltage and Low-level Output Voltage to 22.5.3.7 Requirements to Start Transmission/Reception in Slave Mode: Added.
		511	22.5.4 Special Mode 4 (SIM Mode): • Added the technical update number. • Changed the conditions to generate a transmit interrupt request.
		Multi-master I²C-bus Interface	
		513	Table 23.2 I²C Interface Detection Function: Added “SCLMM” to the Arbitration lost detection row.
		519	23.2.4 I2C0 Control Register 0 (S1D0): Deleted “stop condition” from explanation of bits BC2 to BC0.
		521	23.2.5 I2C0 Clock Control Register (S20): • Changed the last lines of the explanations of bits CCR4 to CCR0 and FASTMODE. • Added the slave address content when the MSLAD bit in the S4D0 register is 0 to Table 23.5.
		528	23.2.8 I2C0 Control Register 2 (S4D0): • Changed ”Slave address compare bit” in the register diagram to “Slave address control bit”. • Added ”Rewrite this bit when the TOE bit is 0.” to the TOSEL bit explanation.
		530	23.2.9 I2C0 Status Register 0 (S10): • Rewrote the LRB bit explanation. • Changed the conditions to become 1 in the AAS bit explanation. • Changed the conditions to become 0 in the PIN bit explanation.
		531	Table 23.10 Functions Enabled by Writing to the S10 Register: Added the setting values for the each communication mode.
		535	23.2.10 I2C0 Status Register 1 (S11): • Changed b7 to b3 from “reserved bits” to “no register bits”. • Added lines 5 and 6 in the AAS0 bit explanation.
		537	23.3.1.2 Bit Rate and Duty Cycle: Added the descriptions about the FASTMODE bit.
		539	23.3.2 Generating a Start Condition: Changed the second to third lines up from Figure 23.6.
		545	23.3.6 Arbitration Lost: Changed “When the ALS bit in the S1D0 register is 1” to “When the ALS bit in the S1D0 register is 0” in the eighth line from the bottom.
		548	Table 23.15 Recommended Values of Bits SSC4 to SSC0 in Standard Clock Mode: Changed the BB Bit Setting/Resetting Time column in the 5 MHz row from “4.125 μs”.
		553	23.3.10.3 Master Reception: Changed the set value to the LSB from 0 to 1 in (A) Slave address transmission.
		559	23.5.2.2 S1D0 Register: Corrected the typos from “S10 Register” to “S1D0 Register”.
		USB Function	
		Chap. 24.	Corrected typos in symbols. (However, no errors were found within the register diagrams.)
		561	Table 24.2 Endpoint Configuration: Added note 1.
		564	24.2.1 USB Interrupt Flag Register 0 (USBIFR0): Added “VBUSMN bit in the USBIFR0 register is 1” to the CFDN explanation.
		572	24.2.5 USB Interrupt Enable Register 0 (USBIER0): Changed the function of the SSRSME bit.
		585	24.2.22 USB Trigger Register 0 (USBTRG0): Added the second to third lines up from the bottom.
		589	24.2.26 USB Endpoint Stall Register 0 (USBEPSTL0): Changed the second bullet in the EP0STLS bit explanation.

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	595	24.2.30 USB Configuration Value Register (USBCVR): Changed “SET_INTERFACE” in the CNFV0 and CNFV1 rows to “Set Configuration”.
		597 to 600	Table 24.5 Write Order and Meanings of the Endpoint Information and Table 24.7 to Table 24.12 Write Value for Endpoint: Deleted “1” from the Alternate setting field.
		602	24.3.2 Internal Power for the USB Module and UVCC Pin: • Changed “leave the UVCC pin open” to “connect the UVCC pin to VCC1” in the last sentence. • Deleted the last sentence.
		603 to 606	24.3.3 Self-Powered Mode Circuit (3.3 V), 24.3.4 Self-Powered Mode Circuit (5.0 V), 24.3.5 Bus-Powered Mode (3.3 V), and 24.3.6 Bus-Powered Mode (5.0 V): Revised from 24.3.3 Bus-powered Mode and 24.3.4 Self-powered Mode in the previous version.
		607	Figure 24.6 USB Module Initial Setting: Deleted “Set power mode” and “ATTACH output ON/OFF selected” in the explanation of the lower flowchart.
		618	24.6.5 Internal Power for USB Module and UVCC Pin: Changed the “to the UVCC pins” in the fourth line to “between the UVCC pin and VSS”.
		619	24.6.6 Settings When Not Using the USB Module: • Changed “leave the UVCC pin open” to “connect the UVCC pin to VCC1”. • Deleted the last sentence.
		619	24.6.8 Entering Wait mode or Stop Mode and 24.6.9 Low Supply Voltage: Added.
		A/D Converter	
		648, 651, 655, 658	Table 25.14 to Table 25.15 Registers and Settings in One-Shot Mode (A/D0, 1), Table 25.18 to Table 25.19 Registers and Settings in Repeat Mode (A/D0, 1), Table 25.22 to Table 25.23 Registers and Settings in Single Sweep Mode (A/D0, 1), Table 25.26 to Table 25.27 Registers and Settings in Repeat Sweep Mode 0 (A/D0, 1): Deleted the lines “Set to 0”.
		649, 652, 656, 659	Figure 25.7 to Figure 25.10 Operation Example: Minor addition to the figure contents.
		662	25.7.1 Analog Input Voltage: Added the section title.
		662	25.7.2 Analog Input Pin: Deleted the bracketed sentence in the second paragraph.
		664	25.7.12 ϕAD: Added.
		D/A Converter	
		667	Figure 26.2 D/A Converter Equivalent Circuit: Changed the direction of the DAiE bit in the DACON register.
		CRC Calculator	
		Chap. 27.	Changed the order of the registers.
		670	27.2.1 SFR Snoop Address Register (CRCSAR): Changed the explanation of bits CRCSR and CRCSW.
		Flash Memory	
		Chap.28.	28.8.4.1 Sequencer Status (Bits SR7 and FMR00), 28.8.4.2 Erase Status (Bits SR5 and FMR07), and 28.8.4.3 Program Status (Bits SR4 and FMR06): Deleted.
		Chap.28.	28.11.1 Functions to Prevent Flash Memory from Being Rewritten: Deleted.
		676	Table 28.2 Flash Memory Rewrite Modes Overview: Added “CPU operating mode” and “On-board rewrite” rows.
		677	28.2 Memory Map: Added the last 2 lines.
		677	Table 28.3 Program ROM 1, Program ROM 2, and Data Flash: Added the User boot program row.
		680	28.3.1 Flash Memory Control Register 0 (FMR0): • Added the conditions to become 0 in the FMR00 bit explanation. • Added lines 4 to 5 of the FMR01 explanation. • Added the last line in the FMR02 explanation. • Added the description for the FMR22 bit to the last paragraph of the FMSTP bit explanation. • Deleted “read lock bit status” from the explanation of bits FMR06 and FMR07.
		682	28.3.2 Flash Memory Control Register 1 (FMR1): Added the FMR11 bit explanation and lines 2 to 3 of the FMR17 explanation.
		684	28.3.4 Flash Memory Control Register 6 (FMR6): Added the lines 3 to 4 of the FMR60 explanation.
		685	28.4 Optional Function Select Area: Added the descriptions for the OFS1 address when shipped.
		685	Figure 28.2 Option Function Select Area: Added.

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	686	28.4.1 Optional Function Select Address 1 (OFS1): • Added the section title. • Deleted the Factory Setting value and RW column. • Changed the Function column of the VDSEL1 bit.
		687	28.7 User Boot Mode: Added.
		687	28.7.1 User Boot Function Deleted “The content of the OFS1 address is valid.” from the third paragraph below Table 28.6.
		689	Table 28.9 Addresses of Selectable Ports for Entry: Divided the Address column into columns “13FF9h” and “13FF8h”.
		689	Table 28.10 Example Settings of User Boot Code Area: Added.
		690	Figure 28.4 Program Starting Address in User Boot Mode: Added.
		691	Table 28.11 EW0 Mode and EW1 Mode: • Changed the EW1 Mode column in the State during auto write and auto erase row. • Changed note 1.
		692	28.8.1 EW0 Mode: • Deleted lines 4 to 5. • Deleted “the flash memory is reset. The flash memory restarts after a certain period of time” from the second bullet below Figure 28.5. • Changed the last paragraph.
		692, 694	Figure 28.5 Setting and Resetting of EW0 Mode and Figure 28.6 Setting and Resetting of EW1 Mode: Added “(Set the CPU clock 10 MHz or lower with one wait)” below “Set registers CM0, CM1, and PM1”.
		693, 695	Table 28.12 and Table 28.13 Modes after Executing Commands: Added.
		694	28.8.2 EW1 Mode: • Deleted lines 3 to 4 in the previous version. • Deleted “the flash memory is reset. The flash memory restarts after a certain period of time” from the third bullet below Figure 28.6. • Added the description for the CSPRO bit to the last paragraph.
		697	Table 28.15 Software Commands: Added note 1.
		699, 700	28.8.5.4 Program Command, 28.8.5.5 Block Erase Command: Deleted the description for the status register in EW0 mode.
		702	Figure 28.13 Read Lock Bit Status Command: • Changed “FMR16 = 0?” to “Read the FMR16 bit”. • Changed “Block is locked” and “Block is not locked” to “Read lock bit status completed”.
		703	28.8.5.8 Block Blank Check Command: Added the explanation below Figure 28.14.
		703	Figure 28.14 Block Blank Check Command: • Changed “FMR07 = 0?” to “FMR06 = 1 FMR07 = 1?” and “Read the FMR07 bit”. • Changed “Blank” and “Not blank” to “Block blank check completed”.
		704	28.8.6 Status Register: Rewritten the explanation about reading of status register as Table 28.16 Difference in Reading of Status Register.
		705	Table 28.18 Errors and FMR0 Register States: • Changed the Error Occurrence Conditions column in the Command sequence error row. • Changed note 1.
		705, 706	Figure 28.15 Full Status Check and 28.8.6.2 Handling Procedure for Errors: Rewritten from Figure 28.11 Full Status Check and Handling Procedure for Errors
		709	28.9.2 Forced Erase Function: Added “the ROMCR bit in the OFS1 address is 1 (ROMCP1 bit enabled)” to the first paragraph.
		709	28.9.3 Standard Serial I/O Mode Disable Function: Added “the ROMCR bit in the OFS1 address is 1 (ROMCP1 bit enabled)” to the second paragraph.
		710, 712	Table 28.21 and Table 28.23 Pin Functions (Flash Memory Standard Serial I/O Mode 1, 2): Added the description of the VREF pin.
		712	28.9.5 Standard Serial I/O Mode 2: Added “The main clock is used.” to line 2.
		713	Figure 28.18 Circuit Application in Standard Serial I/O Mode 2: • Moved P6_5/CLK1 to a lower position. • Added note 1.
		713	28.10.1 ROM Code Protect Function: Added the description for the ROMCR bit.
		714	28.11.1 OFS1 Address and ID Code Storage Address: Added.

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	715	28.11.3.2 CPU Rewrite Mode Select: Added.
		715	28.11.3.7 DMA transfer: Added the description for EW0 mode.
		716	28.11.3.10 Software Command: • Revised from 28.10.3.9 Low Power Mode and On-Chip Oscillator Low Power Mode. • Added (a) to (e).
		716	28.11.3.14 Suspending the Auto-Erase and Auto-Program Operations: Added the details on reset to the first bullet.
		717	28.11.4 User Boot: • Changed the section title from Standard Serial I/O Mode. • Changed “28.10.4.1 User Boot Mode” to “28.11.4.1 User Boot Mode Program” and added the first to seventh bullets.
		Electrical Characteristics	
		Chap. 29.	Moved the measuring conditions in note 1 to below the table title.
		Chap. 29.	Reordered figures and tables in 29.2.2 Timing Requirements (Peripheral Functions and Others) and 29.3.2 Timing Requirements (Peripheral Functions and Others).
		718	Table 29.1 Absolute Maximum Ratings: • Changed the Condition of the V_{cc2} row. • Added the V_{REF} row. • Added a row for the data area value to T_{opr} (Flash program erase). • Added the note 1.
		719	Table 29.2 Recommended Operating Conditions (1/3): Added the $I_{OH(sum)}$ row and deleted note 3.
		720	Table 29.3 Recommended Operating Conditions (2/3): Added the $I_{OL(sum)}$ row and deleted note 3.
		722	Table 29.5 A/D Conversion Characteristics (1/2): Added the Measuring Condition of the Resolution row.
		723	Table 29.6 A/D Conversion Characteristics (2/2): Added the note 5.
		725	Table 29.9 CPU Clock When Operating Flash Memory ($f_{(BCLK)}$): Added the Typ. value of the Low current consumption read mode.
		725	Table 29.10 Flash Memory (Program ROM 1, 2) Electrical Characteristics: • Added a condition to the Read voltage row. • Modified note 1. • Deleted the example stated in note 4.
		726	Table 29.11 Flash Memory (Data Flash) Electrical Characteristics: Changed “128 groups” to “256 groups” in note 4.
		727	Table 29.12 Voltage Detector 0 Electrical Characteristics: Added the condition in the V_{det0} row.
		728	Table 29.15 Power-On Reset Circuit: • Added the V_{por1} and $t_{w(por)}$ row. • Deleted the Condition of t_{rth} row. • Added the last line in note 1.
		728	Figure 29.5 Power-On Reset Circuit Electrical Characteristics: • Changed the signal name “0.1 V” to “V_{por1}”. • Deleted note 2.
		730	Table 29.17 40 MHz On-Chip Oscillator Electrical Characteristics: Changed the Condition in the f_{OCO40M} row.
		732	Table 29.20 Electrical Characteristics (2): Added “ZP, IDU, IDV, IDW” to the V_{T+} - V_{T-} row.
		733	Table 29.21 Electrical Characteristics (3): Added the During flash memory program row and During flash memory erase row.
		738, 756	29.2.2.5 and 29.3.2.5 Timer S Input: Added.
		740, 758	29.2.2.8 and 29.3.2.8 Multi-master I^2C-bus: Added.
		741	Table 29.36 Memory Expansion Mode and Microprocessor Mode: Changed $\overline{RDY}$ input setup time from 30.
		741 to 748, 759 to 766	Table 29.36 to Table 29.39 and Table 29.56 to Table 29.59 Memory Expansion Mode and Microprocessor Mode: Deleted the following: • $\overline{HOLD}$ input setup time • $\overline{HOLD}$ input hold time • $\overline{HLDA}$ output delay time

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	742, 760	Figure 29.16 and Figure 29.29 Timing Diagram: Deleted lower figure (Common to wait state and no wait state settings).
		750	Table 29.40 Electrical Characteristics (1): Added “ZP, IDU, IDV, IDW” to the V_{T+} - V_{T-} row.
		751	Table 29.41 Electrical Characteristics (2): Added the During flash memory program row and During flash memory erase row.
		759	Table 29.56 Memory Expansion Mode and Microprocessor Mode: Changed $\overline{RDY}$ input setup time from 40.
		Usage Notes	
		Chap. 30.	30.1 OFS1 Address and ID Code Storage: Deleted.
		Chap. 30.	30.5.4 Hardware Reset When VCC1 < Vdet0: Deleted.
		Chap. 30.	30.8.2 External Bus: Deleted.
		Chap. 30.	30.18.3 UART (Clock Asynchronous Serial I/O) Mode: Deleted.
		Chap. 30.	30.21.11 Repeat Mode, Repeat Sweep Mode 0: Deleted.
		Chap. 30.	30.24.1 Functions to Prevent Flash Memory from Being Rewritten: Deleted.
		769	30.2.1 Register Settings: Added the description for read-modify-write instructions.
		770	Table 30.3 Read-Modify-Write Instructions: Added.
		772	30.4.1 Power Supply Rising Gradient: Deleted “VCC1 ≤ 3.6 V” from the table.
		772	Figure 30.2 SVCC Timing (3.6 V < VCC1), Figure 30.3 SVCC Timing (VCC1 ≤ 3.6 V): Revised from Figure 30.2 SVCC Timing.
		772	30.4.2 Power-On Reset: Added the "the VDSEL1 bit to 0 (Vdet0_2)" to the setting for power-on reset.
		776	30.5.3 CPU Clock: Added the technical update number.
		777	30.5.5 PLL Frequency Synthesizer: Added.
		778	30.6.1 CPU Clock: Added line 3.
		778	30.6.2 Wait Mode: • Added lines 4 and 5 to the first bullet. • Deleted second bullet in the previous version and added the second to fifth bullets.
		778	30.6.3 Stop Mode: • Changed “until main clock oscillation is stabilized” in line 1 to “for 20 fOCO-S cycles or more”. • Added lines 6 to 8 to the third bullet. • Deleted fourth bullet in the previous version and added fourth to eighth bullets.
		779	30.6.4 Low Current Consumption Read Mode: Added the third bullet.
		779	30.6.5 Slow Read Mode: Added.
		780	30.7.3 $\overline{HOLD}$: Added.
		782	30.9.2 SP Setting: Deleted the descriptions regarding the $\overline{NMI}$ interrupt.
		782	30.9.3 $\overline{NMI}$ Interrupt: Added the second bullet.
		784	30.9.5 Rewriting the Interrupt Control Register and 30.9.6 Instruction to Rewrite the Interrupt Control Register: Rewritten from 30.10.5 Rewriting the Interrupt Control Register in the previous version.
		785	30.9.8 IR bits in the USBINT0IC, USBINT1IC and USBRSMIC registers: Rewritten.
		787	30.11.1 Write to the DMAE Bit in the DMiCON Register (i = 0 to 3): Added the technical update number.
		788	30.12.1.2 Event or Trigger: Added.
		788	30.12.1.3 Influence of $\overline{SD}$: Added.
		792	30.13.3.2 Event: Added.
		793	30.13.4.3 Event or Trigger: Added.
		794	30.14.2 Influence of $\overline{SD}$: Changed the section title and description.
		795	30.15.1 Register Access: Added.
		795	30.15.2 Changing the G1IR Register: Changed the title and description.
		799	30.16.4 Time Reading Procedure in Real-Time Clock Mode: Rewrite the step for “Monitoring by a program 2” as Figure 30.11 Time Data Reading
		800	30.17.2.2 Transmission and 30.17.2.3 Reception: Changed the explanations about the external clock level into bullet lists.
		801	30.17.3.1 Generating Start and Stop Conditions: Added the technical update number.

Revision History	M16C/6C Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
2.00	Feb 07, 2011	802 to 803	30.17.3.3 Low/High-level Input Voltage and Low-level Output Voltage to 30.17.3.7 Requirements to Start Transmission/Reception in Slave Mode: Added.
		803	30.17.4 Special Mode 4 (SIM Mode): • Added the technical update number. • Changed the conditions to generate a transmit interrupt request.
		804	30.18.2.2 S1D0 Register: Corrected the typos from “S10 Register” to “S1D0 Register”.
		805	30.19.5 Internal Power for USB Module and UVCC Pin: Changed the “to the UVCC pins” in the fourth line to “between the UVCC pin and VSS”.
		806	30.19.6 Settings When Not Using the USB Module: • Changed “leave the UVCC pin open” to “connect the UVCC pin to VCC1”. • Deleted the last sentence.
		806	30.19.8 Entering Wait mode or Stop Mode and 24.6.9 Low Supply Voltage: Added.
		807	30.20.1 Analog Input Voltage: Added the section title.
		807	30.20.2 Analog Input Pin: Deleted the bracketed sentence in the second paragraph.
		809	30.20.12 ϕAD: Added.
		811	30.22.1 OFS1 Address and ID Code Storage Address: Added.
		812	30.22.3.2 CPU Rewrite Mode Select: Added.
		812	30.22.3.7 DMA transfer: Added the description for EW0 mode.
		813	30.22.3.10 Software Command: • Revised from 30.23.3.9 Low Power Mode and On-Chip Oscillator Low Power Mode. • Added (a) to (e).
		813	30.22.3.14 Suspending the Auto-Erase and Auto-Program Operations: Added the details on reset to the first bullet.
		814	30.22.4 User Boot: • Changed the section title from Standard Serial I/O Mode. • Changed “30.23.4.1 User Boot Mode” to “30.22.4.1 User Boot Mode Program” and added the first to seventh bullets.

Refer to 1. “Items revised or added in this version” for the items revised or added in this version.

M16C/6C Group User’s Manual: Hardware

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