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Renesas Technology Corp.
Customer Support Dept.
April 1, 2003

mitsubishi 16-bit single-chip microcomputer
m16c family / m16c/60 series

M16C/62
(M16C/62A, M16C/62M)
G r o u p

User's Manual

<http://www.infocom.maec.co.jp/indexe.htm>

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How to Use This Manual

This user's manual is written for the M16C/62A group.

The reader of this manual is expected to have the basic knowledge of electric and logic circuits and microcomputers.

This manual explains a function of the following kind.

- M30620M8A-XXXFP/GP • M30620MAA-XXXFP/GP • M30620MCA-XXXFP/GP
- M30622M4A-XXXFP/GP • M30622M8A-XXXFP/GP • M30622MAA-XXXFP/GP
- M30622MCA-XXXFP/GP • M30624MGA-XXXFP/GP • M30620SAFP/GP
- M30622SAFP/GP • M30620FCAFP/GP • M30624FGAFP/GP

- M30620MCM-XXXFP/GP • M30624MGM-XXXFP/GP • M30620FCMFP/GP
- M30624FGMFP/GP

These products have similar features except for the memories, which differ from one product to another. This manual gives descriptions of M30622MCA-XXXFP. An electric characteristic refer to data sheet responded to. Memories built-in are as shown below. Be careful when writing a program, as the memories have different capacities.

ROM Size (Byte)			
External ROM			M30620SAFP/GP M30622SAFP/GP
256K	M30624MGA-XXXFP/GP	M30624FGAFP/GP	
128K	M30620MCA-XXXFP/GP M30622MCA-XXXFP/GP	M30620FCAFP/GP	
96K	M30620MAA-XXXFP/GP M30622MAA-XXXFP/GP		
64K	M30620M8A-XXXFP/GP M30622M8A-XXXFP/GP		
32K	M30622M4A-XXXFP/GP		
	Mask ROM version	Flash memory version	External ROM version

ROM Size (Byte)		
External ROM		
256K	M30624MGM-XXXFP/GP	M30624FGMFP/GP
128K	M30620MCM-XXXFP/GP	M30620FCMFP/GP
96K		
64K		
32K		
	Mask ROM version	Flash memory version

This manual comprises of five chapters. Use the suggested chapters as a reference for the following topics:

- * To understand hardware specifications Chapter 1 Hardware
- * To understand the basic way of using peripheral features and the operation timing Chapter 2 Peripheral Functions Usage
- * To observe applications of peripheral features Chapter 3 Examples of Peripheral Functions Applications
- * To understand how to use external buses Chapter 4 External Buses
- * To know the difference between the mask ROM Version and external ROM Version Chapter 5 External ROM Version

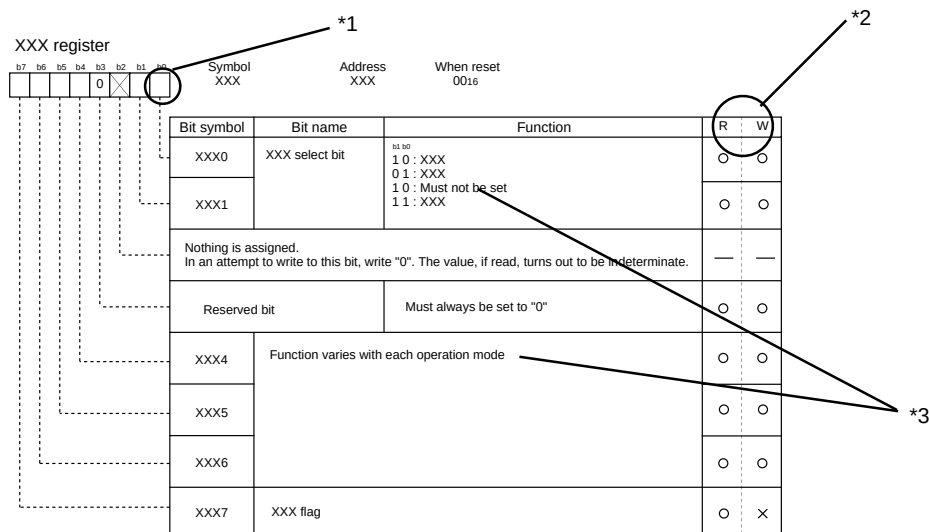
This manual includes a quick reference immediately following the Table of Contents and Table of Contents Classified by Function, indicate the page of the topic to be pursued. An index is also described at the end of this manual.

- * To find a page describing a peripheral function Table of Contents Classified by Function
- * To find a page describing a specific register by the register address Quick Reference to Pages Classified by Address

Extra application note explains follows, and please refer to each application note in addition to above.

- * I²C BUS M16C/62 Group SIMPLE I²C BUS
- * Three-phase motor control timer function ... M16C/62 Group THREE-PHASE MOTOR CONTROL

The figure of each register configuration describes its functions and attributes as follows :



*1

Blank: Set to "0" or "1" according to intended use

0: Set to "0"

1: Set to "1"

X: Nothing is assigned

*2

R: Read

○.....Possible to read

X.....Impossible to read

—.....Nothing is assigned

W: Write

○.....Possible to write

X.....Written value is invalid

When write, value can be "0" or "1"

—.....Nothing is assigned

*3

Terms to use here are explained as follows.

- Nothing is assigned

Nothing is assigned to the bit concerned. When write, set "0" for new function in future plan.

- Must not be set

Not select. The operation at having selected is not guaranteed.

- Reserved bit

Reserved bit. Set the specified value.

- Function varies with each operation mode

Bit function changes according to the mode of peripheral functions.

- Invalid in A mode

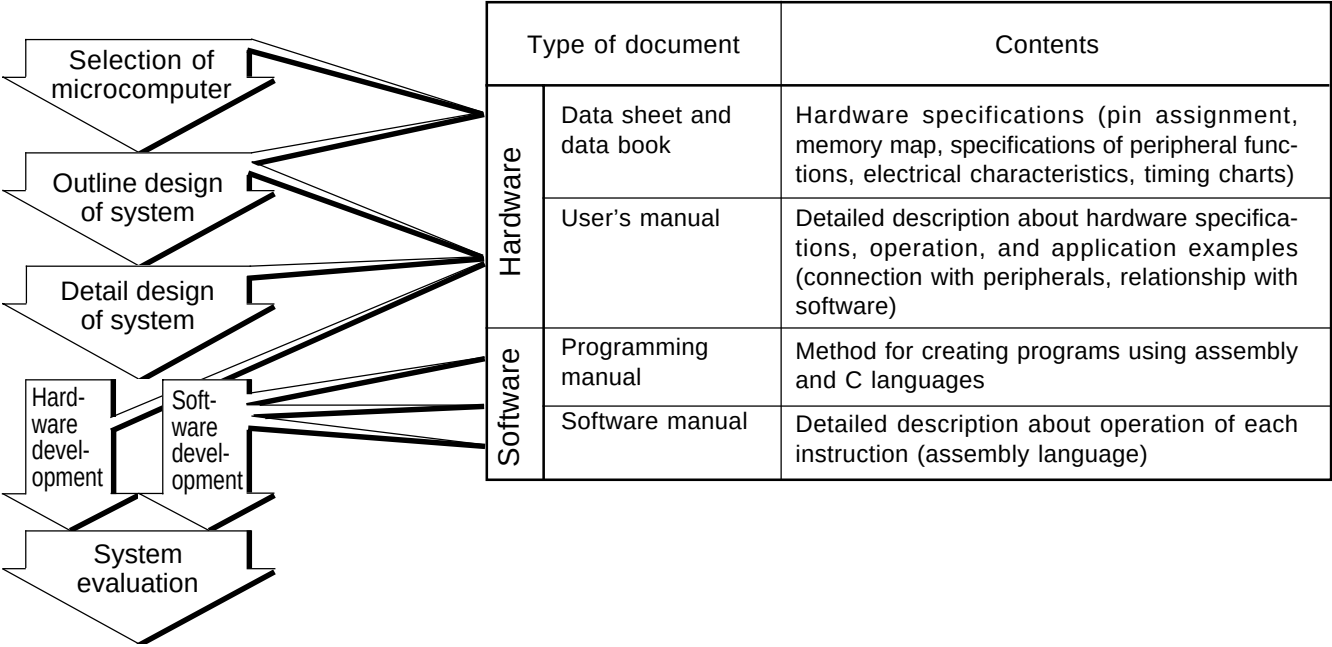
The bit concerned has no function in A mode. Set the specified value.

- Valid when bit A="0"

When bit A is "1", the bit concerned has no function. When bit A is "0", the bit concerned has function.

M16C Family-related document list

Usages
(Microcomputer development flow)



M16C Family Line-up

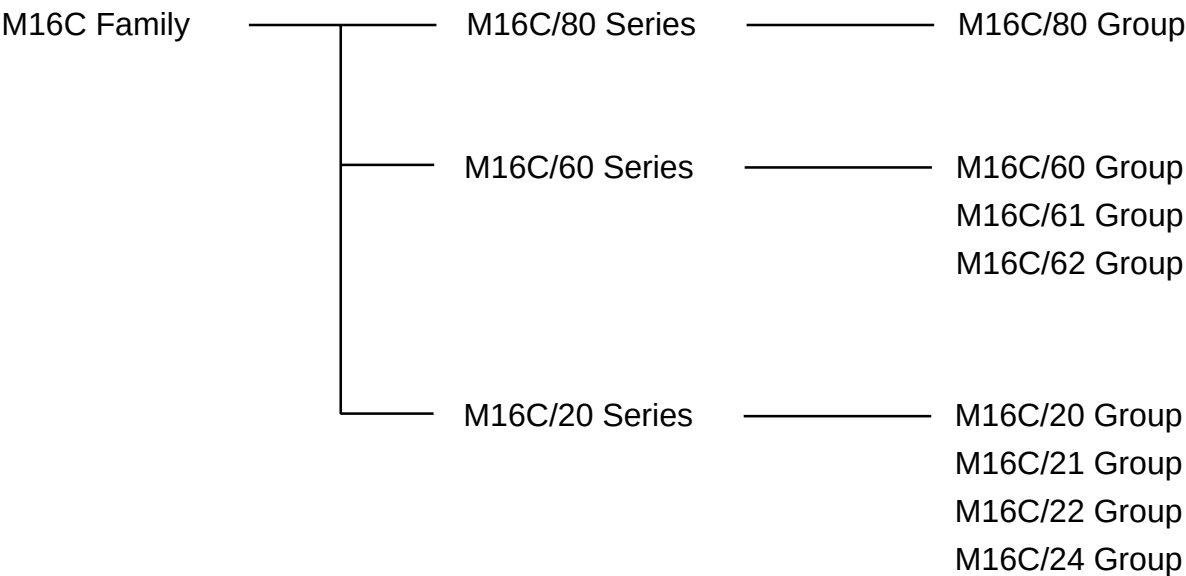


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0001 ₁₆			0041 ₁₆		
0002 ₁₆			0042 ₁₆		
0003 ₁₆			0043 ₁₆		
0004 ₁₆	Processor mode register 0 (PM0)	1-23	0044 ₁₆	INT3 interrupt control register (INT3IC)	
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000D ₁₆			004B ₁₆	DMA0 interrupt control register (DM0IC)	
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002A ₁₆					
002B ₁₆					
002C ₁₆	DMA0 control register (DM0CON)	1-71			
002D ₁₆					
002E ₁₆					
002F ₁₆					
0030 ₁₆					
0031 ₁₆	DMA1 source pointer (SAR1)	1-72			
0032 ₁₆					
0033 ₁₆					
0034 ₁₆					
0035 ₁₆	DMA1 destination pointer (DAR1)	1-72			
0036 ₁₆					
0037 ₁₆					
0038 ₁₆					
0039 ₁₆	DMA1 transfer counter (TCR1)	1-72			
003A ₁₆					
003B ₁₆					
003C ₁₆	DMA1 control register (DM1CON)	1-71			
003D ₁₆					
003E ₁₆					
003F ₁₆					

Note : Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

Quick Reference to Pages Classified by Address

Address	Register	Page
0340 ₁₆	Timer B3, 4, 5 count start flag (TBSR)	1-91
0341 ₁₆		
0342 ₁₆	Timer A1-1 register (TA11)	1-98
0343 ₁₆		
0344 ₁₆	Timer A2-1 register (TA21)	
0345 ₁₆		
0346 ₁₆	Timer A4-1 register (TA41)	1-96
0347 ₁₆		
0348 ₁₆	Three-phase PWM control register 0(INVC0)	
0349 ₁₆	Three-phase PWM control register 1(INVC1)	
034A ₁₆	Three-phase output buffer register 0(IDB0)	1-97
034B ₁₆	Three-phase output buffer register 1(IDB1)	
034C ₁₆	Dead time timer(DTT)	
034D ₁₆	Timer B2 interrupt occurrence frequency set counter(ICTB2)	
034E ₁₆		
034F ₁₆		
0350 ₁₆	Timer B3 register (TB3)	1-91
0351 ₁₆		
0352 ₁₆	Timer B4 register (TB4)	
0353 ₁₆		
0354 ₁₆	Timer B5 register (TB5)	
0355 ₁₆		
0356 ₁₆		
0357 ₁₆		
0358 ₁₆		1-90
0359 ₁₆		
035A ₁₆		
035B ₁₆	Timer B3 mode register (TB3MR)	
035C ₁₆	Timer B4 mode register (TB4MR)	1-61
035D ₁₆	Timer B5 mode register (TB5MR)	
035E ₁₆		
035F ₁₆	Interrupt request cause select register (IFSR)	
0360 ₁₆	SI/O3 transmit/receive register (S3TRR)	1-146
0361 ₁₆		
0362 ₁₆	SI/O3 control register (S3C)	
0363 ₁₆	SI/O3 bit rate generator (S3BRG)	
0364 ₁₆	SI/O4 transmit/receive register (S4TRR)	
0365 ₁₆		
0366 ₁₆	SI/O4 control register (S4C)	
0367 ₁₆	SI/O4 bit rate generator (S4BRG)	
0368 ₁₆		
0369 ₁₆		
036A ₁₆		
036B ₁₆		
036C ₁₆		
036D ₁₆		
036E ₁₆		
036F ₁₆		
0370 ₁₆		
0371 ₁₆		
0372 ₁₆		
0373 ₁₆		
0374 ₁₆		
0375 ₁₆	UART2 special mode register 3 (U2SMR3)	
0376 ₁₆	UART2 special mode register 2 (U2SMR2)	
0377 ₁₆	UART2 special mode register (U2SMR)	
0378 ₁₆	UART2 transmit/receive mode register (U2MR)	
0379 ₁₆	UART2 bit rate generator (U2BRG)	
037A ₁₆	UART2 transmit buffer register (U2TB)	
037B ₁₆		
037C ₁₆	UART2 transmit/receive control register 0 (U2C0)	
037D ₁₆	UART2 transmit/receive control register 1 (U2C1)	
037E ₁₆		
037F ₁₆	UART2 receive buffer register (U2RB)	

Address	Register	Page
0380 ₁₆	Count start flag (TABSR)	1-81
0381 ₁₆	Clock prescaler reset flag (CPSRF)	1-82
0382 ₁₆	One-shot start flag (ONSF)	
0383 ₁₆	Trigger select register (TRGSR)	1-81
0384 ₁₆	Up-down flag (UDF)	
0385 ₁₆		
0386 ₁₆	Timer A0 register (TA0)	1-81
0387 ₁₆		
0388 ₁₆	Timer A1 register (TA1)	
0389 ₁₆		
038A ₁₆	Timer A2 register (TA2)	1-80
038B ₁₆		
038C ₁₆	Timer A3 register (TA3)	
038D ₁₆		
038E ₁₆	Timer A4 register (TA4)	1-91
038F ₁₆		
0390 ₁₆	Timer B0 register (TB0)	
0391 ₁₆		
0392 ₁₆	Timer B1 register (TB1)	1-80
0393 ₁₆		
0394 ₁₆	Timer B2 register (TB2)	
0395 ₁₆		
0396 ₁₆	Timer A0 mode register (TA0MR)	1-90
0397 ₁₆	Timer A1 mode register (TA1MR)	
0398 ₁₆	Timer A2 mode register (TA2MR)	
0399 ₁₆	Timer A3 mode register (TA3MR)	
039A ₁₆	Timer A4 mode register (TA4MR)	1-113
039B ₁₆	Timer B0 mode register (TB0MR)	
039C ₁₆	Timer B1 mode register (TB1MR)	
039D ₁₆	Timer B2 mode register (TB2MR)	
039E ₁₆		
039F ₁₆		
03A0 ₁₆	UART0 transmit/receive mode register (U0MR)	1-113
03A1 ₁₆	UART0 bit rate generator (U0BRG)	1-112
03A2 ₁₆		
03A3 ₁₆	UART0 transmit buffer register (U0TB)	1-114
03A4 ₁₆	UART0 transmit/receive control register 0 (U0C0)	
03A5 ₁₆	UART0 transmit/receive control register 1 (U0C1)	1-115
03A6 ₁₆		1-112
03A7 ₁₆	UART0 receive buffer register (U0RB)	
03A8 ₁₆	UART1 transmit/receive mode register (U1MR)	1-113
03A9 ₁₆	UART1 bit rate generator (U1BRG)	1-112
03AA ₁₆		
03AB ₁₆	UART1 transmit buffer register (U1TB)	1-114
03AC ₁₆	UART1 transmit/receive control register 0 (U1C0)	
03AD ₁₆	UART1 transmit/receive control register 1 (U1C1)	1-115
03AE ₁₆		1-112
03AF ₁₆	UART1 receive buffer register (U1RB)	
03B0 ₁₆	UART transmit/receive control register 2 (UCON)	1-116
03B1 ₁₆		
03B2 ₁₆		
03B3 ₁₆		
03B4 ₁₆		
03B5 ₁₆		1-221
03B6 ₁₆	Flash memory control register 1 (FMR1) (Note 1)	
03B7 ₁₆	Flash memory control register 0 (FMR0) (Note 1)	1-70
03B8 ₁₆	DMA0 request cause select register (DM0SL)	
03B9 ₁₆		1-71
03BA ₁₆	DMA1 request cause select register (DM1SL)	
03BB ₁₆		1-161
03BC ₁₆		
03BD ₁₆	CRC data register (CRCD)	
03BE ₁₆	CRC input register (CRCIN)	
03BF ₁₆		

Note 1 : This register is only exist in flash memory version.

Note 2 : Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

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Address	Register	Page
03C0 ₁₆	A-D register 0 (AD0)	1-152
03C1 ₁₆		
03C2 ₁₆	A-D register 1 (AD1)	
03C3 ₁₆		
03C4 ₁₆	A-D register 2 (AD2)	
03C5 ₁₆		
03C6 ₁₆	A-D register 3 (AD3)	
03C7 ₁₆		
03C8 ₁₆	A-D register 4 (AD4)	
03C9 ₁₆		
03CA ₁₆	A-D register 5 (AD5)	
03CB ₁₆		
03CC ₁₆	A-D register 6 (AD6)	
03CD ₁₆		
03CE ₁₆	A-D register 7 (AD7)	
03CF ₁₆		
03D0 ₁₆		
03D1 ₁₆		
03D2 ₁₆		
03D3 ₁₆		
03D4 ₁₆	A-D control register 2 (ADCON2)	1-152
03D5 ₁₆		1-151
03D6 ₁₆	A-D control register 0 (ADCON0)	
03D7 ₁₆	A-D control register 1 (ADCON1)	1-160
03D8 ₁₆	D-A register 0 (DA0)	
03D9 ₁₆		
03DA ₁₆	D-A register 1 (DA1)	
03DB ₁₆		
03DC ₁₆	D-A control register (DACON)	
03DD ₁₆		
03DE ₁₆		
03DF ₁₆		1-169
03E0 ₁₆	Port P0 register (P0)	
03E1 ₁₆	Port P1 register (P1)	1-168
03E2 ₁₆	Port P0 direction register (PD0)	
03E3 ₁₆	Port P1 direction register (PD1)	1-169
03E4 ₁₆	Port P2 register (P2)	
03E5 ₁₆	Port P3 register (P3)	1-168
03E6 ₁₆	Port P2 direction register (PD2)	
03E7 ₁₆	Port P3 direction register (PD3)	1-169
03E8 ₁₆	Port P4 register (P4)	
03E9 ₁₆	Port P5 register (P5)	1-168
03EA ₁₆	Port P4 direction register (PD4)	
03EB ₁₆	Port P5 direction register (PD5)	1-169
03EC ₁₆	Port P6 register (P6)	
03ED ₁₆	Port P7 register (P7)	1-168
03EE ₁₆	Port P6 direction register (PD6)	
03EF ₁₆	Port P7 direction register (PD7)	1-169
03F0 ₁₆	Port P8 register (P8)	
03F1 ₁₆	Port P9 register (P9)	1-168
03F2 ₁₆	Port P8 direction register (PD8)	
03F3 ₁₆	Port P9 direction register (PD9)	1-169
03F4 ₁₆	Port P10 register (P10)	
03F5 ₁₆		1-168
03F6 ₁₆	Port P10 direction register (PD10)	
03F7 ₁₆		
03F8 ₁₆		
03F9 ₁₆		1-170
03FA ₁₆		
03FB ₁₆		
03FC ₁₆	Pull-up control register 0 (PUR0)	
03FD ₁₆	Pull-up control register 1 (PUR1)	1-171
03FE ₁₆	Pull-up control register 2 (PUR2)	
03FF ₁₆	Port control register (PCR)	

Note : Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

Chapter 1

Hardware

Description

Description

The M16C/62A group of single-chip microcomputers are built using the high-performance silicon gate CMOS process using a M16C/60 Series CPU core and are packaged in a 100-pin plastic molded QFP. These single-chip microcomputers operate using sophisticated instructions featuring a high level of instruction efficiency. With 1M bytes of address space, they are capable of executing instructions at high speed. They also feature a built-in multiplier and DMAC, making them ideal for controlling office, communications, industrial equipment, and other high-speed processing applications.

The M16C/62A group includes a wide range of products with different internal memory types and sizes and various package types.

Features

- Memory capacity ROM (See Figure 1.1.4. ROM Expansion)
RAM 3K to 20K bytes
- Shortest instruction execution time 62.5ns ($f(X_{IN})=16\text{MHz}$, $V_{CC}=5\text{V}$)
100ns ($f(X_{IN})=10\text{MHz}$, $V_{CC}=3\text{V}$, with software one-wait) : Mask ROM, flash memory 5V version
- Supply voltage 4.2V to 5.5V ($f(X_{IN})=16\text{MHz}$, without software wait) : Mask ROM, flash memory 5V version
2.7V to 5.5V ($f(X_{IN})=10\text{MHz}$ with software one-wait) : Mask ROM, flash memory 5V version
- Low power consumption 25.5mW ($f(X_{IN})=10\text{MHz}$, with software one-wait, $V_{CC} = 3\text{V}$)
- Interrupts 25 internal and 8 external interrupt sources, 4 software interrupt sources; 7 levels (including key input interrupt)
- Multifunction 16-bit timer 5 output timers + 6 input timers
- Serial I/O 5 channels (3 for UART or clock synchronous, 2 for clock synchronous)
- DMAC 2 channels (trigger: 24 sources)
- A-D converter 10 bits X 8 channels (Expandable up to 10 channels)
- D-A converter 8 bits X 2 channels
- CRC calculation circuit 1 circuit
- Watchdog timer 1 line
- Programmable I/O 87 lines
- Input port 1 line (P85 shared with $\overline{\text{NMI}}$ pin)
- Memory expansion Available (to a maximum of 1M bytes)
- Chip select output 4 lines
- Clock generating circuit 2 built-in clock generation circuits
(built-in feedback resistor, and external ceramic or quartz oscillator)

Applications

Audio, cameras, office equipment, communications equipment, portable equipment

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Central Processing Unit (CPU)	1-12	Timer	1-78
Reset	1-15	Serial I/O	1-108
Processor Mode	1-22	A-D Converter	1-149
Clock Generating Circuit	1-36	D-A Converter	1-159
Protection	1-46	CRC Calculation Circuit	1-161
Interrupts	1-46	Programmable I/O Ports	1-163
Watchdog Timer	1-66	Electrical characteristic	1-174
DMAC	1-68	Flash memory version	1-217

Pin Configuration

Figures 1.1.1 and 1.1.2 show the pin configurations (top view).

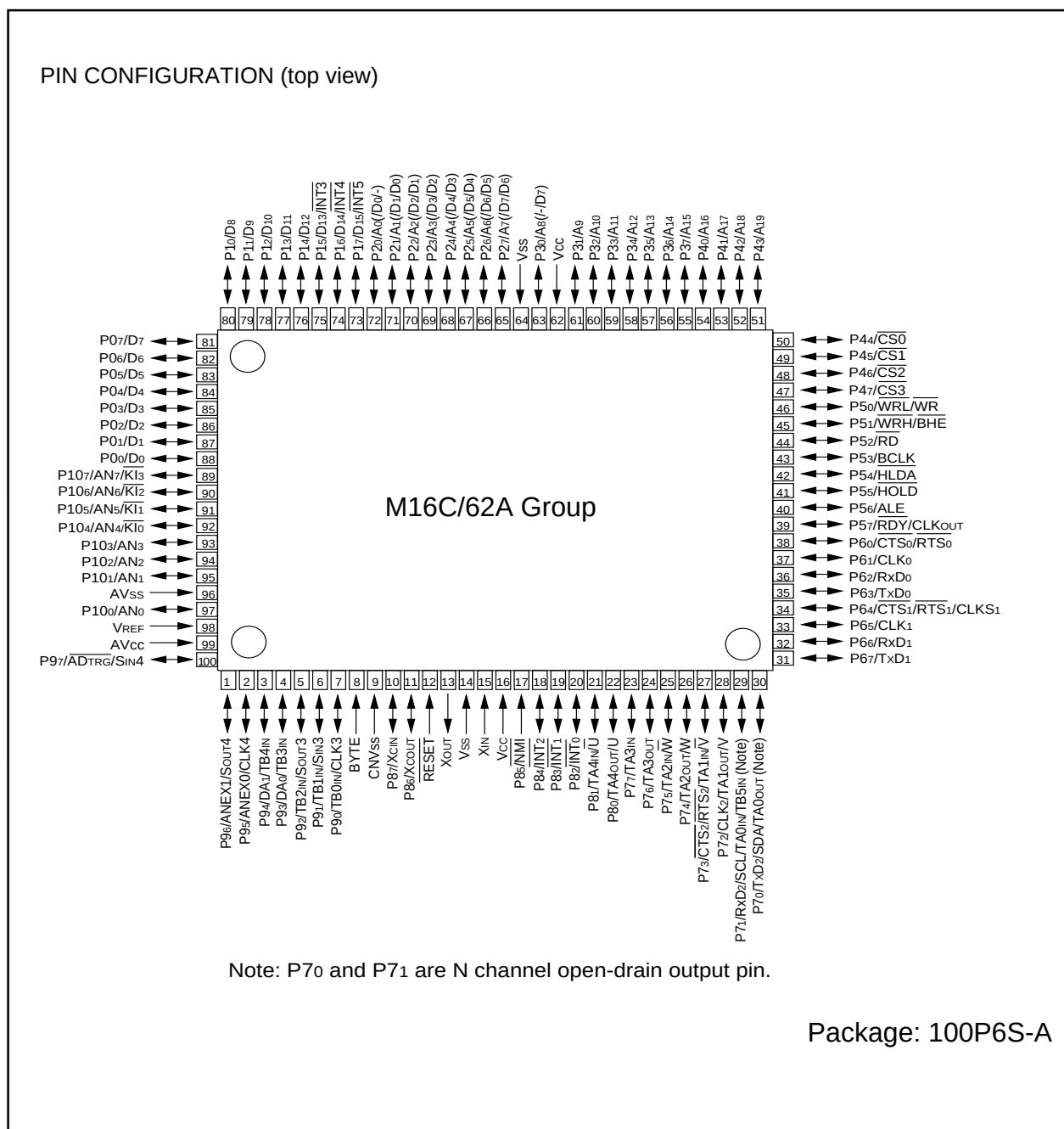


Figure 1.1.1. Pin configuration (top view)

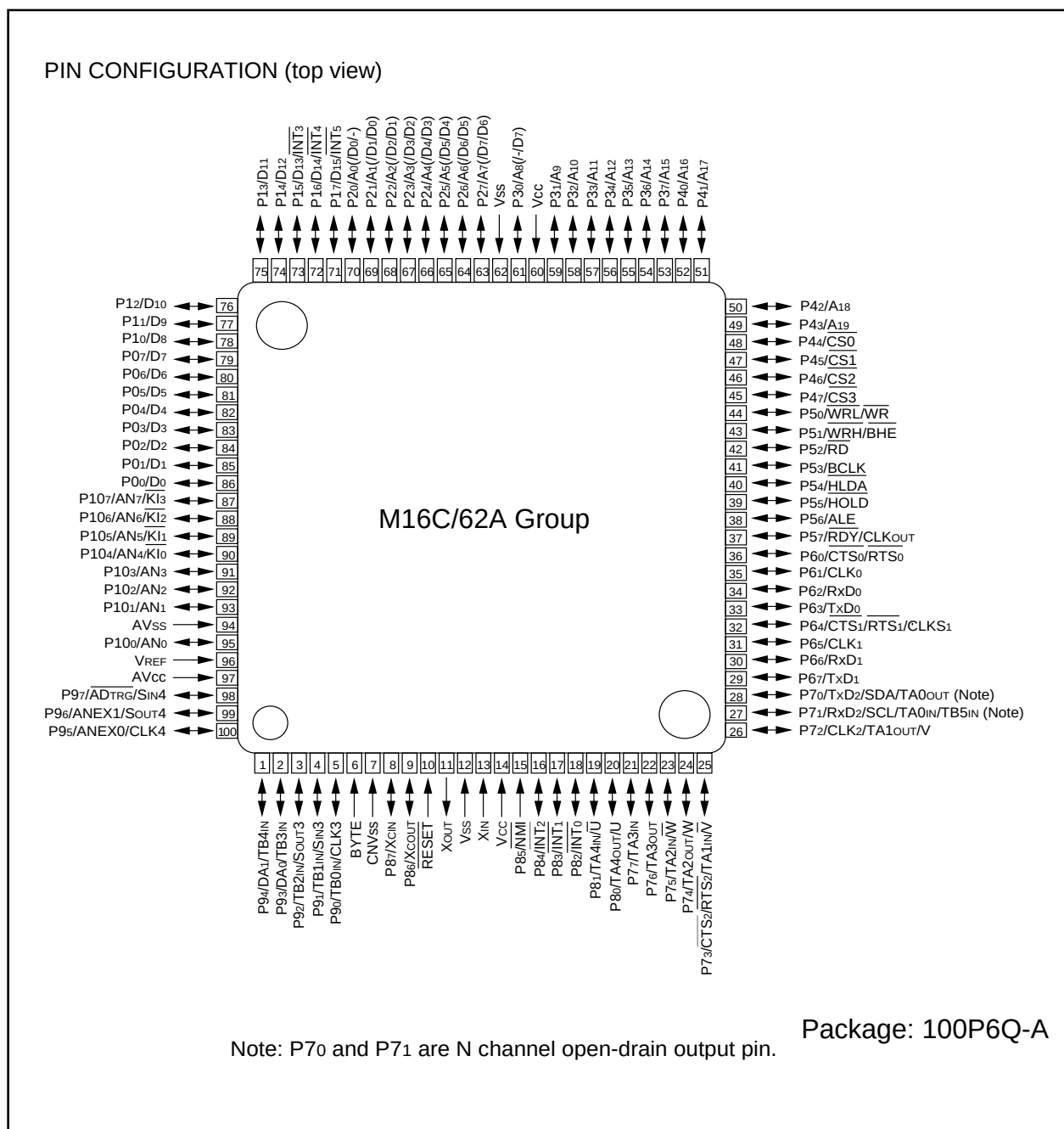


Figure 1.1.2. Pin configuration (top view)

Block Diagram

Figure 1.1.3 is a block diagram of the M16C/62A group.

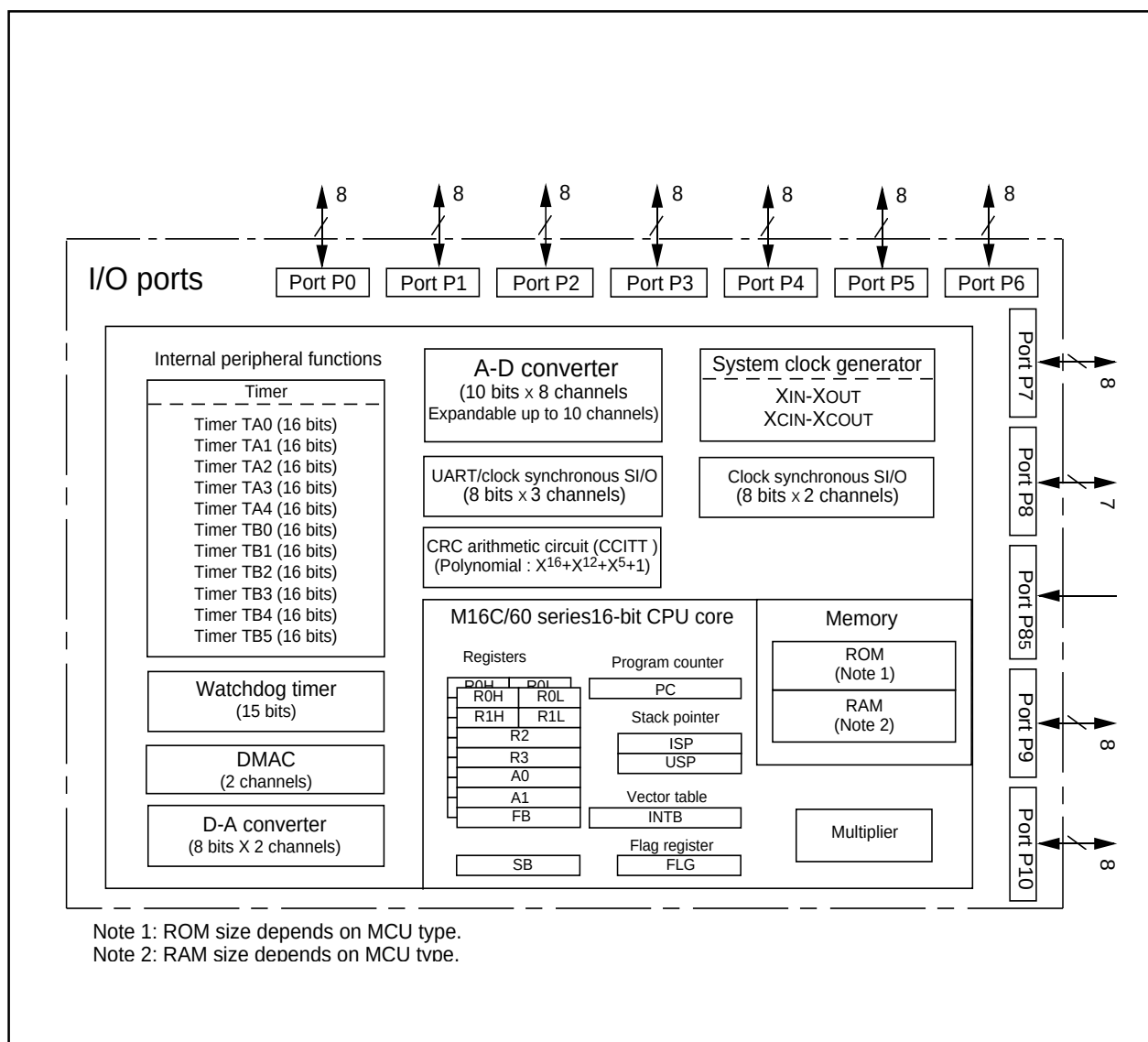


Figure 1.1.3. Block diagram of M16C/62A group

Description

Performance Outline

Table 1.1.1 is a performance outline of M16C/62A group.

Table 1.1.1. Performance outline of M16C/62A group

Item		Performance
Number of basic instructions		91 instructions
Shortest instruction execution time		62.5ns($f(X_{IN})=16\text{MHz}$, $V_{CC}=5\text{V}$) 100ns ($f(X_{IN})=10\text{MHz}$, $V_{CC}=3\text{V}$, with software one-wait) : Mask ROM, flash memory 5V version
Memory capacity	ROM	(See the figure 1.1.4. ROM Expansion)
	RAM	3K to 20K bytes
I/O port	P0 to P10 (except P85)	8 bits x 10, 7 bits x 1
Input port	P85	1 bit x 1
Multifunction timer	TA0, TA1, TA2, TA3, TA4	16 bits x 5
	TB0, TB1, TB2, TB3, TB4, TB5	16 bits x 6
Serial I/O	UART0, UART1, UART2	(UART or clock synchronous) x 3
	SI/O3, SI/O4	(Clock synchronous) x 2
A-D converter		10 bits x (8 + 2) channels
D-A converter		8 bits x 2
DMAC		2 channels (trigger: 24 sources)
CRC calculation circuit		CRC-CCITT
Watchdog timer		15 bits x 1 (with prescaler)
Interrupt		25 internal and 8 external sources, 4 software sources, 7 levels
Clock generating circuit		2 built-in clock generation circuits (built-in feedback resistor, and external ceramic or quartz oscillator)
Supply voltage		4.2V to 5.5V ($f(X_{IN})=16\text{MHz}$, without software wait) : Mask ROM, flash memory 5V version 2.7V to 5.5V ($f(X_{IN})=10\text{MHz}$ with software one-wait) : Mask ROM, flash memory 5V version
Power consumption		25.5mW ($f(X_{IN}) = 10\text{MHz}$, $V_{CC}=3\text{V}$ with software one-wait)
I/O characteristics	I/O withstand voltage	5V
	Output current	5mA
Memory expansion		Available (to a maximum of 1M bytes)
Device configuration		CMOS high performance silicon gate
Package		100-pin plastic mold QFP

Description

Mitsubishi plans to release the following products in the M16C/62A group:

(1) Support for mask ROM version, external ROM version, and flash memory version

(2) ROM capacity

(3) Package

100P6S-A : Plastic molded QFP (mask ROM, and flash memory versions)

100P6Q-A : Plastic molded QFP(mask ROM, and flash memory versions)

ROM Size (Byte)			
External ROM			M30620SAFP/GP M30622SAFP/GP
256K	M30624MGA-XXXFP/GP	M30624FGAFP/GP	
128K	M30620MCA-XXXFP/GP M30622MCA-XXXFP/GP	M30620FCAFP/GP	
96K	M30620MAA-XXXFP/GP M30622MAA-XXXFP/GP		
64K	M30620M8A-XXXFP/GP M30622M8A-XXXFP/GP		
32K	M30622M4A-XXXFP/GP		
	Mask ROM version	Flash memory version	External ROM version

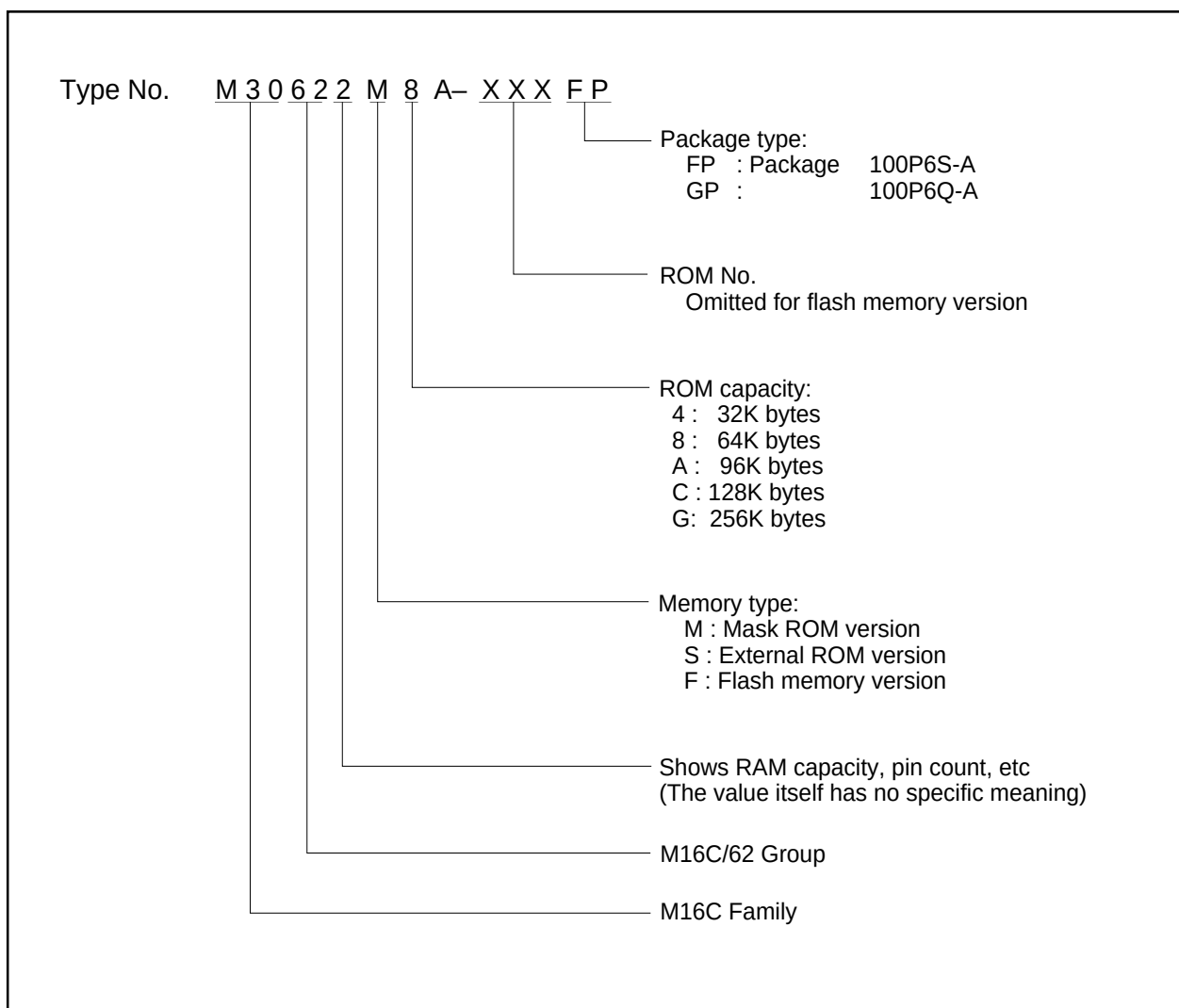
Figure 1.1.4. ROM expansion

The M16C/62A group products currently supported are listed in Table 1.1.2.

Table 1.1.2. M16C/62A group

June, 2001

Type No.	ROM capacity	RAM capacity	Package type	Remarks
M30622M4A-XXXFP	32K byte	3K byte	100P6S-A	Mask ROM version
M30622M4A-XXXGP			100P6Q-A	
M30620M8A-XXXFP			100P6S-A	
M30620M8A-XXXGP	64K byte	10K byte	100P6Q-A	
M30622M8A-XXXFP		4K byte	100P6S-A	
M30622M8A-XXXGP			100P6Q-A	
M30620MAA-XXXFP		10K byte	100P6S-A	
M30620MAA-XXXGP	96K byte	5K byte	100P6Q-A	
M30622MAA-XXXFP			100P6S-A	
M30622MAA-XXXGP			100P6Q-A	
M30620MCA-XXXFP	128K byte	10K byte	100P6S-A	
M30620MCA-XXXGP		5K byte	100P6Q-A	
M30622MCA-XXXFP			100P6S-A	
M30622MCA-XXXGP			100P6Q-A	
M30624MGA-XXXFP	256K byte	20K byte	100P6S-A	
M30624MGA-XXXGP			100P6Q-A	
M30620FCAFP	128K byte	10K byte	100P6S-A	Flash memory 5V version
M30620FCAGP			100P6Q-A	
M30624FGAFP	256K byte	20K byte	100P6S-A	
M30624FGAGP			100P6Q-A	
M30620SAFP	—	10K byte	100P6S-A	External ROM version
M30620SAGP			100P6Q-A	
M30622SAFP		3K byte	100P6S-A	
M30622SAGP			100P6Q-A	

Description**Figure 1.1.5. Type No., memory size, and package**

Pin Description

Pin Description

Pin name	Signal name	I/O type	Function
VCC, VSS	Power supply input		Supply 2.7V to 5.5 V to the VCC pin. Supply 0 V to the VSS pin.
CNVSS	CNVss	Input	This pin switches between processor modes. Connect this pin to the VSS pin when after a reset you want to start operation in single-chip mode (memory expansion mode) or the VCC pin when starting operation in microprocessor mode.
RESET	Reset input	Input	A "L" on this input resets the microcomputer.
XIN XOUT	Clock input Clock output	Input Output	These pins are provided for the main clock generating circuit. Connect a ceramic resonator or crystal between the XIN and the XOUT pins. To use an externally derived clock, input it to the XIN pin and leave the XOUT pin open.
BYTE	External data bus width select input	Input	This pin selects the width of an external data bus. A 16-bit width is selected when this input is "L"; an 8-bit width is selected when this input is "H". This input must be fixed to either "H" or "L". Connect this pin to the VSS pin when not using external data bus.
AVCC	Analog power supply input		This pin is a power supply input for the A-D converter. Connect this pin to VCC.
AVSS	Analog power supply input		This pin is a power supply input for the A-D converter. Connect this pin to VSS.
VREF	Reference voltage input	Input	This pin is a reference voltage input for the A-D converter.
P00 to P07	I/O port P0	Input/output	This is an 8-bit CMOS I/O port. It has an input/output port direction register that allows the user to set each pin for input or output individually. When used for input in single-chip mode, the port can be set to have or not have a pull-up resistor in units of four bits by software. In memory expansion and microprocessor modes, selection of the internal pull-resistor is not available.
D0 to D7		Input/output	When set as a separate bus, these pins input and output data (D0–D7).
P10 to P17	I/O port P1	Input/output	This is an 8-bit I/O port equivalent to P0. P15 to P17 also function as external interrupt pins as selected by software.
D8 to D15		Input/output	When set as a separate bus, these pins input and output data (D8–D15).
P20 to P27	I/O port P2	Input/output	This is an 8-bit I/O port equivalent to P0.
A0 to A7		Output	These pins output 8 low-order address bits (A0–A7).
A0/D0 to A7/D7		Input/output	If the external bus is set as an 8-bit wide multiplexed bus, these pins input and output data (D0–D7) and output 8 low-order address bits (A0–A7) separated in time by multiplexing.
A0 A1/D0 to A7/D6		Output Input/output	If the external bus is set as a 16-bit wide multiplexed bus, these pins input and output data (D0–D6) and output address (A1–A7) separated in time by multiplexing. They also output address (A0).
P30 to P37	I/O port P3	Input/output	This is an 8-bit I/O port equivalent to P0.
A8 to A15		Output	These pins output 8 middle-order address bits (A8–A15).
A8/D7, A9 to A15		Input/output Output	If the external bus is set as a 16-bit wide multiplexed bus, these pins input and output data (D7) and output address (A8) separated in time by multiplexing. They also output address (A9–A15).
P40 to P47	I/O port P4	Input/output	This is an 8-bit I/O port equivalent to P0.
A16 to A19, CS0 to CS3		Output Output	These pins output A16–A19 and CS0–CS3 signals. A16–A19 are 4 high-order address bits. CS0–CS3 are chip select signals used to specify an access space.

Pin Description

Pin Description

Pin name	Signal name	I/O type	Function
P50 to P57	I/O port P5	Input/output	This is an 8-bit I/O port equivalent to P0. In single-chip mode, P57 in this port outputs a divide-by-8 or divide-by-32 clock of X_{IN} or a clock of the same frequency as X_{CIN} as selected by software.
$\overline{WRL}$ / $\overline{WR}$, $\overline{WRH}$ / $\overline{BHE}$, $\overline{RD}$, $\overline{BCLK}$, $\overline{HLDA}$, $\overline{HOLD}$, $\overline{ALE}$, $\overline{RDY}$		Output Output Output Output Output Input Output Input	Output $\overline{WRL}$, $\overline{WRH}$ ($\overline{WR}$ and $\overline{BHE}$), $\overline{RD}$, $\overline{BCLK}$, $\overline{HLDA}$, and $\overline{ALE}$ signals. $\overline{WRL}$ and $\overline{WRH}$, and $\overline{BHE}$ and $\overline{WR}$ can be switched using software control. ■ $\overline{WRL}$, $\overline{WRH}$, and $\overline{RD}$ selected With a 16-bit external data bus, data is written to even addresses when the $\overline{WRL}$ signal is "L" and to the odd addresses when the $\overline{WRH}$ signal is "L". Data is read when $\overline{RD}$ is "L". ■ $\overline{WR}$, $\overline{BHE}$, and $\overline{RD}$ selected Data is written when $\overline{WR}$ is "L". Data is read when $\overline{RD}$ is "L". Odd addresses are accessed when $\overline{BHE}$ is "L". Use this mode when using an 8-bit external data bus. While the input level at the $\overline{HOLD}$ pin is "L", the microcomputer is placed in the hold state. While in the hold state, $\overline{HLDA}$ outputs a "L" level. $\overline{ALE}$ is used to latch the address. While the input level of the $\overline{RDY}$ pin is "L", the microcomputer is in the ready state.
P60 to P67	I/O port P6	Input/output	This is an 8-bit I/O port equivalent to P0. When used for input in single-chip, memory expansion, and microprocessor modes, the port can be set to have or not have a pull-up resistor in units of four bits by software. Pins in this port also function as UART0 and UART1 I/O pins as selected by software.
P70 to P77	I/O port P7	Input/output	This is an 8-bit I/O port equivalent to P6 (P70 and P71 are N channel open-drain output). Pins in this port also function as timer A0–A3, timer B5 or UART2 I/O pins as selected by software.
P80 to P84, P86, P87, P85	I/O port P8 I/O port P85	Input/output Input/output Input	P80 to P84, P86, and P87 are I/O ports with the same functions as P6. Using software, they can be made to function as the I/O pins for timer A4 and the input pins for external interrupts. P86 and P87 can be set using software to function as the I/O pins for a sub clock generation circuit. In this case, connect a quartz oscillator between P86 (X_{COUT} pin) and P87 (X_{CIN} pin). P85 is an input-only port that also functions for NMI. The NMI interrupt is generated when the input at this pin changes from "H" to "L". The NMI function cannot be cancelled using software. The pull-up cannot be set for this pin.
P90 to P97	I/O port P9	Input/output	This is an 8-bit I/O port equivalent to P6. Pins in this port also function as SI/O3, 4 I/O pins, Timer B0–B4 input pins, D-A converter output pins, A-D converter extended input pins, or A-D trigger input pins as selected by software.
P100 to P107	I/O port P10	Input/output	This is an 8-bit I/O port equivalent to P6. Pins in this port also function as A-D converter input pins as selected by software. Furthermore, P104–P107 also function as input pins for the key input interrupt function.

Memory

Operation of Functional Blocks

The M16C/62A group accommodates certain units in a single chip. These units include ROM and RAM to store instructions and data and the central processing unit (CPU) to execute arithmetic/logic operations. Also included are peripheral units such as timers, serial I/O, D-A converter, DMAC, CRC calculation circuit, A-D converter, and I/O ports.

The following explains each unit.

Memory

Figure 1.3.1 is a memory map of the M16C/62A group. The address space extends the 1M bytes from address 00000₁₆ to FFFFF₁₆. From FFFFF₁₆ down is ROM. For example, in the M30622MCA-XXXFP, there is 128K bytes of internal ROM from E0000₁₆ to FFFFF₁₆. The vector table for fixed interrupts such as the reset and $\overline{\text{NMI}}$ are mapped to FFFDC₁₆ to FFFFF₁₆. The starting address of the interrupt routine is stored here. The address of the vector table for timer interrupts, etc., can be set as desired using the internal register (INTB). See the section on interrupts for details.

From 00400₁₆ up is RAM. For example, in the M30622MCA-XXXFP, 5K bytes of internal RAM is mapped to the space from 00400₁₆ to 017FF₁₆. In addition to storing data, the RAM also stores the stack used when calling subroutines and when interrupts are generated.

The SFR area is mapped to 00000₁₆ to 003FF₁₆. This area accommodates the control registers for peripheral devices such as I/O ports, A-D converter, serial I/O, and timers, etc. Figures 1.6.1 to 1.6.3 are location of peripheral unit control registers. Any part of the SFR area that is not occupied is reserved and cannot be used for other purposes.

The special page vector table is mapped to FFE00₁₆ to FFFDB₁₆. If the starting addresses of subroutines or the destination addresses of jumps are stored here, subroutine call instructions and jump instructions can be used as 2-byte instructions, reducing the number of program steps.

In memory expansion mode and microprocessor mode, a part of the spaces are reserved and cannot be used. For example, in the M30622MCA-XXXFP, the following spaces cannot be used.

- The space between 01800₁₆ and 03FFF₁₆ (Memory expansion and microprocessor modes)
- The space between D0000₁₆ and DFFFF₁₆ (Memory expansion mode)

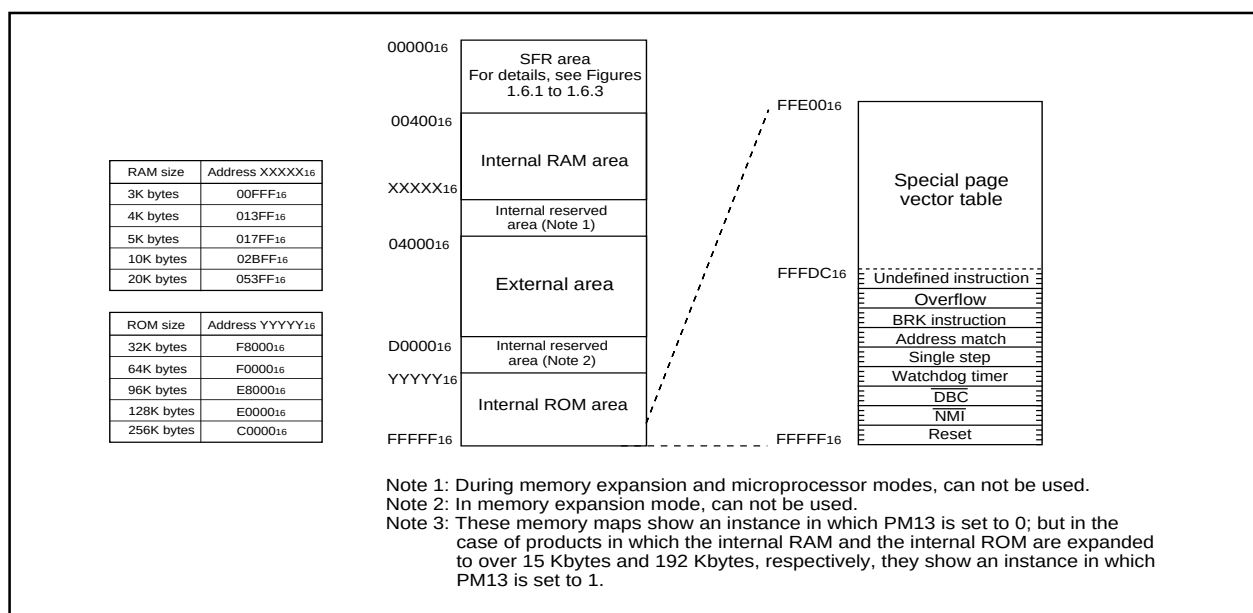


Figure 1.3.1. Memory map

Central Processing Unit (CPU)

The CPU has a total of 13 registers shown in Figure 1.4.1. Seven of these registers (R0, R1, R2, R3, A0, A1, and FB) come in two sets; therefore, these have two register banks.

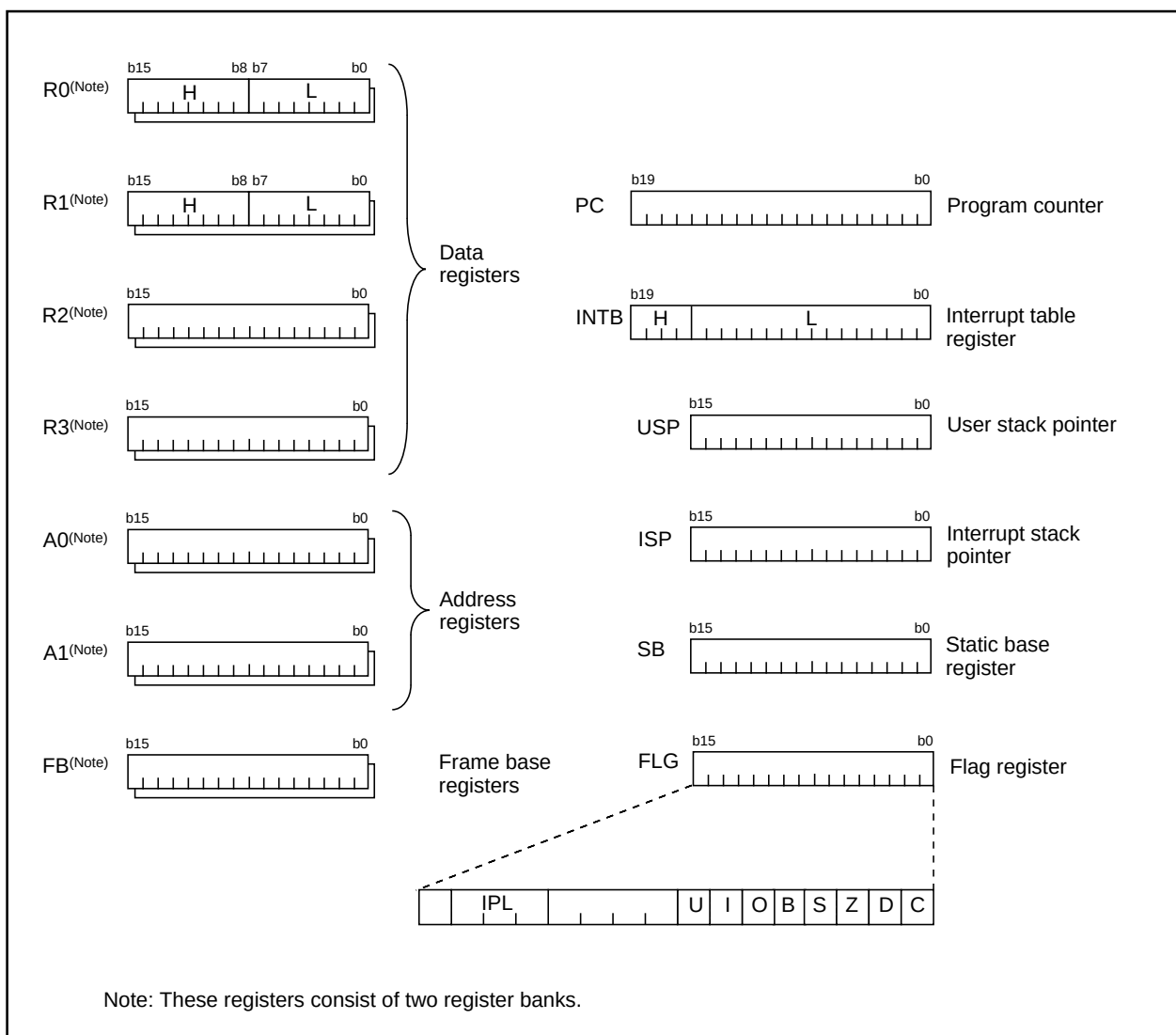


Figure 1.4.1. Central processing unit register

(1) Data registers (R0, R0H, R0L, R1, R1H, R1L, R2, and R3)

Data registers (R0, R1, R2, and R3) are configured with 16 bits, and are used primarily for transfer and arithmetic/logic operations.

Registers R0 and R1 each can be used as separate 8-bit data registers, high-order bits as (R0H/R1H), and low-order bits as (R0L/R1L). In some instructions, registers R2 and R0, as well as R3 and R1 can use as 32-bit data registers (R2R0/R3R1).

(2) Address registers (A0 and A1)

Address registers (A0 and A1) are configured with 16 bits, and have functions equivalent to those of data registers. These registers can also be used for address register indirect addressing and address register relative addressing.

In some instructions, registers A1 and A0 can be combined for use as a 32-bit address register (A1A0).

(3) Frame base register (FB)

Frame base register (FB) is configured with 16 bits, and is used for FB relative addressing.

(4) Program counter (PC)

Program counter (PC) is configured with 20 bits, indicating the address of an instruction to be executed.

(5) Interrupt table register (INTB)

Interrupt table register (INTB) is configured with 20 bits, indicating the start address of an interrupt vector table.

(6) Stack pointer (USP/ISP)

Stack pointer comes in two types: user stack pointer (USP) and interrupt stack pointer (ISP), each configured with 16 bits.

Your desired type of stack pointer (USP or ISP) can be selected by a stack pointer select flag (U flag).

This flag is located at the position of bit 7 in the flag register (FLG).

(7) Static base register (SB)

Static base register (SB) is configured with 16 bits, and is used for SB relative addressing.

(8) Flag register (FLG)

Flag register (FLG) is configured with 11 bits, each bit is used as a flag. Figure 1.4.2 shows the flag register (FLG). The following explains the function of each flag:

- **Bit 0: Carry flag (C flag)**

This flag retains a carry, borrow, or shift-out bit that has occurred in the arithmetic/logic unit.

- **Bit 1: Debug flag (D flag)**

This flag enables a single-step interrupt.

When this flag is "1", a single-step interrupt is generated after instruction execution. This flag is cleared to "0" when the interrupt is acknowledged.

- **Bit 2: Zero flag (Z flag)**

This flag is set to "1" when an arithmetic operation resulted in 0; otherwise, cleared to "0".

- **Bit 3: Sign flag (S flag)**

This flag is set to "1" when an arithmetic operation resulted in a negative value; otherwise, cleared to "0".

- **Bit 4: Register bank select flag (B flag)**

This flag chooses a register bank. Register bank 0 is selected when this flag is "0"; register bank 1 is selected when this flag is "1".

- **Bit 5: Overflow flag (O flag)**

This flag is set to "1" when an arithmetic operation resulted in overflow; otherwise, cleared to "0".

- **Bit 6: Interrupt enable flag (I flag)**

This flag enables a maskable interrupt.

An interrupt is disabled when this flag is "0", and is enabled when this flag is "1". This flag is cleared to "0" when the interrupt is acknowledged.

- **Bit 7: Stack pointer select flag (U flag)**

Interrupt stack pointer (ISP) is selected when this flag is “0” ; user stack pointer (USP) is selected when this flag is “1”.

This flag is cleared to “0” when a hardware interrupt is acknowledged or an INT instruction of software interrupt Nos. 0 to 31 is executed.

- **Bits 8 to 11: Reserved area**

- **Bits 12 to 14: Processor interrupt priority level (IPL)**

Processor interrupt priority level (IPL) is configured with three bits, for specification of up to eight processor interrupt priority levels from level 0 to level 7.

If a requested interrupt has priority greater than the processor interrupt priority level (IPL), the interrupt is enabled.

- **Bit 15: Reserved area**

The C, Z, S, and O flags are changed when instructions are executed. See the software manual for details.

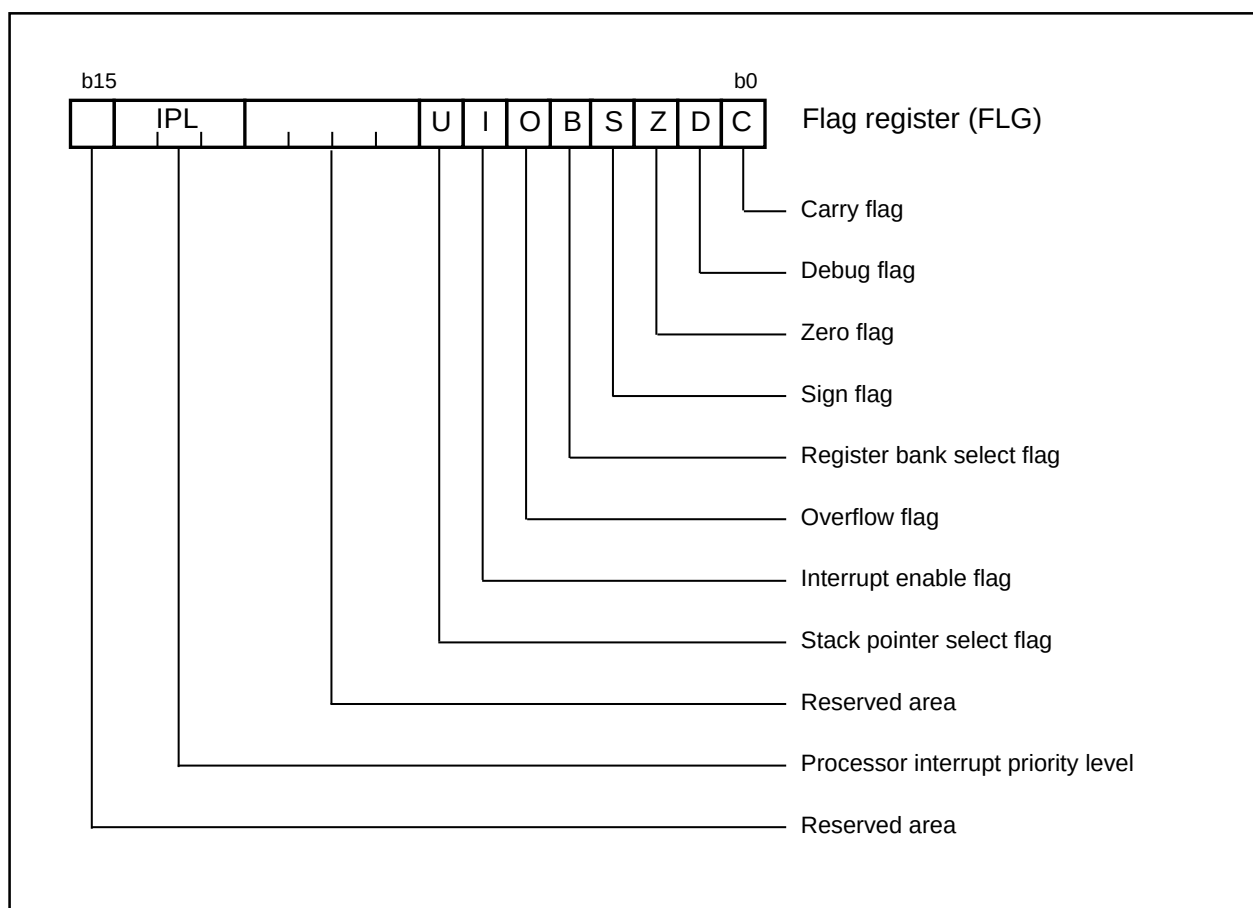


Figure 1.4.2. Flag register (FLG)

Reset

There are two kinds of resets; hardware and software. In both cases, operation is the same after the reset. (See "Software Reset" for details of software resets.) This section explains on hardware resets.

When the supply voltage is in the range where operation is guaranteed, a reset is effected by holding the reset pin level "L" (0.2V_{CC} max.) for at least 20 cycles. When the reset pin level is then returned to the "H" level while main clock is stable, the reset status is cancelled and program execution resumes from the address in the reset vector table.

Figure 1.5.1 shows the example reset circuit. Figure 1.5.2 shows the reset sequence.

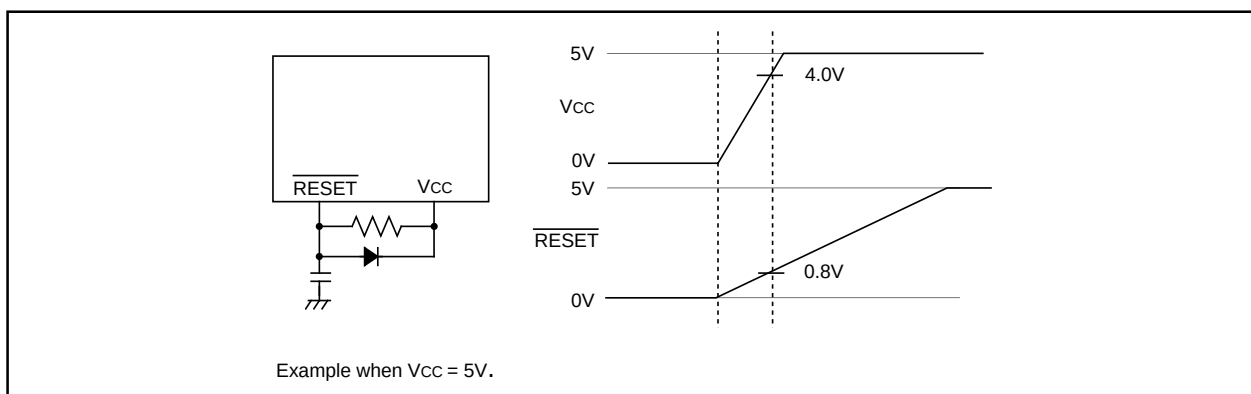


Figure 1.5.1. Example reset circuit

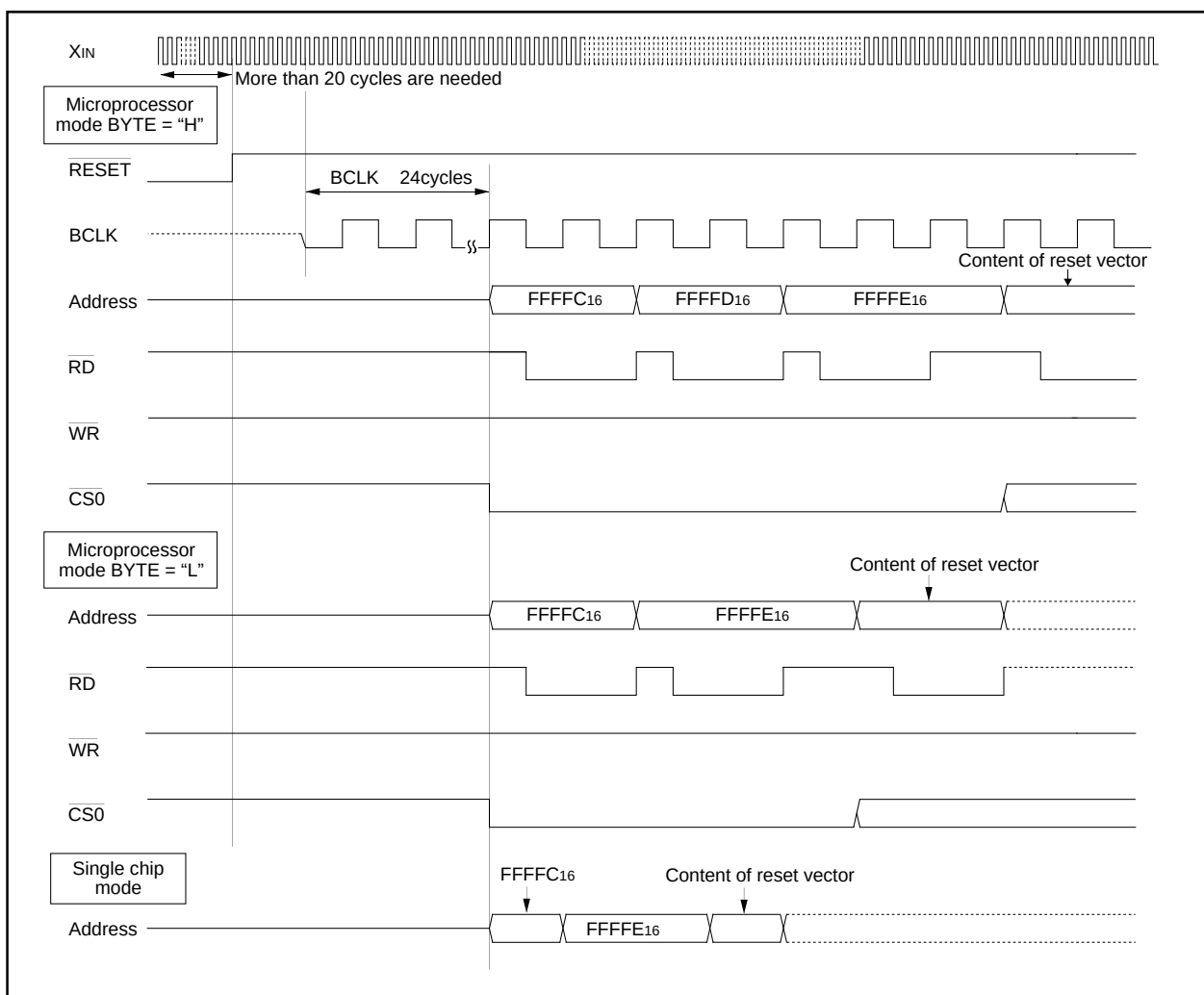


Figure 1.5.2. Reset sequence

Table 1.5.1 shows the statuses of the other pins while the $\overline{\text{RESET}}$ pin level is "L". Figures 1.5.3 and 1.5.4 show the internal status of the microcomputer immediately after the reset is cancelled.

Table 1.5.1. Pin status when $\overline{\text{RESET}}$ pin level is "L"

Pin name	Status		
	CNVss = Vss	CNVss = Vcc	
		BYTE = Vss	BYTE = Vcc
P0	Input port (floating)	Data input (floating)	Data input (floating)
P1	Input port (floating)	Data input (floating)	Input port (floating)
P2, P3, P40 to P43	Input port (floating)	Address output (undefined)	Address output (undefined)
P44	Input port (floating)	$\overline{\text{CS0}}$ output ("H" level is output)	$\overline{\text{CS0}}$ output ("H" level is output)
P45 to P47	Input port (floating)	Input port (floating) (pull-up resistor is on)	Input port (floating) (pull-up resistor is on)
P50	Input port (floating)	$\overline{\text{WR}}$ output ("H" level is output)	$\overline{\text{WR}}$ output ("H" level is output)
P51	Input port (floating)	$\overline{\text{BHE}}$ output (undefined)	$\overline{\text{BHE}}$ output (undefined)
P52	Input port (floating)	$\overline{\text{RD}}$ output ("H" level is output)	$\overline{\text{RD}}$ output ("H" level is output)
P53	Input port (floating)	BCLK output	BCLK output
P54	Input port (floating)	$\overline{\text{HLDA}}$ output (The output value depends on the input to the HOLD pin)	$\overline{\text{HLDA}}$ output (The output value depends on the input to the HOLD pin)
P55	Input port (floating)	$\overline{\text{HOLD}}$ input (floating)	$\overline{\text{HOLD}}$ input (floating)
P56	Input port (floating)	ALE output ("L" level is output)	ALE output ("L" level is output)
P57	Input port (floating)	$\overline{\text{RDY}}$ input (floating)	$\overline{\text{RDY}}$ input (floating)
P6, P7, P80 to P84, P86, P87, P9, P10	Input port (floating)	Input port (floating)	Input port (floating)

(1) Processor mode register 0 (Note 1)	(0004 ₁₆)...	00 ₁₆	(29) UART1 receive interrupt control register	(0054 ₁₆)...	XXXX?000
(2) Processor mode register 1	(0005 ₁₆)...	0000XXXX	(30) Timer A0 interrupt control register	(0055 ₁₆)...	XXXX?000
(3) System clock control register 0	(0006 ₁₆)...	01001000	(31) Timer A1 interrupt control register	(0056 ₁₆)...	XXXX?000
(4) System clock control register 1	(0007 ₁₆)...	00100000	(32) Timer A2 interrupt control register	(0057 ₁₆)...	XXXX?000
(5) Chip select control register	(0008 ₁₆)...	00000001	(33) Timer A3 interrupt control register	(0058 ₁₆)...	XXXX?000
(6) Address match interrupt enable register	(0009 ₁₆)...	XXXXXX00	(34) Timer A4 interrupt control register	(0059 ₁₆)...	XXXX?000
(7) Protect register	(000A ₁₆)...	XXXXXX00	(35) Timer B0 interrupt control register	(005A ₁₆)...	XXXX?000
(8) Watchdog timer control register	(000F ₁₆)...	000???	(36) Timer B1 interrupt control register	(005B ₁₆)...	XXXX?000
(9) Address match interrupt register 0	(0010 ₁₆)...	00 ₁₆	(37) Timer B2 interrupt control register	(005C ₁₆)...	XXXX?000
	(0011 ₁₆)...	00 ₁₆	(38) INTO interrupt control register	(005D ₁₆)...	XX00?000
	(0012 ₁₆)...	XXXXXX0000	(39) INT1 interrupt control register	(005E ₁₆)...	XX00?000
(10) Address match interrupt register 1	(0014 ₁₆)...	00 ₁₆	(40) INT2 interrupt control register	(005F ₁₆)...	XX00?000
	(0015 ₁₆)...	00 ₁₆	(41) Timer B3,4,5 count start flag	(0340 ₁₆)...	000XXXXX
	(0016 ₁₆)...	XXXXXX0000	(42) Three-phase PWM control register 0	(0348 ₁₆)...	00 ₁₆
(11) DMA0 control register	(002C ₁₆)...	000000?000	(43) Three-phase PWM control register 1	(0349 ₁₆)...	00 ₁₆
(12) DMA1 control register	(003C ₁₆)...	000000?000	(44) Three-phase output buffer register 0	(034A ₁₆)...	00 ₁₆
(13) INT3 interrupt control register	(0044 ₁₆)...	XX00?000	(45) Three-phase output buffer register 1	(034B ₁₆)...	00 ₁₆
(14) Timer B5 interrupt control register	(0045 ₁₆)...	XXXX?000	(46) Timer B3 mode register	(035B ₁₆)...	00?XX000
(15) Timer B4 interrupt control register	(0046 ₁₆)...	XXXX?000	(47) Timer B4 mode register	(035C ₁₆)...	00?XX000
(16) Timer B3 interrupt control register	(0047 ₁₆)...	XXXX?000	(48) Timer B5 mode register	(035D ₁₆)...	00?XX000
(17) SI/O4 interrupt control register	(0048 ₁₆)...	XX00?000	(49) Interrupt cause select register	(035F ₁₆)...	00 ₁₆
(18) SI/O3 interrupt control register	(0049 ₁₆)...	XX00?000	(50) SI/O3 control register	(0362 ₁₆)...	40 ₁₆
(19) Bus collision detection interrupt control register	(004A ₁₆)...	XXXX?000	(51) SI/O4 control register	(0366 ₁₆)...	40 ₁₆
(20) DMA0 interrupt control register	(004B ₁₆)...	XXXX?000	(52) UART2 special mode register 3 (Note 2)	(0375 ₁₆)...	?
(21) DMA1 interrupt control register	(004C ₁₆)...	XXXX?000	(53) UART2 special mode register 2	(0376 ₁₆)...	00 ₁₆
(22) Key input interrupt control register	(004D ₁₆)...	XXXX?000	(54) UART2 special mode register	(0377 ₁₆)...	00 ₁₆
(23) A-D conversion interrupt control register	(004E ₁₆)...	XXXX?000	(55) UART2 transmit/receive mode register	(0378 ₁₆)...	00 ₁₆
(24) UART2 transmit interrupt control register	(004F ₁₆)...	XXXX?000	(56) UART2 transmit/receive control register 0	(037C ₁₆)...	00001000
(25) UART2 receive interrupt control register	(0050 ₁₆)...	XXXX?000	(57) UART2 transmit/receive control register 1	(037D ₁₆)...	00000010
(26) UART0 transmit interrupt control register	(0051 ₁₆)...	XXXX?000			
(27) UART0 receive interrupt control register	(0052 ₁₆)...	XXXX?000			
(28) UART1 transmit interrupt control register	(0053 ₁₆)...	XXXX?000			

x : Nothing is mapped to this bit
 ? : Undefined
 The content of other registers and RAM is undefined when the microcomputer is reset. The initial values must therefore be set.

Note 1: When the VCC level is applied to the CNVSS pin, it is 03₁₆ at a reset.
 Note 2: "00₁₆" is read out when set bit 7 (SDDS) of the UART2 special mode register (address 0377₁₆) to "1".

Figure 1.5.3. Device's internal status after a reset is cleared

(58) Count start flag	(0380 ₁₆)...	00 ₁₆	(84) A-D control register 1	(03D7 ₁₆)...	00 ₁₆
(59) Clock prescaler reset flag	(0381 ₁₆)...	0XXXXXX	(85) D-A control register	(03DC ₁₆)...	00 ₁₆
(60) One-shot start flag	(0382 ₁₆)...	00XX0000	(86) Port P0 direction register	(03E2 ₁₆)...	00 ₁₆
(61) Trigger select flag	(0383 ₁₆)...	00 ₁₆	(87) Port P1 direction register	(03E3 ₁₆)...	00 ₁₆
(62) Up-down flag	(0384 ₁₆)...	00 ₁₆	(88) Port P2 direction register	(03E6 ₁₆)...	00 ₁₆
(63) Timer A0 mode register	(0396 ₁₆)...	00 ₁₆	(89) Port P3 direction register	(03E7 ₁₆)...	00 ₁₆
(64) Timer A1 mode register	(0397 ₁₆)...	00 ₁₆	(90) Port P4 direction register	(03EA ₁₆)...	00 ₁₆
(65) Timer A2 mode register	(0398 ₁₆)...	00 ₁₆	(91) Port P5 direction register	(03EB ₁₆)...	00 ₁₆
(66) Timer A3 mode register	(0399 ₁₆)...	00 ₁₆	(92) Port P6 direction register	(03EE ₁₆)...	00 ₁₆
(67) Timer A4 mode register	(039A ₁₆)...	00 ₁₆	(93) Port P7 direction register	(03EF ₁₆)...	00 ₁₆
(68) Timer B0 mode register	(039B ₁₆)...	00?XX000	(94) Port P8 direction register	(03F2 ₁₆)...	00XX0000
(69) Timer B1 mode register	(039C ₁₆)...	00?XX000	(95) Port P9 direction register	(03F3 ₁₆)...	00 ₁₆
(70) Timer B2 mode register	(039D ₁₆)...	00?XX000	(96) Port P10 direction register	(03F6 ₁₆)...	00 ₁₆
(71) UART0 transmit/receive mode register	(03A0 ₁₆)...	00 ₁₆	(97) Pull-up control register 0	(03FC ₁₆)...	00 ₁₆
(72) UART0 transmit/receive control register 0	(03A4 ₁₆)...	00001000	(98) Pull-up control register 1(Note1)	(03FD ₁₆)...	00 ₁₆
(73) UART0 transmit/receive control register 1	(03A5 ₁₆)...	00000010	(99) Pull-up control register 2	(03FE ₁₆)...	00 ₁₆
(74) UART1 transmit/receive mode register	(03A8 ₁₆)...	00 ₁₆	(100) Port control register	(03FF ₁₆)...	00 ₁₆
(75) UART1 transmit/receive control register 0	(03AC ₁₆)...	00001000	(101) Data registers (R0/R1/R2/R3)		0000 ₁₆
(76) UART1 transmit/receive control register 1	(03AD ₁₆)...	00000010	(102) Address registers (A0/A1)		0000 ₁₆
(77) UART transmit/receive control register 2	(03B0 ₁₆)...	XX000000	(103) Frame base register (FB)		0000 ₁₆
(78) Flash memory control register 1 (Note2)	(03B6 ₁₆)...	??XX0000	(104) Interrupt table register (INTB)		00000 ₁₆
(79) Flash memory control register 0 (Note2)	(03B7 ₁₆)...	XX000001	(105) User stack pointer (USP)		0000 ₁₆
(80) DMA0 cause select register	(03B8 ₁₆)...	00 ₁₆	(106) Interrupt stack pointer (ISP)		0000 ₁₆
(81) DMA1 cause select register	(03BA ₁₆)...	00 ₁₆	(107) Static base register (SB)		0000 ₁₆
(82) A-D control register 2	(03D4 ₁₆)...	0000XXXX	(108) Flag register (FLG)		0000 ₁₆
(83) A-D control register 0	(03D6 ₁₆)...	000000??			

x : Nothing is mapped to this bit
? : Undefined

The content of other registers and RAM is undefined when the microcomputer is reset. The initial values must therefore be set.

Note1: When the Vcc level is applied to the CNVSS pin, it is 02₁₆ at a reset.

Note2: This register is only exist in flash memory version.

Figure 1.5.4. Device's internal status after a reset is cleared

0000 ₁₆		0040 ₁₆	
0001 ₁₆		0041 ₁₆	
0002 ₁₆		0042 ₁₆	
0003 ₁₆		0043 ₁₆	
0004 ₁₆	Processor mode register 0 (PM0)	0044 ₁₆	INT3 interrupt control register (INT3IC)
0005 ₁₆	Processor mode register 1 (PM1)	0045 ₁₆	Timer B5 interrupt control register (TB5IC)
0006 ₁₆	System clock control register 0 (CM0)	0046 ₁₆	Timer B4 interrupt control register (TB4IC)
0007 ₁₆	System clock control register 1 (CM1)	0047 ₁₆	Timer B3 interrupt control register (TB3IC)
0008 ₁₆	Chip select control register (CSR)	0048 ₁₆	SI/O4 interrupt control register (S4IC)
0009 ₁₆	Address match interrupt enable register (AIER)		INT5 interrupt control register (INT5IC)
000A ₁₆	Protect register (PRCR)	0049 ₁₆	SI/O3 interrupt control register (S3IC)
000B ₁₆			INT4 interrupt control register (INT4IC)
000C ₁₆		004A ₁₆	Bus collision detection interrupt control register (BCNIC)
000D ₁₆		004B ₁₆	DMA0 interrupt control register (DM0IC)
000E ₁₆	Watchdog timer start register (WDTs)	004C ₁₆	DMA1 interrupt control register (DM1IC)
000F ₁₆	Watchdog timer control register (WDC)	004D ₁₆	Key input interrupt control register (KUPIC)
0010 ₁₆		004E ₁₆	A-D conversion interrupt control register (ADIC)
0011 ₁₆	Address match interrupt register 0 (RMAD0)	004F ₁₆	UART2 transmit interrupt control register (S2TIC)
0012 ₁₆		0050 ₁₆	UART2 receive interrupt control register (S2RIC)
0013 ₁₆		0051 ₁₆	UART0 transmit interrupt control register (S0TIC)
0014 ₁₆		0052 ₁₆	UART0 receive interrupt control register (S0RIC)
0015 ₁₆	Address match interrupt register 1 (RMAD1)	0053 ₁₆	UART1 transmit interrupt control register (S1TIC)
0016 ₁₆		0054 ₁₆	UART1 receive interrupt control register (S1RIC)
0017 ₁₆		0055 ₁₆	Timer A0 interrupt control register (TA0IC)
0018 ₁₆		0056 ₁₆	Timer A1 interrupt control register (TA1IC)
0019 ₁₆		0057 ₁₆	Timer A2 interrupt control register (TA2IC)
001A ₁₆		0058 ₁₆	Timer A3 interrupt control register (TA3IC)
001B ₁₆		0059 ₁₆	Timer A4 interrupt control register (TA4IC)
001C ₁₆		005A ₁₆	Timer B0 interrupt control register (TB0IC)
001D ₁₆		005B ₁₆	Timer B1 interrupt control register (TB1IC)
001E ₁₆		005C ₁₆	Timer B2 interrupt control register (TB2IC)
001F ₁₆		005D ₁₆	INT0 interrupt control register (INT0IC)
0020 ₁₆		005E ₁₆	INT1 interrupt control register (INT1IC)
0021 ₁₆	DMA0 source pointer (SAR0)	005F ₁₆	INT2 interrupt control register (INT2IC)
0022 ₁₆		0060 ₁₆	
0023 ₁₆		0061 ₁₆	
0024 ₁₆		0062 ₁₆	
0025 ₁₆	DMA0 destination pointer (DAR0)	0063 ₁₆	
0026 ₁₆		0064 ₁₆	
0027 ₁₆		0065 ₁₆	
0028 ₁₆			
0029 ₁₆	DMA0 transfer counter (TCR0)		
002A ₁₆			
002B ₁₆			
002C ₁₆	DMA0 control register (DM0CON)		
002D ₁₆			
002E ₁₆			
002F ₁₆			
0030 ₁₆			
0031 ₁₆	DMA1 source pointer (SAR1)		
0032 ₁₆			
0033 ₁₆			
0034 ₁₆			
0035 ₁₆	DMA1 destination pointer (DAR1)		
0036 ₁₆			
0037 ₁₆			
0038 ₁₆			
0039 ₁₆	DMA1 transfer counter (TCR1)		
003A ₁₆			
003B ₁₆			
003C ₁₆	DMA1 control register (DM1CON)		
003D ₁₆			
003E ₁₆			
003F ₁₆			

Note : Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

Figure 1.6.1. Location of peripheral unit control registers (1)

0340 ₁₆	Timer B3, 4, 5 count start flag (TBSR)	0380 ₁₆	Count start flag (TABSR)
0341 ₁₆		0381 ₁₆	Clock prescaler reset flag (CPSRF)
0342 ₁₆		0382 ₁₆	One-shot start flag (ONSF)
0343 ₁₆	Timer A1-1 register (TA11)	0383 ₁₆	Trigger select register (TRGSR)
0344 ₁₆		0384 ₁₆	Up-down flag (UDF)
0345 ₁₆	Timer A2-1 register (TA21)	0385 ₁₆	
0346 ₁₆		0386 ₁₆	Timer A0 (TA0)
0347 ₁₆	Timer A4-1 register (TA41)	0387 ₁₆	
0348 ₁₆	Three-phase PWM control register 0(INVC0)	0388 ₁₆	Timer A1 (TA1)
0349 ₁₆	Three-phase PWM control register 1(INVC1)	0389 ₁₆	
034A ₁₆	Three-phase output buffer register 0(IDB0)	038A ₁₆	Timer A2 (TA2)
034B ₁₆	Three-phase output buffer register 1(IDB1)	038B ₁₆	
034C ₁₆	Dead time timer(DTT)	038C ₁₆	Timer A3 (TA3)
034D ₁₆	Timer B2 interrupt occurrence frequency set counter(ICTB2)	038D ₁₆	
034E ₁₆		038E ₁₆	Timer A4 (TA4)
034F ₁₆		038F ₁₆	
0350 ₁₆		0390 ₁₆	Timer B0 (TB0)
0351 ₁₆	Timer B3 register (TB3)	0391 ₁₆	
0352 ₁₆		0392 ₁₆	Timer B1 (TB1)
0353 ₁₆	Timer B4 register (TB4)	0393 ₁₆	
0354 ₁₆		0394 ₁₆	Timer B2 (TB2)
0355 ₁₆	Timer B5 register (TB5)	0395 ₁₆	
0356 ₁₆		0396 ₁₆	Timer A0 mode register (TA0MR)
0357 ₁₆		0397 ₁₆	Timer A1 mode register (TA1MR)
0358 ₁₆		0398 ₁₆	Timer A2 mode register (TA2MR)
0359 ₁₆		0399 ₁₆	Timer A3 mode register (TA3MR)
035A ₁₆		039A ₁₆	Timer A4 mode register (TA4MR)
035B ₁₆	Timer B3 mode register (TB3MR)	039B ₁₆	Timer B0 mode register (TB0MR)
035C ₁₆	Timer B4 mode register (TB4MR)	039C ₁₆	Timer B1 mode register (TB1MR)
035D ₁₆	Timer B5 mode register (TB5MR)	039D ₁₆	Timer B2 mode register (TB2MR)
035E ₁₆		039E ₁₆	
035F ₁₆	Interrupt cause select register (IFSR)	039F ₁₆	
0360 ₁₆	SI/O3 transmit/receive register (S3TRR)	03A0 ₁₆	UART0 transmit/receive mode register (U0MR)
0361 ₁₆		03A1 ₁₆	UART0 bit rate generator (U0BRG)
0362 ₁₆	SI/O3 control register (S3C)	03A2 ₁₆	
0363 ₁₆	SI/O3 bit rate generator (S3BRG)	03A3 ₁₆	UART0 transmit buffer register (U0TB)
0364 ₁₆	SI/O4 transmit/receive register (S4TRR)	03A4 ₁₆	UART0 transmit/receive control register 0 (U0C0)
0365 ₁₆		03A5 ₁₆	UART0 transmit/receive control register 1 (U0C1)
0366 ₁₆	SI/O4 control register (S4C)	03A6 ₁₆	
0367 ₁₆	SI/O4 bit rate generator (S4BRG)	03A7 ₁₆	UART0 receive buffer register (U0RB)
0368 ₁₆		03A8 ₁₆	UART1 transmit/receive mode register (U1MR)
0369 ₁₆		03A9 ₁₆	UART1 bit rate generator (U1BRG)
036A ₁₆		03AA ₁₆	
036B ₁₆		03AB ₁₆	UART1 transmit buffer register (U1TB)
036C ₁₆		03AC ₁₆	UART1 transmit/receive control register 0 (U1C0)
036D ₁₆		03AD ₁₆	UART1 transmit/receive control register 1 (U1C1)
036E ₁₆		03AE ₁₆	
036F ₁₆		03AF ₁₆	UART1 receive buffer register (U1RB)
0370 ₁₆		03B0 ₁₆	UART transmit/receive control register 2 (U0CON)
0371 ₁₆		03B1 ₁₆	
0372 ₁₆		03B2 ₁₆	
0373 ₁₆		03B3 ₁₆	
0374 ₁₆		03B4 ₁₆	
0375 ₁₆	UART2 special mode register 3(U2SMR3)	03B5 ₁₆	
0376 ₁₆	UART2 special mode register 2(U2SMR2)	03B6 ₁₆	Flash memory control register 1 (FMR1) (Note1)
0377 ₁₆	UART2 special mode register (U2SMR)	03B7 ₁₆	Flash memory control register 0 (FMR0) (Note1)
0378 ₁₆	UART2 transmit/receive mode register (U2MR)	03B8 ₁₆	DMA0 request cause select register (DM0SL)
0379 ₁₆	UART2 bit rate generator (U2BRG)	03B9 ₁₆	
037A ₁₆		03BA ₁₆	DMA1 request cause select register (DM1SL)
037B ₁₆	UART2 transmit buffer register (U2TB)	03BB ₁₆	
037C ₁₆	UART2 transmit/receive control register 0 (U2C0)	03BC ₁₆	
037D ₁₆	UART2 transmit/receive control register 1 (U2C1)	03BD ₁₆	CRC data register (CRCD)
037E ₁₆		03BE ₁₆	CRC input register (CRCIN)
037F ₁₆	UART2 receive buffer register (U2RB)	03BF ₁₆	

Note 1: This register is only exist in flash memory version.

Note 2: Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

Figure 1.6.2. Location of peripheral unit control registers (2)

03C0 ₁₆	A-D register 0 (AD0)
03C1 ₁₆	
03C2 ₁₆	A-D register 1 (AD1)
03C3 ₁₆	
03C4 ₁₆	A-D register 2 (AD2)
03C5 ₁₆	
03C6 ₁₆	A-D register 3 (AD3)
03C7 ₁₆	
03C8 ₁₆	A-D register 4 (AD4)
03C9 ₁₆	
03CA ₁₆	A-D register 5 (AD5)
03CB ₁₆	
03CC ₁₆	A-D register 6 (AD6)
03CD ₁₆	
03CE ₁₆	A-D register 7 (AD7)
03CF ₁₆	
03D0 ₁₆	
03D1 ₁₆	
03D2 ₁₆	
03D3 ₁₆	
03D4 ₁₆	A-D control register 2 (ADCON2)
03D5 ₁₆	
03D6 ₁₆	A-D control register 0 (ADCON0)
03D7 ₁₆	A-D control register 1 (ADCON1)
03D8 ₁₆	D-A register 0 (DA0)
03D9 ₁₆	
03DA ₁₆	D-A register 1 (DA1)
03DB ₁₆	
03DC ₁₆	D-A control register (DACON)
03DD ₁₆	
03DE ₁₆	
03DF ₁₆	
03E0 ₁₆	Port P0 (P0)
03E1 ₁₆	Port P1 (P1)
03E2 ₁₆	Port P0 direction register (PD0)
03E3 ₁₆	Port P1 direction register (PD1)
03E4 ₁₆	Port P2 (P2)
03E5 ₁₆	Port P3 (P3)
03E6 ₁₆	Port P2 direction register (PD2)
03E7 ₁₆	Port P3 direction register (PD3)
03E8 ₁₆	Port P4 (P4)
03E9 ₁₆	Port P5 (P5)
03EA ₁₆	Port P4 direction register (PD4)
03EB ₁₆	Port P5 direction register (PD5)
03EC ₁₆	Port P6 (P6)
03ED ₁₆	Port P7 (P7)
03EE ₁₆	Port P6 direction register (PD6)
03EF ₁₆	Port P7 direction register (PD7)
03F0 ₁₆	Port P8 (P8)
03F1 ₁₆	Port P9 (P9)
03F2 ₁₆	Port P8 direction register (PD8)
03F3 ₁₆	Port P9 direction register (PD9)
03F4 ₁₆	Port P10 (P10)
03F5 ₁₆	
03F6 ₁₆	Port P10 direction register (PD10)
03F7 ₁₆	
03F8 ₁₆	
03F9 ₁₆	
03FA ₁₆	
03FB ₁₆	
03FC ₁₆	Pull-up control register 0 (PUR0)
03FD ₁₆	Pull-up control register 1 (PUR1)
03FE ₁₆	Pull-up control register 2 (PUR2)
03FF ₁₆	Port control register (PCR)

Note : Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

Figure 1.6.3. Location of peripheral unit control registers (3)

Software Reset

Writing “1” to bit 3 of the processor mode register 0 (address 000416) applies a (software) reset to the microcomputer. A software reset has the same effect as a hardware reset. The contents of internal RAM are preserved.

Processor Mode

(1) Types of Processor Mode

One of three processor modes can be selected: single-chip mode, memory expansion mode, and microprocessor mode. The functions of some pins, the memory map, and the access space differ according to the selected processor mode.

- **Single-chip mode**

In single-chip mode, only internal memory space (SFR, internal RAM, and internal ROM) can be accessed. However, after the reset has been released and the operation of shifting from the microprocessor mode has started (“H” applied to the CNVss pin), the internal ROM area cannot be accessed even if the CPU shifts to the single-chip mode.

Ports P0 to P10 can be used as programmable I/O ports or as I/O ports for the internal peripheral functions.

- **Memory expansion mode**

In memory expansion mode, external memory can be accessed in addition to the internal memory space (SFR, internal RAM, and internal ROM). However, after the reset has been released and the operation of shifting from the microprocessor mode has started (“H” applied to the CNVss pin), the internal ROM area cannot be accessed even if the CPU shifts to the memory expansion mode.

In this mode, some of the pins function as the address bus, the data bus, and as control signals. The number of pins assigned to these functions depends on the bus and register settings. (See “Bus Settings” for details.)

- **Microprocessor mode**

In microprocessor mode, the SFR, internal RAM, and external memory space can be accessed. The internal ROM area cannot be accessed.

In this mode, some of the pins function as the address bus, the data bus, and as control signals. The number of pins assigned to these functions depends on the bus width and register settings. (See “Bus Settings” for details.)

(2) Setting Processor Modes

The processor mode is set using the CNVss pin and the processor mode bits (bits 1 and 0 at address 000416). Do not set the processor mode bits to “102”.

Regardless of the level of the CNVss pin, changing the processor mode bits selects the mode. Therefore, never change the processor mode bits when changing the contents of other bits. Do not change the processor mode bits simultaneously with other bits when changing the processor mode bits “012” or “112”. Change the processor mode bits after changing the other bits. Also do not attempt to shift to or from the microprocessor mode within the program stored in the internal ROM area.

- **Applying Vss to CNVss pin**

The microcomputer begins operation in single-chip mode after being reset. Memory expansion mode is selected by writing “012” to the processor mode bits.

- **Applying Vcc to CNVss pin**

The microcomputer starts to operate in microprocessor mode after being reset.

Figure 1.7.1 shows the processor mode register 0 and 1.

Figure 1.7.2 shows the memory maps applicable for each of the modes.

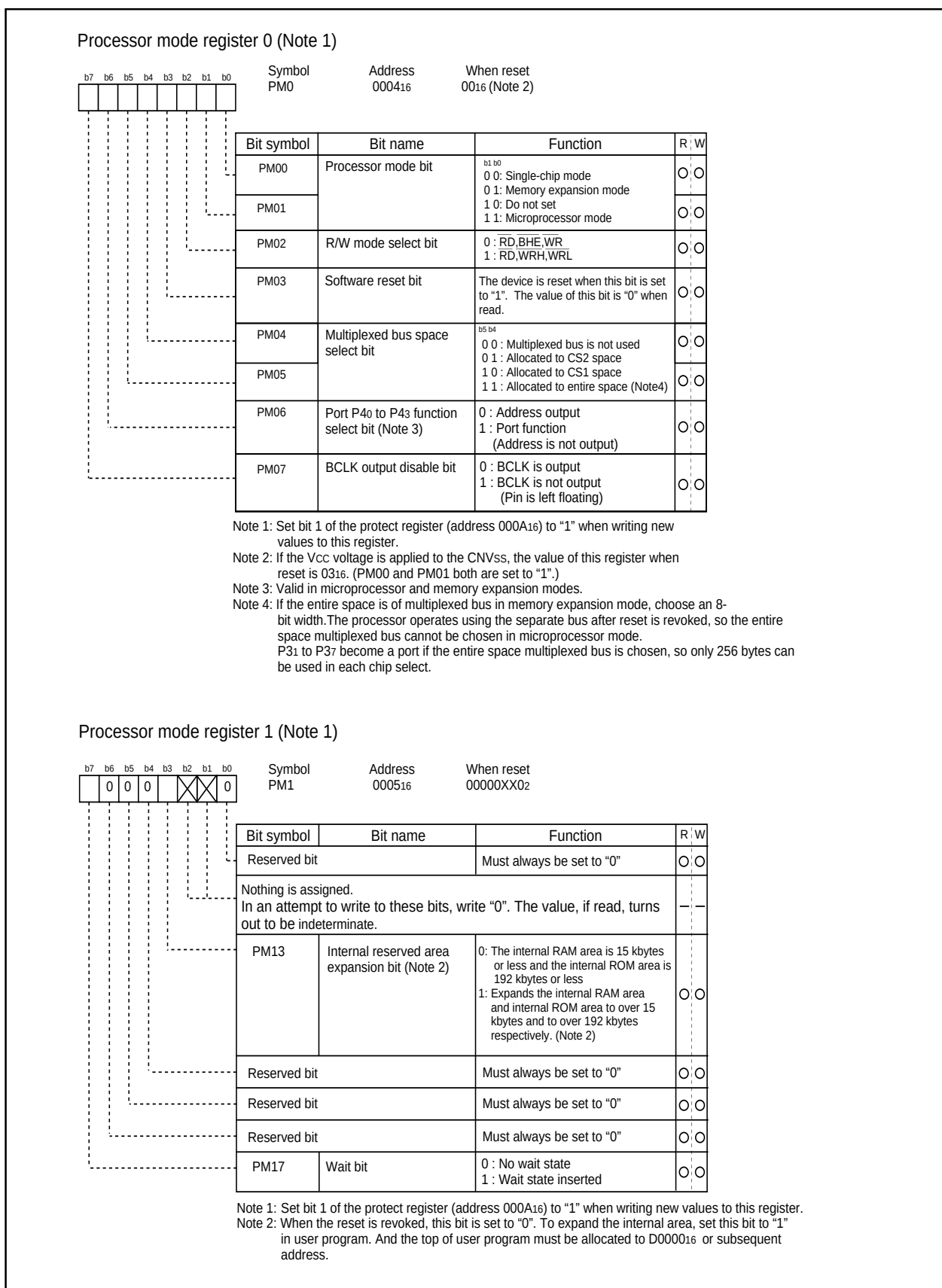


Figure 1.7.1. Processor mode register 0 and 1

Processor Mode

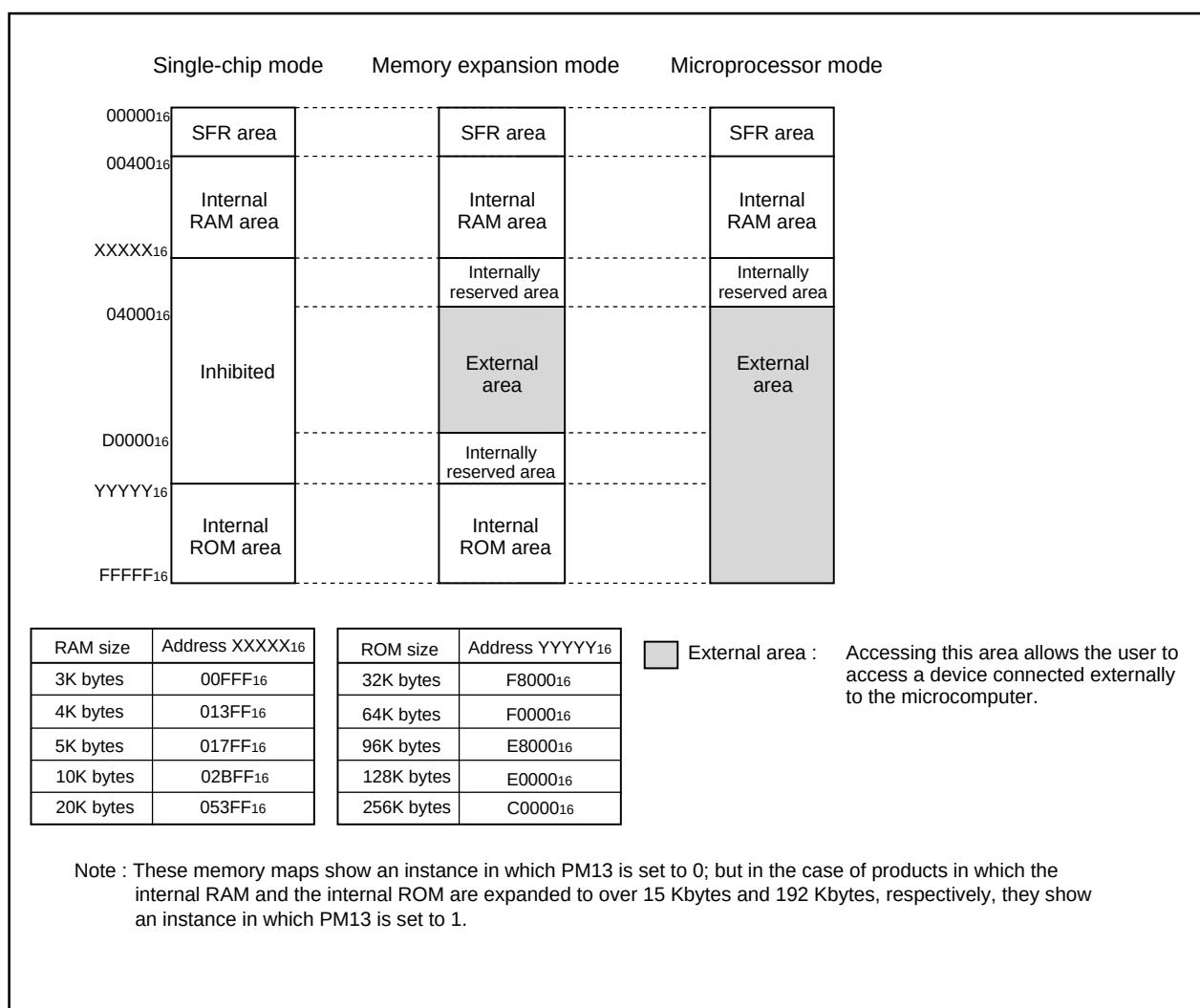


Figure 1.7.2. Memory maps in each processor mode (without memory area expansion, normal mode)

Internal Reserved Area Expansion Bit (PM13)

This bit expands the internal RAM area and the internal ROM area, and changes the chip select area. In M30624MGA/FGA, for example, to set this bit to “1” expands the internal RAM area and the internal ROM area to 20 Kbytes and 256 Kbytes respectively. Refer to Figure 1.7.3 for the chip select area. When the reset is revoked, this bit is set to “0”. To expand the internal area, set this bit to “1” in user program. And the top of user program must be allocated to D0000₁₆ or subsequent address.

In the case of the product in which the internal ROM is 192 Kbytes or less and the internal RAM is 15 Kbytes or less, set this bit to “0” when this product is used in the memory expansion mode or the microprocessor mode. When the product is used in the single chip mode, the internal area is not expanded and any action is not affected, even if this bit is set to “1”.

Figure 1.7.3 shows the memory maps and the chip selection areas effected by PM13 (the internal reserved area expansion bit) in each processor mode for the product having an internal RAM of more than 15K bytes and a ROM of more than 192K bytes.

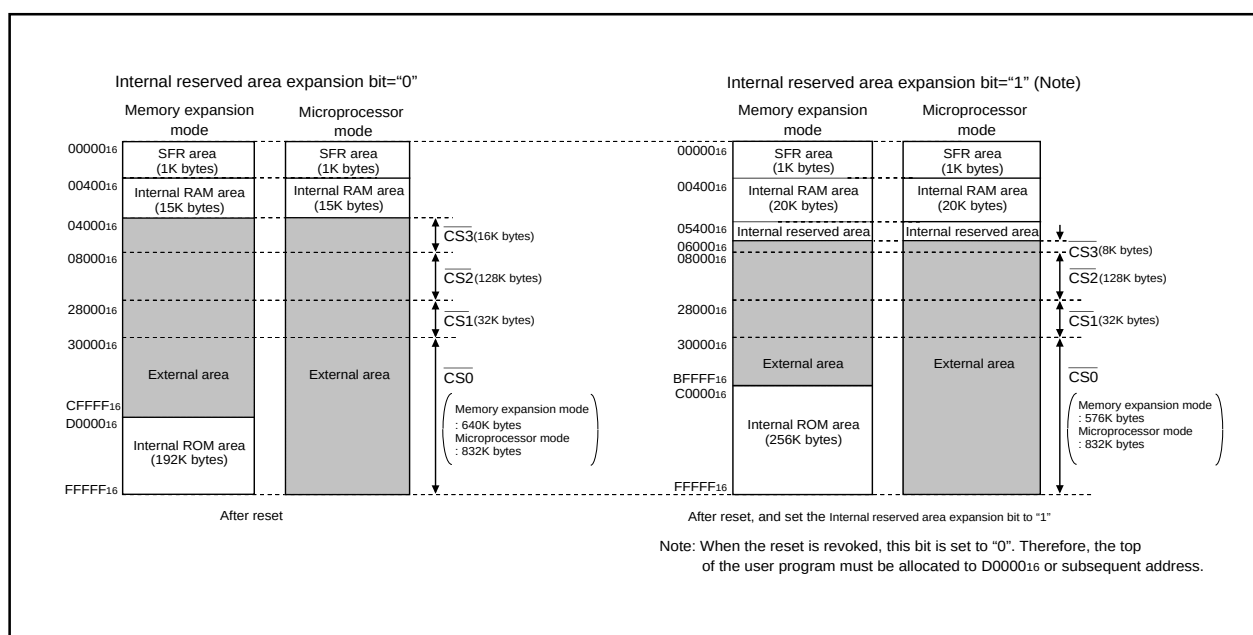


Figure 1.7.3. Memory location and chip select area in each processor mode

Bus Settings

Bus Settings

The BYTE pin and bits 4 to 6 of the processor mode register 0 (address 0004₁₆) are used to change the bus settings.

Table 1.8.1 shows the factors used to change the bus settings.

Table 1.8.1. Factors for switching bus settings

Bus setting	Switching factor
Switching external address bus width	Bit 6 of processor mode register 0
Switching external data bus width	BYTE pin
Switching between separate and multiplex bus	Bits 4 and 5 of processor mode register 0

(1) Selecting external address bus width

The address bus width for external output in the 1M bytes of address space can be set to 16 bits (64K bytes address space) or 20 bits (1M bytes address space). When bit 6 of the processor mode register 0 is set to "1", the external address bus width is set to 16 bits, and P2 and P3 become part of the address bus. P40 to P43 can be used as programmable I/O ports. When bit 6 of processor mode register 0 is set to "0", the external address bus width is set to 20 bits, and P2, P3, and P40 to P43 become part of the address bus.

(2) Selecting external data bus width

The external data bus width can be set to 8 or 16 bits. (Note, however, that only the separate bus can be set.) When the BYTE pin is "L", the bus width is set to 16 bits; when "H", it is set to 8 bits. (The internal bus width is permanently set to 16 bits.) While operating, fix the BYTE pin either to "H" or to "L".

(3) Selecting separate/multiplex bus

The bus format can be set to multiplex or separate bus using bits 4 and 5 of the processor mode register 0.

• Separate bus

In this mode, the data and address are input and output separately. The data bus can be set using the BYTE pin to be 8 or 16 bits. When the BYTE pin is "H", the data bus is set to 8 bits and P0 functions as the data bus and P1 as a programmable I/O port. When the BYTE pin is "L", the data bus is set to 16 bits and P0 and P1 are both used for the data bus.

When the separate bus is used for access, a software wait can be selected.

• Multiplex bus

In this mode, data and address I/O are time multiplexed. With the BYTE pin = "H", the 8 bits from D0 to D7 are multiplexed with A0 to A7.

With the BYTE pin = "L", the 8 bits from D0 to D7 are multiplexed with A1 to A8. D8 to D15 are not multiplexed. In this case, the external devices connected to the multiplexed bus are mapped to the microcomputer's even addresses (every 2nd address). To access these external devices, access the even addresses as bytes.

The ALE signal latches the address. It is output from P56.

Before using the multiplex bus for access, be sure to insert a software wait.

If the entire space is of multiplexed bus in memory expansion mode, choose an 8-bit width.

The processor operates using the separate bus after reset is revoked, so the entire space multiplexed bus cannot be chosen in microprocessor mode.

P31 to P37 become a port if the entire space multiplexed bus is chosen, so only 256 bytes can be used in each chip select.

Bus Settings

Table 1.8.2. Pin functions for each processor mode

Processor mode	Single-chip mode	Memory expansion mode/microprocessor modes				Memory expansion mode
Multiplexed bus space select bit		"01", "10" [Either CS1 or CS2 is for multiplexed bus and others are for separate bus]		"00" (separate bus)		"11" (Note 1) [multiplexed bus for the entire space]
Data bus width BYTE pin level		8 bits "H"	16 bits "L"	8 bits "H"	16 bits "L"	8 bit "H"
P00 to P07	I/O port	Data bus	Data bus	Data bus	Data bus	I/O port
P10 to P17	I/O port	I/O port	Data bus	I/O port	Data bus	I/O port
P20	I/O port	Address bus /data bus(Note 2)	Address bus	Address bus	Address bus	Address bus /data bus
P21 to P27	I/O port	Address bus /data bus(Note 2)	Address bus /data bus(Note 2)	Address bus	Address bus	Address bus /data bus
P30	I/O port	Address bus	Address bus /data bus(Note 2)	Address bus	Address bus	A8/D7
P31 to P37	I/O port	Address bus	Address bus	Address bus	Address bus	I/O port
P40 to P43 Port P40 to P43 function select bit = 1	I/O port	I/O port	I/O port	I/O port	I/O port	I/O port
P40 to P43 Port P40 to P43 function select bit = 0	I/O port	Address bus	Address bus	Address bus	Address bus	I/O port
P44 to P47	I/O port	$\overline{CS}$ (chip select) or programmable I/O port (For details, refer to "Bus control")				
P50 to P53	I/O port	Outputs $\overline{RD}$, $\overline{WRL}$, $\overline{WRH}$, and $\overline{BCLK}$ or $\overline{RD}$, $\overline{BHE}$, $\overline{WR}$, and $\overline{BCLK}$ (For details, refer to "Bus control")				
P54	I/O port	$\overline{HLDA}$	$\overline{HLDA}$	$\overline{HLDA}$	$\overline{HLDA}$	$\overline{HLDA}$
P55	I/O port	$\overline{HOLD}$	$\overline{HOLD}$	$\overline{HOLD}$	$\overline{HOLD}$	$\overline{HOLD}$
P56	I/O port	ALE	ALE	ALE	ALE	ALE
P57	I/O port	$\overline{RDY}$	$\overline{RDY}$	$\overline{RDY}$	$\overline{RDY}$	$\overline{RDY}$

Note 1: If the entire space is of multiplexed bus in memory expansion mode, choose an 8-bit width.

The processor operates using the separate bus after reset is revoked, so the entire space multiplexed bus cannot be chosen in microprocessor mode.

P31 to P37 become a port if the entire space multiplexed bus is chosen, so only 256 bytes can be used in each chip select.

Note 2: Address bus when in separate bus mode.

Bus Control

Bus Control

The following explains the signals required for accessing external devices and software waits. The signals required for accessing the external devices are valid when the processor mode is set to memory expansion mode and microprocessor mode. The software waits are valid in all processor modes.

(1) Address bus/data bus

The address bus consists of the 20 pins A0 to A19 for accessing the 1M bytes of address space.

The data bus consists of the pins for data I/O. When the BYTE pin is "H", the 8 ports D0 to D7 function as the data bus. When BYTE is "L", the 16 ports D0 to D15 function as the data bus.

When a change is made from single-chip mode to memory expansion mode, the value of the address bus is undefined until external memory is accessed.

(2) Chip select signal

The chip select signal is output using the same pins as P44 to P47. Bits 0 to 3 of the chip select control register (address 0008₁₆) set each pin to function as a port or to output the chip select signal. The chip select control register is valid in memory expansion mode and microprocessor mode. In single-chip mode, P44 to P47 function as programmable I/O ports regardless of the value in the chip select control register.

In microprocessor mode, only $\overline{CS0}$ outputs the chip select signal after the reset state has been cancelled. $\overline{CS1}$ to $\overline{CS3}$ function as input ports. Figure 1.9.1 shows the chip select control register.

The chip select signal can be used to split the external area into as many as four blocks. Tables 1.9.1 and 1.9.2 show the external memory areas specified using the chip select signal.

Table 1.9.1. External areas specified by the chip select signals

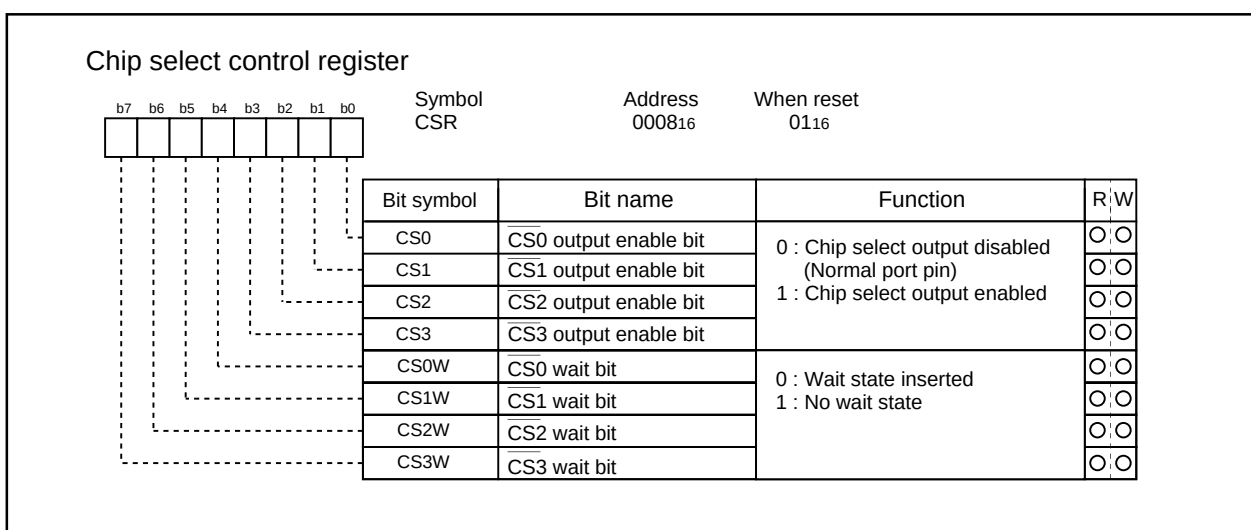
(A product having an internal RAM equal to or less than 15K bytes and a ROM equal to or less than 192K bytes)(Note)

Processor mode	Chip select signal			
	$\overline{CS0}$	$\overline{CS1}$	$\overline{CS2}$	$\overline{CS3}$
Memory expansion mode	30000 ₁₆ to CFFFF ₁₆ (640K bytes)	28000 ₁₆ to 2FFFF ₁₆ (32K bytes)	08000 ₁₆ to 27FFF ₁₆ (128K bytes)	04000 ₁₆ to 07FFF ₁₆ (16K bytes)
Microprocessor mode	30000 ₁₆ to FFFFF ₁₆ (832K bytes)			

Note :Be sure to set bit 3 (PM13) of processor mode register 1 to "0".

Table 1.9.2. External areas specified by the chip select signals**(A product having an internal RAM of more than 15K bytes and a ROM of more than 192K bytes)**

Processor mode	Chip select signal			
	$\overline{\text{CS0}}$	$\overline{\text{CS1}}$	$\overline{\text{CS2}}$	$\overline{\text{CS3}}$
Memory expansion mode	When PM13=0 30000 ₁₆ to CFFFF ₁₆ (640K bytes)	28000 ₁₆ to 2FFFF ₁₆ (32K bytes)	08000 ₁₆ to 27FFF ₁₆ (128K bytes)	When PM13=0 04000 ₁₆ to 07FFF ₁₆ (16K bytes)
	When PM13=1 30000 ₁₆ to BFFFF ₁₆ (576K bytes)			When PM13=1 06000 ₁₆ to 07FFF ₁₆ (8K bytes)
Microprocessor mode	03000 ₁₆ to FFFFF ₁₆ (816K bytes)			

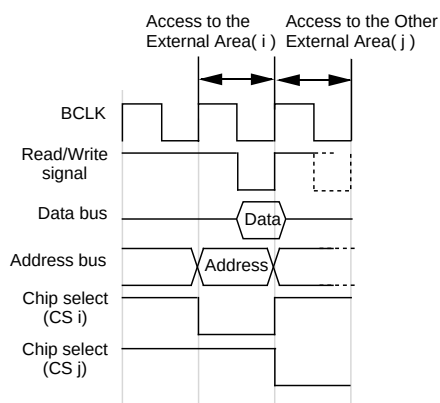
**Figure 1.9.1. Chip select control register**

The timing of the chip select signal changing to “L”(active) is synchronized with the address bus. But the timing of the chip select signal changing to “H” depends on the area which will be accessed in the next cycle. Figure 1.9.2 shows the output example of the address bus and chip select signal.

Bus Control

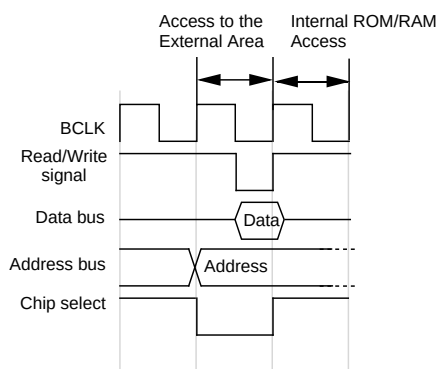
Example 1) After access the external area, both the address signal and the chip select signal change concurrently in the next cycle.

In this example, after access to the external area(i), an access to the area indicated by the other chip select signal(j) will occur in the next cycle. In this case, both the address bus and the chip select signal change between the two cycles.



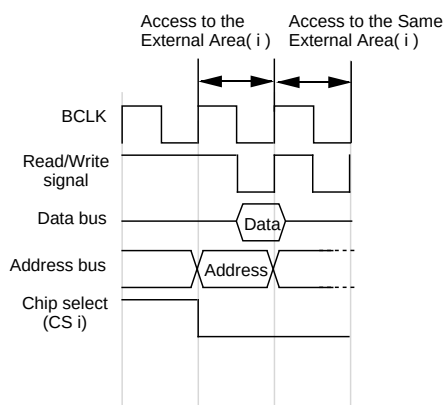
Example 2) After access the external area, only the chip select signal changes in the next cycle (the address bus does not change).

In this example, an access to the internal ROM or the internal RAM in the next cycle will occur, after access to the external area. In this case, the chip select signal changes between the two cycles, but the address does not change.



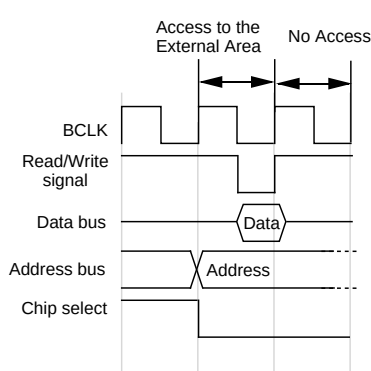
Example 3) After access the external area, only the address bus changes in the next cycle (the chip select signal does not change).

In this example, after access to the external area(i), an access to the area indicated by the same chip select signal(i) will occur in the next cycle. In this case, the address bus changes between the two cycles, but the chip select signal does not change.



Example 4) After access the external area, either the address signal and the chip select signal do not change in the next cycle.

In this example, any access to any area does not occur in the next cycle (either instruction prefetch does not occur). In this case, either the address bus and chip select signal do not change between the two cycles.



Note : These examples show the address bus and chip select signal within the successive two cycles.
According to the combination of these examples, the chip select can be elongated to over 2cycles.

Figure 1.9.2. Output Examples about Address Bus and Chip Select Signal (Separated Bus without Wait)

(3) Read/write signals

With a 16-bit data bus (BYTE pin = "L"), bit 2 of the processor mode register 0 (address 0004₁₆) select the combinations of $\overline{RD}$, $\overline{BHE}$, and $\overline{WR}$ signals or $\overline{RD}$, $\overline{WRL}$, and $\overline{WRH}$ signals. With an 8-bit data bus (BYTE pin = "H"), use the combination of $\overline{RD}$, $\overline{WR}$, and $\overline{BHE}$ signals. (Set bit 2 of the processor mode register 0 (address 0004₁₆) to "0".) Tables 1.9.3 and 1.9.4 show the operation of these signals.

After a reset has been cancelled, the combination of $\overline{RD}$, $\overline{WR}$, and $\overline{BHE}$ signals is automatically selected. When switching to the $\overline{RD}$, $\overline{WRL}$, and $\overline{WRH}$ combination, do not write to external memory until bit 2 of the processor mode register 0 (address 0004₁₆) has been set (Note).

Note: Before attempting to change the contents of the processor mode register 0, set bit 1 of the protect register (address 000A₁₆) to "1".

Table 1.9.3. Operation of $\overline{RD}$, $\overline{WRL}$, and $\overline{WRH}$ signals

Data bus width	$\overline{RD}$	$\overline{WRL}$	$\overline{WRH}$	Status of external data bus
16-bit (BYTE = "L")	L	H	H	Read data
	H	L	H	Write 1 byte of data to even address
	H	H	L	Write 1 byte of data to odd address
	H	L	L	Write data to both even and odd addresses

Table 1.9.4. Operation of $\overline{RD}$, $\overline{WR}$, and $\overline{BHE}$ signals

Data bus width	$\overline{RD}$	$\overline{WR}$	$\overline{BHE}$	A0	Status of external data bus
16-bit (BYTE = "L")	H	L	L	H	Write 1 byte of data to odd address
	L	H	L	H	Read 1 byte of data from odd address
	H	L	H	L	Write 1 byte of data to even address
	L	H	H	L	Read 1 byte of data from even address
	H	L	L	L	Write data to both even and odd addresses
	L	H	L	L	Read data from both even and odd addresses
8-bit (BYTE = "H")	H	L	Not used	H / L	Write 1 byte of data
	L	H	Not used	H / L	Read 1 byte of data

(4) ALE signal

The ALE signal latches the address when accessing the multiplex bus space. Latch the address when the ALE signal falls.

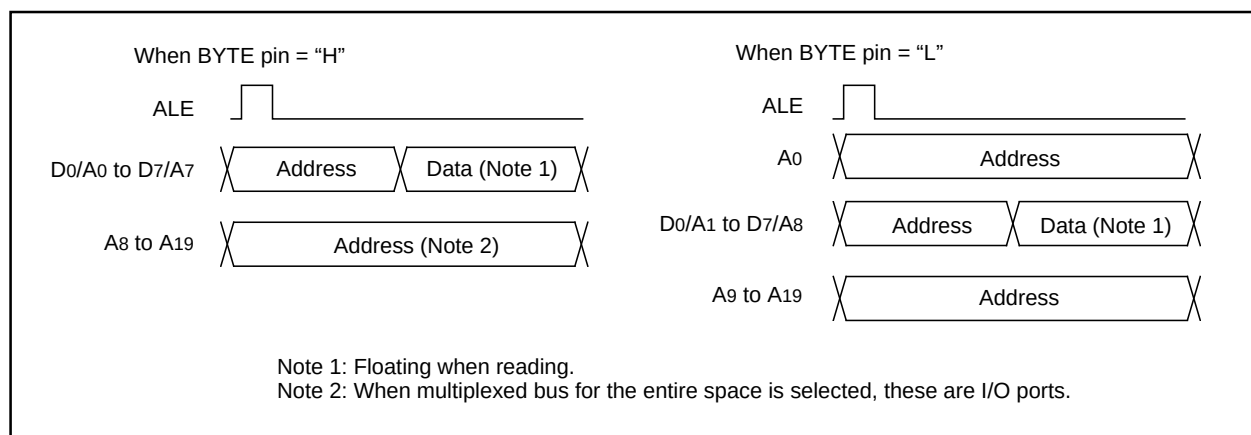


Figure 1.9.3. ALE signal and address/data bus

(5) The $\overline{\text{RDY}}$ signal

$\overline{\text{RDY}}$ is a signal that facilitates access to an external device that requires long access time. As shown in Figure 1.9.4, if an "L" is being input to the $\overline{\text{RDY}}$ at the BCLK falling edge, the bus turns to the wait state. If an "H" is being input to the $\overline{\text{RDY}}$ pin at the BCLK falling edge, the bus cancels the wait state. Table 1.9.5 shows the state of the microcomputer with the bus in the wait state, and Figure 1.9.4 shows an example in which the $\overline{\text{RD}}$ signal is prolonged by the $\overline{\text{RDY}}$ signal.

The $\overline{\text{RDY}}$ signal is valid when accessing the external area during the bus cycle in which bits 4 to 7 of the chip select control register (address 000816) are set to "0". The $\overline{\text{RDY}}$ signal is invalid when setting "1" to all bits 4 to 7 of the chip select control register (address 000816), but the $\overline{\text{RDY}}$ pin should be treated as properly as in non-using.

Table 1.9.5. Microcomputer status in wait state (Note)

Item	Status
Oscillation	On
R/W signal, address bus, data bus, $\overline{\text{CS}}$ ALE signal, $\overline{\text{HLDA}}$, programmable I/O ports	Maintain status when $\overline{\text{RDY}}$ signal received
Internal peripheral circuits	On

Note: The $\overline{\text{RDY}}$ signal cannot be received immediately prior to a software wait.

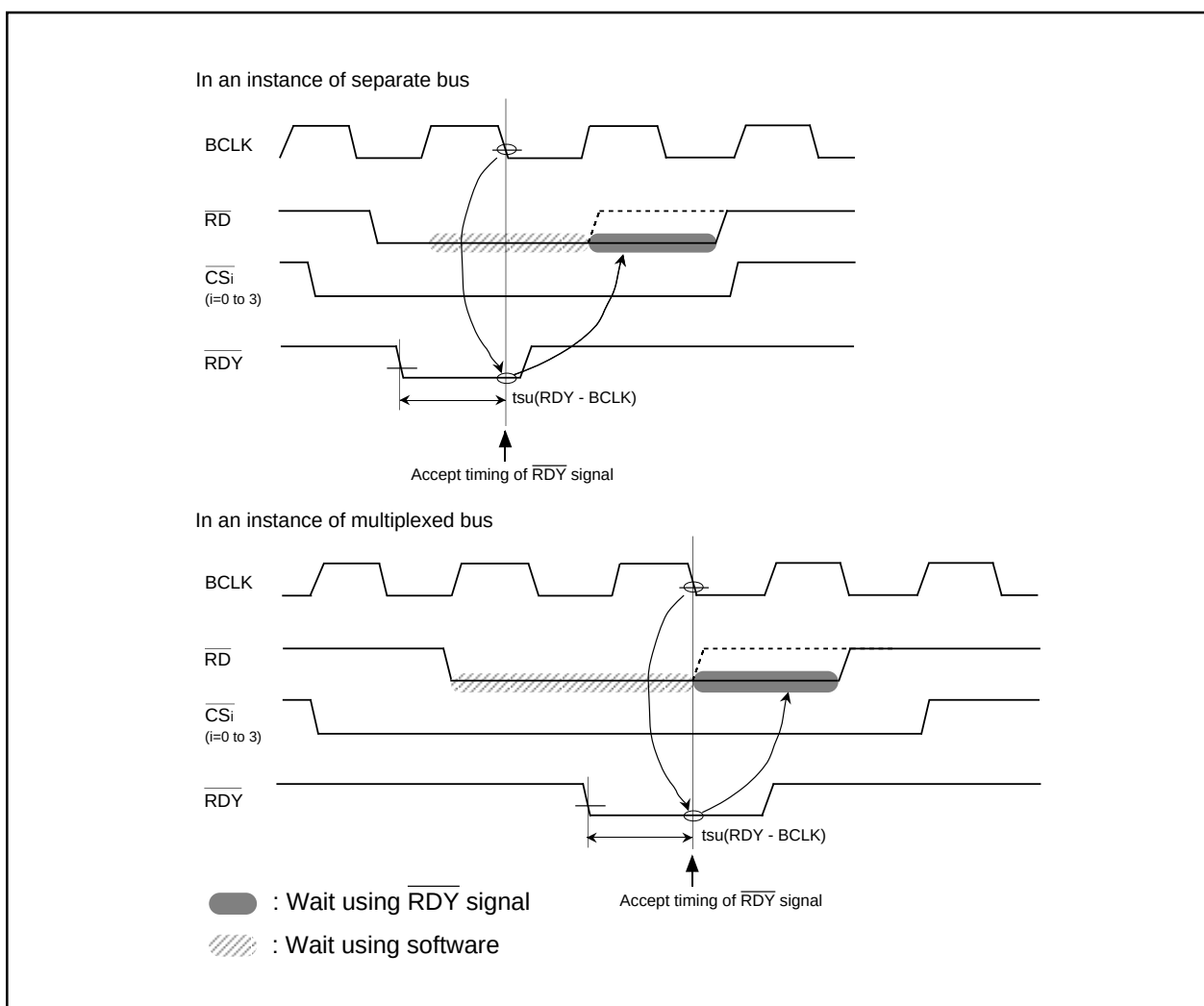


Figure 1.9.4. Example of $\overline{\text{RD}}$ signal extended by $\overline{\text{RDY}}$ signal

(6) Hold signal

The hold signal is used to transfer the bus privileges from the CPU to the external circuits. Inputting “L” to the $\overline{\text{HOLD}}$ pin places the microcomputer in the hold state at the end of the current bus access. This status is maintained and “L” is output from the $\overline{\text{HLDA}}$ pin as long as “L” is input to the $\overline{\text{HOLD}}$ pin. Table 1.9.6 shows the microcomputer status in the hold state.

Bus-using priorities are given to $\overline{\text{HOLD}}$, DMAC, and CPU in order of decreasing precedence.

$\overline{\text{HOLD}} > \text{DMAC} > \text{CPU}$

Figure 1.9.5. Bus-using priorities

Table 1.9.6. Microcomputer status in hold state

Item		Status
Oscillation		ON
R/ $\overline{\text{W}}$ signal, address bus, data bus, $\overline{\text{CS}}$, $\overline{\text{BHE}}$		Floating
Programmable I/O ports	P0, P1, P2, P3, P4, P5	Floating
	P6, P7, P8, P9, P10	Maintains status when hold signal is received
$\overline{\text{HLDA}}$		Output “L”
Internal peripheral circuits		ON (but watchdog timer stops)
ALE signal		Undefined

(7) External bus status when the internal area is accessed

Table 1.9.7 shows the external bus status when the internal area is accessed.

Table 1.9.7. External bus status when the internal area is accessed

Item		SFR accessed	Internal ROM/RAM accessed
Address bus		Address output	Maintain status before accessed address of external area
Data bus	When read	Floating	Floating
	When write	Output data	Undefined
$\overline{\text{RD}}$, $\overline{\text{WR}}$, $\overline{\text{WRL}}$, $\overline{\text{WRH}}$		$\overline{\text{RD}}$, $\overline{\text{WR}}$, $\overline{\text{WRL}}$, $\overline{\text{WRH}}$ output	Output “H”
$\overline{\text{BHE}}$		$\overline{\text{BHE}}$ output	Maintain status before accessed status of external area
$\overline{\text{CS}}$		Output “H”	Output “H”
ALE		Output “L”	Output “L”

(8) BCLK output

The user can choose the BCLK output by use of bit 7 of processor mode register 0 (0004₁₆) (Note). When set to "1", the output floating.

Note: Before attempting to change the contents of the processor mode register 0, set bit 1 of the protect register (address 000A₁₆) to "1".

(9) Software wait

A software wait can be inserted by setting the wait bit (bit 7) of the processor mode register 1 (address 0005₁₆) (Note) and bits 4 to 7 of the chip select control register (address 0008₁₆).

A software wait is inserted in the internal ROM/RAM area and in the external memory area by setting the wait bit of the processor mode register 1. When set to "0", each bus cycle is executed in one BCLK cycle. When set to "1", each bus cycle is executed in two or three BCLK cycles. After the microcomputer has been reset, this bit defaults to "0". When set to "1", a wait is applied to all memory areas (two or three BCLK cycles), regardless of the contents of bits 4 to 7 of the chip select control register. Set this bit after referring to the recommended operating conditions (main clock input oscillation frequency) of the electric characteristics. However, when the user is using the $\overline{\text{RDY}}$ signal, the relevant bit in the chip select control register's bits 4 to 7 must be set to "0".

When the wait bit of the processor mode register 1 is "0", software waits can be set independently for each of the 4 areas selected using the chip select signal. Bits 4 to 7 of the chip select control register correspond to chip selects $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$. When one of these bits is set to "1", the bus cycle is executed in one BCLK cycle. When set to "0", the bus cycle is executed in two or three BCLK cycles. These bits default to "0" after the microcomputer has been reset.

The SFR area is always accessed in two BCLK cycles regardless of the setting of these control bits. Also, insert a software wait if using the multiplex bus to access the external memory area.

Table 1.9.8 shows the software wait and bus cycles. Figure 1.9.6 shows example of bus timing when using software waits.

Note: Before attempting to change the contents of the processor mode register 1, set bit 1 of the protect register (address 000A₁₆) to "1".

Table 1.9.8. Software waits and bus cycles

Area	Bus status	Wait bit	Bits 4 to 7 of chip select control register	Bus cycle
SFR	———	Invalid	Invalid	2 BCLK cycles
Internal ROM/RAM	———	0	Invalid	1 BCLK cycle
	———	1	Invalid	2 BCLK cycles
External memory area	Separate bus	0	1	1 BCLK cycle
	Separate bus	0	0	2 BCLK cycles
	Separate bus	1	0 (Note)	2 BCLK cycles
	Multiplex bus	0	0	3 BCLK cycles
	Multiplex bus	1	0 (Note)	3 BCLK cycles

Note: When using the $\overline{\text{RDY}}$ signal, always set to "0".

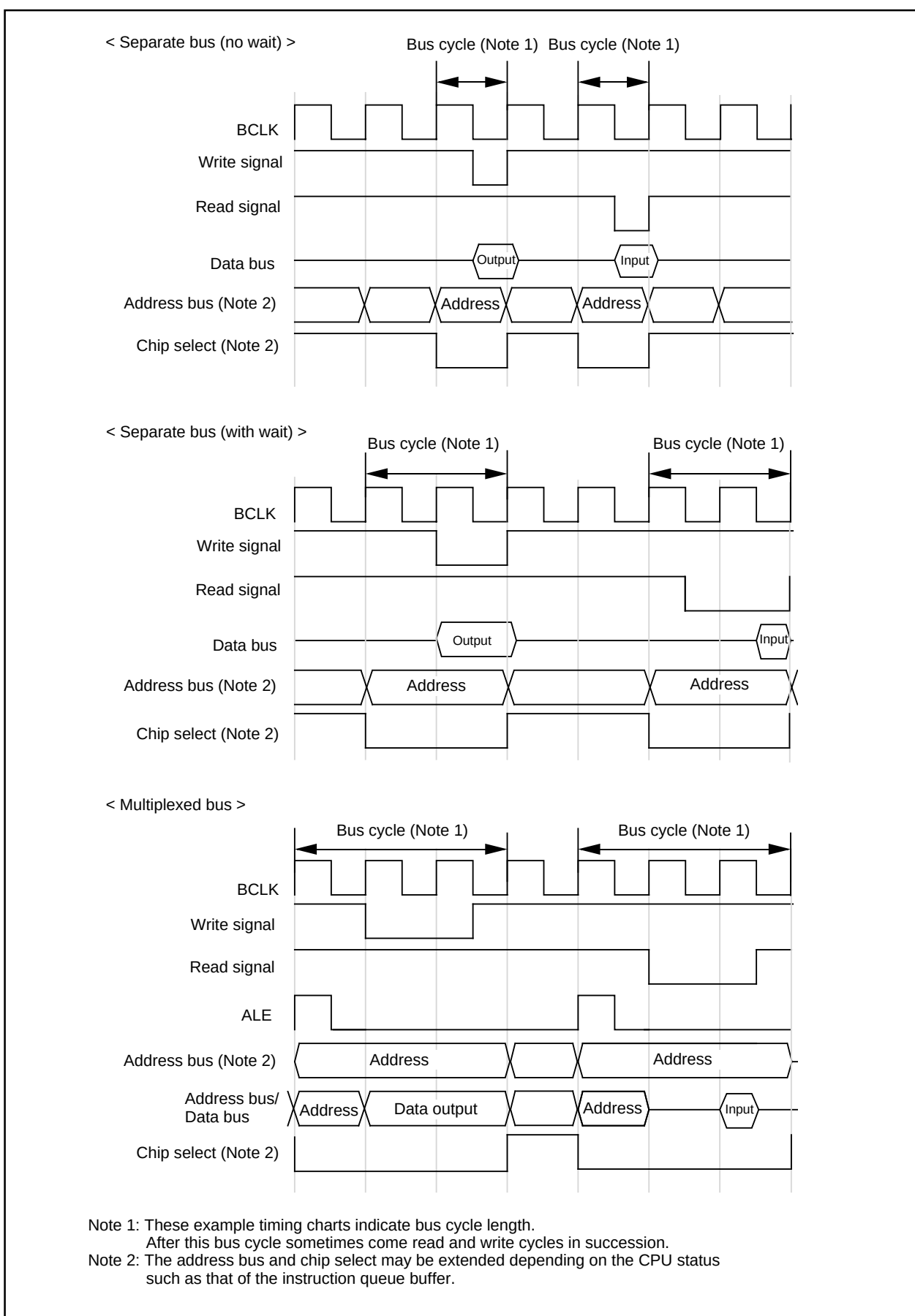


Figure 1.9.6. Typical bus timings using software wait

Clock Generating Circuit

The clock generating circuit contains two oscillator circuits that supply the operating clock sources to the CPU and internal peripheral units.

Table 1.10.1. Main clock and sub-clock generating circuits

	Main clock generating circuit	Sub-clock generating circuit
Use of clock	• CPU's operating clock source • Internal peripheral units' operating clock source	• CPU's operating clock source • Timer A/B's count clock source
Usable oscillator	Ceramic or crystal oscillator	Crystal oscillator
Pins to connect oscillator	XIN, XOUT	XCIN, XCOUT
Oscillation stop/restart function	Available	Available
Oscillator status immediately after reset	Oscillating	Stopped
Other	Externally derived clock can be input	

Example of oscillator circuit

Figure 1.10.1 shows some examples of the main clock circuit, one using an oscillator connected to the circuit, and the other one using an externally derived clock for input. Figure 1.10.2 shows some examples of sub-clock circuits, one using an oscillator connected to the circuit, and the other one using an externally derived clock for input. Circuit constants in Figures 1.10.1 and 1.10.2 vary with each oscillator used. Use the values recommended by the manufacturer of your oscillator.

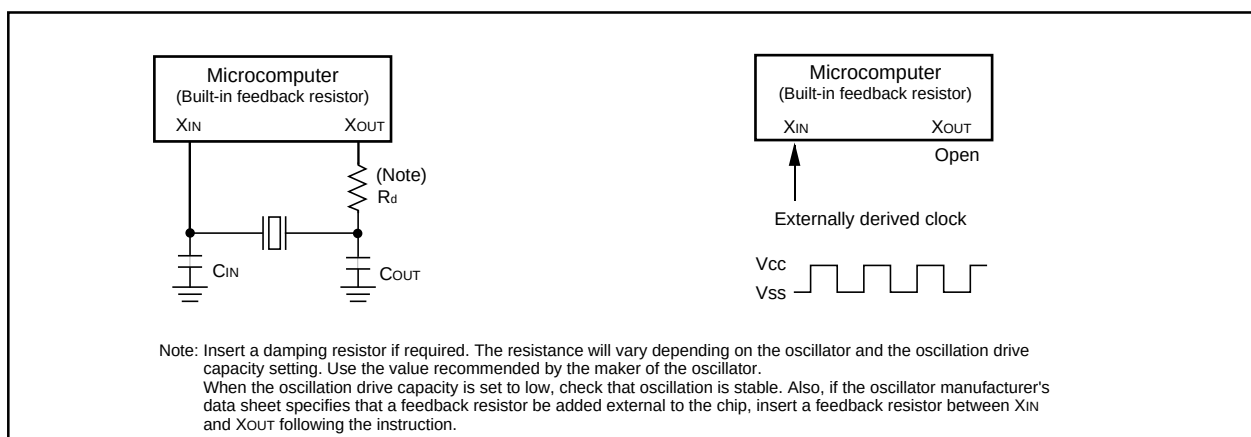


Figure 1.10.1. Examples of main clock

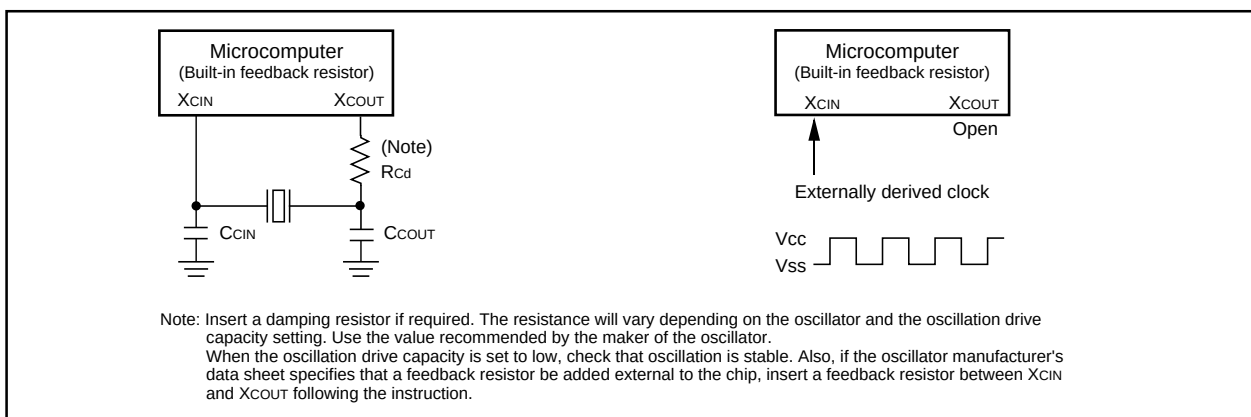


Figure 1.10.2. Examples of sub-clock

Clock Control

Figure 1.10.3 shows the block diagram of the clock generating circuit.

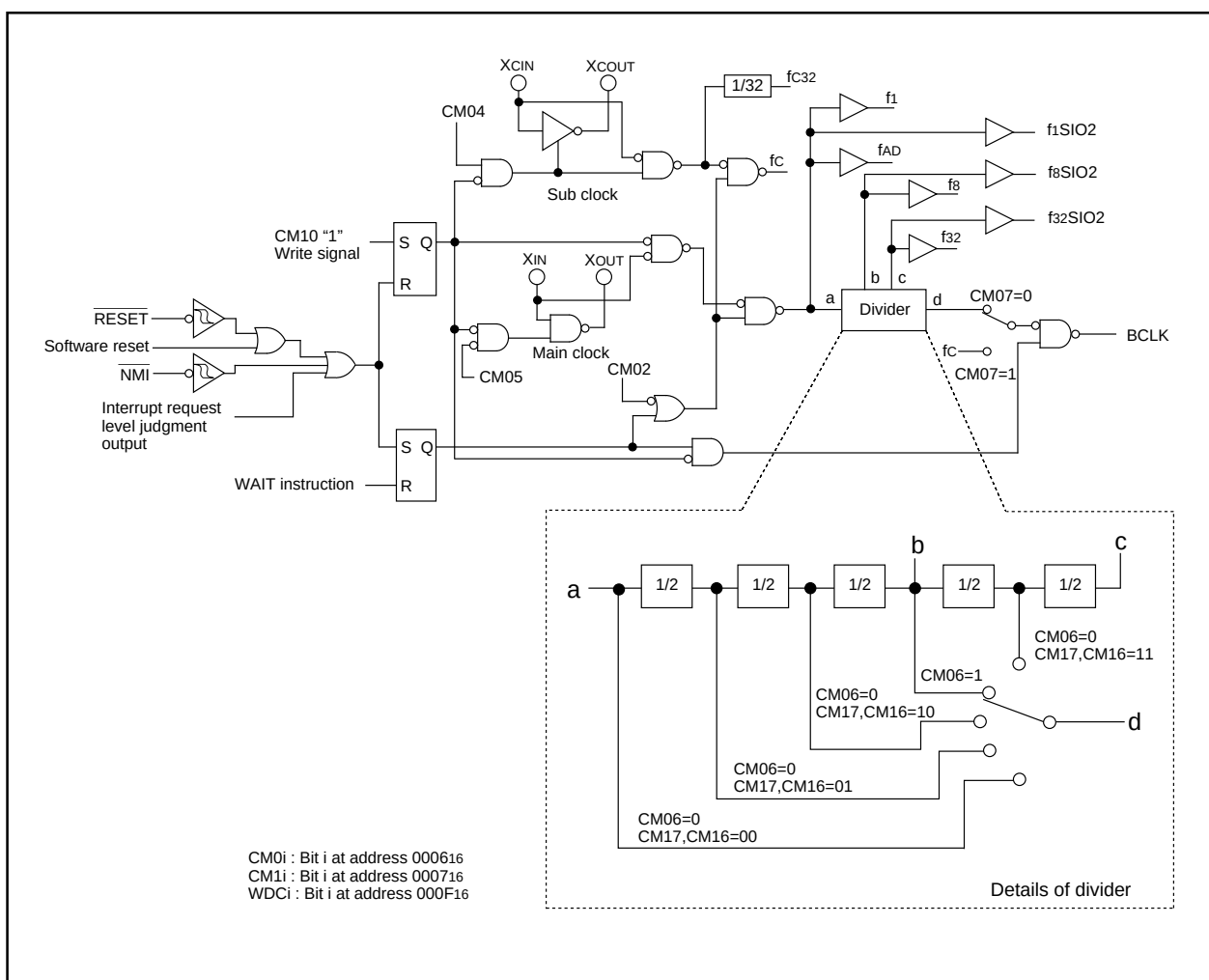


Figure 1.10.3. Clock generating circuit

Clock Generating Circuit

The following paragraphs describes the clocks generated by the clock generating circuit.

(1) Main clock

The main clock is generated by the main clock oscillation circuit. After a reset, the clock is divided by 8 to the BCLK. The clock can be stopped using the main clock stop bit (bit 5 at address 0006₁₆). Stopping the clock, after switching the operating clock source of CPU to the sub-clock, reduces the power dissipation. After the oscillation of the main clock oscillation circuit has stabilized, the drive capacity of the main clock oscillation circuit can be reduced using the X_{IN}-X_{OUT} drive capacity select bit (bit 5 at address 0007₁₆). Reducing the drive capacity of the main clock oscillation circuit reduces the power dissipation. This bit changes to "1" when shifting from high-speed/medium-speed mode to stop mode and at a reset. When shifting from low-speed/low power dissipation mode to stop mode, the value before stop mode is retained.

(2) Sub-clock

The sub-clock is generated by the sub-clock oscillation circuit. No sub-clock is generated after a reset. After oscillation is started using the port Xc select bit (bit 4 at address 0006₁₆), the sub-clock can be selected as the BCLK by using the system clock select bit (bit 7 at address 0006₁₆). However, be sure that the sub-clock oscillation has fully stabilized before switching. After the oscillation of the sub-clock oscillation circuit has stabilized, the drive capacity of the sub-clock oscillation circuit can be reduced using the X_{CIN}-X_{COU}T drive capacity select bit (bit 3 at address 0006₁₆). Reducing the drive capacity of the sub-clock oscillation circuit reduces the power dissipation. This bit changes to "1" when shifting to stop mode and at a reset.

When the X_{CIN}/X_{COU}T is used, set ports P86 and P87 as the input ports without pull-up.

(3) BCLK

The BCLK is the clock that drives the CPU, and is fc or the clock is derived by dividing the main clock by 1, 2, 4, 8, or 16. The BCLK is derived by dividing the main clock by 8 after a reset. The BCLK signal can be output from BCLK pin by the BCLK output disable bit (bit 7 at address 0004₁₆) in the memory expansion and the microprocessor modes.

The main clock division select bit 0 (bit 6 at address 0006₁₆) changes to "1" when shifting from high-speed/medium-speed to stop mode and at reset. When shifting from low-speed/low power dissipation mode to stop mode, the value before stop mode is retained.

(4) Peripheral function clock(f₁, f₈, f₃₂, f_{1SIO2}, f_{8SIO2}, f_{32SIO2}, f_{AD})

The clock for the peripheral devices is derived from the main clock or by dividing it by 1, 8, or 32. The peripheral function clock is stopped by stopping the main clock or by setting the WAIT peripheral function clock stop bit (bit 2 at 0006₁₆) to "1" and then executing a WAIT instruction.

(5) fc32

This clock is derived by dividing the sub-clock by 32. It is used for the timer A and timer B counts.

(6) fc

This clock has the same frequency as the sub-clock. It is used for the BCLK and for the watchdog timer.

Figure 1.10.4 shows the system clock control registers 0 and 1.

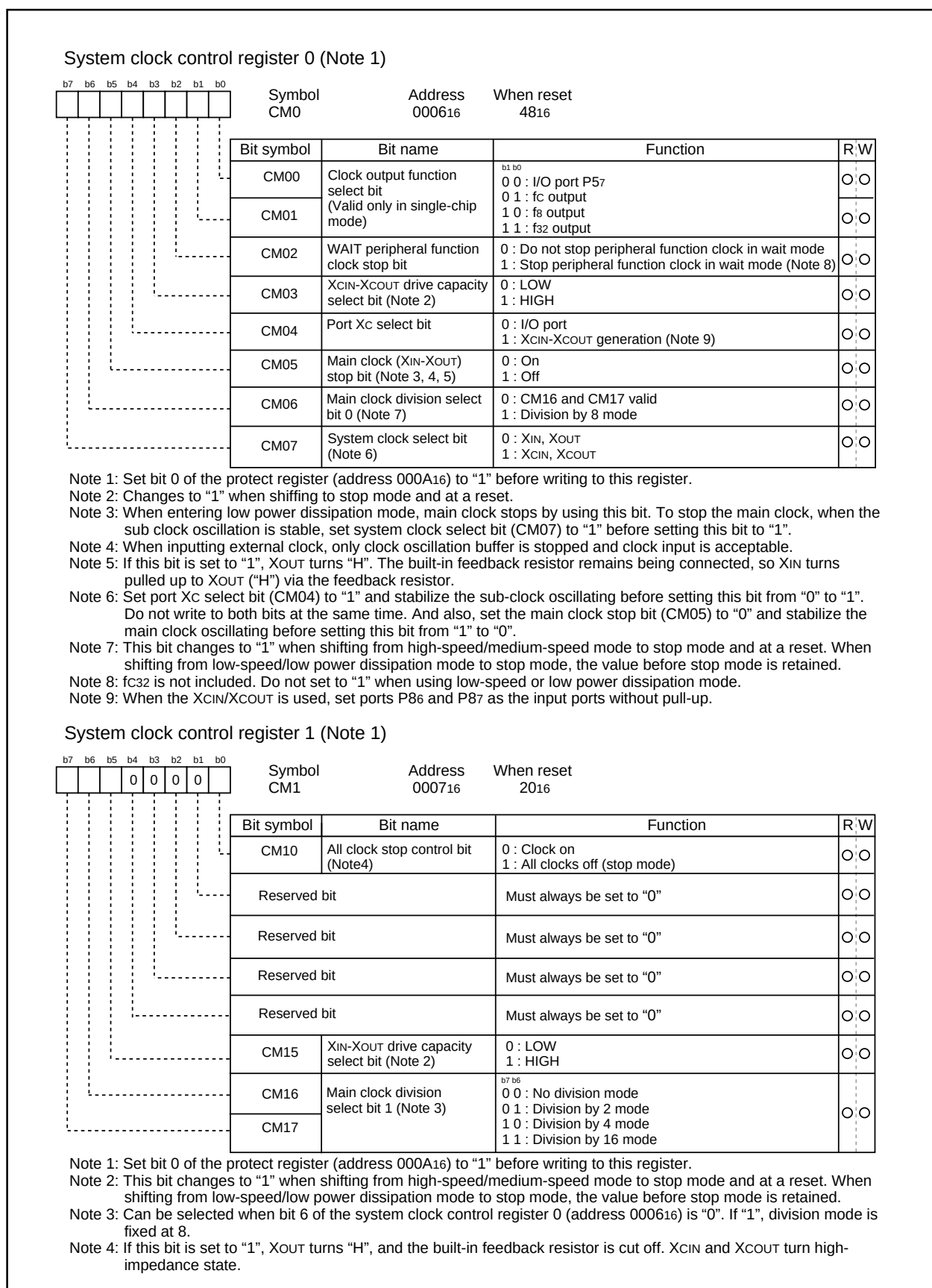


Figure 1.10.4. Clock control registers 0 and 1

Clock Generating Circuit

Clock Output

In single-chip mode, the clock output function select bits (bits 0 and 1 at address 0006₁₆) enable f₈, f₃₂, or fc to be output from the P57/CLKOUT pin. When the WAIT peripheral function clock stop bit (bit 2 at address 0006₁₆) is set to "1", the output of f₈ and f₃₂ stops when a WAIT instruction is executed.

Stop Mode

Writing "1" to the all-clock stop control bit (bit 0 at address 0007₁₆) stops all oscillation and the microcomputer enters stop mode. In stop mode, the content of the internal RAM is retained provided that V_{CC} remains above 2V.

Because the oscillation, BCLK, f₁ to f₃₂, f₁SIO2 to f₃₂SIO2, fc, fc32, and fAD stops in stop mode, peripheral functions such as the A-D converter and watchdog timer do not function. However, timer A and timer B operate provided that the event counter mode is set to an external pulse, and UARTi(i = 0 to 2), SI/O3,4 functions provided an external clock is selected. Table 1.10.2 shows the status of the ports in stop mode. Stop mode is cancelled by a hardware reset or an interrupt. If an interrupt is to be used to cancel stop mode, that interrupt must first have been enabled, and the priority level of the interrupt which is not used to cancel must have been changed to 0. If returning by an interrupt, that interrupt routine is executed. If only a hardware reset or an $\overline{\text{NMI}}$ interrupt is used to cancel stop mode, change the priority level of all interrupt to 0, then shift to stop mode.

When shifting from high-speed/medium-speed mode to stop mode and at a reset, the main clock division select bit 0 (bit 6 at address 0006₁₆) is set to "1". When shifting from low-speed/low power dissipation mode to stop mode, the value before stop mode is retained.

Table 1.10.2. Port status during stop mode

Pin		Memory expansion mode Microprocessor mode	Single-chip mode
Address bus, data bus, $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$, $\overline{\text{BHE}}$		Retains status before stop mode	
RD, WR, $\overline{\text{WRL}}$, $\overline{\text{WRH}}$		"H"	
HLDA, BCLK		"H"	
ALE		"H"	
Port		Retains status before stop mode	
CLKOUT	When fc selected	Valid only in single-chip mode	"H"
	When f ₈ , f ₃₂ selected	Valid only in single-chip mode	Retains status before stop mode

Wait Mode

When a WAIT instruction is executed, the BCLK stops and the microcomputer enters the wait mode. In this mode, oscillation continues but the BCLK and watchdog timer stop. Writing “1” to the WAIT peripheral function clock stop bit and executing a WAIT instruction stops the clock being supplied to the internal peripheral functions, allowing power dissipation to be reduced. However, peripheral function clock fc32 does not stop so that the peripherals using fc32 do not contribute to the power saving. When the MCU running in low-speed or low power dissipation mode, do not enter WAIT mode with this bit set to “1”. Table 1.10.3 shows the status of the ports in wait mode.

Wait mode is cancelled by a hardware reset or an interrupt. If an interrupt is used to cancel wait mode, that interrupt must first have been enabled, and the priority level of the interrupt which is not used to cancel must have been changed to 0. If returning by an interrupt, the clock in which the WAIT instruction executed is set to BCLK by the microcomputer, and the action is resumed from the interrupt routine. If only a hardware reset or an $\overline{\text{NMI}}$ interrupt is used to cancel wait mode, change the priority level of all interrupt to 0, then shift to wait mode.

Table 1.10.3. Port status during wait mode

Pin		Memory expansion mode Microprocessor mode	Single-chip mode
Address bus, data bus, $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$, $\overline{\text{BHE}}$		Retains status before wait mode	
$\overline{\text{RD}}$, $\overline{\text{WR}}$, $\overline{\text{WRL}}$, $\overline{\text{WRH}}$		“H”	
$\overline{\text{HLDA}}$, BCLK		“H”	
ALE		“H”	
Port		Retains status before wait mode	Retains status before wait mode
CLKOUT	When fc selected	Valid only in single-chip mode	Does not stop
	When f8, f32 selected	Valid only in single-chip mode	Does not stop when the WAIT peripheral function clock stop bit is “0”. When the WAIT peripheral function clock stop bit is “1”, the status immediately prior to entering wait mode is maintained.

Status Transition of BCLK

Status Transition of BCLK

Power dissipation can be reduced and low-voltage operation achieved by changing the count source for BCLK. Table 1.10.4 shows the operating modes corresponding to the settings of system clock control registers 0 and 1.

When reset, the device starts in division by 8 mode. The main clock division select bit 0(bit 6 at address 000616) changes to “1” when shifting from high-speed/medium-speed to stop mode and at a reset. When shifting from low-speed/low power dissipation mode to stop mode, the value before stop mode is retained. The following shows the operational modes of BCLK.

(1) Division by 2 mode

The main clock is divided by 2 to obtain the BCLK.

(2) Division by 4 mode

The main clock is divided by 4 to obtain the BCLK.

(3) Division by 8 mode

The main clock is divided by 8 to obtain the BCLK. When reset, the device starts operating from this mode. Before the user can go from this mode to no division mode, division by 2 mode, or division by 4 mode, the main clock must be oscillating stably. When going to low-speed or lower power consumption mode, make sure the sub-clock is oscillating stably.

(4) Division by 16 mode

The main clock is divided by 16 to obtain the BCLK.

(5) No-division mode

The main clock is divided by 1 to obtain the BCLK.

(6) Low-speed mode

fc is used as the BCLK. Note that oscillation of both the main and sub-clocks must have stabilized before transferring from this mode to another or vice versa. At least 2 to 3 seconds are required after the sub-clock starts. Therefore, the program must be written to wait until this clock has stabilized immediately after powering up and after stop mode is cancelled.

(7) Low power dissipation mode

fc is the BCLK and the main clock is stopped.

Note : Before the count source for BCLK can be changed from XIN to XCIN or vice versa, the clock to which the count source is going to be switched must be oscillating stably. Allow a wait time in software for the oscillation to stabilize before switching over the clock.

Table 1.10.4. Operating modes dictated by settings of system clock control registers 0 and 1

CM17	CM16	CM07	CM06	CM05	CM04	Operating mode of BCLK
0	1	0	0	0	Invalid	Division by 2 mode
1	0	0	0	0	Invalid	Division by 4 mode
Invalid	Invalid	0	1	0	Invalid	Division by 8 mode
1	1	0	0	0	Invalid	Division by 16 mode
0	0	0	0	0	Invalid	No-division mode
Invalid	Invalid	1	Invalid	0	1	Low-speed mode
Invalid	Invalid	1	Invalid	1	1	Low power dissipation mode

Power control

The following is a description of the three available power control modes:

Modes

Power control is available in three modes.

(a) Normal operation mode

- **High-speed mode**

Divide-by-1 frequency of the main clock becomes the BCLK. The CPU operates with the BCLK. Each peripheral function operates according to its assigned clock.

- **Medium-speed mode**

Divide-by-2, divide-by-4, divide-by-8, or divide-by-16 frequency of the main clock becomes the BCLK. The CPU operates with the BCLK. Each peripheral function operates according to its assigned clock.

- **Low-speed mode**

fc becomes the BCLK. The CPU operates according to the fc clock. The fc clock is supplied by the subclock. Each peripheral function operates according to its assigned clock.

- **Low power dissipation mode**

The main clock operating in low-speed mode is stopped. The CPU operates according to the fc clock. The fc clock is supplied by the subclock. The only peripheral functions that operate are those with the subclock selected as the count source.

(b) Wait mode

The CPU operation is stopped. The oscillators do not stop.

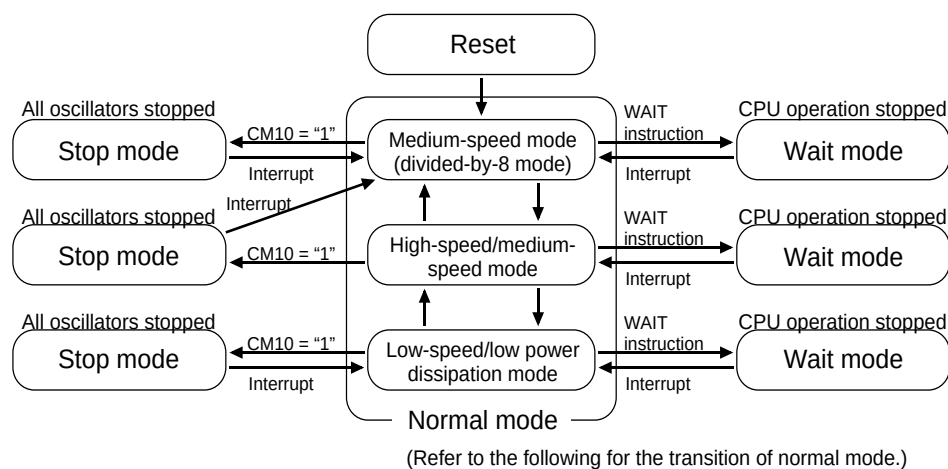
(c) Stop mode

All oscillators stop. The CPU and all built-in peripheral functions stop. This mode, among the three modes listed here, is the most effective in decreasing power consumption.

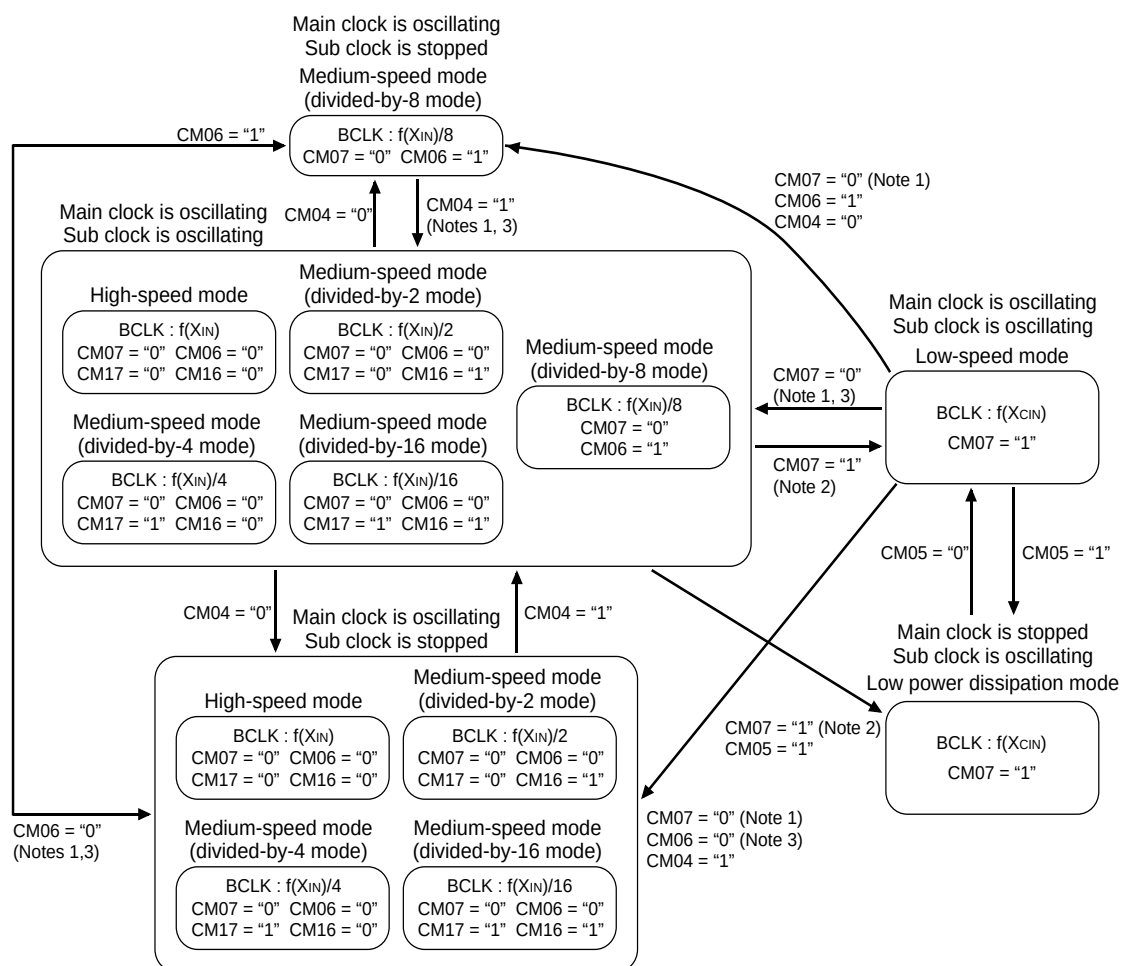
Figure 1.10.5 is the state transition diagram of the above modes.

Power control

Transition of stop mode, wait mode



Transition of normal mode



Note 1: Switch clock after oscillation of main clock is sufficiently stable.

Note 2: Switch clock after oscillation of sub clock is sufficiently stable.

Note 3: Change CM06 after changing CM17 and CM16.

Note 4: Transit in accordance with arrow.

Figure 1.10.5. State transition diagram of Power control mode

Protection

Protection

The protection function is provided so that the values in important registers cannot be changed in the event that the program runs out of control. Figure 1.10.6 shows the protect register. The values in the processor mode register 0 (address 0004₁₆), processor mode register 1 (address 0005₁₆), system clock control register 0 (address 0006₁₆), system clock control register 1 (address 0007₁₆), port P9 direction register (address 03F3₁₆), SI/O3 control register (address 0362₁₆) and SI/O4 control register (address 0366₁₆) can only be changed when the respective bit in the protect register is set to "1". Therefore, important outputs can be allocated to port P9.

If, after "1" (write-enabled) has been written to the port P9 direction register and SI/O_i control register (i=3,4) write-enable bit (bit 2 at address 000A₁₆), a value is written to any address, the bit automatically reverts to "0" (write-inhibited). However, the system clock control registers 0 and 1 write-enable bit (bit 0 at 000A₁₆) and processor mode register 0 and 1 write-enable bit (bit 1 at 000A₁₆) do not automatically return to "0" after a value has been written to an address. The program must therefore be written to return these bits to "0".

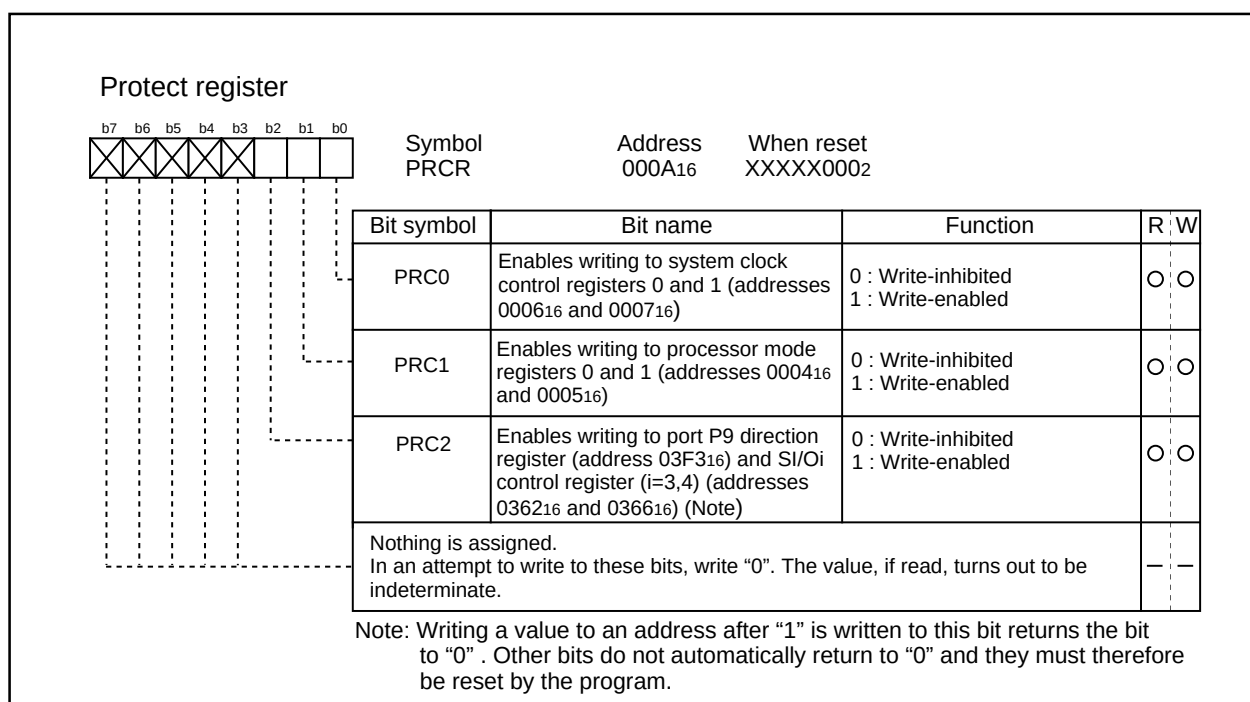


Figure 1.10.6. Protect register

Overview of Interrupt

Type of Interrupts

Figure 1.11.1 lists the types of interrupts.

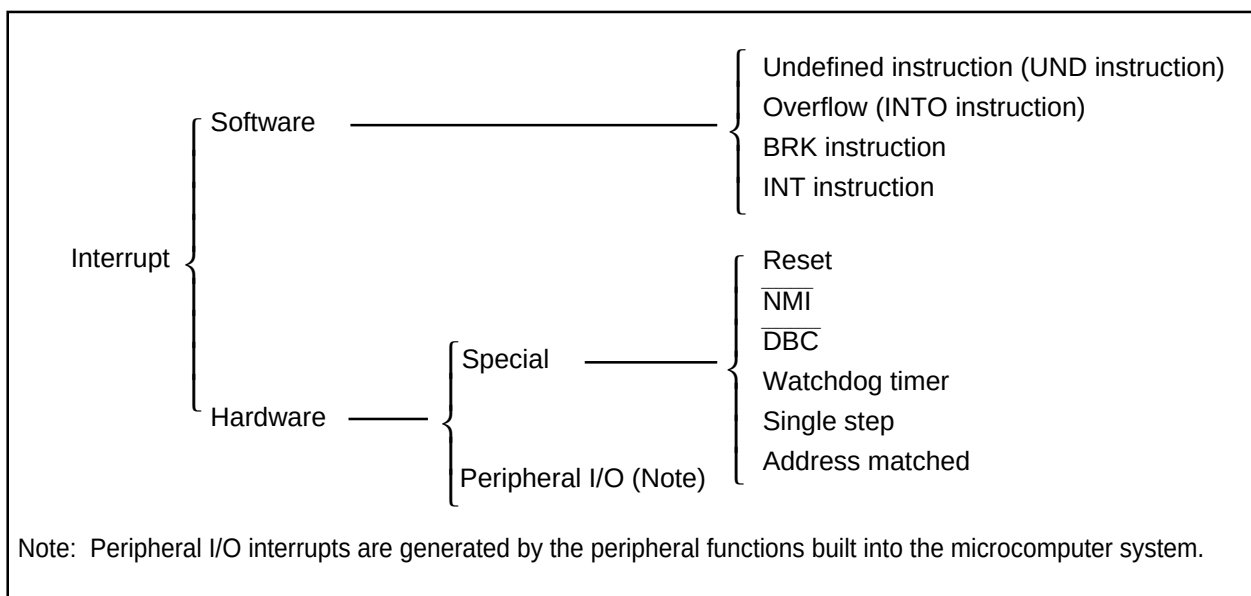


Figure 1.11.1. Classification of interrupts

- Maskable interrupt : An interrupt which can be enabled (disabled) by the interrupt enable flag (I flag) or whose interrupt priority **can be changed** by priority level.
- Non-maskable interrupt : An interrupt which cannot be enabled (disabled) by the interrupt enable flag (I flag) or whose interrupt priority **cannot be changed** by priority level.

Software Interrupts

A software interrupt occurs when executing certain instructions. Software interrupts are non-maskable interrupts.

- **Undefined instruction interrupt**

An undefined instruction interrupt occurs when executing the UND instruction.

- **Overflow interrupt**

An overflow interrupt occurs when executing the INTO instruction with the overflow flag (O flag) set to "1". The following are instructions whose O flag changes by arithmetic:

ABS, ADC, ADCF, ADD, CMP, DIV, DIVU, DIVX, NEG, RMPA, SBB, SHA, SUB

- **BRK interrupt**

A BRK interrupt occurs when executing the BRK instruction.

- **INT interrupt**

An INT interrupt occurs when specifying one of software interrupt numbers 0 through 63 and executing the INT instruction. Software interrupt numbers 0 through 31 are assigned to peripheral I/O interrupts, so executing the INT instruction allows executing the same interrupt routine that a peripheral I/O interrupt does.

The stack pointer (SP) used for the INT interrupt is dependent on which software interrupt number is involved.

So far as software interrupt numbers 0 through 31 are concerned, the microcomputer saves the stack pointer assignment flag (U flag) when it accepts an interrupt request. If change the U flag to "0" and select the interrupt stack pointer (ISP), and then execute an interrupt sequence. When returning from the interrupt routine, the U flag is returned to the state it was before the acceptance of interrupt request. So far as software numbers 32 through 63 are concerned, the stack pointer does not make a shift.

Hardware Interrupts

Hardware interrupts are classified into two types — special interrupts and peripheral I/O interrupts.

(1) Special interrupts

Special interrupts are non-maskable interrupts.

- **Reset**

Reset occurs if an “L” is input to the $\overline{\text{RESET}}$ pin.

- **$\overline{\text{NMI}}$ interrupt**

An $\overline{\text{NMI}}$ interrupt occurs if an “L” is input to the $\overline{\text{NMI}}$ pin.

- **$\overline{\text{DBC}}$ interrupt**

This interrupt is exclusively for the debugger, do not use it in other circumstances.

- **Watchdog timer interrupt**

Generated by the watchdog timer.

- **Single-step interrupt**

This interrupt is exclusively for the debugger, do not use it in other circumstances. With the debug flag (D flag) set to “1”, a single-step interrupt occurs after one instruction is executed.

- **Address match interrupt**

An address match interrupt occurs immediately before the instruction held in the address indicated by the address match interrupt register is executed with the address match interrupt enable bit set to “1”. If an address other than the first address of the instruction in the address match interrupt register is set, no address match interrupt occurs.

(2) Peripheral I/O interrupts

A peripheral I/O interrupt is generated by one of built-in peripheral functions. Built-in peripheral functions are dependent on classes of products, so the interrupt factors too are dependent on classes of products. The interrupt vector table is the same as the one for software interrupt numbers 0 through 31 the INT instruction uses. Peripheral I/O interrupts are maskable interrupts.

- **Bus collision detection interrupt**

This is an interrupt that the serial I/O bus collision detection generates.

- **DMA0 interrupt, DMA1 interrupt**

These are interrupts that DMA generates.

- **Key-input interrupt**

A key-input interrupt occurs if an “L” is input to the $\overline{\text{KI}}$ pin.

- **A-D conversion interrupt**

This is an interrupt that the A-D converter generates.

- **UART0, UART1, UART2/NACK, SI/O3 and SI/O4 transmission interrupt**

These are interrupts that the serial I/O transmission generates.

- **UART0, UART1, UART2/ACK, SI/O3 and SI/O4 reception interrupt**

These are interrupts that the serial I/O reception generates.

- **Timer A0 interrupt through timer A4 interrupt**

These are interrupts that timer A generates

- **Timer B0 interrupt through timer B5 interrupt**

These are interrupts that timer B generates.

- **$\overline{\text{INT0}}$ interrupt through $\overline{\text{INT5}}$ interrupt**

An $\overline{\text{INT}}$ interrupt occurs if either a rising edge or a falling edge or a both edge is input to the $\overline{\text{INT}}$ pin.

Interrupts and Interrupt Vector Tables

If an interrupt request is accepted, a program branches to the interrupt routine set in the interrupt vector table. Set the first address of the interrupt routine in each vector table. Figure 1.11.2 shows the format for specifying the address.

Two types of interrupt vector tables are available — fixed vector table in which addresses are fixed and variable vector table in which addresses can be varied by the setting.

	MSB	LSB
Vector address + 0	Low address	
Vector address + 1	Mid address	
Vector address + 2	0 0 0 0	High address
Vector address + 3	0 0 0 0	0 0 0 0

Figure 1.11.2. Format for specifying interrupt vector addresses

• Fixed vector tables

The fixed vector table is a table in which addresses are fixed. The vector tables are located in an area extending from FFFDC₁₆ to FFFFF₁₆. One vector table comprises four bytes. Set the first address of interrupt routine in each vector table. Table 1.11.1 shows the interrupts assigned to the fixed vector tables and addresses of vector tables.

Table 1.11.1. Interrupts assigned to the fixed vector tables and addresses of vector tables

Interrupt source	Vector table addresses Address (L) to address (H)	Remarks
Undefined instruction	FFFD _{C16} to FFFD _{F16}	Interrupt on UND instruction
Overflow	FFFE ₀₁₆ to FFFE ₃₁₆	Interrupt on INTO instruction
BRK instruction	FFFE ₄₁₆ to FFFE ₇₁₆	If the vector contains FF ₁₆ , program execution starts from the address shown by the vector in the variable vector table
Address match	FFFE ₈₁₆ to FFFE _{B16}	There is an address-matching interrupt enable bit
Single step (Note)	FFFE _{C16} to FFFE _{F16}	Do not use
Watchdog timer	FFFF ₀₁₆ to FFFF ₃₁₆	
DBC (Note)	FFFF ₄₁₆ to FFFF ₇₁₆	Do not use
NMI	FFFF ₈₁₆ to FFFF _{B16}	External interrupt by input to $\overline{\text{NMI}}$ pin
Reset	FFFF _{C16} to FFFF _{F16}	

Note: Interrupts used for debugging purposes only.

Interrupt

• Variable vector tables

The addresses in the variable vector table can be modified, according to the user's settings. Indicate the first address using the interrupt table register (INTB). The 256-byte area subsequent to the address the INTB indicates becomes the area for the variable vector tables. One vector table comprises four bytes. Set the first address of the interrupt routine in each vector table. Table 1.11.2 shows the interrupts assigned to the variable vector tables and addresses of vector tables.

Table 1.11.2. Interrupts assigned to the variable vector tables and addresses of vector tables

Software interrupt number	Vector table address Address (L) to address (H)	Interrupt source	Remarks
Software interrupt number 0	+0 to +3 (Note 1)	BRK instruction	Cannot be masked I flag
Software interrupt number 4	+16 to +19 (Note 1)	INT3	
Software interrupt number 5	+20 to +23 (Note 1)	Timer B5	
Software interrupt number 6	+24 to +27 (Note 1)	Timer B4	
Software interrupt number 7	+28 to +31 (Note 1)	Timer B3	
Software interrupt number 8	+32 to +35 (Note 1)	SI/O4/INT5 (Note 2)	
Software interrupt number 9	+36 to +39 (Note 1)	SI/O3/INT4 (Note 2)	
Software interrupt number 10	+40 to +43 (Note 1)	Bus collision detection	
Software interrupt number 11	+44 to +47 (Note 1)	DMA0	
Software interrupt number 12	+48 to +51 (Note 1)	DMA1	
Software interrupt number 13	+52 to +55 (Note 1)	Key input interrupt	
Software interrupt number 14	+56 to +59 (Note 1)	A-D	
Software interrupt number 15	+60 to +63 (Note 1)	UART2 transmit/NACK (Note 3)	
Software interrupt number 16	+64 to +67 (Note 1)	UART2 receive/ACK (Note 3)	
Software interrupt number 17	+68 to +71 (Note 1)	UART0 transmit	
Software interrupt number 18	+72 to +75 (Note 1)	UART0 receive	
Software interrupt number 19	+76 to +79 (Note 1)	UART1 transmit	
Software interrupt number 20	+80 to +83 (Note 1)	UART1 receive	
Software interrupt number 21	+84 to +87 (Note 1)	Timer A0	
Software interrupt number 22	+88 to +91 (Note 1)	Timer A1	
Software interrupt number 23	+92 to +95 (Note 1)	Timer A2	
Software interrupt number 24	+96 to +99 (Note 1)	Timer A3	
Software interrupt number 25	+100 to +103 (Note 1)	Timer A4	
Software interrupt number 26	+104 to +107 (Note 1)	Timer B0	
Software interrupt number 27	+108 to +111 (Note 1)	Timer B1	
Software interrupt number 28	+112 to +115 (Note 1)	Timer B2	
Software interrupt number 29	+116 to +119 (Note 1)	INT0	
Software interrupt number 30	+120 to +123 (Note 1)	INT1	
Software interrupt number 31	+124 to +127 (Note 1)	INT2	
Software interrupt number 32 to Software interrupt number 63	+128 to +131 (Note 1) to +252 to +255 (Note 1)	Software interrupt	Cannot be masked I flag

Note 1: Address relative to address in interrupt table register (INTB).

Note 2: It is selected by interrupt request cause bit (bit 6, 7 in address 035F16).

Note 3: When IIC mode is selected, NACK and ACK interrupts are selected.

Interrupt Control

Descriptions are given here regarding how to enable or disable maskable interrupts and how to set the priority to be accepted. What is described here does not apply to non-maskable interrupts.

Enable or disable a maskable interrupt using the interrupt enable flag (I flag), interrupt priority level selection bit, or processor interrupt priority level (IPL). Whether an interrupt request is present or absent is indicated by the interrupt request bit. The interrupt request bit and the interrupt priority level selection bit are located in the interrupt control register of each interrupt. Also, the interrupt enable flag (I flag) and the IPL are located in the flag register (FLG).

Figure 1.11.3 shows the memory map of the interrupt control registers.

Interrupt

Interrupt control register (Note 2)

Symbol	Address	When reset
TBiC(i=3 to 5)	0045 ₁₆ to 0047 ₁₆	XXXXX0002
BCNiC	004A ₁₆	XXXXX0002
DMiC(i=0, 1)	004B ₁₆ , 004C ₁₆	XXXXX0002
KUPiC	004D ₁₆	XXXXX0002
ADiC	004E ₁₆	XXXXX0002
SiTiC(i=0 to 2)	0051 ₁₆ , 0053 ₁₆ , 004F ₁₆	XXXXX0002
SiRiC(i=0 to 2)	0052 ₁₆ , 0054 ₁₆ , 0050 ₁₆	XXXXX0002
TAiC(i=0 to 4)	0055 ₁₆ to 0059 ₁₆	XXXXX0002
TBiC(i=0 to 2)	005A ₁₆ to 005C ₁₆	XXXXX0002

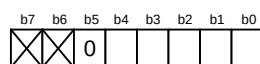


Bit symbol	Bit name	Function	R	W
ILVL0	Interrupt priority level select bit	b2 b1 b0 0 0 0 : Level 0 (interrupt disabled) 0 0 1 : Level 1 0 1 0 : Level 2 0 1 1 : Level 3 1 0 0 : Level 4 1 0 1 : Level 5 1 1 0 : Level 6 1 1 1 : Level 7	○	○
ILVL1			○	○
ILVL2			○	○
IR	Interrupt request bit	0 : Interrupt not requested 1 : Interrupt requested	○	○ (Note 1)
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be indeterminate.			—	—

Note 1: This bit can only be accessed for reset (= 0), but cannot be accessed for set (= 1).

Note 2: To rewrite the interrupt control register, do so at a point that does not generate the interrupt request for that register. For details, see the precautions for interrupts.

Symbol	Address	When reset
INTiC(i=3)	0044 ₁₆	XX00X0002
SiC/INTjC (i=4, 3)	0048 ₁₆ , 0049 ₁₆	XX00X0002
(j=5, 4)	0048 ₁₆ , 0049 ₁₆	XX00X0002
INTiC(i=0 to 2)	005D ₁₆ to 005F ₁₆	XX00X0002



Bit symbol	Bit name	Function	R	W
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	○	○
ILVL1			○	○
ILVL2			○	○
IR	Interrupt request bit	0: Interrupt not requested 1: Interrupt requested	○	○ (Note 1)
POL	Polarity select bit	0 : Selects falling edge 1 : Selects rising edge	○	○
Reserved bit		Must always be set to "0"	○	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be indeterminate.			—	—

Note 1: This bit can only be accessed for reset (= 0), but cannot be accessed for set (= 1).

Note 2: To rewrite the interrupt control register, do so at a point that does not generate the interrupt request for that register. For details, see the precautions for interrupts.

Figure 1.11.3. Interrupt control registers

Interrupt Enable Flag (I flag)

The interrupt enable flag (I flag) controls the enabling and disabling of maskable interrupts. Setting this flag to “1” enables all maskable interrupts; setting it to “0” disables all maskable interrupts. This flag is set to “0” after reset.

Interrupt Request Bit

The interrupt request bit is set to “1” by hardware when an interrupt is requested. After the interrupt is accepted and jumps to the corresponding interrupt vector, the request bit is set to “0” by hardware. The interrupt request bit can also be set to “0” by software. (Do not set this bit to “1”).

Interrupt Priority Level Select Bit and Processor Interrupt Priority Level (IPL)

Set the interrupt priority level using the interrupt priority level select bit, which is one of the component bits of the interrupt control register. When an interrupt request occurs, the interrupt priority level is compared with the IPL. The interrupt is enabled only when the priority level of the interrupt is higher than the IPL. Therefore, setting the interrupt priority level to “0” disables the interrupt.

Table 1.11.3 shows the settings of interrupt priority levels and Table 1.11.4 shows the interrupt levels enabled, according to the contents of the IPL.

The following are conditions under which an interrupt is accepted:

- interrupt enable flag (I flag) = “1”
- interrupt request bit = “1”
- interrupt priority level > IPL

The interrupt enable flag (I flag), the interrupt request bit, the interrupt priority select bit, and the IPL are independent, and they are not affected by one another.

Table 1.11.3. Settings of interrupt priority levels

Interrupt priority level select bit	Interrupt priority level	Priority order
b2 b1 b0 0 0 0	Level 0 (interrupt disabled)	_____
0 0 1	Level 1	Low ↓ High
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	

Table 1.11.4. Interrupt levels enabled according to the contents of the IPL

IPL	Enabled interrupt priority levels
IPL ₂ IPL ₁ IPL ₀ 0 0 0	Interrupt levels 1 and above are enabled
0 0 1	Interrupt levels 2 and above are enabled
0 1 0	Interrupt levels 3 and above are enabled
0 1 1	Interrupt levels 4 and above are enabled
1 0 0	Interrupt levels 5 and above are enabled
1 0 1	Interrupt levels 6 and above are enabled
1 1 0	Interrupt levels 7 and above are enabled
1 1 1	All maskable interrupts are disabled

Rewrite the interrupt control register

To rewrite the interrupt control register, do so at a point that does not generate the interrupt request for that register. If there is possibility of the interrupt request occur, rewrite the interrupt control register after the interrupt is disabled. The program examples are described as follow:

Example 1:

```
INT_SWITCH1:
  FCLR    I           ; Disable interrupts.
  AND.B   #00h, 0055h ; Clear TA0IC int. priority level and int. request bit.
  NOP                     ; Four NOP instructions are required when using HOLD function.
  NOP
  FSET    I           ; Enable interrupts.
```

Example 2:

```
INT_SWITCH2:
  FCLR    I           ; Disable interrupts.
  AND.B   #00h, 0055h ; Clear TA0IC int. priority level and int. request bit.
  MOV.W   MEM, R0      ; Dummy read.
  FSET    I           ; Enable interrupts.
```

Example 3:

```
INT_SWITCH3:
  PUSHC   FLG          ; Push Flag register onto stack
  FCLR    I           ; Disable interrupts.
  AND.B   #00h, 0055h ; Clear TA0IC int. priority level and int. request bit.
  POPC    FLG          ; Enable interrupts.
```

The reason why two NOP instructions (four when using the HOLD function) or dummy read are inserted before FSET I in Examples 1 and 2 is to prevent the interrupt enable flag I from being set before the interrupt control register is rewritten due to effects of the instruction queue.

When a instruction to rewrite the interrupt control register is executed but the interrupt is disabled, the interrupt request bit is not set sometimes even if the interrupt request for that register has been generated. This will depend on the instruction. If this creates problems, use the below instructions to change the register.

Instructions : AND, OR, BCLR, BSET

Interrupt Sequence

An interrupt sequence — what are performed over a period from the instant an interrupt is accepted to the instant the interrupt routine is executed — is described here.

If an interrupt occurs during execution of an instruction, the processor determines its priority when the execution of the instruction is completed, and transfers control to the interrupt sequence from the next cycle. 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.

In the interrupt sequence, the processor carries out the following in sequence given:

- (1) CPU gets the interrupt information (the interrupt number and interrupt request level) by reading address 00000₁₆. After this, the corresponding interrupt request bit becomes "0".
- (2) Saves the content of the flag register (FLG) as it was immediately before the start of interrupt sequence in the temporary register (Note) within the CPU.
- (3) Sets the interrupt enable flag (I flag), the debug flag (D flag), and the stack pointer select flag (U flag) to "0" (the U flag, however does not change if the INT instruction, in software interrupt numbers 32 through 63, is executed)
- (4) Saves the content of the temporary register (Note) within the CPU in the stack area.
- (5) Saves the content of the program counter (PC) in the stack area.
- (6) Sets the interrupt priority level of the accepted instruction in the IPL.

After the interrupt sequence is completed, the processor resumes executing instructions from the first address of the interrupt routine.

Note: This register cannot be utilized by the user.

Interrupt Response Time

'Interrupt response time' is the period between the instant an interrupt occurs and the instant the first instruction within the interrupt routine has been executed. This time comprises the period from the occurrence of an interrupt to the completion of the instruction under execution at that moment (a) and the time required for executing the interrupt sequence (b). Figure 1.11.4 shows the interrupt response time.

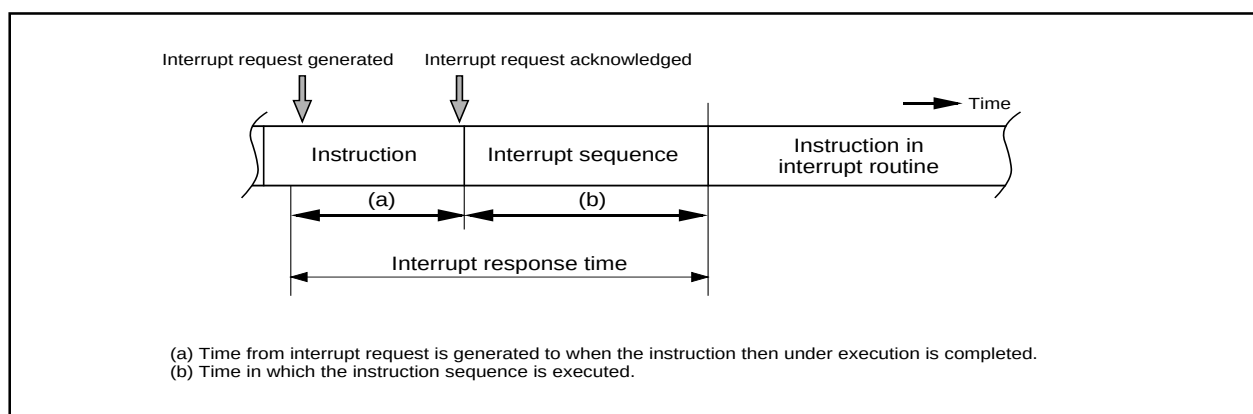


Figure 1.11.4. Interrupt response time

Interrupt

Time (a) is dependent on the instruction under execution. Thirty cycles is the maximum required for the DIVX instruction (without wait).

Time (b) is as shown in Table 1.11.5.

Table 1.11.5. Time required for executing the interrupt sequence

Interrupt vector address	Stack pointer (SP) value	16-Bit bus, without wait	8-Bit bus, without wait
Even	Even	18 cycles (Note 1)	20 cycles (Note 1)
Even	Odd	19 cycles (Note 1)	20 cycles (Note 1)
Odd (Note 2)	Even	19 cycles (Note 1)	20 cycles (Note 1)
Odd (Note 2)	Odd	20 cycles (Note 1)	20 cycles (Note 1)

Note 1: Add 2 cycles in the case of a $\overline{\text{DBC}}$ interrupt; add 1 cycle in the case either of an address match interrupt or of a single-step interrupt.

Note 2: Locate an interrupt vector address in an even address, if possible.

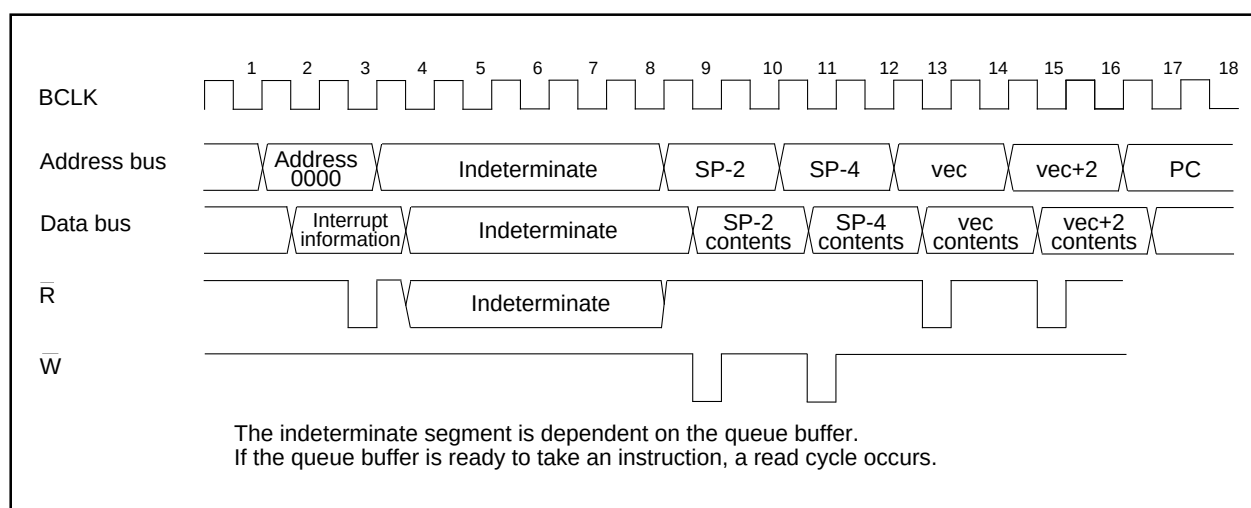


Figure 1.11.5. Time required for executing the interrupt sequence

Variation of IPL when Interrupt Request is Accepted

If an interrupt request is accepted, the interrupt priority level of the accepted interrupt is set in the IPL.

If an interrupt request, that does not have an interrupt priority level, is accepted, one of the values shown in Table 1.11.6 is set in the IPL.

Table 1.11.6. Relationship between interrupts without interrupt priority levels and IPL

Interrupt sources without priority levels	Value set in the IPL
Watchdog timer, NMI	7
Reset	0
Other	Not changed

Saving Registers

In the interrupt sequence, only the contents of the flag register (FLG) and that of the program counter (PC) are saved in the stack area.

First, the processor saves the four higher-order bits of the program counter, and 4 upper-order bits and 8 lower-order bits of the FLG register, 16 bits in total, in the stack area, then saves 16 lower-order bits of the program counter. Figure 1.11.6 shows the state of the stack as it was before the acceptance of the interrupt request, and the state the stack after the acceptance of the interrupt request.

Save other necessary registers at the beginning of the interrupt routine using software. Using the PUSHM instruction alone can save all the registers except the stack pointer (SP).

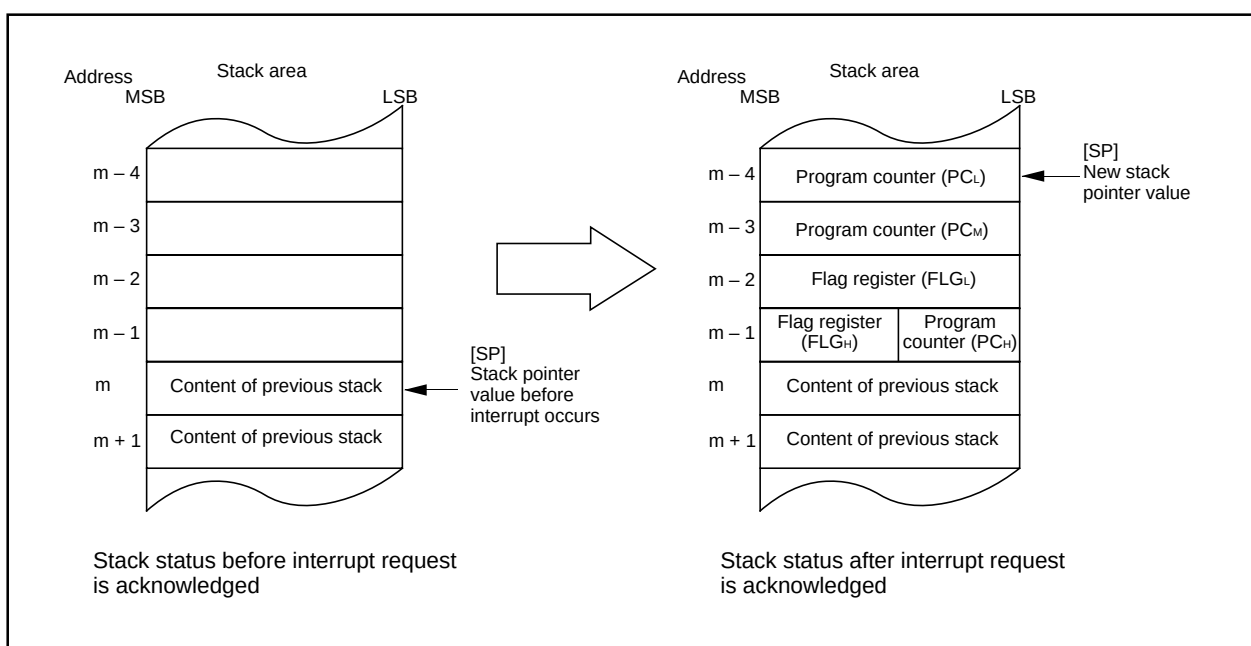


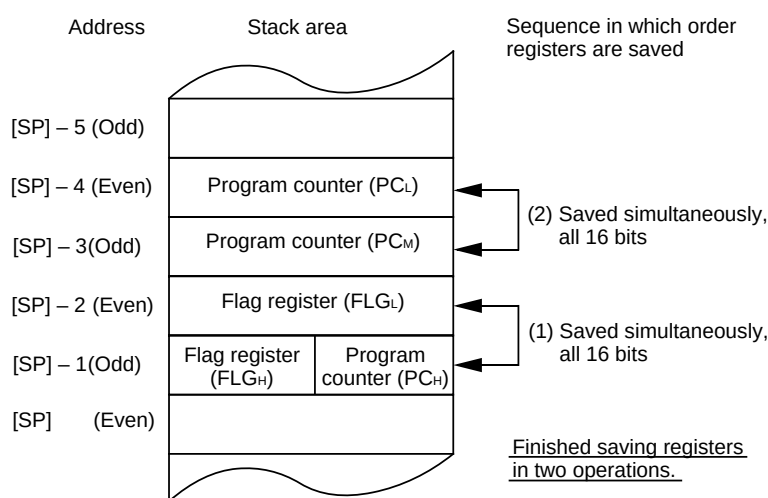
Figure 1.11.6. State of stack before and after acceptance of interrupt request

Interrupt

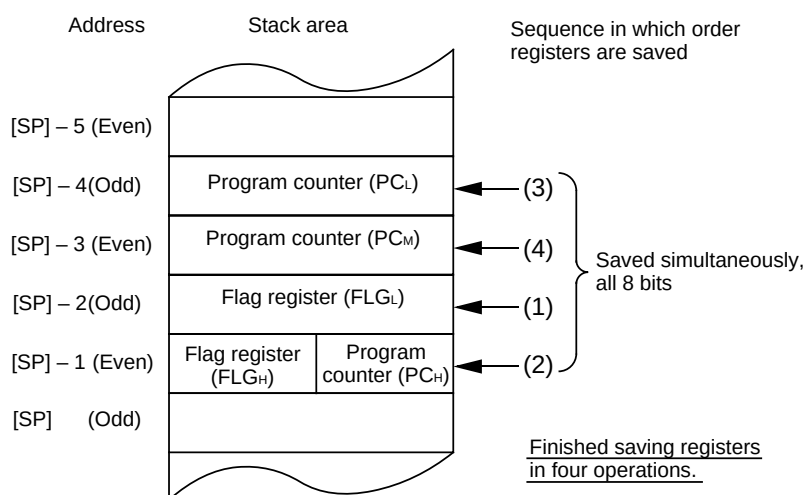
The operation of saving registers carried out in the interrupt sequence is dependent on whether the content of the stack pointer (Note) , at the time of acceptance of an interrupt request, is even or odd. If the content of the stack pointer (Note) is even, the content of the flag register (FLG) and the content of the program counter (PC) are saved, 16 bits at a time. If odd, their contents are saved in two steps, 8 bits at a time. Figure 1.11.7 shows the operation of the saving registers.

Note: When any INT instruction in software numbers 32 to 63 has been executed, this is the stack pointer indicated by the U flag. Otherwise, it is the interrupt stack pointer (ISP).

(1) Stack pointer (SP) contains even number



(2) Stack pointer (SP) contains odd number



Note: [SP] denotes the initial value of the stack pointer (SP) when interrupt request is acknowledged. After registers are saved, the SP content is [SP] minus 4.

Figure 1.11.7. Operation of saving registers

Returning from an Interrupt Routine

Executing the REIT instruction at the end of an interrupt routine returns the contents of the flag register (FLG) as it was immediately before the start of interrupt sequence and the contents of the program counter (PC), both of which have been saved in the stack area. Then control returns to the program that was being executed before the acceptance of the interrupt request, so that the suspended process resumes. Return the other registers saved by software within the interrupt routine using the POPM or similar instruction before executing the REIT instruction.

Interrupt Priority

If there are two or more interrupt requests occurring at a point in time within a single sampling (checking whether interrupt requests are made), the interrupt assigned a higher priority is accepted.

Assign an arbitrary priority to maskable interrupts (peripheral I/O interrupts) using the interrupt priority level select bit. If the same interrupt priority level is assigned, however, the interrupt assigned a higher hardware priority is accepted.

Priorities of the special interrupts, such as Reset (dealt with as an interrupt assigned the highest priority), watchdog timer interrupt, etc. are regulated by hardware.

Figure 1.11.8 shows the priorities of hardware interrupts.

Software interrupts are not affected by the interrupt priority. If an instruction is executed, control branches invariably to the interrupt routine.

Reset > $\overline{\text{NMI}}$ > $\overline{\text{DBC}}$ > Watchdog timer > Peripheral I/O > Single step > Address match

Figure 1.11.8. Hardware interrupts priorities

Interrupt resolution circuit

When two or more interrupts are generated simultaneously, this circuit selects the interrupt with the highest priority level. Figure 1.11.9 shows the circuit that judges the interrupt priority level.

Interrupt

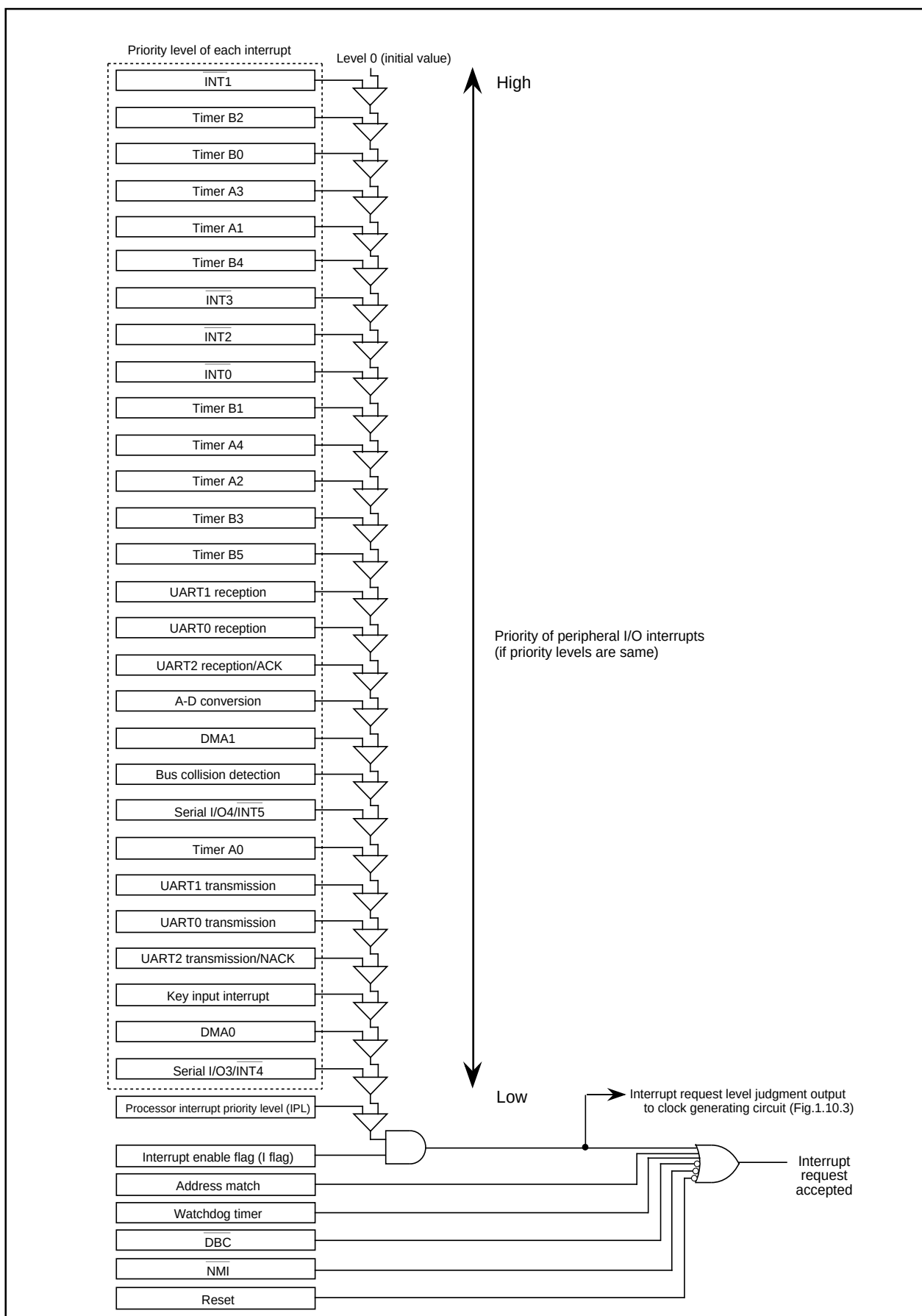


Figure 1.11.9. Maskable interrupts priorities (peripheral I/O interrupts)

INT Interrupt

INT0 to INT5 are triggered by the edges of external inputs. The edge polarity is selected using the polarity select bit.

Of interrupt control registers, 0048₁₆ is used both as serial I/O4 and external interrupt INT5 input control register, and 0049₁₆ is used both as serial I/O3 and as external interrupt INT4 input control register. Use the interrupt request cause select bits - bits 6 and 7 of the interrupt request cause select register (035F₁₆) - to specify which interrupt request cause to select. After having set an interrupt request cause, be sure to clear the corresponding interrupt request bit before enabling an interrupt.

Either of the interrupt control registers - 0048₁₆, 0049₁₆ - has the polarity-switching bit. Be sure to set this bit to "0" to select an serial I/O as the interrupt request cause.

As for external interrupt input, an interrupt can be generated both at the rising edge and at the falling edge by setting "1" in the INT_i interrupt polarity switching bit of the interrupt request cause select register (035F₁₆). To select both edges, set the polarity switching bit of the corresponding interrupt control register to 'falling edge' ("0").

Figure 1.11.10 shows the Interrupt request cause select register.

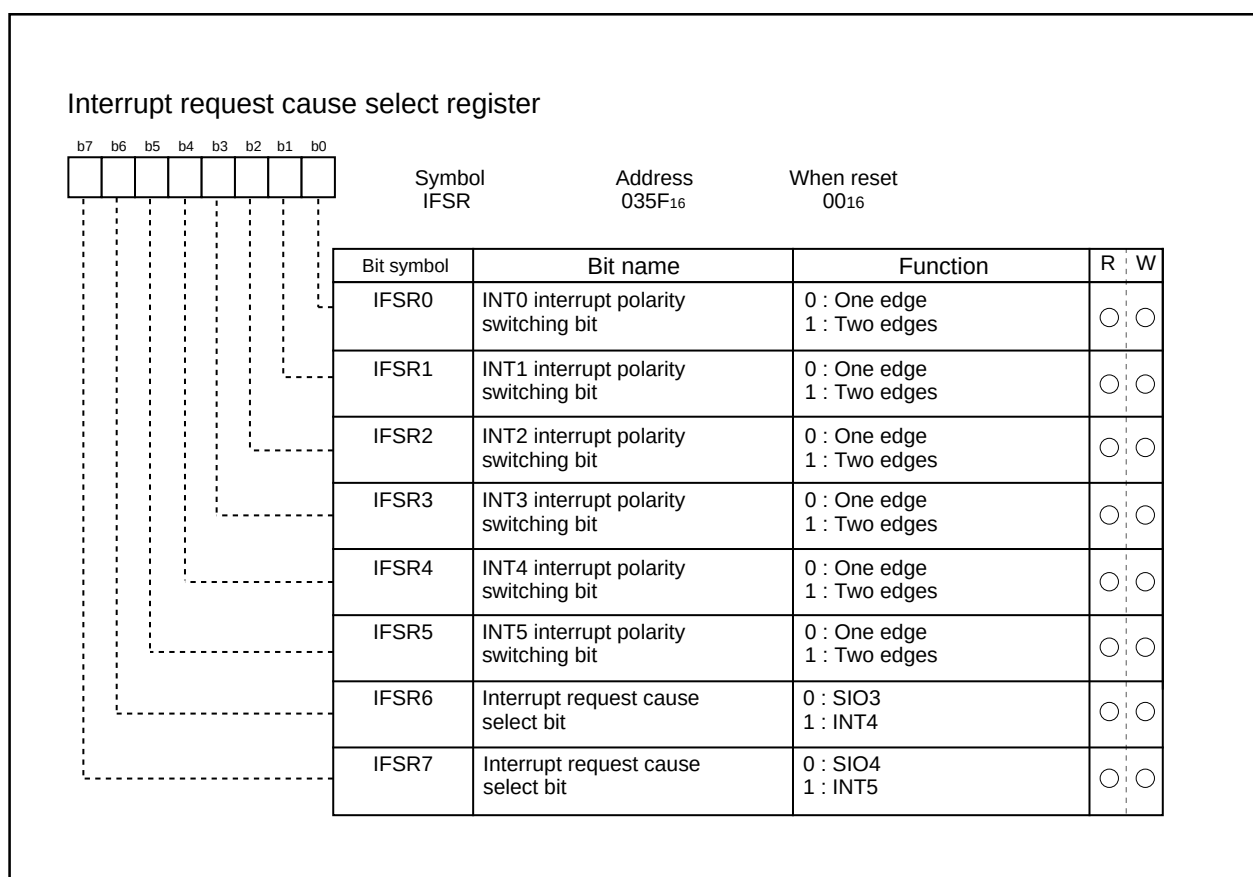


Figure 1.11.10. Interrupt request cause select register

$\overline{\text{NMI}}$ Interrupt

$\overline{\text{NMI}}$ Interrupt

An $\overline{\text{NMI}}$ interrupt is generated when the input to the P85/ $\overline{\text{NMI}}$ pin changes from “H” to “L”. The $\overline{\text{NMI}}$ interrupt is a non-maskable external interrupt. The pin level can be checked in the port P85 register (bit 5 at address 03F016).

This pin cannot be used as a normal port input.

Key Input Interrupt

If the direction register of any of P104 to P107 is set for input and a falling edge is input to that port, a key input interrupt is generated. A key input interrupt can also be used as a key-on wakeup function for cancelling the wait mode or stop mode. However, if you intend to use the key input interrupt, do not use P104 to P107 as A-D input ports. Figure 1.11.11 shows the block diagram of the key input interrupt. Note that if an “L” level is input to any pin that has not been disabled for input, inputs to the other pins are not detected as an interrupt.

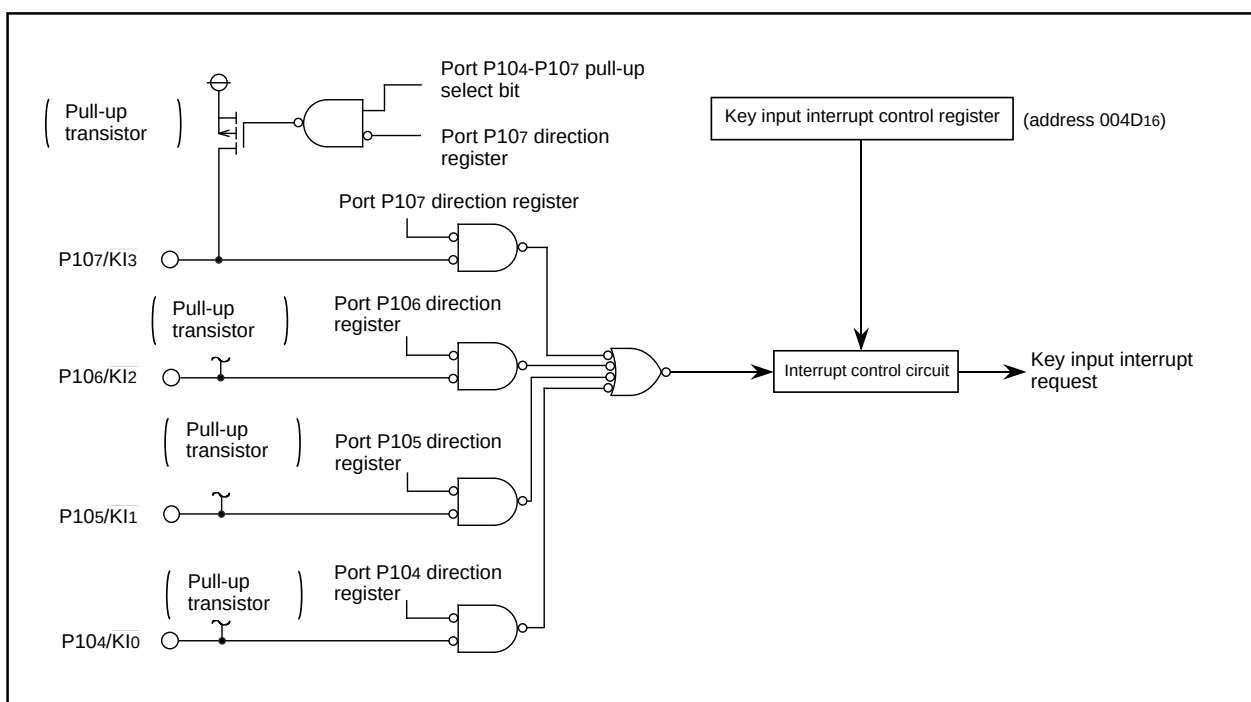


Figure 1.11.11. Block diagram of key input interrupt

Address Match Interrupt

An address match interrupt is generated when the address match interrupt address register contents match the program counter value. Two address match interrupts can be set, each of which can be enabled and disabled by an address match interrupt enable bit. Address match interrupts are not affected by the interrupt enable flag (I flag) and processor interrupt priority level (IPL). For an address match interrupt, the value of the program counter (PC) that is saved to the stack area varies depending on the instruction being executed. Note that when using the external data bus in width of 8 bits, the address match interrupt cannot be used for external area.

Figure 1.11.12 shows the address match interrupt-related registers.

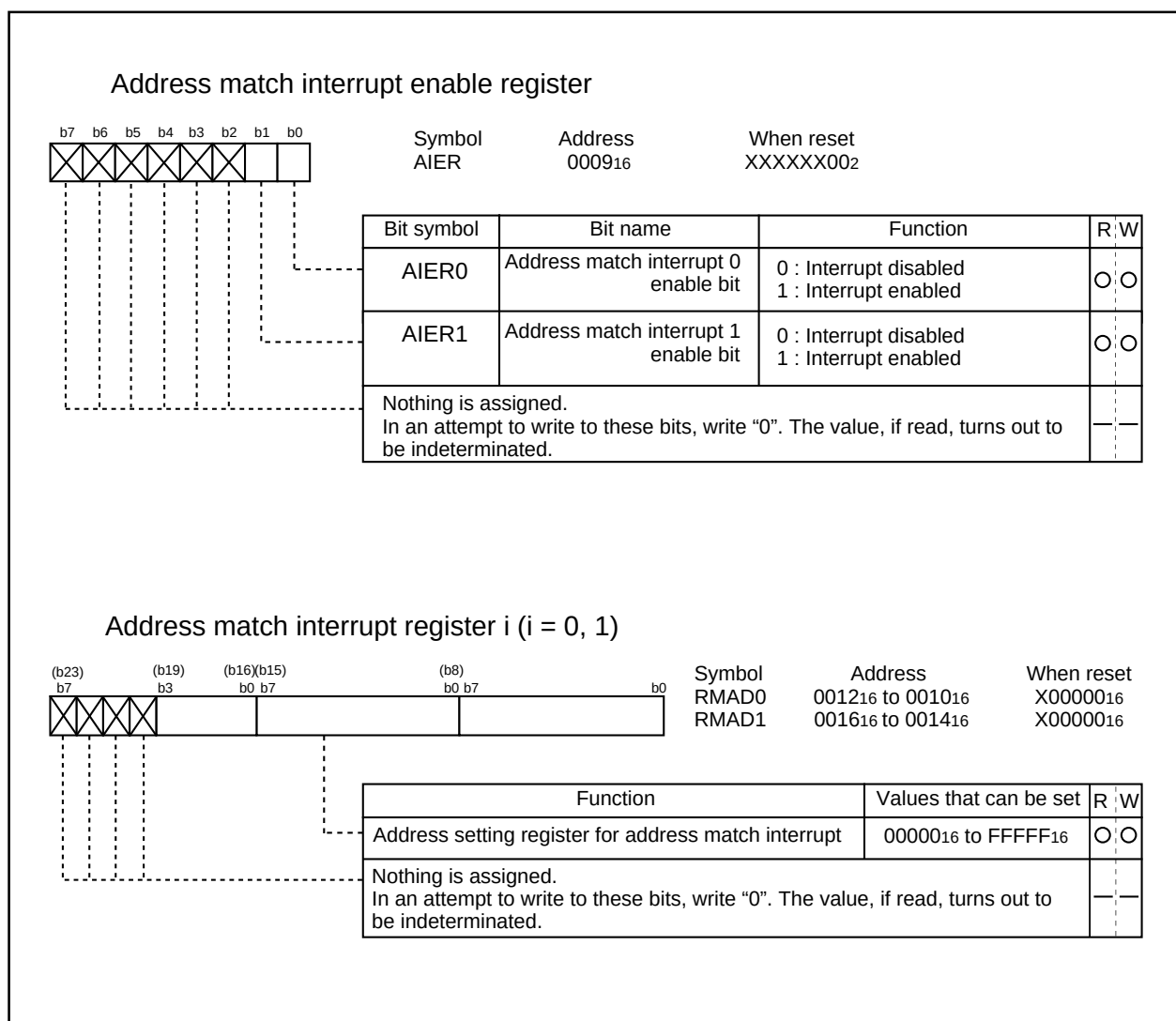


Figure 1.11.12. Address match interrupt-related registers

Precautions for Interrupts

(1) Reading address 00000₁₆

- When maskable interrupt is occurred, CPU reads the interrupt information (the interrupt number and interrupt request level) in the interrupt sequence.

The interrupt request bit of the certain interrupt written in address 00000₁₆ will then be set to "0".

Even if the address 00000₁₆ is read out by software, "0" is set to the enabled highest priority interrupt source request bit. Therefore interrupt can be canceled and unexpected interrupt can occur.

Do not read address 00000₁₆ by software.

(2) Setting the stack pointer

- The value of the stack pointer immediately after reset is initialized to 0000₁₆. Accepting an interrupt before setting a value in the stack pointer may become a factor of runaway. Be sure to set a value in the stack pointer before accepting an interrupt. When using the $\overline{\text{NMI}}$ interrupt, initialize the stack pointer at the beginning of a program. Concerning the first instruction immediately after reset, generating any interrupts including the $\overline{\text{NMI}}$ interrupt is prohibited.

(3) The $\overline{\text{NMI}}$ interrupt

- The $\overline{\text{NMI}}$ interrupt can not be disabled. Be sure to connect $\overline{\text{NMI}}$ pin to Vcc via a pull-up resistor if unused. Be sure to work on it.
- The $\overline{\text{NMI}}$ pin also serves as P85, which is exclusively input. Reading the contents of the P8 register allows reading the pin value. Use the reading of this pin only for establishing the pin level at the time when the $\overline{\text{NMI}}$ interrupt is input.
- Do not reset the CPU with the input to the $\overline{\text{NMI}}$ pin being in the "L" state.
- Do not attempt to go into stop mode with the input to the $\overline{\text{NMI}}$ pin being in the "L" state. With the input to the $\overline{\text{NMI}}$ being in the "L" state, the CM10 is fixed to "0", so attempting to go into stop mode is turned down.
- Do not attempt to go into wait mode with the input to the $\overline{\text{NMI}}$ pin being in the "L" state. With the input to the $\overline{\text{NMI}}$ pin being in the "L" state, the CPU stops but the oscillation does not stop, so no power is saved. In this instance, the CPU is returned to the normal state by a later interrupt.
- Signals input to the $\overline{\text{NMI}}$ pin require an "L" level of 1 clock or more, from the operation clock of the CPU.

(4) External interrupt

- Either an "L" level or an "H" level of at least 250 ns width is necessary for the signal input to pins $\overline{\text{INT0}}$ through $\overline{\text{INT5}}$ regardless of the CPU operation clock.
- When the polarity of the $\overline{\text{INT0}}$ to $\overline{\text{INT5}}$ pins is changed, the interrupt request bit is sometimes set to "1". After changing the polarity, set the interrupt request bit to "0". Figure 1.11.13 shows the procedure for changing the $\overline{\text{INT}}$ interrupt generate factor.

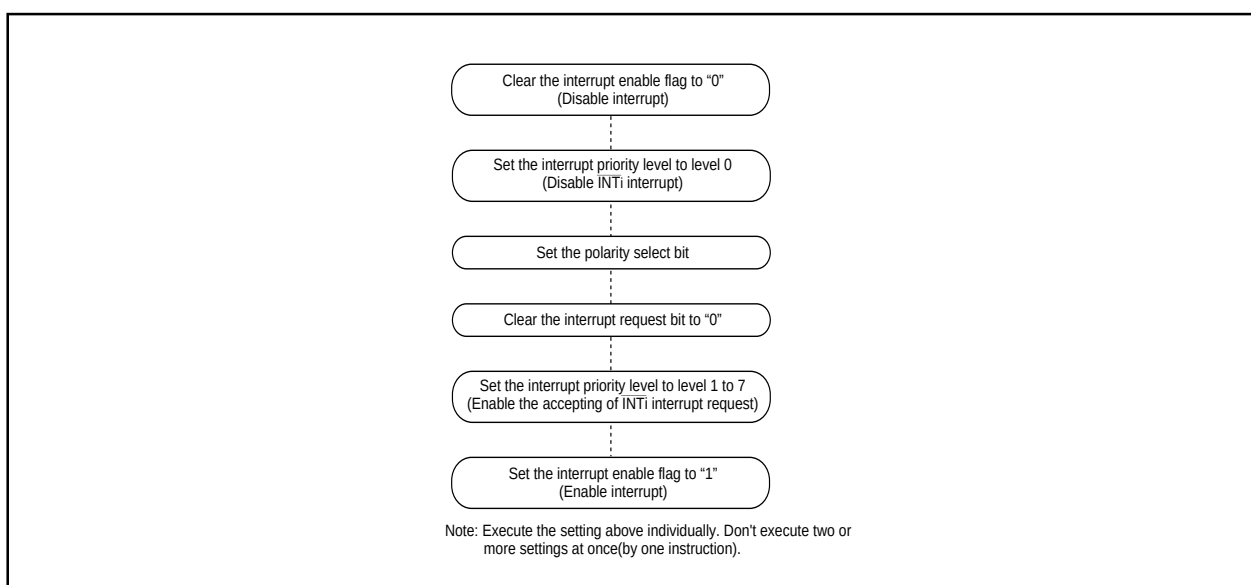


Figure 1.11.13. Switching condition of INT interrupt request

(5) Rewrite the interrupt control register

- To rewrite the interrupt control register, do so at a point that does not generate the interrupt request for that register. If there is possibility of the interrupt request occur, rewrite the interrupt control register after the interrupt is disabled. The program examples are described as follow:

Example 1:

```

INT_SWITCH1:
  FCLR    I          ; Disable interrupts.
  AND.B   #00h, 0055h ; Clear TA0IC int. priority level and int. request bit.
  NOP
  NOP      ; Four NOP instructions are required when using HOLD function.
  FSET    I          ; Enable interrupts.

```

Example 2:

```

INT_SWITCH2:
  FCLR    I          ; Disable interrupts.
  AND.B   #00h, 0055h ; Clear TA0IC int. priority level and int. request bit.
  MOV.W   MEM, R0     ; Dummy read.
  FSET    I          ; Enable interrupts.

```

Example 3:

```

INT_SWITCH3:
  PUSHC   FLG         ; Push Flag register onto stack
  FCLR    I          ; Disable interrupts.
  AND.B   #00h, 0055h ; Clear TA0IC int. priority level and int. request bit.
  POPC    FLG         ; Enable interrupts.

```

The reason why two NOP instructions (four when using the HOLD function) or dummy read are inserted before FSET I in Examples 1 and 2 is to prevent the interrupt enable flag I from being set before the interrupt control register is rewritten due to effects of the instruction queue.

- When a instruction to rewrite the interrupt control register is executed but the interrupt is disabled, the interrupt request bit is not set sometimes even if the interrupt request for that register has been generated. This will depend on the instruction. If this creates problems, use the below instructions to change the register.

Instructions : AND, OR, BCLR, BSET

Watchdog Timer

Watchdog Timer

The watchdog timer has the function of detecting when the program is out of control. Therefore, we recommend using the watchdog timer to improve reliability of a system. The watchdog timer is a 15-bit counter which down-counts the clock derived by dividing the BCLK using the prescaler. A watchdog timer interrupt is generated when an underflow occurs in the watchdog timer. When X_{IN} is selected for the BCLK, bit 7 of the watchdog timer control register (address 000F₁₆) selects the prescaler division ratio (by 16 or by 128). When X_{CIN} is selected as the BCLK, the prescaler is set for division by 2 regardless of bit 7 of the watchdog timer control register (address 000F₁₆). Thus the watchdog timer's period can be calculated as given below. The watchdog timer's period is, however, subject to an error due to the prescaler.

With X_{IN} chosen for BCLK

$$\text{Watchdog timer period} = \frac{\text{prescaler dividing ratio (16 or 128)} \times \text{watchdog timer count (32768)}}{\text{BCLK}}$$

With X_{CIN} chosen for BCLK

$$\text{Watchdog timer period} = \frac{\text{prescaler dividing ratio (2)} \times \text{watchdog timer count (32768)}}{\text{BCLK}}$$

For example, suppose that BCLK runs at 16 MHz and that 16 has been chosen for the dividing ratio of the prescaler, then the watchdog timer's period becomes approximately 32.8 ms.

The watchdog timer is initialized by writing to the watchdog timer start register (address 000E₁₆) and when a watchdog timer interrupt request is generated. The prescaler is initialized only when the microcomputer is reset. After a reset is cancelled, the watchdog timer and prescaler are both stopped. The count is started by writing to the watchdog timer start register (address 000E₁₆). In stop mode, wait mode and hold state, the watchdog timer and prescaler are stopped. Counting is resumed from the held value when the modes or state are released.

Figure 1.12.1 shows the block diagram of the watchdog timer. Figure 1.12.2 shows the watchdog timer-related registers.

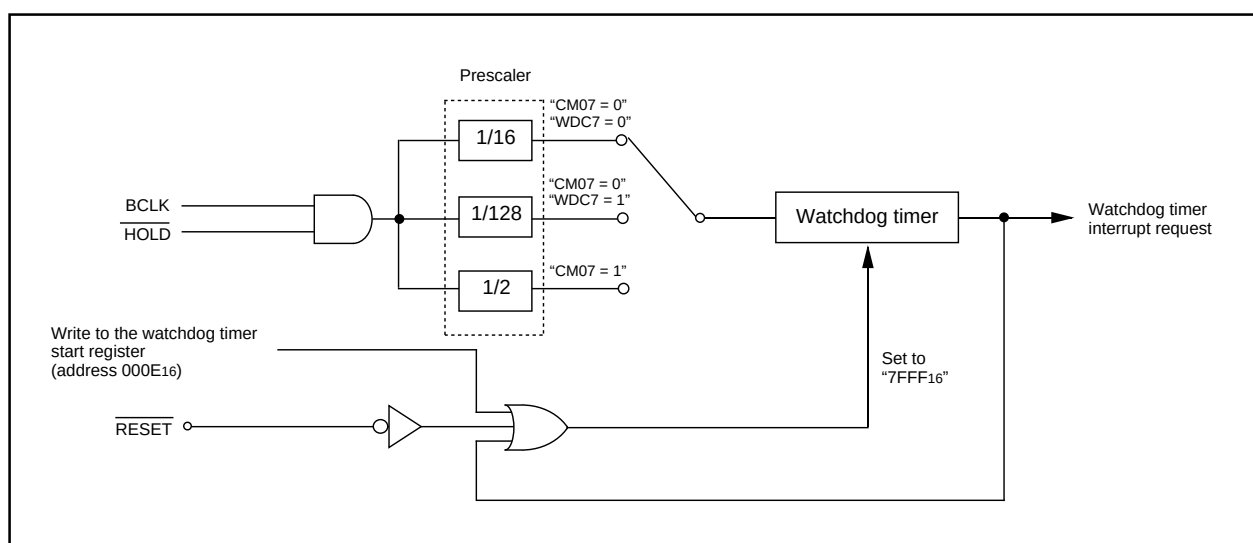


Figure 1.12.1. Block diagram of watchdog timer

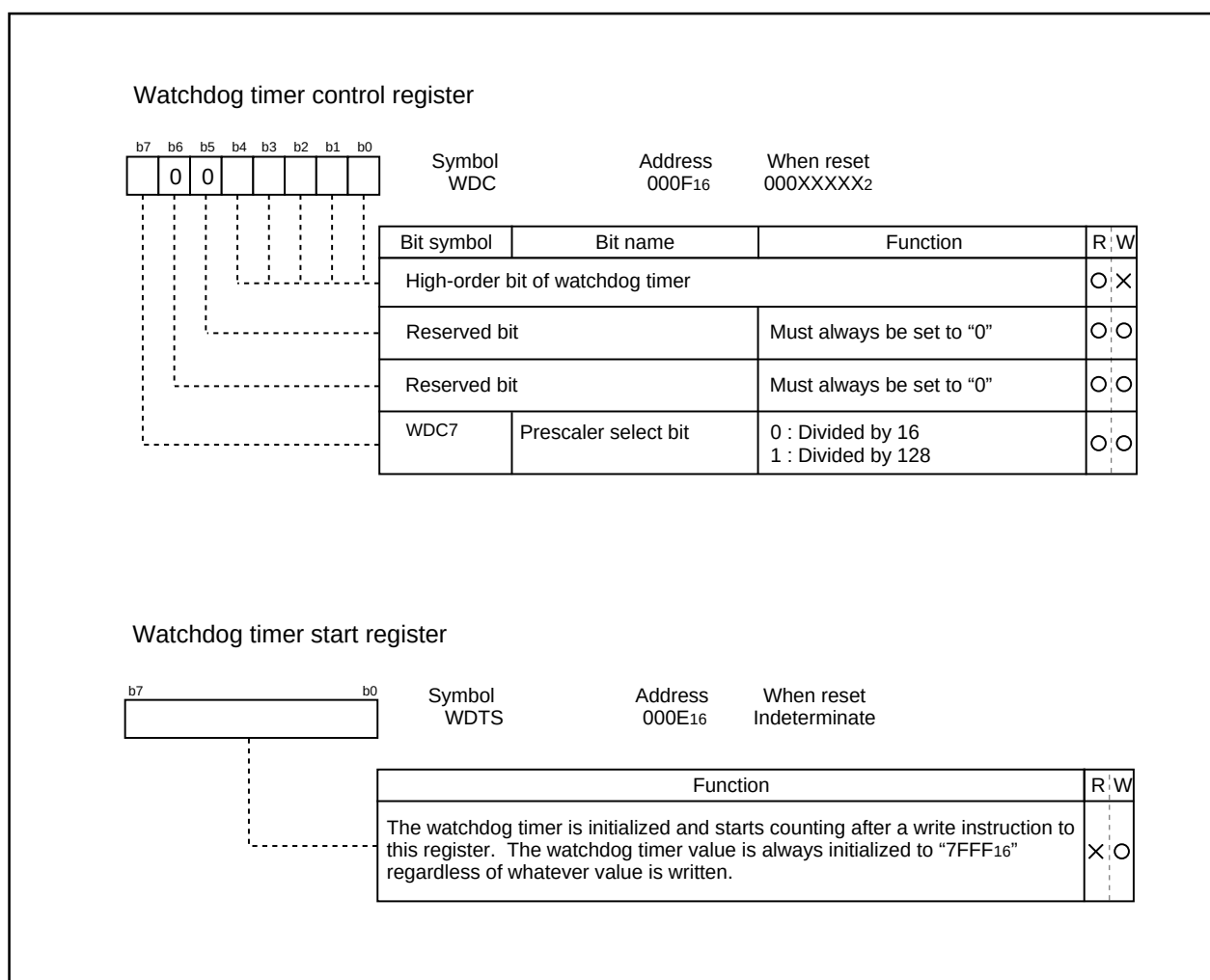


Figure 1.12.2. Watchdog timer control and start registers

DMAC

DMAC

This microcomputer has two DMAC (direct memory access controller) channels that allow data to be sent to memory without using the CPU. DMAC shares the same data bus with the CPU. The DMAC is given a higher right of using the bus than the CPU, which leads to working the cycle stealing method. On this account, the operation from the occurrence of DMA transfer request signal to the completion of 1-word (16-bit) or 1-byte (8-bit) data transfer can be performed at high speed. Figure 1.13.1 shows the block diagram of the DMAC. Table 1.13.1 shows the DMAC specifications. Figures 1.13.2 to 1.13.4 show the registers used by the DMAC.

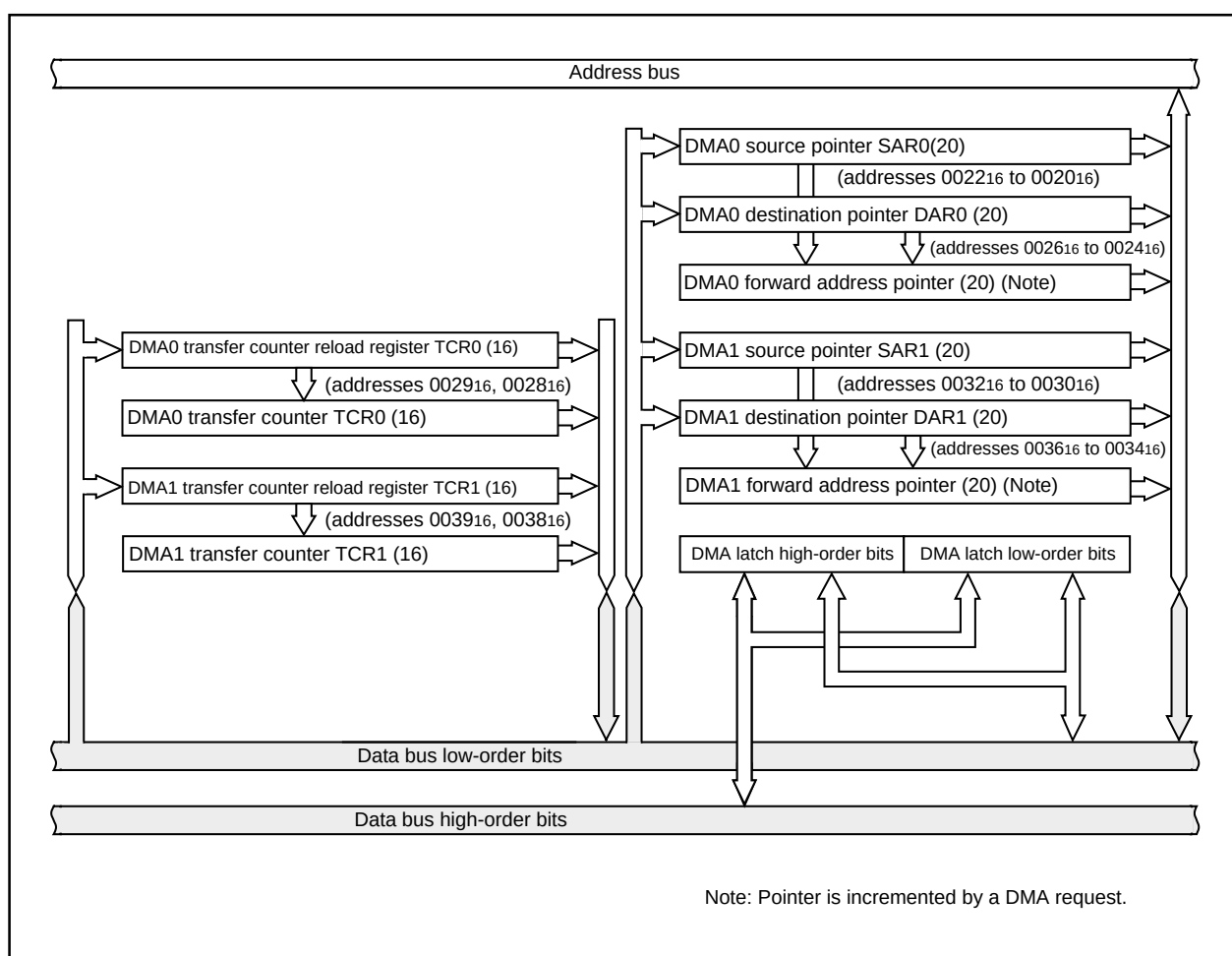


Figure 1.13.1. Block diagram of DMAC

Either a write signal to the software DMA request bit or an interrupt request signal is used as a DMA transfer request signal. But the DMA transfer is affected neither by the interrupt enable flag (I flag) nor by the interrupt priority level. The DMA transfer doesn't affect any interrupts either.

If the DMAC is active (the DMA enable bit is set to 1), data transfer starts every time a DMA transfer request signal occurs. If the cycle of the occurrences of DMA transfer request signals is higher than the DMA transfer cycle, there can be instances in which the number of transfer requests doesn't agree with the number of transfers. For details, see the description of the DMA request bit.

DMAC

Table 1.13.1. DMAC specifications

Item	Specification
No. of channels	2 (cycle steal method)
Transfer memory space	• From any address in the 1M bytes space to a fixed address • From a fixed address to any address in the 1M bytes space • From a fixed address to a fixed address (Note that DMA-related registers [0020 ₁₆ to 003F ₁₆] cannot be accessed)
Maximum No. of bytes transferred	128K bytes (with 16-bit transfers) or 64K bytes (with 8-bit transfers)
DMA request factors (Note)	Falling edge of $\overline{\text{INT0}}$ or $\overline{\text{INT1}}$ or both edge Timer A0 to timer A4 interrupt requests Timer B0 to timer B5 interrupt requests UART0 transfer and reception interrupt requests UART1 transfer and reception interrupt requests UART2 transfer and reception interrupt requests Serial I/O3, 4 interrupt requests A-D conversion interrupt requests Software triggers
Channel priority	DMA0 takes precedence if DMA0 and DMA1 requests are generated simultaneously
Transfer unit	8 bits or 16 bits
Transfer address direction	forward/fixed (forward direction cannot be specified for both source and destination simultaneously)
Transfer mode	• Single transfer mode After the transfer counter underflows, the DMA enable bit turns to "0", and the DMAC turns inactive • Repeat transfer mode After the transfer counter underflows, the value of the transfer counter reload register is reloaded to the transfer counter. The DMAC remains active unless a "0" is written to the DMA enable bit.
DMA interrupt request generation timing	When an underflow occurs in the transfer counter
Active	When the DMA enable bit is set to "1", the DMAC is active. When the DMAC is active, data transfer starts every time a DMA transfer request signal occurs.
Inactive	• When the DMA enable bit is set to "0", the DMAC is inactive. • After the transfer counter underflows in single transfer mode
Reload timing for forward address pointer and transfer counter	At the time of starting data transfer immediately after turning the DMAC active, the value of one of source pointer and destination pointer - the one specified for the forward direction - is reloaded to the forward direction address pointer, and the value of the transfer counter reload register is reloaded to the transfer counter.
Writing to register	Registers specified for forward direction transfer are always write enabled. Registers specified for fixed address transfer are write-enabled when the DMA enable bit is "0".
Reading the register	Can be read at any time. However, when the DMA enable bit is "1", reading the register set up as the forward register is the same as reading the value of the forward address pointer.

Note: DMA transfer is not effective to any interrupt. DMA transfer is affected neither by the interrupt enable flag (I flag) nor by the interrupt priority level.

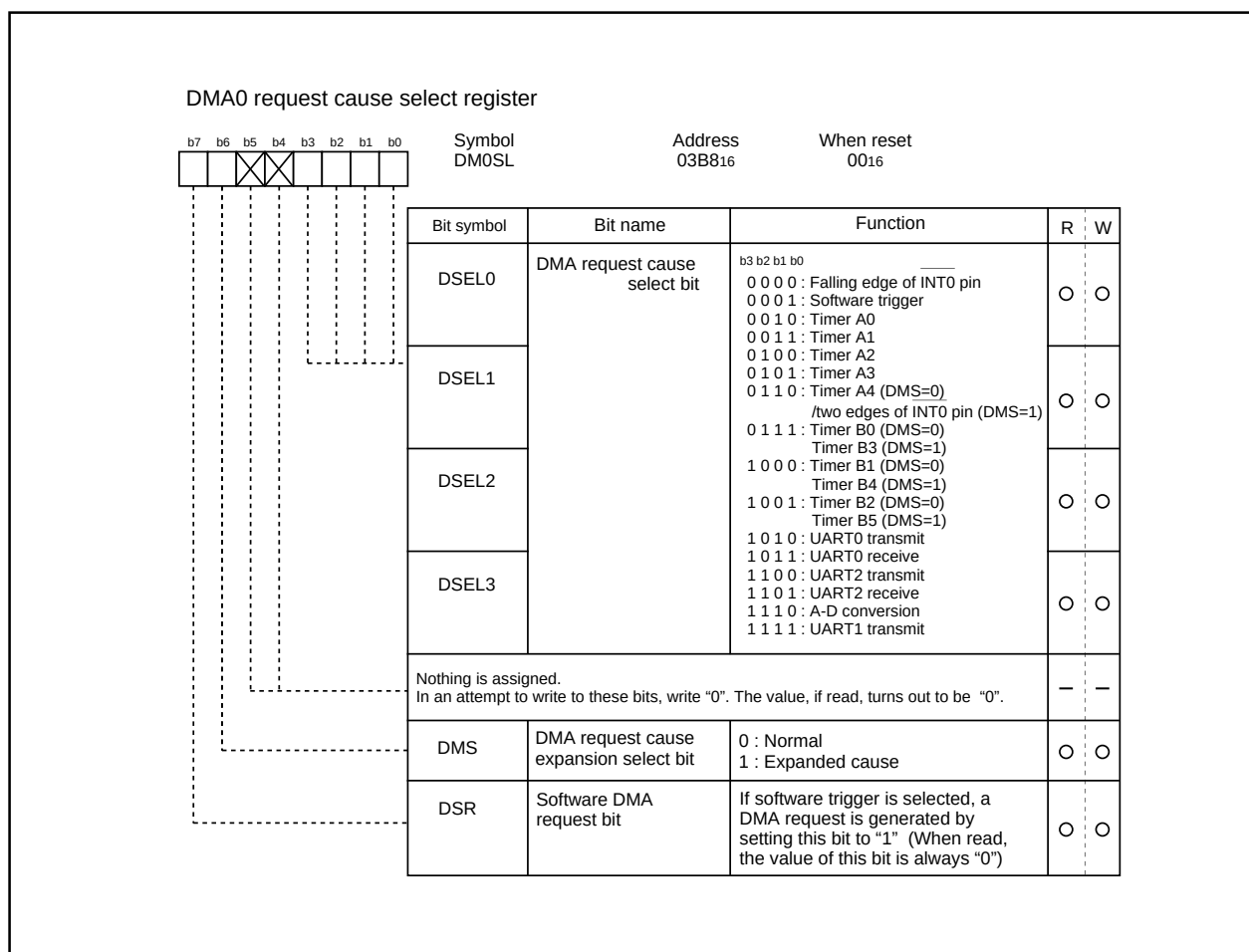
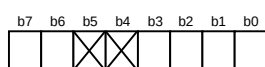


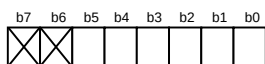
Figure 1.13.2. DMAC register (1)

DMA1 request cause select register

Symbol
DM1SLAddress
03BA₁₆When reset
00₁₆

Bit symbol	Bit name	Function	R	W
DSEL0	DMA request cause select bit	b3 b2 b1 b0 0 0 0 0 : Falling edge of INT1 pin 0 0 0 1 : Software trigger 0 0 1 0 : Timer A0 0 0 1 1 : Timer A1 0 1 0 0 : Timer A2 0 1 0 1 : Timer A3(DMS=0) /serial I/O3 (DMS=1) 0 1 1 0 : Timer A4 (DMS=0) /serial I/O4 (DMS=1) 0 1 1 1 : Timer B0 (DMS=0) /two edges of INT1 (DMS=1) 1 0 0 0 : Timer B1 1 0 0 1 : Timer B2 1 0 1 0 : UART0 transmit 1 0 1 1 : UART0 receive 1 1 0 0 : UART2 transmit 1 1 0 1 : UART2 receive 1 1 1 0 : A-D conversion 1 1 1 1 : UART1 receive	○	○
DSEL1		○	○	
DSEL2		○	○	
DSEL3		○	○	
Nothing is assigned. In an attempt to write to these bits, write “0”. The value, if read, turns out to be “0”.			—	—
DMS	DMA request cause expansion select bit	0 : Normal 1 : Expanded cause	○	○
DSR	Software DMA request bit	If software trigger is selected, a DMA request is generated by setting this bit to “1” (When read, the value of this bit is always “0”)	○	○

DMAi control register

Symbol
DMiCON(i=0,1)Address
002C₁₆, 003C₁₆When reset
00000X00₂

Bit symbol	Bit name	Function	R	W
DMBIT	Transfer unit bit select bit	0 : 16 bits 1 : 8 bits	○	○
DMASL	Repeat transfer mode select bit	0 : Single transfer 1 : Repeat transfer	○	○
DMAS	DMA request bit (Note 1)	0 : DMA not requested 1 : DMA requested	○	○ (Note 2)
DMAE	DMA enable bit	0 : Disabled 1 : Enabled	○	○
DSD	Source address direction select bit (Note 3)	0 : Fixed 1 : Forward	○	○
DAD	Destination address direction select bit (Note 3)	0 : Fixed 1 : Forward	○	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".			—	—

Note 1: DMA request can be cleared by resetting the bit.

Note 2: This bit can only be set to "0".

Note 3: Source address direction select bit and destination address direction select bit cannot be set to "1" simultaneously.

Figure 1.13.3. DMAC register (2)

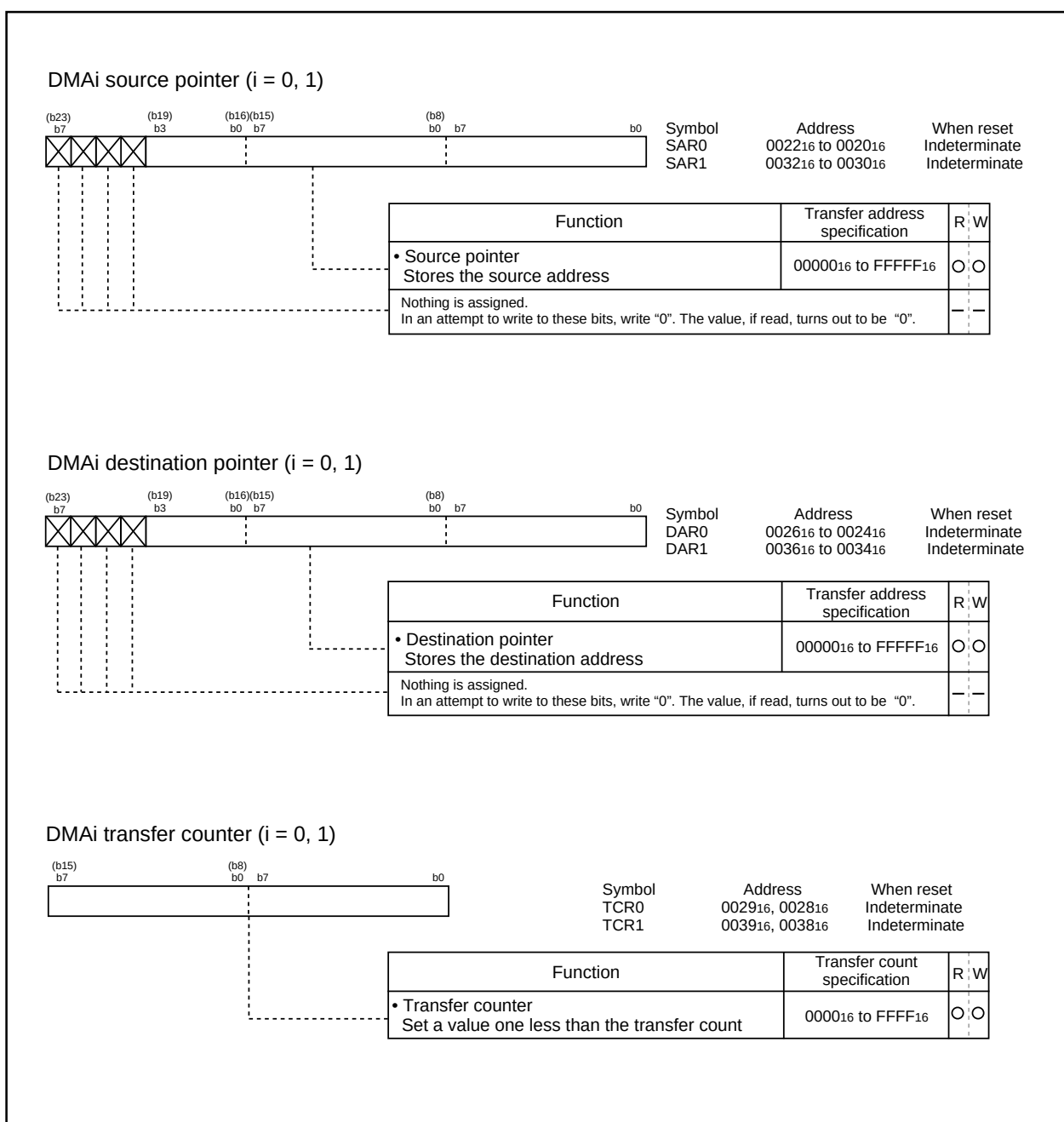


Figure 1.13.4. DMAC register (3)

(1) Transfer cycle

The transfer cycle consists of the bus cycle in which data is read from memory or from the SFR area (source read) and the bus cycle in which the data is written to memory or to the SFR area (destination write). The number of read and write bus cycles depends on the source and destination addresses. In memory expansion mode and microprocessor mode, the number of read and write bus cycles also depends on the level of the BYTE pin. Also, the bus cycle itself is longer when software waits are inserted.

(a) Effect of source and destination addresses

When 16-bit data is transferred on a 16-bit data bus, and the source and destination both start at odd addresses, there are one more source read cycle and destination write cycle than when the source and destination both start at even addresses.

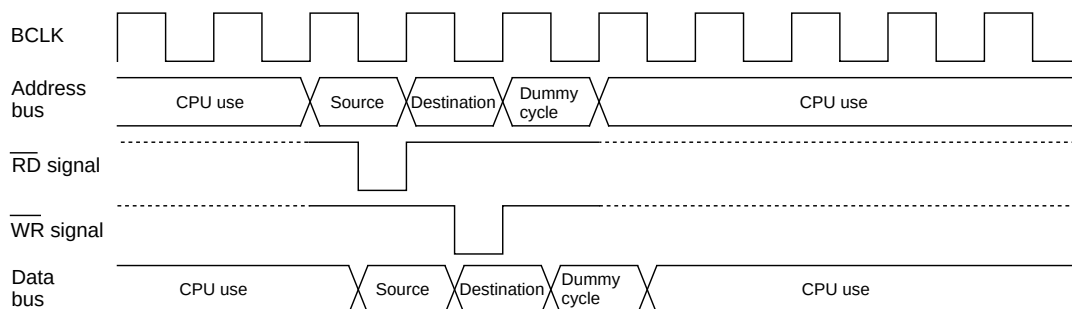
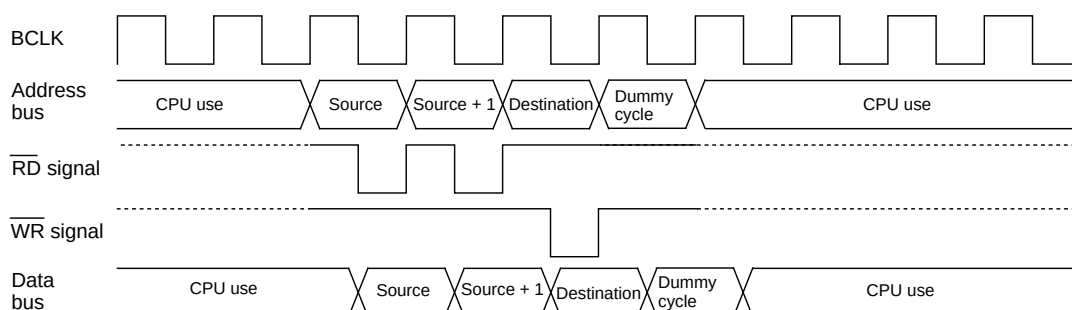
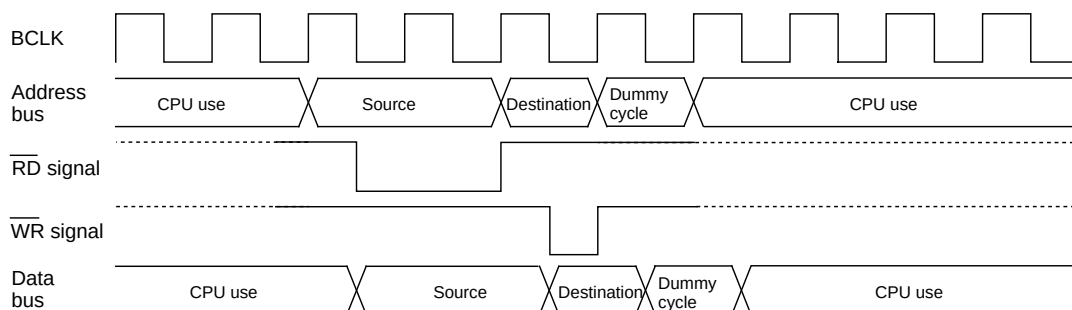
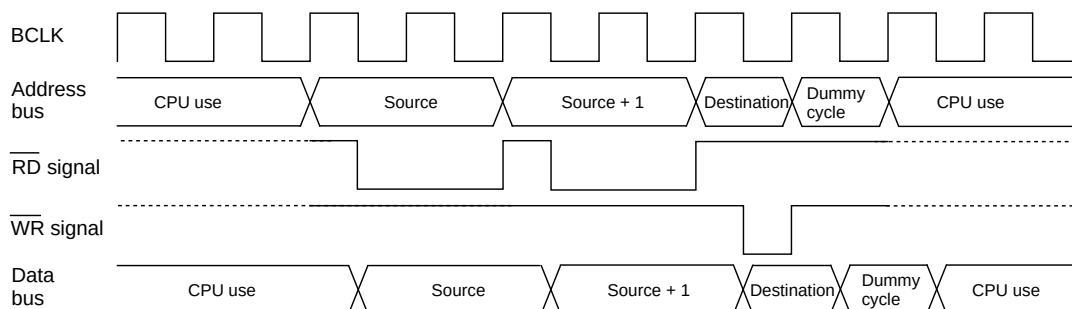
(b) Effect of BYTE pin level

When transferring 16-bit data over an 8-bit data bus (BYTE pin = "H") in memory expansion mode and microprocessor mode, the 16 bits of data are sent in two 8-bit blocks. Therefore, two bus cycles are required for reading the data and two are required for writing the data. Also, in contrast to when the CPU accesses internal memory, when the DMAC accesses internal memory (internal ROM, internal RAM, and SFR), these areas are accessed using the data size selected by the BYTE pin.

(c) Effect of software wait

When the SFR area or a memory area with a software wait is accessed, the number of cycles is increased for the wait by 1 bus cycle. The length of the cycle is determined by BCLK.

Figure 1.13.5 shows the example of the transfer cycles for a source read. For convenience, the destination write cycle is shown as one 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 the transfer cycle, remember to apply the respective conditions to both the destination write cycle and the source read cycle. For example (2) in Figure 1.13.5, if data is being transferred in 16-bit units on an 8-bit bus, two bus cycles are required for both the source read cycle and the destination write cycle.

(1) 8-bit transfers**16-bit transfers and the source address is even.****(2) 16-bit transfers and the source address is odd****Transferring 16-bit data on an 8-bit data bus (In this case, there are also two destination cycles).****(3) One wait is inserted into the source read under the conditions in (1)****(4) One wait is inserted into the source read under the conditions in (2)****(When 16-bit data is transferred on an 8-bit data bus, there are two destination cycles).**

Note: The same timing changes occur with the respective conditions at the destination as at the source.

Figure 1.13.5. Example of the transfer cycles for a source read

DMAC

(2) DMAC transfer cycles

Any combination of even or odd transfer read and write addresses is possible. Table 1.13.2 shows the number of DMAC transfer cycles.

The number of DMAC transfer cycles can be calculated as follows:

$$\text{No. of transfer cycles per transfer unit} = \text{No. of read cycles} \times j + \text{No. of write cycles} \times k$$

Table 1.13.2. No. of DMAC transfer cycles

Transfer unit	Bus width	Access address	Single-chip mode		Memory expansion mode Microprocessor mode	
			No. of read cycles	No. of write cycles	No. of read cycles	No. of write cycles
8-bit transfers (DMBIT= "1")	16-bit (BYTE= "L")	Even	1	1	1	1
		Odd	1	1	1	1
	8-bit (BYTE = "H")	Even	—	—	1	1
		Odd	—	—	1	1
16-bit transfers (DMBIT= "0")	16-bit (BYTE = "L")	Even	1	1	1	1
		Odd	2	2	2	2
	8-bit (BYTE = "H")	Even	—	—	2	2
		Odd	—	—	2	2

Coefficient j, k

Internal memory			External memory		
Internal ROM/RAM No wait	Internal ROM/RAM With wait	SFR area	Separate bus No wait	Separate bus With wait	Multiplex bus
1	2	2	1	2	3

DMA enable bit

Setting the DMA enable bit to "1" makes the DMAC active. The DMAC carries out the following operations at the time data transfer starts immediately after DMAC is turned active.

- (1) Reloads the value of one of the source pointer and the destination pointer - the one specified for the forward direction - to the forward direction address pointer.
- (2) Reloads the value of the transfer counter reload register to the transfer counter.

Thus overwriting "1" to the DMA enable bit with the DMAC being active carries out the operations given above, so the DMAC operates again from the initial state at the instant "1" is overwritten to the DMA enable bit.

DMA request bit

The DMAC can generate a DMA transfer request signal triggered by a factor chosen in advance out of DMA request factors for each channel.

DMA request factors include the following.

- * Factors effected by using the interrupt request signals from the built-in peripheral functions and software DMA factors (internal factors) effected by a program.

- * External factors effected by utilizing the input from external interrupt signals.

For the selection of DMA request factors, see the descriptions of the DMAi factor selection register.

The DMA request bit turns to "1" if the DMA transfer request signal occurs regardless of the DMAC's state (regardless of whether the DMA enable bit is set to "1" or "0"). It turns to "0" immediately before data transfer starts.

In addition, it can be set to "0" by use of a program, but cannot be set to "1".

There can be instances in which a change in DMA request factor selection bit causes the DMA request bit to turn to "1". So be sure to set the DMA request bit to "0" after the DMA request factor selection bit is changed.

The DMA request bit turns to "1" if a DMA transfer request signal occurs, and turns to "0" immediately before data transfer starts. If the DMAC is active, data transfer starts immediately, so the value of the DMA request bit, if read by use of a program, turns out to be "0" in most cases. To examine whether the DMAC is active, read the DMA enable bit.

Here follows the timing of changes in the DMA request bit.

(1) Internal factors

Except the DMA request factors triggered by software, the timing for the DMA request bit to turn to "1" due to an internal factor is the same as the timing for the interrupt request bit of the interrupt control register to turn to "1" due to several factors.

Turning the DMA request bit to "0" due to an internal factor is timed to be effected immediately before the transfer starts.

(2) External factors

An external factor is a factor caused to occur by the leading edge of input from the $\overline{\text{INT}}_i$ pin (i depends on which DMAC channel is used).

Selecting the $\overline{\text{INT}}_i$ pins as external factors using the DMA request factor selection bit causes input from these pins to become the DMA transfer request signals.

The timing for the DMA request bit to turn to "1" when an external factor is selected synchronizes with the signal's edge applicable to the function specified by the DMA request factor selection bit (synchronizes with the trailing edge of the input signal to each $\overline{\text{INT}}_i$ pin, for example).

With an external factor selected, the DMA request bit is timed to turn to "0" immediately before data transfer starts similarly to the state in which an internal factor is selected.

(3) The priorities of channels and DMA transfer timing

If a DMA transfer request signal falls on a single sampling cycle (a sampling cycle means one period from the leading edge to the trailing edge of BCLK), the DMA request bits of applicable channels concurrently turn to "1". If the channels are active at that moment, DMA0 is given a high priority to start data transfer. When DMA0 finishes data transfer, it gives the bus right to the CPU. When the CPU finishes single bus access, then DMA1 starts data transfer and gives the bus right to the CPU.

An example in which DMA transfer is carried out in minimum cycles at the time when DMA transfer request signals due to external factors concurrently occur.

Figure 1.13.6 An example of DMA transfer effected by external factors.

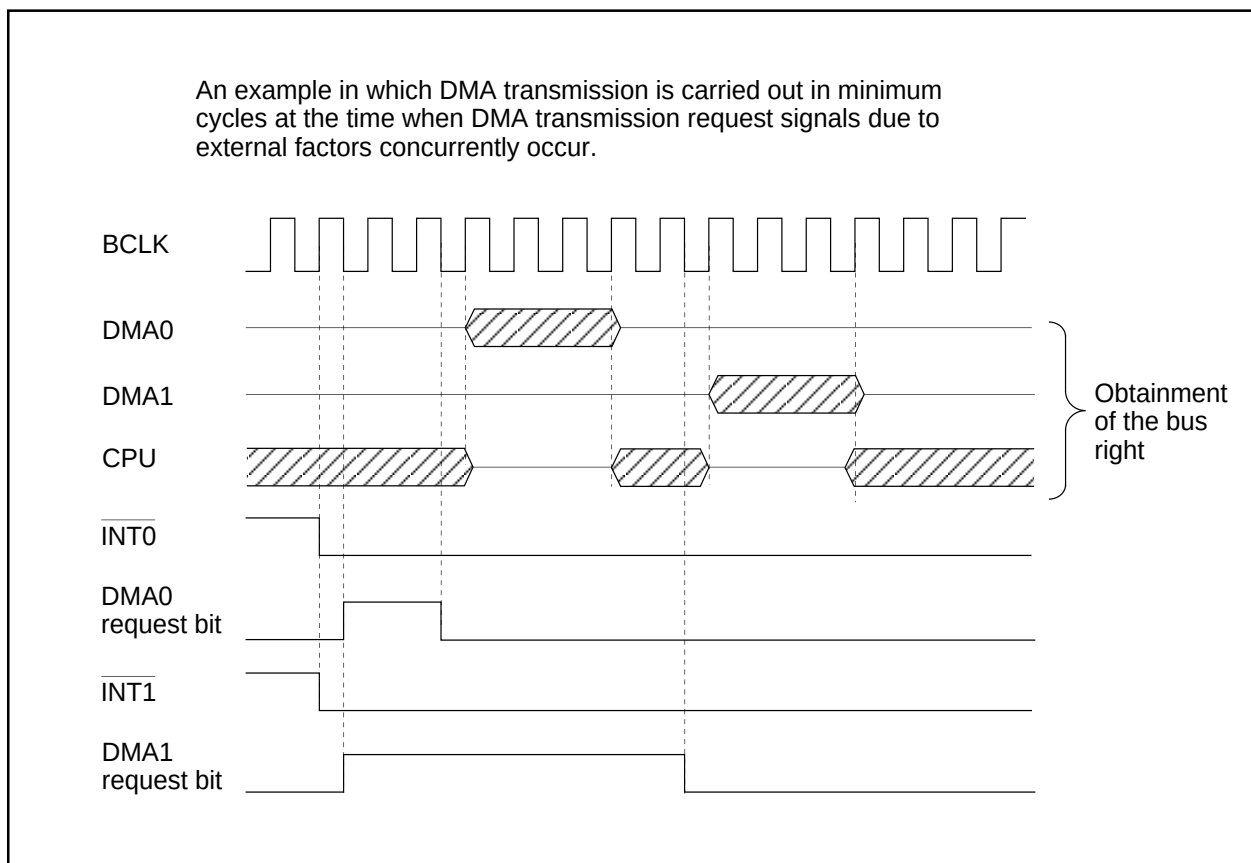


Figure 1.13.6. An example of DMA transfer effected by external factors

Timer

Timer

There are eleven 16-bit timers. These timers can be classified by function into timers A (five) and timers B (six). All these timers function independently. Figures 1.14.1 and 1.14.2 show the block diagram of timers.

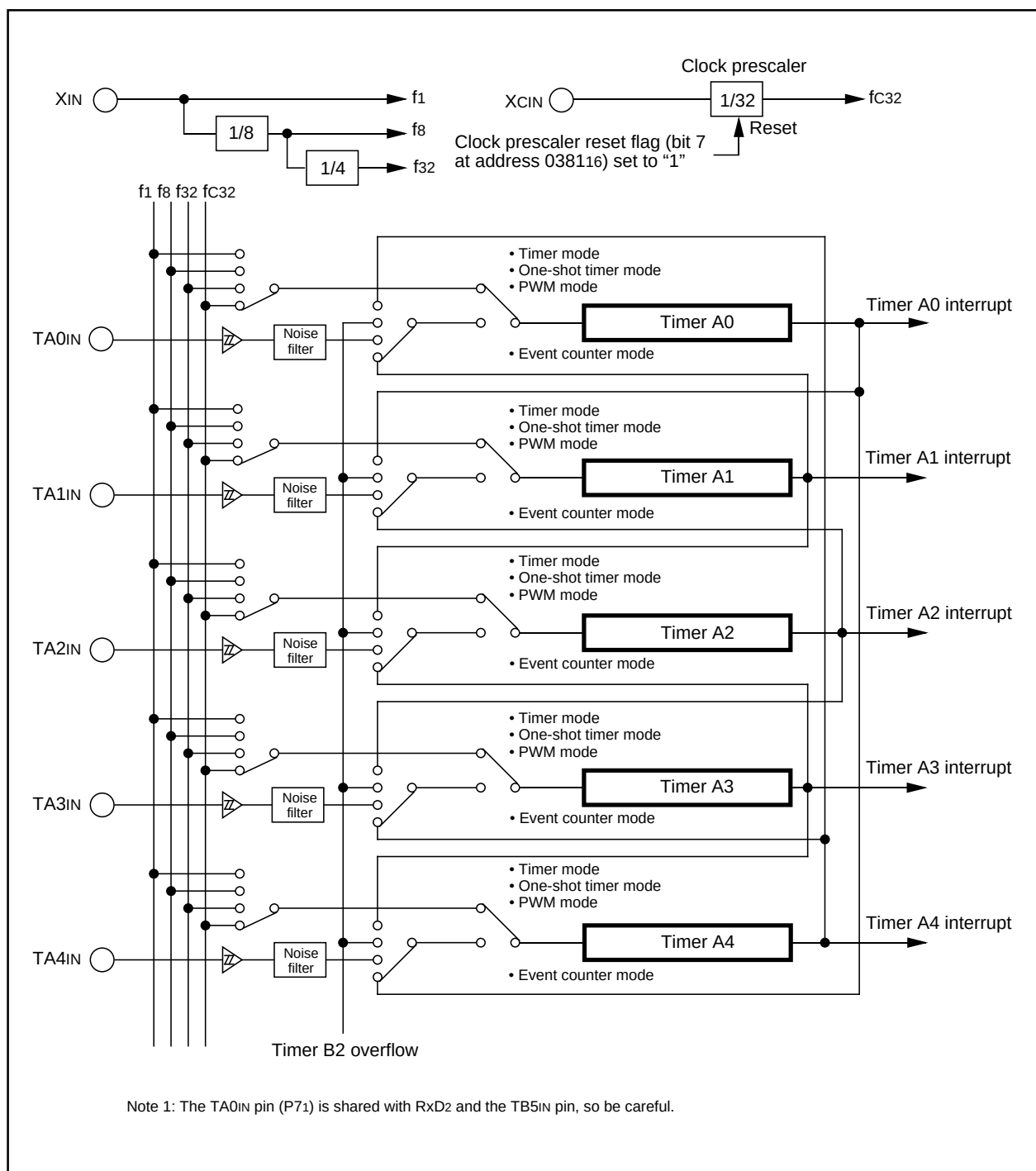


Figure 1.14.1. Timer A block diagram

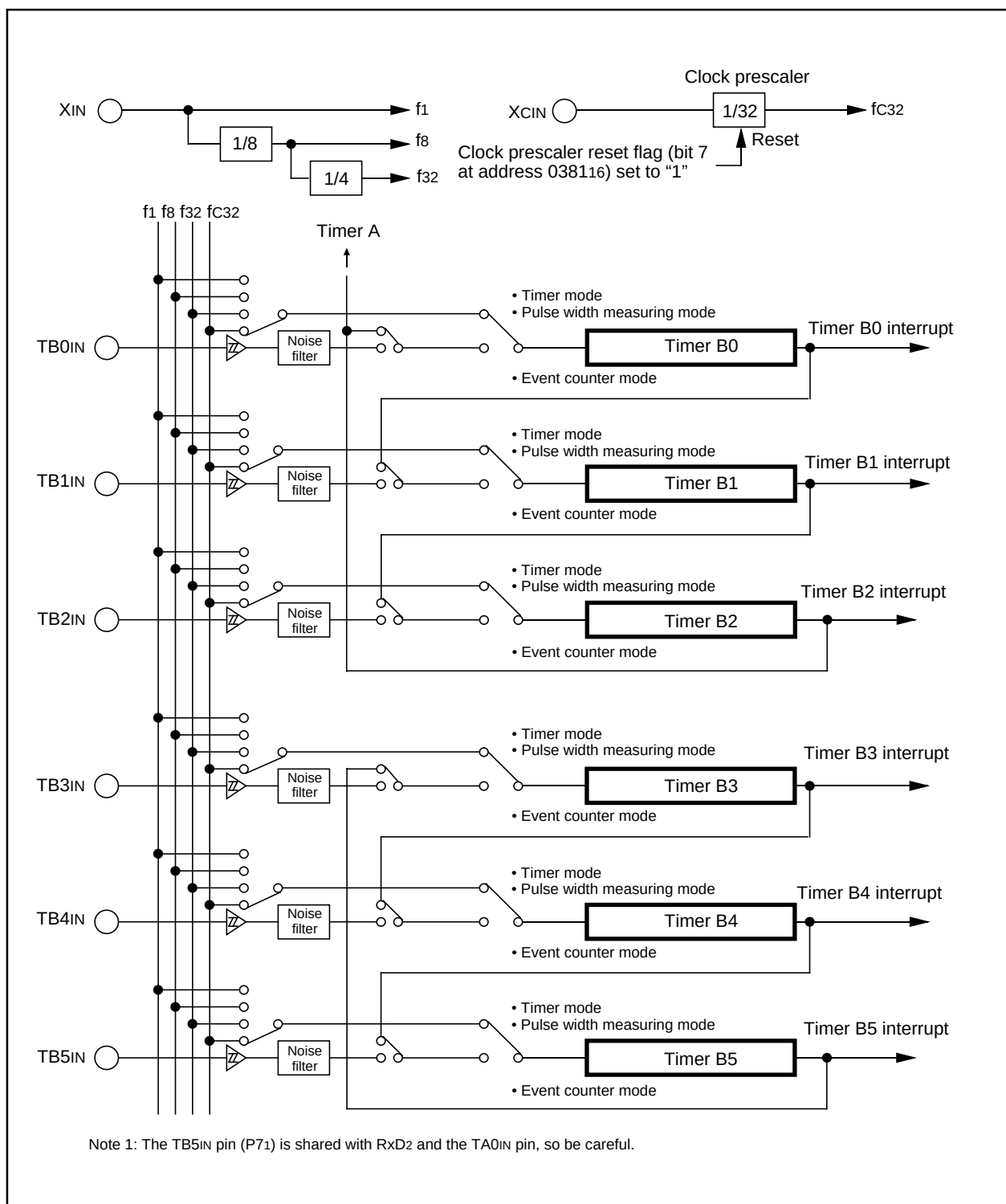


Figure 1.14.2. Timer B block diagram

Timer A

Timer A

Figure 1.14.3 shows the block diagram of timer A. Figures 1.14.4 to 1.14.6 show the timer A-related registers.

Except in event counter mode, timers A0 through A4 all have the same function. Use the timer Ai mode register (i = 0 to 4) bits 0 and 1 to choose the desired mode.

Timer A has the four operation modes listed as follows:

- Timer mode: The timer counts an internal count source.
- Event counter mode: The timer counts pulses from an external source or a timer over flow.
- One-shot timer mode: The timer stops counting when the count reaches "000016".
- Pulse width modulation (PWM) mode: The timer outputs pulses of a given width.

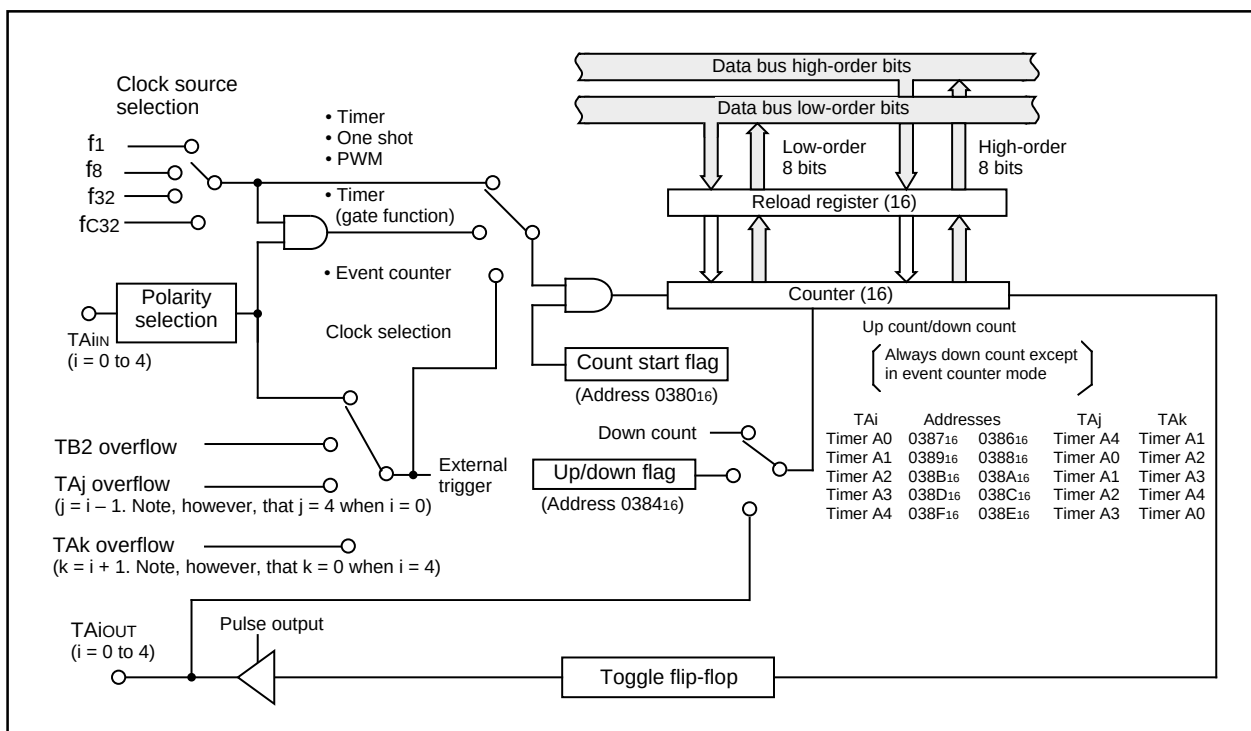


Figure 1.14.3. Block diagram of timer A

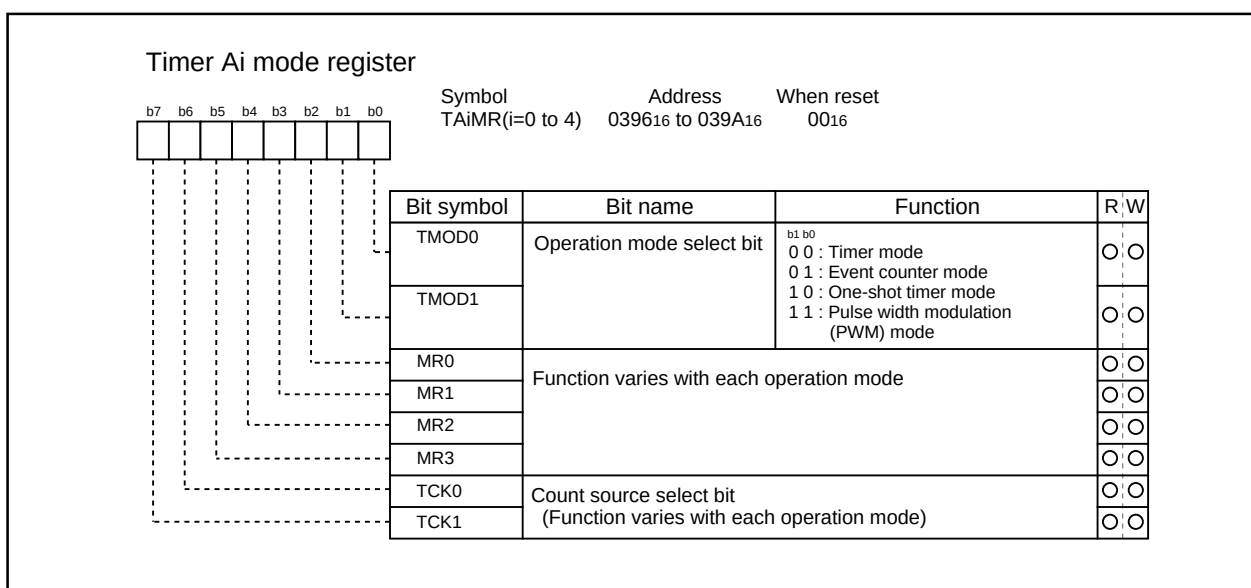


Figure 1.14.4. Timer A-related registers (1)

Timer A

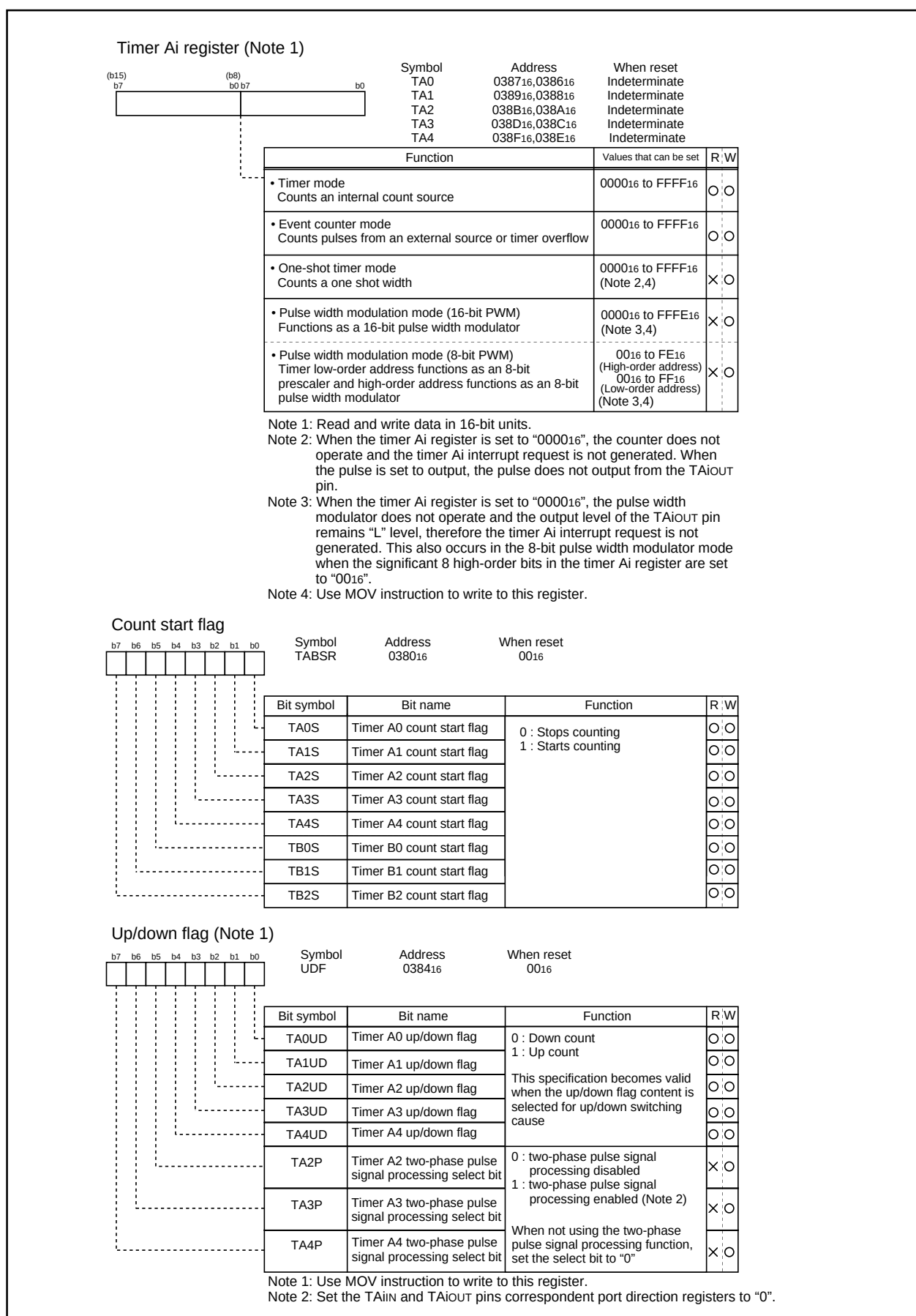


Figure 1.14.5. Timer A-related registers (2)

Timer A

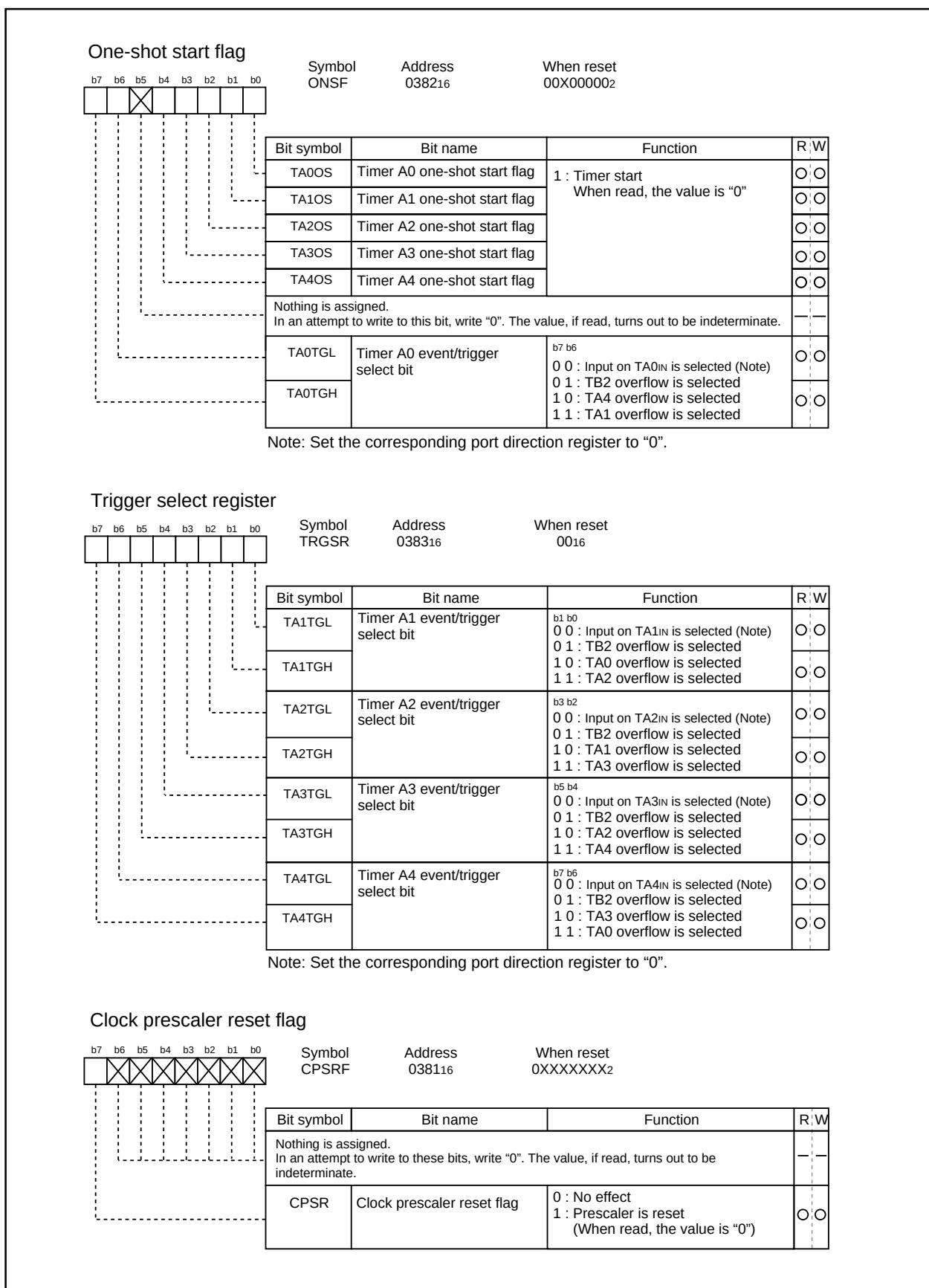


Figure 1.14.6. Timer A-related registers (3)

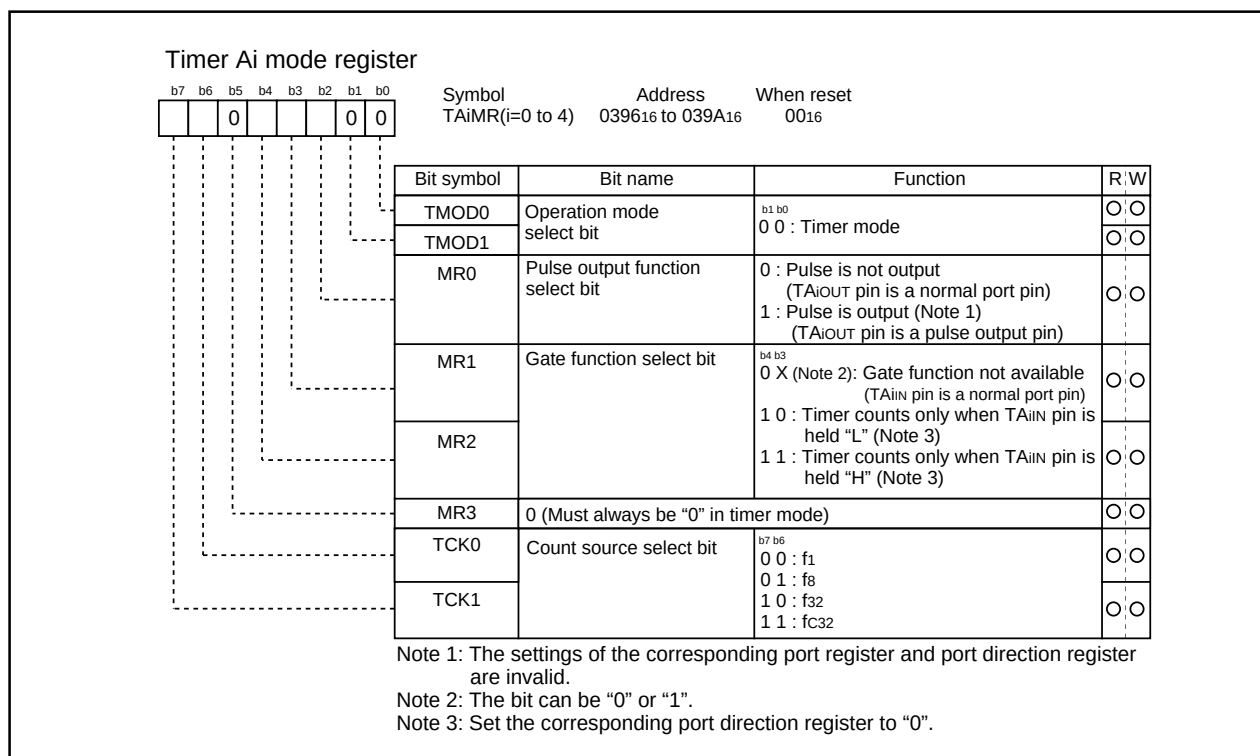
Timer A

(1) Timer mode

In this mode, the timer counts an internally generated count source. (See Table 1.14.1.) Figure 1.14.7 shows the timer Ai mode register in timer mode.

Table 1.14.1. Specifications of timer mode

Item	Specification
Count source	f ₁ , f ₈ , f ₃₂ , f _{C32}
Count operation	- Down count - When the timer underflows, it reloads the reload register contents before continuing counting
Divide ratio	1/(n+1) n : Set value
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	When the timer underflows
TAiIN pin function	Programmable I/O port or gate input
TAiOUT pin function	Programmable I/O port or pulse output
Read from timer	Count value can be read out by reading timer Ai register
Write to timer	- When counting stopped When a value is written to timer Ai register, it is written to both reload register and counter - When counting in progress When a value is written to timer Ai register, it is written to only reload register (Transferred to counter at next reload time)
Select function	- Gate function Counting can be started and stopped by the TAiIN pin's input signal - Pulse output function Each time the timer underflows, the TAiOUT pin's polarity is reversed

**Figure 1.14.7. Timer Ai mode register in timer mode**

Timer A

(2) Event counter mode

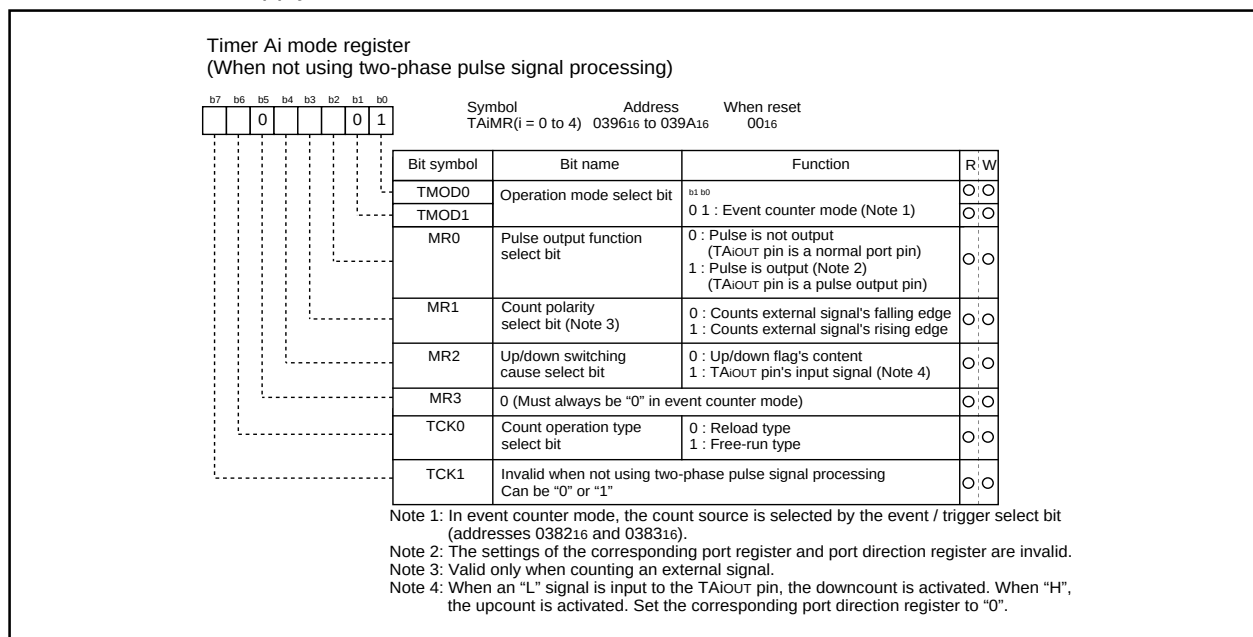
In this mode, the timer counts an external signal or an internal timer's overflow. Timers A0 and A1 can count a single-phase external signal. Timers A2, A3, and A4 can count a single-phase and a two-phase external signal. Table 1.14.2 lists timer specifications when counting a single-phase external signal. Figure 1.14.8 shows the timer Ai mode register in event counter mode.

Table 1.14.3 lists timer specifications when counting a two-phase external signal. Figure 1.14.9 shows the timer Ai mode register in event counter mode.

Table 1.14.2. Timer specifications in event counter mode (when not processing two-phase pulse signal)

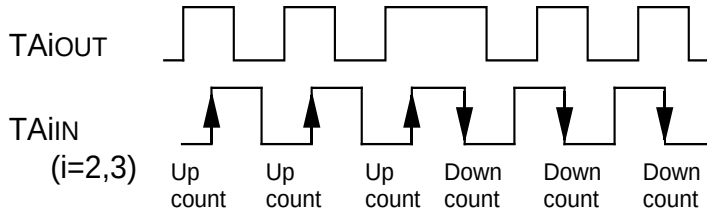
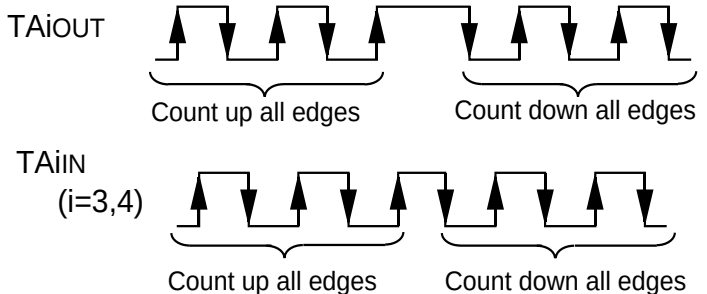
Item	Specification
Count source	- External signals input to TAIN pin (effective edge can be selected by software) - TB2 overflow, TAJ overflow
Count operation	- Up count or down count can be selected by external signal or software - When the timer overflows or underflows, it reloads the reload register contents before continuing counting (Note)
Divide ratio	$1 / (FFFF_{16} - n + 1)$ for up count $1 / (n + 1)$ for down count n : Set value
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	The timer overflows or underflows
TAin pin function	Programmable I/O port or count source input
TAiout pin function	Programmable I/O port, pulse output, or up/down count select input
Read from timer	Count value can be read out by reading timer Ai register
Write to timer	- When counting stopped When a value is written to timer Ai register, it is written to both reload register and counter - When counting in progress When a value is written to timer Ai register, it is written to only reload register (Transferred to counter at next reload time)
Select function	- Free-run count function Even when the timer overflows or underflows, the reload register content is not reloaded to it - Pulse output function Each time the timer overflows or underflows, the TAIOUT pin's polarity is reversed

Note: This does not apply when the free-run function is selected.

**Figure 1.14.8. Timer Ai mode register in event counter mode**

Timer A

Table 1.14.3. Timer specifications in event counter mode (when processing two-phase pulse signal with timers A2, A3, and A4)

Item	Specification
Count source	• Two-phase pulse signals input to TAIIN or TAIOUT pin
Count operation	• Up count or down count can be selected by two-phase pulse signal • When the timer overflows or underflows, the reload register content is reloaded and the timer starts over again (Note 1)
Divide ratio	$1/ (FFFF_{16} - n + 1)$ for up count $1/ (n + 1)$ for down count n : Set value
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	Timer overflows or underflows
TAiIN pin function	Two-phase pulse input (Set the TAIIN pin correspondent port direction register to "0".)
TAiOUT pin function	Two-phase pulse input (Set the TAIOUT pin correspondent port direction register to "0".)
Read from timer	Count value can be read out by reading timer A2, A3, or A4 register
Write to timer	• When counting stopped When a value is written to timer A2, A3, or A4 register, it is written to both reload register and counter • When counting in progress When a value is written to timer A2, A3, or A4 register, it is written to only reload register. (Transferred to counter at next reload time.)
Select function (Note 2)	• Normal processing operation (timer A2 and timer A3) The timer counts up rising edges or counts down falling edges on the TAIIN pin when input signal on the TAIOUT pin is "H".  • Multiply-by-4 processing operation (timer A3 and timer A4) If the phase relationship is such that the TAIIN pin goes "H" when the input signal on the TAIOUT pin is "H", the timer counts up rising and falling edges on the TAIOUT and TAIIN pins. If the phase relationship is such that the TAIIN pin goes "L" when the input signal on the TAIOUT pin is "H", the timer counts down rising and falling edges on the TAIOUT and TAIIN pins. 

Note 1: This does not apply when the free-run function is selected.

Note 2: Timer A3 alone can be selected. Timer A2 is fixed to normal processing operation, and timer A4 is fixed to multiply-by-4 processing operation.

Timer A

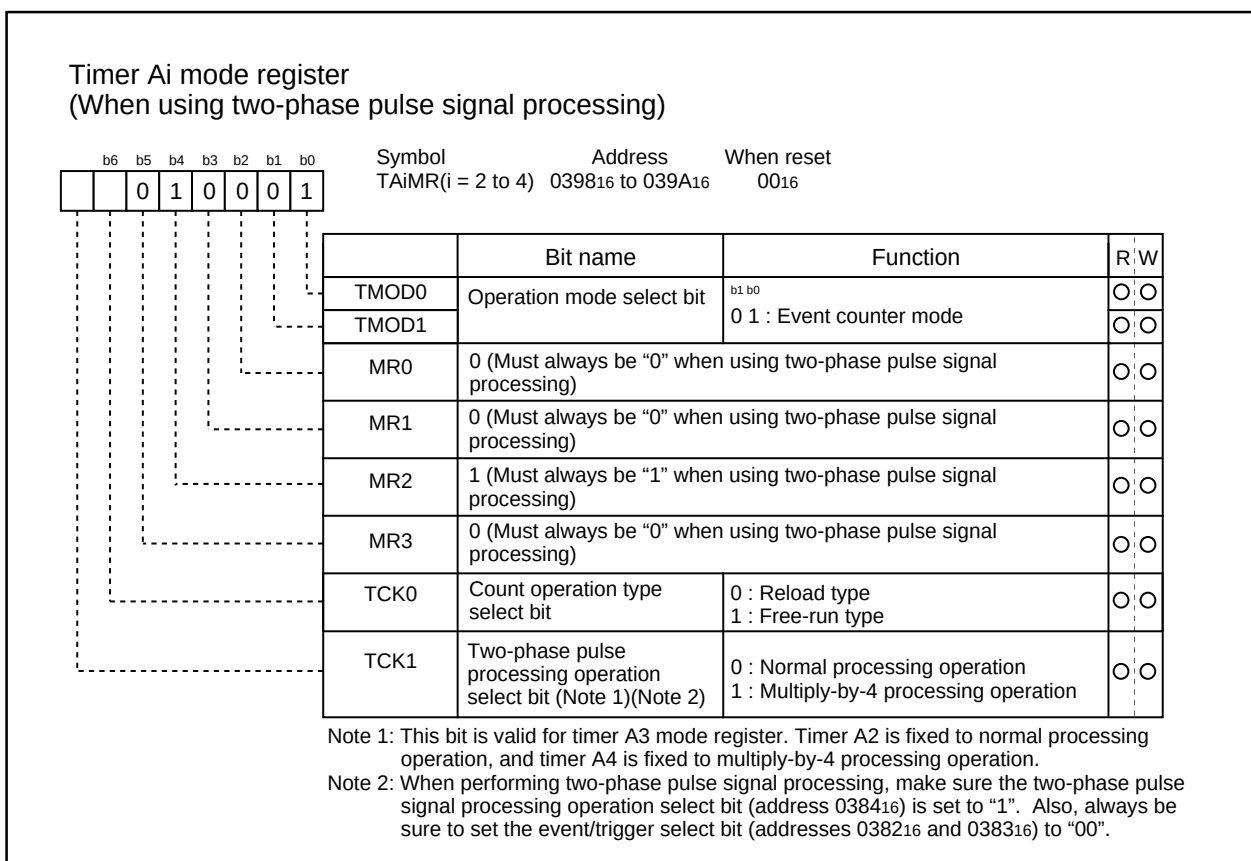


Figure 1.14.9. Timer Ai mode register in event counter mode

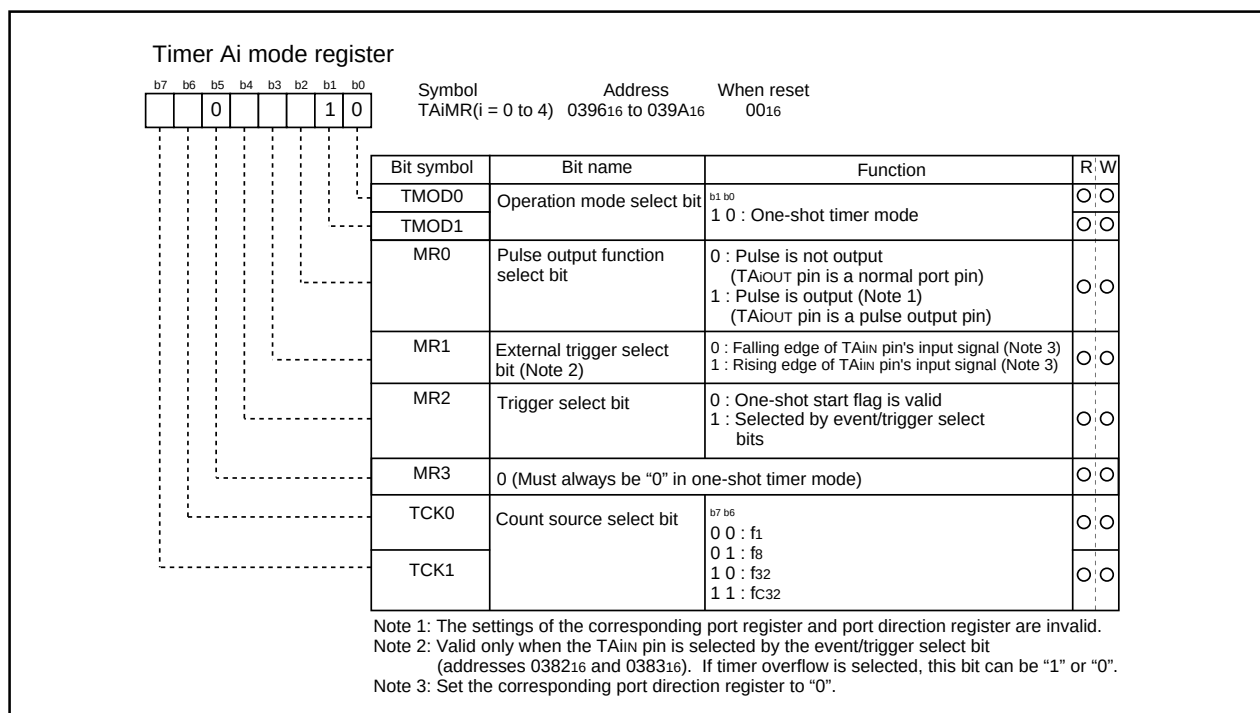
Timer A

(3) One-shot timer mode

In this mode, the timer operates only once. (See Table 1.14.4.) When a trigger occurs, the timer starts up and continues operating for a given period. Figure 1.14.10 shows the timer Ai mode register in one-shot timer mode.

Table 1.14.4. Timer specifications in one-shot timer mode

Item	Specification
Count source	f ₁ , f ₈ , f ₃₂ , f _{C32}
Count operation	- The timer counts down - When the count reaches 0000₁₆, the timer stops counting after reloading a new count - If a trigger occurs when counting, the timer reloads a new count and restarts counting
Divide ratio	1/n n : Set value
Count start condition	- An external trigger is input - The timer overflows - The one-shot start flag is set (= 1)
Count stop condition	- A new count is reloaded after the count has reached 0000₁₆ - The count start flag is reset (= 0)
Interrupt request generation timing	The count reaches 0000 ₁₆
TAiIN pin function	Programmable I/O port or trigger input
TAiOUT pin function	Programmable I/O port or pulse output
Read from timer	When timer Ai register is read, it indicates an indeterminate value
Write to timer	- When counting stopped When a value is written to timer Ai register, it is written to both reload register and counter - When counting in progress When a value is written to timer Ai register, it is written to only reload register (Transferred to counter at next reload time)

**Figure 1.14.10. Timer Ai mode register in one-shot timer mode**

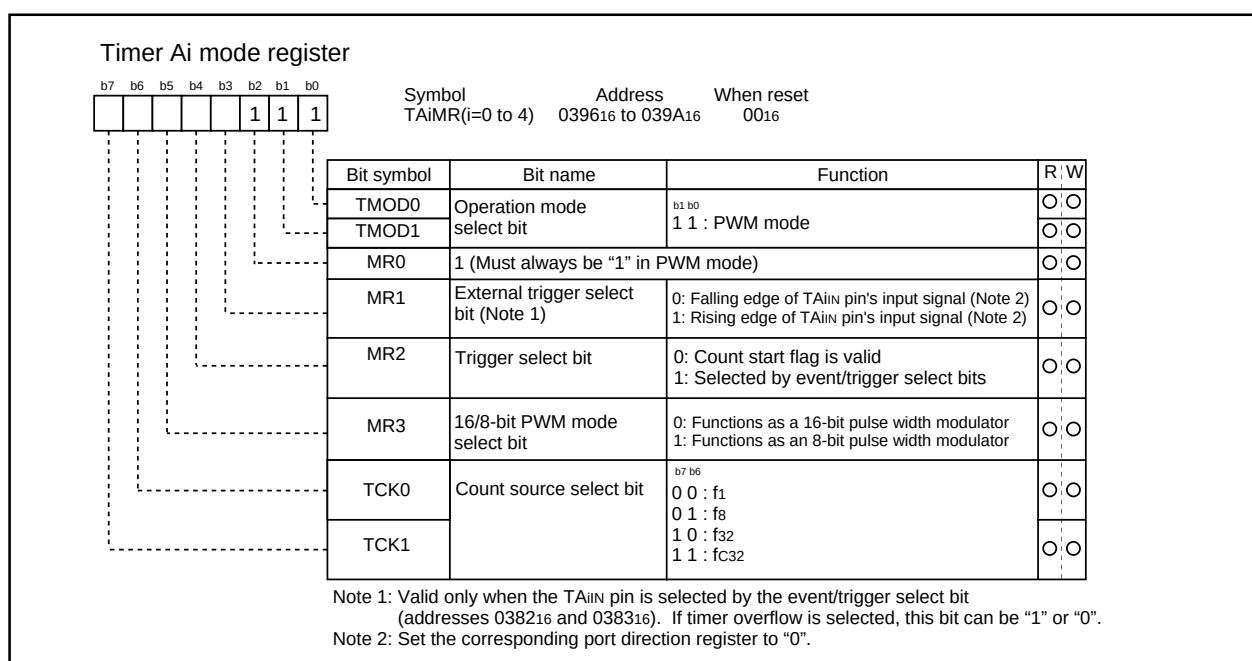
Timer A

(4) Pulse width modulation (PWM) mode

In this mode, the timer outputs pulses of a given width in succession. (See Table 1.14.5.) In this mode, the counter functions as either a 16-bit pulse width modulator or an 8-bit pulse width modulator. Figure 1.14.11 shows the timer Ai mode register in pulse width modulation mode. Figure 1.14.12 shows the example of how a 16-bit pulse width modulator operates. Figure 1.14.13 shows the example of how an 8-bit pulse width modulator operates.

Table 1.14.5. Timer specifications in pulse width modulation mode

Item	Specification
Count source	f ₁ , f ₈ , f ₃₂ , f _{c32}
Count operation	- The timer counts down (operating as an 8-bit or a 16-bit pulse width modulator) - The timer reloads a new count at a rising edge of PWM pulse and continues counting - The timer is not affected by a trigger that occurs when counting
16-bit PWM	- High level width n / f_i n: Set value - Cycle time $(2^{16}-1) / f_i$ fixed
8-bit PWM	- High level width $n \times (m+1) / f_i$ n: values set to timer Ai register's high-order address - Cycle time $(2^8-1) \times (m+1) / f_i$ m: values set to timer Ai register's low-order address
Count start condition	- External trigger is input - The timer overflows - The count start flag is set (= 1)
Count stop condition	The count start flag is reset (= 0)
Interrupt request generation timing	PWM pulse goes "L"
TAiIN pin function	Programmable I/O port or trigger input
TAiOUT pin function	Pulse output
Read from timer	When timer Ai register is read, it indicates an indeterminate value
Write to timer	- When counting stopped When a value is written to timer Ai register, it is written to both reload register and counter - When counting in progress When a value is written to timer Ai register, it is written to only reload register (Transferred to counter at next reload time)

**Figure 1.14.11. Timer Ai mode register in pulse width modulation mode**

Timer A

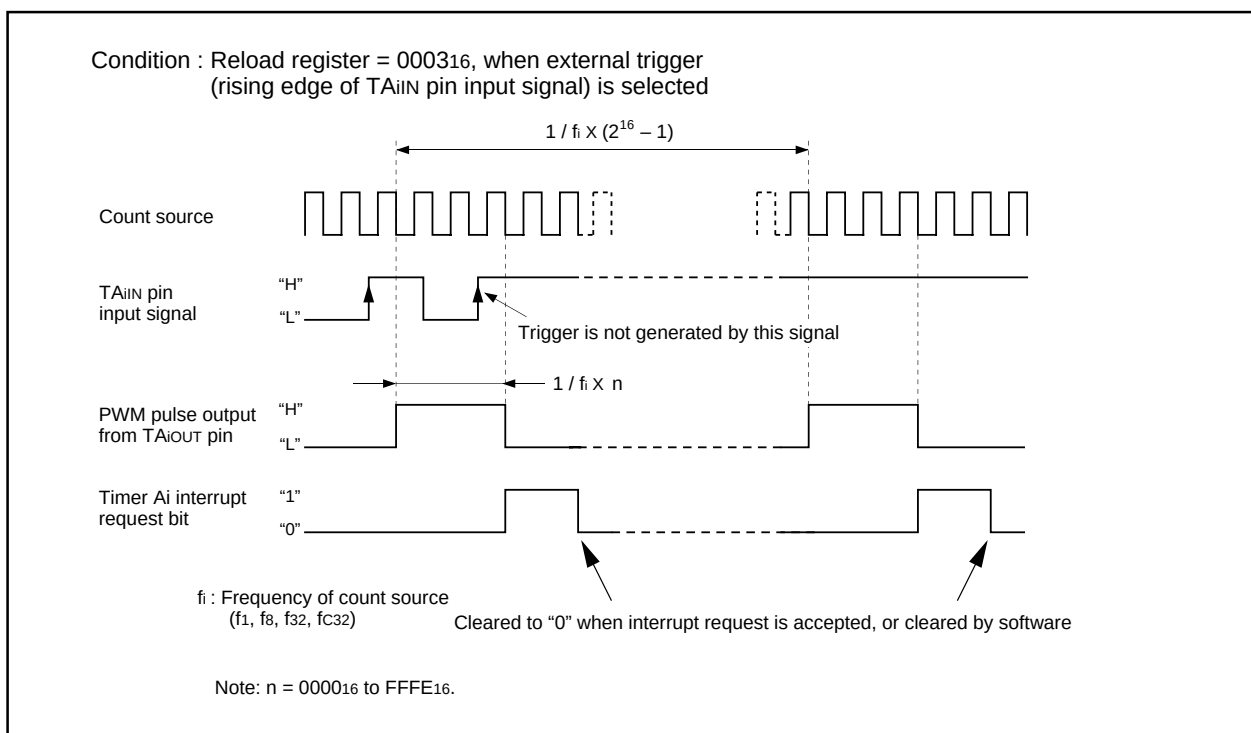


Figure 1.14.12. Example of how a 16-bit pulse width modulator operates

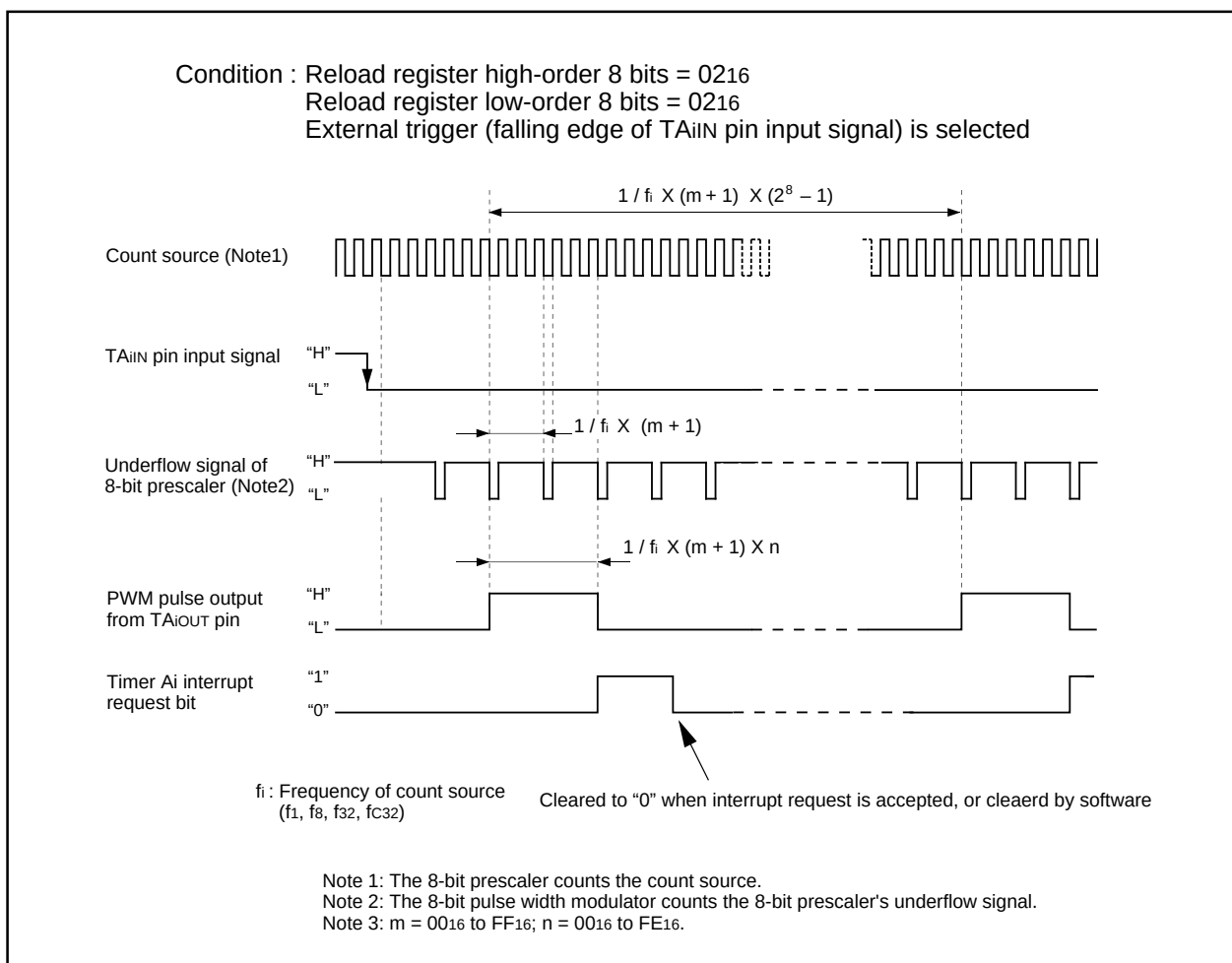


Figure 1.14.13. Example of how an 8-bit pulse width modulator operates

Timer B

Timer B

Figure 1.14.14 shows the block diagram of timer B. Figures 1.14.15 and 1.14.16 show the timer B-related registers.

Use the timer Bi mode register ($i = 0$ to 5) bits 0 and 1 to choose the desired mode.

Timer B has three operation modes listed as follows:

- Timer mode: The timer counts an internal count source.
- Event counter mode: The timer counts pulses from an external source or a timer overflow.
- Pulse period/pulse width measuring mode: The timer measures an external signal's pulse period or pulse width.

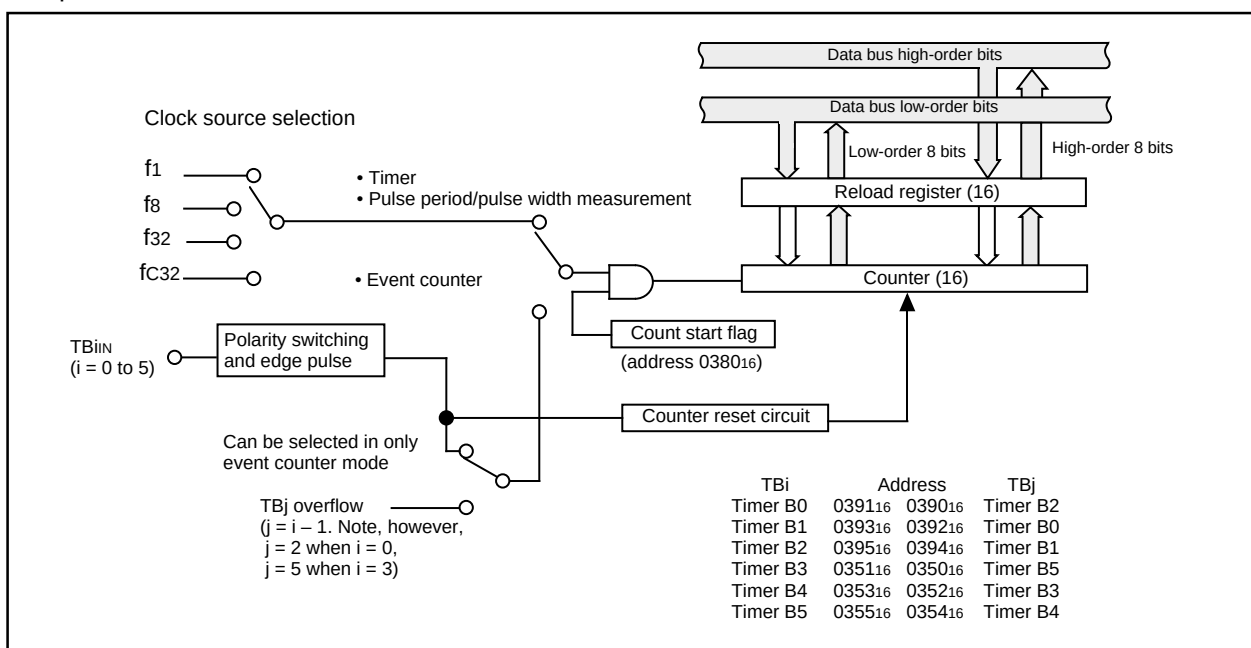


Figure 1.14.14. Block diagram of timer B

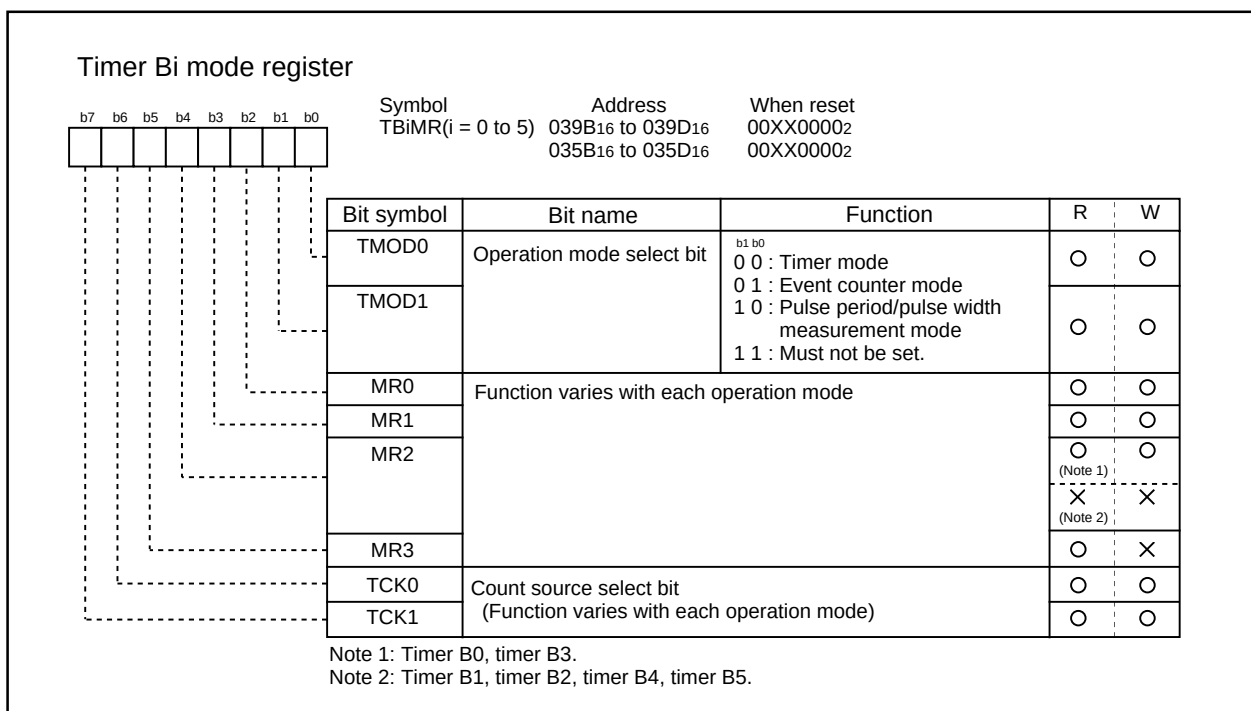


Figure 1.14.15. Timer B-related registers (1)

Timer B

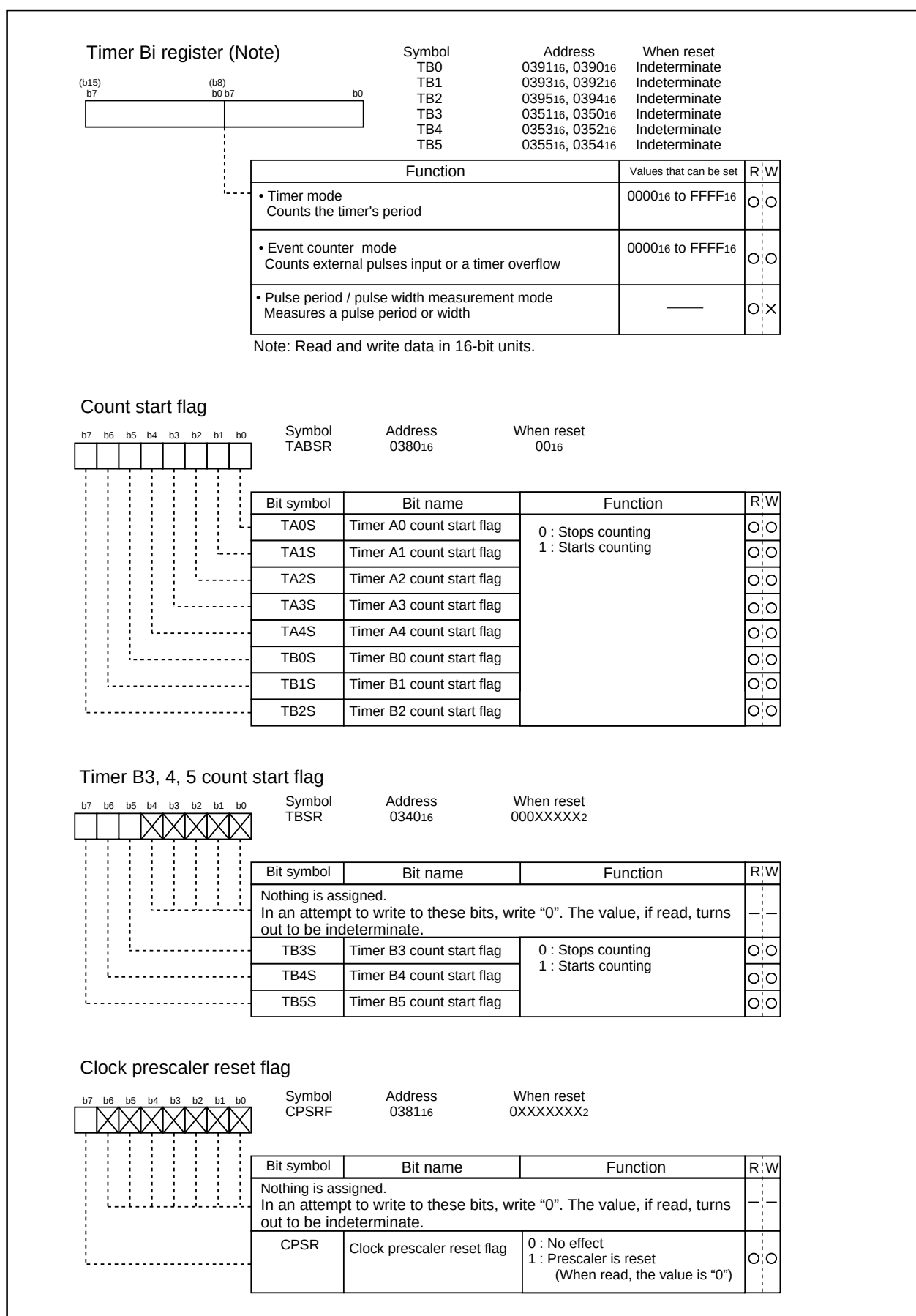


Figure 1.14.16. Timer B-related registers (2)

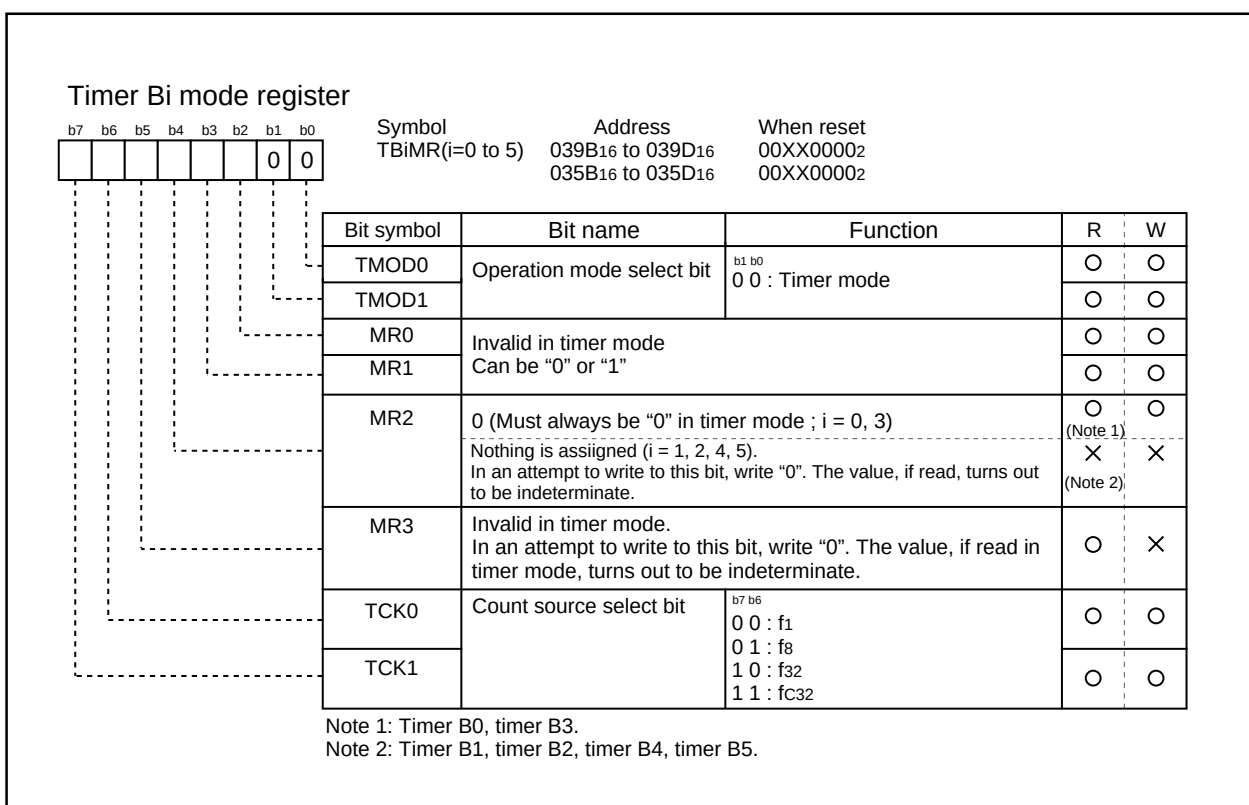
Timer B

(1) Timer mode

In this mode, the timer counts an internally generated count source. (See Table 1.14.6.) Figure 1.14.17 shows the timer Bi mode register in timer mode.

Table 1.14.6. Timer specifications in timer mode

Item	Specification
Count source	f1, f8, f32, fc32
Count operation	- Counts down - When the timer underflows, it reloads the reload register contents before continuing counting
Divide ratio	1/(n+1) n : Set value
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	The timer underflows
TBiIN pin function	Programmable I/O port
Read from timer	Count value is read out by reading timer Bi register
Write to timer	- When counting stopped When a value is written to timer Bi register, it is written to both reload register and counter - When counting in progress When a value is written to timer Bi register, it is written to only reload register (Transferred to counter at next reload time)

**Figure 1.14.17. Timer Bi mode register in timer mode**

Timer B

(2) Event counter mode

In this mode, the timer counts an external signal or an internal timer's overflow. (See Table 1.14.7.)

Figure 1.14.18 shows the timer Bi mode register in event counter mode.

Table 1.14.7. Timer specifications in event counter mode

Item	Specification
Count source	- External signals input to TBiIn pin - Effective edge of count source can be a rising edge, a falling edge, or falling and rising edges as selected by software
Count operation	- Counts down - When the timer underflows, it reloads the reload register contents before continuing counting
Divide ratio	$1/(n+1)$ n : Set value
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	The timer underflows
TBiIn pin function	Count source input
Read from timer	Count value can be read out by reading timer Bi register
Write to timer	- When counting stopped When a value is written to timer Bi register, it is written to both reload register and counter - When counting in progress When a value is written to timer Bi register, it is written to only reload register (Transferred to counter at next reload time)

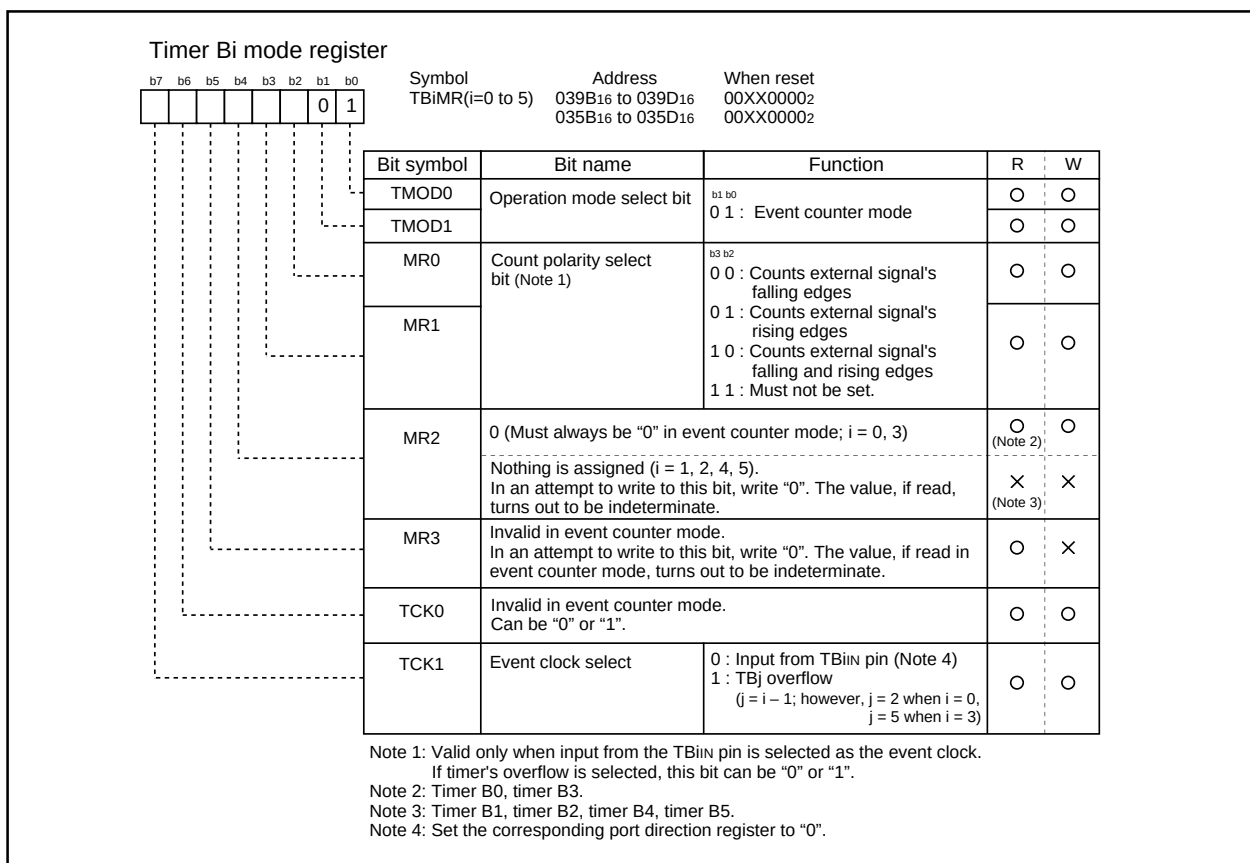


Figure 1.14.18. Timer Bi mode register in event counter mode

Timer B

(3) Pulse period/pulse width measurement mode

In this mode, the timer measures the pulse period or pulse width of an external signal. (See Table 1.14.8.)

Figure 1.14.19 shows the timer Bi mode register in pulse period/pulse width measurement mode. Figure

1.14.20 shows the operation timing when measuring a pulse period. Figure 1.14.21 shows the operation

timing when measuring a pulse width.

Table 1.14.8. Timer specifications in pulse period/pulse width measurement mode

Item	Specification
Count source	f1, f8, f32, fc32
Count operation	• Up count • Counter value "000016" is transferred to reload register at measurement pulse's effective edge and the timer continues counting
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	• When measurement pulse's effective edge is input (Note 1) • When an overflow occurs. (Simultaneously, the timer Bi overflow flag changes to "1". The timer Bi overflow flag changes to "0" when the count start flag is "1" and a value is written to the timer Bi mode register.)
TBiIN pin function	Measurement pulse input
Read from timer	When timer Bi register is read, it indicates the reload register's content (measurement result) (Note 2)
Write to timer	Cannot be written to

Note 1: An interrupt request is not generated when the first effective edge is input after the timer has started counting.

Note 2: The value read out from the timer Bi register is indeterminate until the second effective edge is input after the timer has started counting.

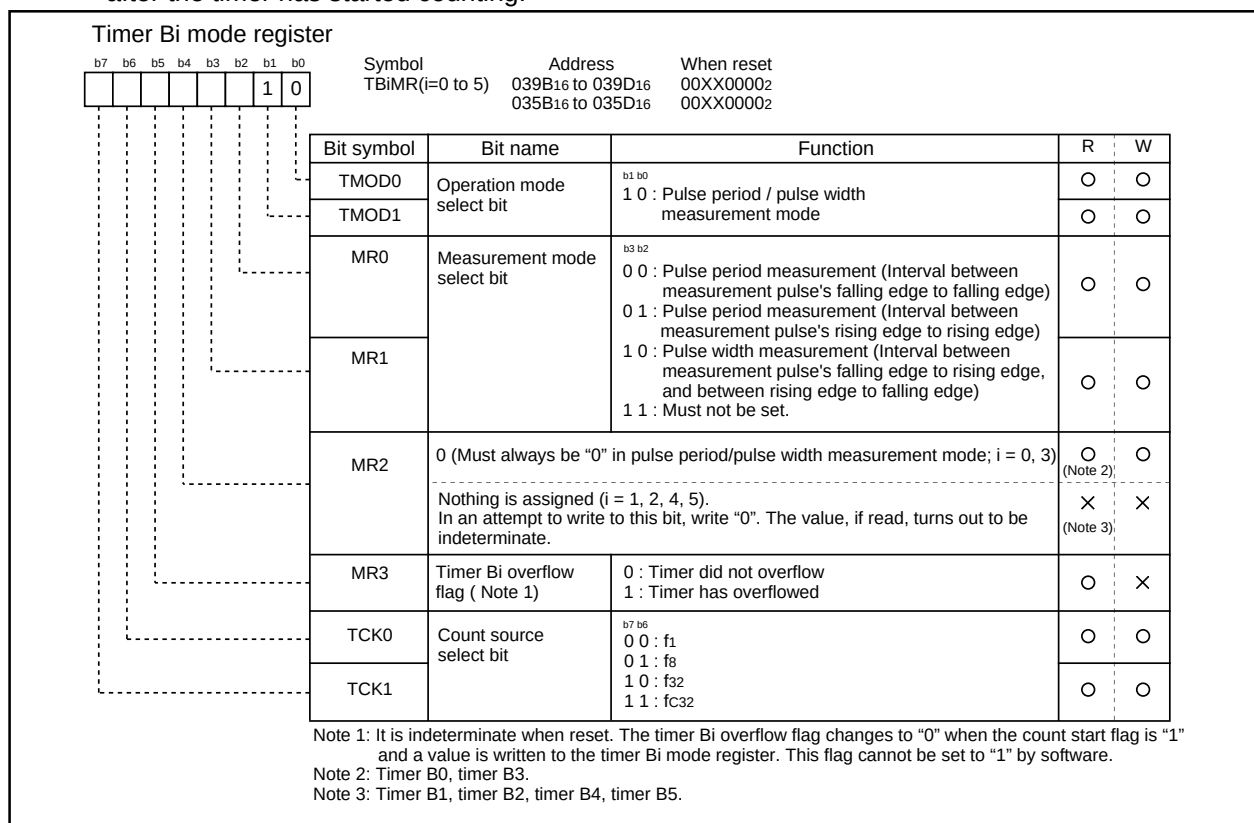


Figure 1.14.19. Timer Bi mode register in pulse period/pulse width measurement mode

Timer B

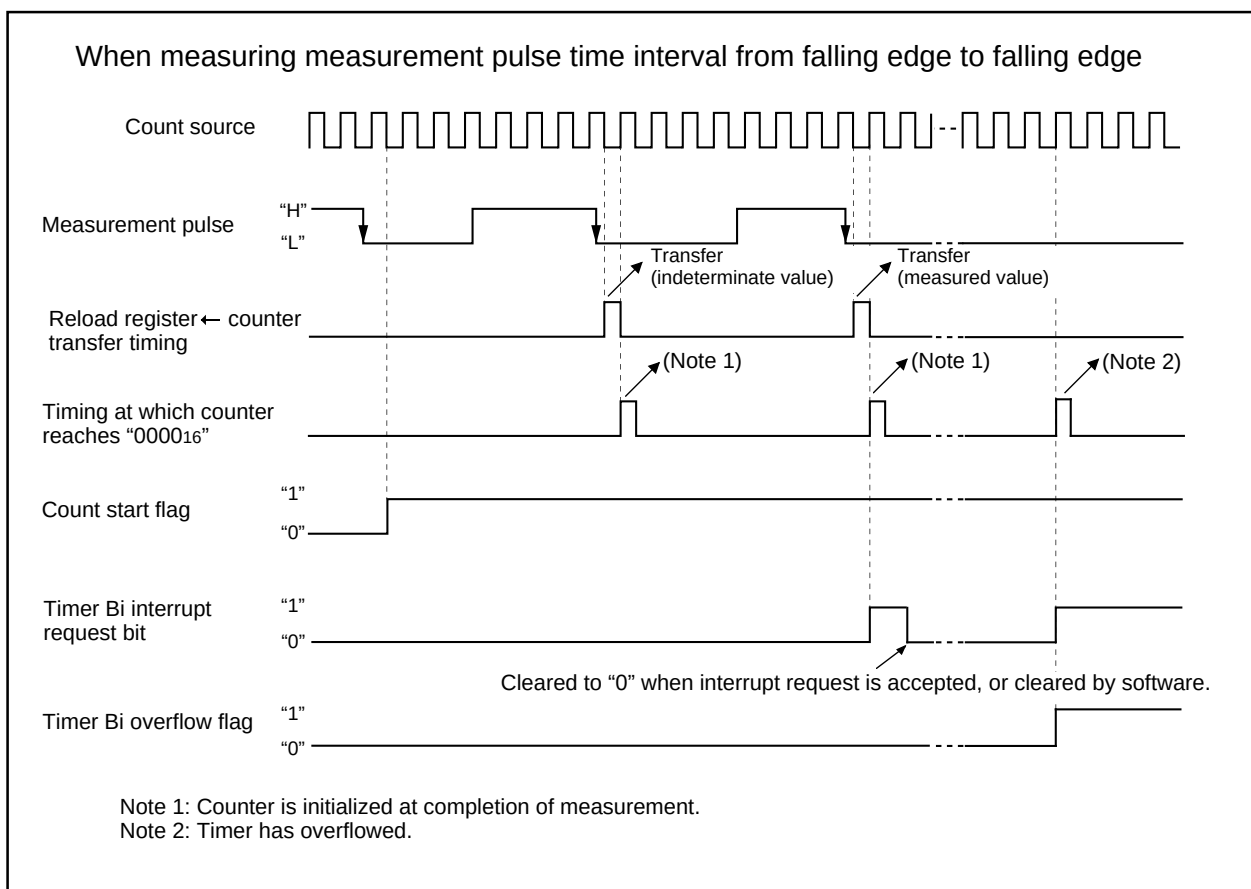


Figure 1.14.20. Operation timing when measuring a pulse period

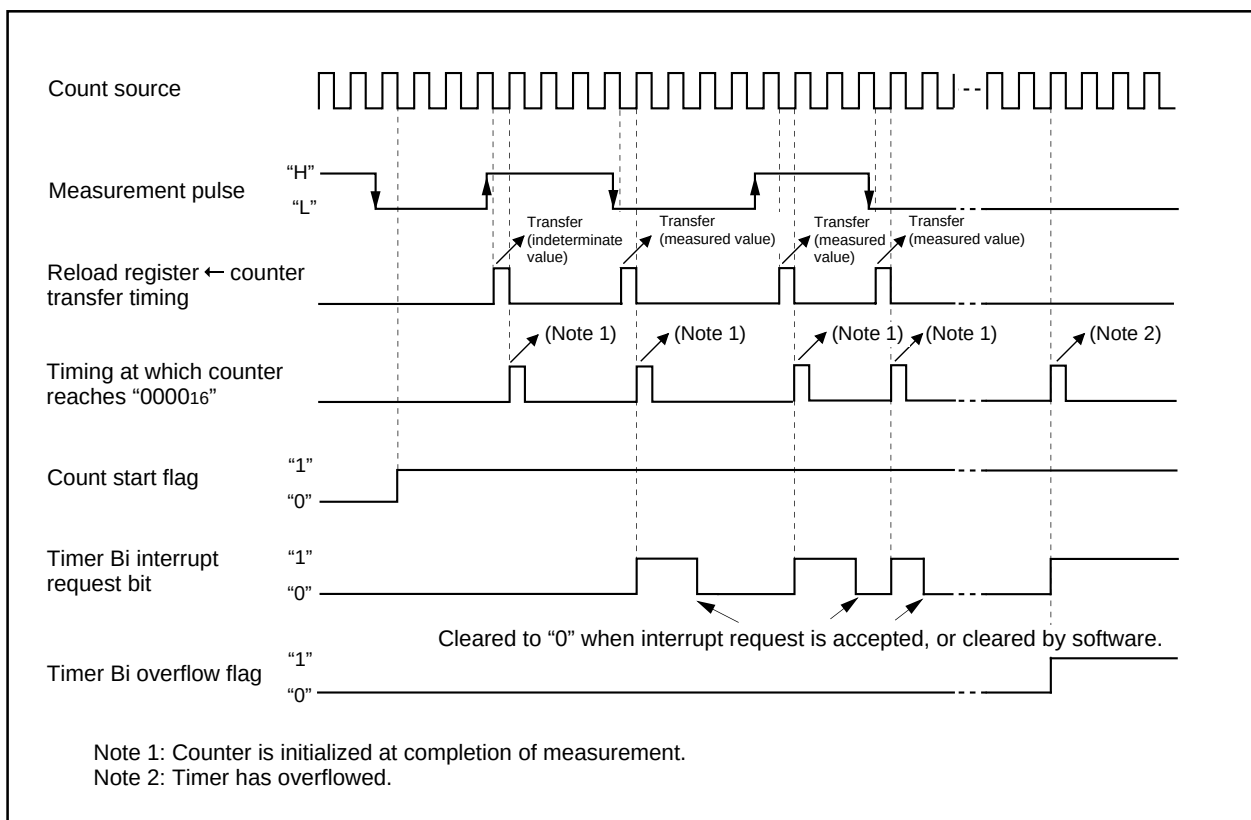


Figure 1.14.21. Operation timing when measuring a pulse width

Timers' functions for three-phase motor control

Timers' functions for three-phase motor control

Use of more than one built-in timer A and timer B provides the means of outputting three-phase motor driving waveforms.

Figures 1.15.1 to 1.15.3 show registers related to timers for three-phase motor control.

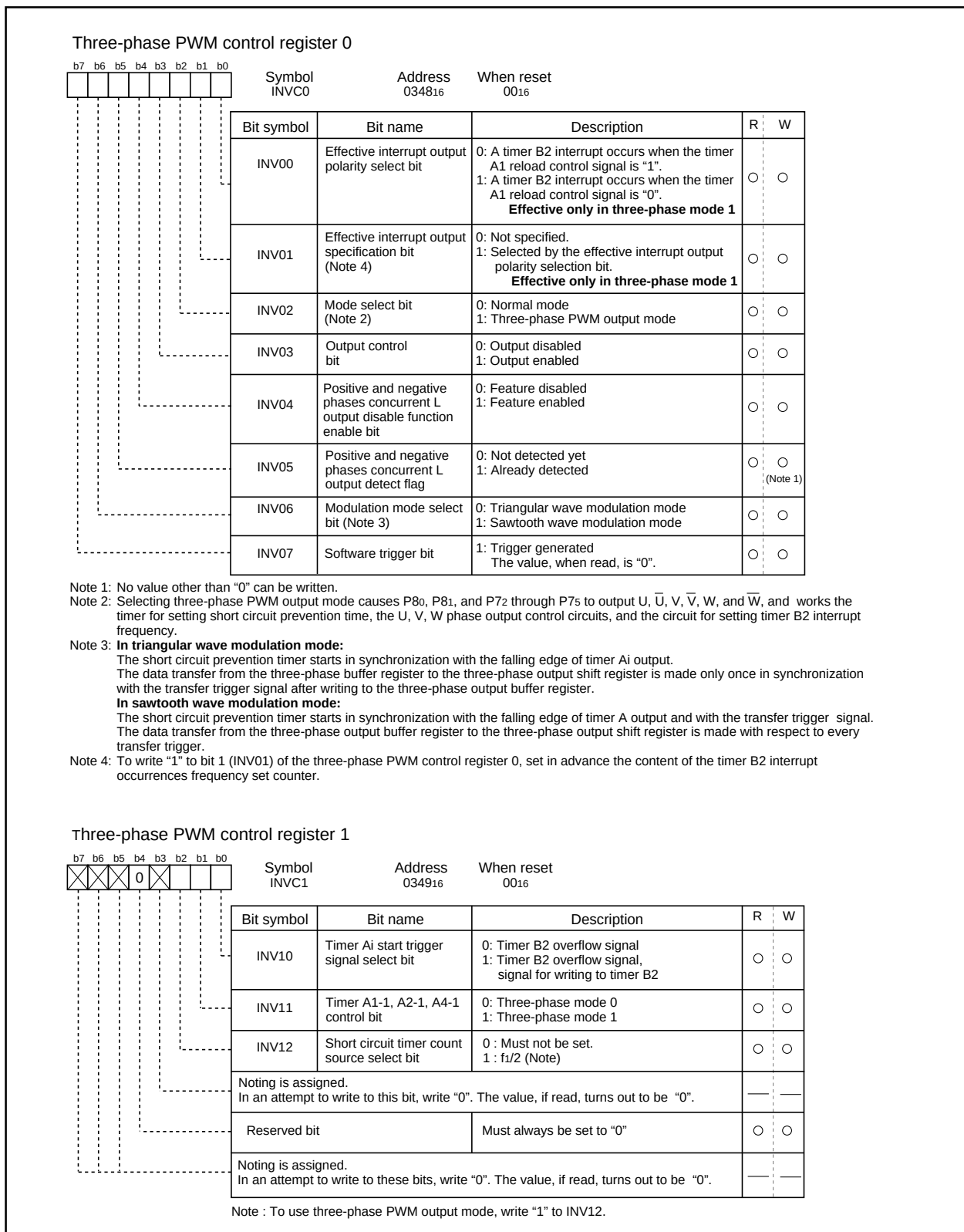
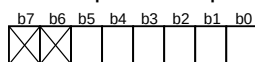


Figure 1.15.1. Registers related to timers for three-phase motor control

Timers' functions for three-phase motor control

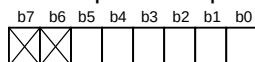
Three-phase output buffer register 0

Symbol
IDB0Address
034A₁₆When reset
00₁₆

Bit Symbol	Bit name	Function	R	W
DU0	U phase output buffer 0	Setting in U phase output buffer 0	(Note)	○
DUB0	$\bar{U}$ phase output buffer 0	Setting in $\bar{U}$ phase output buffer 0	(Note)	○
DV0	V phase output buffer 0	Setting in V phase output buffer 0	(Note)	○
DVB0	$\bar{V}$ phase output buffer 0	Setting in $\bar{V}$ phase output buffer 0	(Note)	○
DW0	W phase output buffer 0	Setting in W phase output buffer 0	(Note)	○
DWB0	$\bar{W}$ phase output buffer 0	Setting in $\bar{W}$ phase output buffer 0	(Note)	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".			—	—

Note: When executing read instruction of this register, the contents of three-phase shift register is read out.

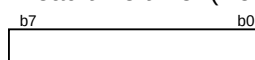
Three-phase output buffer register 1

Symbol
IDB1Address
034B₁₆When reset
00₁₆

Bit Symbol	Bit name	Function	R	W
DU1	U phase output buffer 1	Setting in U phase output buffer 1	(Note)	○
DUB1	$\bar{U}$ phase output buffer 1	Setting in $\bar{U}$ phase output buffer 1	(Note)	○
DV1	V phase output buffer 1	Setting in V phase output buffer 1	(Note)	○
DVB1	$\bar{V}$ phase output buffer 1	Setting in $\bar{V}$ phase output buffer 1	(Note)	○
DW1	W phase output buffer 1	Setting in W phase output buffer 1	(Note)	○
DWB1	$\bar{W}$ phase output buffer 1	Setting in $\bar{W}$ phase output buffer 1	(Note)	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".			—	—

Note: When executing read instruction of this register, the contents of three-phase shift register is read out.

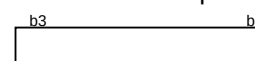
Dead time timer (Note)

Symbol
DTTAddress
034C₁₆When reset
Indeterminate

Function	Values that can be set	R	W
Set dead time timer	1 to 255	—	○

Note: Use MOV instruction to write to this register.

Timer B2 interrupt occurrences frequency set counter (Note 1, 2, 3)

Symbol
ICTB2Address
034D₁₆When reset
Indeterminate

Function	Values that can be set	R	W
Set occurrence frequency of timer B2 interrupt request	1 to 15	—	○

Note 1: In setting 1 to bit 1 (INV01) - the effective interrupt output specification bit - of three-phase PWM control register 0, do not change the B2 interrupt occurrences frequency set counter to deal with the timer function for three-phase motor control.

Note 2: Do not write at the timing of an overflow occurrence in timer B2.

Note 3: Use MOV instruction to write to this register.

Figure 1.15.2. Registers related to timers for three-phase motor control

Timers' functions for three-phase motor control

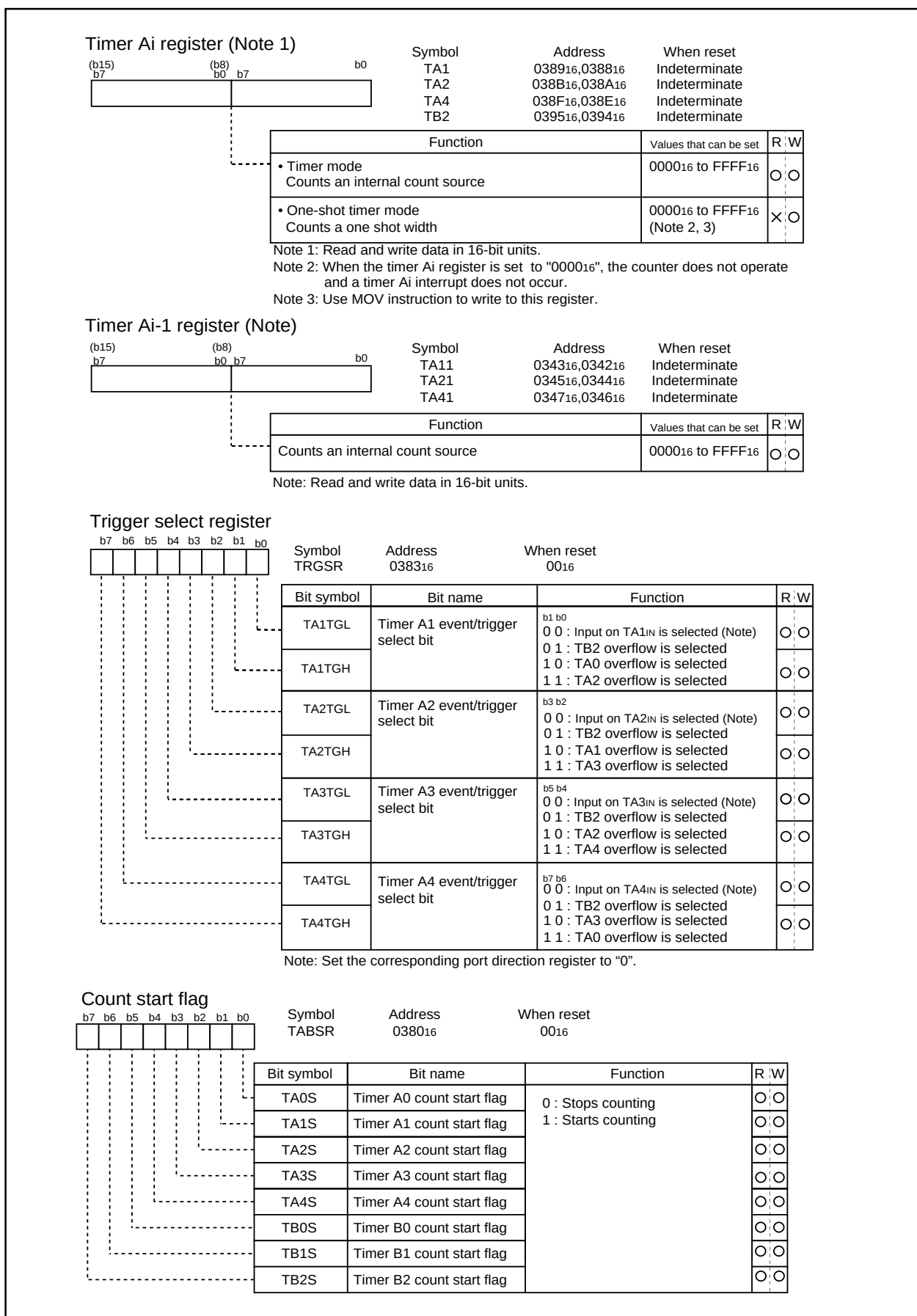


Figure 1.15.3. Registers related to timers for three-phase motor control

Timers' functions for three-phase motor control

Three-phase motor driving waveform output mode (three-phase PWM output mode)

Setting "1" in the mode select bit (bit 2 at 034816) shown in Figure 1.15.1 - causes three-phase PWM output mode that uses four timers A1, A2, A4, and B2 to be selected. As shown in Figure 1.15.4, set timers A1, A2, and A4 in one-shot timer mode, set the trigger in timer B2, and set timer B2 in timer mode using the respective timer mode registers.

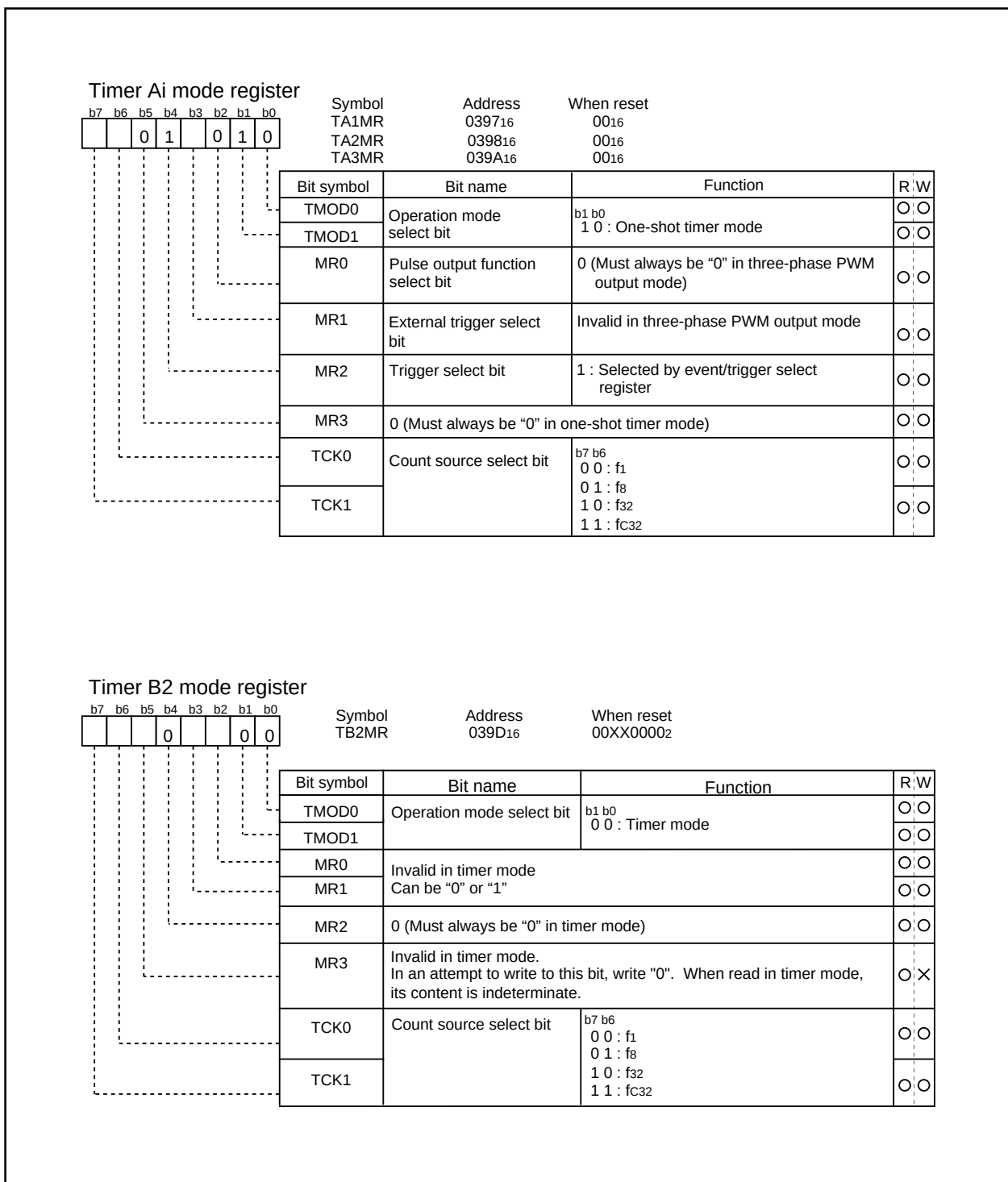


Figure 1.15.4. Timer mode registers in three-phase PWM output mode

Timers' functions for three-phase motor control

Figure 1.15.5 shows the block diagram for three-phase PWM output mode. In three-phase PWM output mode, the positive-phase waveforms (U phase, V phase, and W phase) and negative waveforms ($\bar{U}$ phase, $\bar{V}$ phase, and $\bar{W}$ phase), six waveforms in total, are output from P80, P81, P72, P73, P74, and P75 as active on the "L" level. Of the timers used in this mode, timer A4 controls the U phase and $\bar{U}$ phase, timer A1 controls the V phase and $\bar{V}$ phase, and timer A2 controls the W phase and $\bar{W}$ phase respectively; timer B2 controls the periods of one-shot pulse output from timers A4, A1, and A2.

In outputting a waveform, dead time can be set so as to cause the "L" level of the positive waveform output (U phase, V phase, and W phase) not to lap over the "L" level of the negative waveform output ($\bar{U}$ phase, $\bar{V}$ phase, and $\bar{W}$ phase).

To set short circuit time, use three 8-bit timers sharing the reload register for setting dead time. A value from 1 through 255 can be set as the count of the timer for setting dead time. The timer for setting dead time works as a one-shot timer. If a value is written to the dead time timer (034C16), the value is written to the reload register shared by the three timers for setting dead time.

Any of the timers for setting dead time takes the value of the reload register into its counter, if a start trigger comes from its corresponding timer, and performs a down count in line with the clock source selected by the dead time timer count source select bit (bit 2 at 034916). The timer can receive another trigger again before the workings due to the previous trigger are completed. In this instance, the timer performs a down count from the reload register's content after its transfer, provoked by the trigger, to the timer for setting dead time.

Since the timer for setting dead time works as a one-shot timer, it starts outputting pulses if a trigger comes; it stops outputting pulses as soon as its content becomes 0016, and waits for the next trigger to come.

The positive waveforms (U phase, V phase, and W phase) and the negative waveforms ($\bar{U}$ phase, $\bar{V}$ phase, and $\bar{W}$ phase) in three-phase PWM output mode are output from respective ports by means of setting "1" in the output control bit (bit 3 at 034816). Setting "0" in this bit causes the ports to be the state of set by port direction register. This bit can be set to "0" not only by use of the applicable instruction, but by entering a falling edge in the $\overline{\text{NMI}}$ terminal or by resetting. Also, if "1" is set in the positive and negative phases concurrent L output disable function enable bit (bit 4 at 034816) causes one of the pairs of U phase and $\bar{U}$ phase, V phase and $\bar{V}$ phase, and W phase and $\bar{W}$ phase concurrently go to "L", as a result, the port becomes the state of set by port direction register.

Timers' functions for three-phase motor control

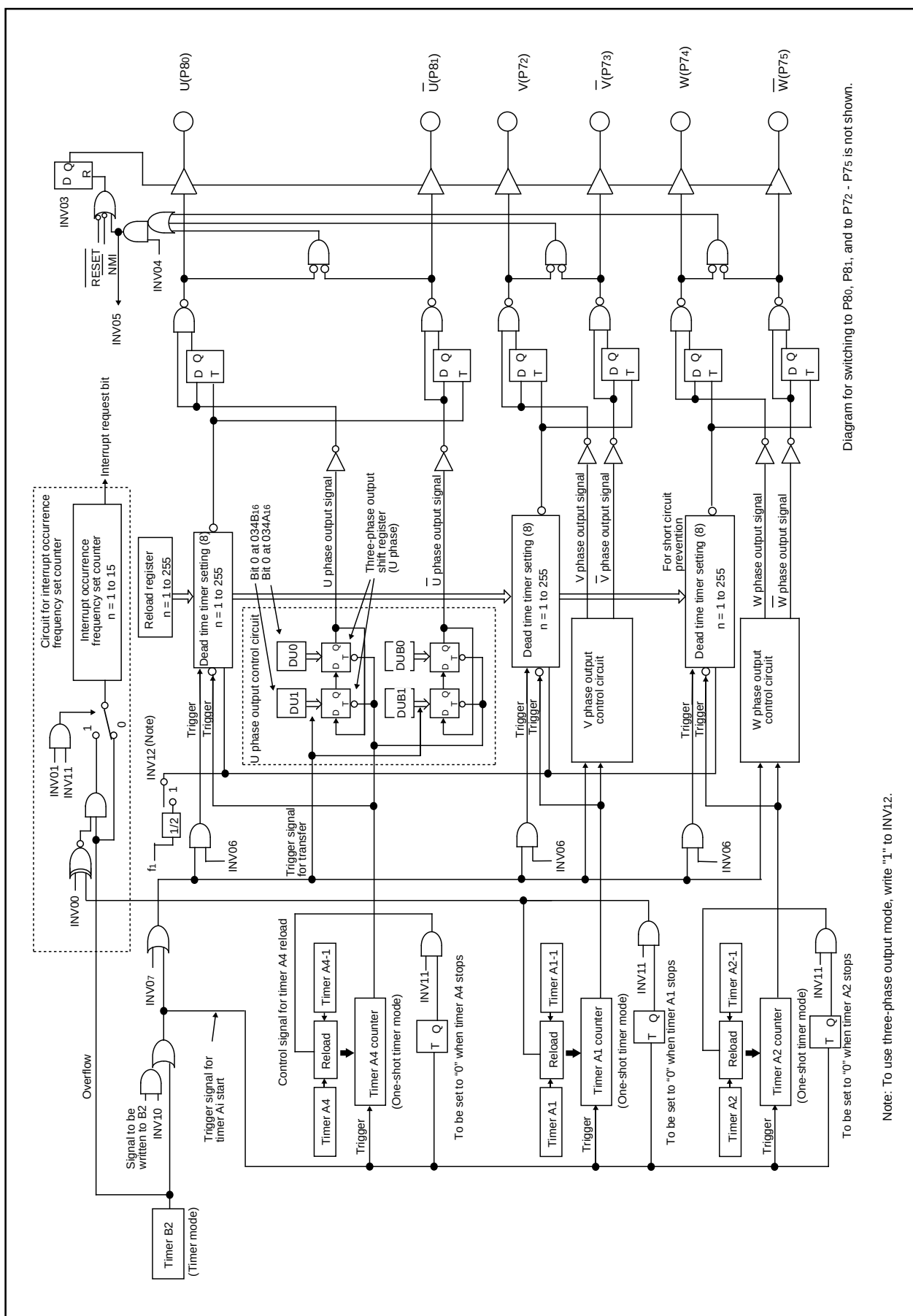


Figure 1.15.5. Block diagram for three-phase PWM output mode

Timers' functions for three-phase motor control

Triangular wave modulation

To generate a PWM waveform of triangular wave modulation, set "0" in the modulation mode select bit (bit 6 at 0348₁₆). Also, set "1" in the timers A4-1, A1-1, A2-1 control bit (bit 1 at 0349₁₆). In this mode, each of timers A4, A1, and A2 has two timer registers, and alternately reloads the timer register's content to the counter every time timer B2 counter's content becomes 0000₁₆. If "0" is set to the effective interrupt output specification bit (bit 1 at 0348₁₆), the frequency of interrupt requests that occur every time the timer B2 counter's value becomes 0000₁₆ can be set by use of the timer B2 counter (034D₁₆) for setting the frequency of interrupt occurrences. The frequency of occurrences is given by (setting; setting $\neq$ 0).

Setting "1" in the effective interrupt output specification bit (bit 1 at 0348₁₆) provides the means to choose which value of the timer A1 reload control signal to use, "0" or "1", to cause timer B2's interrupt request to occur. To make this selection, use the effective interrupt output polarity selection bit (bit 0 at 0348₁₆).

An example of U phase waveform is shown in Figure 1.15.6, and the description of waveform output workings is given below. Set "1" in DU0 (bit 0 at 034A₁₆). And set "0" in DUB0 (bit 1 at 034A₁₆). In addition, set "0" in DU1 (bit 0 at 034B₁₆) and set "1" in DUB1 (bit 1 at 034B₁₆). Also, set "0" in the effective interrupt output specification bit (bit 1 at 0348₁₆) to set a value in the timer B2 interrupt occurrence frequency set counter. By this setting, a timer B2 interrupt occurs when the timer B2 counter's content becomes 0000₁₆ as many as (setting) times. Furthermore, set "1" in the effective interrupt output specification bit (bit 1 at 0348₁₆), set "0" in the effective interrupt output polarity select bit (bit 0 at 0348₁₆) and set "1" in the interrupt occurrence frequency set counter (034D₁₆). These settings cause a timer B2 interrupt to occur every other interval when the U phase output goes to "H".

When the timer B2 counter's content becomes 0000₁₆, timer A4 starts outputting one-shot pulses. In this instance, the content of DU1 (bit 0 at 034B₁₆) and that of DU0 (bit 0 at 034A₁₆) are set in the three-phase output shift register (U phase), the content of DUB1 (bit 1 at 034B₁₆) and that of DUB0 (bit 1 at 034A₁₆) are set in the three-phase output shift register ($\bar{U}$ phase). After triangular wave modulation mode is selected, however, no setting is made in the shift register even though the timer B2 counter's content becomes 0000₁₆.

The value of DU0 and that of DUB0 are output to the U terminal (P80) and to the $\bar{U}$ terminal (P81) respectively. When the timer A4 counter counts the value written to timer A4 (038F₁₆, 038E₁₆) and when timer A4 finishes outputting one-shot pulses, the three-phase shift register's content is shifted one position, and the value of DU1 and that of DUB1 are output to the U phase output signal and to $\bar{U}$ phase output signal respectively. At this time, one-shot pulses are output from the timer for setting dead time used for setting the time over which the "L" level of the U phase waveform does not lap over the "L" level of the $\bar{U}$ phase waveform, which has the opposite phase of the former. The U phase waveform output that started from the "H" level keeps its level until the timer for setting dead time finishes outputting one-shot pulses even though the three-phase output shift register's content changes from "1" to "0" by the effect of the one-shot pulses. When the timer for setting dead time finishes outputting one-shot pulses, "0" already shifted in the three-phase shift register goes effective, and the U phase waveform changes to the "L" level. When the timer B2 counter's content becomes 0000₁₆, the timer A4 counter starts counting the value written to timer A4-1 (0347₁₆, 0346₁₆), and starts outputting one-shot pulses. When timer A4 finishes outputting one-shot pulses, the three-phase shift register's content is shifted one position, but if the three-phase output shift register's content changes from "0" to "1" as a result of the shift, the output level changes from "L" to "H" without waiting for the timer for setting dead time to finish outputting one-shot pulses. A U phase waveform is generated by these workings repeatedly. With the exception that the three-phase output shift register on the $\bar{U}$ phase side is used, the workings in generating a $\bar{U}$ phase waveform, which has the opposite phase of the U phase waveform, are the same as in generating a U

Timers' functions for three-phase motor control

phase waveform. In this way, a waveform can be picked up from the applicable terminal in a manner in which the "L" level of the U phase waveform doesn't lap over that of the $\bar{U}$ phase waveform, which has the opposite phase of the U phase waveform. The width of the "L" level too can be adjusted by varying the values of timer B2, timer A4, and timer A4-1. In dealing with the V and W phases, and $\bar{V}$ and $\bar{W}$ phases, the latter are of opposite phase of the former, have the corresponding timers work similarly to dealing with the U and $\bar{U}$ phases to generate an intended waveform.

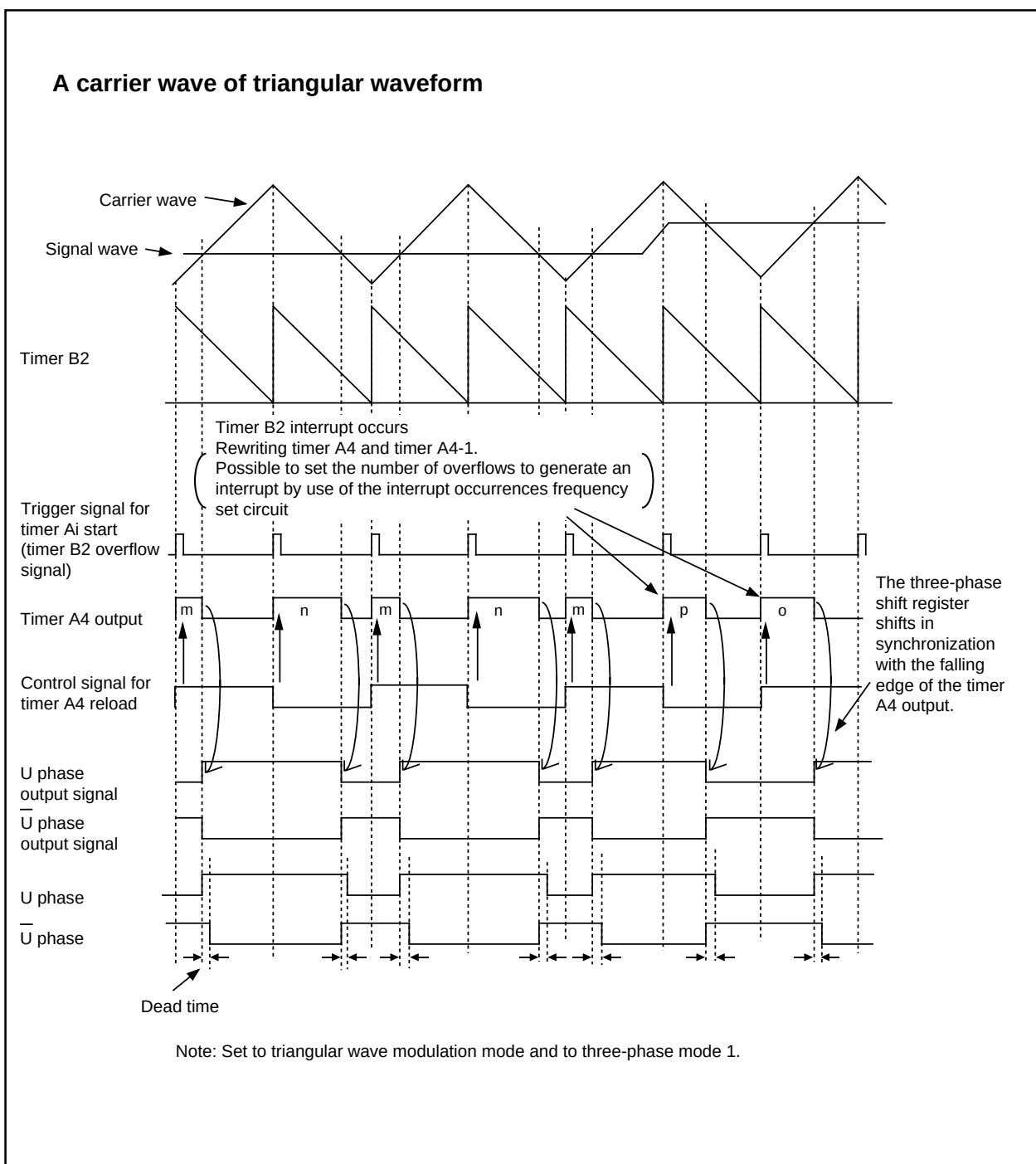


Figure 1.15.6. Timing chart of operation (1)

Timers' functions for three-phase motor control

Assigning certain values to DU0 (bit 0 at 034A16) and DUB0 (bit 1 at 034A16), and to DU1 (bit 0 at 034B16) and DUB1 (bit 1 at 034B16) allows the user to output the waveforms as shown in Figure 1.15.7, that is, to output the U phase alone, to fix $\bar{U}$ phase to "H", to fix the U phase to "H," or to output the $\bar{U}$ phase alone.

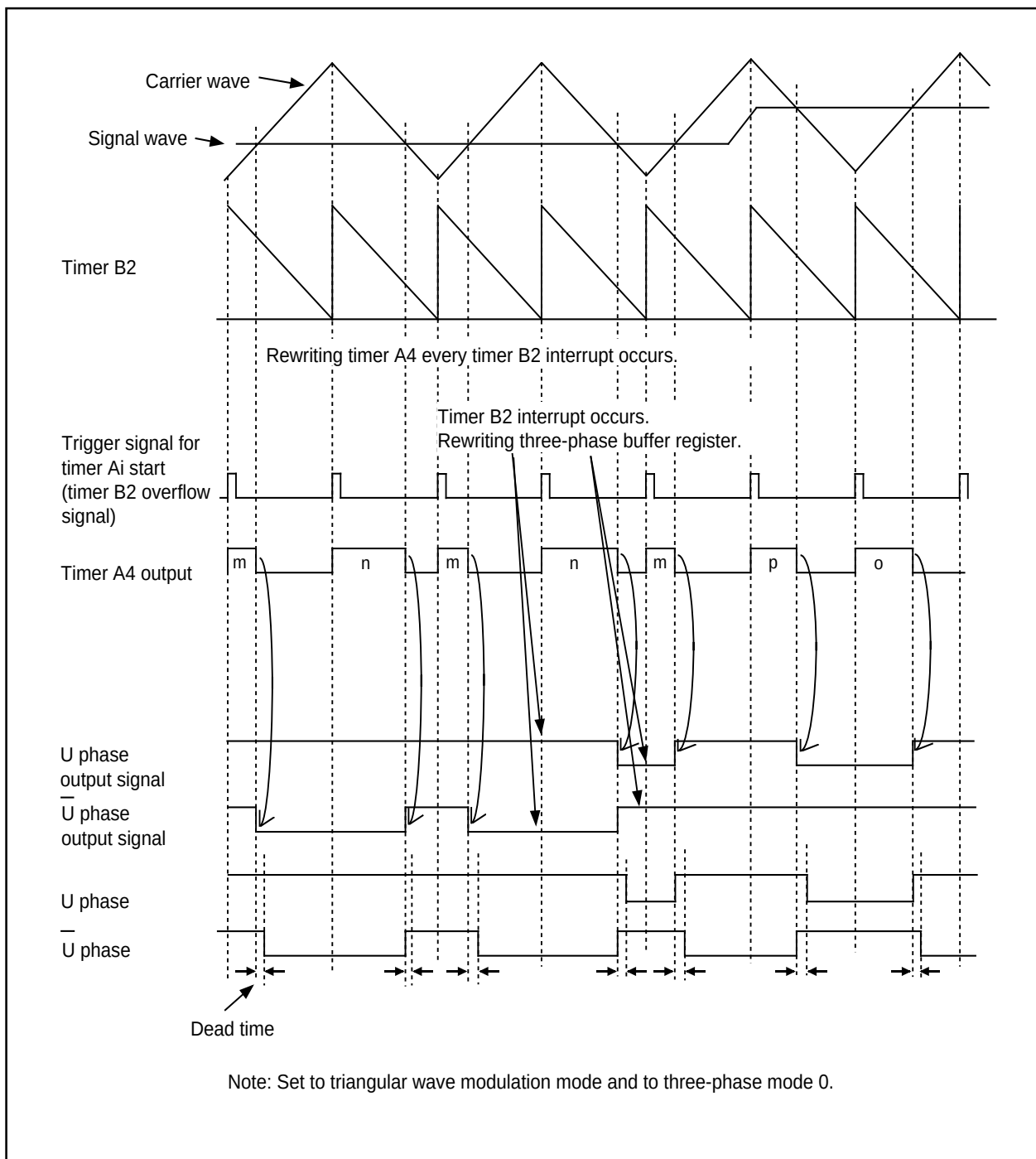


Figure 1.15.7. Timing chart of operation (2)

Timers' functions for three-phase motor control

Sawtooth modulation

To generate a PWM waveform of sawtooth wave modulation, set "1" in the modulation mode select bit (bit 6 at 0348₁₆). Also, set "0" in the timers A4-1, A1-1, and A2-1 control bit (bit 1 at 0349₁₆). In this mode, the timer registers of timers A4, A1, and A2 comprise conventional timers A4, A1, and A2 alone, and reload the corresponding timer register's content to the counter every time the timer B2 counter's content becomes 0000₁₆. The effective interrupt output specification bit (bit 1 at 0348₁₆) and the effective interrupt output polarity select bit (bit 0 at 0348₁₆) go nullified.

An example of U phase waveform is shown in Figure 1.15.8, and the description of waveform output workings is given below. Set "1" in DU0 (bit 0 at 034A₁₆), and set "0" in DUB0 (bit 1 at 034A₁₆). In addition, set "0" in DU1 (bit 0 at 034A₁₆) and set "1" in DUB1 (bit 1 at 034A₁₆).

When the timer B2 counter's content becomes 0000₁₆, timer B2 generates an interrupt, and timer A4 starts outputting one-shot pulses at the same time. In this instance, the contents of the three-phase buffer registers DU1 and DU0 are set in the three-phase output shift register (U phase), and the contents of DUB1 and DUB0 are set in the three-phase output shift register ($\bar{U}$ phase). After this, the three-phase buffer register's content is set in the three-phase shift register every time the timer B2 counter's content becomes 0000₁₆.

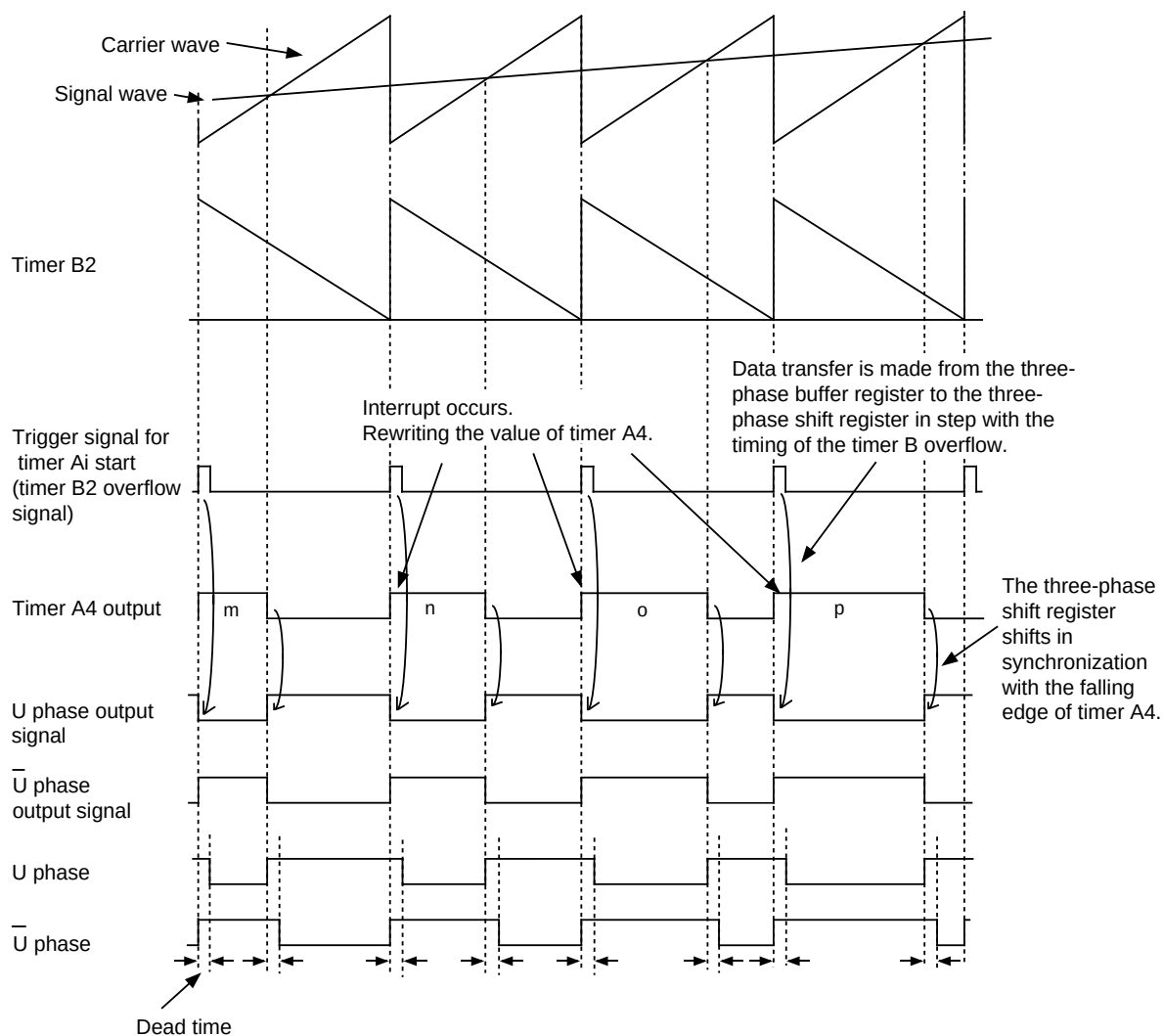
The value of DU0 and that of DUB0 are output to the U terminal (P80) and to the $\bar{U}$ terminal (P81) respectively. When the timer A4 counter counts the value written to timer A4 (038F₁₆, 038E₁₆) and when timer A4 finishes outputting one-shot pulses, the three-phase output shift register's content is shifted one position, and the value of DU1 and that of DUB1 are output to the U phase output signal and to the $\bar{U}$ output signal respectively. At this time, one-shot pulses are output from the timer for setting dead time used for setting the time over which the "L" level of the U phase waveform doesn't lap over the "L" level of the $\bar{U}$ phase waveform, which has the opposite phase of the former. The U phase waveform output that started from the "H" level keeps its level until the timer for setting dead time finishes outputting one-shot pulses even though the three-phase output shift register's content changes from "1" to "0" by the effect of the one-shot pulses. When the timer for setting dead time finishes outputting one-shot pulses, 0 already shifted in the three-phase shift register goes effective, and the U phase waveform changes to the "L" level. When the timer B2 counter's content becomes 0000₁₆, the contents of the three-phase buffer registers DU1 and DU0 are set in the three-phase output shift register (U phase), and the contents of DUB1 and DUB0 are set in the three-phase output shift register ($\bar{U}$ phase) again.

A U phase waveform is generated by these workings repeatedly. With the exception that the three-phase output shift register on the $\bar{U}$ phase side is used, the workings in generating a $\bar{U}$ phase waveform, which has the opposite phase of the U phase waveform, are the same as in generating a U phase waveform. In this way, a waveform can be picked up from the applicable terminal in a manner in which the "L" level of the U phase waveform doesn't lap over that of the $\bar{U}$ phase waveform, which has the opposite phase of the U phase waveform. The width of the "L" level too can be adjusted by varying the values of timer B2 and timer A4. In dealing with the V and W phases, and $\bar{V}$ and $\bar{W}$ phases, the latter are of opposite phase of the former, have the corresponding timers work similarly to dealing with the U and $\bar{U}$ phases to generate an intended waveform.

Setting "1" both in DUB0 and in DUB1 provides a means to output the U phase alone and to fix the $\bar{U}$ phase output to "H" as shown in Figure 1.15.9.

Timers' functions for three-phase motor control

A carrier wave of sawtooth waveform



Note: Set to sawtooth modulation mode and to three-phase mode 0.

Figure 1.15.8. Timing chart of operation (3)

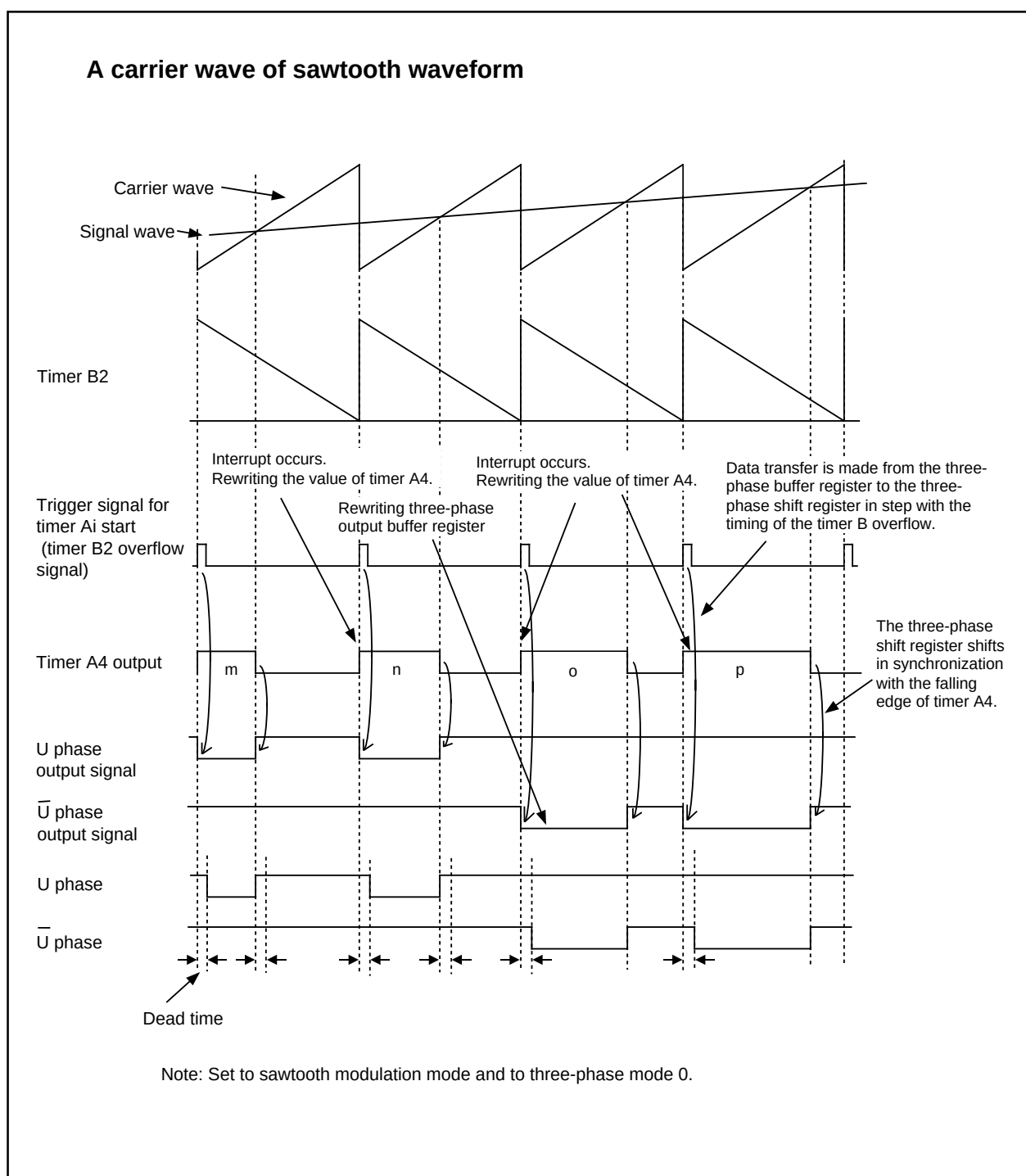


Figure 1.15.9. Timing chart of operation (4)

Serial I/O

Serial I/O

Serial I/O is configured as five channels: UART0, UART1, UART2, S I/O3 and S I/O4.

UART0 to 2

UART0, UART1 and UART2 each have an exclusive timer to generate a transfer clock, so they operate independently of each other.

Figure 1.16.1 shows the block diagram of UART0, UART1 and UART2. Figures 1.16.2 and 1.16.3 show the block diagram of the transmit/receive unit.

UARTi (i = 0 to 2) has two operation modes: a clock synchronous serial I/O mode and a clock asynchronous serial I/O mode (UART mode). The contents of the serial I/O mode select bits (bits 0 to 2 at addresses 03A0₁₆, 03A8₁₆ and 0378₁₆) determine whether UARTi is used as a clock synchronous serial I/O or as a UART. Although a few functions are different, UART0, UART1 and UART2 have almost the same functions. UART2, in particular, is used for the SIM interface with some extra settings added in clock-asynchronous serial I/O mode (Note). It also has the bus collision detection function that generates an interrupt request if the TxD pin and the RxD pin are different in level.

Table 1.16.1 shows the comparison of functions of UART0 through UART2, and Figures 1.16.4 to 1.16.9 show the registers related to UARTi.

Note: SIM : Subscriber Identity Module

Table 1.16.1. Comparison of functions of UART0 through UART2

Function	UART0	UART1	UART2
CLK polarity selection	Possible (Note 1)	Possible (Note 1)	Possible (Note 1)
LSB first / MSB first selection	Possible (Note 1)	Possible (Note 1)	Possible (Note 2)
Continuous receive mode selection	Possible (Note 1)	Possible (Note 1)	Possible (Note 1)
Transfer clock output from multiple pins selection	Impossible	Possible (Note 1)	Impossible
Serial data logic switch	Impossible	Impossible	Possible (Note 4)
Sleep mode selection	Possible (Note 3)	Possible (Note 3)	Impossible
TxD, RxD I/O polarity switch	Impossible	Impossible	Possible
TxD, RxD port output format	CMOS output	CMOS output	N-channel open-drain output
Parity error signal output	Impossible	Impossible	Possible (Note 4)
Bus collision detection	Impossible	Impossible	Possible

Note 1: Only when clock synchronous serial I/O mode.

Note 2: Only when clock synchronous serial I/O mode and 8-bit UART mode.

Note 3: Only when UART mode.

Note 4: Using for SIM interface.

Serial I/O

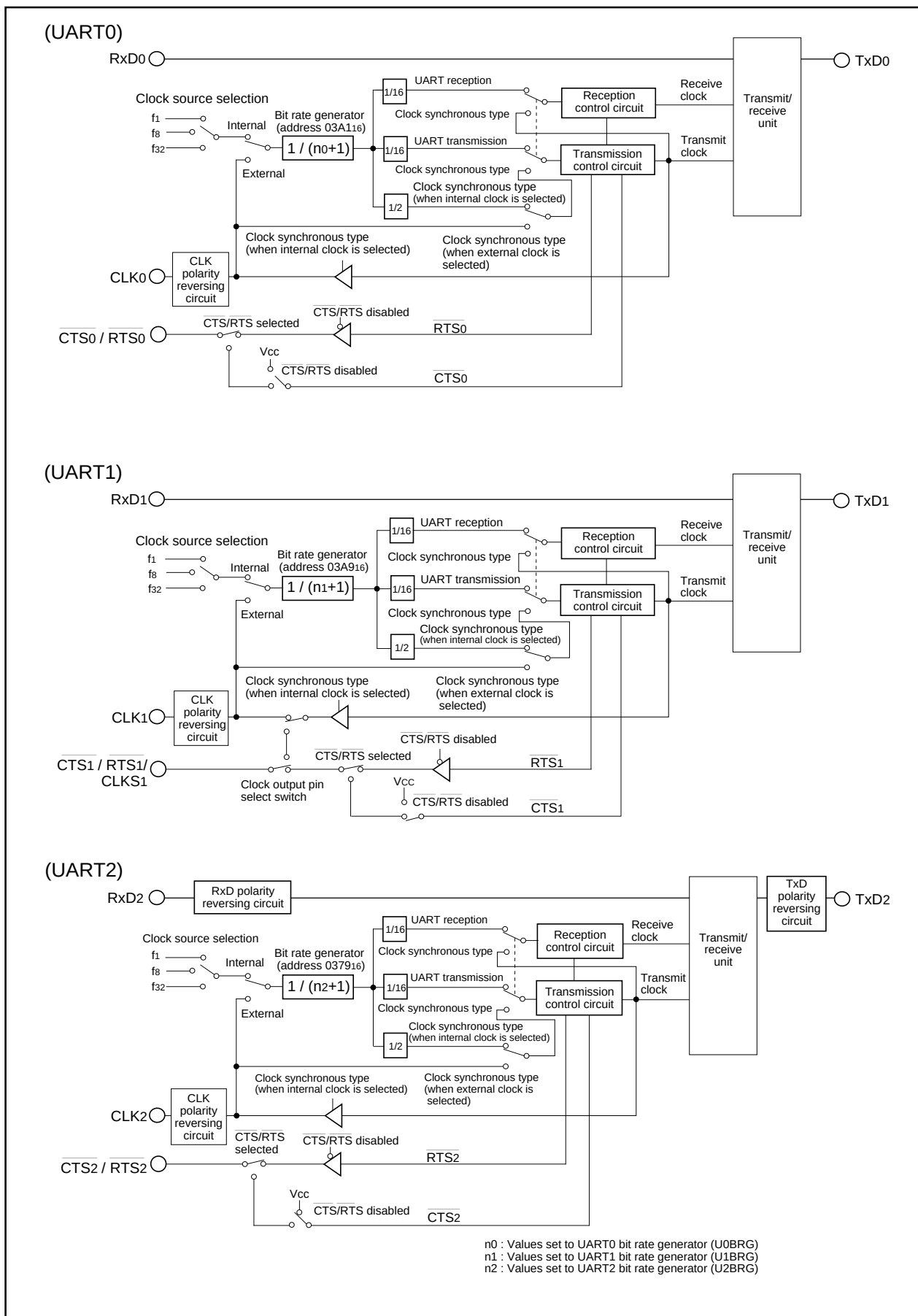


Figure 1.16.1. Block diagram of UARTi (i = 0 to 2)

Serial I/O

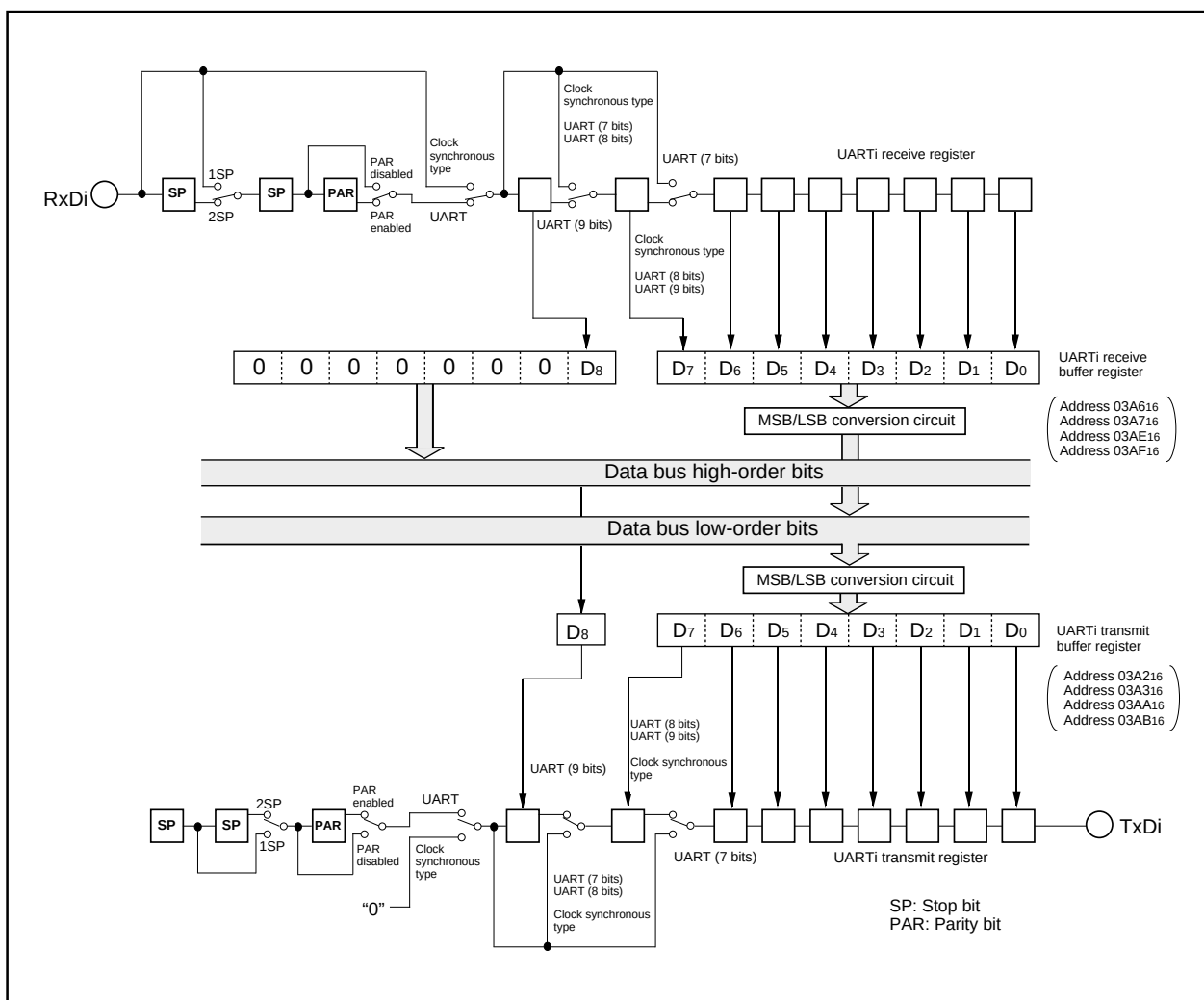


Figure 1.16.2. Block diagram of UARTi (i = 0, 1) transmit/receive unit

Serial I/O

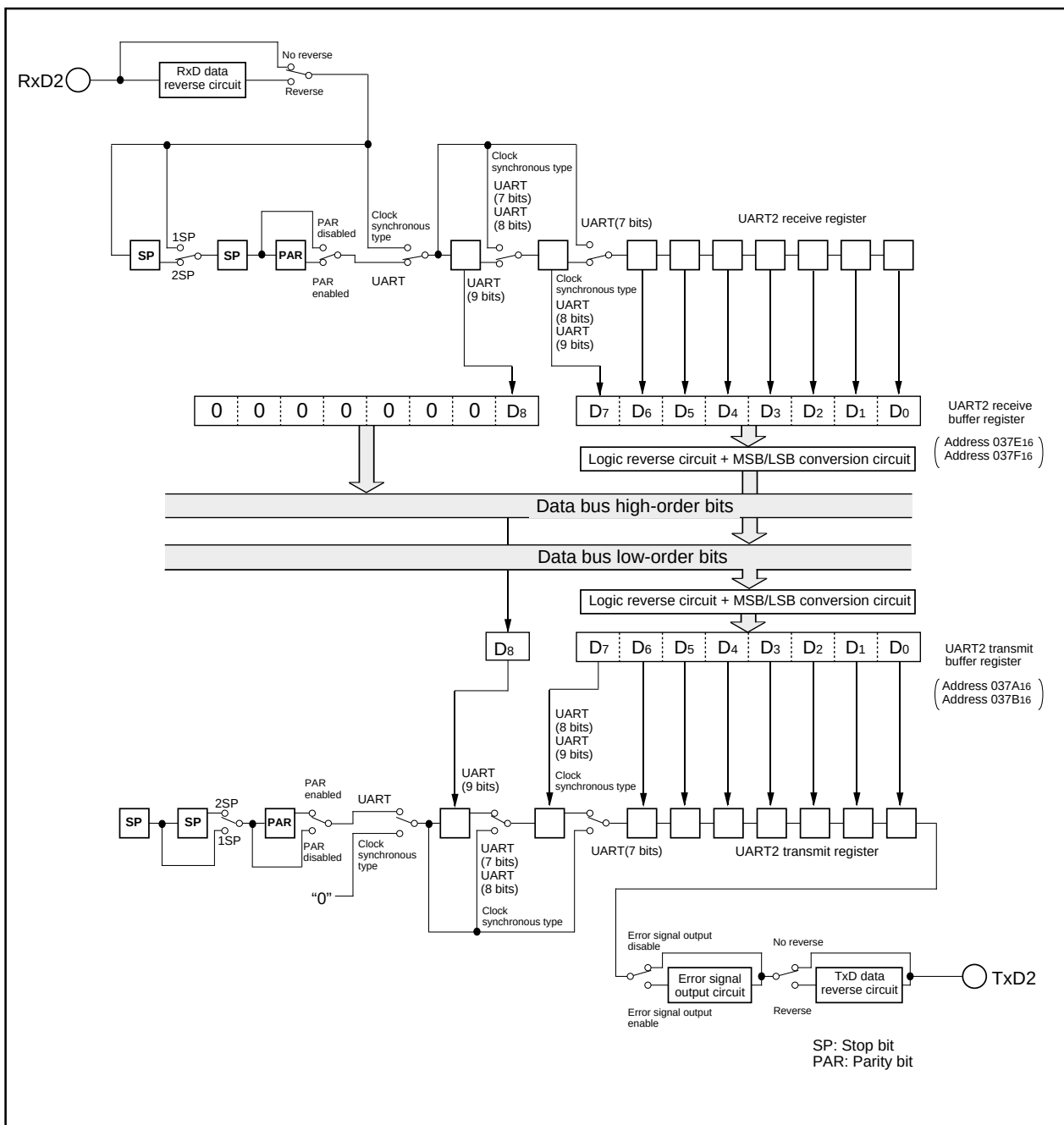


Figure 1.16.3. Block diagram of UART2 transmit/receive unit

Serial I/O

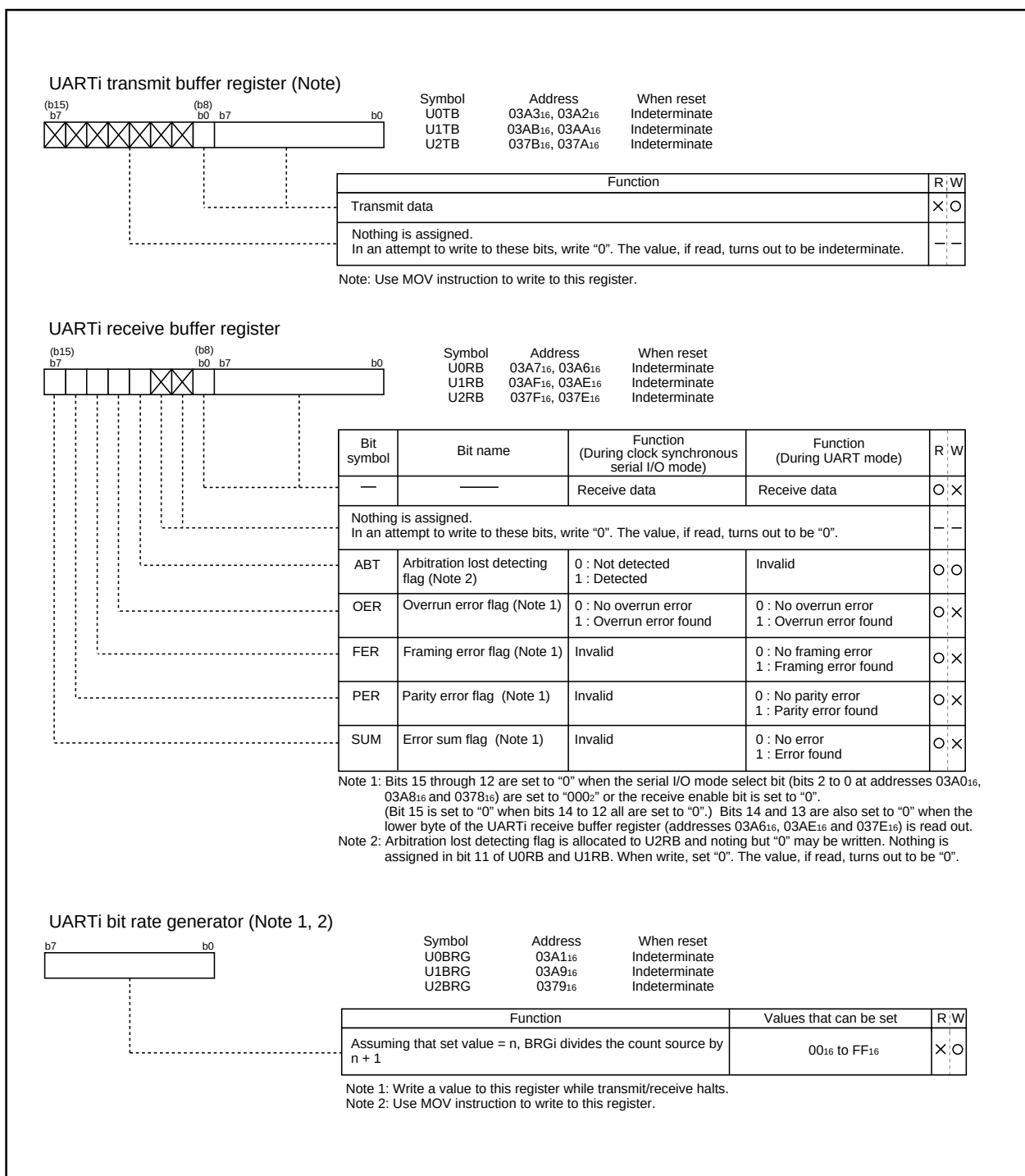


Figure 1.16.4. Serial I/O-related registers (1)

Serial I/O

UARTi transmit/receive mode register

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
b7					
b6					
b5					
b4					
b3					
b2					
b1					
b0					
SMD0	Serial I/O mode select bit	Must be fixed to 001 b2 b1 b0 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	b2 b1 b0 1 0 0 : Transfer data 7 bits long 1 0 1 : Transfer data 8 bits long 1 1 0 : Transfer data 9 bits long 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	○	○
SMD1				○	○
SMD2				○	○
CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock (Note)	0 : Internal clock 1 : External clock (Note)	○	○
STPS	Stop bit length select bit	Invalid	0 : One stop bit 1 : Two stop bits	○	○
PRY	Odd/even parity select bit	Invalid	Valid when bit 6 = "1" 0 : Odd parity 1 : Even parity	○	○
PRYE	Parity enable bit	Invalid	0 : Parity disabled 1 : Parity enabled	○	○
SLEP	Sleep select bit	Must always be "0"	0 : Sleep mode deselected 1 : Sleep mode selected	○	○

Note : Set the corresponding port direction register to "0".

UART2 transmit/receive mode register

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
b7					
b6					
b5					
b4					
b3					
b2					
b1					
b0					
SMD0	Serial I/O mode select bit	Must be fixed to 001 b2 b1 b0 0 0 0 : Serial I/O invalid 0 1 0 : (Note 1) 0 1 1 : Must not be set. 1 1 1 : Must not be set.	b2 b1 b0 1 0 0 : Transfer data 7 bits long 1 0 1 : Transfer data 8 bits long 1 1 0 : Transfer data 9 bits long 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	○	○
SMD1				○	○
SMD2				○	○
CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock (Note 2)	Must always be "0"	○	○
STPS	Stop bit length select bit	Invalid	0 : One stop bit 1 : Two stop bits	○	○
PRY	Odd/even parity select bit	Invalid	Valid when bit 6 = "1" 0 : Odd parity 1 : Even parity	○	○
PRYE	Parity enable bit	Invalid	0 : Parity disabled 1 : Parity enabled	○	○
IOPOL	TxD, RxD I/O polarity reverse bit	0 : No reverse 1 : Reverse Usually set to "0"	0 : No reverse 1 : Reverse Usually set to "0"	○	○

Note 1: Bit 2 to bit 0 are set to "0102" when I²C mode is used.

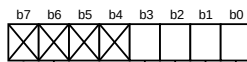
Note 2: Set the corresponding port direction register to "0".

Figure 1.16.5. Serial I/O-related registers (2)

Figure 1.16.6. Serial I/O-related registers (3)

Serial I/O

UARTi transmit/receive control register 1



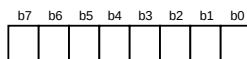
Symbol
UiC1(i=0,1)

Address
03A516, 03AD16

When reset
0216

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
TE	Transmit enable bit	0 : Transmission disabled 1 : Transmission enabled	0 : Transmission disabled 1 : Transmission enabled	○	○
TI	Transmit buffer empty flag	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	○	×
RE	Receive enable bit	0 : Reception disabled 1 : Reception enabled	0 : Reception disabled 1 : Reception enabled	○	○
RI	Receive complete flag	0 : No data present in receive buffer register 1 : Data present in receive buffer register	0 : No data present in receive buffer register 1 : Data present in receive buffer register	○	×
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".					—

UART2 transmit/receive control register 1



Symbol
U2C1

Address
037D16

When reset
0216

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
TE	Transmit enable bit	0 : Transmission disabled 1 : Transmission enabled	0 : Transmission disabled 1 : Transmission enabled	○	○
TI	Transmit buffer empty flag	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	○	×
RE	Receive enable bit	0 : Reception disabled 1 : Reception enabled	0 : Reception disabled 1 : Reception enabled	○	○
RI	Receive complete flag	0 : No data present in receive buffer register 1 : Data present in receive buffer register	0 : No data present in receive buffer register 1 : Data present in receive buffer register	○	×
U2IRS	UART2 transmit interrupt cause select bit	0 : Transmit buffer empty (TI = 1) 1 : Transmit is completed (TXEPT = 1)	0 : Transmit buffer empty (TI = 1) 1 : Transmit is completed (TXEPT = 1)	○	○
U2RRM	UART2 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enabled	Must always be "0"	○	○
U2LCH	Data logic select bit	0 : No reverse 1 : Reverse	0 : No reverse 1 : Reverse	○	○
U2ERE	Error signal output enable bit	Must be fixed to "0"	0 : Output disabled 1 : Output enabled	○	○

Figure 1.16.7. Serial I/O-related registers (4)

Serial I/O

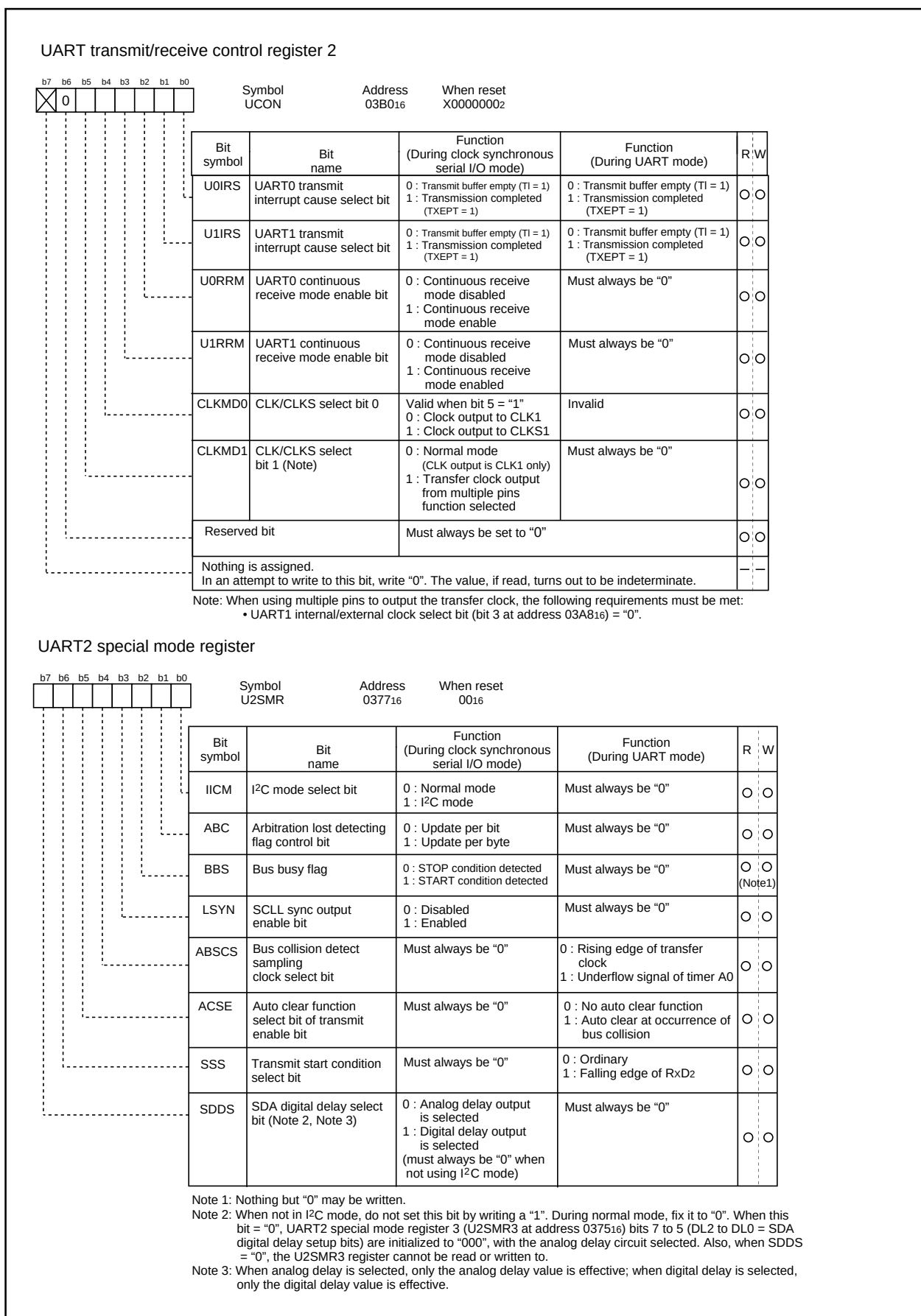


Figure 1.16.8. Serial I/O-related registers (5)

Serial I/O

UART2 special mode register 2 (I²C bus exclusive use register)

b7	b6	b5	b4	b3	b2	b1	b0	Symbol U2SMR2	Address 0376 ₁₆	When reset 00 ₁₆

UART2 special mode register 3 (I²C bus exclusive use register)

b7	b6	b5	b4	b3	b2	b1	b0	Symbol U2SMR3	Address 0375 ₁₆	When reset Indeterminate (However, when SDDS = "1", the initial value is "0016")
							</			

Note 1: This bit can be read or written to when UART2 special mode register (U2SMR at address 0377₁₆) bit 7 (SDDS: SDA digital delay select bit) = "1". When the initial value of UART2 special mode register 3 (U2SMR3) is read after setting SDDS = "1", the value is "00₁₆". When writing to UART2 special mode register 3 (U2SMR3) after setting SDDS = "1", be sure to write 0's to bits 0–4. When SDDS = "0", this register cannot be written to; when read, the value is indeterminate.

Note 2: These bits are initialized to "000" when SDDS = "0", with the analog delay circuit selected. After a reset, these bits are set to "000", with the analog delay circuit selected. However, because these bits can be read only when SDDS = "1", the value read from these bits when SDDS = "0" is indeterminate.

Note 3: When analog delay is selected, only the analog delay value is effective; when digital delay is selected, only the digital delay value is effective.

Note 4: The amount of delay varies with the load on SCL and SDA pins. Also, when using an external clock, the amount of delay increases by about 100 ns, so be sure to take this into account when using the device.

Figure 1.16.9. Serial I/O-related registers (6)

Clock synchronous serial I/O mode

(1) Clock synchronous serial I/O mode

The clock synchronous serial I/O mode uses a transfer clock to transmit and receive data. Tables 1.16.2 and 1.16.3 list the specifications of the clock synchronous serial I/O mode. Figure 1.16.10 shows the UARTi transmit/receive mode register.

Table 1.16.2. Specifications of clock synchronous serial I/O mode (1)

Item	Specification
Transfer data format	Transfer data length: 8 bits
Transfer clock	- When internal clock is selected (bit 3 at addresses 03A0₁₆, 03A8₁₆, 0378₁₆ = "0") : $f_i / 2(n+1)$ (Note 1) $f_i = f_1, f_8, f_{32}$ - When external clock is selected (bit 3 at addresses 03A0₁₆, 03A8₁₆, 0378₁₆ = "1") : Input from CLKi pin
Transmission/reception control	CTS function, $\overline{\text{RTS}}$ function, CTS and $\overline{\text{RTS}}$ function invalid: selectable
Transmission start condition	- To start transmission, the following requirements must be met: - Transmit enable bit (bit 0 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" - Transmit buffer empty flag (bit 1 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "0" - When $\overline{\text{CTS}}$ function selected, $\overline{\text{CTS}}$ input level = "L" - Furthermore, if external clock is selected, the following requirements must also be met: - CLKi polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "0": CLKi input level = "H" - CLKi polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "1": CLKi input level = "L"
Reception start condition	- To start reception, the following requirements must be met: - Receive enable bit (bit 2 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" - Transmit enable bit (bit 0 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" - Transmit buffer empty flag (bit 1 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "0" - Furthermore, if external clock is selected, the following requirements must also be met: - CLKi polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "0": CLKi input level = "H" - CLKi polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "1": CLKi input level = "L"
Interrupt request generation timing	- When transmitting - Transmit interrupt cause select bit (bits 0, 1 at address 03B0₁₆, bit 4 at address 037D₁₆) = "0": Interrupts requested when data transfer from UARTi transfer buffer register to UARTi transmit register is completed - Transmit interrupt cause select bit (bits 0, 1 at address 03B0₁₆, bit 4 at address 037D₁₆) = "1": Interrupts requested when data transmission from UARTi transfer register is completed - When receiving - Interrupts requested when data transfer from UARTi receive register to UARTi receive buffer register is completed
Error detection	Overflow error (Note 2) This error occurs when the next data is ready before contents of UARTi receive buffer register are read out

Note 1: "n" denotes the value 00₁₆ to FF₁₆ that is set to the UART bit rate generator.

Note 2: If an overrun error occurs, the UARTi receive buffer will have the next data written in. Note also that the UARTi receive interrupt request bit does not change.

Clock synchronous serial I/O mode**Table 1.16.3. Specifications of clock synchronous serial I/O mode (2)**

Item	Specification
Select function	• CLK polarity selection Whether transmit data is output/input timing at the rising edge or falling edge of the transfer clock can be selected • LSB first/MSB first selection Whether transmission/reception begins with bit 0 or bit 7 can be selected • Continuous receive mode selection Reception is enabled simultaneously by a read from the receive buffer register • Transfer clock output from multiple pins selection (UART1) UART1 transfer clock can be chosen by software to be output from one of the two pins set • Switching serial data logic (UART2) Whether to reverse data in writing to the transmission buffer register or reading the reception buffer register can be selected. • Tx/D, Rx/D I/O polarity reverse (UART2) This function is reversing Tx/D port output and Rx/D port input. All I/O data level is reversed.

Clock synchronous serial I/O mode

UARTi transmit/receive mode registers

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

Symbol
UiMR(i=0,1)

Address
03A0₁₆, 03A8₁₆

When reset
00₁₆

Bit symbol	Bit name	Function	R	W
SMD0	Serial I/O mode select bit	b2 b1 b0 0 0 1 : Clock synchronous serial I/O mode	○	○
SMD1			○	○
SMD2			○	○
CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock (Note)	○	○
STPS	Invalid in clock synchronous serial I/O mode		○	○
PRY			○	○
PRYE			○	○
SLEP	0 (Must always be “0” in clock synchronous serial I/O mode)		○	○

Note : Set the corresponding port direction register to "0".

UART2 transmit/receive mode register

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

Symbol
U2MR

Address
0378₁₆

When reset
00₁₆

Bit symbol	Bit name	Function	R/W
SMD0	Serial I/O mode select bit	b2 b1 b0 0 0 1 : Clock synchronous serial I/O mode	○/○
SMD1			○/○
SMD2			○/○
CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock (Note 2)	○/○
STPS	Invalid in clock synchronous serial I/O mode		○/○
PRY			○/○
PRYE			○/○
IOPOL	TxD, RxD I/O polarity reverse bit (Note 1)	0 : No reverse 1 : Reverse	○/○

Note 1: Usually set to "0".

Note 2: Set the corresponding port direction register to "0".

Figure 1.16.10. UARTi transmit/receive mode register in clock synchronous serial I/O mode

Clock synchronous serial I/O mode

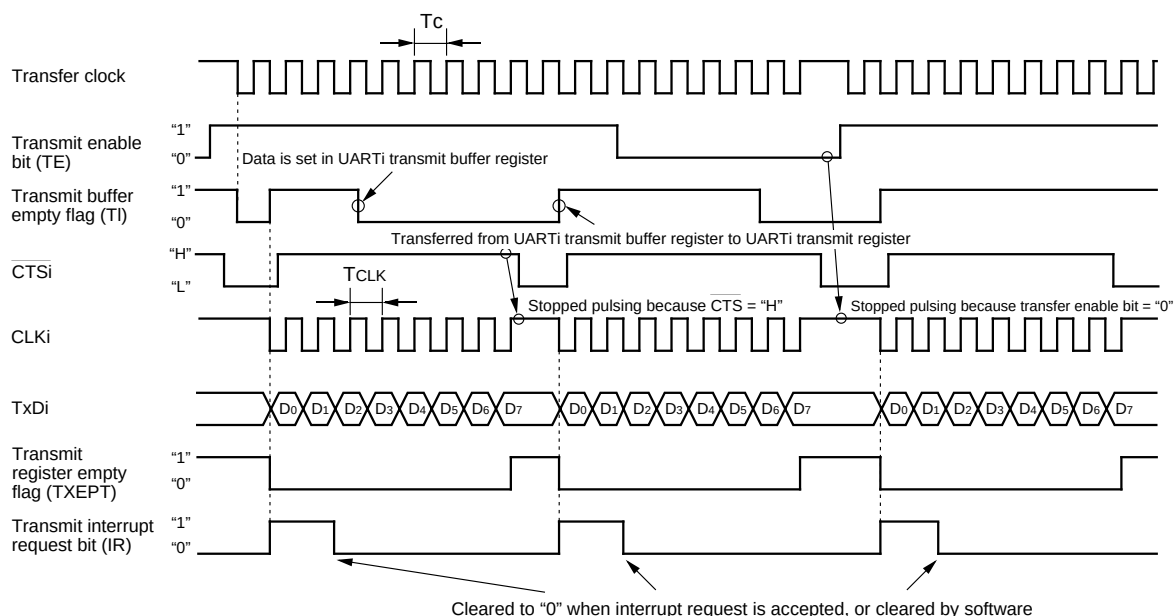
Table 1.16.4 lists the functions of the input/output pins during clock synchronous serial I/O mode. This table shows the pin functions when the transfer clock output from multiple pins function is not selected. Note that for a period from when the UARTi operation mode is selected to when transfer starts, the TxDi pin outputs an "H". (If the N-channel open-drain is selected, this pin is in floating state.)

Table 1.16.4. Input/output pin functions in clock synchronous serial I/O mode(when transfer clock output from multiple pins is not selected)

Pin name	Function	Method of selection
TxDi (P63, P67, P70)	Serial data output	(Outputs dummy data when performing reception only)
RxDi (P62, P66, P71)	Serial data input	Port P62, P66 and P71 direction register (bits 2 and 6 at address 03EE16, bit 1 at address 03EF16) = "0" (Can be used as an input port when performing transmission only)
CLKi (P61, P65, P72)	Transfer clock output	Internal/external clock select bit (bit 3 at address 03A016, 03A816, 037816) = "0"
	Transfer clock input	Internal/external clock select bit (bit 3 at address 03A016, 03A816, 037816) = "1" Port P61, P65 and P72 direction register (bits 1 and 5 at address 03EE16, bit 2 at address 03EF16) = "0"
$\overline{\text{CTS}}/\overline{\text{RTS}}$ (P60, P64, P73)	$\overline{\text{CTS}}$ input	$\overline{\text{CTS}}/\overline{\text{RTS}}$ disable bit (bit 4 at address 03A416, 03AC16, 037C16) = "0" $\overline{\text{CTS}}/\overline{\text{RTS}}$ function select bit (bit 2 at address 03A416, 03AC16, 037C16) = "0" Port P60, P64 and P73 direction register (bits 0 and 4 at address 03EE16, bit 3 at address 03EF16) = "0"
	RTS output	$\overline{\text{CTS}}/\overline{\text{RTS}}$ disable bit (bit 4 at address 03A416, 03AC16, 037C16) = "0" $\overline{\text{CTS}}/\overline{\text{RTS}}$ function select bit (bit 2 at address 03A416, 03AC16, 037C16) = "1"
	Programmable I/O port	$\overline{\text{CTS}}/\overline{\text{RTS}}$ disable bit (bit 4 at address 03A416, 03AC16, 037C16) = "1"

Clock synchronous serial I/O mode

• Example of transmit timing (when internal clock is selected)



• Example of receive timing (when external clock is selected)

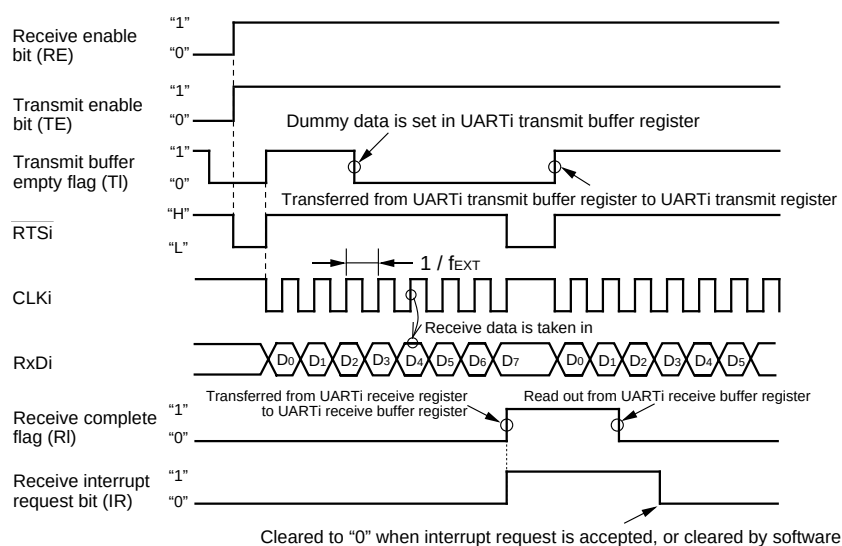


Figure 1.16.11. Typical transmit/receive timings in clock synchronous serial I/O mode

Clock synchronous serial I/O mode

(a) Polarity select function

As shown in Figure 1.16.12, the CLK polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) allows selection of the polarity of the transfer clock.

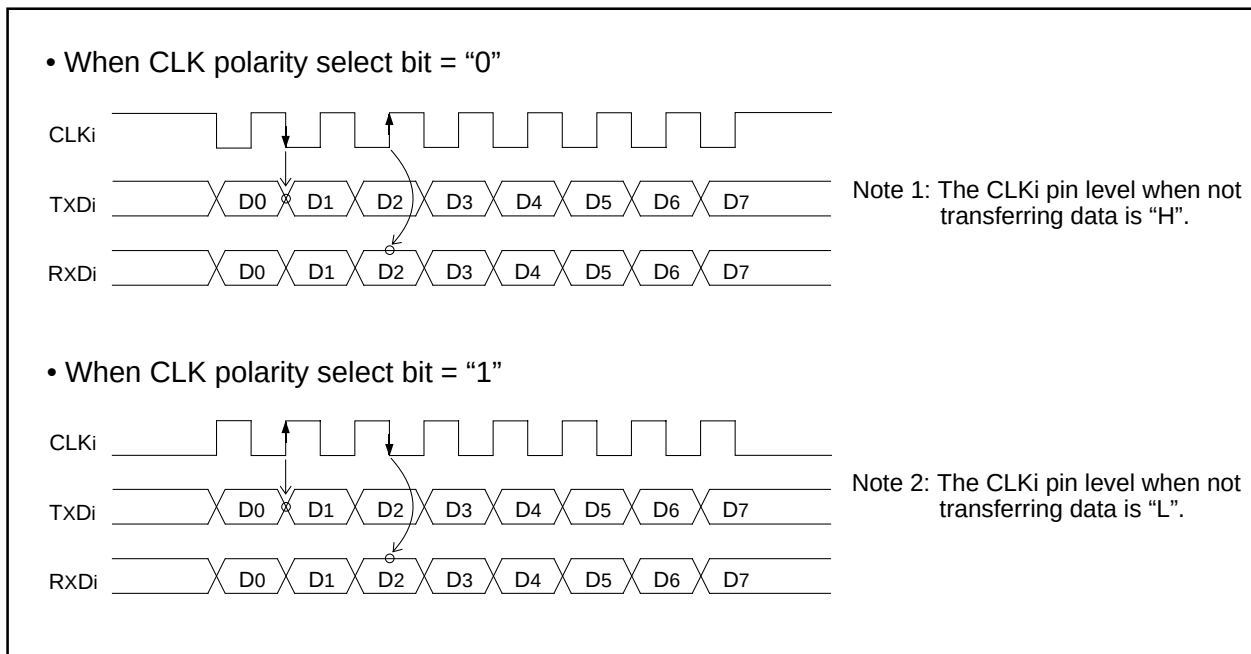


Figure 1.16.12. Polarity of transfer clock

(b) LSB first/MSB first select function

As shown in Figure 1.16.13, when the transfer format select bit (bit 7 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "0", the transfer format is "LSB first"; when the bit = "1", the transfer format is "MSB first".

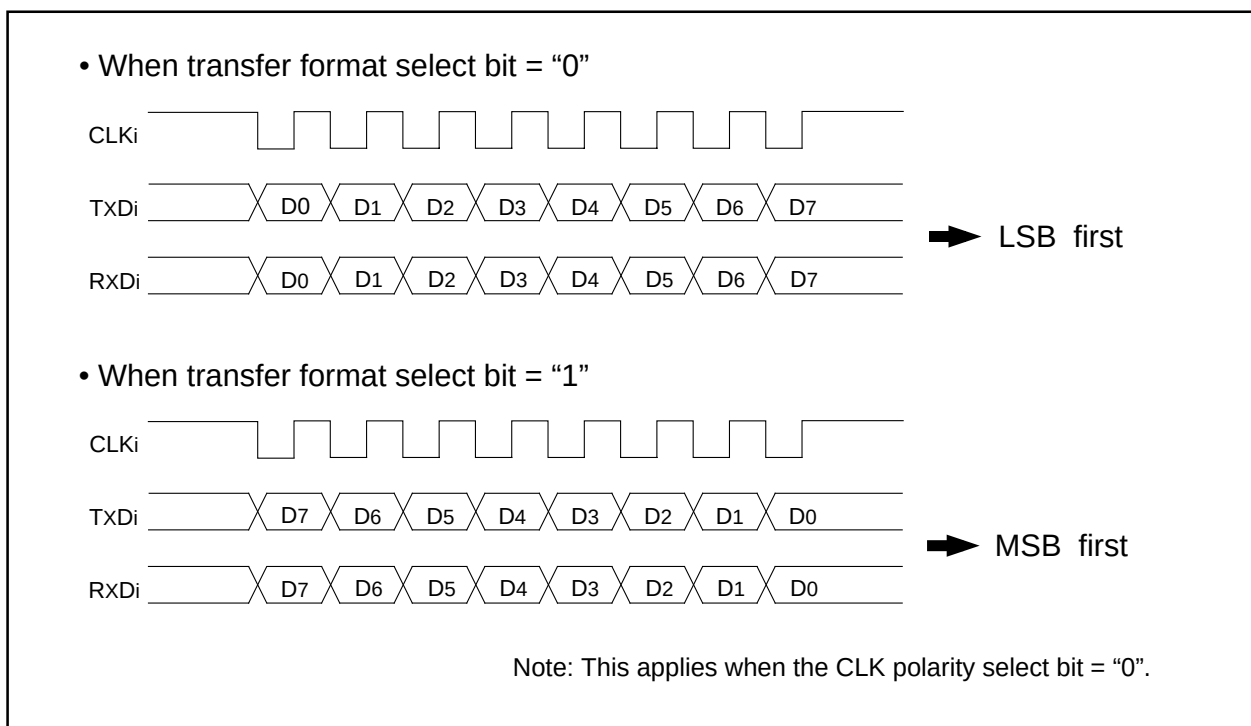


Figure 1.16.13. Transfer format

Clock synchronous serial I/O mode

(c) Transfer clock output from multiple pins function (UART1)

This function allows the setting two transfer clock output pins and choosing one of the two to output a clock by using the CLK and CLKS select bit (bits 4 and 5 at address 03B016). (See Figure 1.16.14.) The multiple pins function is valid only when the internal clock is selected for UART1.

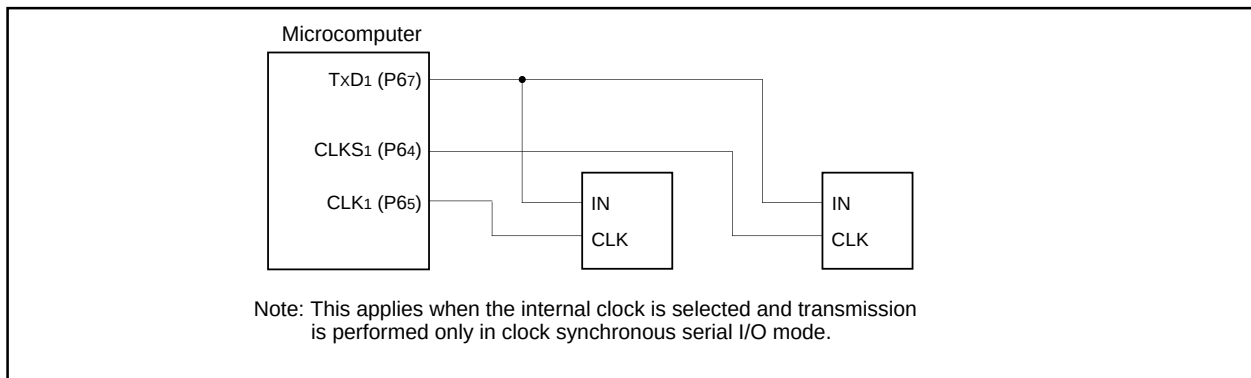


Figure 1.16.14. The transfer clock output from the multiple pins function usage

(d) Continuous receive mode

If the continuous receive mode enable bit (bits 2 and 3 at address 03B016, bit 5 at address 037D16) is set to "1", the unit is placed in continuous receive mode. In this mode, when the receive buffer register is read out, the unit simultaneously goes to a receive enable state without having to set dummy data to the transmit buffer register back again.

(e) Serial data logic switch function (UART2)

When the data logic select bit (bit6 at address 037D16) = "1", and writing to transmit buffer register or reading from receive buffer register, data is reversed. Figure 1.16.15 shows the example of serial data logic switch timing.

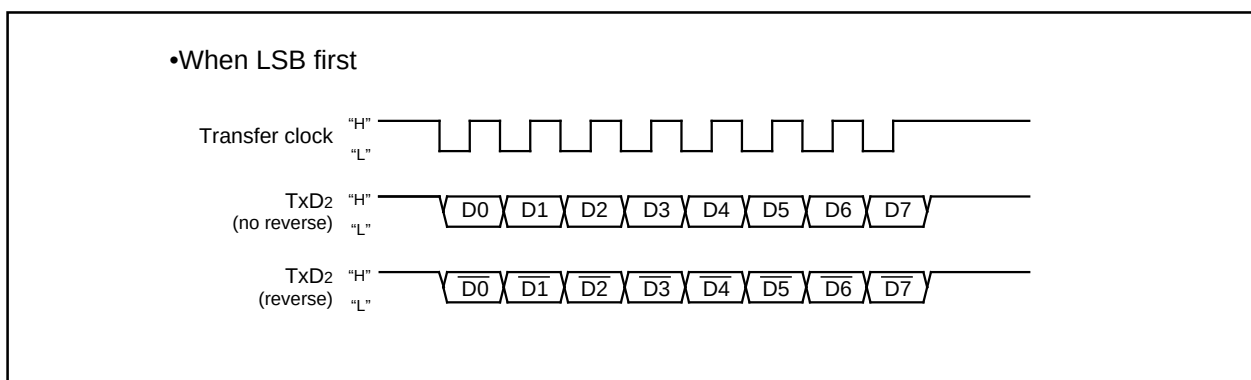


Figure 1.16.15. Serial data logic switch timing

Clock asynchronous serial I/O (UART) mode

(2) Clock asynchronous serial I/O (UART) mode

The UART mode allows transmitting and receiving data after setting the desired transfer rate and transfer data format. Tables 1.16.5 and 1.16.6 list the specifications of the UART mode. Figure 1.16.16 shows the UARTi transmit/receive mode register.

Table 1.16.5. Specifications of UART Mode (1)

Item	Specification
Transfer data format	• Character bit (transfer data): 7 bits, 8 bits, or 9 bits as selected • Start bit: 1 bit • Parity bit: Odd, even, or nothing as selected • Stop bit: 1 bit or 2 bits as selected
Transfer clock	• When internal clock is selected (bit 3 at addresses 03A0₁₆, 03A8₁₆, 0378₁₆ = "0") : $f_i/16(n+1)$ (Note 1) $f_i = f_1, f_8, f_{32}$ • When external clock is selected (bit 3 at addresses 03A0₁₆, 03A8₁₆ = "1") : $f_{EXT}/16(n+1)$ (Note 1) (Note 2) (Do not set external clock for UART2)
Transmission/reception control	• CTS function, RTS function, CTS and RTS function invalid: selectable
Transmission start condition	• To start transmission, the following requirements must be met: - Transmit enable bit (bit 0 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" - Transmit buffer empty flag (bit 1 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "0" - When CTS function selected, CTS input level = "L"
Reception start condition	• To start reception, the following requirements must be met: - Receive enable bit (bit 2 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" - Start bit detection
Interrupt request generation timing	• When transmitting - Transmit interrupt cause select bits (bits 0,1 at address 03B0₁₆, bit4 at address 037D₁₆) = "0": Interrupts requested when data transfer from UARTi transfer buffer register to UARTi transmit register is completed - Transmit interrupt cause select bits (bits 0, 1 at address 03B0₁₆, bit4 at address 037D₁₆) = "1": Interrupts requested when data transmission from UARTi transfer register is completed • When receiving - Interrupts requested when data transfer from UARTi receive register to UARTi receive buffer register is completed
Error detection	• Overrun error (Note 3) This error occurs when the next data is ready before contents of UARTi receive buffer register are read out • Framing error This error occurs when the number of stop bits set is not detected • Parity error This error occurs when if parity is enabled, the number of 1's in parity and character bits does not match the number of 1's set • Error sum flag This flag is set (= 1) when any of the overrun, framing, and parity errors is encountered

Note 1: 'n' denotes the value 00₁₆ to FF₁₆ that is set to the UARTi bit rate generator.

Note 2: f_{EXT} is input from the CLKi pin.

Note 3: If an overrun error occurs, the UARTi receive buffer will have the next data written in. Note also that the UARTi receive interrupt request bit does not change.

Clock asynchronous serial I/O (UART) mode

Table 1.16.6. Specifications of UART Mode (2)

Item	Specification
Select function	• Sleep mode selection (UART0, UART1) This mode is used to transfer data to and from one of multiple slave micro-computers • Serial data logic switch (UART2) This function is reversing logic value of transferring data. Start bit, parity bit and stop bit are not reversed. • Tx/D, Rx/D I/O polarity switch (UART2) This function is reversing Tx/D port output and Rx/D port input. All I/O data level is reversed.

Clock asynchronous serial I/O (UART) mode

UARTi transmit / receive mode registers

b7 b6 b5 b4 b3 b2 b1 b0								Symbol	Address	When reset	
								UiMR(i=0,1)	03A0 ₁₆ , 03A8 ₁₆	00 ₁₆	
								Bit symbol	Bit name	Function	R/W
								SMD0	Serial I/O mode select bit	b2 b1 b0 1 0 0 : Transfer data 7 bits long 1 0 1 : Transfer data 8 bits long 1 1 0 : Transfer data 9 bits long	
								SMD1			
								SMD2			
								CKDIR	Internal / external clock select bit	0 : Internal clock 1 : External clock (Note)	
								STPS	Stop bit length select bit	0 : One stop bit 1 : Two stop bits	
								PRY	Odd / even parity select bit	Valid when bit 6 = “1” 0 : Odd parity 1 : Even parity	
								PRYE	Parity enable bit	0 : Parity disabled 1 : Parity enabled	
								SLEP	Sleep select bit	0 : Sleep mode deselected 1 : Sleep mode selected	

Note : Set the corresponding port direction register to "0".

UART2 transmit / receive mode register

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	When reset	
								U2MR	0378 ₁₆	00 ₁₆	
								Bit symbol	Bit name	Function	R/W
								SMD0	Serial I/O mode select bit	b2 b1 b0 1 0 0 : Transfer data 7 bits long 1 0 1 : Transfer data 8 bits long 1 1 0 : Transfer data 9 bits long	○ ○
								SMD1			○ ○
								SMD2			○ ○
								CKDIR	Internal / external clock select bit	Must always be “0”	○ ○
								STPS	Stop bit length select bit	0 : One stop bit 1 : Two stop bits	○ ○
								PRY	Odd / even parity select bit	Valid when bit 6 = “1” 0 : Odd parity 1 : Even parity	○ ○
								PRYE	Parity enable bit	0 : Parity disabled 1 : Parity enabled	○ ○
								IOPOL	TxD, RxD I/O polarity reverse bit (Note)	0 : No reverse 1 : Reverse	○ ○

Note: Usually set to "0".

Figure 1.16.16. UARTi transmit/receive mode register in UART mode

Clock asynchronous serial I/O (UART) mode

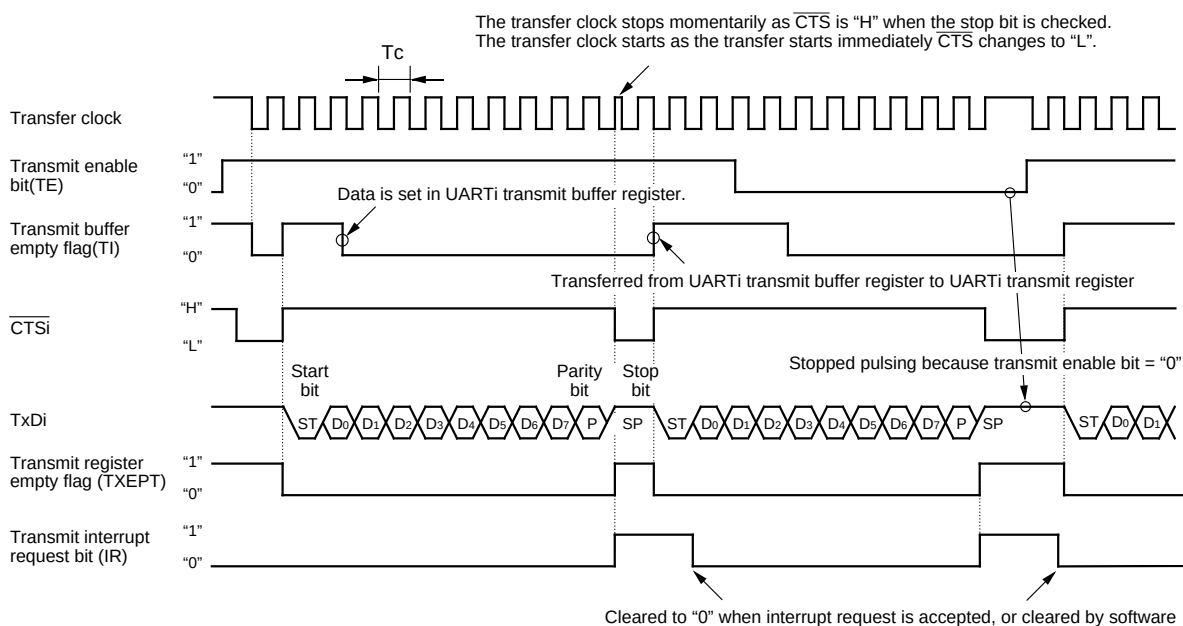
Table 1.16.7 lists the functions of the input/output pins during UART mode. Note that for a period from when the UARTi operation mode is selected to when transfer starts, the TxDi pin outputs an "H". (If the N-channel open-drain is selected, this pin is in floating state.)

Table 1.16.7. Input/output pin functions in UART mode

Pin name	Function	Method of selection
TxDi (P63, P67, P70)	Serial data output	
RxDi (P62, P66, P71)	Serial data input	Port P62, P66 and P71 direction register (bits 2 and 6 at address 03EE16, bit 1 at address 03EF16) = "0" (Can be used as an input port when performing transmission only)
CLKi (P61, P65, P72)	Programmable I/O port	Internal/external clock select bit (bit 3 at address 03A016, 03A816, 037816) = "0"
	Transfer clock input	Internal/external clock select bit (bit 3 at address 03A016, 03A816) = "1" Port P61, P65 direction register (bits 1 and 5 at address 03EE16) = "0" (Do not set external clock for UART2)
CTSi/RTSi (P60, P64, P73)	CTS input	CTS/RTS disable bit (bit 4 at address 03A416, 03AC16, 037C16) = "0" CTS/RTS function select bit (bit 2 at address 03A416, 03AC16, 037C16) = "0" Port P60, P64 and P73 direction register (bits 0 and 4 at address 03EE16, bit 3 at address 03EF16) = "0"
	RTS output	CTS/RTS disable bit (bit 4 at address 03A416, 03AC16, 037C16) = "0" CTS/RTS function select bit (bit 2 at address 03A416, 03AC16, 037C16) = "1"
	Programmable I/O port	CTS/RTS disable bit (bit 4 at address 03A416, 03AC16, 037C16) = "1"

Clock asynchronous serial I/O (UART) mode

• Example of transmit timing when transfer data is 8 bits long (parity enabled, one stop bit)



Shown in () are bit symbols.

The above timing applies to the following settings :

- Parity is enabled.
- One stop bit.
- CTS function is selected.
- Transmit interrupt cause select bit = "1".

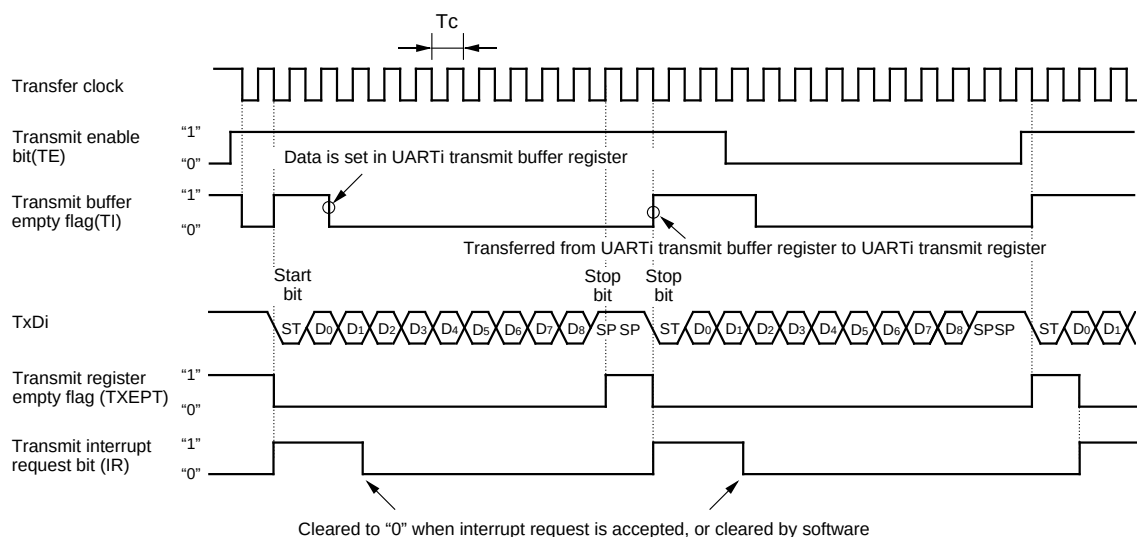
$$T_c = 16(n + 1) / f_i \text{ or } 16(n + 1) / f_{EXT}$$

f_i : frequency of BRGi count source (f_1, f_8, f_{32})

f_{EXT} : frequency of BRGi count source (external clock)

n : value set to BRGi

• Example of transmit timing when transfer data is 9 bits long (parity disabled, two stop bits)



Shown in () are bit symbols.

The above timing applies to the following settings :

- Parity is disabled.
- Two stop bits.
- CTS function is disabled.
- Transmit interrupt cause select bit = "0".

$$T_c = 16(n + 1) / f_i \text{ or } 16(n + 1) / f_{EXT}$$

f_i : frequency of BRGi count source (f_1, f_8, f_{32})

f_{EXT} : frequency of BRGi count source (external clock)

n : value set to BRGi

Figure 1.16.17. Typical transmit timings in UART mode(UART0,UART1)

Clock asynchronous serial I/O (UART) mode

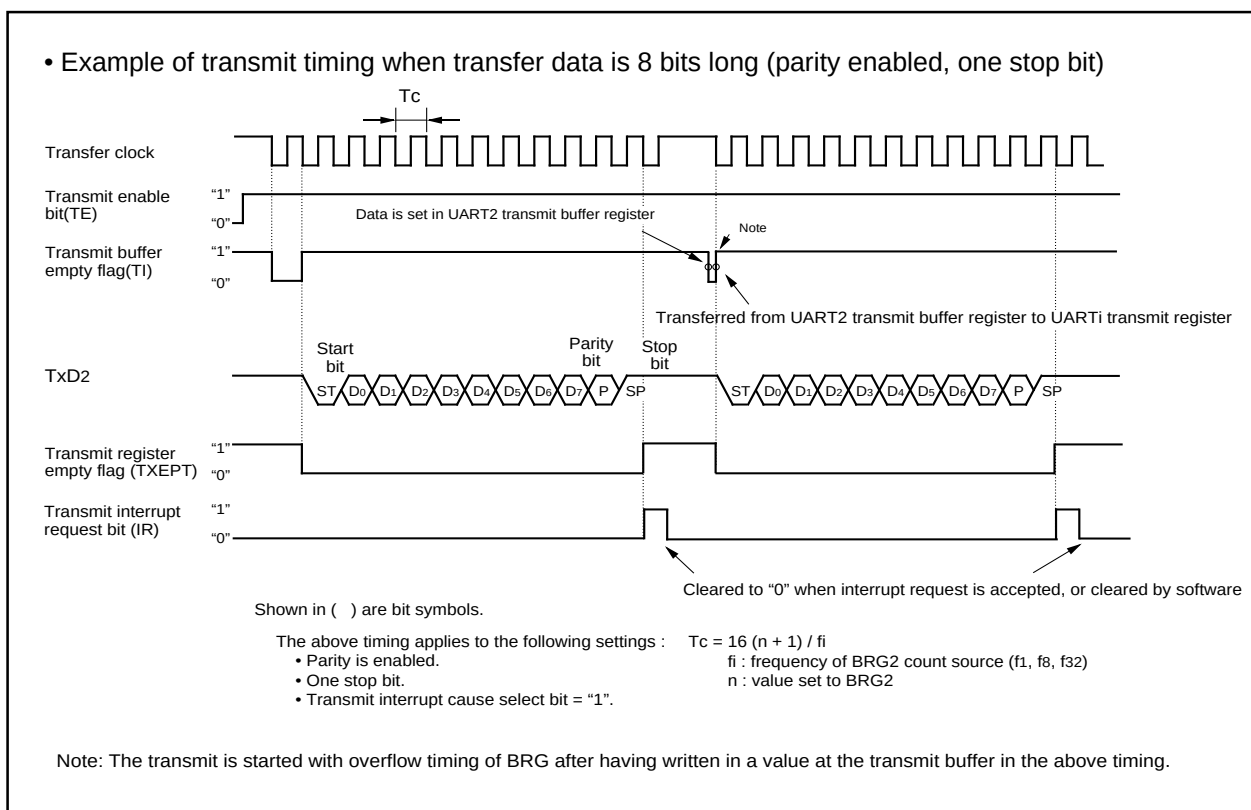


Figure 1.16.18. Typical transmit timings in UART mode(UART2)

Clock asynchronous serial I/O (UART) mode

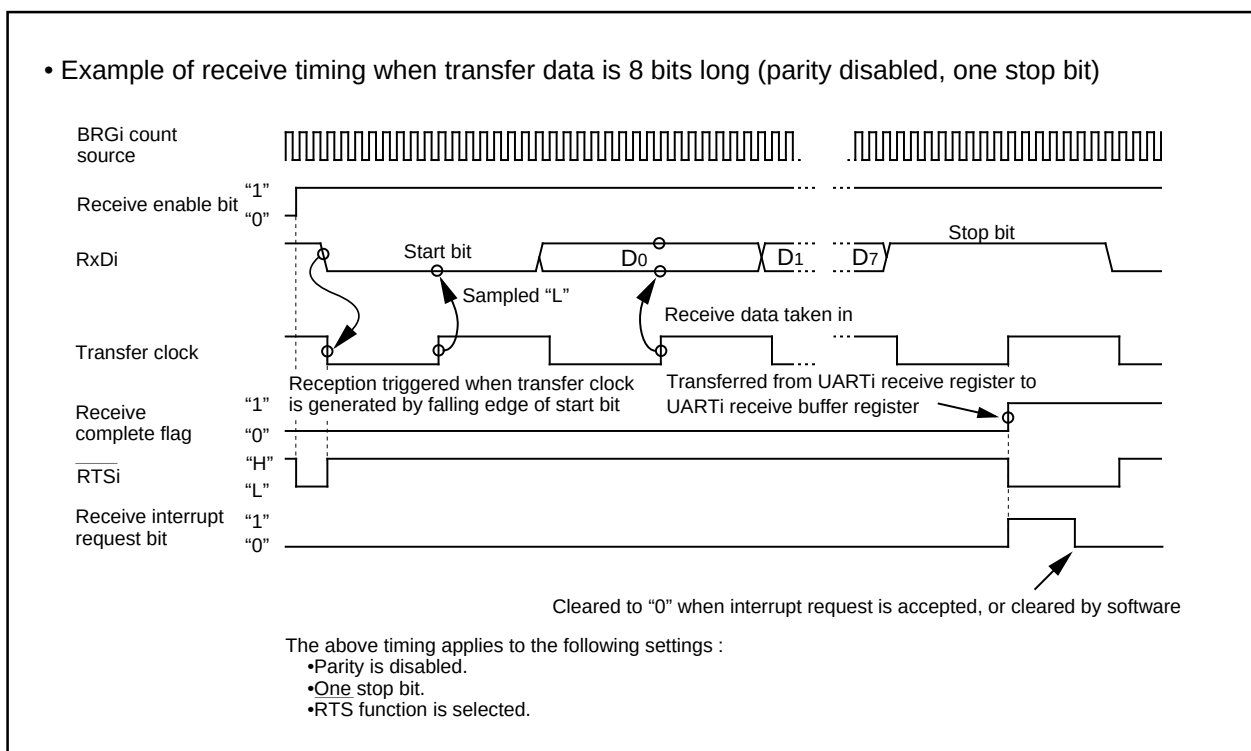


Figure 1.16.19. Typical receive timing in UART mode

(a) Sleep mode (UART0, UART1)

This mode is used to transfer data between specific microcomputers among multiple microcomputers connected using UARTi. The sleep mode is selected when the sleep select bit (bit 7 at addresses 03A016, 03A816) is set to "1" during reception. In this mode, the unit performs receive operation when the MSB of the received data = "1" and does not perform receive operation when the MSB = "0".

(b) Function for switching serial data logic (UART2)

When the data logic select bit (bit 6 of address 037D16) is assigned 1, data is inverted in writing to the transmission buffer register or reading the reception buffer register. Figure 1.16.20 shows the example of timing for switching serial data logic.

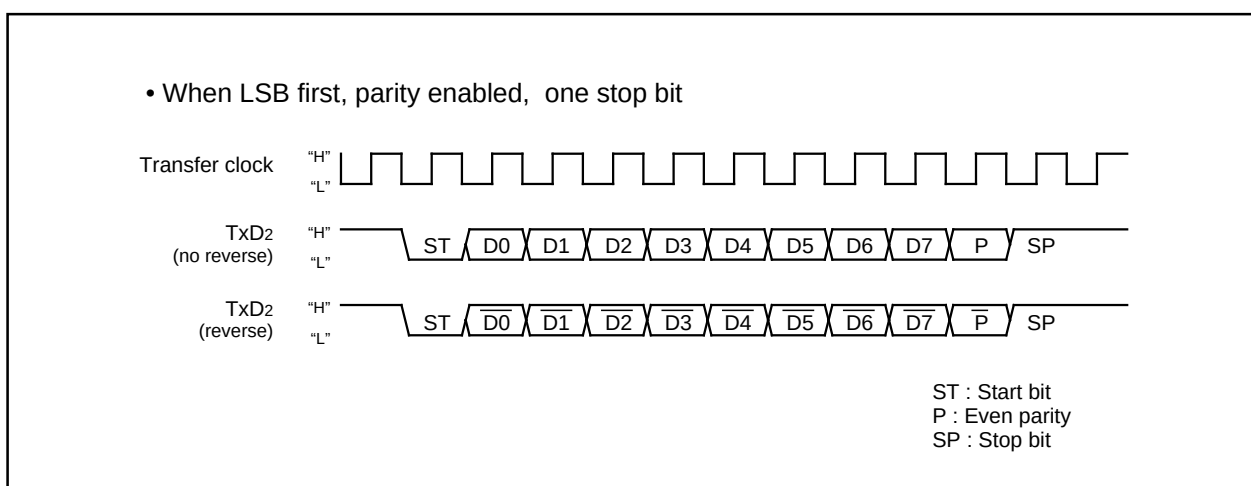


Figure 1.16.20. Timing for switching serial data logic

Clock asynchronous serial I/O (UART) mode

(c) TxD, RxD I/O polarity reverse function (UART2)

This function is to reverse TxD pin output and RxD pin input. The level of any data to be input or output (including the start bit, stop bit(s), and parity bit) is reversed. Set this function to "0" (not to reverse) for usual use.

(d) Bus collision detection function (UART2)

This function is to sample the output level of the TxD pin and the input level of the RxD pin at the rising edge of the transfer clock; if their values are different, then an interrupt request occurs. Figure 1.16.21 shows the example of detection timing of a bus collision (in UART mode).

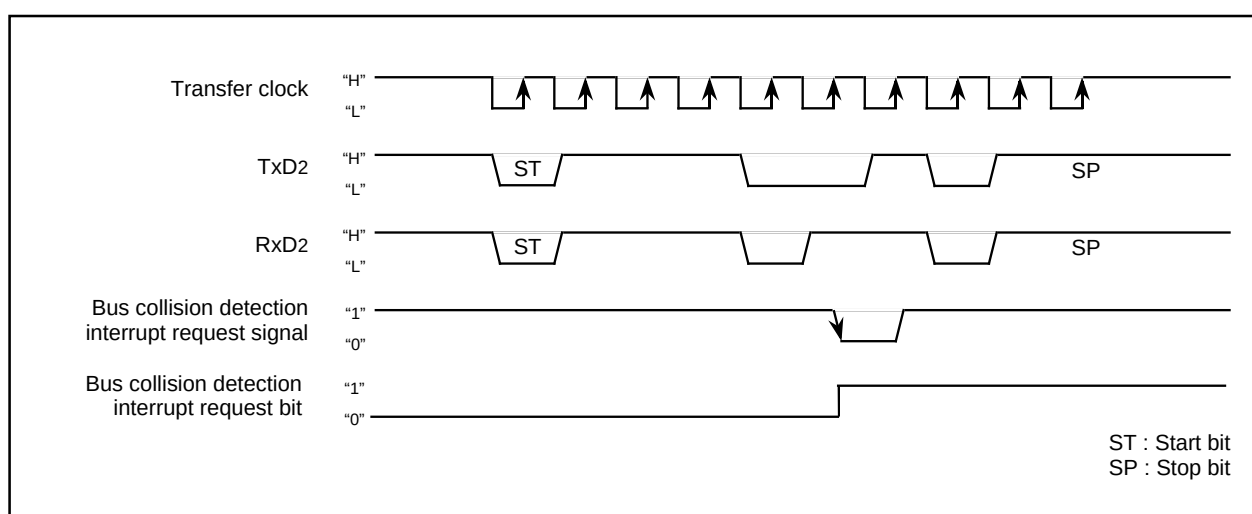


Figure 1.16.21. Detection timing of a bus collision (in UART mode)

Clock asynchronous serial I/O (UART) mode

(3) Clock-asynchronous serial I/O mode (used for the SIM interface)

The SIM interface is used for connecting the microcomputer with a memory card or the like; adding some extra settings in UART2 clock-asynchronous serial I/O mode allows the user to effect this function. Table 1.16.8 shows the specifications of clock-asynchronous serial I/O mode (used for the SIM interface).

Table 1.16.8. Specifications of clock-asynchronous serial I/O mode (used for the SIM interface)

Item	Specification
Transfer data format	• Transfer data 8-bit UART mode (bit 2 through bit 0 of address 0378₁₆ = "1012") • One stop bit (bit 4 of address 0378₁₆ = "0") • With the direct format chosen - Set parity to "even" (bit 5 and bit 6 of address 0378₁₆ = "1" and "1" respectively) - Set data logic to "direct" (bit 6 of address 037D₁₆ = "0"). - Set transfer format to LSB (bit 7 of address 037C₁₆ = "0"). • With the inverse format chosen - Set parity to "odd" (bit 5 and bit 6 of address 0378₁₆ = "0" and "1" respectively) - Set data logic to "inverse" (bit 6 of address 037D₁₆ = "1") - Set transfer format to MSB (bit 7 of address 037C₁₆ = "1")
Transfer clock	• With the internal clock chosen (bit 3 of address 0378₁₆ = "0") : $f_i / 16 (n + 1)$ (Note 1) : $f_i = f_1, f_8, f_{32}$ (Do not set external clock)
Transmission / reception control	• Disable the $\overline{\text{CTS}}$ and $\overline{\text{RTS}}$ function (bit 4 of address 037C₁₆ = "1")
Other settings	• The sleep mode select function is not available for UART2 • Set transmission interrupt factor to "transmission completed" (bit 4 of address 037D₁₆ = "1")
Transmission start condition	• To start transmission, the following requirements must be met: - Transmit enable bit (bit 0 of address 037D₁₆) = "1" - Transmit buffer empty flag (bit 1 of address 037D₁₆) = "0"
Reception start condition	• To start reception, the following requirements must be met: - Reception enable bit (bit 2 of address 037D₁₆) = "1" - Detection of a start bit
Interrupt request generation timing	• When transmitting - When data transmission from the UART2 transmit register is completed (bit 4 of address 037D₁₆ = "1") • When receiving - When data transfer from the UART2 receive register to the UART2 receive buffer register is completed
Error detection	• Overrun error (see the specifications of clock-asynchronous serial I/O) (Note 2) • Framing error (see the specifications of clock-asynchronous serial I/O) • Parity error (see the specifications of clock-asynchronous serial I/O) - On the reception side, an "L" level is output from the TxD₂ pin by use of the parity error signal output function (bit 7 of address 037D₁₆ = "1") when a parity error is detected - On the transmission side, a parity error is detected by the level of input to the RxD₂ pin when a transmission interrupt occurs • The error sum flag (see the specifications of clock-asynchronous serial I/O)

Note 1: 'n' denotes the value 00₁₆ to FF₁₆ that is set to the UART2 bit rate generator.

Note 2: If an overrun error occurs, the UART2 receive buffer will have the next data written in. Note also that the UART2 receive interrupt request bit does not change.

Clock asynchronous serial I/O (UART) mode

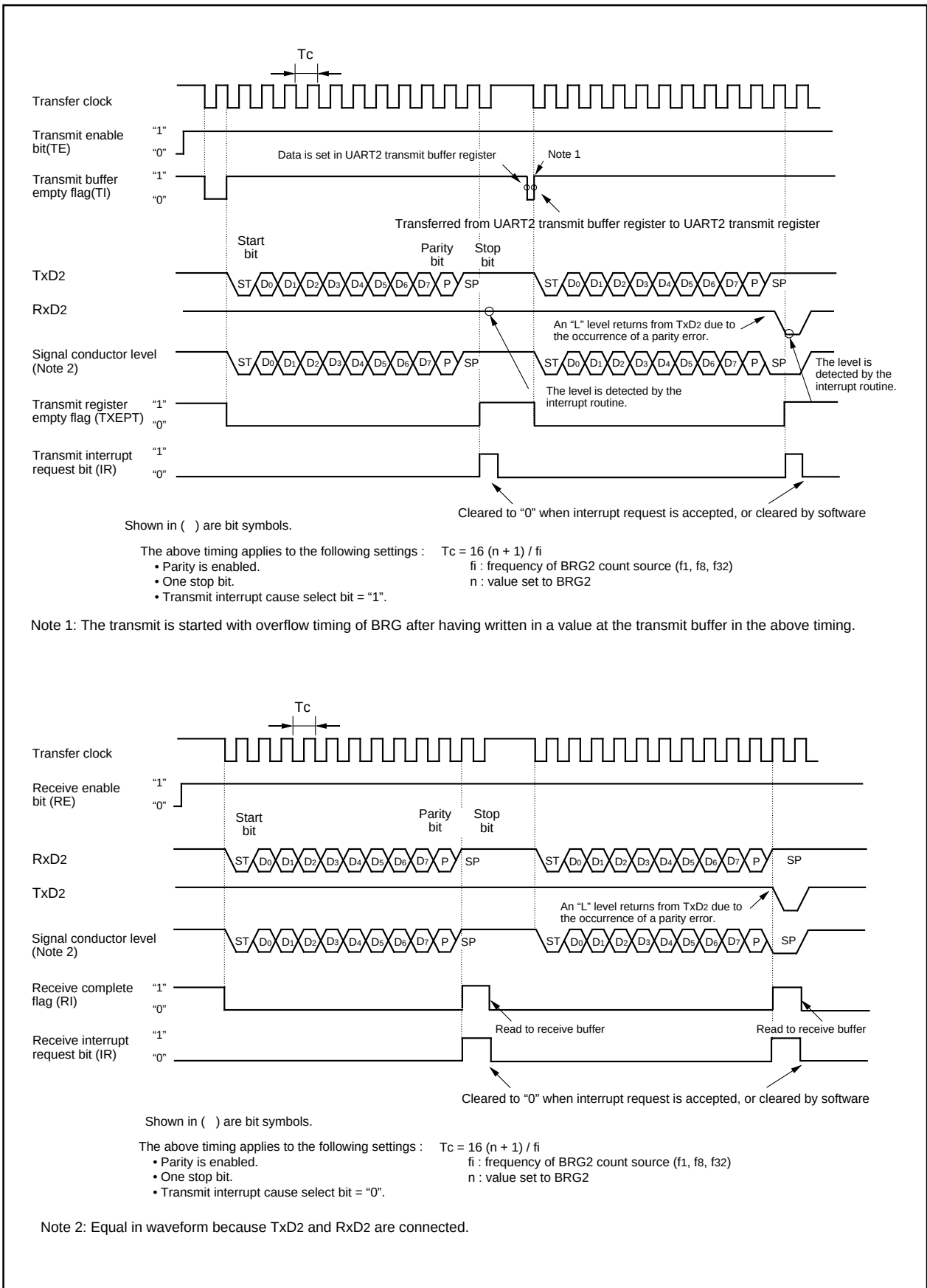


Figure 1.16.22. Typical transmit/receive timing in UART mode (used for the SIM interface)

Clock asynchronous serial I/O (UART) mode

(a) Function for outputting a parity error signal

During reception, with the error signal output enable bit (bit 7 of address 037D16) assigned "1", you can output an "L" level from the TxD2 pin when a parity error is detected. And during transmission, comparing with the case in which the error signal output enable bit (bit 7 of address 037D16) is assigned "0", the transmission completion interrupt occurs in the half cycle later of the transfer clock. Therefore parity error signals can be detected by a transmission completion interrupt program. Figure 1.16.23 shows the output timing of the parity error signal.

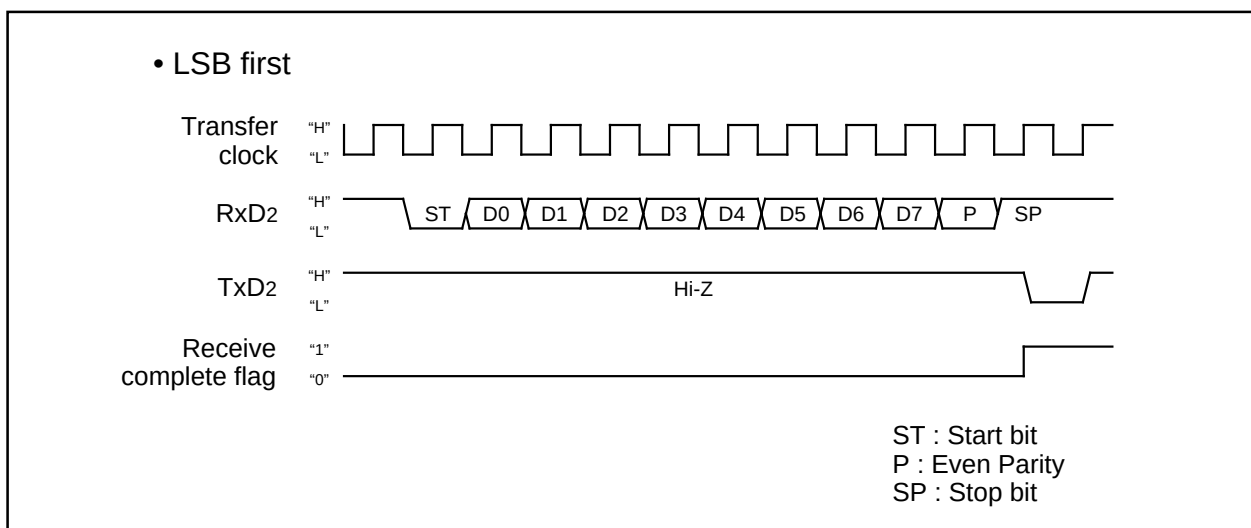


Figure 1.16.23. Output timing of the parity error signal

(b) Direct format/inverse format

Connecting the SIM card allows you to switch between direct format and inverse format. If you choose the direct format, D0 data is output from TxD2. If you choose the inverse format, D7 data is inverted and output from TxD2.

Figure 1.16.24 shows the SIM interface format.

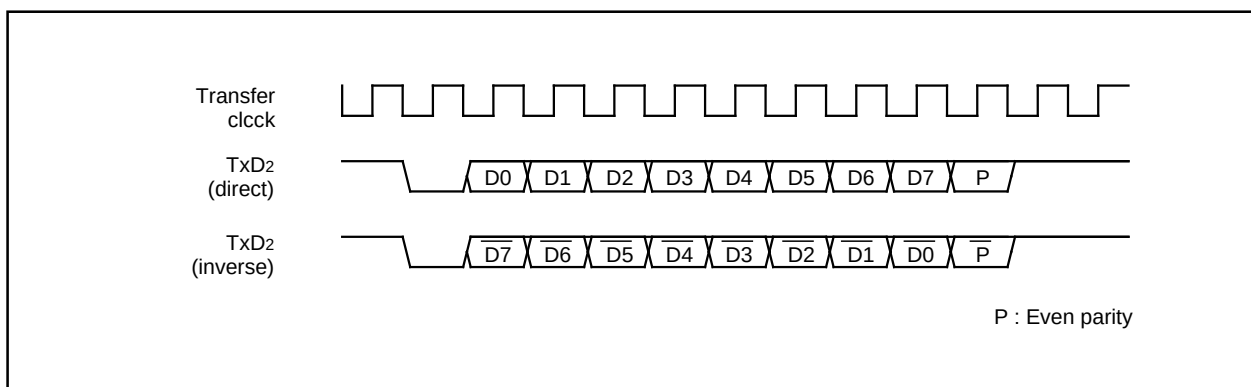


Figure 1.16.24. SIM interface format

Clock asynchronous serial I/O (UART) mode

Figure 1.16.25 shows the example of connecting the SIM interface. Connect TxD2 and RxD2 and apply pull-up.

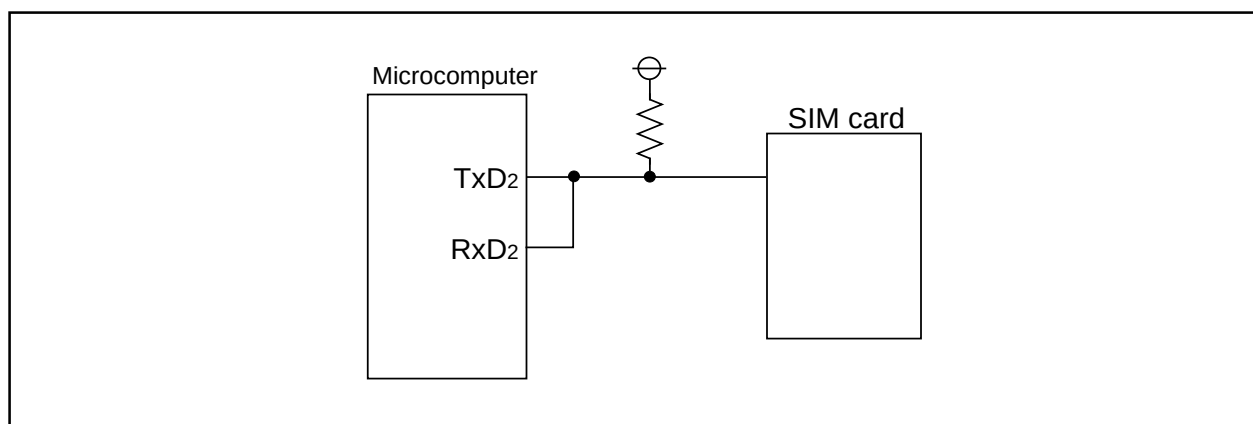


Figure 1.16.25. Connecting the SIM interface

UART2 Special Mode Register

UART2 Special Mode Register

The UART2 special mode register (address 037716) is used to control UART2 in various ways.

Figure 1.16.26 shows the UART2 special mode register.

Bit 0 of the UART2 special mode register (037716) is used as the I²C mode select bit.

Setting "1" in the I²C mode select bit (bit 0) goes the circuit to achieve the I²C bus (simplified I²C bus) interface effective.

Table 1.16.9 shows the relation between the I²C mode select bit and respective control workings.

Since this function uses clock-synchronous serial I/O mode, set this bit to "0" in UART mode.

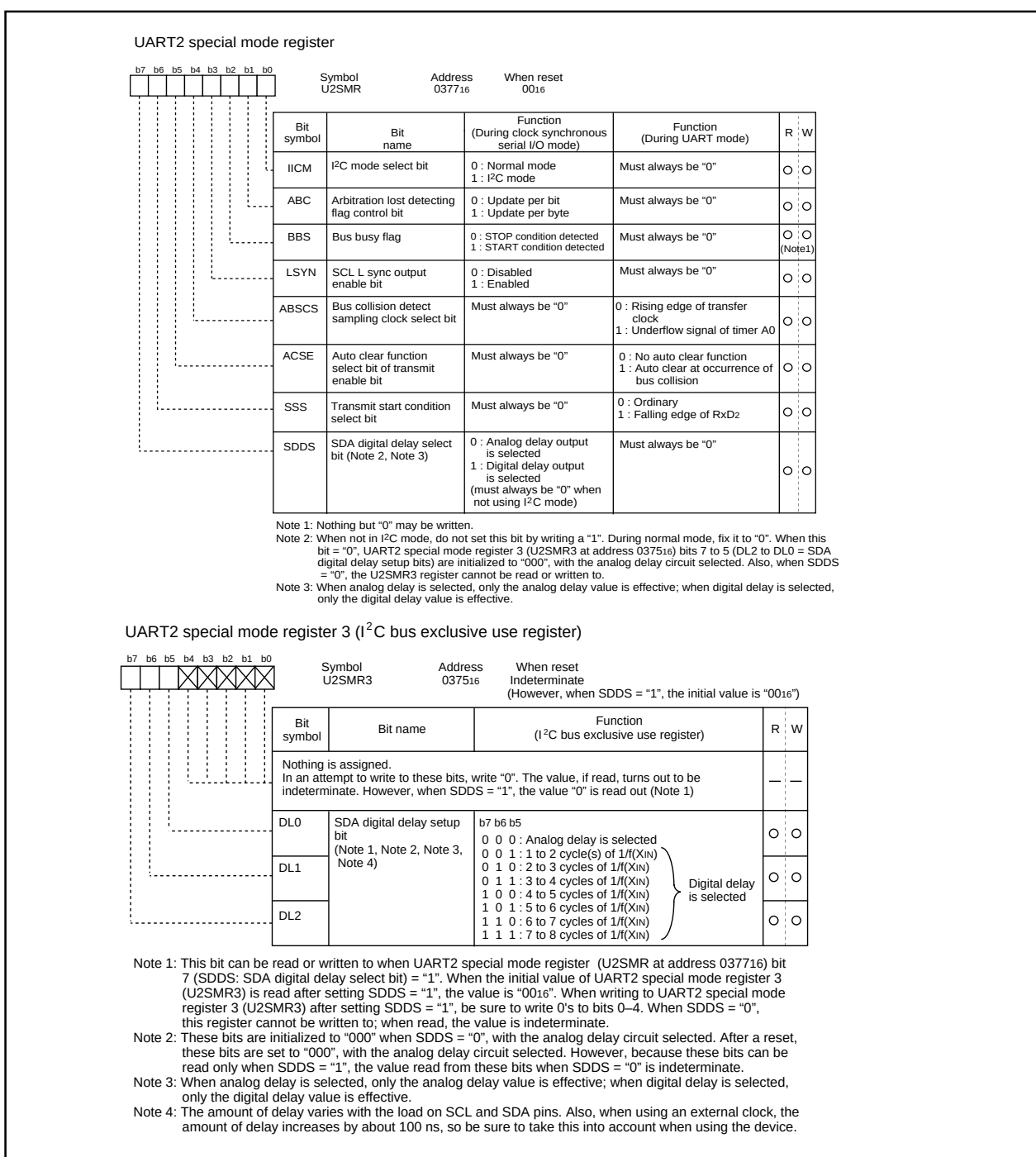
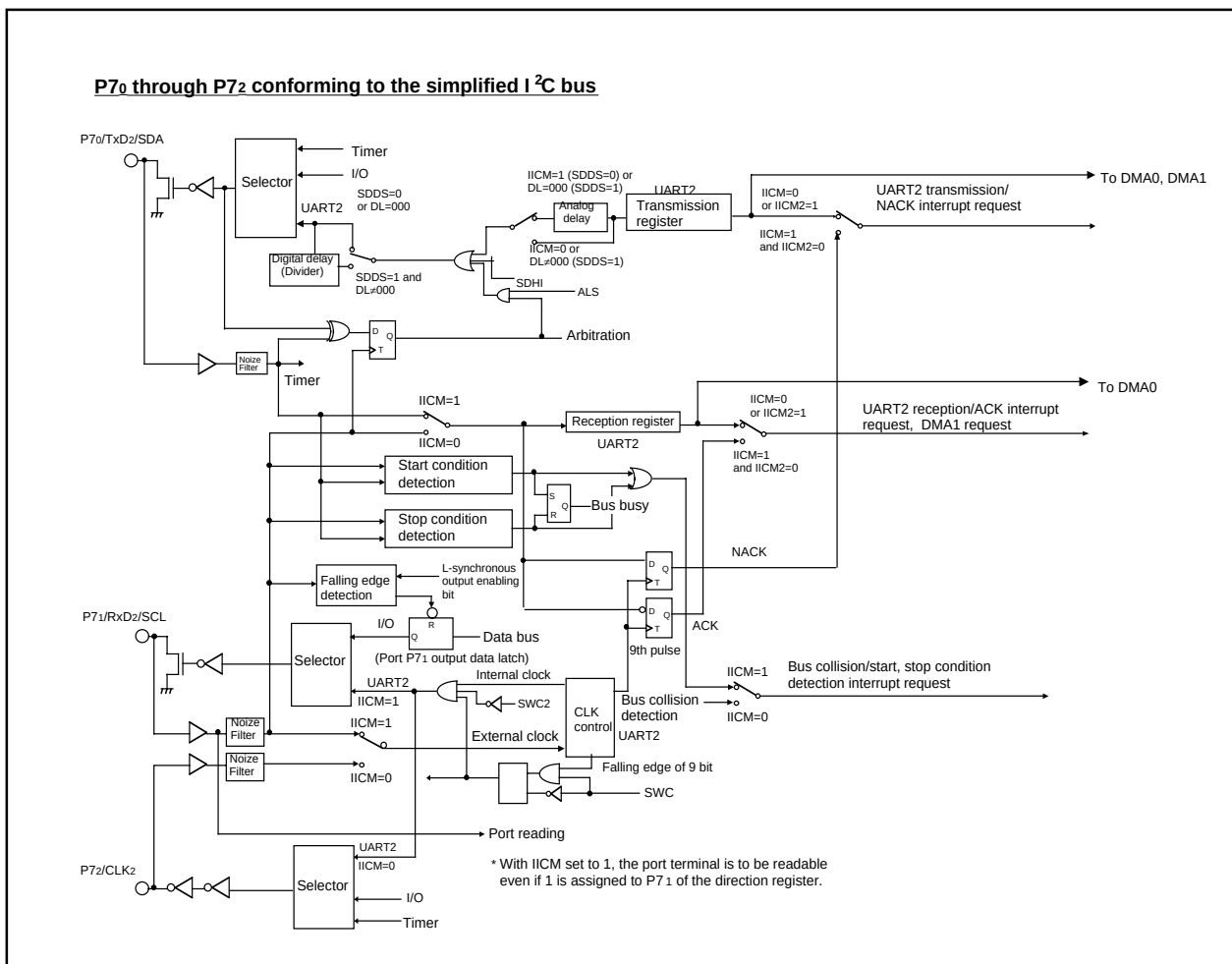


Figure 1.16.26. UART2 special mode register

UART2 Special Mode Register

Figure 1.16.27. Functional block diagram for I²C modeTable 1.16.9. Features in I²C mode

	Function	Normal mode	I ² C mode (Note 1)
1	Factor of interrupt number 10 (Note 2)	Bus collision detection	Start condition detection or stop condition detection
2	Factor of interrupt number 15 (Note 2)	UART2 transmission	No acknowledgment detection (NACK)
3	Factor of interrupt number 16 (Note 2)	UART2 reception	Acknowledgment detection (ACK)
4	UART2 transmission output delay	Not delayed	Delayed
5	P70 at the time when UART2 is in use	TxD2 (output)	SDA (input/output) (Note 3)
6	P71 at the time when UART2 is in use	RxD2 (input)	SCL (input/output)
7	P72 at the time when UART2 is in use	CLK2	P72
8	DMA1 factor at the time when 1 1 0 1 is assigned to the DMA request factor selection bits	UART2 reception	Acknowledgment detection (ACK)
9	Noise filter width	15ns	50ns
10	Reading P71	Reading the terminal when 0 is assigned to the direction register	Reading the terminal regardless of the value of the direction register
11	Initial value of UART2 output	H level (when 0 is assigned to the CLK polarity select bit)	The value set in latch P70 when the port is selected

Note 1: Make the settings given below when I²C mode is in use.

Set 0 1 0 in bits 2, 1, 0 of the UART2 transmission/reception mode register.

Disable the RTS/CTS function. Choose the MSB First function.

Note 2: Follow the steps given below to switch from a factor to another.

1. Disable the interrupt of the corresponding number.

2. Switch from a factor to another.

3. Reset the interrupt request flag of the corresponding number.

4. Set an interrupt level of the corresponding number.

Note 3: Set an initial value of SDA transmission output when serial I/O is invalid.

UART2 Special Mode Register

Figure 1.16.27 shows the functional block diagram for I²C mode. Setting “1” in the I²C mode select bit (IICM) causes ports P70, P71, and P72 to work as data transmission-reception terminal SDA, clock input-output terminal SCL, and port P72 respectively. A delay circuit is added to the SDA transmission output, so the SDA output changes after SCL fully goes to “L”. The SDA digital delay select bit (bit 7 at address 037716) can be used to select between analog delay and digital delay. When digital delay is selected, the amount of delay can be selected in the range of 2 cycles to 8 cycles of f1 using UART2 special mode register 3 (at address 037516). Delay circuit select conditions are shown in Table 1.16.10.

Table 1.16.10. Delay circuit select conditions

	Register value			Contents
	IICM	SDDS	DL	
Digital delay is selected	1	1	001 to 111	When digital delay is selected, no analog delay is added. Only digital delay is effective.
Analog delay is selected	1	1	000	When DL is set to “000”, analog delay is selected no matter what value is set in SDDS.
		0	(000)	When SDDS is set to “0”, DL is initialized, so that DL = “000”.
No delay	0	0	(000)	When IICM = “0”, no delay circuit is selected. When IICM = “0”, however, always make sure SDDS = “0”.

An attempt to read Port P71 (SCL) results in getting the terminal's level regardless of the content of the port direction register. The initial value of SDA transmission output in this mode goes to the value set in port P70. The interrupt factors of the bus collision detection interrupt, UART2 transmission interrupt, and of UART2 reception interrupt turn to the start/stop condition detection interrupt, acknowledgment non-detection interrupt, and acknowledgment detection interrupt respectively.

The start condition detection interrupt refers to the interrupt that occurs when the falling edge of the SDA terminal (P70) is detected with the SCL terminal (P71) staying “H”. The stop condition detection interrupt refers to the interrupt that occurs when the rising edge of the SDA terminal (P70) is detected with the SCL terminal (P71) staying “H”. The bus busy flag (bit 2 of the UART2 special mode register) is set to “1” by the start condition detection, and set to “0” by the stop condition detection.

The acknowledgment non-detection interrupt refers to the interrupt that occurs when the SDA terminal level is detected still staying “H” at the rising edge of the 9th transmission clock. The acknowledgment detection interrupt refers to the interrupt that occurs when SDA terminal's level is detected already went to “L” at the 9th transmission clock. Also, assigning 1 1 0 1 (UART2 reception) to the DMA1 request factor select bits provides the means to start up the DMA transfer by the effect of acknowledgment detection.

Bit 1 of the UART2 special mode register (037716) is used as the arbitration lost detecting flag control bit. Arbitration means the act of detecting the nonconformity between transmission data and SDA terminal data at the timing of the SCL rising edge. This detecting flag is located at bit 11 of the UART2 reception buffer register (037F16, 037E16), and “1” is set in this flag when nonconformity is detected. Use the arbitration lost detecting flag control bit to choose which way to use to update the flag, bit by bit or byte by byte. When setting this bit to “1” and updated the flag byte by byte if nonconformity is detected, the arbitration lost detecting flag is set to “1” at the falling edge of the 9th transmission clock.

If update the flag byte by byte, must judge and clear (“0”) the arbitration lost detecting flag after completing the first byte acknowledge detect and before starting the next one byte transmission.

Bit 3 of the UART2 special mode register is used as SCL- and L-synchronous output enable bit. Setting this bit to “1” goes the P71 data register to “0” in synchronization with the SCL terminal level going to “L”.

UART2 Special Mode Register

Some other functions added are explained here. Figure 1.16.28 shows their workings.

Bit 4 of the UART2 special mode register is used as the bus collision detect sampling clock select bit. The bus collision detect interrupt occurs when the RxD2 level and TxD2 level do not match, but the nonconformity is detected in synchronization with the rising edge of the transfer clock signal if the bit is set to "0". If this bit is set to "1", the nonconformity is detected at the timing of the overflow of timer A0 rather than at the rising edge of the transfer clock.

Bit 5 of the UART2 special mode register is used as the auto clear function select bit of transmit enable bit. Setting this bit to "1" automatically resets the transmit enable bit to "0" when "1" is set in the bus collision detect interrupt request bit (nonconformity).

Bit 6 of the UART2 special mode register is used as the transmit start condition select bit. Setting this bit to "1" starts the TxD transmission in synchronization with the falling edge of the RxD terminal.

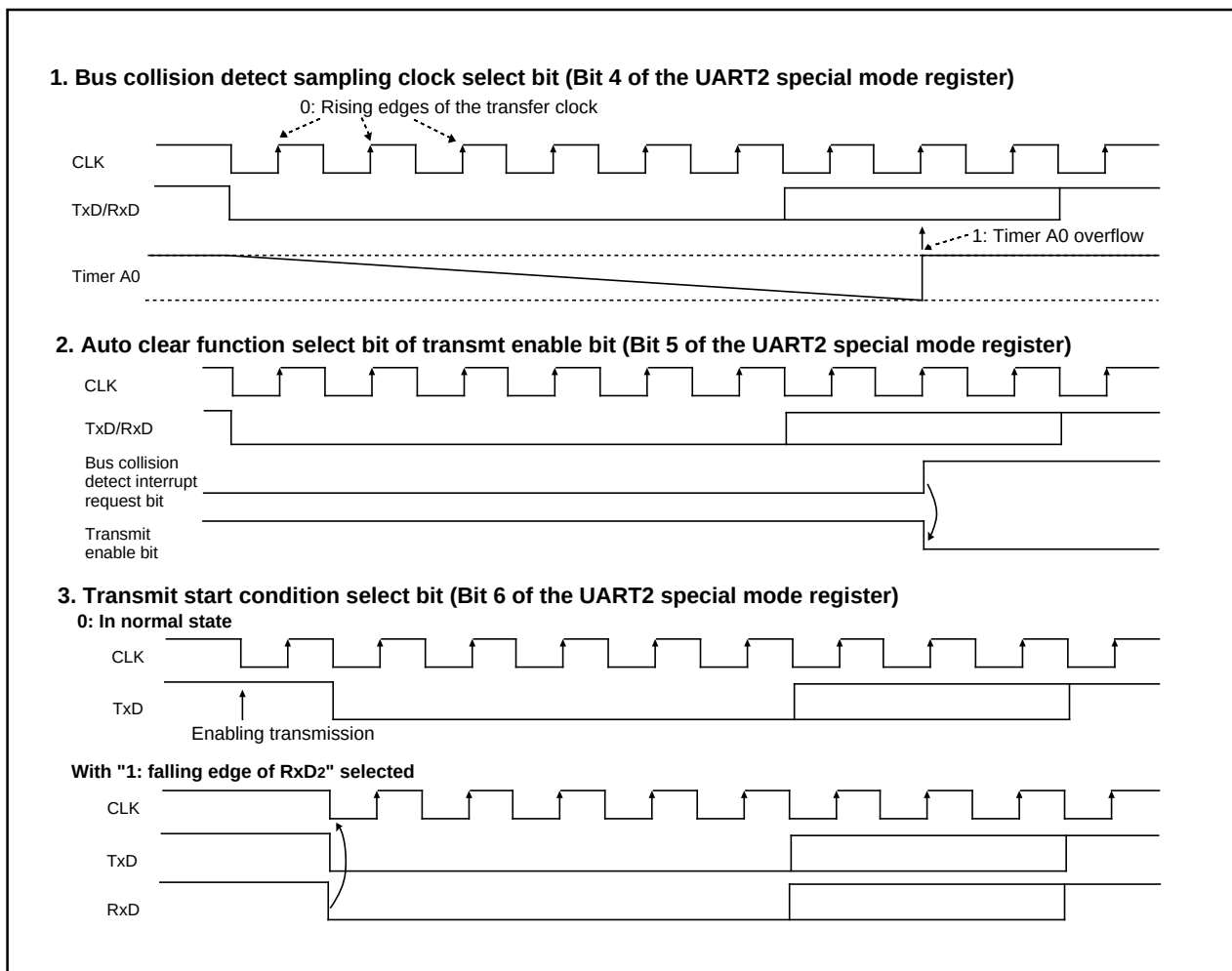


Figure 1.16.28. Some other functions added

UART2 Special Mode Register 2

UART2 Special Mode Register 2

UART2 special mode register 2 (address 037616) is used to further control UART2 in I²C mode. Figure 1.16.29 shows the UART2 special mode register 2.

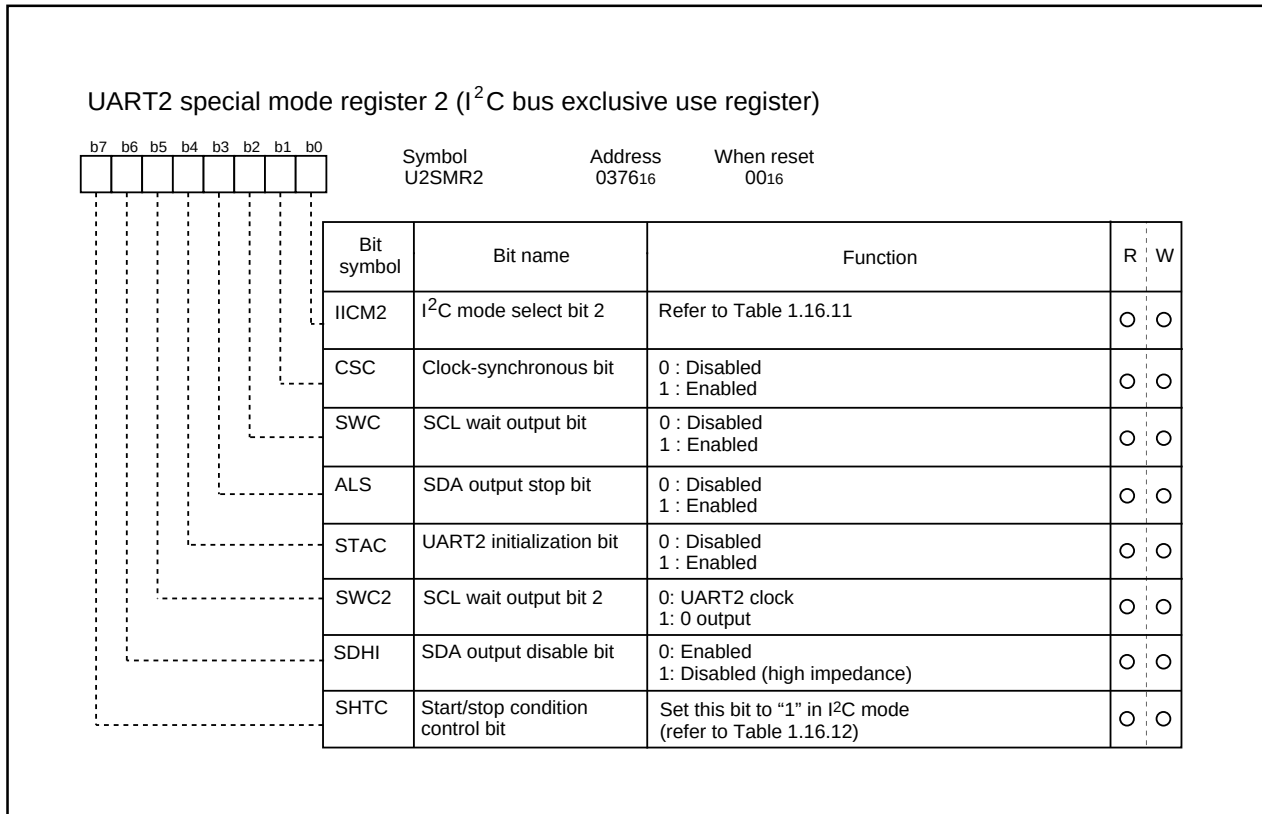


Figure 1.16.29. UART2 special mode register 2

UART2 Special Mode Register 2

Bit 0 of the UART2 special mode register 2 (address 037616) is used as the I²C mode select bit 2. Table 1.16.11 shows the types of control to be changed by I²C mode select bit 2 when the I²C mode select bit is set to "1". Table 1.16.12 shows the timing characteristics of detecting the start condition and the stop condition. Set the start/stop condition control bit (bit 7 of UART2 special mode register 2) to "1" in I²C mode.

Table 1.16.11. Functions changed by I²C mode select bit 2

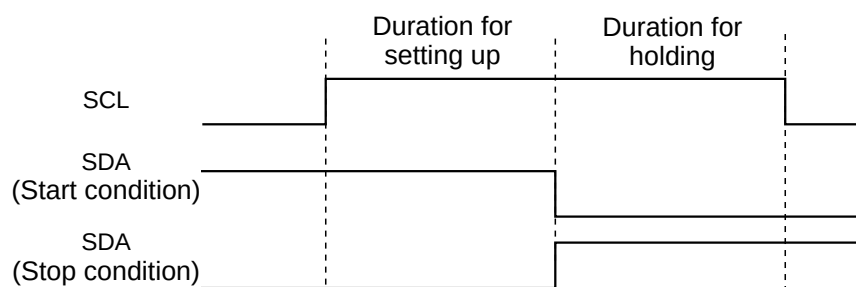
	Function	IICM2 = 0	IICM2 = 1
1	Factor of interrupt number 15	No acknowledgment detection (NACK)	UART2 transmission (the rising edge of the final bit of the clock)
2	Factor of interrupt number 16	Acknowledgment detection (ACK)	UART2 reception (the falling edge of the final bit of the clock)
3	DMA1 factor at the time when 1 1 0 1 is assigned to the DMA request factor selection bits	Acknowledgment detection (ACK)	UART2 reception (the falling edge of the final bit of the clock)
4	Timing for transferring data from the UART2 reception shift register to the reception buffer.	The rising edge of the final bit of the reception clock	The falling edge of the final bit of the reception clock
5	Timing for generating a UART2 reception/ACK interrupt request	The rising edge of the final bit of the reception clock	The falling edge of the final bit of the reception clock

Table 1.16.12. Timing characteristics of detecting the start condition and the stop condition (Note 1)

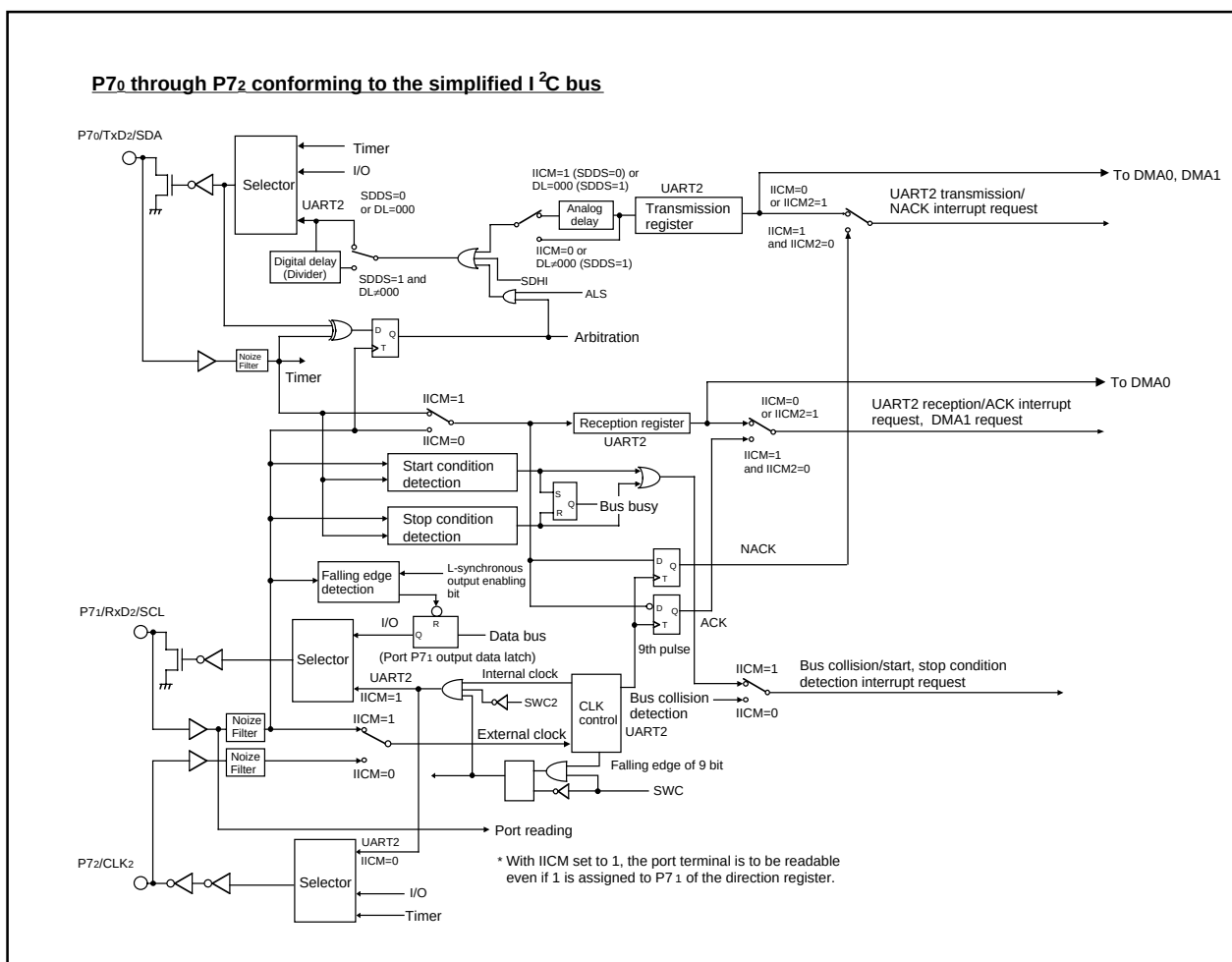
3 to 6 cycles < duration for setting-up (Note 2)
3 to 6 cycles < duration for holding (Note 2)

Note 1 : When the start/stop condition control bit SHTC is "1".

Note 2 : "Cycles" is in terms of the input oscillation frequency $f(X_{IN})$ of the main clock.



UART2 Special Mode Register 2

Figure 1.16.30. Functional block diagram for I²C mode

Functions available in I²C mode are shown in Figure 1.16.30 — a functional block diagram.

Bit 3 of the UART2 special mode register 2 (address 0376₁₆) is used as the SDA output stop bit. Setting this bit to “1” causes an arbitration loss to occur, and the SDA pin turns to high-impedance state at the instant when the arbitration lost detecting flag is set to “1”.

Bit 1 of the UART2 special mode register 2 (address 0376₁₆) is used as the clock synchronization bit. With this bit set to “1” at the time when the internal SCL is set to “H”, the internal SCL turns to “L” if the falling edge is found in the SCL pin; and the baud rate generator reloads the set value, and start counting within the “L” interval. When the internal SCL changes from “L” to “H” with the SCL pin set to “L”, stops counting the baud rate generator, and starts counting it again when the SCL pin turns to “H”. Due to this function, the UART2 transmission-reception clock becomes the logical product of the signal flowing through the internal SCL and that flowing through the SCL pin. This function operates over the period from the moment earlier by a half cycle than falling edge of the UART2 first clock to the rising edge of the ninth bit. To use this function, choose the internal clock for the transfer clock.

Bit 2 of the UART2 special mode register 2 (0376₁₆) is used as the SCL wait output bit. Setting this bit to “1” causes the SCL pin to be fixed to “L” at the falling edge of the ninth bit of the clock. Setting this bit to “0” frees the output fixed to “L”.

UART2 Special Mode Register 2

Bit 4 of the UART2 special mode register 2 (address 0376₁₆) is used as the UART2 initialization bit. Setting this bit to “1”, and when the start condition is detected, the microcomputer operates as follows.

- (1) The transmission shift register is initialized, and the content of the transmission register is transferred to the transmission shift register. This starts transmission by dealing with the clock entered next as the first bit. The UART2 output value, however, doesn't change until the first bit data is output after the entrance of the clock, and remains unchanged from the value at the moment when the microcomputer detected the start condition.
- (2) The reception shift register is initialized, and the microcomputer starts reception by dealing with the clock entered next as the first bit.
- (3) The SCL wait output bit turns to “1”. This turns the SCL pin to “L” at the falling edge of the ninth bit of the clock.

Starting to transmit/receive signals to/from UART2 using this function doesn't change the value of the transmission buffer empty flag. To use this function, choose the external clock for the transfer clock.

Bit 5 of the UART2 special mode register 2 (0376₁₆) is used as the SCL pin wait output bit 2. Setting this bit to “1” with the serial I/O specified allows the user to forcibly output an “1” from the SCL pin even if UART2 is in operation. Setting this bit to “0” frees the “L” output from the SCL pin, and the UART2 clock is input/output.

Bit 6 of the UART2 special mode register 2 (0376₁₆) is used as the SDA output disable bit. Setting this bit to “1” forces the SDA pin to turn to the high-impedance state. Refrain from changing the value of this bit at the rising edge of the UART2 transfer clock. There can be instances in which arbitration lost detecting flag is turned on.

S I/O3, 4

S I/O3, 4

S I/O3 and S I/O4 are exclusive clock-synchronous serial I/Os.

Figure 1.16.31 shows the S I/O3, 4 block diagram, and Figure 1.16.32 shows the S I/O3, 4 related register.

Table 1.16.13 shows the specifications of S I/O3, 4.

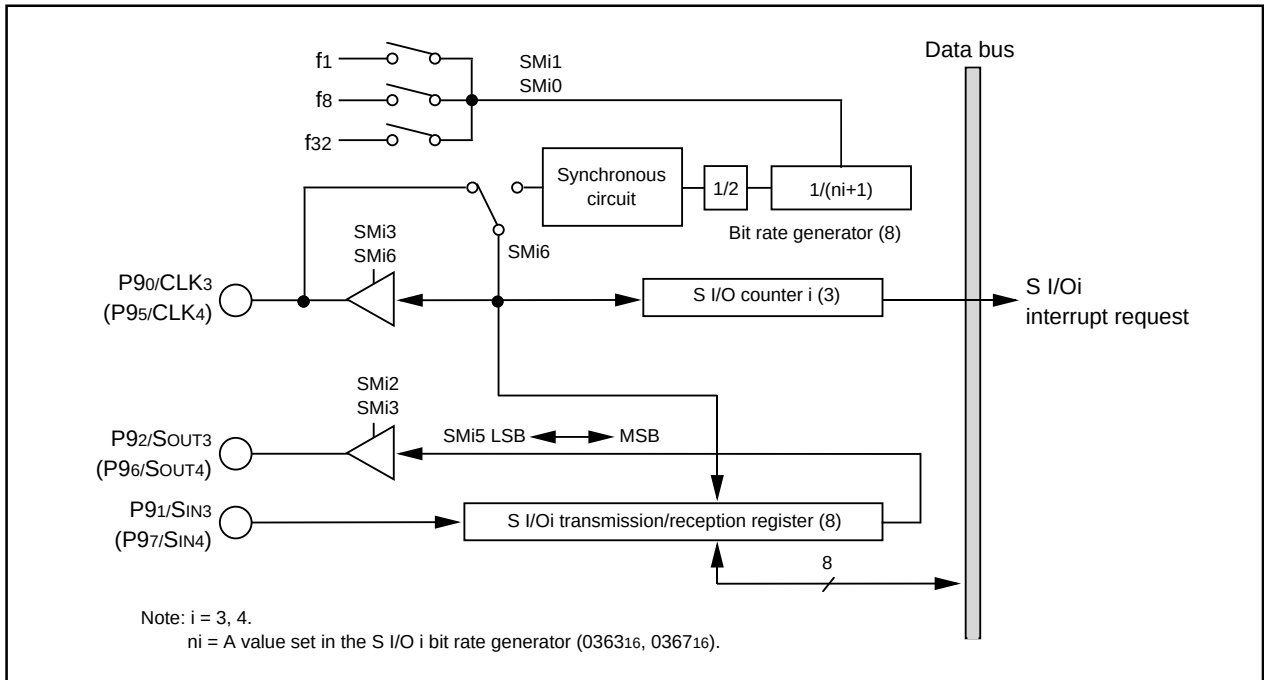
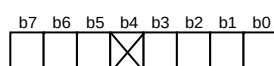


Figure 1.16.31. S I/O3, 4 block diagram

S I/O3, 4

S I/Oi control register (i = 3, 4) (Note 1)



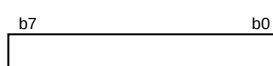
Symbol Address When reset
SiC 0362₁₆, 0366₁₆ 40₁₆

Bit symbol	Bit name	Description	R	W
SMi0	Internal synchronous clock select bit	b1 b0 : Selecting f ₁ 0 0 : Selecting f ₈ 0 1 : Selecting f ₈ 1 0 : Selecting f ₃₂ 1 1 : Must not be set.	○	○
SMi1			○	○
SMi2		0 : Souti output 1 : Souti output disable(high impedance)	○	○
SMi3		0 : Input-output port 1 : Souti output, CLK function	○	○
	Nothing is assigned. In an attempt to write to this bit, write "0". The value, if read, turns out to be "0".		—	—
SMi5	Transfer direction select bit	0 : LSB first 1 : MSB first	○	○
SMi6	Synchronous clock select bit (Note 2)	0 : External clock 1 : Internal clock	○	○
SMi7	Souti initial value set bit	Effective when SMi3 = 0 0 : L output 1 : H output	○	○

Note 1: Set "1" in bit 2 of the protection register (000A₁₆) in advance to write to the S I/Oi control register (i = 3, 4).

Note 2: When using the port as an input/output port by setting the S I/Oi port select bit (i = 3, 4) to "0", be sure to set the sync clock select bit to "1".

S I/Oi bit rate generator (Note 1, 2)



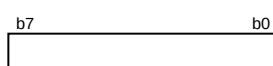
Symbol Address When reset
S3BRG 0363₁₆ Indeterminate
S4BRG 0367₁₆ Indeterminate

Indeterminate	Values that can be set	R	W
Assuming that set value = n, BRGi divides the count source by n + 1	00 ₁₆ to FF ₁₆		○

Note 1: Write a value to this register while transmit/receive halts.

Note 2: Use MOV instruction to write to this register.

S I/Oi transmit/receive register (Note)



Symbol Address When reset
S3TRR 0360₁₆ Indeterminate
S4TRR 0364₁₆ Indeterminate

Indeterminate	R	W
Transmission/reception starts by writing data to this register. After transmission/reception finishes, reception data is input.	○	○

Note: Write a value to this register while transmit/receive halts.

Figure 1.16.32. S I/O3, 4 related register

Table 1.16.13. Specifications of S I/O3, 4

Item	Specifications
Transfer data format	• Transfer data length: 8 bits
Transfer clock	• With the internal clock selected (bit 6 of 0362₁₆, 0366₁₆ = "1"): $f_1/2(n_i+1)$, $f_8/2(n_i+1)$, $f_{32}/2(n_i+1)$ (Note 1) • With the external clock selected (bit 6 of 0362₁₆, 0366₁₆ = 0): Input from the CLK_i terminal (Note 2)
Conditions for transmission/reception start	• To start transmit/reception, the following requirements must be met: - Select the synchronous clock (use bit 6 of 0362₁₆, 0366₁₆). - Select a frequency dividing ratio if the internal clock has been selected (use bits 0 and 1 of 0362₁₆, 0366₁₆). - SOUT_i initial value set bit (use bit 7 of 0362₁₆, 0366₁₆) = 1. - S I/O_i port select bit (bit 3 of 0362₁₆, 0366₁₆) = 1. - Select the transfer direction (use bit 5 of 0362₁₆, 0366₁₆) - Write transfer data to SI/O_i transmit/receive register (0360₁₆, 0364₁₆) • To use S I/O_i interrupts, the following requirements must be met: - Clear the SI/O_i interrupt request bit before writing transfer data to the SI/O_i transmit/receive register (bit 3 of 0049₁₆, 0048₁₆) = 0.
Interrupt request generation timing	• Rising edge of the last transfer clock. (Note 3)
Select function	• LSB first or MSB first selection Whether transmission/reception begins with bit 0 (LSB) or bit 7 (MSB) can be selected. • Function for setting an SOUT_i initial value selection When using an external clock for the transfer clock, the user can choose the SOUT_i pin output level during a non-transfer time. For details on how to set, see Figure 1.16.33.
Precaution	• Unlike UART0–2, SI/O_i (i = 3, 4) is not divided for transfer register and buffer. Therefore, do not write the next transfer data to the SI/O_i transmit/receive register (addresses 0360₁₆, 0364₁₆) during a transfer. • When the internal clock is selected for the transfer clock, SOUT_i holds the last data for a 1/2 transfer clock period after it finished transferring and then goes to a high-impedance state. However, if the transfer data is written to the SI/O_i transmit/receive register (addresses 0360₁₆, 0364₁₆) during this time, SOUT_i is placed in the high-impedance state immediately upon writing and the data hold time is thereby reduced.

Note 1: n is a value from 00₁₆ through FF₁₆ set in the S I/O_i bit rate generator (i = 3, 4).

Note 2: With the external clock selected:

- Before data can be written to the SI/O_i transmit/receive register (addresses 0360₁₆, 0364₁₆), the CLK_i pin input must be in the high state. Also, before rewriting the SI/O_i Control Register (addresses 0362₁₆, 0366₁₆)'s bit 7 (SOUT_i initial value set bit), make sure the CLK_i pin input is held high.
- The S I/O_i circuit keeps on with the shift operation as long as the synchronous clock is entered in it, so stop the synchronous clock at the instant when it counts to eight. The internal clock, if selected, automatically stops.

Note 3: If the internal clock is used for the synchronous clock, the transfer clock signal stops at the "H" state.

■ Functions for setting an Souti initial value

When using an external clock for the transfer clock, the SOUTi pin output level during a non-transfer time can be set to the high or the low state. Figure 1.16.33 shows the timing chart for setting an SOUTi initial value and how to set it.

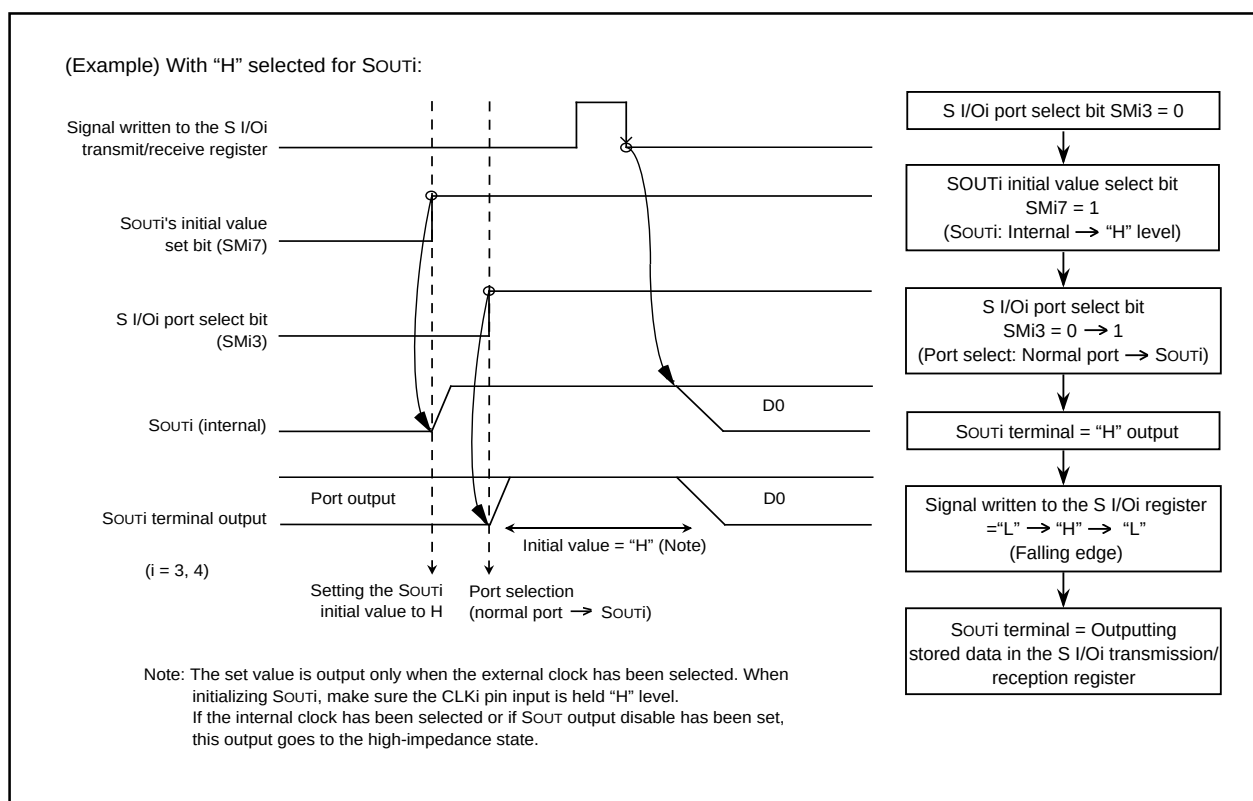


Figure 1.16.33. Timing chart for setting SOUTi's initial value and how to set it

■ S I/Oi operation timing

Figure 1.16.34 shows the S I/Oi operation timing

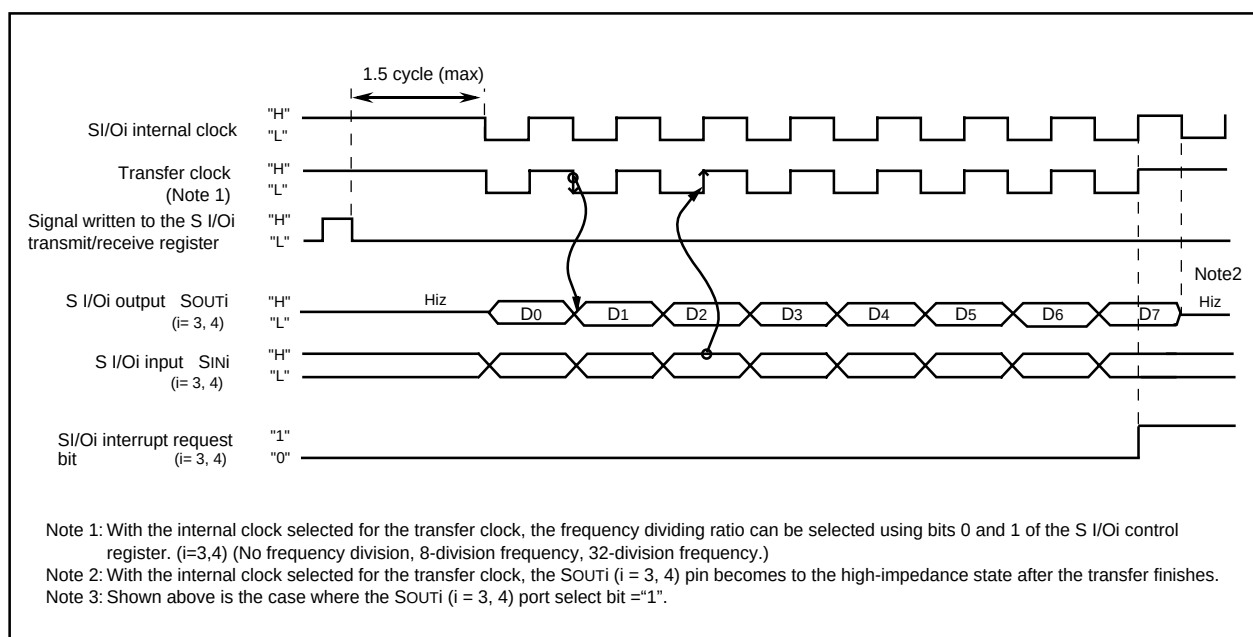


Figure 1.16.34. S I/Oi operation timing chart

A-D Converter

A-D Converter

The A-D converter consists of one 10-bit successive approximation A-D converter circuit with a capacitive coupling amplifier. Pins P100 to P107, P95, and P96 also function as the analog signal input pins. The direction registers of these pins for A-D conversion must therefore be set to input. The Vref connect bit (bit 5 at address 03D716) can be used to isolate the resistance ladder of the A-D converter from the reference voltage input pin (VREF) when the A-D converter is not used. Doing so stops any current flowing into the resistance ladder from VREF, reducing the power dissipation. When using the A-D converter, start A-D conversion only after setting bit 5 of 03D716 to connect VREF. The result of A-D conversion is stored in the A-D registers of the selected pins. When set to 10-bit precision, the low 8 bits are stored in the even addresses and the high 2 bits in the odd addresses. When set to 8-bit precision, the low 8 bits are stored in the even addresses.

Table 1.17.1 shows the performance of the A-D converter. Figure 1.17.1 shows the block diagram of the A-D converter, and Figures 1.17.2 and 1.17.3 show the A-D converter-related registers.

Table 1.17.1. Performance of A-D converter

Item	Performance
Method of A-D conversion	Successive approximation (capacitive coupling amplifier)
Analog input voltage (Note 1)	0V to AVCC (VCC)
Operating clock ϕ_{AD} (Note 2)	VCC = 5V fAD/divide-by-2 of fAD/divide-by-4 of fAD, fAD=f(XIN) VCC = 3V divide-by-2 of fAD/divide-by-4 of fAD, fAD=f(XIN)
Resolution	8-bit or 10-bit (selectable)
Absolute precision	VCC = 5V • Without sample and hold function $\pm 3\text{LSB}$ • With sample and hold function (8-bit resolution) $\pm 2\text{LSB}$ • With sample and hold function (10-bit resolution) AN0 to AN7 input : $\pm 3\text{LSB}$ ANEX0 and ANEX1 input (including mode in which external operation amp is connected) : $\pm 7\text{LSB}$ VCC = 3V • Without sample and hold function (8-bit resolution) $\pm 2\text{LSB}$
Operating modes	One-shot mode, repeat mode, single sweep mode, repeat sweep mode 0, and repeat sweep mode 1
Analog input pins	8pins (AN0 to AN7) + 2pins (ANEX0 and ANEX1)
A-D conversion start condition	• Software trigger A-D conversion starts when the A-D conversion start flag changes to "1" • External trigger (can be retrigged) A-D conversion starts when the A-D conversion start flag is "1" and the $\overline{\text{ADTRG}}/\text{P97}$ input changes from "H" to "L"
Conversion speed per pin	• Without sample and hold function 8-bit resolution: 49 ϕ_{AD} cycles, 10-bit resolution: 59 ϕ_{AD} cycles • With sample and hold function 8-bit resolution: 28 ϕ_{AD} cycles, 10-bit resolution: 33 ϕ_{AD} cycles

Note 1: Does not depend on use of sample and hold function.

Note 2: Divide the frequency if f(XIN) exceeds 10MHz, and make ϕ_{AD} frequency equal to or less than 10MHz.

Without sample and hold function, set the ϕ_{AD} frequency to 250kHz min.

With the sample and hold function, set the ϕ_{AD} frequency to 1MHz min.

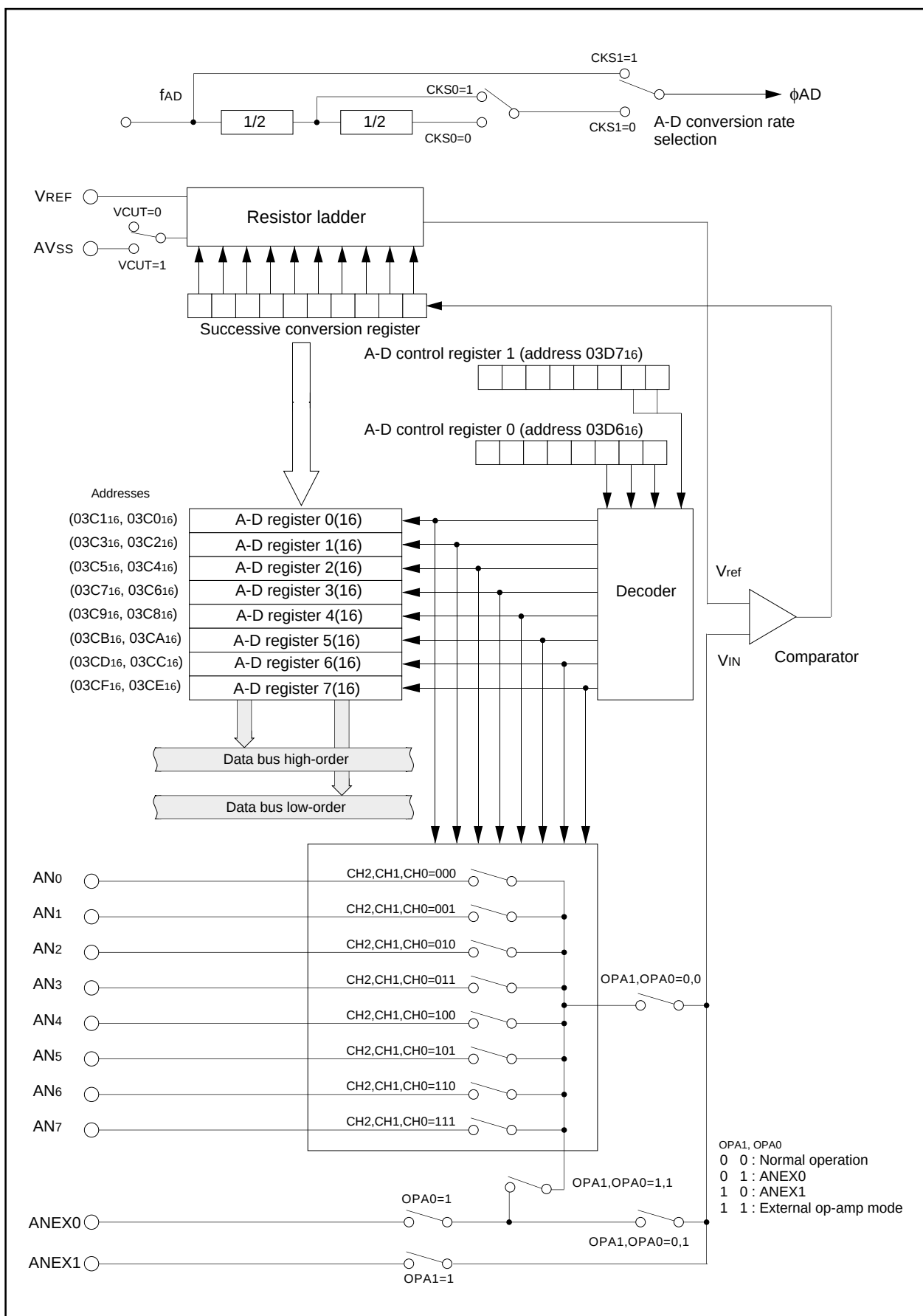


Figure 1.17.1. Block diagram of A-D converter

A-D Converter

A-D control register 0 (Note 1)

Bit	Symbol	Address	When reset
b7 b6 b5 b4 b3 b2 b1 b0	ADCON0	03D616	0000XXX2

Bit symbol	Bit name	Function	R/W
CH0	Analog input pin select bit	b2 b1 b0 0 0 0 : AN0 is selected 0 0 1 : AN1 is selected 0 1 0 : AN2 is selected 0 1 1 : AN3 is selected 1 0 0 : AN4 is selected 1 0 1 : AN5 is selected 1 1 0 : AN6 is selected 1 1 1 : AN7 is selected (Note 2)	○ ○
CH1			○ ○
CH2			○ ○
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 Repeat sweep mode 1 (Note 2)	○ ○
MD1			○ ○
TRG	Trigger select bit	0 : Software trigger 1 : ADTRG trigger	○ ○
ADST	A-D conversion start flag	0 : A-D conversion disabled 1 : A-D conversion started	○ ○
CKS0	Frequency select bit 0	0 : fAD/4 is selected 1 : fAD/2 is selected	○ ○

Note 1: If the A-D control register is rewritten during A-D conversion, the conversion result is indeterminate.

Note 2: When changing A-D operation mode, set analog input pin again.

A-D control register 1 (Note)

Bit	Symbol	Address	When reset
b7 b6 b5 b4 b3 b2 b1 b0	ADCON1	03D716	0016

Bit symbol	Bit name	Function	R/W
SCAN0	A-D sweep pin select bit	When single sweep and repeat sweep mode 0 are selected b1 b0 0 0 : AN0, AN1 (2 pins) 0 1 : AN0 to AN3 (4 pins) 1 0 : AN0 to AN5 (6 pins) 1 1 : AN0 to AN7 (8 pins)	○ ○
SCAN1		When repeat sweep mode 1 is selected b1 b0 0 0 : AN0 (1 pin) 0 1 : AN0, AN1 (2 pins) 1 0 : AN0 to AN2 (3 pins) 1 1 : AN0 to AN3 (4 pins)	○ ○
MD2	A-D operation mode select bit 1	0 : Any mode other than repeat sweep mode 1 1 : Repeat sweep mode 1	○ ○
BITS	8/10-bit mode select bit	0 : 8-bit mode 1 : 10-bit mode	○ ○
CKS1	Frequency select bit 1	0 : fAD/2 or fAD/4 is selected 1 : fAD is selected	○ ○
VCUT	Vref connect bit	0 : Vref not connected 1 : Vref connected	○ ○
OPA0	External op-amp connection mode bit	b7 b6 0 0 : ANEX0 and ANEX1 are not used 0 1 : ANEX0 input is A-D converted 1 0 : ANEX1 input is A-D converted 1 1 : External op-amp connection mode	○ ○
OPA1			○ ○

Note: If the A-D control register is rewritten during A-D conversion, the conversion result is indeterminate.

Figure 1.17.2. A-D converter-related registers (1)

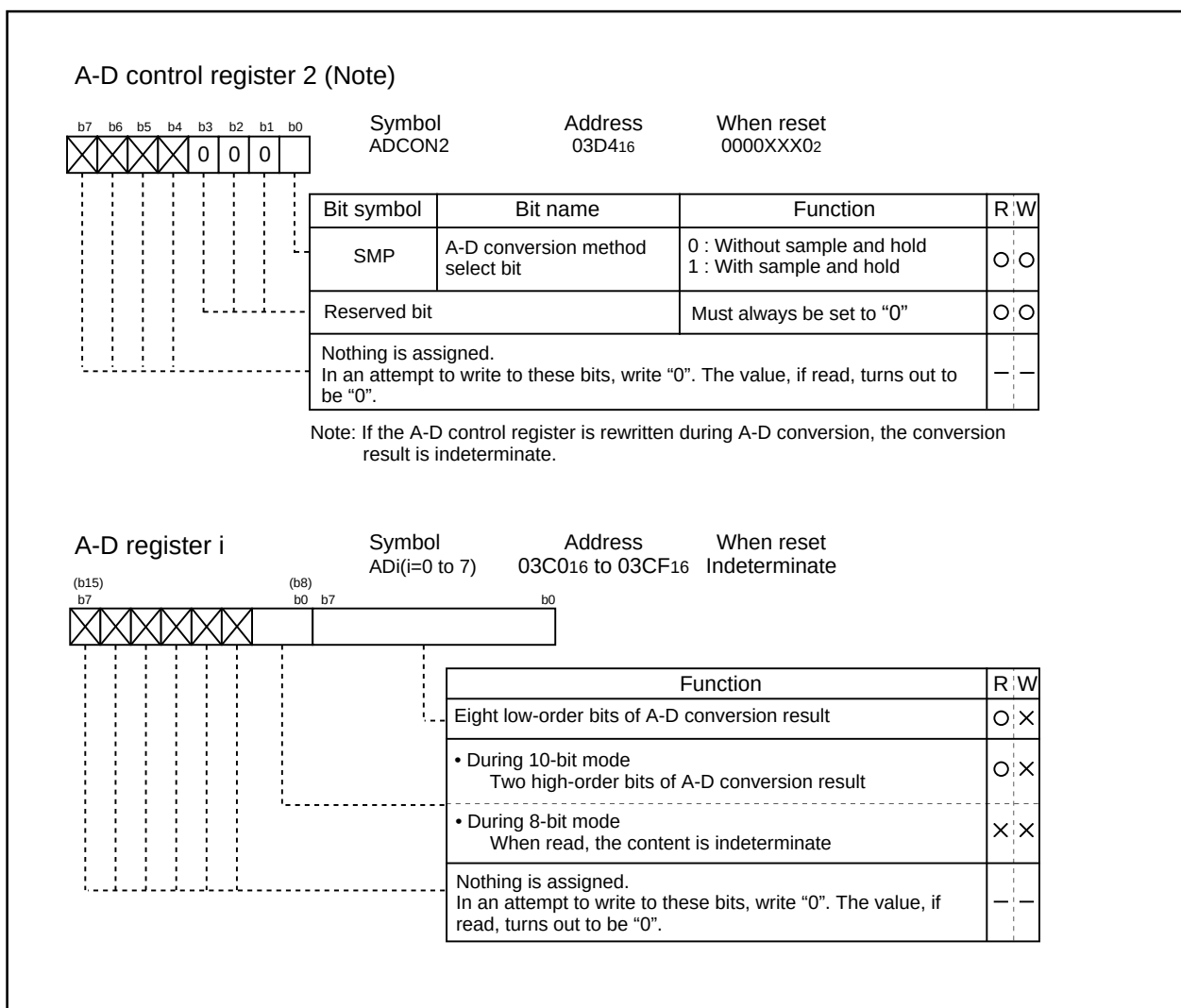


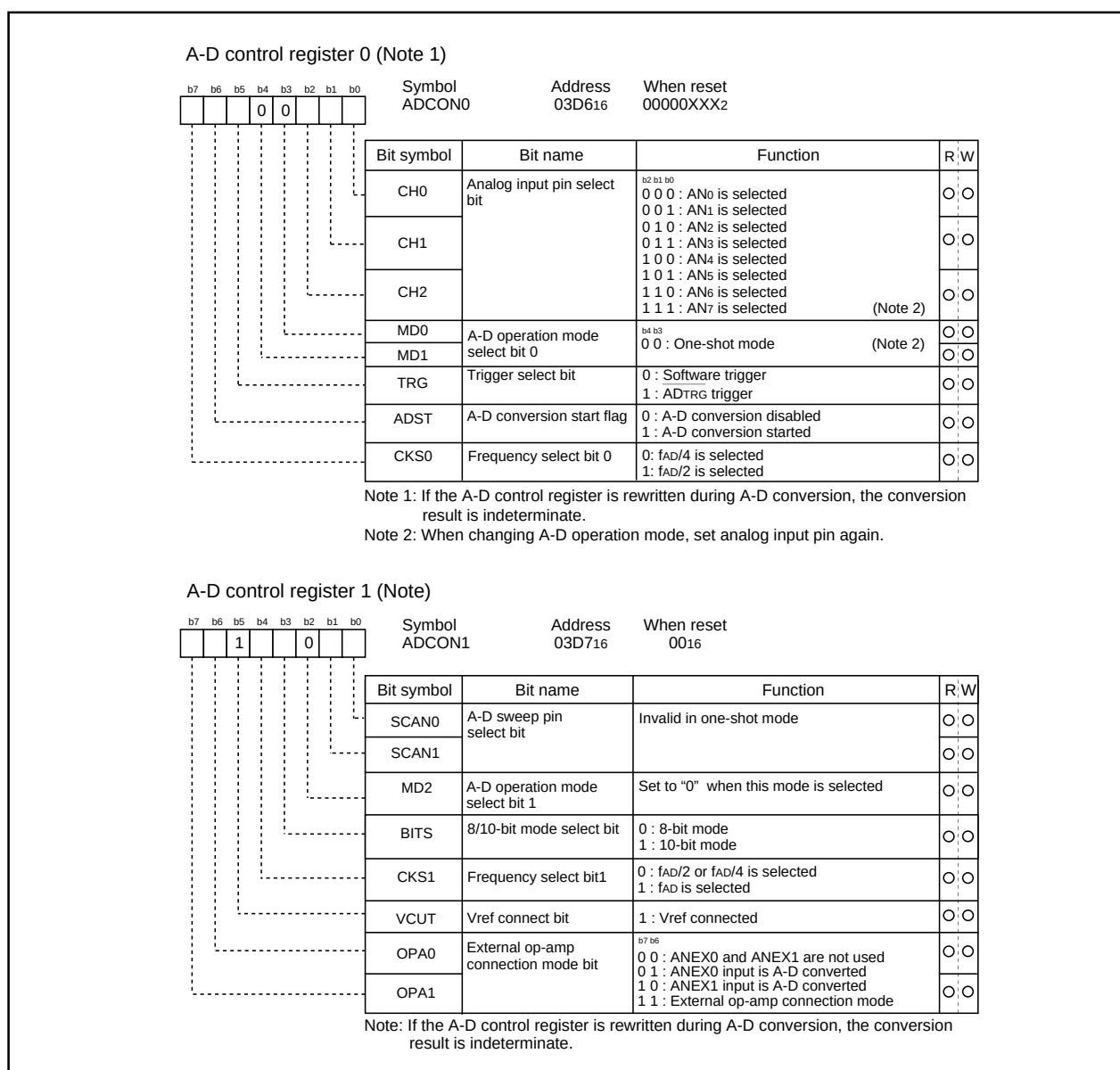
Figure 1.17.3. A-D converter-related registers (2)

(1) One-shot mode

In one-shot mode, the pin selected using the analog input pin select bit is used for one-shot A-D conversion. Table 1.17.2 shows the specifications of one-shot mode. Figure 1.17.4 shows the A-D control register in one-shot mode.

Table 1.17.2. One-shot mode specifications

Item	Specification
Function	The pin selected by the analog input pin select bit is used for one A-D conversion
Start condition	Writing "1" to A-D conversion start flag
Stop condition	- End of A-D conversion (A-D conversion start flag changes to "0", except when external trigger is selected) - Writing "0" to A-D conversion start flag
Interrupt request generation timing	End of A-D conversion
Input pin	One of AN ₀ to AN ₇ , as selected
Reading of result of A-D converter	Read A-D register corresponding to selected pin

**Figure 1.17.4. A-D conversion register in one-shot mode**

A-D Converter

(2) Repeat mode

In repeat mode, the pin selected using the analog input pin select bit is used for repeated A-D conversion. Table 1.17.3 shows the specifications of repeat mode. Figure 1.17.5 shows the A-D control register in repeat mode.

Table 1.17.3. Repeat mode specifications

Item	Specification
Function	The pin selected by the analog input pin select bit is used for repeated A-D conversion
Star condition	Writing "1" to A-D conversion start flag
Stop condition	Writing "0" to A-D conversion start flag
Interrupt request generation timing	None generated
Input pin	One of AN0 to AN7, as selected
Reading of result of A-D converter	Read A-D register corresponding to selected pin (at any time)

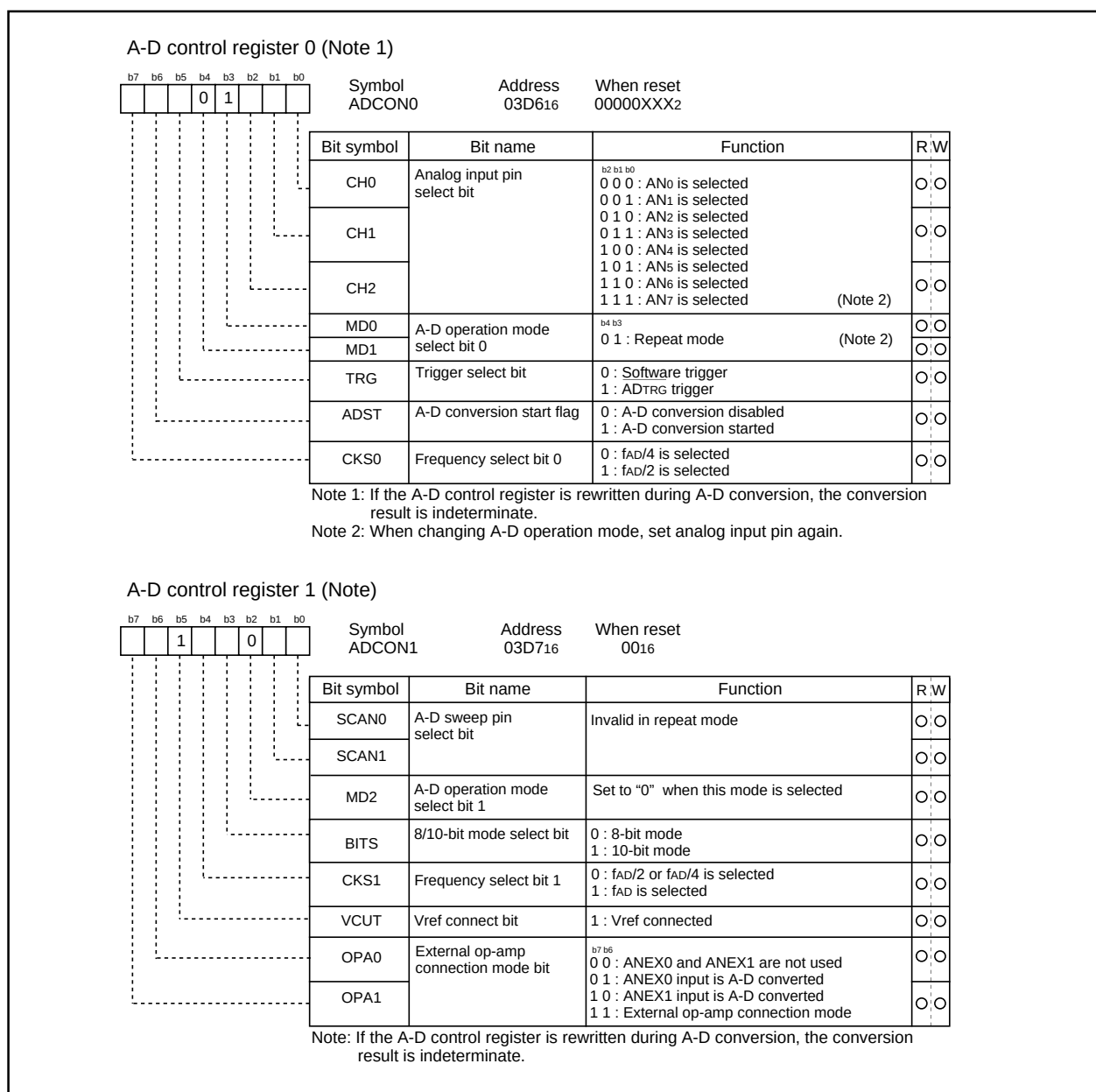


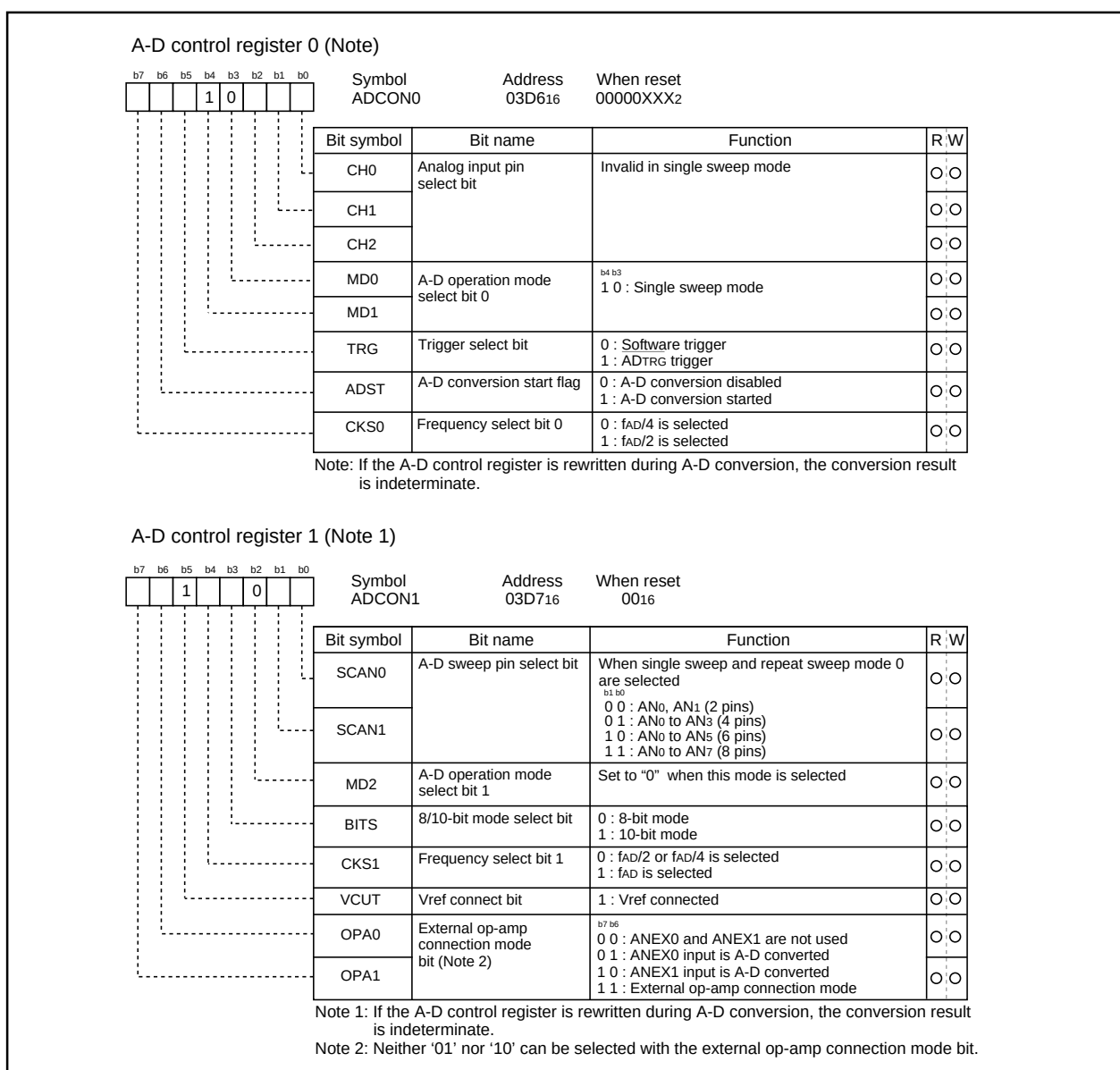
Figure 1.17.5. A-D conversion register in repeat mode

(3) Single sweep mode

In single sweep mode, the pins selected using the A-D sweep pin select bit are used for one-by-one A-D conversion. Table 1.17.4 shows the specifications of single sweep mode. Figure 1.17.6 shows the A-D control register in single sweep mode.

Table 1.17.4. Single sweep mode specifications

Item	Specification
Function	The pins selected by the A-D sweep pin select bit are used for one-by-one A-D conversion
Start condition	Writing "1" to A-D converter start flag
Stop condition	- End of A-D conversion (A-D conversion start flag changes to "0", except when external trigger is selected) - Writing "0" to A-D conversion start flag
Interrupt request generation timing	End of A-D conversion
Input pin	AN0 and AN1 (2 pins), AN0 to AN3 (4 pins), AN0 to AN5 (6 pins), or AN0 to AN7 (8 pins)
Reading of result of A-D converter	Read A-D register corresponding to selected pin

**Figure 1.17.6. A-D conversion register in single sweep mode**

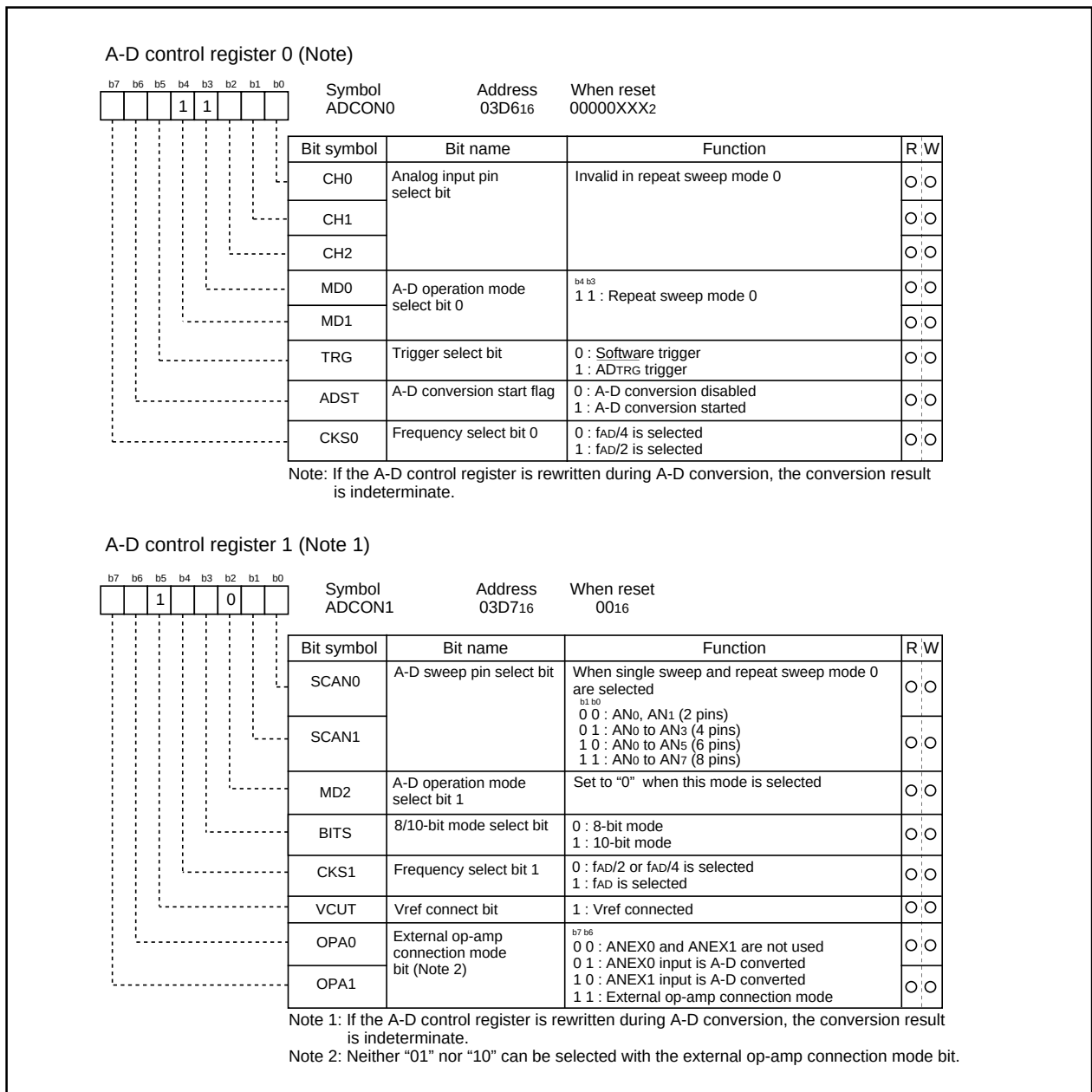
A-D Converter

(4) Repeat sweep mode 0

In repeat sweep mode 0, the pins selected using the A-D sweep pin select bit are used for repeat sweep A-D conversion. Table 1.17.5 shows the specifications of repeat sweep mode 0. Figure 1.17.7 shows the A-D control register in repeat sweep mode 0.

Table 1.17.5. Repeat sweep mode 0 specifications

Item	Specification
Function	The pins selected by the A-D sweep pin select bit are used for repeat A-D conversion
Start condition	Writing "1" to A-D conversion start flag
Stop condition	Writing "0" to A-D conversion start flag
Interrupt request generation timing	None generated
Input pin	AN ₀ and AN ₁ (2 pins), AN ₀ to AN ₃ (4 pins), AN ₀ to AN ₅ (6 pins), or AN ₀ to AN ₇ (8 pins)
Reading of result of A-D converter	Read A-D register corresponding to selected pin (at any time)

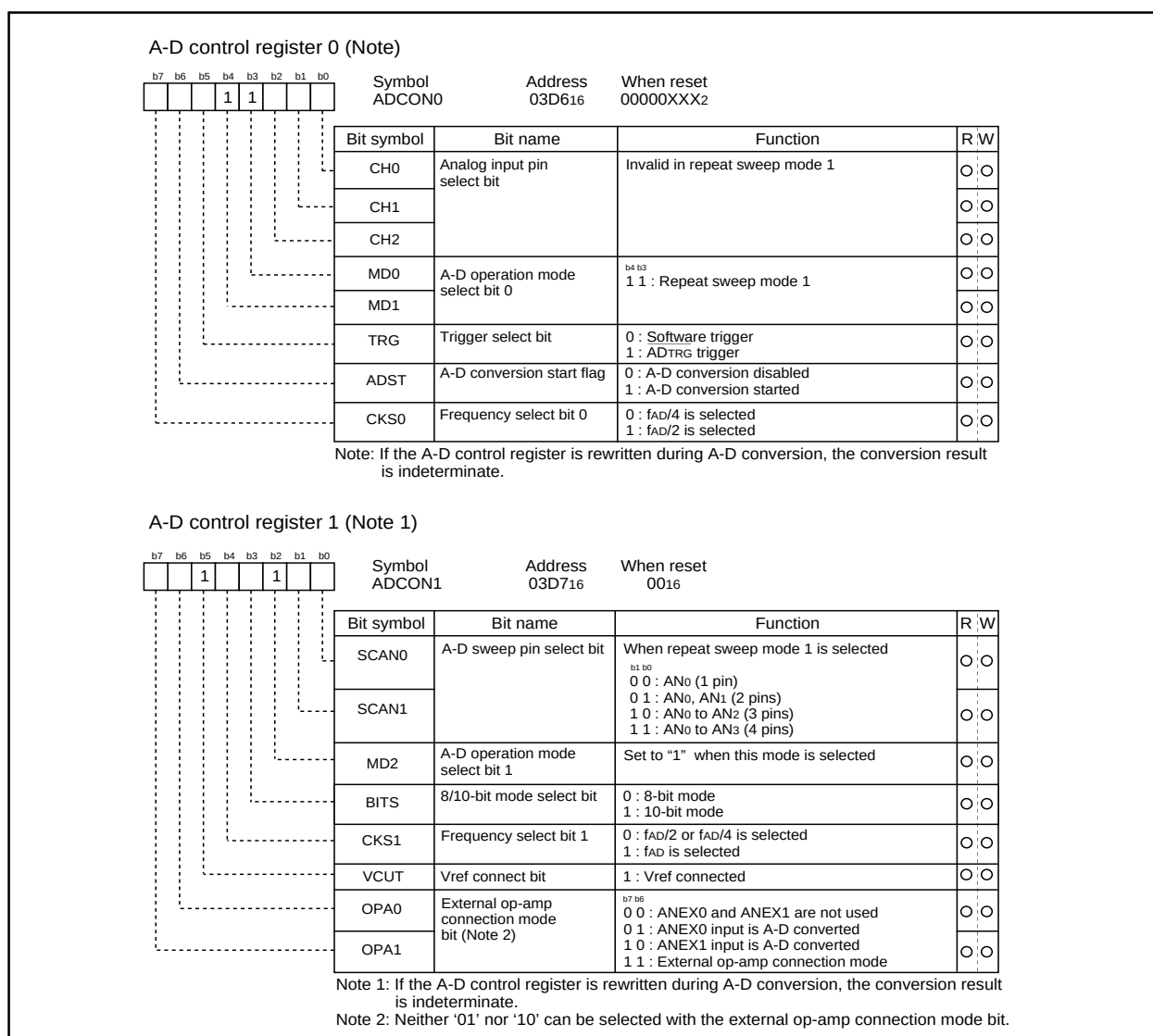
**Figure 1.17.7. A-D conversion register in repeat sweep mode 0**

(5) Repeat sweep mode 1

In repeat sweep mode 1, all pins are used for A-D conversion with emphasis on the pin or pins selected using the A-D sweep pin select bit. Table 1.17.6 shows the specifications of repeat sweep mode 1. Figure 1.17.8 shows the A-D control register in repeat sweep mode 1.

Table 1.17.6. Repeat sweep mode 1 specifications

Item	Specification
Function	All pins perform repeat A-D conversion, with emphasis on the pin or pins selected by the A-D sweep pin select bit Example : AN ₀ selected AN ₀ → AN ₁ → AN ₀ → AN ₂ → AN ₀ → AN ₃ , etc
Start condition	Writing "1" to A-D conversion start flag
Stop condition	Writing "0" to A-D conversion start flag
Interrupt request generation timing	None generated
Input pin	With emphasis on these pins ; AN ₀ (1 pin), AN ₀ and AN ₁ (2 pins), AN ₀ to AN ₂ (3 pins), AN ₀ to AN ₃ (4 pins)
Reading of result of A-D converter	Read A-D register corresponding to selected pin (at any time)

**Figure 1.17.8. A-D conversion register in repeat sweep mode 1**

(a) Sample and hold

Sample and hold is selected by setting bit 0 of the A-D control register 2 (address 03D4₁₆) to "1". When sample and hold is selected, the rate of conversion of each pin increases. As a result, a 28 ϕ_{AD} cycle is achieved with 8-bit resolution and 33 ϕ_{AD} with 10-bit resolution. Sample and hold can be selected in all modes. However, in all modes, be sure to specify before starting A-D conversion whether sample and hold is to be used.

(b) Extended analog input pins

In one-shot mode and repeat mode, the input via the extended analog input pins ANEX0 and ANEX1 can also be converted from analog to digital.

When bit 6 of the A-D control register 1 (address 03D7₁₆) is "1" and bit 7 is "0", input via ANEX0 is converted from analog to digital. The result of conversion is stored in A-D register 0.

When bit 6 of the A-D control register 1 (address 03D7₁₆) is "0" and bit 7 is "1", input via ANEX1 is converted from analog to digital. The result of conversion is stored in A-D register 1.

(c) External operation amp connection mode

In this mode, multiple external analog inputs via the extended analog input pins, ANEX0 and ANEX1, can be amplified together by just one operation amp and used as the input for A-D conversion.

When bit 6 of the A-D control register 1 (address 03D7₁₆) is "1" and bit 7 is "1", input via AN₀ to AN₇ is output from ANEX0. The input from ANEX1 is converted from analog to digital and the result stored in the corresponding A-D register. The speed of A-D conversion depends on the response of the external operation amp. Do not connect the ANEX0 and ANEX1 pins directly. Figure 1.17.9 is an example of how to connect the pins in external operation amp mode.

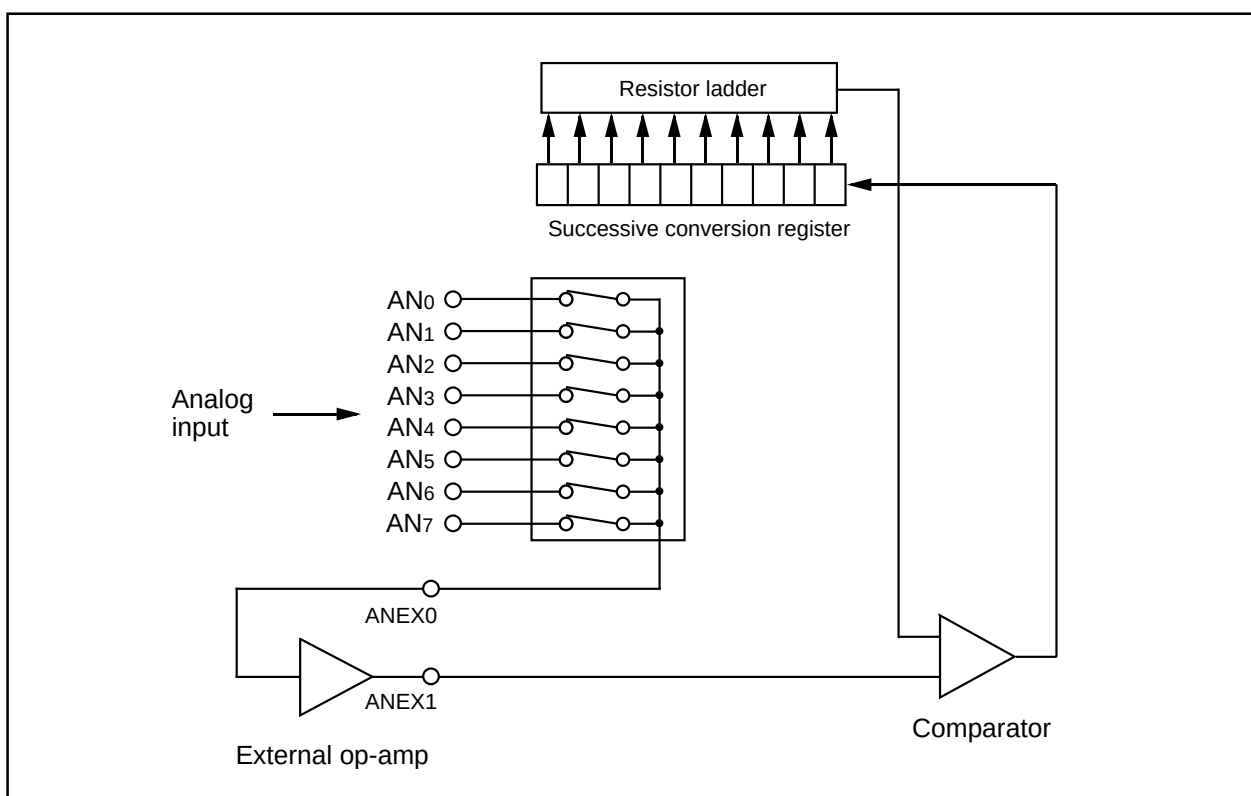


Figure 1.17.9. Example of external op-amp connection mode

D-A Converter

D-A Converter

This is an 8-bit, R-2R type D-A converter. The microcomputer contains two independent D-A converters of this type.

D-A conversion is performed when a value is written to the corresponding D-A register. Bits 0 and 1 (D-A output enable bits) of the D-A control register decide if the result of conversion is to be output. Do not set the target port to output mode if D-A conversion is to be performed. When the D-A output is enabled, the pull-up function of the corresponding port is automatically disabled.

Output analog voltage (V) is determined by a set value (n : decimal) in the D-A register.

$$V = V_{REF} \times n / 256 \quad (n = 0 \text{ to } 255)$$

V_{REF} : reference voltage

Table 1.18.1 lists the performance of the D-A converter. Figure 1.18.1 shows the block diagram of the D-A converter. Figure 1.18.2 shows the D-A control register. Figure 1.18.3 shows the D-A converter equivalent circuit.

Table 1.18.1. Performance of D-A converter

Item	Performance
Conversion method	R-2R method
Resolution	8 bits
Analog output pin	2 channels

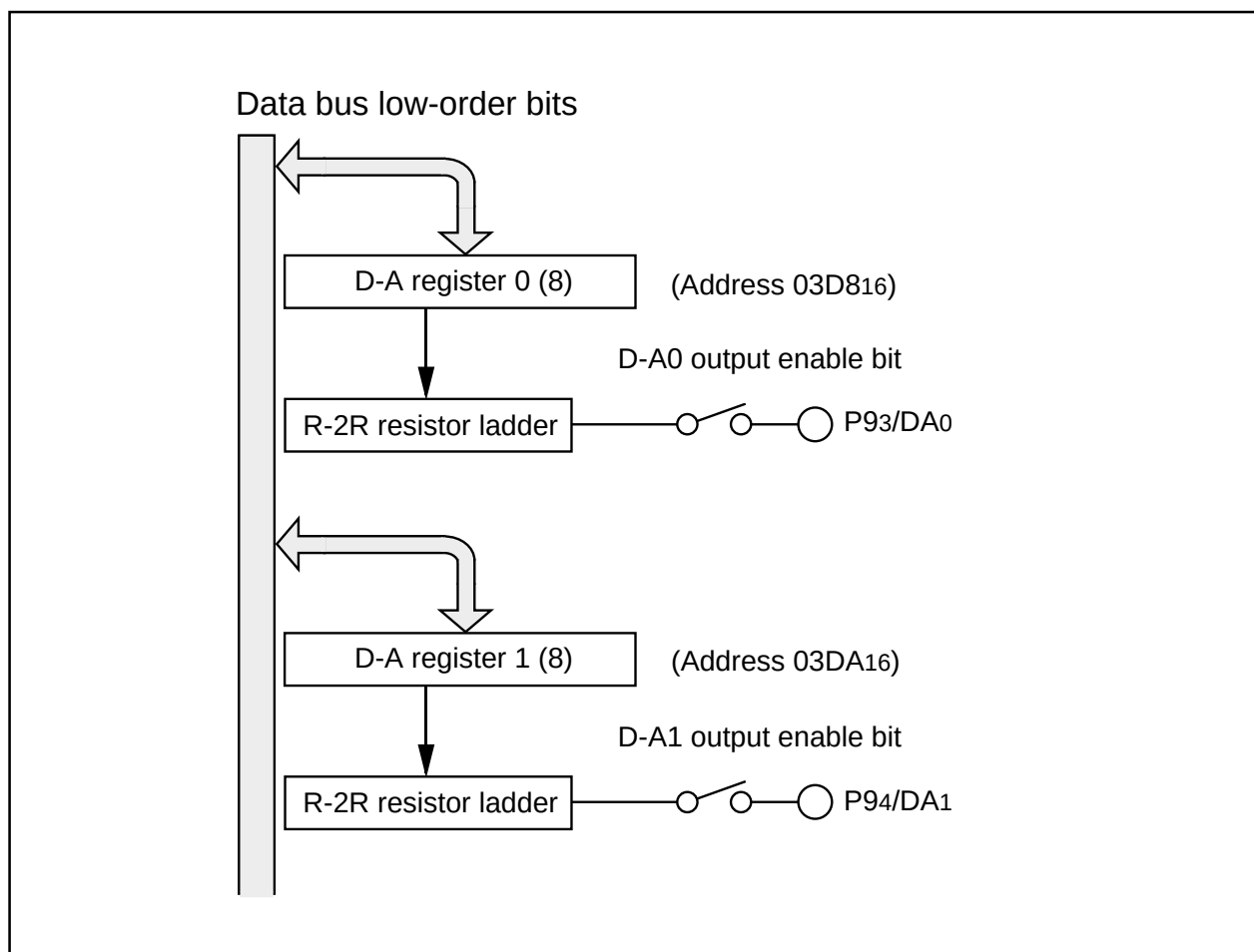


Figure 1.18.1. Block diagram of D-A converter

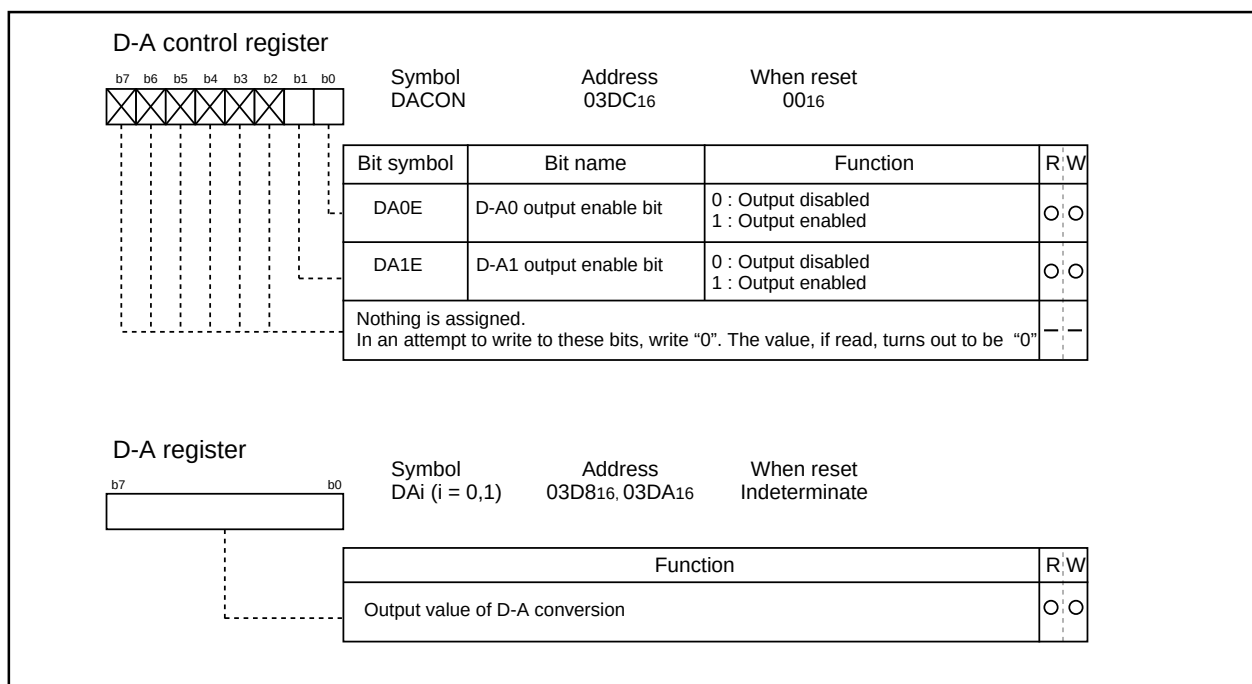


Figure 1.18.2. D-A control register

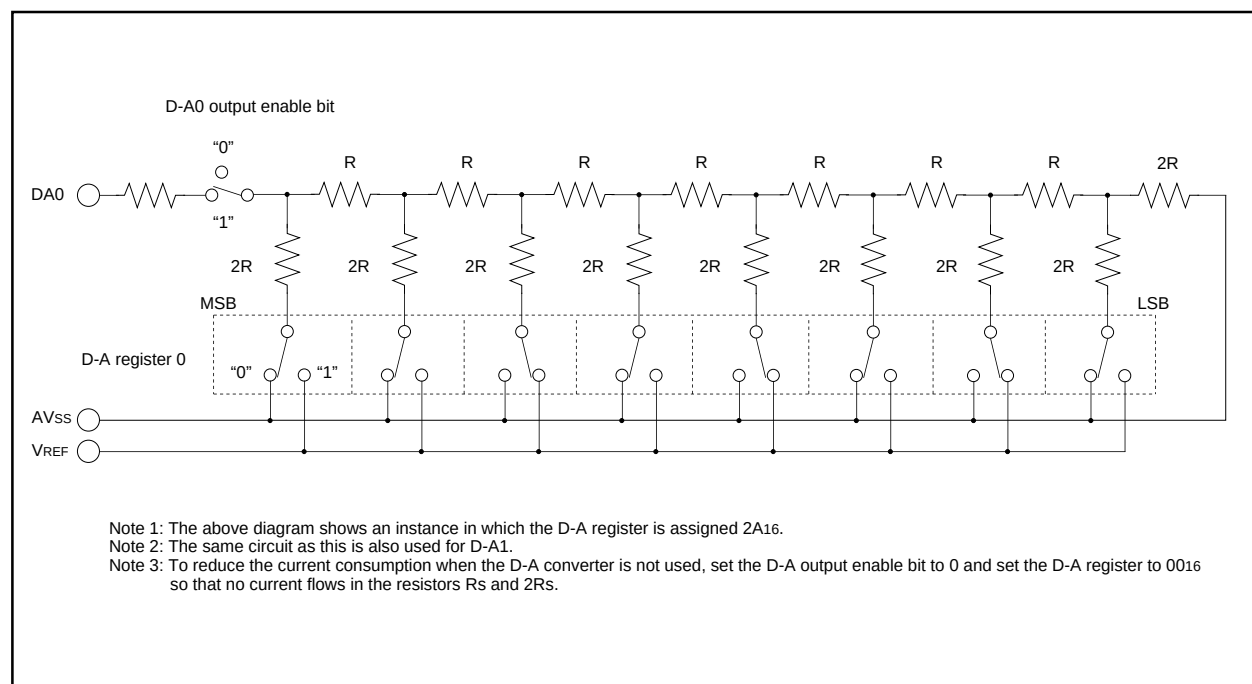


Figure 1.18.3. D-A converter equivalent circuit

CRC Calculation Circuit

The Cyclic Redundancy Check (CRC) calculation circuit detects an error in data blocks. The microcomputer uses a generator polynomial of CRC_CCITT ($X^{16} + X^{12} + X^5 + 1$) to generate CRC code.

The CRC code is a 16-bit code generated for a block of a given data length in multiples of 8 bits. The CRC code is set in a CRC data register each time one byte of data is transferred to a CRC input register after writing an initial value into the CRC data register. Generation of CRC code for one byte of data is completed in two machine cycles.

Figure 1.19.1 shows the block diagram of the CRC circuit. Figure 1.19.2 shows the CRC-related registers. Figure 1.19.3 shows the calculation example using the CRC calculation circuit.

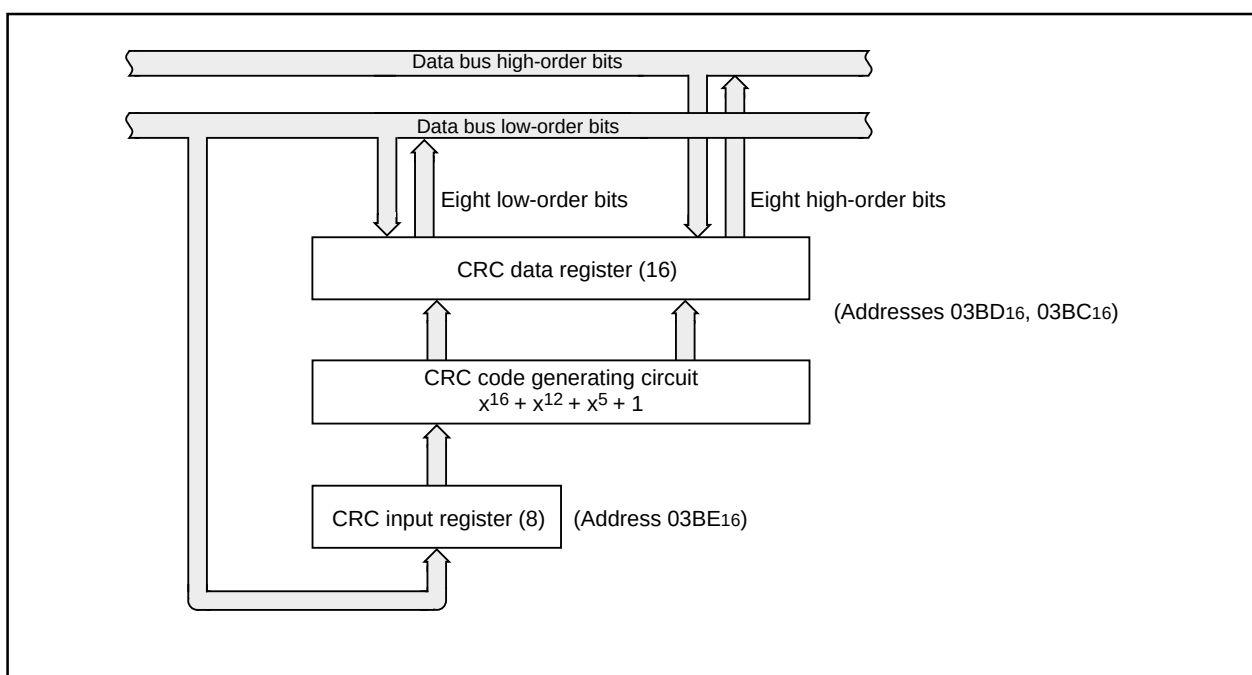


Figure 1.19.1. Block diagram of CRC circuit

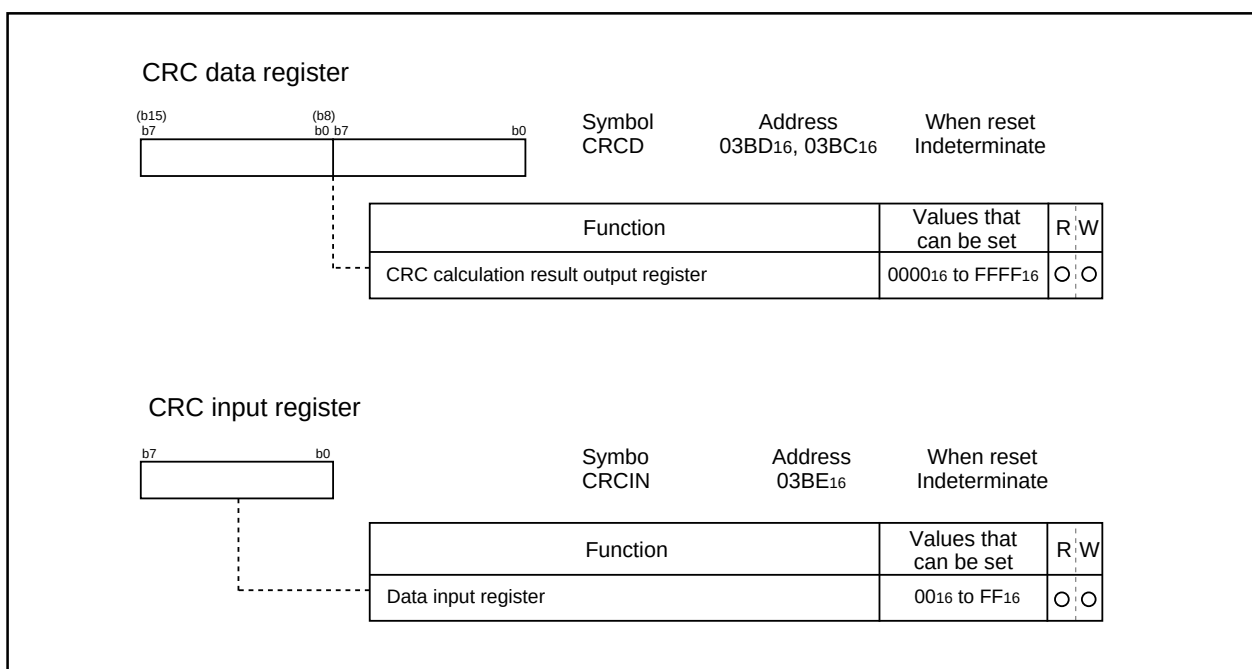


Figure 1.19.2. CRC-related registers

CRC

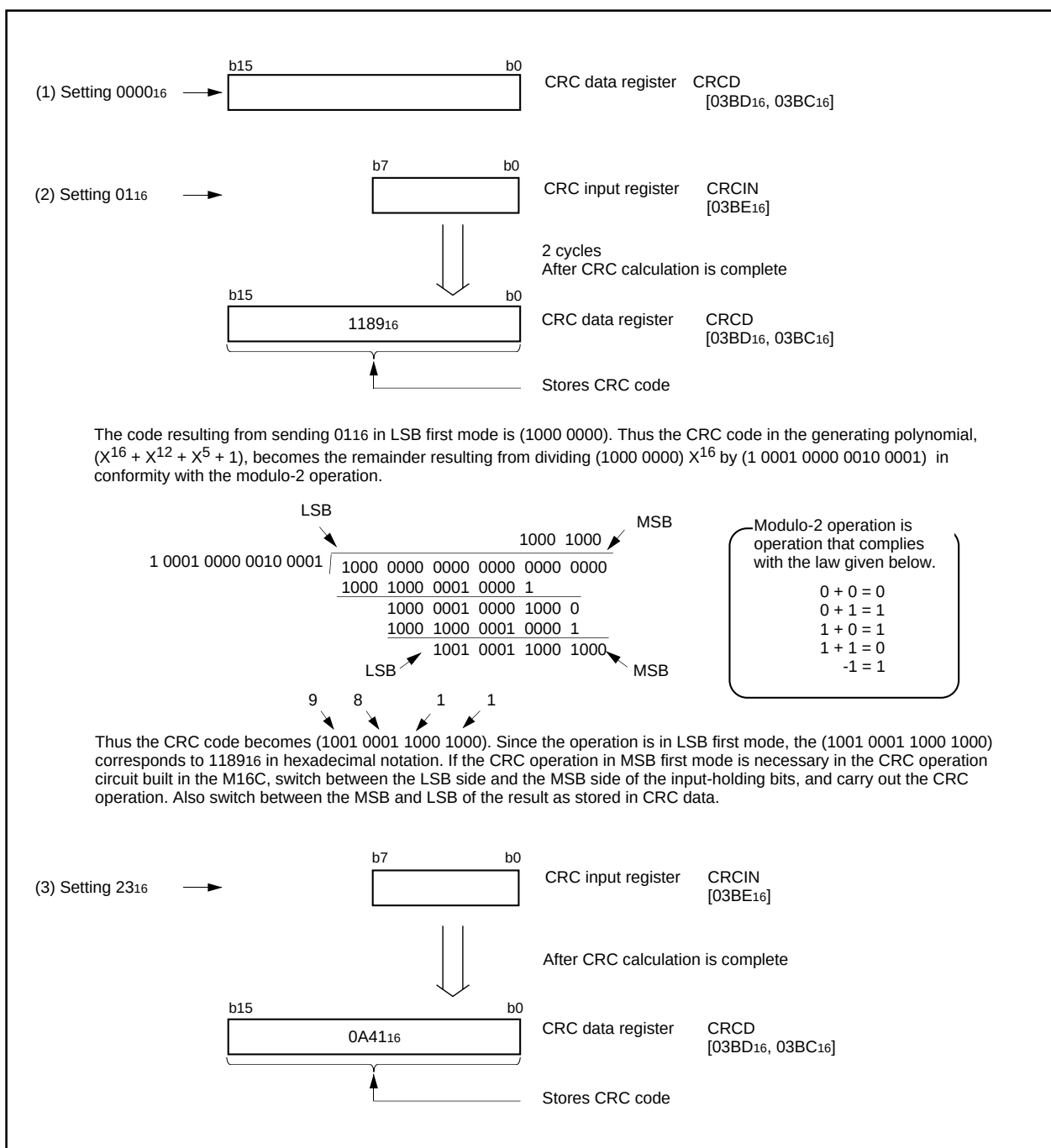


Figure 1.19.3. Calculation example using the CRC calculation circuit

Programmable I/O Port

Programmable I/O Ports

There are 87 programmable I/O ports: P0 to P10 (excluding P85). Each port can be set independently for input or output using the direction register. A pull-up resistance for each block of 4 ports can be set. P85 is an input-only port and has no built-in pull-up resistance.

Figures 1.20.1 to 1.20.4 show the programmable I/O ports. Figure 1.20.5 shows the I/O pins.

Each pin functions as a programmable I/O port and as the I/O for the built-in peripheral devices.

To use the pins as the inputs for the built-in peripheral devices, set the direction register of each pin to input mode. When the pins are used as the outputs for the built-in peripheral devices (other than the D-A converter), they function as outputs regardless of the contents of the direction registers. When pins are to be used as the outputs for the D-A converter, do not set the direction registers to output mode. See the descriptions of the respective functions for how to set up the built-in peripheral devices.

(1) Direction registers

Figure 1.20.6 shows the direction registers.

These registers are used to choose the direction of the programmable I/O ports. Each bit in these registers corresponds one for one to each I/O pin.

In memory expansion and microprocessor mode, the contents of corresponding direction register of pins A0 to A19, D0 to D15, $\overline{CS0}$ to $\overline{CS3}$, $\overline{RD}$, $\overline{WRL/WR}$, $\overline{WRH/BHE}$, ALE, $\overline{RDY}$, $\overline{HOLD}$, $\overline{HLDA}$ and BCLK cannot be modified.

Note: There is no direction register bit for P85.

(2) Port registers

Figure 1.20.7 shows the port registers.

These registers are used to write and read data for input and output to and from an external device. A port register consists of a port latch to hold output data and a circuit to read the status of a pin. Each bit in port registers corresponds one for one to each I/O pin.

In memory expansion and microprocessor mode, the contents of corresponding port register of pins A0 to A19, D0 to D15, $\overline{CS0}$ to $\overline{CS3}$, $\overline{RD}$, $\overline{WRL/WR}$, $\overline{WRH/BHE}$, ALE, $\overline{RDY}$, $\overline{HOLD}$, $\overline{HLDA}$ and BCLK cannot be modified.

(3) Pull-up control registers

Figure 1.20.8 shows the pull-up control registers.

The pull-up control register can be set to apply a pull-up resistance to each block of 4 ports. When ports are set to have a pull-up resistance, the pull-up resistance is connected only when the direction register is set for input.

However, in memory expansion mode and microprocessor mode, the pull-up control register of P0 to P3, P40 to P43, and P5 is invalid. The contents of register can be changed, but the pull-up resistance is not connected.

(4) Port control register

Figure 1.20.9 shows the port control register.

The bit 0 of port control register is used to read port P1 as follows:

0 : When port P1 is input port, port input level is read.

When port P1 is output port, the contents of port P1 register is read.

1 : The contents of port P1 register is read always.

This register is valid in the following:

- External bus width is 8 bits in microprocessor mode or memory expansion mode.
- Port P1 can be used as a port in multiplexed bus for the entire space.

Programmable I/O Port

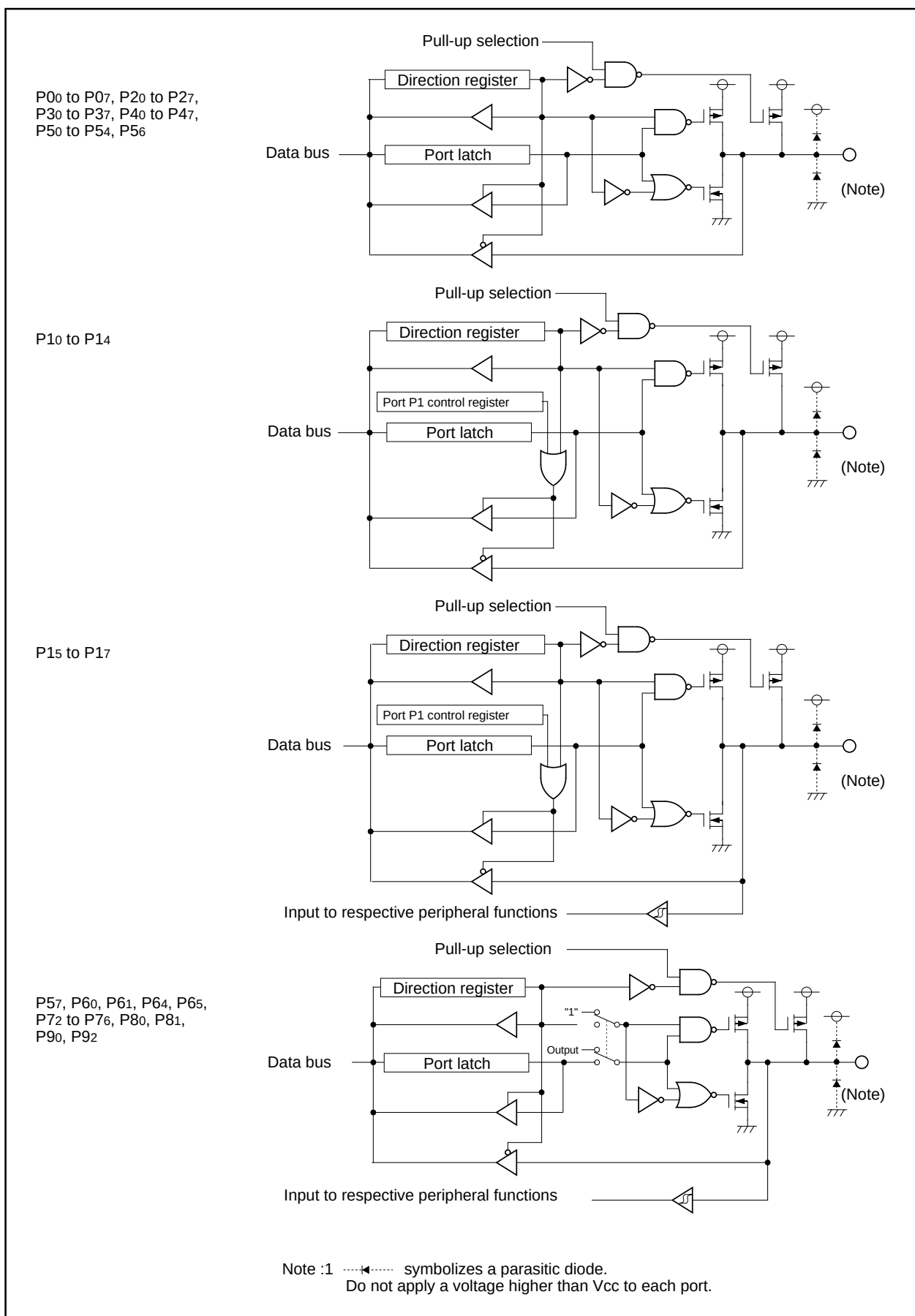


Figure 1.20.1. Programmable I/O ports (1)

Programmable I/O Port

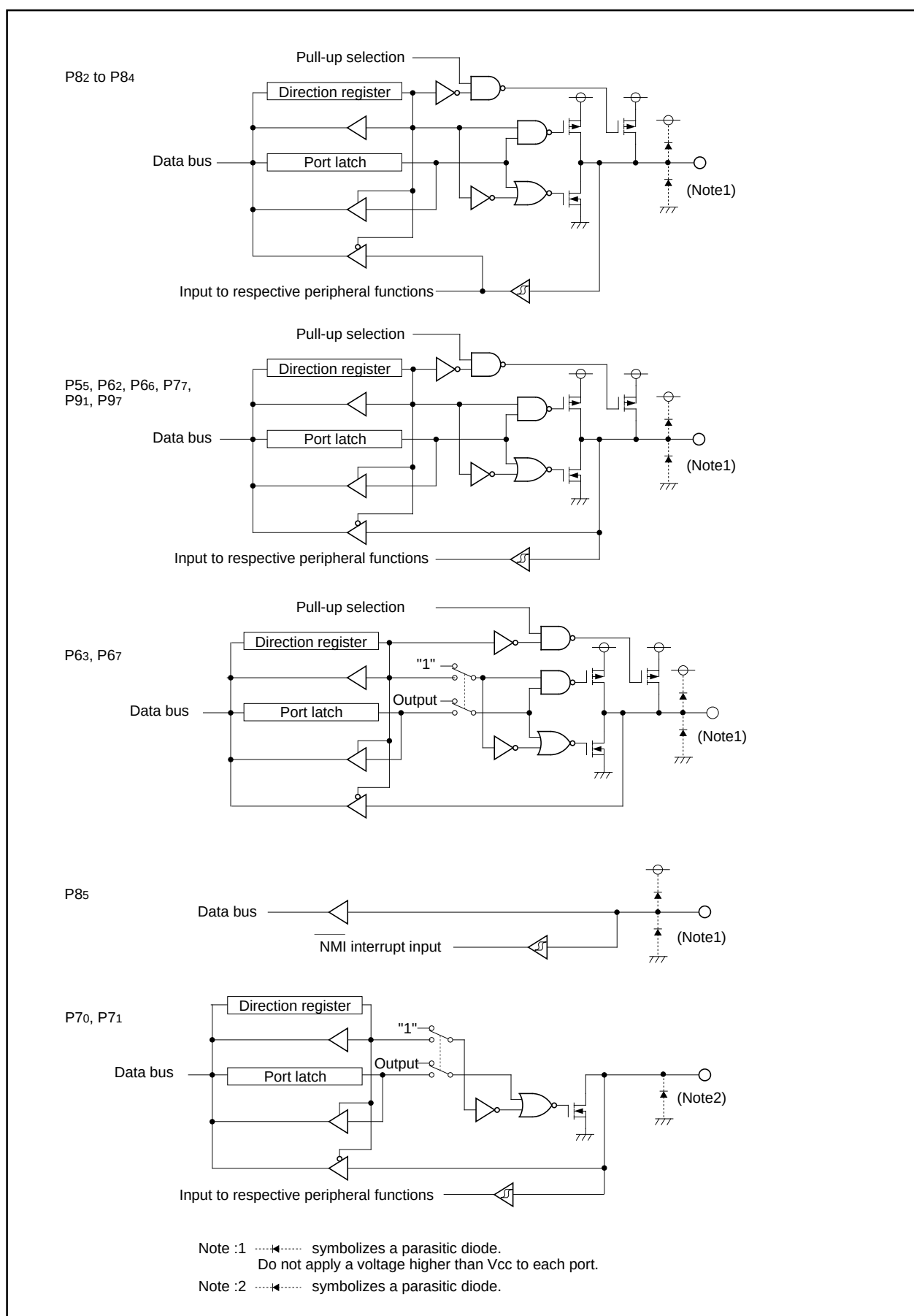


Figure 1.20.2. Programmable I/O ports (2)

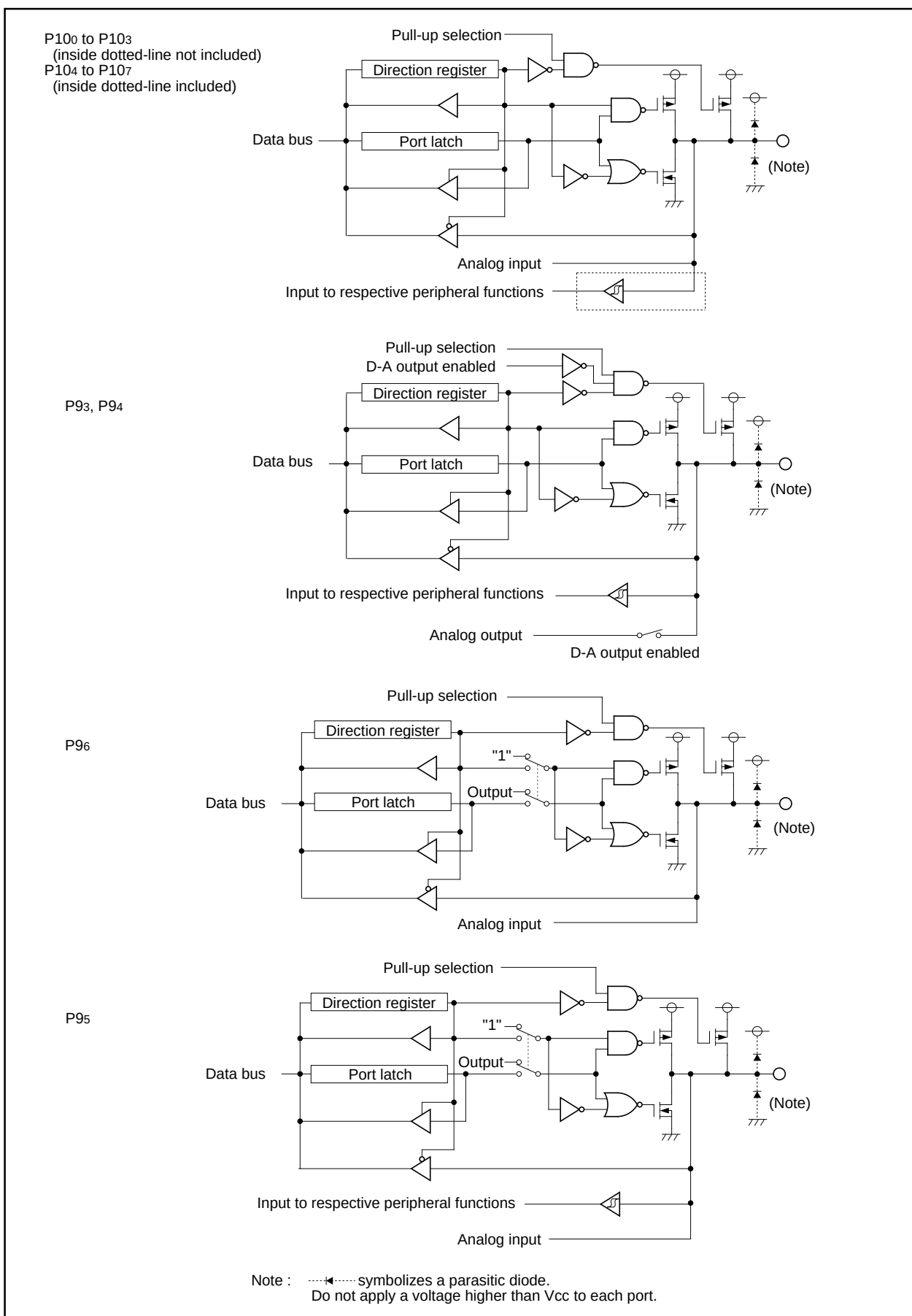


Figure 1.20.3. Programmable I/O ports (3)

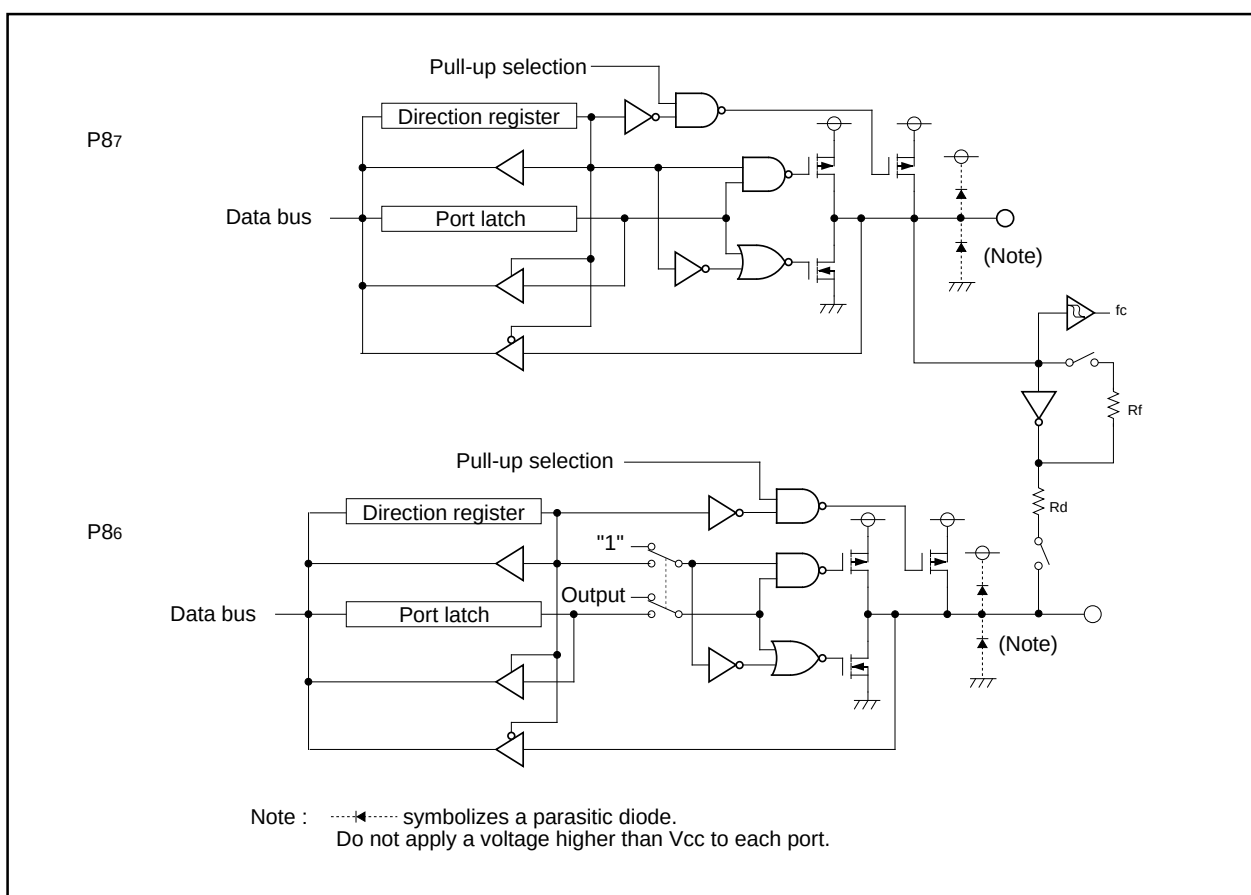


Figure 1.20.4. Programmable I/O ports (4)

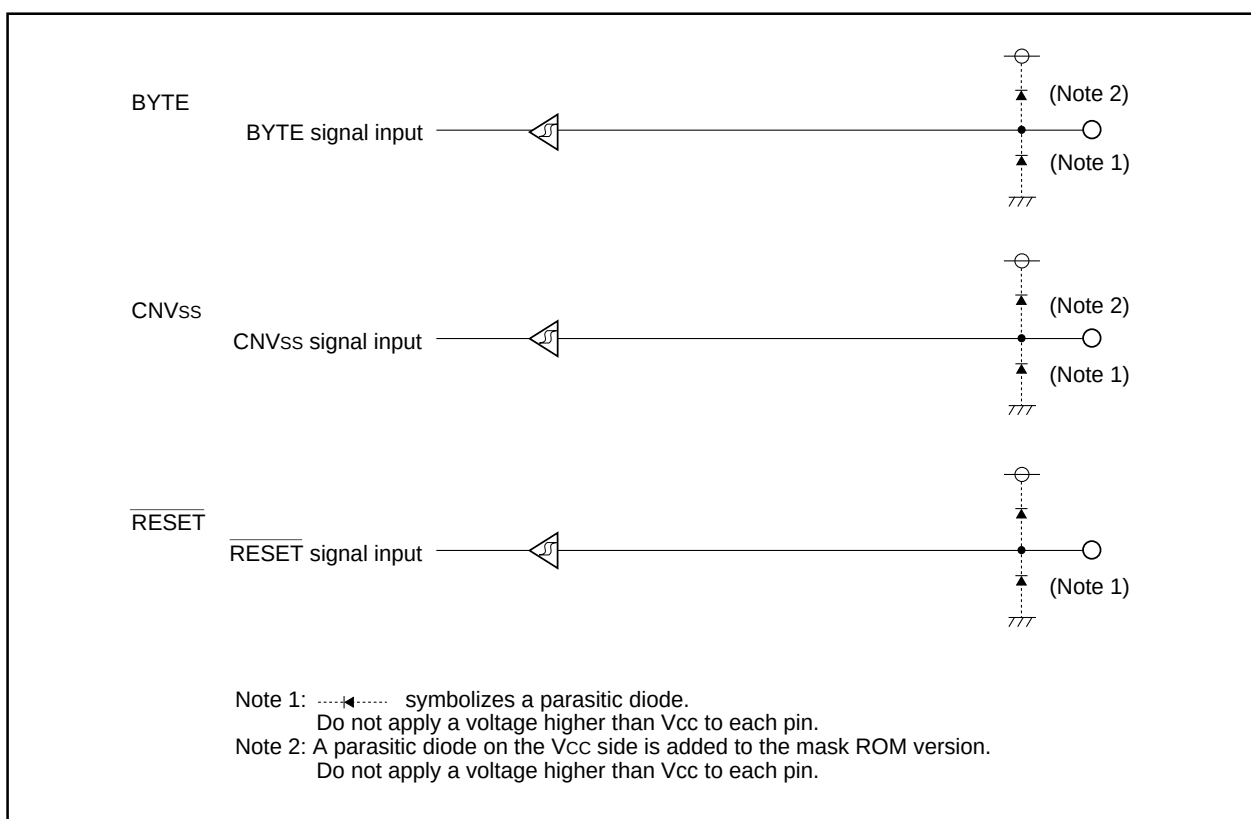


Figure 1.20.5. I/O pins

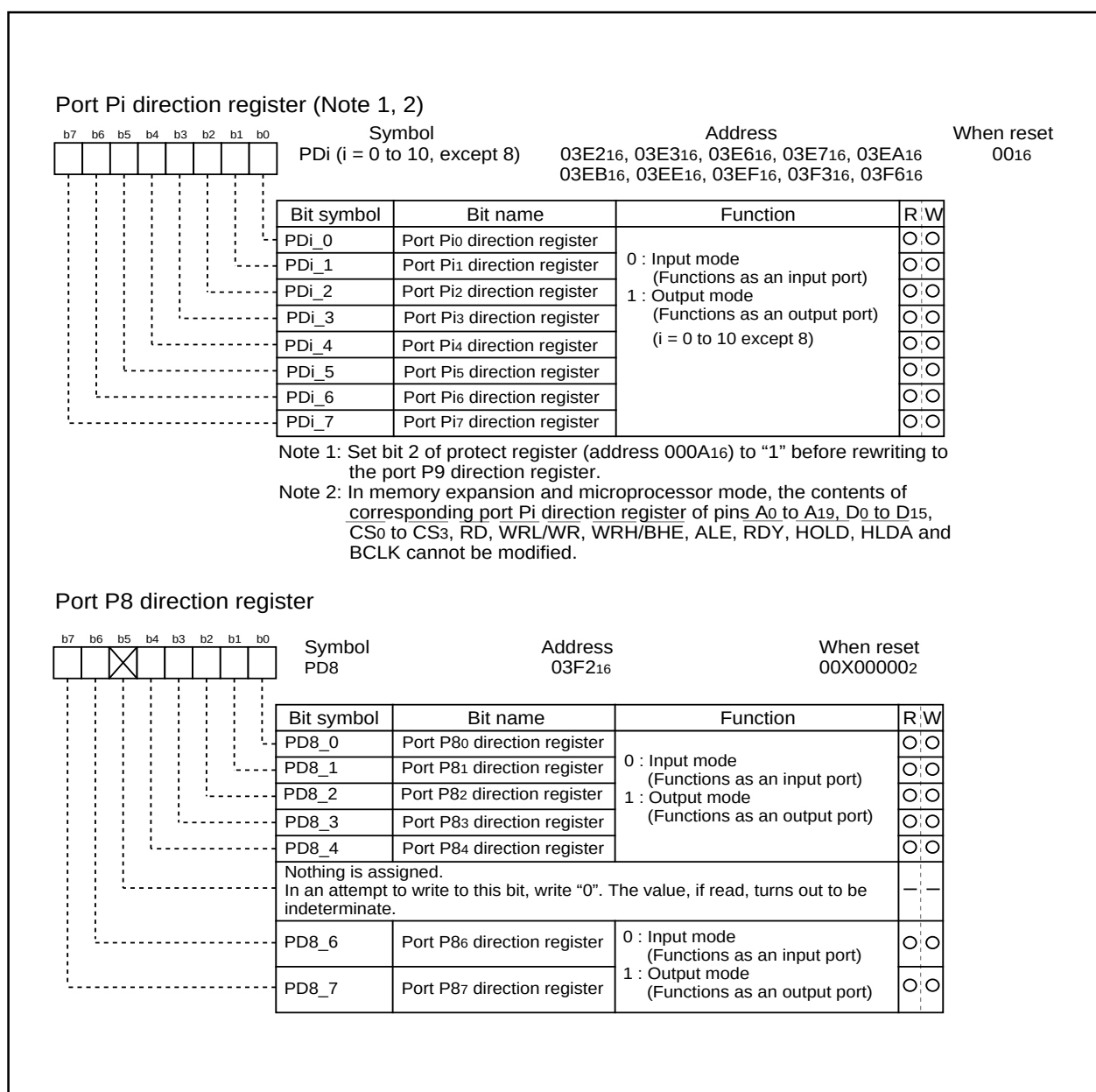


Figure 1.20.6. Direction register

Port Pi register (Note 2)

Symbol	Address	When reset
Pi (i = 0 to 10, except 8)	03E0 ₁₆ , 03E1 ₁₆ , 03E4 ₁₆ , 03E5 ₁₆ , 03E8 ₁₆ 03E9 ₁₆ , 03EC ₁₆ , 03ED ₁₆ , 03F1 ₁₆ , 03F4 ₁₆	Indeterminate Indeterminate

Bit symbol	Bit name	Function	R:W
Pi_0	Port Pi ₀ register	Data is input and output to and from each pin by reading and writing to and from each corresponding bit 0 : "L" level data 1 : "H" level data (Note 1) (i = 0 to 10 except 8)	○:○
Pi_1	Port Pi ₁ register		○:○
Pi_2	Port Pi ₂ register		○:○
Pi_3	Port Pi ₃ register		○:○
Pi_4	Port Pi ₄ register		○:○
Pi_5	Port Pi ₅ register		○:○
Pi_6	Port Pi ₆ register		○:○
Pi_7	Port Pi ₇ register		○:○

Note 1: Since P7₀ and P7₁ are N-channel open drain ports, the data is high-impedance.

Note 2: In memory expansion and microprocessor mode, the contents of corresponding port Pi register of pins A₀ to A₁₉, D₀ to D₁₅, CS₀ to CS₃, RD, WRL/WR, WRH/BHE, ALE, RDY, HOLD, HLDA and BCLK cannot be modified.

Port P8 register

Symbol	Address	When reset
P8	03F0 ₁₆	Indeterminate

Bit symbol	Bit name	Function	R:W
P8_0	Port P8 ₀ register	Data is input and output to and from each pin by reading and writing to and from each corresponding bit (except for P8 ₅) 0 : "L" level data 1 : "H" level data	○:○
P8_1	Port P8 ₁ register		○:○
P8_2	Port P8 ₂ register		○:○
P8_3	Port P8 ₃ register		○:○
P8_4	Port P8 ₄ register		○:○
P8_5	Port P8 ₅ register		○:×
P8_6	Port P8 ₆ register		○:○
P8_7	Port P8 ₇ register		○:○

Figure 1.20.7. Port register

Programmable I/O Port

Pull-up control register 0 (Note)

b7	b6	b5	b4	b3	b2	b1	b0	Symbol PUR0	Address 03FC ₁₆	When reset 00 ₁₆

Note : In memory expansion and microprocessor mode, the content of this register can be changed, but the pull-up resistance is not connected.

Pull-up control register 1

b7	b6	b5	b4	b3	b2	b1	b0	Symbol PUR1	Address 03FD ₁₆	When reset 00 ₁₆ (Note 2)	
								Bit symbol	Bit name	Function	R/W
								PU10	P40 to P43 pull-up (Note 3)	The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high	☐ ☐
								PU11	P44 to P47 pull-up		☐ ☐
								PU12	P50 to P53 pull-up (Note 3)		☐ ☐
								PU13	P54 to P57 pull-up		☐ ☐
								PU14	P60 to P63 pull-up		☐ ☐
								PU15	P64 to P67 pull-up		☐ ☐
								PU16	P72 to P73 pull-up (Note 1)		☐ ☐
								PU17	P74 to P77 pull-up		☐ ☐

Note 1: Since P70 and P71 are N-channel open drain ports, pull-up is not available for them.

Note 2: When the Vcc level is being impressed to the CNVss terminal, this register becomes to 02₁₆ when reset (PU11 becomes to "1").

Note 3: In memory expansion and microprocessor mode, the content of these bits can be changed, but the pull-up resistance is not connected.

Pull-up control register 2

b7	b6	b5	b4	b3	b2	b1	b0	Symbol PUR2	Address 03FE ₁₆	When reset 00 ₁₆	
Bit symbol		Bit name		Function			R		W		
PU20		P8 ₀ to P8 ₃ pull-up		The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high			○		○		
PU21		P8 ₄ to P8 ₇ pull-up (Except P8 ₅)					○		○		
PU22		P9 ₀ to P9 ₃ pull-up					○		○		
PU23		P9 ₄ to P9 ₇ pull-up					○		○		
PU24		P10 ₀ to P10 ₃ pull-up					○		○		
PU25		P10 ₄ to P10 ₇ pull-up					○		○		
Nothing is assigned. In an attempt to write to these bits, write “0”. The value, if read, turns out to be “0”.								—		—	
								—		—	

Figure 1.20.8. Pull-up control register

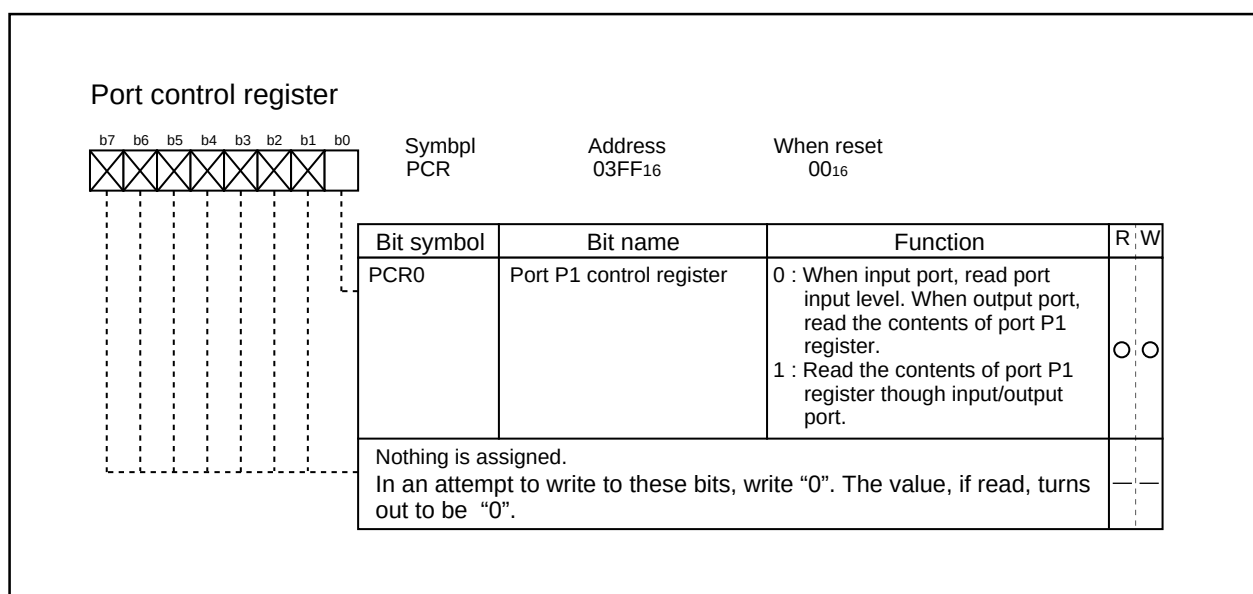


Figure 1.20.9. Port control register

Programmable I/O Port

Table 1.20.1. Example connection of unused pins in single-chip mode

Pin name	Connection
Ports P0 to P10 (excluding P85)	After setting for input mode, connect every pin to Vss via a resistor (pull-down); or after setting for output mode, leave these pins open.
XOUT (Note)	Open
$\overline{\text{NMI}}$	Connect via resistor to Vcc (pull-up)
AVcc	Connect to Vcc
AVss, VREF, BYTE	Connect to Vss

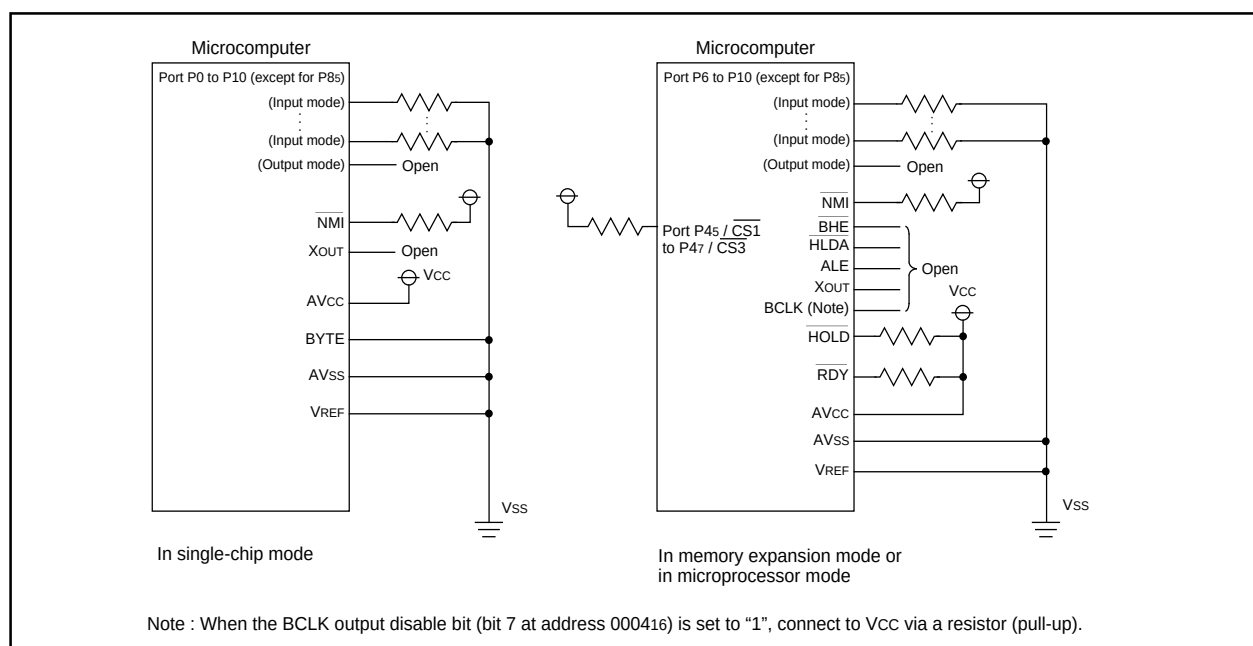
Note: With external clock input to XIN pin.

Table 1.20.2. Example connection of unused pins in memory expansion mode and microprocessor mode

Pin name	Connection
Ports P6 to P10 (excluding P85)	After setting for input mode, connect every pin to Vss via a resistor (pull-down); or after setting for output mode, leave these pins open.
P45 / $\overline{\text{CS1}}$ to P47 / $\overline{\text{CS3}}$	Set ports to input mode, set output enable bits of $\overline{\text{CS1}}$ through $\overline{\text{CS3}}$ to 0, and connect to Vcc via resistors (pull-up).
$\overline{\text{BHE}}$, ALE, $\overline{\text{HLDA}}$, XOUT (Note 1), BCLK (Note 2)	Open
$\overline{\text{HOLD}}$, RDY, $\overline{\text{NMI}}$	Connect via resistor to Vcc (pull-up)
AVcc	Connect to Vcc
AVss, VREF	Connect to Vss

Note 1: With external clock input to XIN pin.

Note 2: When the BCLK output disable bit (bit 7 at address 000416) is set to "1", connect to Vcc via a resistor (pull-up).

**Figure 1.20.10. Example connection of unused pins**

Items to be submitted when ordering masked ROM version

Please submit the following when ordering masked ROM products:

- (1) Mask ROM confirmation form
- (2) Mask specification sheet
- (3) ROM data : Floppy disks *

*: 3.5-inch double-sided high-density disk (IBM format) is required per pattern.

Electrical characteristics

Table 1.23.1. Absolute maximum ratings

Symbol	Parameter		Condition	Rated value	Unit
V _{cc}	Supply voltage		V _{cc} =AV _{cc}	-0.3 to 6.5	V
AV _{cc}	Analog supply voltage		V _{cc} =AV _{cc}	-0.3 to 6.5	V
V _i	Input voltage	RESET, CNV _{ss} , BYTE, 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 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇ , VREF, X _{IN}		-0.3 to V _{cc} +0.3	V
		P7 ₀ , P7 ₁		-0.3 to 6.5	V
V _o	Output voltage	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 , X _{OUT}		-0.3 to V _{cc} +0.3	V
		P7 ₀ , P7 ₁		-0.3 to 6.5	V
P _d	Power dissipation		T _{opr} =25°C	300	mW
T _{opr}	Operating ambient temperature			-20 to 85 / -40 to 85 (Note)	°C
T _{stg}	Storage temperature			-65 to 150	°C

Note : Specify a product of -40°C to 85°C to use it.

Electrical characteristics

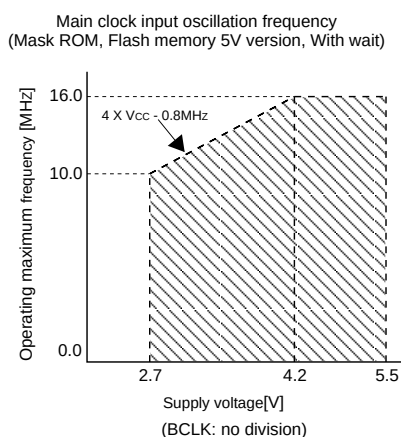
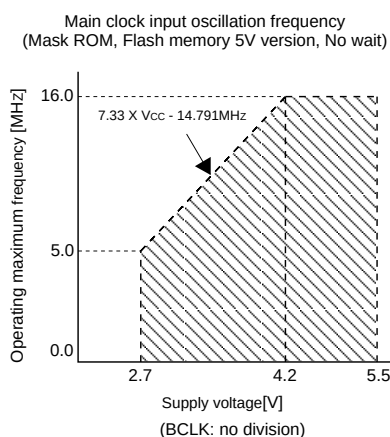
Table 1.23.2. Recommended operating conditions (referenced to $V_{CC} = 2.7V$ to $5.5V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (Note 3) unless otherwise specified)

Symbol	Parameter			Standard			Unit
				Min	Typ.	Max.	
Vcc	Supply voltage			2.7	5.0	5.5	V
AVcc	Analog supply voltage				Vcc		V
Vss	Supply voltage				0		V
AVss	Analog supply voltage				0		V
VIH	HIGH input voltage	P31 to P37, P40 to P47, P50 to P57, P60 to P67, P72 to P77, P80 to P87, P90 to P97, P100 to P107, XIN, RESET, CNVss, BYTE		0.8Vcc		Vcc	V
		P70 ,P71		0.8Vcc		6.5	V
		P00 to P07, P10 to P17, P20 to P27, P30 (during single-chip mode)		0.8Vcc		Vcc	V
		P00 to P07, P10 to P17, P20 to P27, P30 (data input function during memory expansion and microprocessor modes)		0.5Vcc		Vcc	V
VIL	LOW input voltage	P31 to P37, P40 to P47, P50 to P57, P60 to P67, P70 to P77, P80 to P87, P90 to P97, P100 to P107, XIN, RESET, CNVss, BYTE		0		0.2Vcc	V
		P00 to P07, P10 to P17, P20 to P27, P30 (during single-chip mode)		0		0.2Vcc	V
		P00 to P07, P10 to P17, P20 to P27, P30 (data input function during memory expansion and microprocessor modes)		0		0.16Vcc	V
IOH (peak)	HIGH peak output current	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P47, P50 to P57, P60 to P67, P72 to P77, P80 to P84, P86, P87, P90 to P97, P100 to P107				-10.0	mA
IOH (avg)	HIGH average output current	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P47, P50 to P57, P60 to P67, P72 to P77, P80 to P84, P86, P87, P90 to P97, P100 to P107				-5.0	mA
IOL (peak)	LOW peak output current	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P47, P50 to P57, P60 to P67, P70 to P77, P80 to P84, P86, P87, P90 to P97, P100 to P107				10.0	mA
IOL (avg)	LOW average output current	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P47, P50 to P57, P60 to P67, P70 to P77, P80 to P84, P86, P87, P90 to P97, P100 to P107				5.0	mA
f(XIN)	Main clock input oscillation frequency	No wait	Mask ROM version, Flash memory 5V version (Note 5)	Vcc=4.2V to 5.5V	0	16	MHz
				Vcc=2.7V to 4.2V	0	7.33 X Vcc -14.791	MHz
		With wait	Mask ROM version, Flash memory 5V version (Note 5)	Vcc=4.2V to 5.5V	0	16	MHz
				Vcc=2.7V to 4.2V	0	4 X Vcc -0.8	MHz
f(XCIN)	Subclock oscillation frequency				32.768	50	kHz

Note 1: The mean output current is the mean value within 100ms.

Note 2: The total $I_{OL}(\text{peak})$ for ports P0, P1, P2, P86, P87, P9, and P10 must be 80mA max. The total $I_{OH}(\text{peak})$ for ports P0, P1, P2, P86, P87, P9, and P10 must be 80mA max. The total $I_{OL}(\text{peak})$ for ports P3, P4, P5, P6, P7, and P80 to P84 must be 80mA max. The total $I_{OH}(\text{peak})$ for ports P3, P4, P5, P6, P72 to P77, and P80 to P84 must be 80mA max.Note 3: Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Note 4: Relationship between main clock oscillation frequency and supply voltage.

Note 5: Execute case without wait, program / erase of flash memory by $V_{CC}=4.2V$ to $5.5V$ and $f(\text{BCLK}) \leq 6.25$ MHz. Execute case with wait, program / erase of flash memory by $V_{CC}=4.2V$ to $5.5V$ and $f(\text{BCLK}) \leq 12.5$ MHz.

Electrical characteristics (V_{CC} = 5V)V_{CC} = 5V**Table 1.23.3. A-D conversion characteristics (referenced to V_{CC} = AV_{CC} = V_{REF} = 2.7V to 5.5V, V_{SS} = AV_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 4) unless otherwise specified)**

Symbol	Parameter		Measuring condition	Standard			Unit
				Min.	Typ.	Max.	
–	Resolution		V _{REF} = V _{CC}			10	Bits
–	Absolute accuracy	Sample & hold function not available	V _{REF} = V _{CC} = 5V			±3	LSB
		Sample & hold function available(10bit)	V _{REF} = V _{CC} = 5V			±3	LSB
		Sample & hold function available(8bit)	V _{REF} = V _{CC} = 5V			±2	LSB
		Sample & hold function not available(8bit)	V _{REF} = V _{CC} = 3V, ØAD = f _{AD} /2			±2	LSB
RLADDER	Ladder resistance		V _{REF} = V _{CC}	10		40	kΩ
t _{CONV}	Conversion time(10bit), Sample & hold function available		V _{REF} = V _{CC} = 5V, ØAD = 10MHz	3.3			µs
t _{CONV}	Conversion time(8bit), Sample & hold function available		V _{REF} = V _{CC} = 5V, ØAD = 10MHz	2.8			µs
t _{CONV}	Conversion time(8bit), Sample & hold function not available		V _{REF} = V _{CC} = 3V, ØAD = f _{AD} /2 = 5MHz	9.8			µs
t _{SAMP}	Sampling time			0.3			µs
V _{REF}	Reference voltage			2.7		V _{CC}	V
V _{IA}	Analog input voltage			0		V _{REF}	V

Note 1: Do f(X_{IN}) in range of main clock input oscillation frequency prescribed with recommended operating conditions of table 1.23.2. Divide the f_{AD} if f(X_{IN}) exceeds 10MHz, and make AD operation clock frequency (ØAD) equal to or lower than 10MHz. And divide the f_{AD} if V_{CC} is less than 4.2V, and make AD operation clock frequency (ØAD) equal to or lower than f_{AD}/2.

Note 2: A case without sample & hold function turn AD operation clock frequency (ØAD) into 250 kHz or more in addition to a limit of Note 1.
A case with sample & hold function turn AD operation clock frequency (ØAD) into 1MHz or more in addition to a limit of Note 1.

Note 3: Connect AV_{CC} pin to V_{CC} pin and apply the same electric potential.

Note 4: Specify a product of -40°C to 85°C to use it.

Table 1.23.4. D-A conversion characteristics (referenced to V_{CC} = V_{REF} = 2.7V to 5.5V, V_{SS} = AV_{SS} = 0V, at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 2) unless otherwise specified)

Symbol	Parameter	Measuring condition	Standard			Unit
			Min.	Typ.	Max.	
–	Resolution				8	Bits
–	Absolute accuracy				1.0	%
t _{su}	Setup time				3	µs
R _o	Output resistance		4	10	20	kΩ
I _{VREF}	Reference power supply input current	(Note 1)			1.5	mA

Note 1: This applies when using one D-A converter, with the D-A register for the unused D-A converter set to "0016".

The A-D converter's ladder resistance is not included.

Also, when D-A register contents are not "00 16", the current I_{VREF} always flows even though V_{ref} may have been set to be unconnected by the A-D control register.

Note 2: Specify a product of -40°C to 85°C to use it.

Table 1.23.5. Flash memory version electrical characteristics(referenced to V_{CC} = 4.2V to 5.5V, at Topr = 0 to 60°C unless otherwise specified)

Parameter	Standard			Unit
	Min.	Typ.	Max	
Page program time		6	120	ms
Block erase time		50	600	ms
Erase all unlocked blocks time		50 X n (Note)	600 X n (Note)	ms
Lock bit program time		6	120	ms

Note : n denotes the number of block erases.

Electrical characteristics (V_{CC} = 5V)V_{CC} = 5V**Table 1.23.6. Electrical characteristics (referenced to V_{CC} = 4.2V to 5.5V, V_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 2), f(X_{IN}) = 16MHz unless otherwise specified)**

Symbol	Parameter		Measuring condition	Standard			Unit
				Min	Typ.	Max.	
V _{OH}	HIGH output voltage	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	I _{OH} = -5mA	3.0			V
V _{OH}	HIGH output voltage	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	I _{OH} = -200μA	4.7			V
V _{OH}	HIGH output voltage	X _{OUT}	HIGHPOWER	I _{OH} = -1mA	3.0		V
			LOWPOWER	I _{OH} = -0.5mA	3.0		
	HIGH output voltage	X _{COUT}	HIGHPOWER	With no load applied		3.0	V
			LOWPOWER	With no load applied		1.6	
V _{OL}	LOW output voltage	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 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	I _{OL} = 5mA			2.0	V
V _{OL}	LOW output voltage	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 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	I _{OL} = 200μA			0.45	V
V _{OL}	LOW output voltage	X _{OUT}	HIGHPOWER	I _{OL} = 1mA		2.0	V
			LOWPOWER	I _{OL} = 0.5mA		2.0	
	LOW output voltage	X _{COUT}	HIGHPOWER	With no load applied		0	V
			LOWPOWER	With no load applied		0	
V _{T+} -V _{T-}	Hysteresis	HOLD, RDY, TA0 _{IN} to TA4 _{IN} , TB0 _{IN} to TB5 _{IN} , INT0 to INT5, NMI, ADTRG, CTS0 to CTS2, SCL, SDA, CLK0 to CLK4, TA2 _{OUT} to TA4 _{OUT} , K10 to K13, RxD0 to RxD2, S1N3, S1N4		0.2		1.0	V
V _{T+} -V _{T-}	Hysteresis	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 , X _{IN} , RESET, CNVss, BYTE	V _I = 5V			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 , X _{IN} , RESET, CNVss, BYTE	V _I = 0V			-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 = 0V	30.0	50.0	167.0	kΩ
R _{IXIN}	Feedback resistance	X _{IN}			1.0		MΩ
R _{IXCIN}	Feedback resistance	X _{CIN}			6.0		MΩ
V _{RAM}	RAM retention voltage		When clock is stopped	2.0			V
I _{CC}	Power supply current	In single-chip mode, the output pins are open and other pins are V _{SS}	Mask ROM version	f(X _{IN}) = 16MHz Square wave, no division	30.0	50.0	mA
			Flash memory 5V version	f(X _{IN}) = 16MHz Square wave, no division	32.5	50.0	mA
			Mask ROM version	f(X _{CIN}) = 32kHz Square wave	90.0		μA
			Flash memory 5V version	f(X _{CIN}) = 32kHz Square wave, in RAM	90.0		μA
			Flash memory 5V version	f(X _{CIN}) = 32kHz Square wave, in flash memory	2.2		mA
			Flash memory 5V version, Program	f(X _{IN}) = 16MHz Square wave, Division by 4	25		mA
			Flash memory 5V version, Erase	f(X _{IN}) = 16MHz Square wave, Division by 4	28		mA
				f(X _{CIN}) = 32kHz When a WAIT instruction is executed (Note 1)	4.0	10 (Topr = 25°C)	μA
				Topr = 25°C when clock is stopped		1.0	μA
				Topr = 85°C when clock is stopped		20.0	μA

Note 1: With one timer operated using fc32.

Note 2: Specify a product of -40°C to 85°C to use it.

Timing (V_{CC} = 5V)V_{CC} = 5V

Timing requirements (referenced to V_{CC} = 5V, V_{SS} = 0V at T_{opr} = – 20°C to 85°C / – 40°C to 85°C (*) unless otherwise specified)

* : Specify a product of -40°C to 85°C to use it.

Table 1.23.7. External clock input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t _c	External clock input cycle time	62.5		ns
t _{w(H)}	External clock input HIGH pulse width	25		ns
t _{w(L)}	External clock input LOW pulse width	25		ns
t _r	External clock rise time		15	ns
t _f	External clock fall time		15	ns

Table 1.23.8. Memory expansion and microprocessor modes

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t _{ac1} (RD-DB)	Data input access time (no wait)		(Note)	ns
t _{ac2} (RD-DB)	Data input access time (with wait)		(Note)	ns
t _{ac3} (RD-DB)	Data input access time (when accessing multiplex bus area)		(Note)	ns
t _{su} (DB-RD)	Data input setup time	40		ns
t _{su} (RDY-BCLK)	RDY input setup time	30		ns
t _{su} (HOLD-BCLK)	HOLD input setup time	40		ns
t _h (RD-DB)	Data input hold time	0		ns
t _h (BCLK-RDY)	RDY input hold time	0		ns
t _h (BCLK-HOLD)	HOLD input hold time	0		ns
t _d (BCLK-HLDA)	HLDA output delay time		40	ns

Note: Calculated according to the BCLK frequency as follows:

$$t_{ac1}(\text{RD} - \text{DB}) = \frac{10^9}{f(\text{BCLK}) \times 2} - 45 \quad [\text{ns}]$$

$$t_{ac2}(\text{RD} - \text{DB}) = \frac{3 \times 10^9}{f(\text{BCLK}) \times 2} - 45 \quad [\text{ns}]$$

$$t_{ac3}(\text{RD} - \text{DB}) = \frac{3 \times 10^9}{f(\text{BCLK}) \times 2} - 45 \quad [\text{ns}]$$

Timing (V_{CC} = 5V)V_{CC} = 5V

**Timing requirements (referenced to V_{CC} = 5V, V_{SS} = 0V at T_{opr} = – 20°C to 85°C / – 40°C to 85°C (*))
unless otherwise specified)**

* : Specify a product of -40°C to 85°C to use it.

Table 1.23.9. Timer A input (counter input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t _c (TA)	TAiN input cycle time	100		ns
t _w (TAH)	TAiN input HIGH pulse width	40		ns
t _w (TAL)	TAiN input LOW pulse width	40		ns

Table 1.23.10. Timer A input (gating input in timer mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t _c (TA)	TAiN input cycle time	400		ns
t _w (TAH)	TAiN input HIGH pulse width	200		ns
t _w (TAL)	TAiN input LOW pulse width	200		ns

Table 1.23.11. Timer A input (external trigger input in one-shot timer mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t _c (TA)	TAiN input cycle time	200		ns
t _w (TAH)	TAiN input HIGH pulse width	100		ns
t _w (TAL)	TAiN input LOW pulse width	100		ns

Table 1.23.12. Timer A input (external trigger input in pulse width modulation mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t _w (TAH)	TAiN input HIGH pulse width	100		ns
t _w (TAL)	TAiN input LOW pulse width	100		ns

Table 1.23.13. Timer A input (up/down input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t _c (UP)	TAiOUT input cycle time	2000		ns
t _w (UPH)	TAiOUT input HIGH pulse width	1000		ns
t _w (UPL)	TAiOUT input LOW pulse width	1000		ns
t _{su} (UP-TiN)	TAiOUT input setup time	400		ns
t _h (TiN-UP)	TAiOUT input hold time	400		ns

Timing ($V_{CC} = 5V$) $V_{CC} = 5V$

Timing requirements (referenced to $V_{CC} = 5V$, $V_{SS} = 0V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (*) unless otherwise specified)

* : Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Table 1.23.14. Timer B input (counter input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiN input cycle time (counted on one edge)	100		ns
$t_{w(TBH)}$	TBiN input HIGH pulse width (counted on one edge)	40		ns
$t_{w(TBL)}$	TBiN input LOW pulse width (counted on one edge)	40		ns
$t_{c(TB)}$	TBiN input cycle time (counted on both edges)	200		ns
$t_{w(TBH)}$	TBiN input HIGH pulse width (counted on both edges)	80		ns
$t_{w(TBL)}$	TBiN input LOW pulse width (counted on both edges)	80		ns

Table 1.23.15. Timer B input (pulse period measurement mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiN input cycle time	400		ns
$t_{w(TBH)}$	TBiN input HIGH pulse width	200		ns
$t_{w(TBL)}$	TBiN input LOW pulse width	200		ns

Table 1.23.16. Timer B input (pulse width measurement mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiN input cycle time	400		ns
$t_{w(TBH)}$	TBiN input HIGH pulse width	200		ns
$t_{w(TBL)}$	TBiN input LOW pulse width	200		ns

Table 1.23.17. A-D trigger input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(AD)}$	ADTRG input cycle time (trigger able minimum)	1000		ns
$t_{w(ADL)}$	ADTRG input LOW pulse width	125		ns

Table 1.23.18. Serial I/O

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	30		ns
$t_{h(C-D)}$	RxDi input hold time	90		ns

Table 1.23.19. External interrupt $\overline{INT_i}$ inputs

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(INH)}$	$\overline{INT_i}$ input HIGH pulse width	250		ns
$t_{w(INL)}$	$\overline{INT_i}$ input LOW pulse width	250		ns

V_{CC} = 5V

Switching characteristics (referenced to V_{CC} = 5V, V_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 3), CM15 = “1” unless otherwise specified)

Table 1.23.20. Memory expansion mode and microprocessor mode (no wait)

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
t _d (BCLK-AD)	Address output delay time	Figure 1.23.1		25	ns
t _h (BCLK-AD)	Address output hold time (BCLK standard)		4		ns
t _h (RD-AD)	Address output hold time (RD standard)		0		ns
t _h (WR-AD)	Address output hold time (WR standard)		0		ns
t _d (BCLK-CS)	Chip select output delay time			25	ns
t _h (BCLK-CS)	Chip select output hold time (BCLK standard)		4		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			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 (BCLK standard)			40	ns
t _h (BCLK-DB)	Data output hold time (BCLK standard)		4		ns
t _d (DB-WR)	Data output delay time (WR standard)		(Note1)		ns
t _h (WR-DB)	Data output hold time (WR standard)(Note2)		0		ns

Note 1: Calculated according to the BCLK frequency as follows:

$$t_d(\text{DB} - \text{WR}) = \frac{10^9}{f(\text{BCLK}) \times 2} - 40 \quad [\text{ns}]$$

Note 2: This is standard value shows the timing when the output is off, and doesn't show hold time of data bus.
Hold time of data bus is different by capacitor volume and pull-up (pull-down) resistance value.

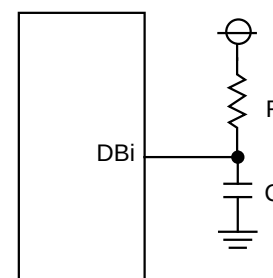
Hold time of data bus is expressed in

$$t = -CR \times \ln(1 - V_{OL} / V_{CC})$$

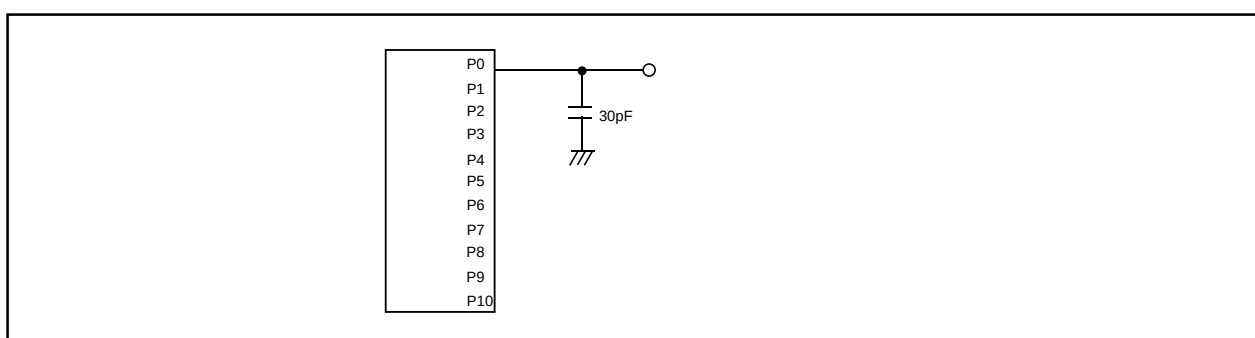
by a circuit of the right figure.

For example, when V_{OL} = 0.2V_{CC}, C = 30pF, R = 1kΩ, hold time of output “L” level is

$$t = -30\text{pF} \times 1\text{k}\Omega \times \ln(1 - 0.2V_{CC} / V_{CC}) \\ = 6.7\text{ns}.$$



Note 3: Specify a product of -40°C to 85°C to use it.

**Figure 1.23.1. Port P0 to P10 measurement circuit**

Timing (V_{CC} = 5V)V_{CC} = 5V

Switching characteristics (referenced to V_{CC} = 5V, V_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 3), CM15 = “1” unless otherwise specified)

**Table 1.23.21. Memory expansion mode and microprocessor mode
(with wait, accessing external memory)**

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
t _d (BCLK-AD)	Address output delay time	Figure 1.23.1		25	ns
t _h (BCLK-AD)	Address output hold time (BCLK standard)		4		ns
t _h (RD-AD)	Address output hold time (RD standard)		0		ns
t _h (WR-AD)	Address output hold time (WR standard)		0		ns
t _d (BCLK-CS)	Chip select output delay time			25	ns
t _h (BCLK-CS)	Chip select output hold time (BCLK standard)		4		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			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 (BCLK standard)			40	ns
t _h (BCLK-DB)	Data output hold time (BCLK standard)		4		ns
t _d (DB-WR)	Data output delay time (WR standard)		(Note1)		ns
t _h (WR-DB)	Data output hold time (WR standard)(Note2)		0		ns

Note 1: Calculated according to the BCLK frequency as follows:

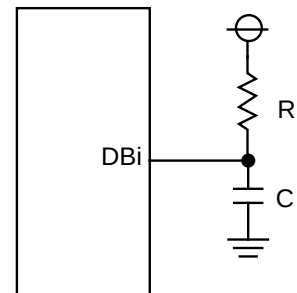
$$t_d(\text{DB} - \text{WR}) = \frac{10^9}{f(\text{BCLK})} - 40 \quad [\text{ns}]$$

Note 2: This is standard value shows the timing when the output is off, and doesn't show hold time of data bus.
Hold time of data bus is different by capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in

$$t = -CR \times \ln(1 - V_{OL} / V_{CC})$$
by a circuit of the right figure.
For example, when V_{OL} = 0.2V_{CC}, C = 30pF, R = 1kΩ, hold time of output “L” level is

$$t = -30\text{pF} \times 1\text{k}\Omega \times \ln(1 - 0.2V_{CC} / V_{CC}) \\ = 6.7\text{ns}.$$

Note 3: Specify a product of -40°C to 85°C to use it.



Timing (V_{CC} = 5V)V_{CC} = 5V

Switching characteristics (referenced to V_{CC} = 5V, V_{SS} = 0V at T_{opr} = – 20°C to 85°C / – 40°C to 85°C (Note 2), CM15 = “1” unless otherwise specified)

Table 1.23.22. Memory expansion mode and microprocessor mode
(with wait, accessing external memory, multiplex bus area selected)

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
t _d (BCLK-AD)	Address output delay time	Figure 1.23.1		25	ns
t _h (BCLK-AD)	Address output hold time (BCLK standard)		4		ns
t _h (RD-AD)	Address output hold time (RD standard)		(Note1)		ns
t _h (WR-AD)	Address output hold time (WR standard)		(Note1)		ns
t _d (BCLK-CS)	Chip select output delay time			25	ns
t _h (BCLK-CS)	Chip select output hold time (BCLK standard)		4		ns
t _h (RD-CS)	Chip select output hold time (RD standard)		(Note1)		ns
t _h (WR-CS)	Chip select output hold time (WR standard)		(Note1)		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 (BCLK standard)			40	ns
t _h (BCLK-DB)	Data output hold time (BCLK standard)		4		ns
t _d (DB-WR)	Data output delay time (WR standard)		(Note1)		ns
t _h (WR-DB)	Data output hold time (WR standard)		(Note1)		ns
t _d (BCLK-ALE)	ALE signal output delay time (BCLK standard)			25	ns
t _h (BCLK-ALE)	ALE signal output hold time (BCLK standard)		– 4		ns
t _d (AD-ALE)	ALE signal output delay time (Address standard)		(Note1)		ns
t _h (ALE-AD)	ALE signal output hold time (Address standard)		30		ns
t _d (AD-RD)	Post-address RD signal output delay time		0		ns
t _d (AD-WR)	Post-address WR signal output delay time		0		ns
t _d (RD-AD)	Address output floating start time			8	ns

Note 1: Calculated according to the BCLK frequency as follows:

$$t_h(\text{RD} - \text{AD}) = \frac{10^9}{f(\text{BCLK}) \times 2} \quad [\text{ns}]$$

$$t_h(\text{WR} - \text{AD}) = \frac{10^9}{f(\text{BCLK}) \times 2} \quad [\text{ns}]$$

$$t_h(\text{RD} - \text{CS}) = \frac{10^9}{f(\text{BCLK}) \times 2} \quad [\text{ns}]$$

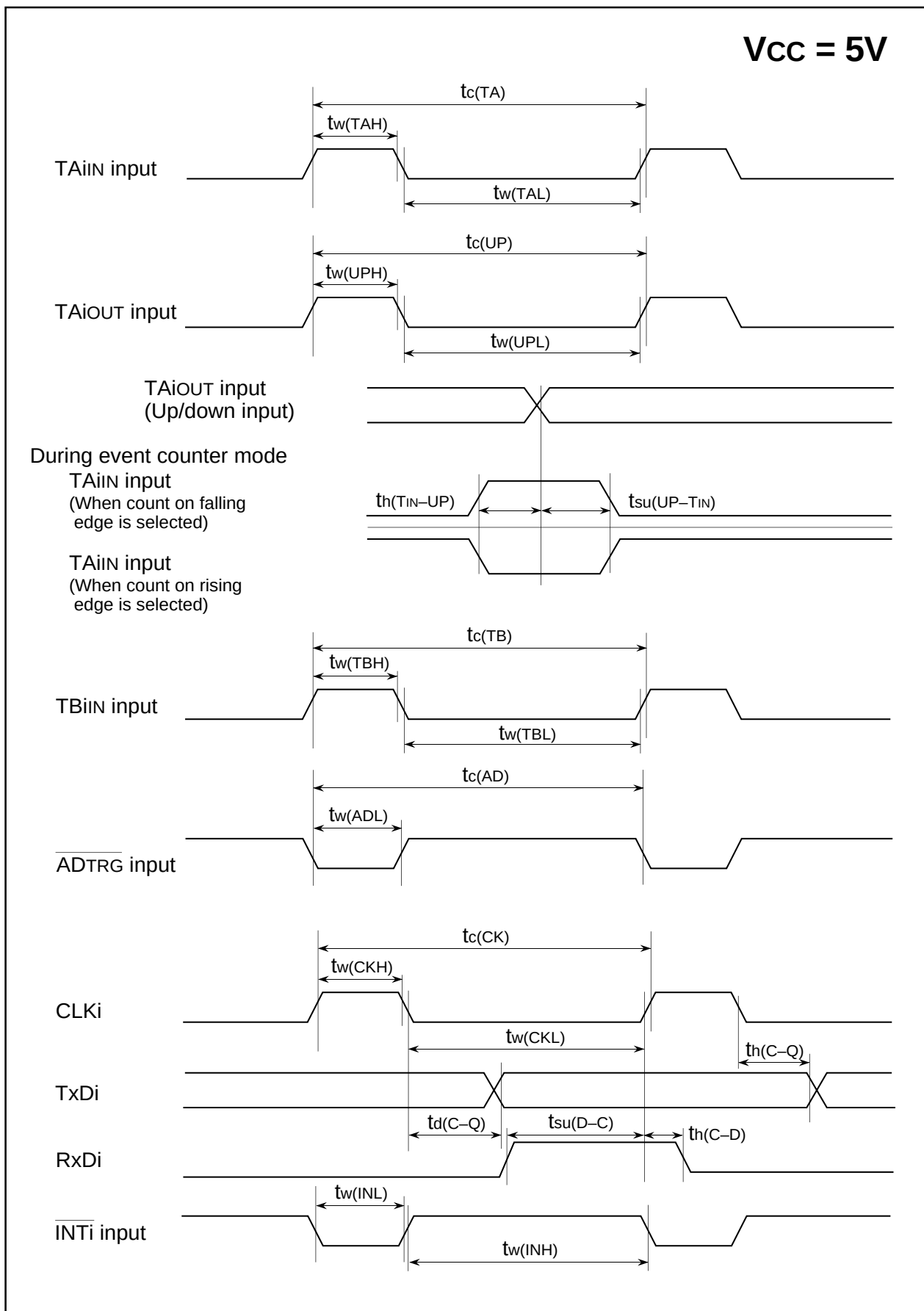
$$t_h(\text{WR} - \text{CS}) = \frac{10^9}{f(\text{BCLK}) \times 2} \quad [\text{ns}]$$

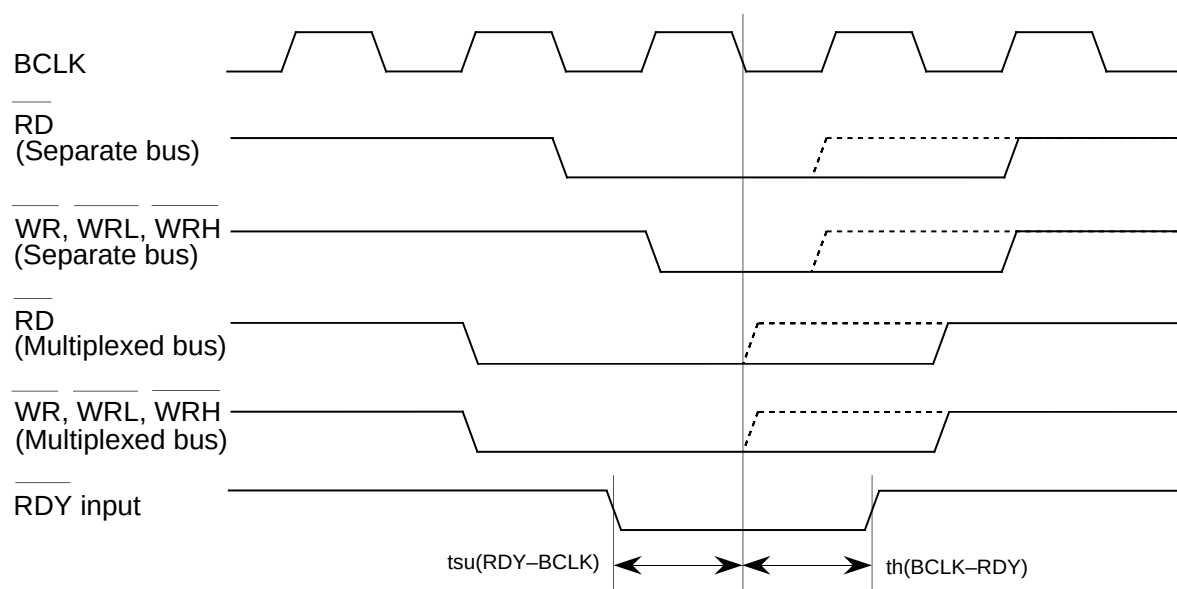
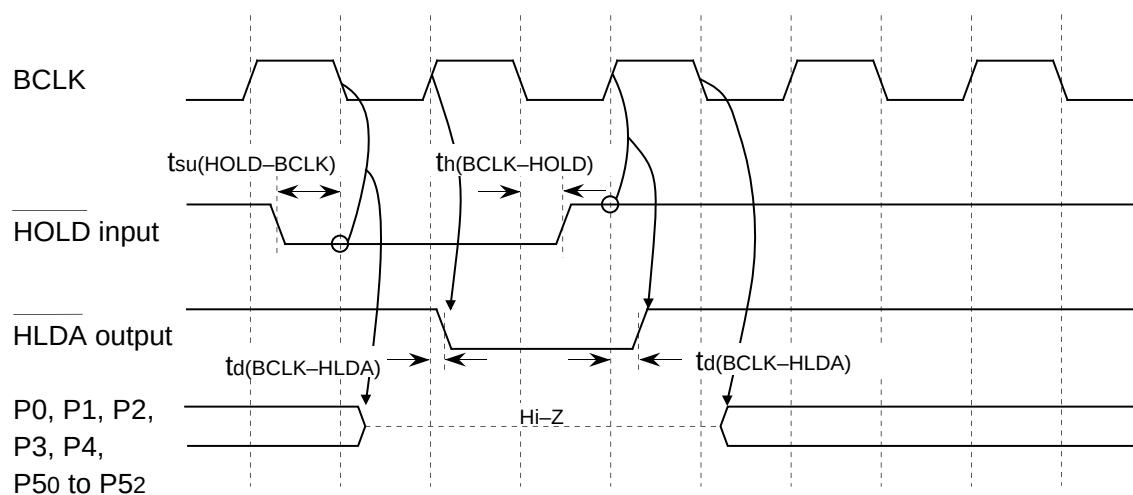
$$t_d(\text{DB} - \text{WR}) = \frac{10^9 \times 3}{f(\text{BCLK}) \times 2} - 40 \quad [\text{ns}]$$

$$t_h(\text{WR} - \text{DB}) = \frac{10^9}{f(\text{BCLK}) \times 2} \quad [\text{ns}]$$

$$t_d(\text{AD} - \text{ALE}) = \frac{10^9}{f(\text{BCLK}) \times 2} - 25 \quad [\text{ns}]$$

Note 2: Specify a product of –40°C to 85°C to use it.

Timing ($V_{CC} = 5V$)Figure 1.23.2. $V_{CC} = 5V$ timing diagram (1)

Timing ($V_{CC} = 5V$) **$V_{CC} = 5V$** **Memory Expansion Mode and Microprocessor Mode****(Valid only with wait)****(Valid with or without wait)**

Note: The above pins are set to high-impedance regardless of the input level of the BYTE pin and bit (PM06) of processor mode register 0 selects the function of ports P40 to P43.

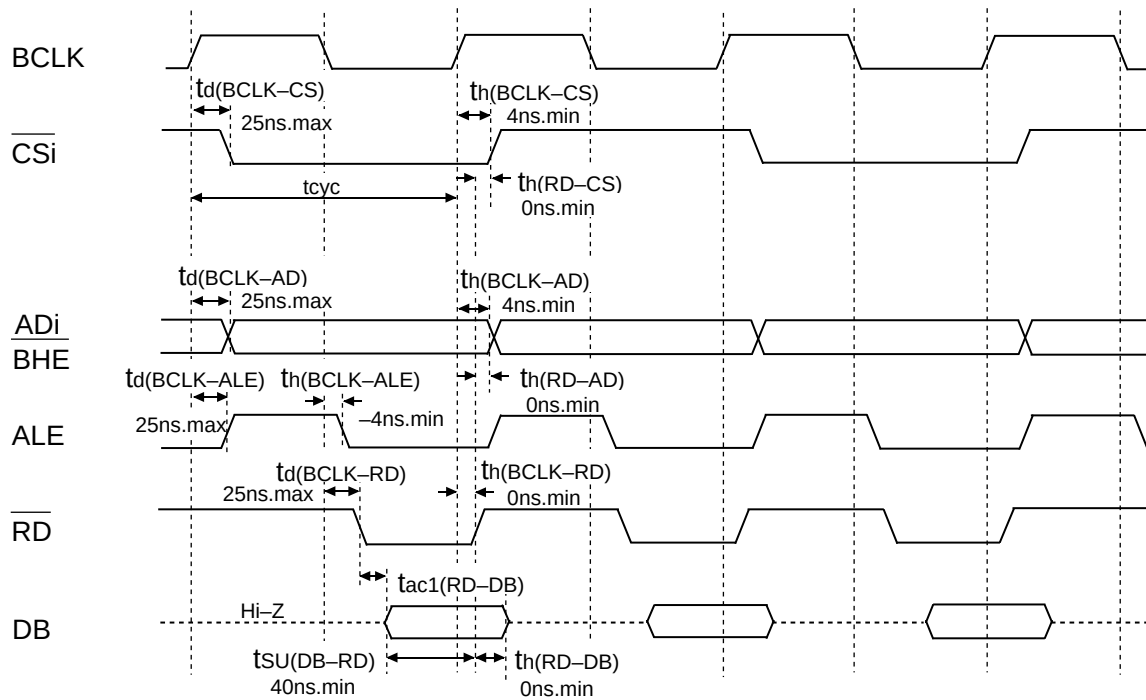
Measuring conditions :

- $V_{CC}=5V$
- Input timing voltage : Determined with $V_{IL}=1.0V$, $V_{IH}=4.0V$
- Output timing voltage : Determined with $V_{OL}=2.5V$, $V_{OH}=2.5V$

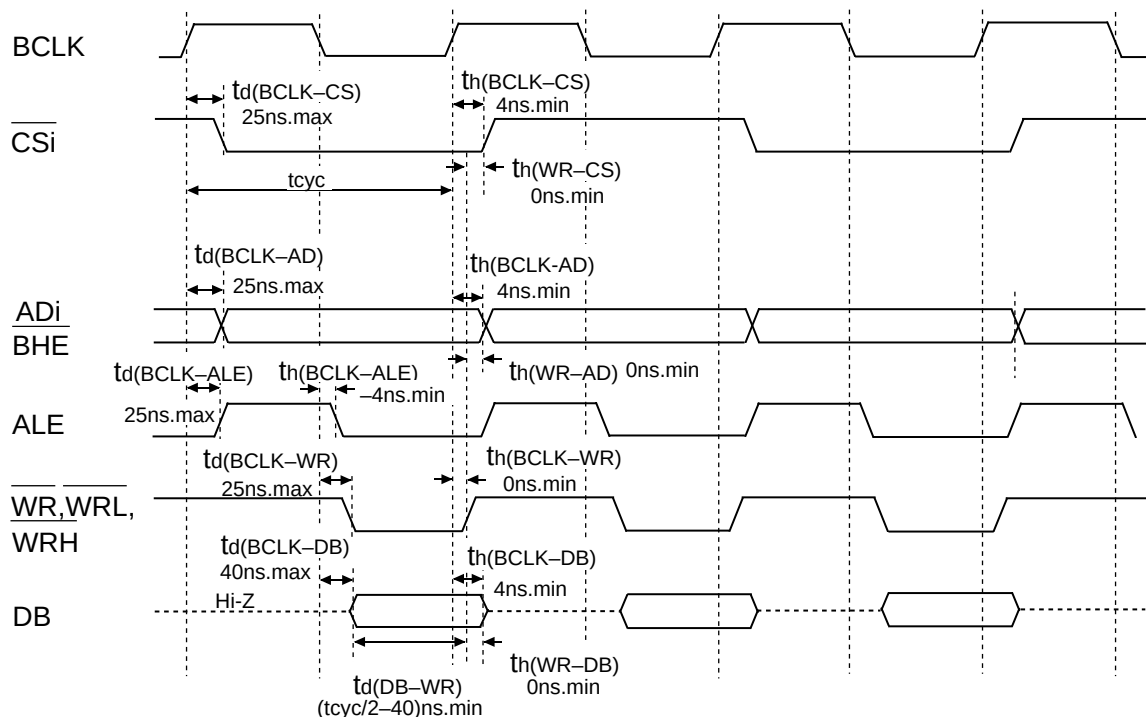
Figure 1.23.3. $V_{CC} = 5V$ timing diagram (2)

Timing ($V_{CC} = 5V$)Memory Expansion Mode and Microprocessor Mode
(With no wait) $V_{CC} = 5V$

Read timing

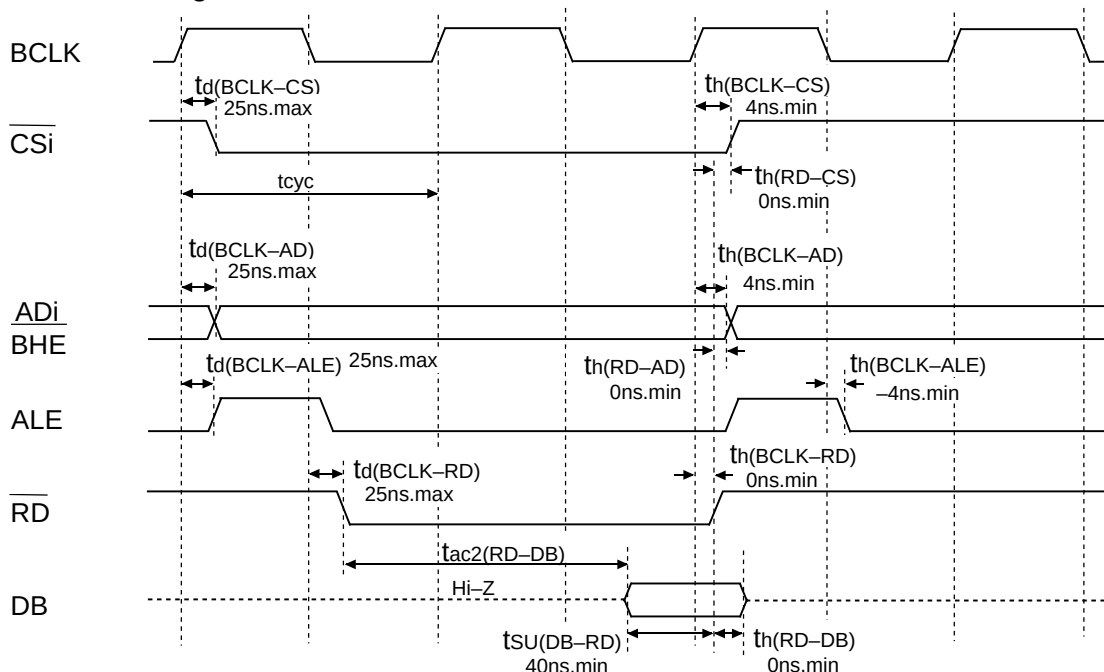


Write timing

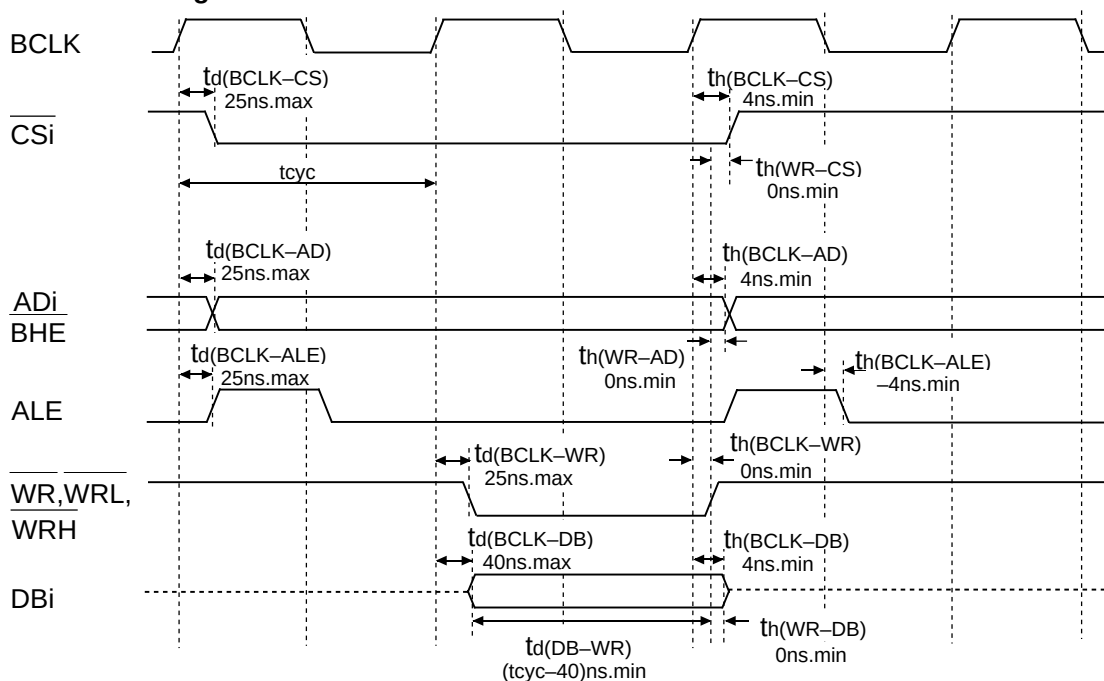
Figure 1.23.4. $V_{CC} = 5V$ timing diagram (3)

Timing ($V_{CC} = 5V$)Memory Expansion Mode and Microprocessor Mode
(When accessing external memory area with wait) $V_{CC} = 5V$

Read timing



Write timing



Measuring conditions :

- $V_{CC}=5V$
- Input timing voltage : Determined with: $V_{IL}=0.8V$, $V_{IH}=2.5V$
- Output timing voltage : Determined with: $V_{OL}=0.8V$, $V_{OH}=2.0V$

Figure 1.23.5. $V_{CC} = 5V$ timing diagram (4)

Timing (Vcc = 5V)

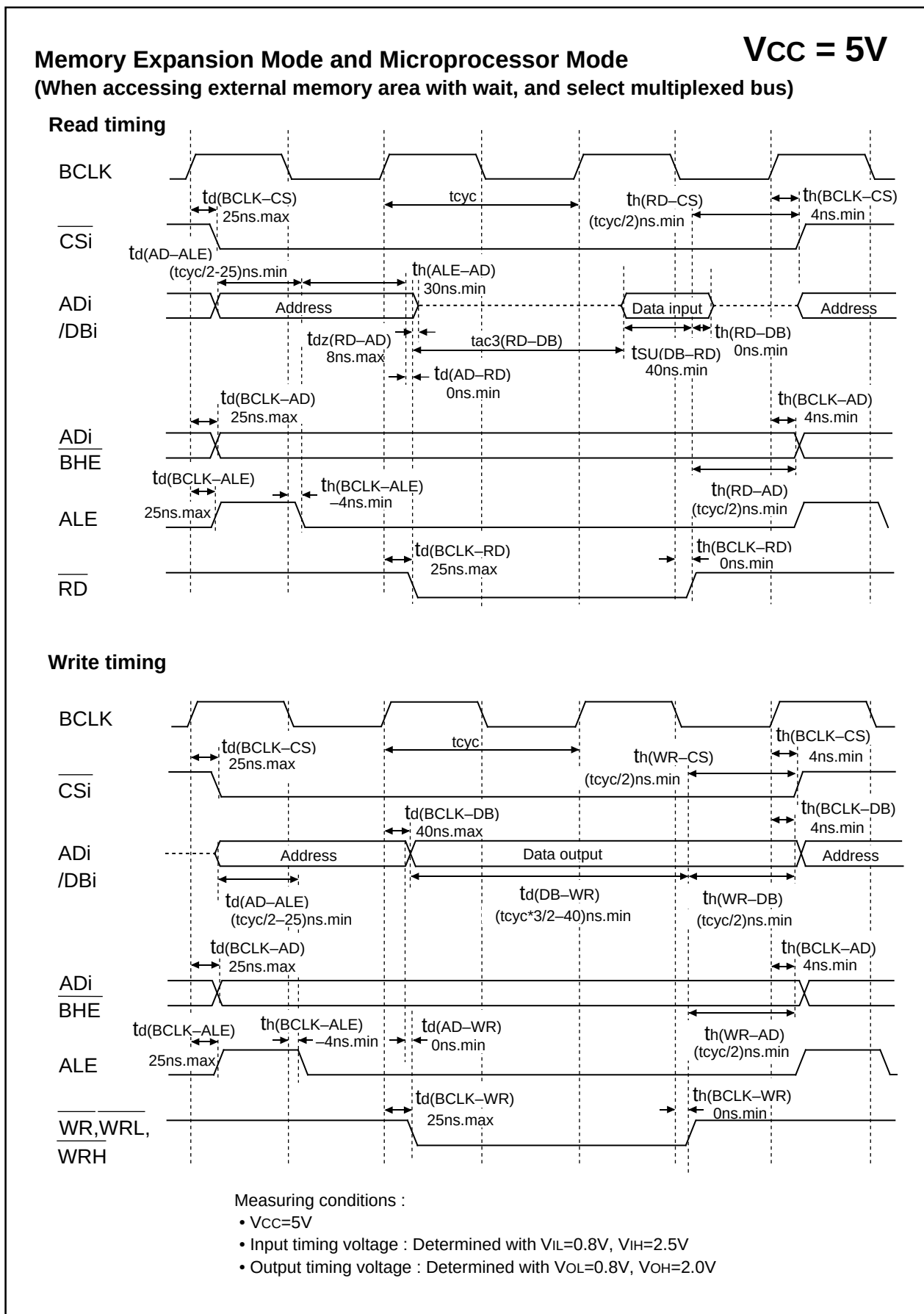


Figure 1.23.6. Vcc = 5V timing diagram (5)

Electrical characteristics (V_{CC} = 3V)V_{CC} = 3V**Table 1.23.23. Electrical characteristics (referenced to V_{CC} = 2.7 to 3.3V, V_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 1), f(X_{IN}) = 10MHz (Note 2) with wait unless otherwise specified)**

Symbol	Parameter		Measuring condition	Standard			Unit
				Min	Typ.	Max.	
V _{OH}	HIGH output voltage	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	I _{OH} = -1mA	2.5			V
V _{OH}	HIGH output voltage	X _{OUT}	HIGHPOWER	I _{OH} = -0.1mA	2.5		V
			LOWPOWER	I _{OH} = -50μA	2.5		
	HIGH output voltage	X _{COUT}	HIGHPOWER	With no load applied		3.0	V
			LOWPOWER	With no load applied		1.6	
V _{OL}	LOW output voltage	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 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	I _{OL} = 1mA			0.5	V
V _{OL}	LOW output voltage	X _{OUT}	HIGHPOWER	I _{OL} = 0.1mA		0.5	V
			LOWPOWER	I _{OL} = 50μA		0.5	
	LOW output voltage	X _{COUT}	HIGHPOWER	With no load applied	0		V
			LOWPOWER	With no load applied	0		
V _{T+} -V _{T-}	Hysteresis	HOLD, RDY, TA0 _{IN} to TA4 _{IN} , TB0 _{IN} to TB5 _{IN} , INT0 to INT5, NMI, ADTRG, CTS0 to CTS2, SCL, SDA CLK0 to CLK4, TA2 _{OUT} to TA4 _{OUT} , KI0 to KI3, RxD0 to RxD2, S _{IN} 3, S _{IN} 4		0.2		0.8	V
V _{T+} -V _{T-}	Hysteresis	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 , X _{IN} , RESET, CNVss, BYTE	V _I = 3V			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 , X _{IN} , RESET, CNVss, BYTE	V _I = 0V			-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 = 0V	66.0	120.0	500.0	kΩ
R _{IXIN}	Feedback resistance	X _{IN}			3.0		MΩ
R _{IXCIN}	Feedback resistance	X _{CIN}			10.0		MΩ
V _{RAM}	RAM retention voltage		When clock is stopped	2.0			V
I _{CC}	Power supply current	In single-chip mode, the output pins are open and other pins are Vss	Mask ROM version	f(X _{IN}) = 10MHz Square wave, no division	8.5	21.25	mA
			Flash memory 5V version	f(X _{IN}) = 10MHz Square wave, no division	12.0	21.25	
			Mask ROM version	f(X _{CIN}) = 32kHz Square wave	40.0		μA
			Flash memory 5V version	f(X _{CIN}) = 32kHz Square wave, in RAM	40.0		
			Flash memory 5V version	f(X _{CIN}) = 32kHz Square wave, in flash memory	800		μA
				f(X _{CIN}) = 32kHz When a WAIT instruction is executed. Oscillation capacity High (Note 3)	2.8	10 (Topr = 25°C)	
				f(X _{CIN}) = 32kHz When a WAIT instruction is executed. Oscillation capacity Low (Note 3)	0.9	10 (Topr = 25°C)	μA
				Topr = 25°C when clock is stopped		1.0	
				Topr = 85°C when clock is stopped		20.0	

Note 1: Specify a product of -40°C to 85°C to use it.

Note 2: 10 MHz for the mask ROM version and flash memory 5V version.

Note 3: With one timer operated using fc32.

Timing (V_{CC} = 3V)V_{CC} = 3V

Timing requirements (referenced to V_{CC} = 3V, V_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (*) unless otherwise specified)

* : Specify a product of -40°C to 85°C to use it.

Table 1.23.24. External clock input

Symbol	Parameter		Standard		Unit
			Min.	Max.	
t _c	External clock input cycle time	Mask ROM, Flash memory 5V version	100		ns
t _{w(H)}	External clock input HIGH pulse width	Mask ROM, Flash memory 5V version	40		ns
t _{w(L)}	External clock input LOW pulse width	Mask ROM, Flash memory 5V version	40		ns
t _r	External clock rise time			18	ns
t _f	External clock fall time			18	ns

Table 1.23.25. Memory expansion and microprocessor modes

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t _{ac1} (RD-DB)	Data input access time (no wait)		(Note)	ns
t _{ac2} (RD-DB)	Data input access time (with wait)		(Note)	ns
t _{ac3} (RD-DB)	Data input access time (when accessing multiplex bus area)		(Note)	ns
t _{su} (DB-RD)	Data input setup time	80		ns
t _{su} (RDY-BCLK)	RDY input setup time	60		ns
t _{su} (HOLD-BCLK)	HOLD input setup time	80		ns
t _h (RD-DB)	Data input hold time	0		ns
t _h (BCLK-RDY)	RDY input hold time	0		ns
t _h (BCLK-HOLD)	HOLD input hold time	0		ns
t _d (BCLK-HLDA)	HLDA output delay time		100	ns

Note: Calculated according to the BCLK frequency as follows:

$$t_{ac1}(RD - DB) = \frac{10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

$$t_{ac2}(RD - DB) = \frac{3 \times 10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

$$t_{ac3}(RD - DB) = \frac{3 \times 10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

Timing ($V_{CC} = 3V$) $V_{CC} = 3V$

Timing requirements (referenced to $V_{CC} = 3V$, $V_{SS} = 0V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (*) unless otherwise specified)

* : Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Table 1.23.26. 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 1.23.27. 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 1.23.28. 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 1.23.29. Timer A input (external trigger input in pulse width modulation 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

Table 1.23.30. Timer A input (up/down input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(UP)}$	TAiOUT input cycle time	3000		ns
$t_{w(UPH)}$	TAiOUT input HIGH pulse width	1500		ns
$t_{w(UPL)}$	TAiOUT input LOW pulse width	1500		ns
$t_{su(UP-TIN)}$	TAiOUT input setup time	600		ns
$t_{h(TIN-UP)}$	TAiOUT input hold time	600		ns

Timing ($V_{CC} = 3V$) $V_{CC} = 3V$

Timing requirements (referenced to $V_{CC} = 3V$, $V_{SS} = 0V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (*) unless otherwise specified)

* : Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Table 1.23.31. 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)	160		ns
$t_{w(TBL)}$	TBiin input LOW pulse width (counted on both edges)	160		ns

Table 1.23.32. 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 1.23.33. 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

Table 1.23.34. A-D trigger input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(AD)}$	$\overline{ADTRG}$ input cycle time (trigger able minimum)	1500		ns
$t_{w(ADL)}$	$\overline{ADTRG}$ input LOW pulse width	200		ns

Table 1.23.35. Serial I/O

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	50		ns
$t_{h(C-D)}$	RxDi input hold time	90		ns

Table 1.23.36. External interrupt $\overline{INTi}$ inputs

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

Timing (V_{CC} = 3V)V_{CC} = 3V

Switching characteristics (referenced to V_{CC} = 3V, V_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 3), CM15="1" unless otherwise specified)

Table 1.23.37. Memory expansion and microprocessor modes (with no wait)

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
t _d (BCLK-AD)	Address output delay time	Figure 1.23.7		60	ns
t _h (BCLK-AD)	Address output hold time (BCLK standard)		4		ns
t _h (RD-AD)	Address output hold time (RD standard)		0		ns
t _h (WR-AD)	Address output hold time (WR standard)		0		ns
t _d (BCLK-CS)	Chip select output delay time			60	ns
t _h (BCLK-CS)	Chip select output hold time (BCLK standard)		4		ns
t _d (BCLK-ALE)	ALE signal output delay time			60	ns
t _h (BCLK-ALE)	ALE signal output hold time		– 4		ns
t _d (BCLK-RD)	RD signal output delay time			60	ns
t _h (BCLK-RD)	RD signal output hold time		0		ns
t _d (BCLK-WR)	WR signal output delay time			60	ns
t _h (BCLK-WR)	WR signal output hold time		0		ns
t _d (BCLK-DB)	Data output delay time (BCLK standard)			80	ns
t _h (BCLK-DB)	Data output hold time (BCLK standard)		4		ns
t _d (DB-WR)	Data output delay time (WR standard)		(Note1)		ns
t _h (WR-DB)	Data output hold time (WR standard)(Note2)		0		ns

Note 1: Calculated according to the BCLK frequency as follows:

$$t_d(\text{DB} - \text{WR}) = \frac{10^9}{f(\text{BCLK}) \times 2} - 80 \quad [\text{ns}]$$

Note 2: This is standard value shows the timing when the output is off, and doesn't show hold time of data bus.

Hold time of data bus is different by capacitor volume and pull-up (pull-down) resistance value.

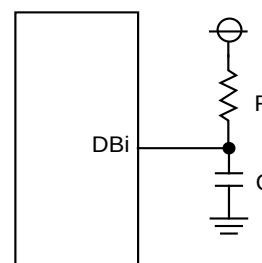
Hold time of data bus is expressed in

$$t = -CR \times \ln(1 - V_{OL} / V_{CC})$$

by a circuit of the right figure.

For example, when V_{OL} = 0.2V_{CC}, C = 30pF, R = 1kΩ, hold time of output "L" level is

$$t = -30\text{pF} \times 1\text{k}\Omega \times \ln(1 - 0.2V_{CC} / V_{CC}) \\ = 6.7\text{ns}.$$



Note 3: Specify a product of -40°C to 85°C to use it.

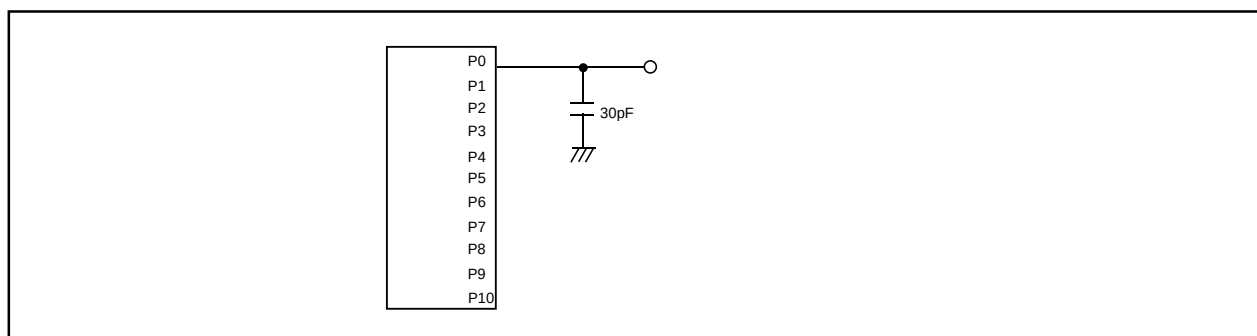


Figure 1.23.7. Port P0 to P10 measurement circuit

Timing (V_{CC} = 3V)V_{CC} = 3V

Switching characteristics (referenced to V_{CC} = 3V, V_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 3), CM15="1" unless otherwise specified)

Table 1.23.38. Memory expansion and microprocessor modes
(when accessing external memory area with wait)

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
t _d (BCLK-AD)	Address output delay time	Figure 1.23.7		60	ns
t _h (BCLK-AD)	Address output hold time (BCLK standard)		4		ns
t _h (RD-AD)	Address output hold time (RD standard)		0		ns
t _h (WR-AD)	Address output hold time (WR standard)		0		ns
t _d (BCLK-CS)	Chip select output delay time			60	ns
t _h (BCLK-CS)	Chip select output hold time (BCLK standard)		4		ns
t _d (BCLK-ALE)	ALE signal output delay time			60	ns
t _h (BCLK-ALE)	ALE signal output hold time		– 4		ns
t _d (BCLK-RD)	RD signal output delay time			60	ns
t _h (BCLK-RD)	RD signal output hold time		0		ns
t _d (BCLK-WR)	WR signal output delay time			60	ns
t _h (BCLK-WR)	WR signal output hold time		0		ns
t _d (BCLK-DB)	Data output delay time (BCLK standard)			80	ns
t _h (BCLK-DB)	Data output hold time (BCLK standard)		4		ns
t _d (DB-WR)	Data output delay time (WR standard)		(Note1)		ns
t _h (WR-DB)	Data output hold time (WR standard)(Note2)		0		ns

Note 1: Calculated according to the BCLK frequency as follows:

$$t_d(\text{DB} - \text{WR}) = \frac{10^9}{f(\text{BCLK})} - 80 \quad [\text{ns}]$$

Note 2: This is standard value shows the timing when the output is off, and doesn't show hold time of data bus.

Hold time of data bus is different by capacitor volume and pull-up (pull-down) resistance value.

Hold time of data bus is expressed in

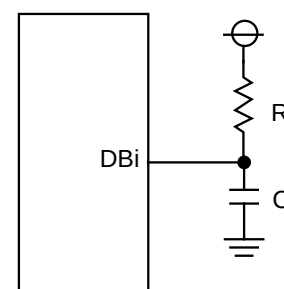
$$t = -CR \times \ln(1 - V_{OL} / V_{CC})$$

by a circuit of the right figure.

For example, when V_{OL} = 0.2V_{CC}, C = 30pF, R = 1kΩ, hold time of output "L" level is

$$t = -30\text{pF} \times 1\text{k}\Omega \times \ln(1 - 0.2V_{CC} / V_{CC}) \\ = 6.7\text{ns}.$$

Note 3: Specify a product of -40°C to 85°C to use it.



Timing (V_{CC} = 3V)V_{CC} = 3V

Switching characteristics (referenced to V_{CC} = 3V, V_{SS} = 0V at Topr = – 20°C to 85°C / – 40°C to 85°C (Note 2), CM15="1" unless otherwise specified)

Table 1.23.39. Memory expansion and microprocessor modes
(when accessing external memory area with wait, and select multiplexed bus)

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
t _d (BCLK-AD)	Address output delay time	Figure 1.23.7		60	ns
t _h (BCLK-AD)	Address output hold time (BCLK standard)		4		ns
t _h (RD-AD)	Address output hold time (RD standard)		(Note1)		ns
t _h (WR-AD)	Address output hold time (WR standard)		(Note1)		ns
t _d (BCLK-CS)	Chip select output delay time			60	ns
t _h (BCLK-CS)	Chip select output hold time (BCLK standard)		4		ns
t _h (RD-CS)	Chip select output hold time (RD standard)		(Note1)		ns
t _h (WR-CS)	Chip select output hold time (WR standard)		(Note1)		ns
t _d (BCLK-RD)	RD signal output delay time			60	ns
t _h (BCLK-RD)	RD signal output hold time		0		ns
t _d (BCLK-WR)	WR signal output delay time			60	ns
t _h (BCLK-WR)	WR signal output hold time		0		ns
t _d (BCLK-DB)	Data output delay time (BCLK standard)			80	ns
t _h (BCLK-DB)	Data output hold time (BCLK standard)		4		ns
t _d (DB-WR)	Data output delay time (WR standard)		(Note1)		ns
t _h (WR-DB)	Data output hold time (WR standard)		(Note1)		ns
t _d (BCLK-ALE)	ALE signal output delay time (BCLK standard)			60	ns
t _h (BCLK-ALE)	ALE signal output hold time (BCLK standard)		– 4		ns
t _d (AD-ALE)	ALE signal output delay time (Address standard)		(Note1)		ns
t _h (ALE-AD)	ALE signal output hold time (Address standard)		50		ns
t _d (AD-RD)	Post-address RD signal output delay time		0		ns
t _d (AD-WR)	Post-address WR signal output delay time		0		ns
t _{dZ} (RD-AD)	Address output floating start time			8	ns

Note: Calculated according to the BCLK frequency as follows:

$$t_h(RD - AD) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$t_h(WR - AD) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$t_h(RD - CS) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

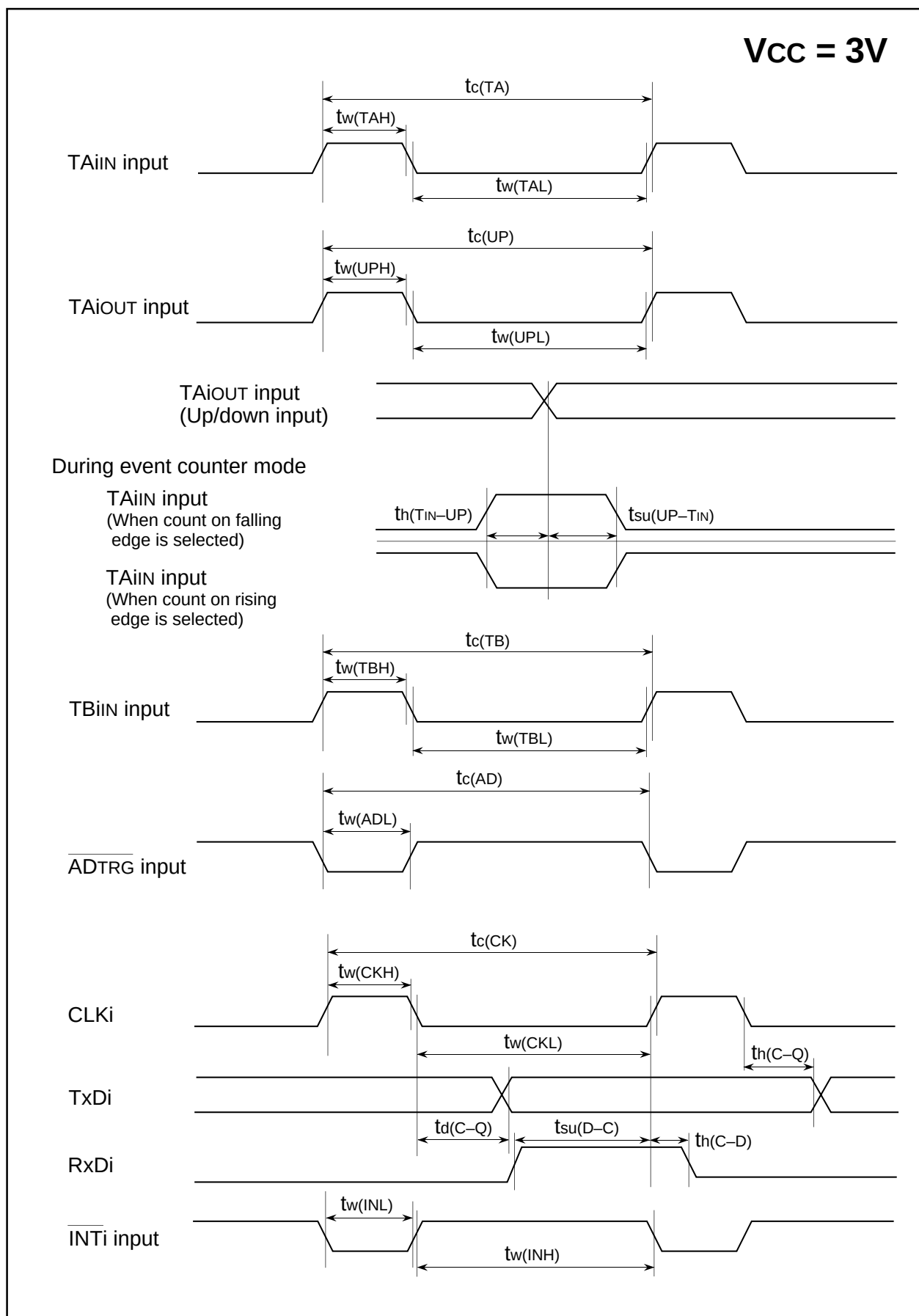
$$t_h(WR - CS) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

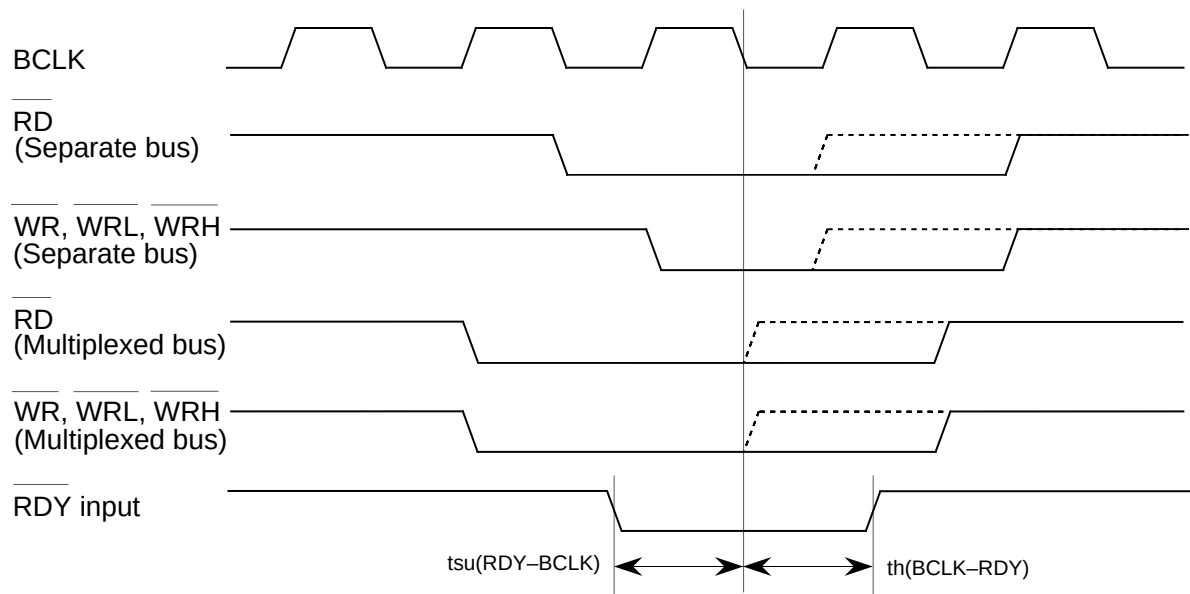
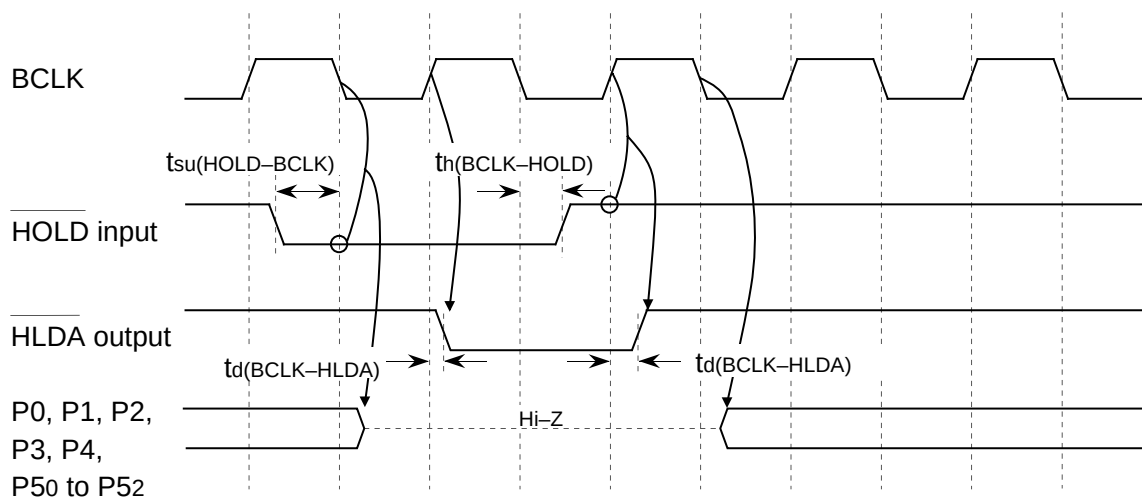
$$t_d(DB - WR) = \frac{10^9 \times 3}{f(BCLK) \times 2} - 80 \quad [ns]$$

$$t_h(WR - DB) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$t_d(AD - ALE) = \frac{10^9}{f(BCLK) \times 2} - 45 \quad [ns]$$

Note 2: Specify a product of -40°C to 85°C to use it.

Timing ($V_{CC} = 3V$)Figure 1.23.8. $V_{CC} = 3V$ timing diagram (1)

Timing ($V_{CC} = 3V$) **$V_{CC} = 3V$** **Memory Expansion Mode and Microprocessor Mode****(Valid only with wait)****(Valid with or without wait)**

Note: The above pins are set to high-impedance regardless of the input level of the BYTE pin and bit (PM06) of processor mode register 0 selects the function of ports P40 to P43.

Measuring conditions :

- $V_{CC}=3V$
- Input timing voltage : Determined with $V_{IL}=0.6V$, $V_{IH}=2.4V$
- Output timing voltage : Determined with $V_{OL}=1.5V$, $V_{OH}=1.5V$

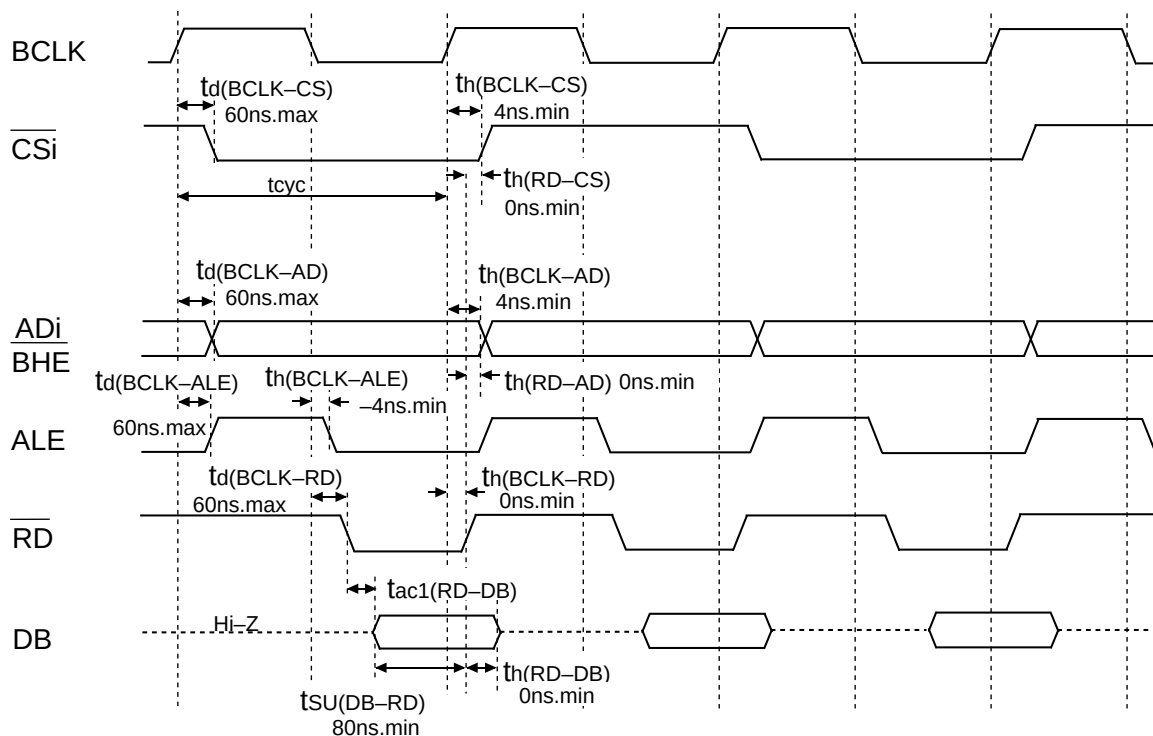
Figure 1.23.9. $V_{CC} = 3V$ timing diagram (2)

Timing ($V_{CC} = 3V$)

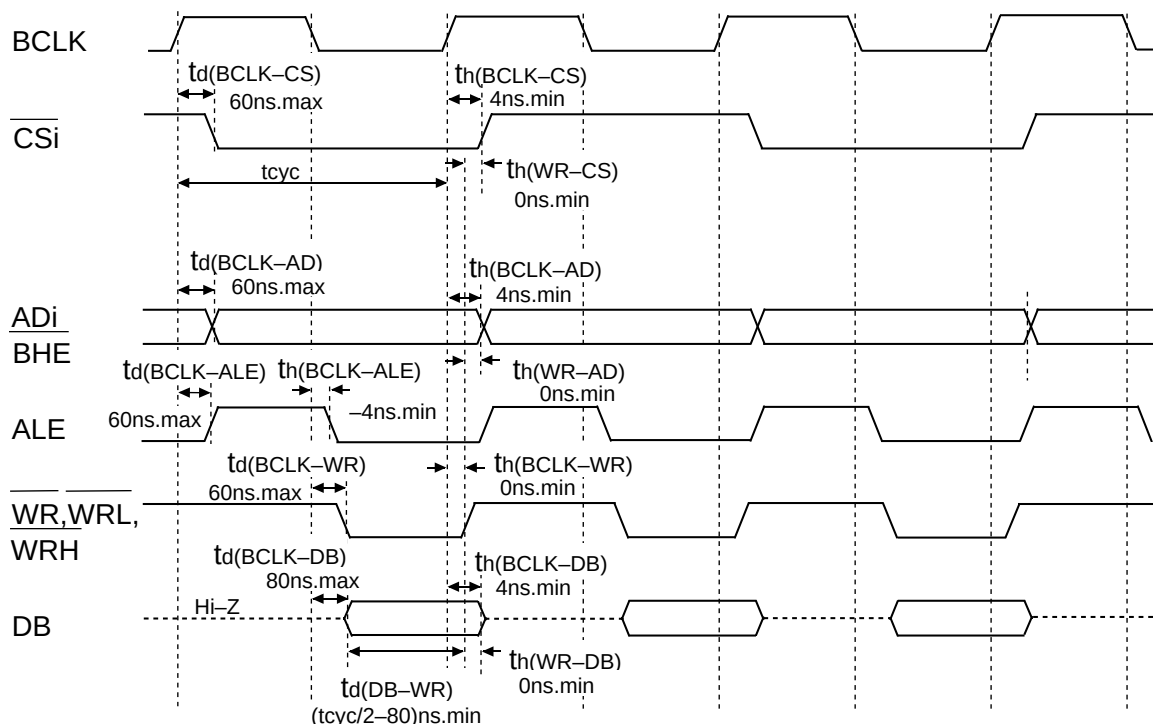
Memory Expansion Mode and Microprocessor Mode (With no wait)

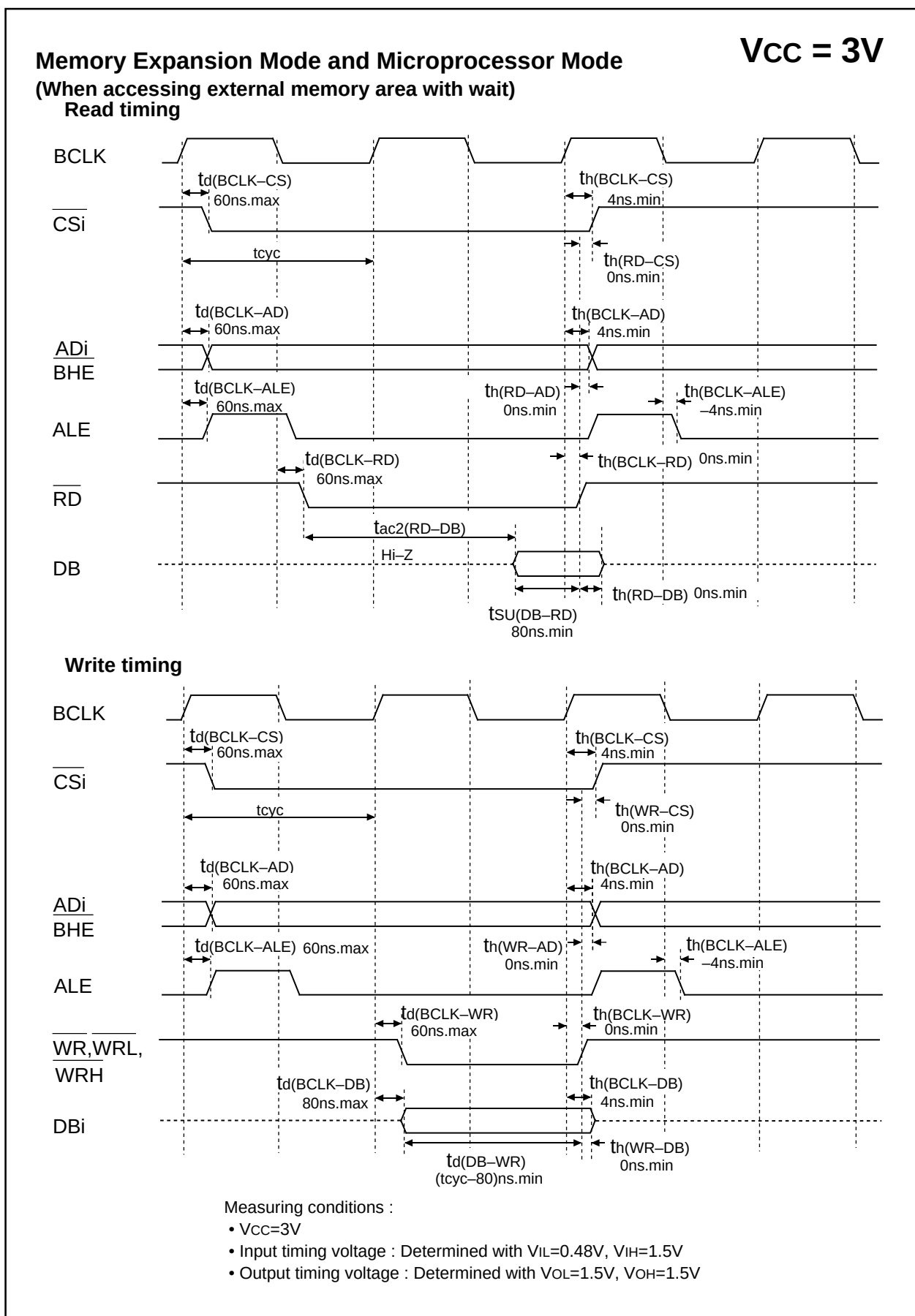
 $V_{CC} = 3V$

Read timing



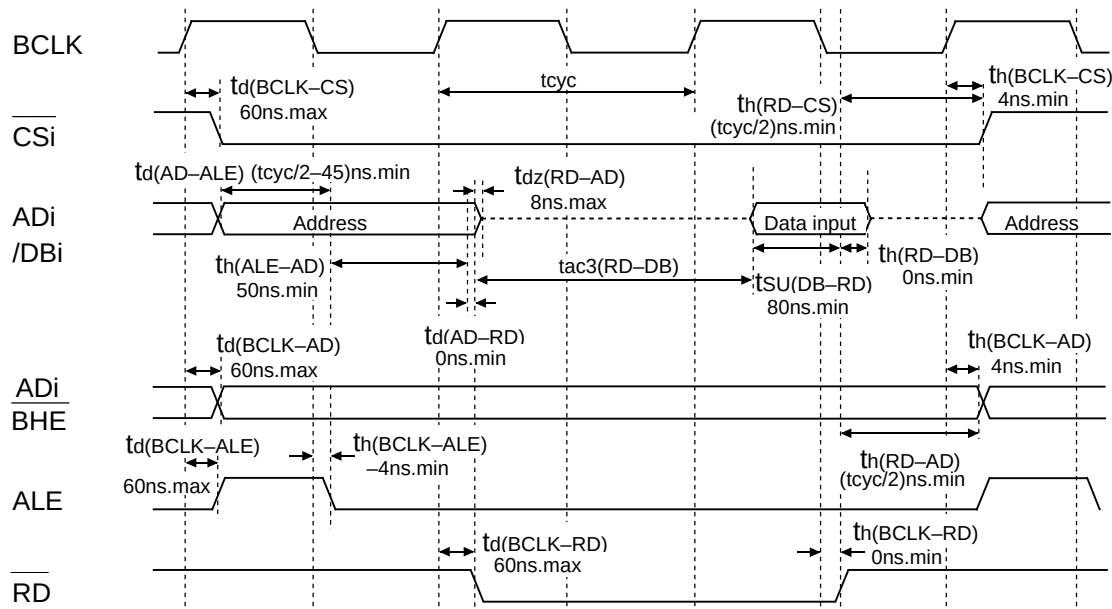
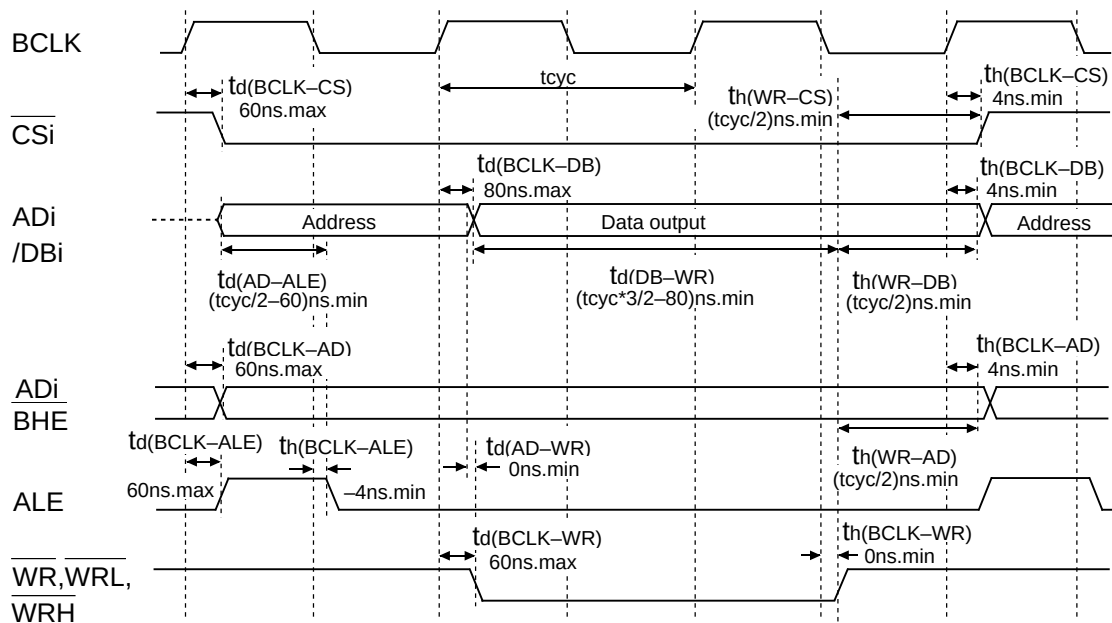
Write timing

Figure 1.23.10. $V_{CC} = 3V$ timing diagram (3)

Timing ($V_{CC} = 3V$)Figure 1.23.11. $V_{CC} = 3V$ timing diagram (4)

Timing ($V_{CC} = 3V$) **$V_{CC} = 3V$** **Memory Expansion Mode and Microprocessor Mode**

(When accessing external memory area with wait, and select multiplexed bus)

Read timing**Write timing**

Measuring conditions :

- $V_{CC}=3V$
- Input timing voltage : Determined with $V_{IL}=0.48V, V_{IH}=1.5V$
- Output timing voltage : Determined with $V_{OL}=1.5V, V_{OH}=1.5V$

Figure 1.23.12. $V_{CC} = 3V$ timing diagram (5)

GZZ-SH13-36B<96A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30620M8A-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

* Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
	Date issued	Date :			

***1. Check sheet**

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30620M8A-XXXFP ☐ M30620M8A-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

***2. Mark specification**

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30620M8A-XXXFP, submit the 100P6S mark specification sheet. For the M30620M8A-XXXGP, submit the 100P6Q mark specification sheet.

***3. Usage Conditions**

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of XIN-XOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(XIN) =

 MHz

GZZ-SH13-36B<96A0>

Mask ROM number

**MITSUBISHI ELECTRIC-CHIP 16-BIT
MICROCOMPUTER M30620M8A-XXXFP/GP
MASK ROM CONFIRMATION FORM**

(2) Which kind of XCIN-XCOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

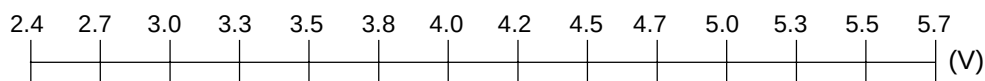
$f(\text{XCIN}) =$ kHz

(3) Which operation mode do you use?

- ☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

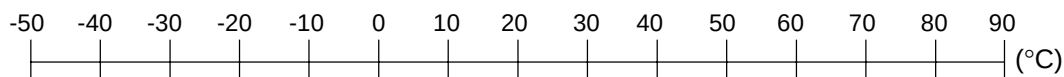
(4) Which operating supply voltage do you use?

(Circle the operating voltage range of use)



(5) Which operating ambient temperature do you use?

(Circle the operating temperature range of use)



(6) Do you use I²C (Inter IC) bus function?

- ☐ Not use ☐ Use

(7) Do you use IE (Inter Equipment) bus function?

- ☐ Not use ☐ Use

Thank you cooperation.

※4. Special item (Indicate none if there is not specified item)

GZZ-SH13-37B<96A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30620MAA-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

* Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
	Date issued	Date :			

***1. Check sheet**

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30620MAA-XXXFP ☐ M30620MAA-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

***2. Mark specification**

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30620MAA-XXXFP, submit the 100P6S mark specification sheet. For the M30620MAA-XXXGP, submit the 100P6Q mark specification sheet.

***3. Usage Conditions**

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of XIN-XOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(XIN) =

 MHz

GZZ-SH13-37B<96A0>

Mask ROM number	

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30620MAA-XXXXP/GP
 MASK ROM CONFIRMATION FORM**

(2) Which kind of XCIN-XCOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

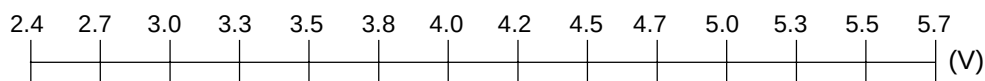
$f(XCIN) =$ kHz

(3) Which operation mode do you use?

- ☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

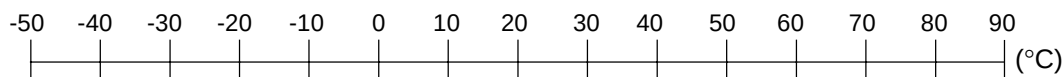
(4) Which operating supply voltage do you use?

(Circle the operating voltage range of use)



(5) Which operating ambient temperature do you use?

(Circle the operating temperature range of use)



(6) Do you use I²C (Inter IC) bus function?

- ☐ Not use ☐ Use

(7) Do you use IE (Inter Equipment) bus function?

- ☐ Not use ☐ Use

Thank you cooperation.

※4. Special item (Indicate none if there is not specified item)

GZZ-SH13-28B<95A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30620MCA-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

* Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
	Date issued	Date :			

*1. Check sheet

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30620MCA-XXXFP ☐ M30620MCA-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

*2. Mark specification

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30620MCA-XXXFP, submit the 100P6S mark specification sheet. For the M30620MCA-XXXGP, submit the 100P6Q mark specification sheet.

*3. Usage Conditions

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of XIN-XOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(XIN) =

 MHz

GZZ-SH13-40B<96A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30622M4A-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

* Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
	Date issued	Date :			

*1. Check sheet

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30622M4A-XXXFP ☐ M30622M4A-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

*2. Mark specification

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30622M4A-XXXFP, submit the 100P6S mark specification sheet. For the M30622M4A-XXXGP, submit the 100P6Q mark specification sheet.

*3. Usage Conditions

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of XIN-XOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(XIN) =

 MHz

GZZ-SH13-40B<96A0>

Mask ROM number	

**mitsubishi electric-chip 16-bit
 MICROCOMPUTER M30622M4A-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

(2) Which kind of XCIN-XCOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

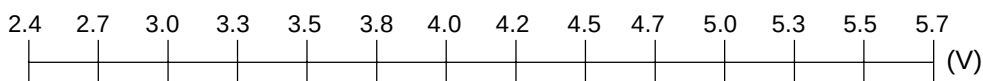
$f(XCIN) =$ kHz

(3) Which operation mode do you use?

- ☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

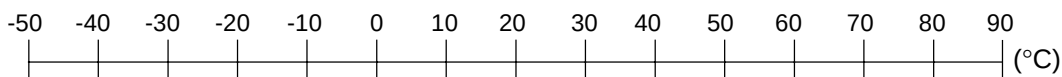
(4) Which operating supply voltage do you use?

(Circle the operating voltage range of use)



(5) Which operating ambient temperature do you use?

(Circle the operating temperature range of use)



(6) Do you use I²C (Inter IC) bus function?

- ☐ Not use ☐ Use

(7) Do you use IE (Inter Equipment) bus function?

- ☐ Not use ☐ Use

Thank you cooperation.

※4. Special item (Indicate none if there is not specified item)

GZZ-SH13-38B<96A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30622M8A-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

* Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
	Date issued	Date :			

*1. Check sheet

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30622M8A-XXXFP ☐ M30622M8A-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

*2. Mark specification

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30622M8A-XXXFP, submit the 100P6S mark specification sheet. For the M30622M8A-XXXGP, submit the 100P6Q mark specification sheet.

*3. Usage Conditions

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of XIN-XOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(XIN) =

 MHz

GZZ-SH13-38B<96A0>

Mask ROM number

**mitsubishi electric-chip 16-bit
microcomputer M30622M8A-XXXFP/GP
mask ROM confirmation form**

(2) Which kind of XCIN-XCOUT oscillation circuit is used?

☐ Ceramic resonator

☐ Quartz-crystal oscillator

☐ External clock input

☐ Other ()

What frequency do not use?

$f(XCIN) =$ kHz

(3) Which operation mode do you use?

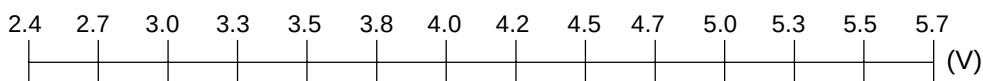
☐ Single-chip mode

☐ Memory expansion mode

☐ Microprocessor mode

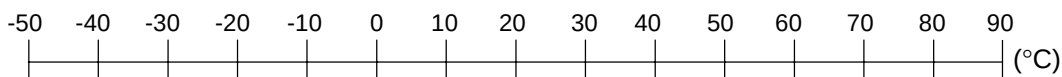
(4) Which operating supply voltage do you use?

(Circle the operating voltage range of use)



(5) Which operating ambient temperature do you use?

(Circle the operating temperature range of use)



(6) Do you use I²C (Inter IC) bus function?

☐ Not use

☐ Use

(7) Do you use IE (Inter Equipment) bus function?

☐ Not use

☐ Use

Thank you cooperation.

※4. Special item (Indicate none if there is not specified item)

GZZ-SH13-34B<96A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30622MAA-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

*	Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
		Date issued	Date :			

*1. Check sheet

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30622MAA-XXXFP ☐ M30622MAA-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

*2. Mark specification

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30622MAA-XXXFP, submit the 100P6S mark specification sheet. For the M30622MAA-XXXGP, submit the 100P6Q mark specification sheet.

*3. Usage Conditions

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of XIN-XOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(XIN) =

 MHz

GZZ-SH13-39B<96A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30622MCA-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

* Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
	Date issued	Date :			

*1. Check sheet

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30622MCA-XXXFP ☐ M30622MCA-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

*2. Mark specification

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30622MCA-XXXFP, submit the 100P6S mark specification sheet. For the M30622MCA-XXXGP, submit the 100P6Q mark specification sheet.

*3. Usage Conditions

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of XIN-XOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(XIN) =

 MHz

GZZ-SH13-39B<96A0>

Mask ROM number	

**mitsubishi electric-chip 16-bit
 MICROCOMPUTER M30622MCA-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

(2) Which kind of XCIN-XCOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

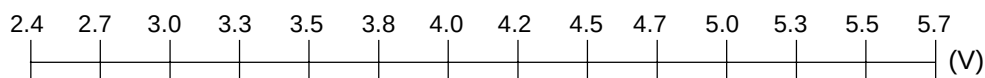
$f(XCIN) =$ kHz

(3) Which operation mode do you use?

- ☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

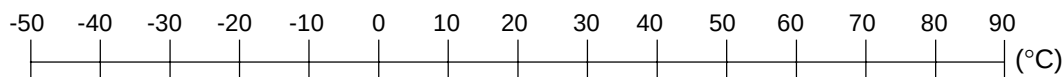
(4) Which operating supply voltage do you use?

(Circle the operating voltage range of use)



(5) Which operating ambient temperature do you use?

(Circle the operating temperature range of use)



(6) Do you use I²C (Inter IC) bus function?

- ☐ Not use ☐ Use

(7) Do you use IE (Inter Equipment) bus function?

- ☐ Not use ☐ Use

Thank you cooperation.

※4. Special item (Indicate none if there is not specified item)

GZZ-SH13-30B<95A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
 MICROCOMPUTER M30624MGA-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

* Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
	Date issued	Date :			

***1. Check sheet**

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30624MGA-XXXFP ☐ M30624MGA-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

***2. Mark specification**

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30624MGA-XXXFP, submit the 100P6S mark specification sheet. For the M30624MGA-XXXGP, submit the 100P6Q mark specification sheet.

***3. Usage Conditions**

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of X_{IN}-X_{OUT} oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(X_{IN}) =

 MHz

GZZ-SH13-30B<95A0>

Mask ROM number	

**mitsubishi electric-chip 16-bit
 MICROCOMPUTER M30624MGA-XXXFP/GP
 MASK ROM CONFIRMATION FORM**

(2) Which kind of XCIN-XCOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

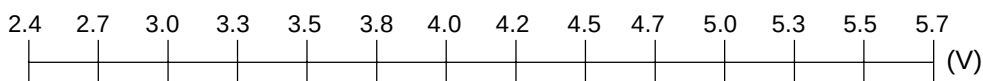
$f(XCIN) =$ kHz

(3) Which operation mode do you use?

- ☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

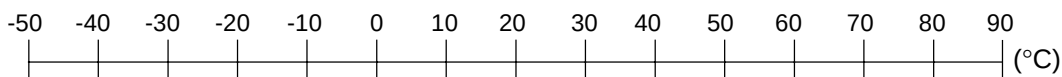
(4) Which operating supply voltage do you use?

(Circle the operating voltage range of use)



(5) Which operating ambient temperature do you use?

(Circle the operating temperature range of use)



(6) Do you use I²C (Inter IC) bus function?

- ☐ Not use ☐ Use

(7) Do you use IE (Inter Equipment) bus function?

- ☐ Not use ☐ Use

Thank you cooperation.

※4. Special item (Indicate none if there is not specified item)

Description (Flash Memory Version)

Outline Performance

Table 1.25.1 shows the outline performance of the M16C/62A (flash memory version).

Table 1.25.1. Outline performance of the M16C/62A (flash memory version)

Item		Performance
Flash memory operation mode		Three modes (parallel I/O, standard serial I/O, CPU rewrite)
Erase block division	User ROM area	See Figure 1.25.1
	Boot ROM area	One division (8 Kbytes) (Note)
Program method		In units of pages (in units of 256 bytes)
Erase method		Collective erase/block erase
Program/erase control method		Program/erase control by software command
Protect method		Protected for each block by lock bit
Number of commands		8 commands
Program/erase count		100 times
Data retention		10 years
ROM code protect		Parallel I/O and standard serial I/O modes are supported.

Note: The boot ROM area contains a standard serial I/O mode control program which is stored in it when shipped from the factory. This area can be erased and programmed in only parallel I/O mode.

Description (Flash Memory Version)**Flash Memory**

The M16C/62A (flash memory version) contains the flash memory that can be rewritten with a single voltage. For this flash memory, three flash memory modes are available in which to read, program, and erase: parallel I/O and standard serial I/O modes in which the flash memory can be manipulated using a programmer and a CPU rewrite mode in which the flash memory can be manipulated by the Central Processing Unit (CPU). Each mode is detailed in the pages to follow.

The flash memory is divided into several blocks as shown in Figure 1.25.1, so that memory can be erased one block at a time. Each block has a lock bit to enable or disable execution of an erase or program operation, allowing for data in each block to be protected.

In addition to the ordinary user ROM area to store a microcomputer operation control program, the flash memory has a boot ROM area that is used to store a program to control rewriting in CPU rewrite and standard serial I/O modes. This boot ROM area has had a standard serial I/O mode control program stored in it when shipped from the factory. However, the user can write a rewrite control program in this area that suits the user's application system. This boot ROM area can be rewritten in only parallel I/O mode.

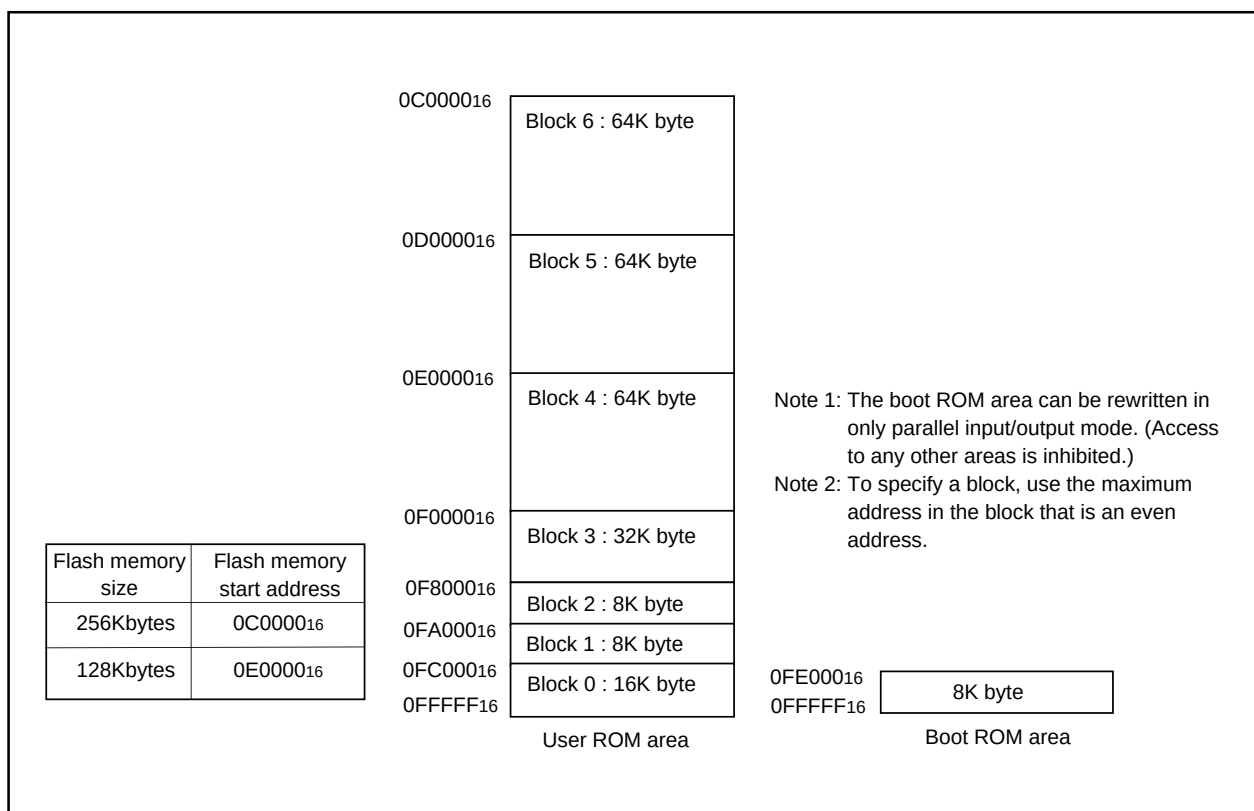


Figure 1.25.1. Block diagram of flash memory version

CPU Rewrite Mode (Flash Memory Version)

CPU Rewrite Mode

In CPU rewrite mode, the on-chip flash memory can be operated on (read, program, or erase) under control of the Central Processing Unit (CPU).

In CPU rewrite mode, only the user ROM area shown in Figure 1.25.1 can be rewritten; the boot ROM area cannot be rewritten. Make sure the program and block erase commands are issued for only the user ROM area and each block area.

The control program for CPU rewrite mode can be stored in either user ROM or boot ROM area. In the CPU rewrite mode, because the flash memory cannot be read from the CPU, the rewrite control program must be transferred to any area other than the internal flash memory before it can be executed.

Microcomputer Mode and Boot Mode

The control program for CPU rewrite mode must be written into the user ROM or boot ROM area in parallel I/O mode beforehand. (If the control program is written into the boot ROM area, the standard serial I/O mode becomes unusable.)

See Figure 1.25.1 for details about the boot ROM area.

Normal microcomputer mode is entered when the microcomputer is reset with pulling CNVss pin low. In this case, the CPU starts operating using the control program in the user ROM area.

When the microcomputer is reset by pulling the P5s pin low, the CNVss pin high, and the P5o pin high, the CPU starts operating using the control program in the boot ROM area. This mode is called the “boot” mode. The control program in the boot ROM area can also be used to rewrite the user ROM area.

Block Address

Block addresses refer to the maximum even address of each block. These addresses are used in the block erase command, lock bit program command, and read lock status command.

CPU Rewrite Mode (Flash Memory Version)

Outline Performance (CPU Rewrite Mode)

In the CPU rewrite mode, the CPU erases, programs and reads the internal flash memory as instructed by software commands. Operations must be executed from a memory other than the internal flash memory, such as the internal RAM.

When the CPU rewrite mode select bit (bit 1 at address 03B716) is set to "1", transition to CPU rewrite mode occurs and software commands can be accepted.

In the CPU rewrite mode, write to and read from software commands and data into even-numbered address ("0" for byte address A0) in 16-bit units. Always write 8-bit software commands into even-numbered address. Commands are ignored with odd-numbered addresses.

Use software commands to control program and erase operations. Whether a program or erase operation has terminated normally or in error can be verified by reading the status register.

Figure 1.26.1 shows the flash memory control register 0 and the flash memory control register 1.

Bit 0 of the flash memory control register 0 is the RY/B $\bar{Y}$ status flag used exclusively to read the operating status of the flash memory. During programming and erase operations, it is "0". Otherwise, it is "1".

Bit 1 of the flash memory control register 0 is the CPU rewrite mode select bit. The CPU rewrite mode is entered by setting this bit to "1", so that software commands become acceptable. In CPU rewrite mode, the CPU becomes unable to access the internal flash memory directly. Therefore, write bit 1 in an area other than the internal flash memory. Also only when $\overline{\text{NMI}}$ pin is "H" level. To set this bit to "1", it is necessary to write "0" and then write "1" in succession. The bit can be set to "0" by only writing a "0".

Bit 2 of the flash memory control register 0 is a lock bit disable select bit. By setting this bit to "1", it is possible to disable erase and write protect (block lock) effectuated by the lock bit data. The lock bit disable select bit only disables the lock bit function; it does not change the lock data bit value. However, if an erase operation is performed when this bit = "1", the lock bit data that is "0" (locked) is set to "1" (unlocked) after erasure. To set this bit to "1", it is necessary to write "0" and then write "1" in succession. This bit can be manipulated only when the CPU rewrite mode select bit = "1".

Bit 3 of the flash memory control register 0 is the flash memory reset bit used to reset the control circuit of the internal flash memory. This bit is used when exiting CPU rewrite mode and when flash memory access has failed. When the CPU rewrite mode select bit is "1", writing "1" for this bit resets the control circuit. To release the reset, it is necessary to set this bit to "0".

Bit 5 of the flash memory control register 0 is a user ROM area select bit which is effective in only boot mode. If this bit is set to "1" in boot mode, the area to be accessed is switched from the boot ROM area to the user ROM area. When the CPU rewrite mode needs to be used in boot mode, set this bit to "1". Note that if the microcomputer is booted from the user ROM area, it is always the user ROM area that can be accessed and this bit has no effect. When in boot mode, the function of this bit is effective regardless of whether the CPU rewrite mode is on or off. Write to this bit only when executing out of an area other than the internal flash memory.

Bit 3 of the flash memory control register 1 turns power supply to the internal flash memory on/off. When this bit is set to "1", power is not supplied to the internal flash memory, thus power consumption can be reduced. However, in this state, the internal flash memory cannot be accessed. To set this bit to "1", it is necessary to write "0" and then write "1" in succession. Use this bit mainly in the low speed mode (when XCIN is the count source of BCLK).

When the CPU is shifted to the stop or wait modes, power to the internal flash memory is automatically shut off. It is reconnected automatically when CPU operation is restored. Therefore, it is not particularly necessary to set flash memory control register 1.

CPU Rewrite Mode (Flash Memory Version)

Figure 1.26.2 shows a flowchart for setting/releasing the CPU rewrite mode. Figure 1.26.3 shows a flowchart for shifting to the low speed mode. Always perform operation as indicated in these flowcharts.

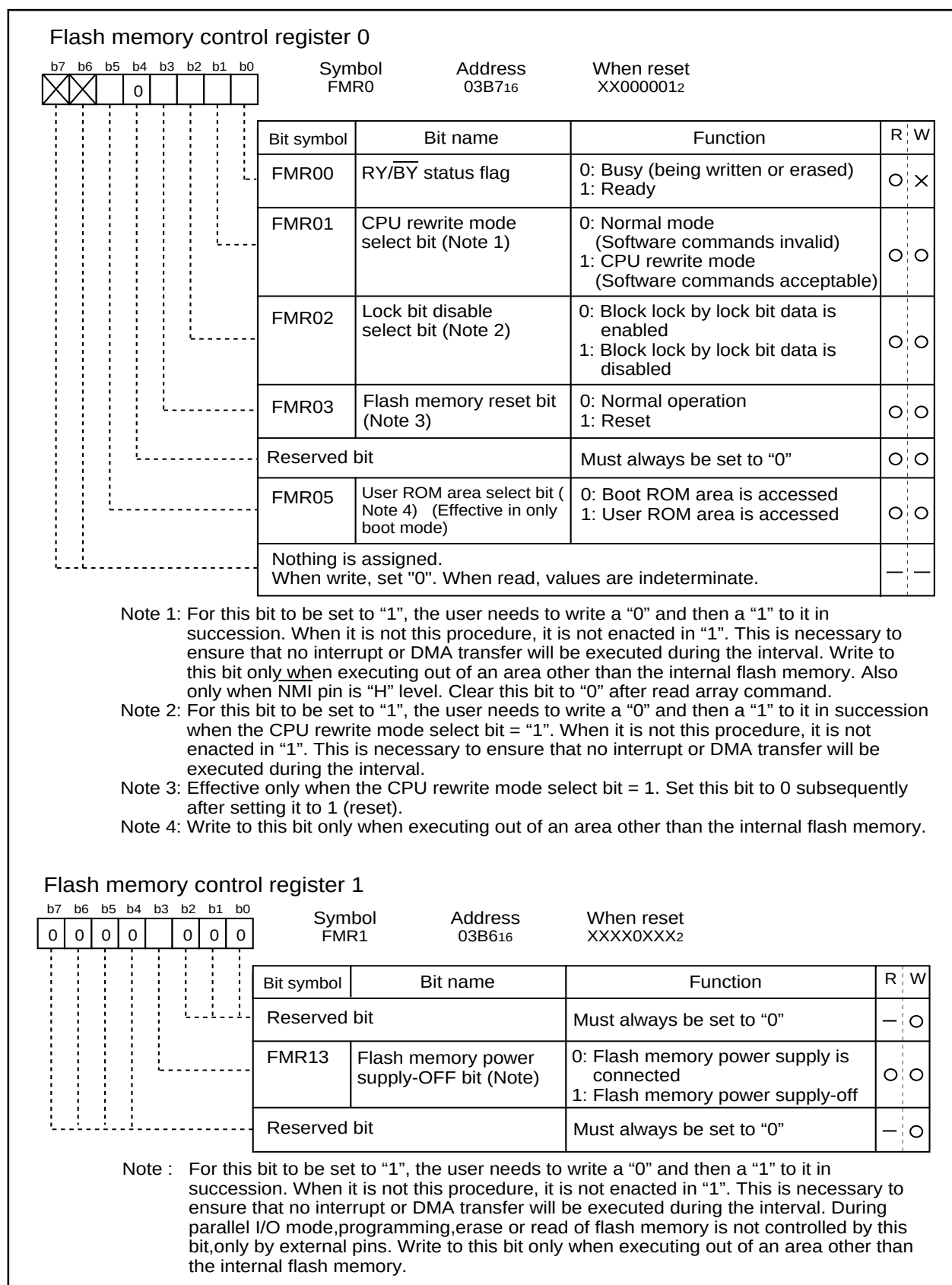


Figure 1.26.1. Flash memory control registers

CPU Rewrite Mode (Flash Memory Version)

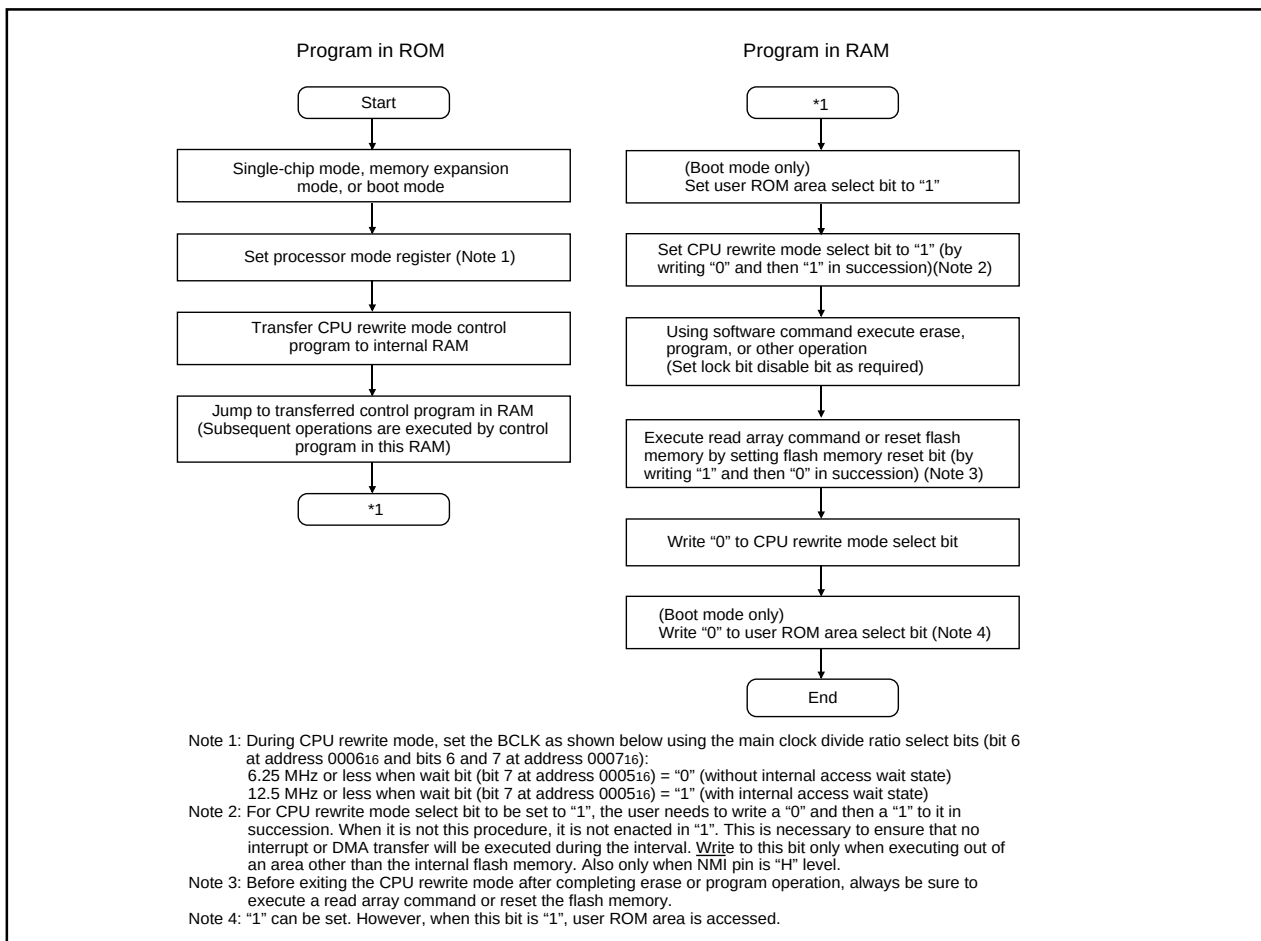


Figure 1.26.2. CPU rewrite mode set/reset flowchart

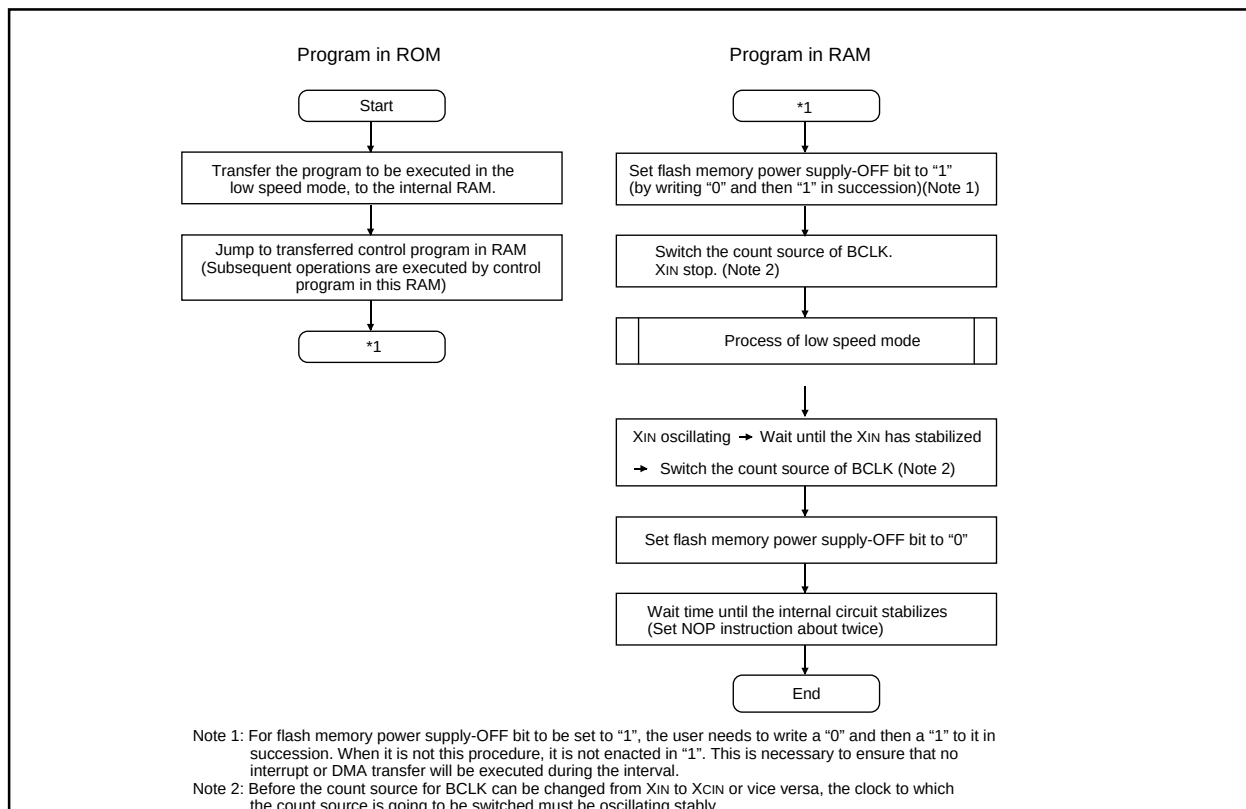


Figure 1.26.3. Shifting to the low speed mode flowchart

CPU Rewrite Mode (Flash Memory Version)

Precautions on CPU Rewrite Mode

Described below are the precautions to be observed when rewriting the flash memory in CPU rewrite mode.

(1) Operation speed

During CPU rewrite mode, set the BCLK as shown below using the main clock divide ratio select bit (bit 6 at address 0006₁₆ and bits 6 and 7 at address 0007₁₆):

6.25 MHz or less when wait bit (bit 7 at address 0005₁₆) = 0 (without internal access wait state)

12.5 MHz or less when wait bit (bit 7 at address 0005₁₆) = 1 (with internal access wait state)

(2) Instructions inhibited against use

The instructions listed below cannot be used during CPU rewrite mode because they refer to the internal data of the flash memory:

UND instruction, INTO instruction, JMPS instruction, JSRS instruction, and BRK instruction

(3) Interrupts inhibited against use

The address match interrupt cannot be used during CPU rewrite mode because they refer to the internal data of the flash memory. If interrupts have their vector in the variable vector table, they can be used by transferring the vector into the RAM area. The $\overline{\text{NMI}}$ and watchdog timer interrupts can be used because the flash memory control register 0 and 1 is forcibly initialized and return to normal mode when each interrupt occurs. But it is needed that the jump addresses for each interrupt are set in the fixed vector table and there is an interrupt program. Since the rewrite operation is halted when the $\overline{\text{NMI}}$ and watchdog timer interrupts occur, it is needed that CPU rewriting mode select bit is set to "1" and the erase/program operation is performed over again.

(4) Internal reserved area expansion bit (Bit 3 at address 0005₁₆)

The reserved area of the internal memory can be changed by using the internal reserved area expansion bit (bit 3 at address 0005₁₆). However, if the CPU rewrite mode select bit (bit 1 at address 03B7₁₆) is set to 1, the internal reserved area expansion bit (bit 3 at address 0005₁₆) also is set to 1 automatically. Similarly, if the CPU rewrite mode select bit (bit 1 at address 03B7₁₆) is set to 0, the internal reserved area expansion bit (bit 3 at address 0005₁₆) also is set to 0 automatically.

The precautions above apply to the products which RAM size is over 15 Kbytes or flash memory size is over 192 Kbytes.

(5) Reset

Reset input is always accepted. After a reset, the addresses 0C0000₁₆ through 0CFFFF₁₆ are made a reserved area and cannot be accessed. Therefore, if your product has this area in the user ROM area, do not write any address of this area to the reset vector. This area is made accessible by changing the internal reserved area expansion bit (bit 3 at address 0005₁₆) in a program.

(6) Access disable

Write CPU rewrite mode select bit, flash memory power supply-OFF bit and user ROM area select bit only when executing out of an area other than the internal flash memory.

(7) How to access

For CPU rewrite mode select bit, lock bit disable select bit, and flash memory power supply-OFF bit to be set to "1", the user needs to write a "0" and then a "1" to it in succession. When it is not this procedure, it is not enacted in "1". This is necessary to ensure that no interrupt or DMA transfer will be executed during the interval.

Write CPU rewrite mode select bit only when executing out of an area other than the internal flash memory. Also only when $\overline{\text{NMI}}$ pin is "H" level.

CPU Rewrite Mode (Flash Memory Version)

(8) Writing in the user ROM area

If power is lost while rewriting blocks that contain the flash rewrite program with the CPU rewrite mode, those blocks may not be correctly rewritten and it is possible that the flash memory can no longer be rewritten after that. Therefore, it is recommended to use the standard serial I/O mode or parallel I/O mode to rewrite these blocks.

(9) Using the lock bit

To use the CPU rewrite mode, use a boot program that can set and cancel the lock command.

CPU Rewrite Mode (Flash Memory Version)**Software Commands**

Table 1.26.1 lists the software commands available with the M16C/62A (flash memory version).

After setting the CPU rewrite mode select bit to 1, write a software command to specify an erase or program operation. Note that when entering a software command, the upper byte (D8 to D15) is ignored.

The content of each software command is explained below.

Table 1.26.1. List of software commands (CPU rewrite mode)

Command	First bus cycle			Second bus cycle			Third bus cycle		
	Mode	Address	Data (D0 to D7)	Mode	Address	Data (D0 to D7)	Mode	Address	Data (D0 to D7)
Read array	Write	X (Note 6)	FF ₁₆						
Read status register	Write	X	70 ₁₆	Read	X	SRD (Note 2)			
Clear status register	Write	X	50 ₁₆						
Page program (Note 3)	Write	X	41 ₁₆	Write	WA0 (Note 3)	WD0 (Note 3)	Write	WA1	WD1
Block erase	Write	X	20 ₁₆	Write	BA (Note 4)	D0 ₁₆			
Erase all unlock block	Write	X	A7 ₁₆	Write	X	D0 ₁₆			
Lock bit program	Write	X	77 ₁₆	Write	BA	D0 ₁₆			
Read lock bit status	Write	X	71 ₁₆	Read	BA	D ₆ (Note 5)			

Note 1: When a software command is input, the high-order byte of data (D8 to D15) is ignored.

Note 2: SRD = Status Register Data

Note 3: WA = Write Address, WD = Write Data

WA and WD must be set sequentially from 00₁₆ to FE₁₆ (byte address; however, an even address). The page size is 256 bytes.

Note 4: BA = Block Address (Enter the maximum address of each block that is an even address.)

Note 5: D₆ corresponds to the block lock status. Block not locked when D₆ = 1, block locked when D₆ = 0.

Note 6: X denotes a given address in the user ROM area (that is an even address).

Read Array Command (FF₁₆)

The read array mode is entered by writing the command code "FF₁₆" in the first bus cycle. When an even address to be read is input in one of the bus cycles that follow, the content of the specified address is read out at the data bus (D0–D15), 16 bits at a time.

The read array mode is retained intact until another command is written.

Read Status Register Command (70₁₆)

When the command code "70₁₆" is written in the first bus cycle, the content of the status register is read out at the data bus (D0–D7) by a read in the second bus cycle.

The status register is explained in the next section.

Clear Status Register Command (50₁₆)

This command is used to clear the bits SR3 to 5 of the status register after they have been set. These bits indicate that operation has ended in an error. To use this command, write the command code "50₁₆" in the first bus cycle.

Page Program Command (41₁₆)

Page program allows for high-speed programming in units of 256 bytes. Page program operation starts when the command code "41₁₆" is written in the first bus cycle. In the second bus cycle through the 129th bus cycle, the write data is sequentially written 16 bits at a time. At this time, the addresses A0-A7 need to be incremented by 2 from "00₁₆" to "FE₁₆." When the system finishes loading the data, it starts an auto write operation (data program and verify operation).

Whether the auto write operation is completed can be confirmed by reading the status register or the flash memory control register 0. At the same time the auto write operation starts, the read status register mode is automatically entered, so the content of the status register can be read out. The status register bit 7 (SR7) is set to 0 at the same time the auto write operation starts and is returned to 1 upon completion of the auto write operation. In this case, the read status register mode remains active until the Read Array command (FF₁₆) or Read Lock Bit Status command (71₁₆) is written or the flash memory is reset using its reset bit.

The RY/ $\overline{\text{BY}}$ status flag of the flash memory control register 0 is 0 during auto write operation and 1 when the auto write operation is completed as is the status register bit 7.

After the auto write operation is completed, the status register can be read out to know the result of the auto write operation. For details, refer to the section where the status register is detailed.

Figure 1.26.4 shows an example of a page program flowchart.

Each block of the flash memory can be write protected by using a lock bit. For details, refer to the section where the data protect function is detailed.

Additional writes to the already programmed pages are prohibited.

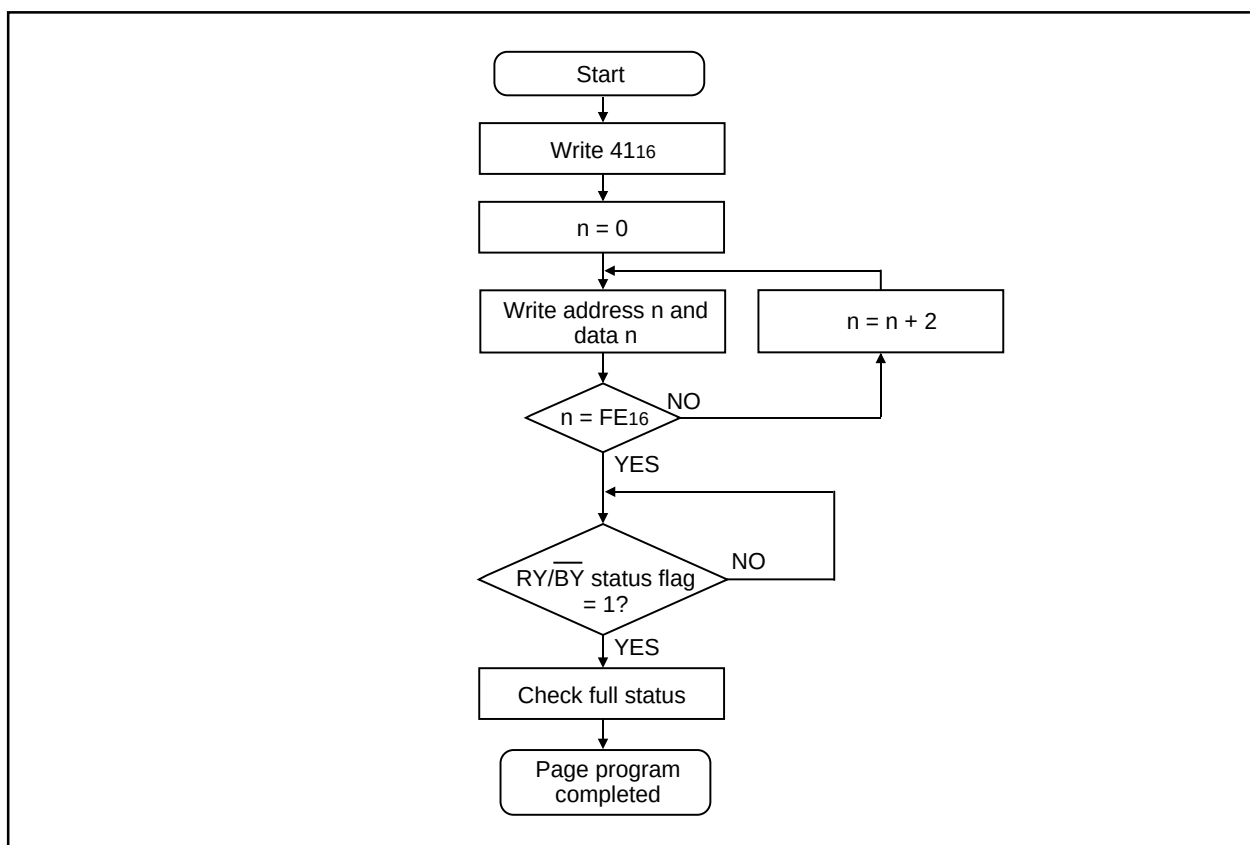


Figure 1.26.4. Page program flowchart

CPU Rewrite Mode (Flash Memory Version)

Block Erase Command (2016/D016)

By writing the command code "2016" in the first bus cycle and the confirmation command code "D016" in the second bus cycle that follows to the block address of a flash memory block, the system initiates an auto erase (erase and erase verify) operation.

Whether the auto erase operation is completed can be confirmed by reading the status register or the flash memory control register 0. At the same time the auto erase operation starts, the read status register mode is automatically entered, so the content of the status register can be read out. The status register bit 7 (SR7) is set to 0 at the same time the auto erase operation starts and is returned to 1 upon completion of the auto erase operation. In this case, the read status register mode remains active until the Read Array command (FF16) or Read Lock Bit Status command (7116) is written or the flash memory is reset using its reset bit.

The RY/ $\overline{\text{BY}}$ status flag of the flash memory control register 0 is 0 during auto erase operation and 1 when the auto erase operation is completed as is the status register bit 7.

After the auto erase operation is completed, the status register can be read out to know the result of the auto erase operation. For details, refer to the section where the status register is detailed.

Figure 1.26.5 shows an example of a block erase flowchart.

Each block of the flash memory can be protected against erasure by using a lock bit. For details, refer to the section where the data protect function is detailed.

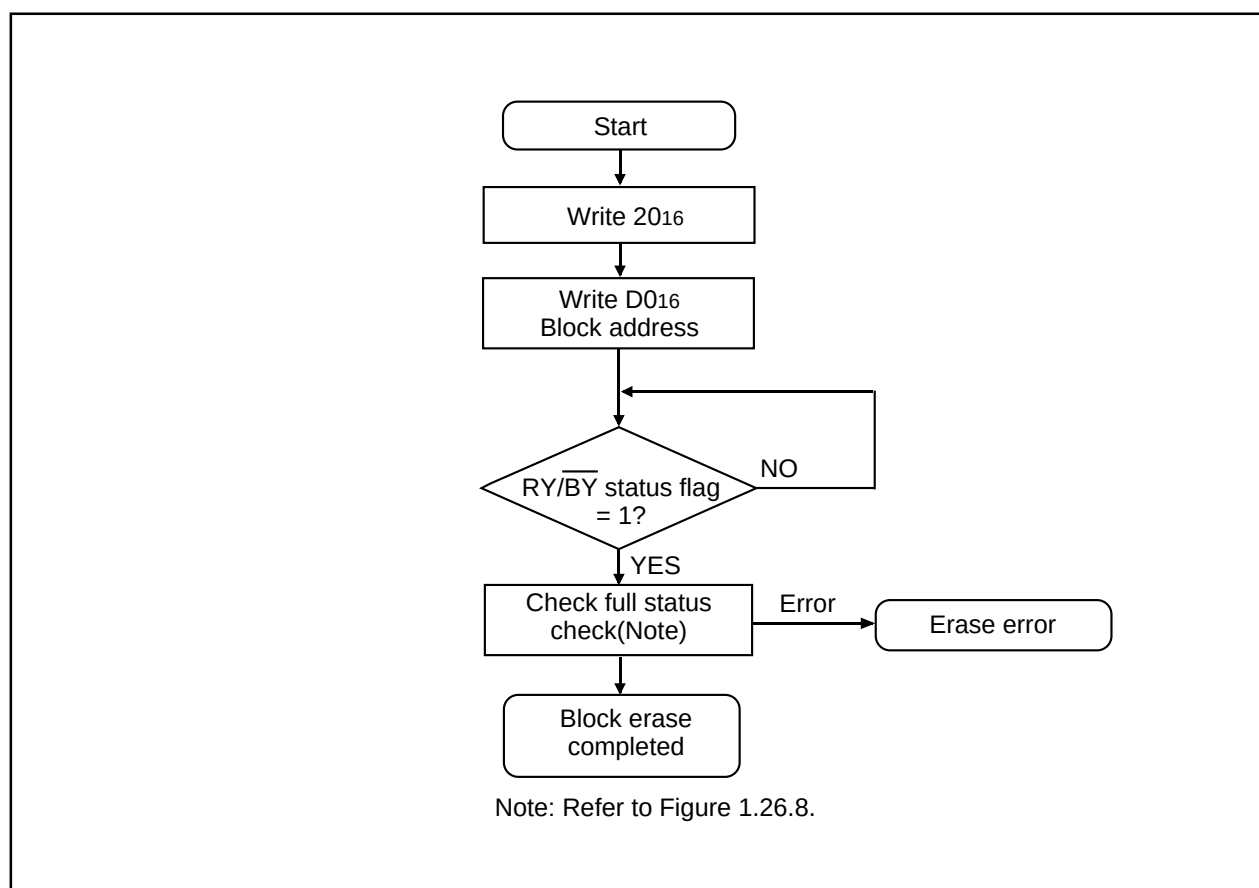


Figure 1.26.5. Block erase flowchart

CPU Rewrite Mode (Flash Memory Version)

Erase All Unlock Blocks Command (A7₁₆/D0₁₆)

By writing the command code "A7₁₆" in the first bus cycle and the confirmation command code "D0₁₆" in the second bus cycle that follows, the system starts erasing blocks successively.

Whether the erase all unlock blocks command is terminated can be confirmed by reading the status register or the flash memory control register 0, in the same way as for block erase. Also, the status register can be read out to know the result of the auto erase operation.

When the lock bit disable select bit of the flash memory control register 0 = 1, all blocks are erased no matter how the lock bit is set. On the other hand, when the lock bit disable select bit = 0, the function of the lock bit is effective and only nonlocked blocks (where lock bit data = 1) are erased.

Lock Bit Program Command (77₁₆/D0₁₆)

By writing the command code "77₁₆" in the first bus cycle and the confirmation command code "D0₁₆" in the second bus cycle that follows to the block address of a flash memory block, the system sets the lock bit for the specified block to 0 (locked).

Figure 1.26.6 shows an example of a lock bit program flowchart. The status of the lock bit (lock bit data) can be read out by a read lock bit status command.

Whether the lock bit program command is terminated can be confirmed by reading the status register or the flash memory control register 0, in the same way as for page program.

For details about the function of the lock bit and how to reset the lock bit, refer to the section where the data protect function is detailed.

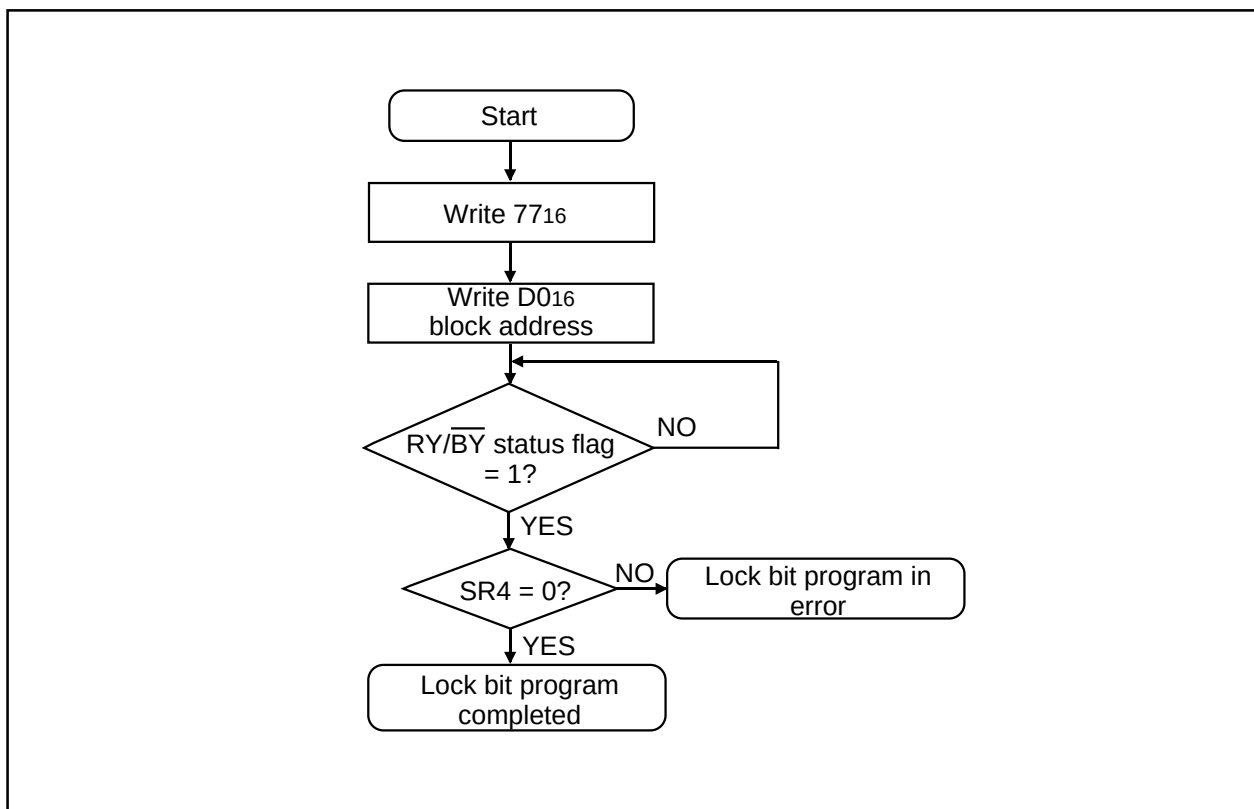


Figure 1.26.6. Lock bit program flowchart

CPU Rewrite Mode (Flash Memory Version)

Read Lock Bit Status Command (7116)

By writing the command code "7116" in the first bus cycle and then the block address of a flash memory block in the second bus cycle that follows, the system reads out the status of the lock bit of the specified block on to the data bus(D6).

Figure 1.26.7 shows an example of a read lock bit program flowchart.

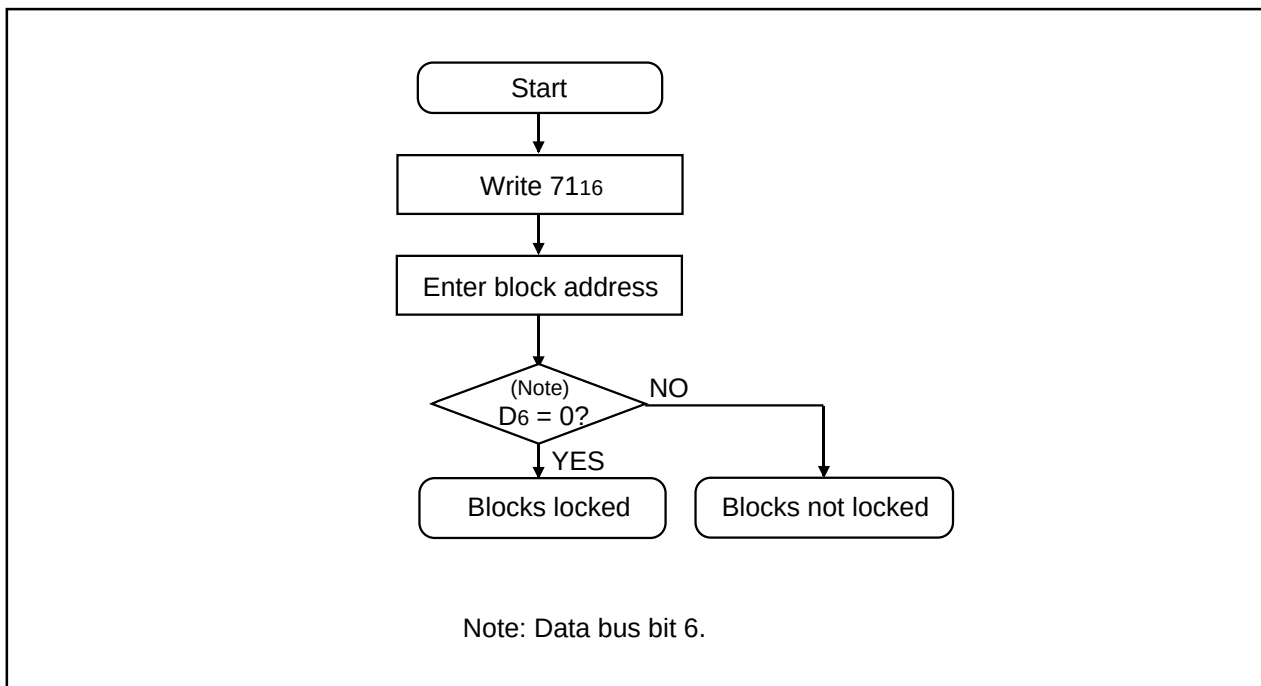


Figure 1.26.7. Read lock bit status flowchart

Data Protect Function (Block Lock)

Each block in Figure 1.25.1 has a nonvolatile lock bit to specify that the block be protected (locked) against erase/write. The lock bit program command is used to set the lock bit to 0 (locked). The lock bit of each block can be read out using the read lock bit status command.

Whether block lock is enabled or disabled is determined by the status of the lock bit and how the flash memory control register 0's lock bit disable select bit is set.

- (1) When the lock bit disable select bit = "0", a specified block can be locked or unlocked by the lock bit status (lock bit data). Blocks whose lock bit data = "0" are locked, so they are disabled against erase/write. On the other hand, the blocks whose lock bit data = "1" are not locked, so they are enabled for erase/write.
- (2) When the lock bit disable select bit = "1", all blocks are nonlocked regardless of the lock bit data, so they are enabled for erase/write. In this case, the lock bit data that is "0" (locked) is set to "1" (nonlocked) after erasure, so that the lock bit-actuated lock is removed.

Status Register

The status register indicates the operating status of the flash memory and whether an erase or program operation has terminated normally or in an error. The content of this register can be read out by only writing the read status register command (70₁₆). Table 1.26.2 details the status register.

The status register is cleared by writing the Clear Status Register command (50₁₆).

After a reset, the status register is set to "80₁₆."

Each bit in this register is explained below.

Write state machine (WSM) status (SR7)

After power-on, the write state machine (WSM) status is set to "1".

The write state machine (WSM) status indicates the operating status of the device, as for output on the RY/ $\overline{\text{BY}}$ pin. This status bit is set to "0" during auto write or auto erase operation and is set to "1" upon completion of these operations.

Erase status (SR5)

The erase status informs the operating status of auto erase operation to the CPU. When an erase error occurs, it is set to "1".

The erase status is reset to "0" when cleared.

CPU Rewrite Mode (Flash Memory Version)

Program status (SR4)

The program status informs the operating status of auto write operation to the CPU. When a write error occurs, it is set to "1".

The program status is reset to "0" when cleared.

When an erase command is in error (which occurs if the command entered after the block erase command (20₁₆) is not the confirmation command (D0₁₆), both the program status and erase status (SR5) are set to "1".

When the program status or erase status = "1", only the following flash commands will be accepted: Read Array, Read Status Register, and Clear Status Register.

Also, in one of the following cases, both SR4 and SR5 are set to "1" (command sequence error):

- (1) When the valid command is not entered correctly
- (2) When the data entered in the second bus cycle of lock bit program (77₁₆/D0₁₆), block erase (20₁₆/D0₁₆), or erase all unlock blocks (A7₁₆/D0₁₆) is not the D0₁₆ or FF₁₆. However, if FF₁₆ is entered, read array is assumed and the command that has been set up in the first bus cycle is canceled.

Block status after program (SR3)

If excessive data is written (phenomenon whereby the memory cell becomes depressed which results in data not being read correctly), "1" is set for the program status after-program at the end of the page write operation. In other words, when writing ends successfully, "80₁₆" is output; when writing fails, "90₁₆" is output; and when excessive data is written, "88₁₆" is output.

Table 1.26.2. Definition of each bit in status register

Each bit of SRD	Status name	Definition	
		"1"	"0"
SR7 (bit7)	Write state machine (WSM) status	Ready	Busy
SR6 (bit6)	Reserved	-	-
SR5 (bit5)	Erase status	Terminated in error	Terminated normally
SR4 (bit4)	Program status	Terminated in error	Terminated normally
SR3 (bit3)	Block status after program	Terminated in error	Terminated normally
SR2 (bit2)	Reserved	-	-
SR1 (bit1)	Reserved	-	-
SR0 (bit0)	Reserved	-	-

CPU Rewrite Mode (Flash Memory Version)

Full Status Check

By performing full status check, it is possible to know the execution results of erase and program operations. Figure 1.26.8 shows a full status check flowchart and the action to be taken when each error occurs.

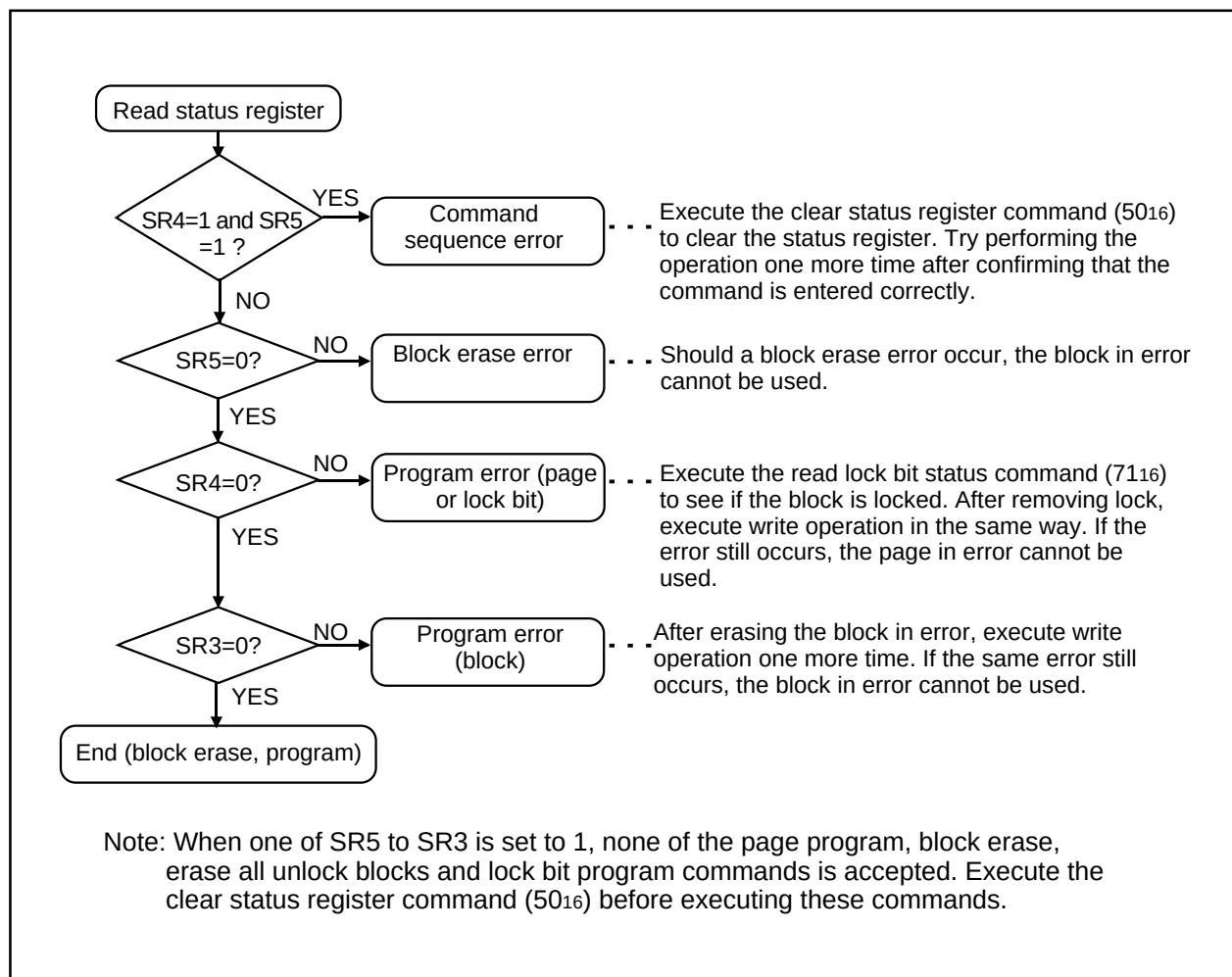


Figure 1.26.8. Full status check flowchart and remedial procedure for errors

Functions To Inhibit Rewriting Flash Memory Version

To prevent the contents of the flash memory version from being read out or rewritten easily, the device incorporates a ROM code protect function for use in parallel I/O mode and an ID code check function for use in standard serial I/O mode.

ROM code protect function

The ROM code protect function is used to prohibit reading out or modifying the contents of the flash memory during parallel I/O mode and is set by using the ROM code protect control address register (0FFFFFF₁₆). Figure 1.27.1 shows the ROM code protect control address (0FFFFFF₁₆). (This address exists in the user ROM area.)

If one of the pair of ROM code protect bits is set to 0, ROM code protect is turned on, so that the contents of the flash memory version are protected against readout and modification. ROM code protect is implemented in two levels. If level 2 is selected, the flash memory is protected even against readout by a shipment inspection LSI tester, etc. When an attempt is made to select both level 1 and level 2, level 2 is selected by default.

If both of the two ROM code protect reset bits are set to "00," ROM code protect is turned off, so that the contents of the flash memory version can be read out or modified. Once ROM code protect is turned on, the contents of the ROM code protect reset bits cannot be modified in parallel I/O mode. Use the serial I/O or some other mode to rewrite the contents of the ROM code protect reset bits.

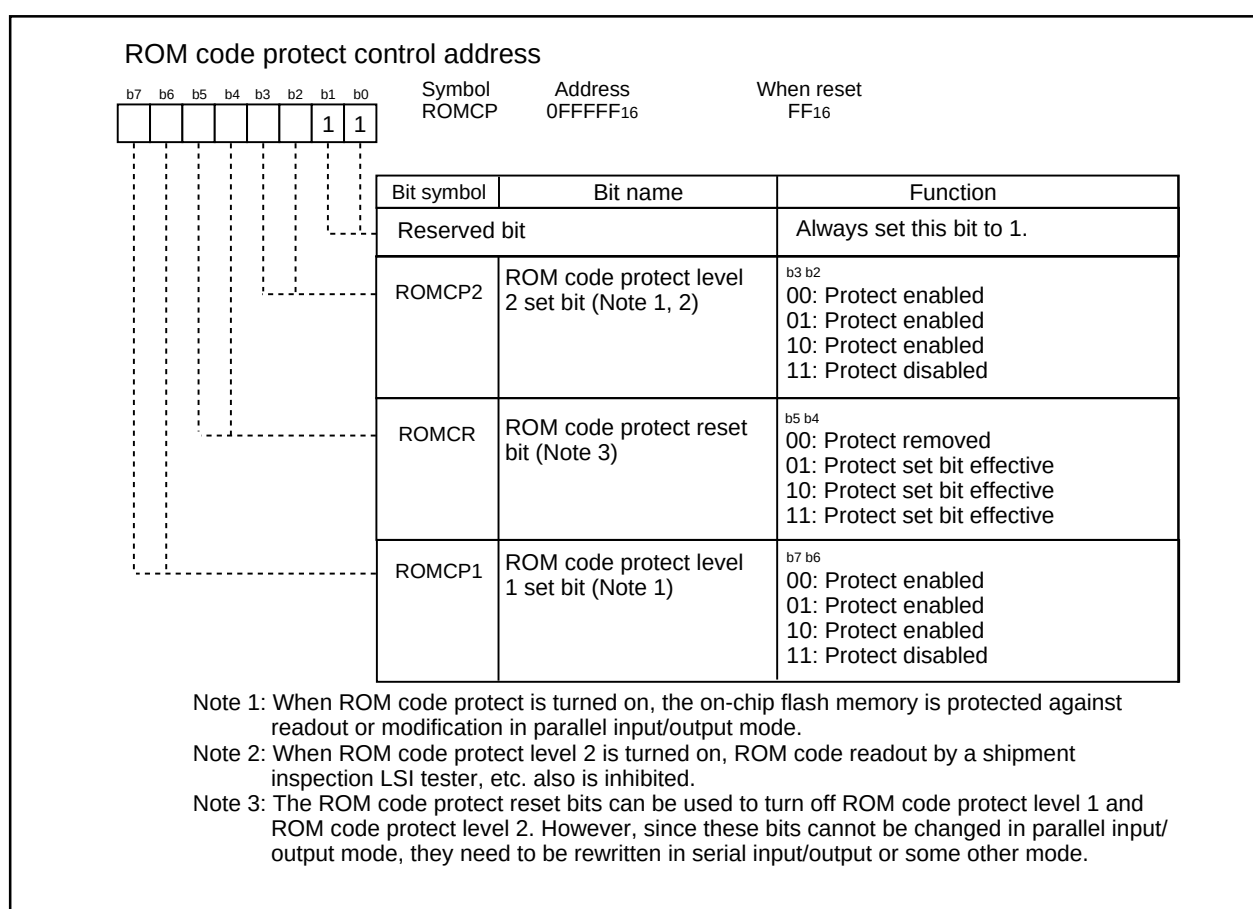


Figure 1.27.1. ROM code protect control address

ID Code Check Function

Use this function in standard serial I/O mode. When the contents of the flash memory are not blank, the ID code sent from the peripheral unit is compared with the ID code written in the flash memory to see if they match. If the ID codes do not match, the commands sent from the peripheral unit are not accepted. The ID code consists of 8-bit data, the areas of which, beginning with the first byte, are 0FFFD₁₆, 0FFFE₃₁₆, 0FFFE_{B16}, 0FFFE_{F16}, 0FFFF₃₁₆, 0FFFF₇₁₆, and 0FFFF_{B16}. Write a program which has had the ID code preset at these addresses to the flash memory.

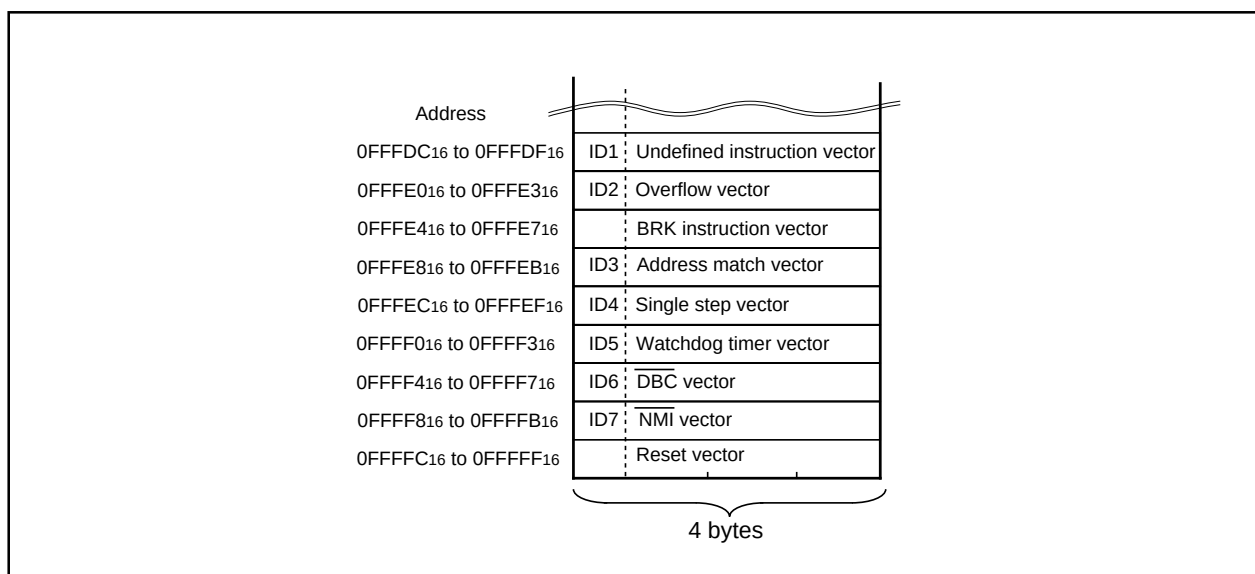


Figure 1.27.2. ID code store addresses

Appendix Parallel I/O Mode (Flash Memory Version)

Parallel I/O Mode

The parallel I/O mode inputs and outputs the software commands, addresses and data needed to operate (read, program, erase, etc.) the internal flash memory. This I/O is parallel.

Use an exclusive programmer supporting M16C/62A (flash memory version).

Refer to the instruction manual of each programmer maker for the details of use.

User ROM and Boot ROM Areas

In parallel I/O mode, the user ROM and boot ROM areas shown in Figure 1.25.1 can be rewritten. Both areas of flash memory can be operated on in the same way.

Program and block erase operations can be performed in the user ROM area. The user ROM area and its blocks are shown in Figure 1.25.1.

The boot ROM area is 8 Kbytes in size. In parallel I/O mode, it is located at addresses 0FE000₁₆ through 0FFFFF₁₆. Make sure program and block erase operations are always performed within this address range. (Access to any location outside this address range is prohibited.)

In the boot ROM area, an erase block operation is applied to only one 8 Kbyte block. The boot ROM area has had a standard serial I/O mode control program stored in it when shipped from the Mitsubishi factory. Therefore, using the device in standard serial input/output mode, you do not need to write to the boot ROM area.

Appendix Standard Serial I/O Mode (Flash Memory Version)

Pin functions (Flash memory standard serial I/O mode)

Pin	Name	I/O	Description
Vcc,Vss	Power input		Apply program/erase protection voltage to Vcc pin and 0 V to Vss pin.
CNVss	CNVss	I	Connect to Vcc pin.
RESET	Reset input	I	Reset input pin. While reset is "L" level, a 20 cycle or longer clock must be input to XIN pin.
XIN	Clock input	I	Connect a ceramic resonator or crystal oscillator between XIN and XOUT pins. To input an externally generated clock, input it to XIN pin and open XOUT pin.
XOUT	Clock output	O	
BYTE	BYTE	I	Connect this pin to Vss or Vcc.
AVcc, AVss	Analog power supply input		Connect AVss to Vss and AVcc to Vcc, respectively.
VREF	Reference voltage input	I	Enter the reference voltage for AD from this pin.
P00 to P07	Input port P0	I	Input "H" or "L" level signal or open.
P10 to P17	Input port P1	I	Input "H" or "L" level signal or open.
P20 to P27	Input port P2	I	Input "H" or "L" level signal or open.
P30 to P37	Input port P3	I	Input "H" or "L" level signal or open.
P40 to P47	Input port P4	I	Input "H" or "L" level signal or open.
P51 to P54, P56, P57	Input port P5	I	Input "H" or "L" level signal or open.
P50	CE input	I	Input "H" level signal.
P55	EPM input	I	Input "L" level signal.
P60 to P63	Input port P6	I	Input "H" or "L" level signal or open.
P64	BUSY output	O	Standard serial I/O mode 1: BUSY signal output pin Standard serial I/O mode 2: Monitors the boot program operation check signal output pin.
P65	SCLK input	I	Standard serial I/O mode 1: Serial clock input pin Standard serial I/O mode 2: Input "L".
P66	RxD input	I	Serial data input pin
P67	TxD output	O	Serial data output pin
P70 to P77	Input port P7	I	Input "H" or "L" level signal or open.
P80 to P84, P86, P87	Input port P8	I	Input "H" or "L" level signal or open.
P85	NMI input	I	Connect this pin to Vcc.
P90 to P97	Input port P9	I	Input "H" or "L" level signal or open.
P100 to P107	Input port P10	I	Input "H" or "L" level signal or open.

Appendix Standard Serial I/O Mode (Flash Memory Version)

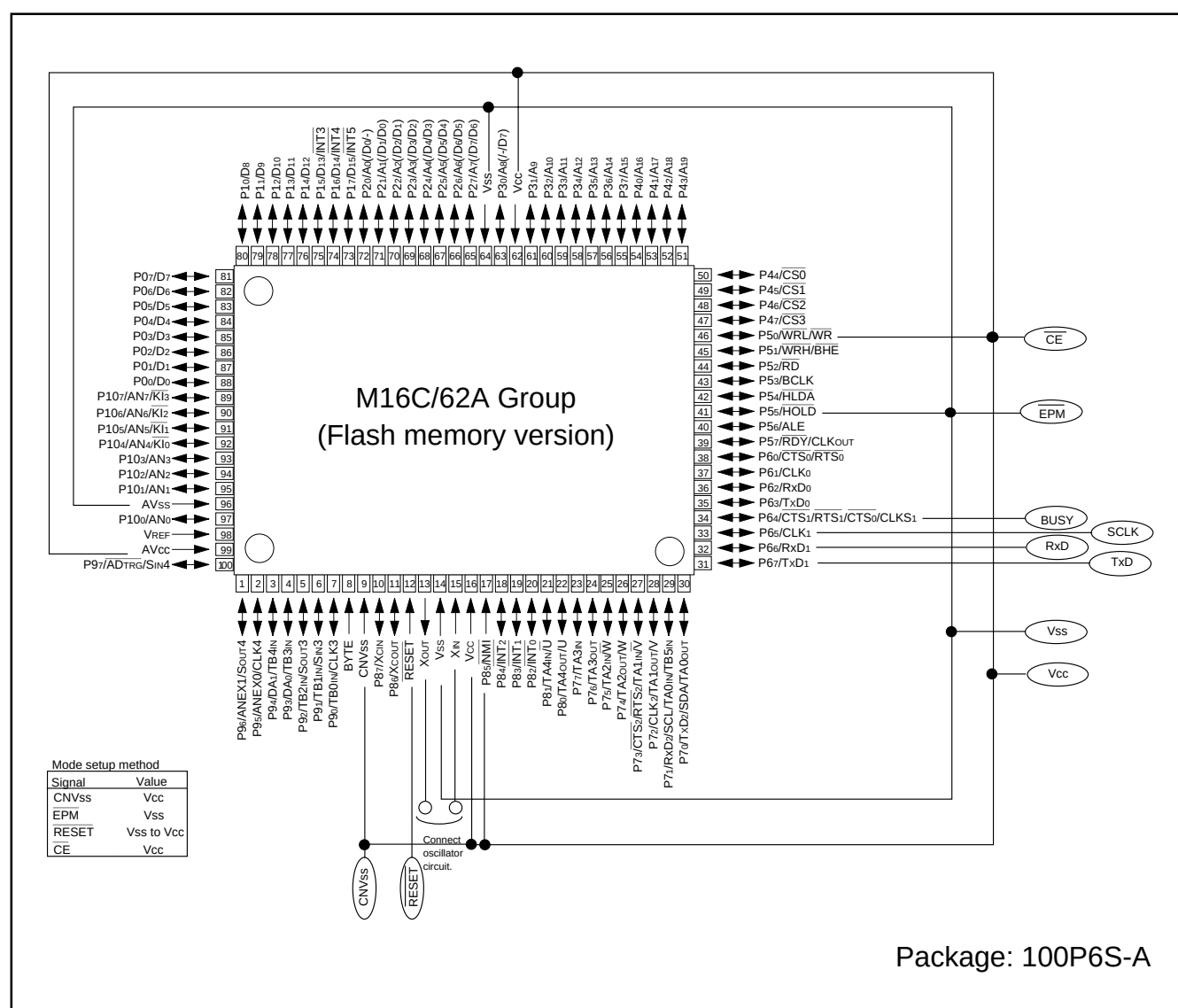


Figure 1.29.1. Pin connections for serial I/O mode (1)

Appendix Standard Serial I/O Mode (Flash Memory Version)

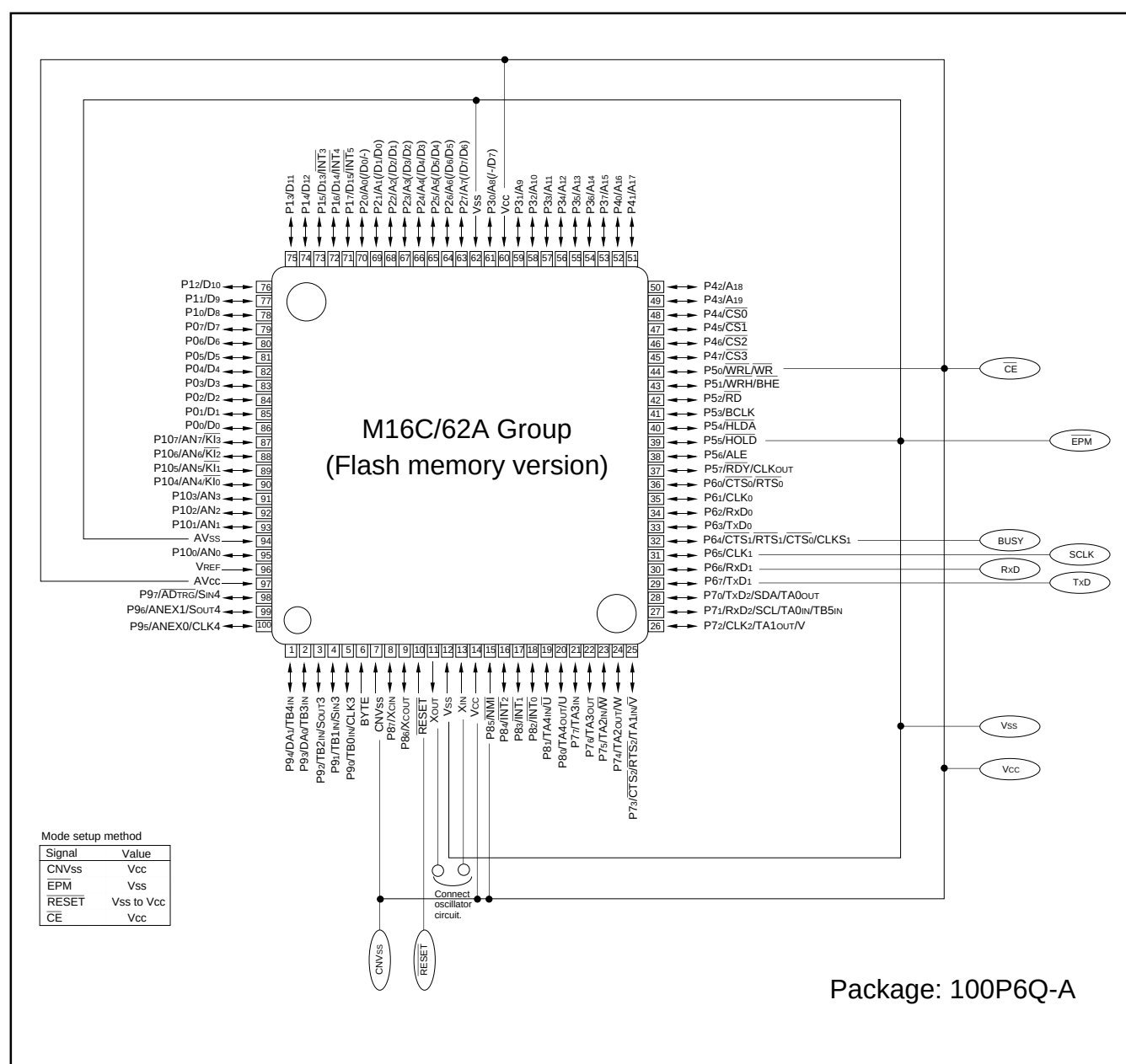


Figure 1.29.2. Pin connections for serial I/O mode (2)

Appendix Standard Serial I/O Mode (Flash Memory Version)

Standard serial I/O mode

The standard serial I/O mode inputs and outputs the software commands, addresses and data needed to operate (read, program, erase, etc.) the internal flash memory. This I/O is serial. There are actually two standard serial I/O modes: mode 1, which is clock synchronized, and mode 2, which is asynchronous. Both modes require a purpose-specific peripheral unit.

The standard serial I/O mode is different from the parallel I/O mode in that the CPU controls flash memory rewrite (uses the CPU's rewrite mode), rewrite data input and so forth. It is started when the reset is released, which is done when the P50 ($\overline{CE}$) pin is "H" level, the P55 ($\overline{EPM}$) pin "L" level and the CNVss pin "H" level. (In the ordinary command mode, set CNVss pin to "L" level.)

This control program is written in the boot ROM area when the product is shipped from Mitsubishi. Accordingly, make note of the fact that the standard serial I/O mode cannot be used if the boot ROM area is rewritten in the parallel I/O mode. Figures 1.29.1 and 1.29.2 show the pin connections for the standard serial I/O mode. Serial data I/O uses UART1 and transfers the data serially in 8-bit units. Standard serial I/O switches between mode 1 (clock synchronized) and mode 2 (clock asynchronous) according to the level of CLK1 pin when the reset is released.

To use standard serial I/O mode 1 (clock synchronized), set the CLK1 pin to "H" level and release the reset. The operation uses the four UART1 pins CLK1, RxD1, TxD1 and RTS1 (BUSY). The CLK1 pin is the transfer clock input pin through which an external transfer clock is input. The TxD1 pin is for CMOS output. The RTS1 (BUSY) pin outputs an "L" level when ready for reception and an "H" level when reception starts.

To use standard serial I/O mode 2 (clock asynchronous), set the CLK1 pin to "L" level and release the reset. The operation uses the two UART1 pins RxD1 and TxD1.

In the standard serial I/O mode, only the user ROM area indicated in Figure 1.29.19 can be rewritten. The boot ROM cannot.

In the standard serial I/O mode, a 7-byte ID code is used. When there is data in the flash memory, commands sent from the peripheral unit are not accepted unless the ID code matches.

Overview of standard serial I/O mode 1 (clock synchronized)

In standard serial I/O mode 1, software commands, addresses and data are input and output between the MCU and peripheral units (serial programmer, etc.) using 4-wire clock-synchronized serial I/O (UART1). Standard serial I/O mode 1 is engaged by releasing the reset with the P65 (CLK1) pin "H" level.

In reception, software commands, addresses and program data are synchronized with the rise of the transfer clock that is input to the CLK1 pin, and are then input to the MCU via the RxD1 pin. In transmission, the read data and status are synchronized with the fall of the transfer clock, and output from the TxD1 pin.

The TxD1 pin is for CMOS output. Transfer is in 8-bit units with LSB first.

When busy, such as during transmission, reception, erasing or program execution, the RTS1 (BUSY) pin is "H" level. Accordingly, always start the next transfer after the RTS1 (BUSY) pin is "L" level.

Also, data and status registers in memory can be read after inputting software commands. Status, such as the operating state of the flash memory or whether a program or erase operation ended successfully or not, can be checked by reading the status register. Here following are explained software commands, status registers, etc.

Appendix Standard Serial I/O Mode 1 (Flash Memory Version)

Software Commands

Table 1.29.1 lists software commands. In the standard serial I/O mode 1, erase operations, programs and reading are controlled by transferring software commands via the RxD1 pin. Software commands are explained here below.

Table 1.29.1. Software commands (Standard serial I/O mode 1)

	Control command	1st byte transfer	2nd byte	3rd byte	4th byte	5th byte	6th byte		When ID is not verified
1	Page read	FF ₁₆	Address (middle)	Address (high)	Data output	Data output	Data output	Data output to 259th byte	Not acceptable
2	Page program	41 ₁₆	Address (middle)	Address (high)	Data input	Data input	Data input	Data input to 259th byte	Not acceptable
3	Block erase	20 ₁₆	Address (middle)	Address (high)	D0 ₁₆				Not acceptable
4	Erase all unlocked blocks	A7 ₁₆	D0 ₁₆						Not acceptable
5	Read status register	70 ₁₆	SRD output	SRD1 output					Acceptable
6	Clear status register	50 ₁₆							Not acceptable
7	Read lock bit status	71 ₁₆	Address (middle)	Address (high)	Lock bit data output				Not acceptable
8	Lock bit program	77 ₁₆	Address (middle)	Address (high)	D0 ₁₆				Not acceptable
9	Lock bit enable	7A ₁₆							Not acceptable
10	Lock bit disable	75 ₁₆							Not acceptable
11	ID check function	F5 ₁₆	Address (low)	Address (middle)	Address (high)	ID size	ID1	To ID7	Acceptable
12	Download function	FA ₁₆	Size (low)	Size (high)	Check-sum	Data input	To required number of times		Not acceptable
13	Version data output function	FB ₁₆	Version data output	Version data output	Version data output	Version data output	Version data output	Version data output to 9th byte	Acceptable
14	Boot ROM area output function	FC ₁₆	Address (middle)	Address (high)	Data output	Data output	Data output	Data output to 259th byte	Not acceptable
15	Read check data	FD ₁₆	Check data (low)	Check data (high)					Not acceptable

Note 1: Shading indicates transfer from flash memory microcomputer to peripheral unit. All other data is transferred from the peripheral unit to the flash memory microcomputer.

Note 2: SRD refers to status register data. SRD1 refers to status register 1 data.

Note 3: All commands can be accepted when the flash memory is totally blank.

Page Read Command

This command reads the specified page (256 bytes) in the flash memory sequentially one byte at a time. Execute the page read command as explained here following.

- (1) Transfer the "FF16" command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) From the 4th byte onward, data (D0–D7) for the page (256 bytes) specified with addresses A8 to A23 will be output sequentially from the smallest address first in sync with the fall of the clock.

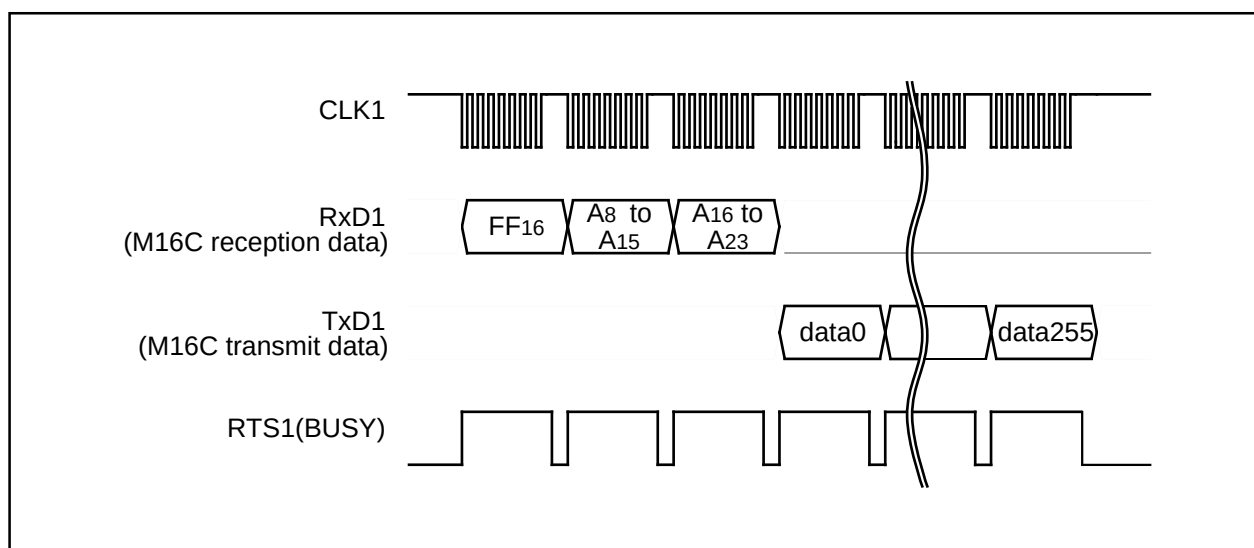


Figure 1.29.3. Timing for page read

Read Status Register Command

This command reads status information. When the "7016" command code is sent with the 1st byte, the contents of the status register (SRD) specified with the 2nd byte and the contents of status register 1 (SRD1) specified with the 3rd byte are read.

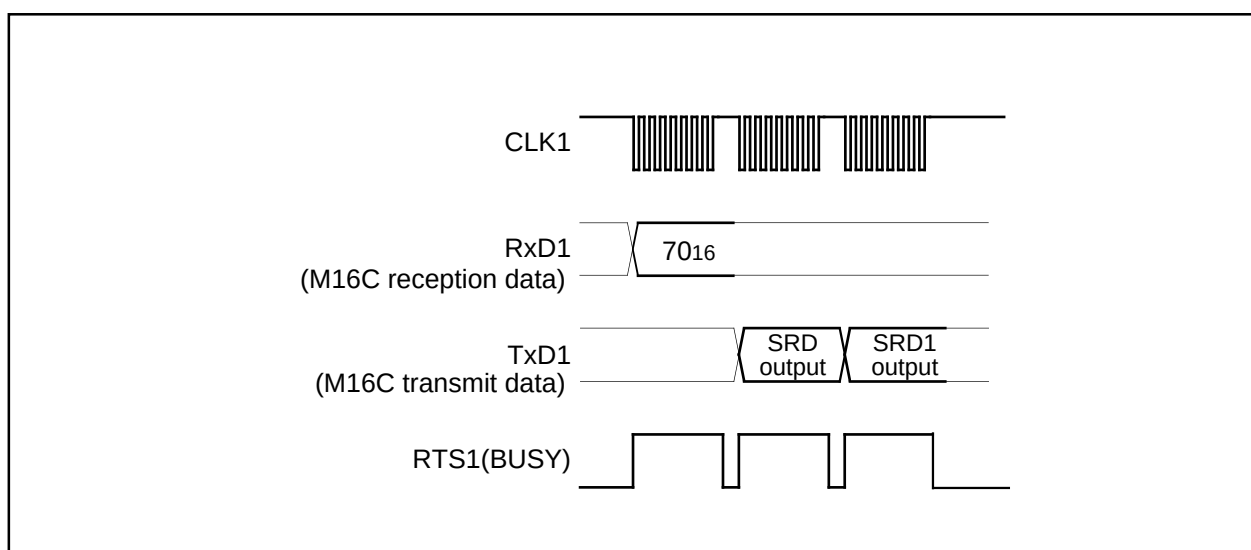


Figure 1.29.4. Timing for reading the status register

Clear Status Register Command

This command clears the bits (SR3–SR5) which are set when the status register operation ends in error. When the “50₁₆” command code is sent with the 1st byte, the aforementioned bits are cleared. When the clear status register operation ends, the RTS1 (BUSY) signal changes from the “H” to the “L” level.

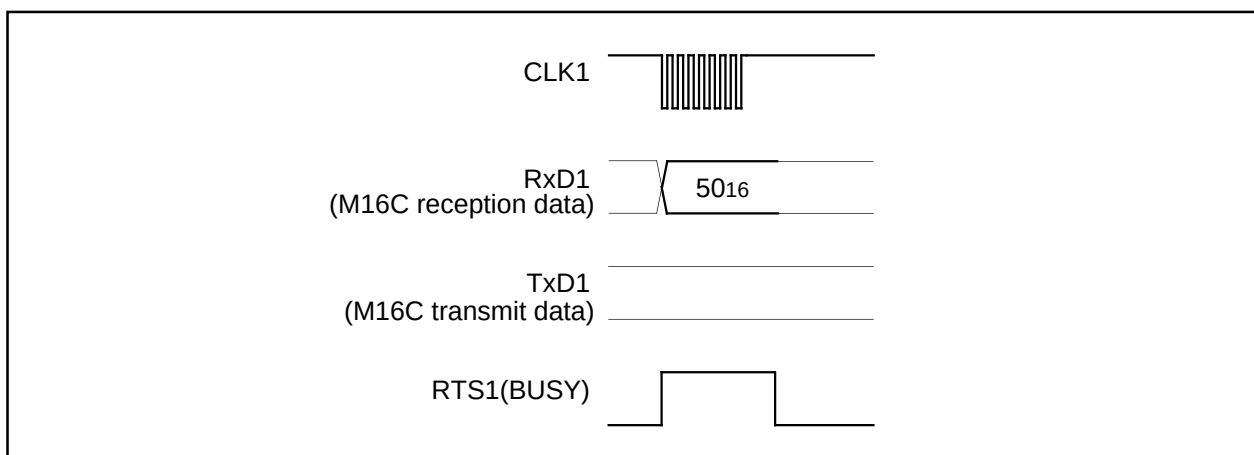


Figure 1.29.5. Timing for clearing the status register

Page Program Command

This command writes the specified page (256 bytes) in the flash memory sequentially one byte at a time. Execute the page program command as explained here following.

- (1) Transfer the “41₁₆” command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) From the 4th byte onward, as write data (D0–D7) for the page (256 bytes) specified with addresses A8 to A23 is input sequentially from the smallest address first, that page is automatically written.

When reception setup for the next 256 bytes ends, the RTS1 (BUSY) signal changes from the “H” to the “L” level. The result of the page program can be known by reading the status register. For more information, see the section on the status register.

Each block can be write-protected with the lock bit. For more information, see the section on the data protection function. Additional writing is not allowed with already programmed pages.

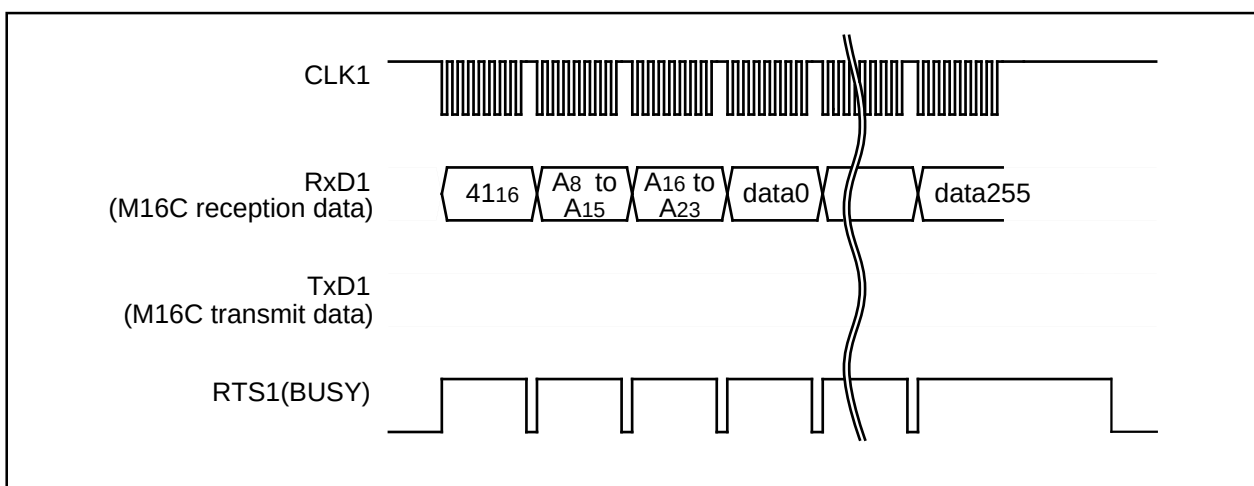


Figure 1.29.6. Timing for the page program

Block Erase Command

This command erases the data in the specified block. Execute the block erase command as explained here following.

- (1) Transfer the "2016" command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) Transfer the verify command code "D016" with the 4th byte. With the verify command code, the erase operation will start for the specified block in the flash memory. Write the highest address of the specified block for addresses A8 to A23.

When block erasing ends, the RTS1 (BUSY) signal changes from the "H" to the "L" level. After block erase ends, the result of the block erase operation can be known by reading the status register. For more information, see the section on the status register.

Each block can be erase-protected with the lock bit. For more information, see the section on the data protection function.

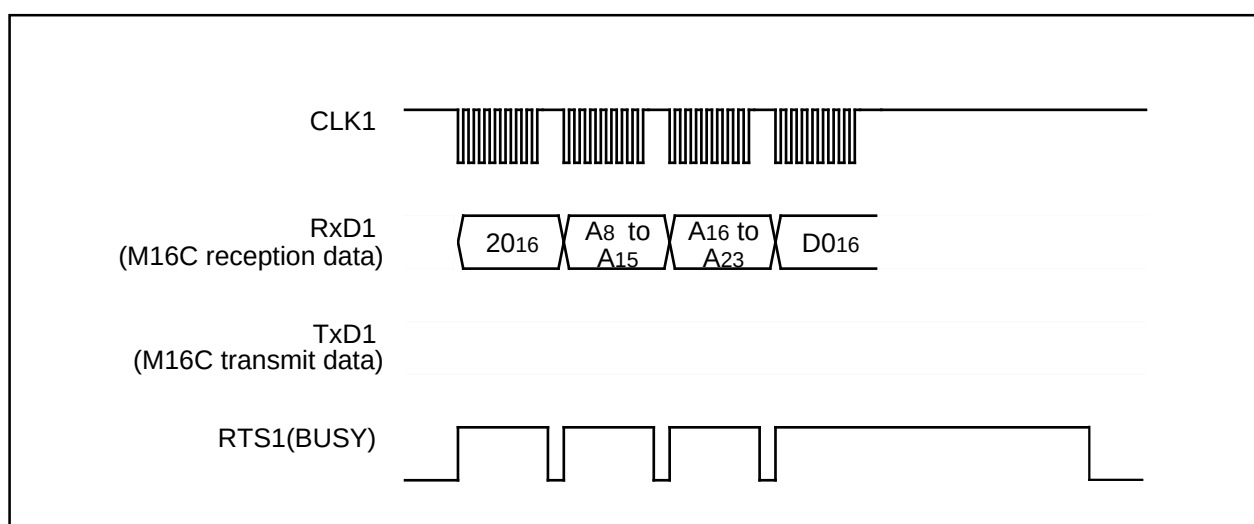


Figure 1.29.7. Timing for block erasing

Erase All Unlocked Blocks Command

This command erases the content of all blocks. Execute the erase all unlocked blocks command as explained here following.

- (1) Transfer the "A7₁₆" command code with the 1st byte.
- (2) Transfer the verify command code "D0₁₆" with the 2nd byte. With the verify command code, the erase operation will start and continue for all blocks in the flash memory.

When block erasing ends, the RTS₁ (BUSY) signal changes from the "H" to the "L" level. The result of the erase operation can be known by reading the status register. Each block can be erase-protected with the lock bit. For more information, see the section on the data protection function.

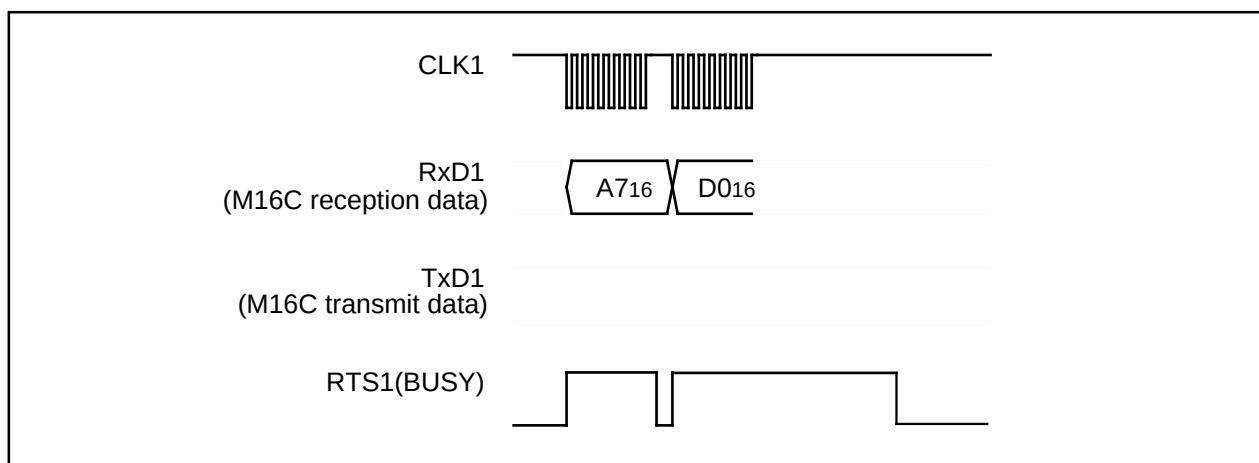


Figure 1.29.8. Timing for erasing all unlocked blocks

Lock Bit Program Command

This command writes "0" (lock) for the lock bit of the specified block. Execute the lock bit program command as explained here following.

- (1) Transfer the "77₁₆" command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) Transfer the verify command code "D0₁₆" with the 4th byte. With the verify command code, "0" is written for the lock bit of the specified block. Write the highest address of the specified block for addresses A8 to A23.

When writing ends, the RTS₁ (BUSY) signal changes from the "H" to the "L" level. Lock bit status can be read with the read lock bit status command. For information on the lock bit function, reset procedure and so on, see the section on the data protection function.

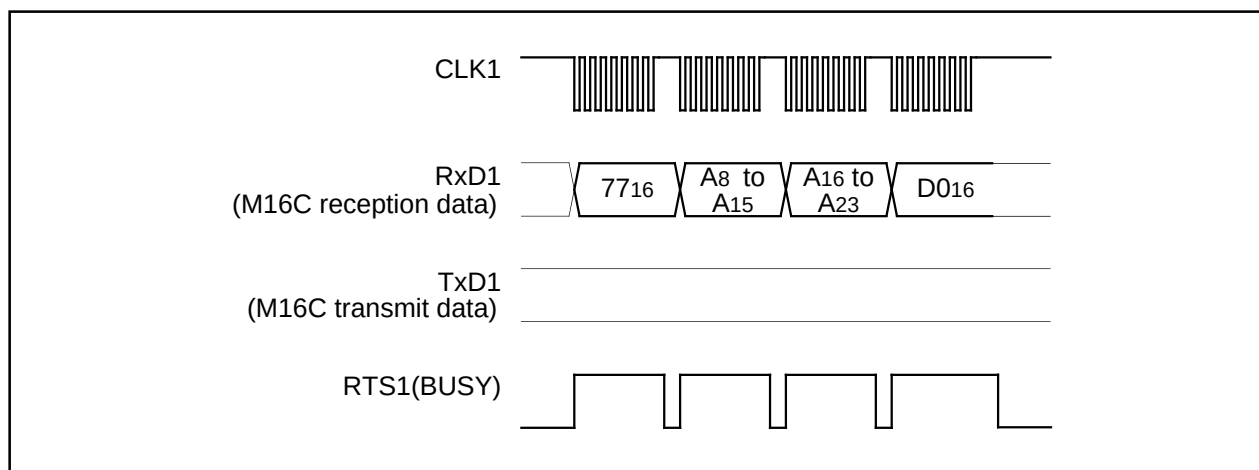


Figure 1.29.9. Timing for the lock bit program

Read Lock Bit Status Command

This command reads the lock bit status of the specified block. Execute the read lock bit status command as explained here following.

- (1) Transfer the "7116" command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) The lock bit data of the specified block is output with the 4th byte. The lock bit data is the 6th bit(D6) of the output data. Write the highest address of the specified block for addresses A8 to A23.

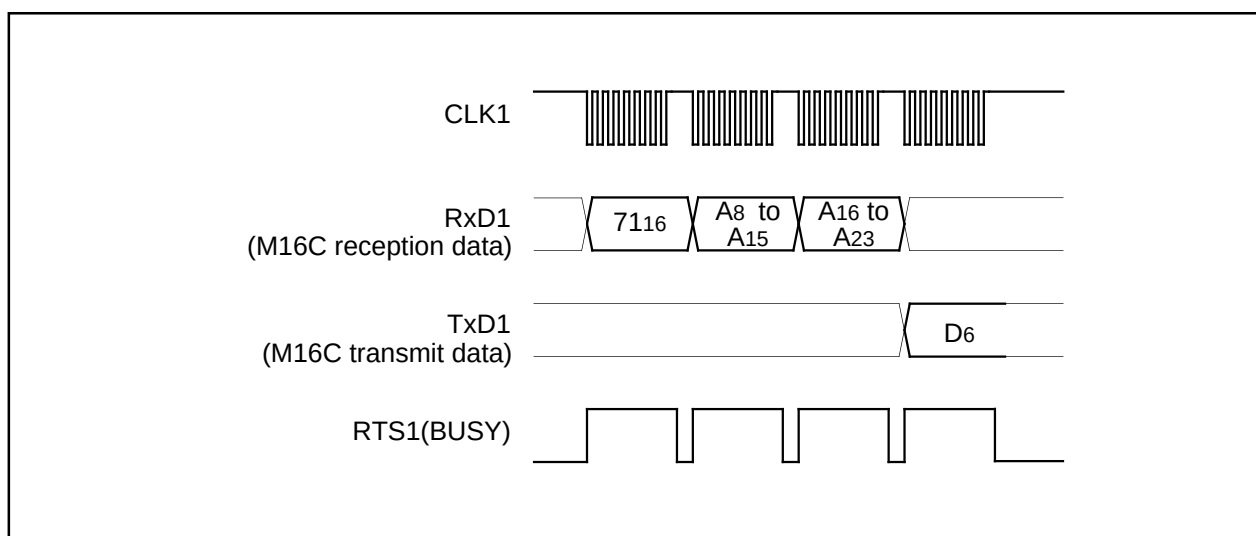


Figure 1.29.10. Timing for reading lock bit status

Lock Bit Enable Command

This command enables the lock bit in blocks whose bit was disabled with the lock bit disable command. The command code "7A16" is sent with the 1st byte of the serial transmission. This command only enables the lock bit function; it does not set the lock bit itself.

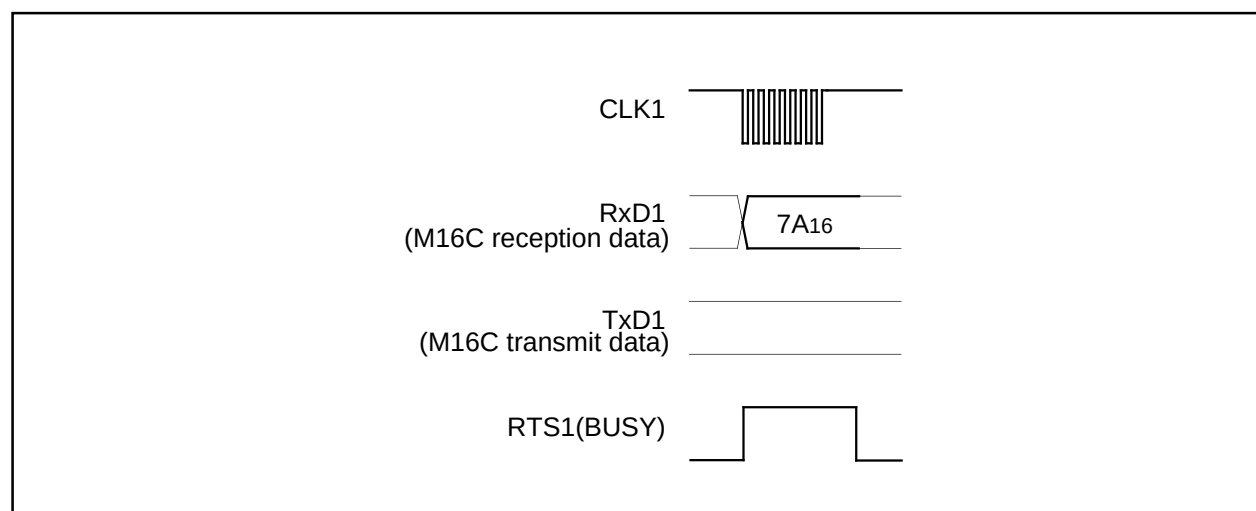


Figure 1.29.11. Timing for enabling the lock bit

Lock Bit Disable Command

This command disables the lock bit. The command code “7516” is sent with the 1st byte of the serial transmission. This command only disables the lock bit function; it does not set the lock bit itself. However, if an erase command is executed after executing the lock bit disable command, “0” (locked) lock bit data is set to “1” (unlocked) after the erase operation ends. In any case, after the reset is cancelled, the lock bit is enabled.

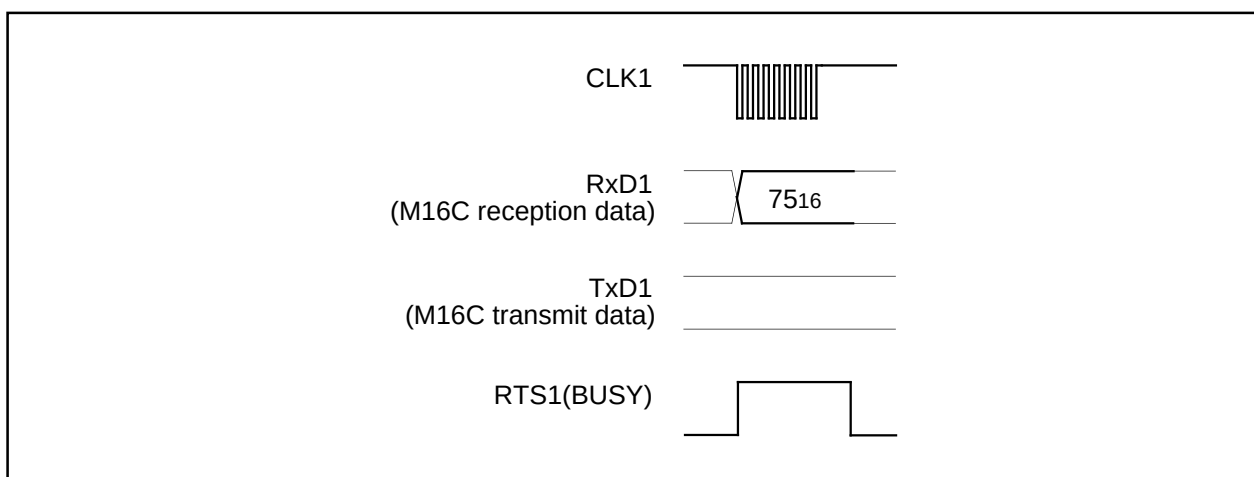


Figure 1.29.12. Timing for disabling the lock bit

Download Command

This command downloads a program to the RAM for execution. Execute the download command as explained here following.

- (1) Transfer the “FA16” command code with the 1st byte.
- (2) Transfer the program size with the 2nd and 3rd bytes.
- (3) Transfer the check sum with the 4th byte. The check sum is added to all data sent with the 5th byte onward.
- (4) The program to execute is sent with the 5th byte onward.

When all data has been transmitted, if the check sum matches, the downloaded program is executed. The size of the program will vary according to the internal RAM.

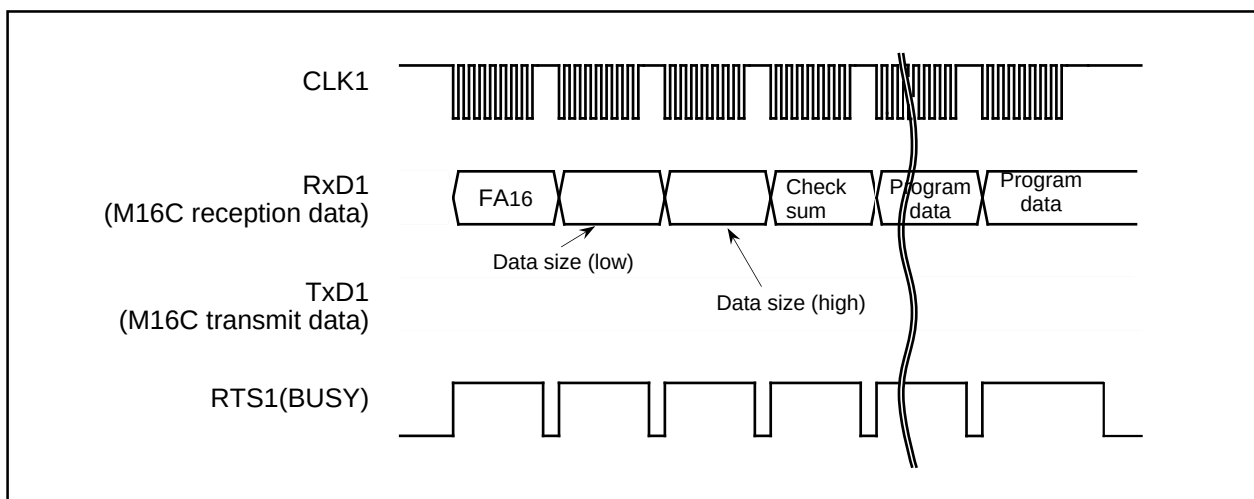


Figure 1.29.13. Timing for download

Appendix Standard Serial I/O Mode 1 (Flash Memory Version)

Version Information Output Command

This command outputs the version information of the control program stored in the boot area. Execute the version information output command as explained here following.

- (1) Transfer the "FB16" command code with the 1st byte.
- (2) The version information will be output from the 2nd byte onward. This data is composed of 8 ASCII code characters.

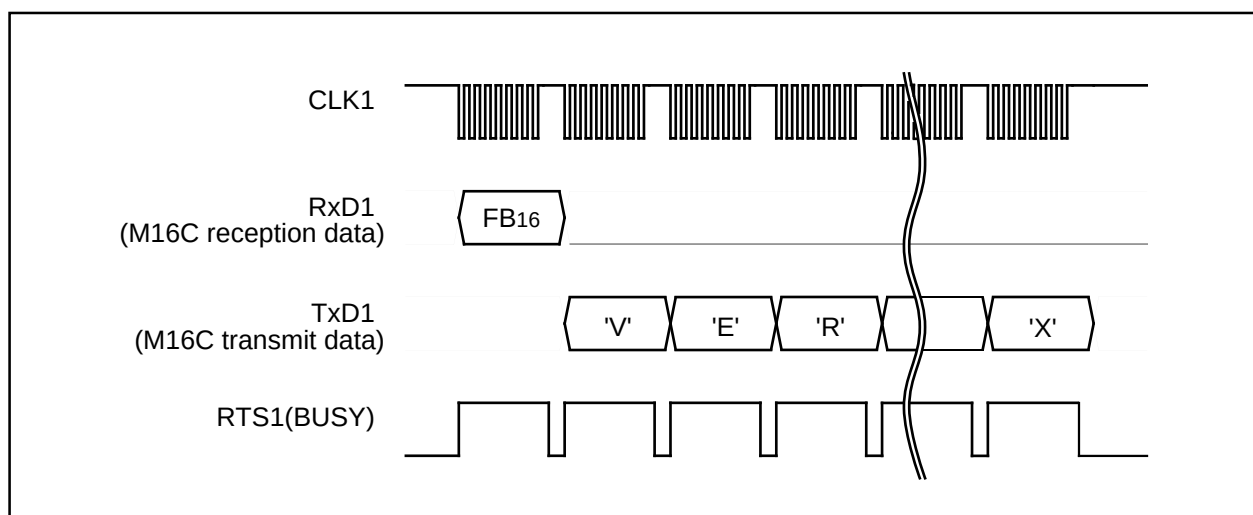


Figure 1.29.14. Timing for version information output

Boot ROM Area Output Command

This command outputs the control program stored in the boot ROM area in one page blocks (256 bytes). Execute the boot ROM area output command as explained here following.

- (1) Transfer the "FC16" command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) From the 4th byte onward, data (D0–D7) for the page (256 bytes) specified with addresses A8 to A23 will be output sequentially from the smallest address first, in sync with the fall of the clock.

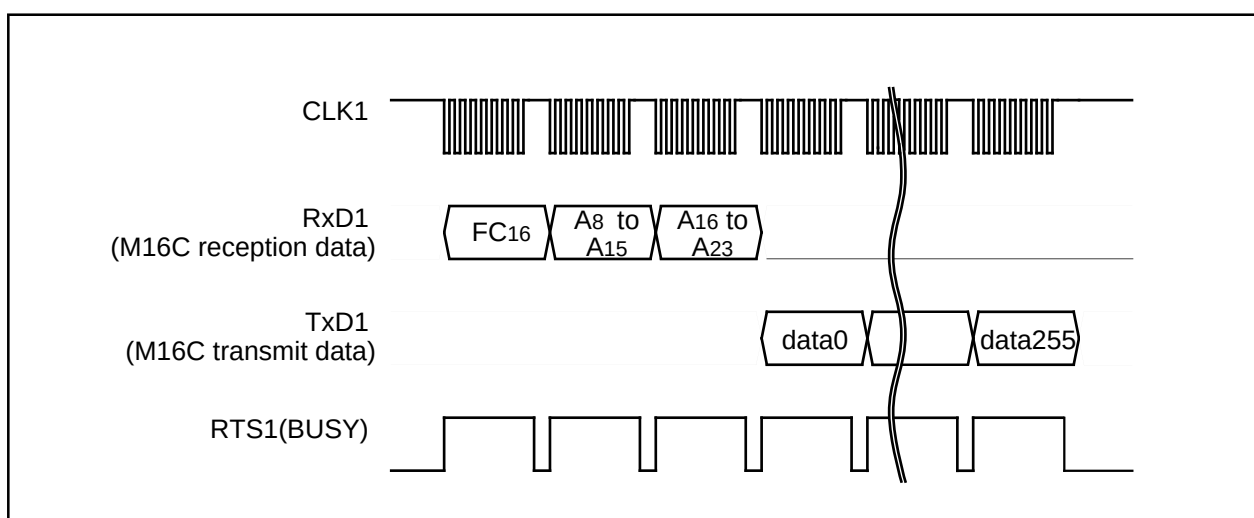


Figure 1.29.15. Timing for boot ROM area output

ID Check

This command checks the ID code. Execute the boot ID check command as explained here following.

- (1) Transfer the "F5₁₆" command code with the 1st byte.
- (2) Transfer addresses A0 to A7, A8 to A15 and A16 to A23 of the 1st byte of the ID code with the 2nd, 3rd and 4th bytes respectively.
- (3) Transfer the number of data sets of the ID code with the 5th byte.
- (4) The ID code is sent with the 6th byte onward, starting with the 1st byte of the code.

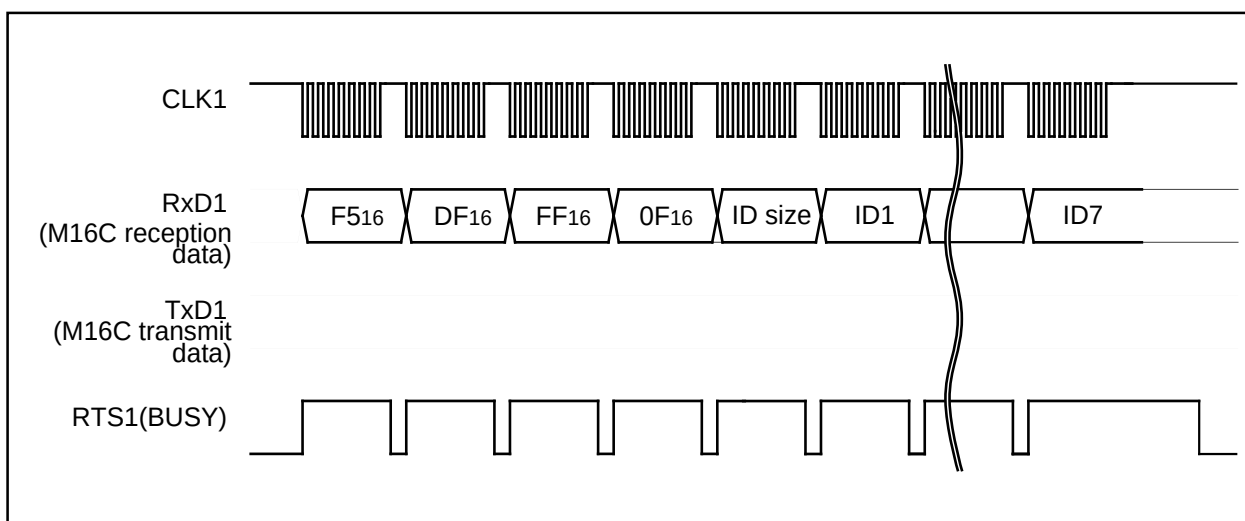


Figure 1.29.16. Timing for the ID check

ID Code

When the flash memory is not blank, the ID code sent from the peripheral units and the ID code written in the flash memory are compared to see if they match. If the codes do not match, the command sent from the peripheral units is not accepted. An ID code contains 8 bits of data. Area is, from the 1st byte, addresses 0FFFD₁₆, 0FFFE₃₁₆, 0FFFE_{B16}, 0FFFE_{F16}, 0FFFF₃₁₆, 0FFFF₇₁₆ and 0FFFF_{B16}. Write a program into the flash memory, which already has the ID code set for these addresses.

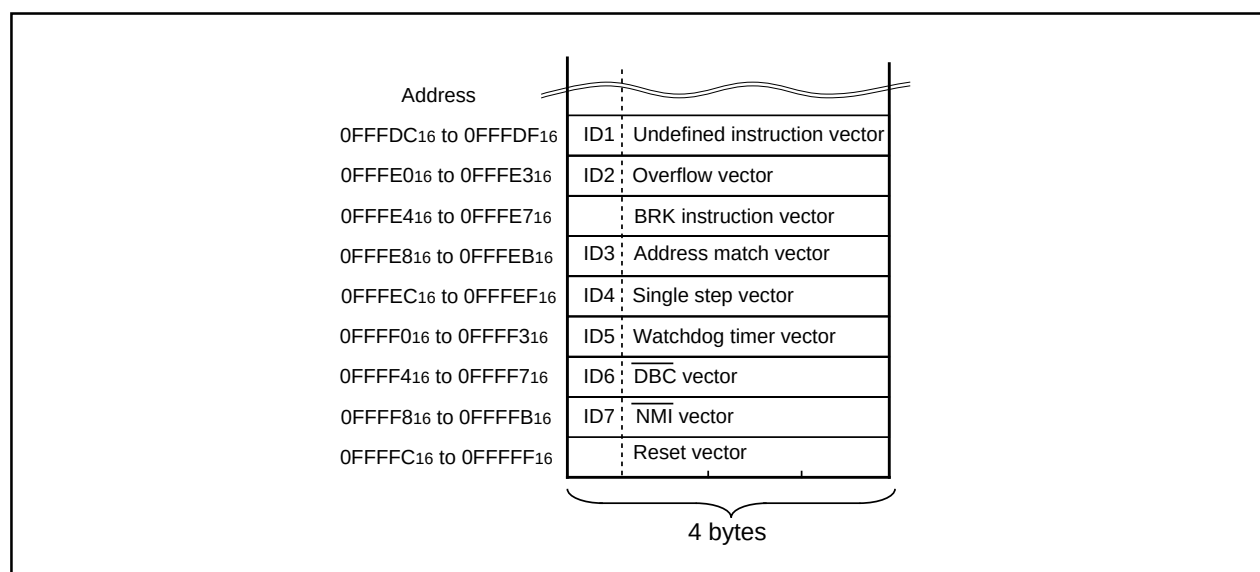


Figure 1.29.17. ID code storage addresses

Read Check Data

This command reads the check data that confirms that the write data, which was sent with the page program command, was successfully received.

- (1) Transfer the "FD16" command code with the 1st byte.
- (2) The check data (low) is received with the 2nd byte and the check data (high) with the 3rd.

To use this read check data command, first execute the command and then initialize the check data. Next, execute the page program command the required number of times. After that, when the read check command is executed again, the check data for all of the read data that was sent with the page program command during this time is read. The check data is the result of CRC operation of write data.

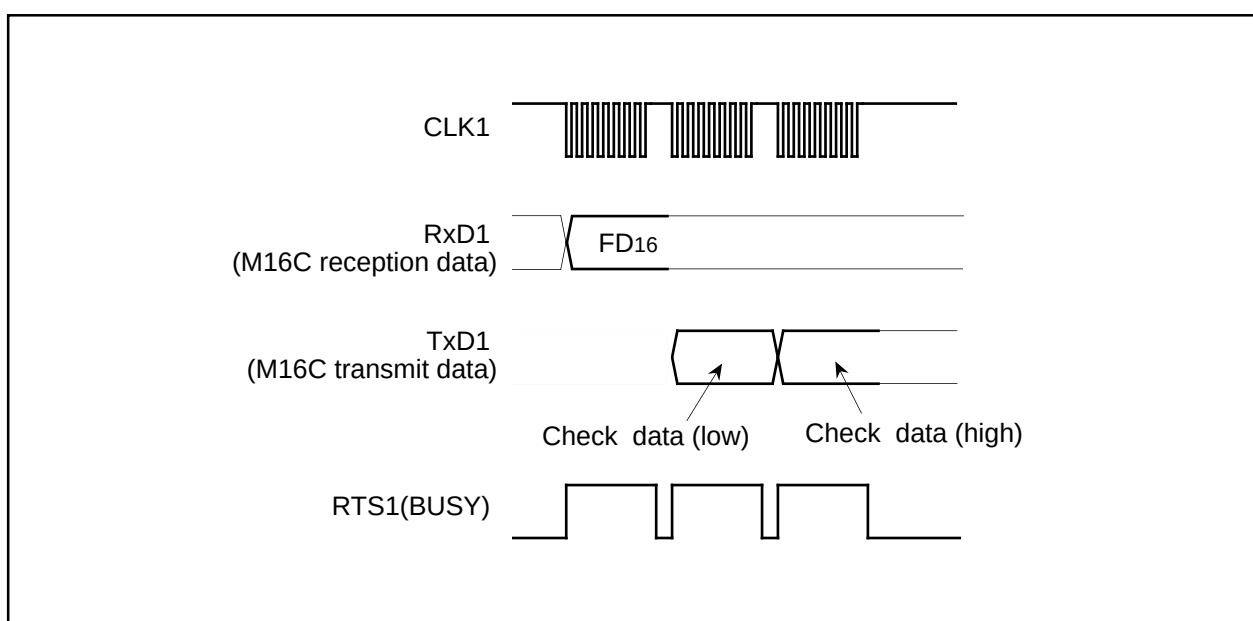


Figure 1.29.18. Timing for the read check data

Data Protection (Block Lock)

Each of the blocks in Figure 1.29.19 have a nonvolatile lock bit that specifies protection (block lock) against erasing/writing. A block is locked (writing "0" for the lock bit) with the lock bit program command. Also, the lock bit of any block can be read with the read lock bit status command.

Block lock disable/enable is determined by the status of the lock bit itself and execution status of the lock bit disable and lock enable bit commands.

- (1) After the reset has been cancelled and the lock bit enable command executed, the specified block can be locked/unlocked using the lock bit (lock bit data). Blocks with a "0" lock bit data are locked and cannot be erased or written in. On the other hand, blocks with a "1" lock bit data are unlocked and can be erased or written in.
- (2) After the lock bit disable command has been executed, all blocks are unlocked regardless of lock bit data status and can be erased or written in. In this case, lock bit data that was "0" (locked) before the block was erased is set to "1" (unlocked) after erasing, therefore the block is actually unlocked with the lock bit.

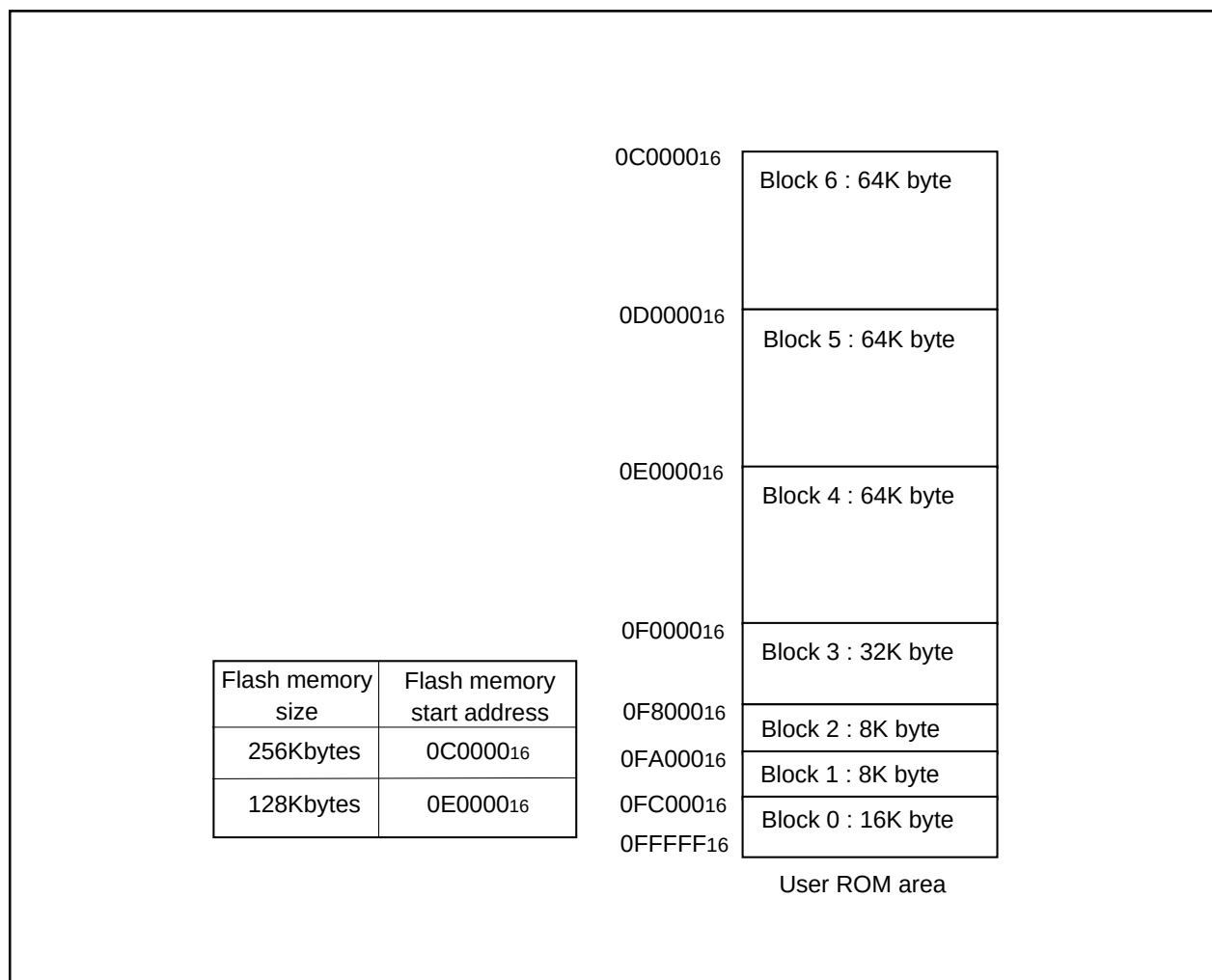


Figure 1.29.19. Blocks in the user area

Status Register (SRD)

The status register indicates operating status of the flash memory and status such as whether an erase operation or a program ended successfully or in error. It can be read by writing the read status register command (70₁₆). Also, the status register is cleared by writing the clear status register command (50₁₆). Table 1.29.2 gives the definition of each status register bit. After clearing the reset, the status register outputs "80₁₆".

Table 1.29.2. Status register (SRD)

SRD0 bits	Status name	Definition	
		"1"	"0"
SR7 (bit7)	Write state machine (WSM) status	Ready	Busy
SR6 (bit6)	Reserved	-	-
SR5 (bit5)	Erase status	Terminated in error	Terminated normally
SR4 (bit4)	Program status	Terminated in error	Terminated normally
SR3 (bit3)	Block status after program	Terminated in error	Terminated normally
SR2 (bit2)	Reserved	-	-
SR1 (bit1)	Reserved	-	-
SR0 (bit0)	Reserved	-	-

Write State Machine (WSM) Status (SR7)

The write state machine (WSM) status indicates the operating status of the flash memory. When power is turned on, "1" (ready) is set for it. The bit is set to "0" (busy) during an auto write or auto erase operation, but it is set back to "1" when the operation ends.

Erase Status (SR5)

The erase status reports the operating status of the auto erase operation. If an erase error occurs, it is set to "1". When the erase status is cleared, it is set to "0".

Program Status (SR4)

The program status reports the operating status of the auto write operation. If a write error occurs, it is set to "1". When the program status is cleared, it is set to "0".

Block Status After Program (SR3)

If excessive data is written (phenomenon whereby the memory cell becomes depressed which results in data not being read correctly), "1" is set for the block status after-program at the end of the page write operation. In other words, when writing ends successfully, "80₁₆" is output; when writing fails, "90₁₆" is output; and when excessive data is written, "88₁₆" is output.

If "1" is written for any of the SR5, SR4 or SR3 bits, the page program, block erase, erase all unlocked blocks and lock bit program commands are not accepted. Before executing these commands, execute the clear status register command (50₁₆) and clear the status register.

Status Register 1 (SRD1)

Status register 1 indicates the status of serial communications, results from ID checks and results from check sum comparisons. It can be read after the SRD by writing the read status register command (7016). Also, status register 1 is cleared by writing the clear status register command (5016).

Table 1.29.3 gives the definition of each status register 1 bit. "0016" is output when power is turned ON and the flag status is maintained even after the reset.

Table 1.29.3. Status register 1 (SRD1)

SRD1 bits	Status name	Definition	
		"1"	"0"
SR15 (bit7)	Boot update completed bit	Update completed	Not update
SR14 (bit6)	Reserved	-	-
SR13 (bit5)	Reserved	-	-
SR12 (bit4)	Check sum match bit	Match	Mismatch
SR11 (bit3) SR10 (bit2)	ID check completed bits	00 01 10 11	Not verified Verification mismatch Reserved Verified
SR9 (bit1)	Data receive time out	Time out	Normal operation
SR8 (bit0)	Reserved	-	-

Boot Update Completed Bit (SR15)

This flag indicates whether the control program was downloaded to the RAM or not, using the download function.

Check Sum Match Bit (SR12)

This flag indicates whether the check sum matches or not when a program, is downloaded for execution using the download function.

ID Check Completed Bits (SR11 and SR10)

These flags indicate the result of ID checks. Some commands cannot be accepted without an ID check.

Data Receive Time Out (SR9)

This flag indicates when a time out error is generated during data reception. If this flag is attached during data reception, the received data is discarded and the microcomputer returns to the command wait state.

Full Status Check

Results from executed erase and program operations can be known by running a full status check. Figure 1.29.20 shows a flowchart of the full status check and explains how to remedy errors which occur.

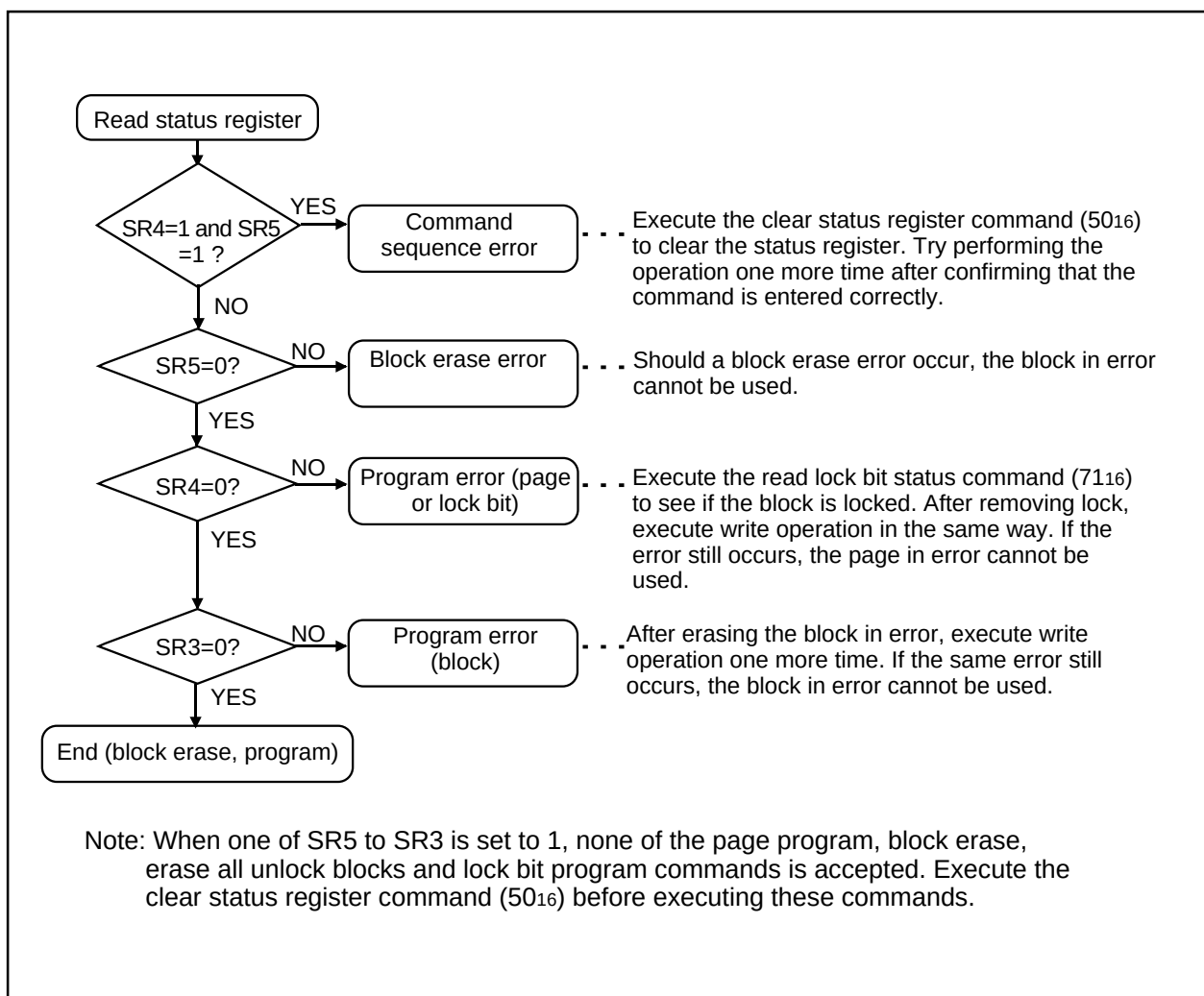


Figure 1.29.20. Full status check flowchart and remedial procedure for errors

Example Circuit Application for The Standard Serial I/O Mode 1

The below figure shows a circuit application for the standard serial I/O mode 1. Control pins will vary according to programmer, therefore see the peripheral unit manual for more information.

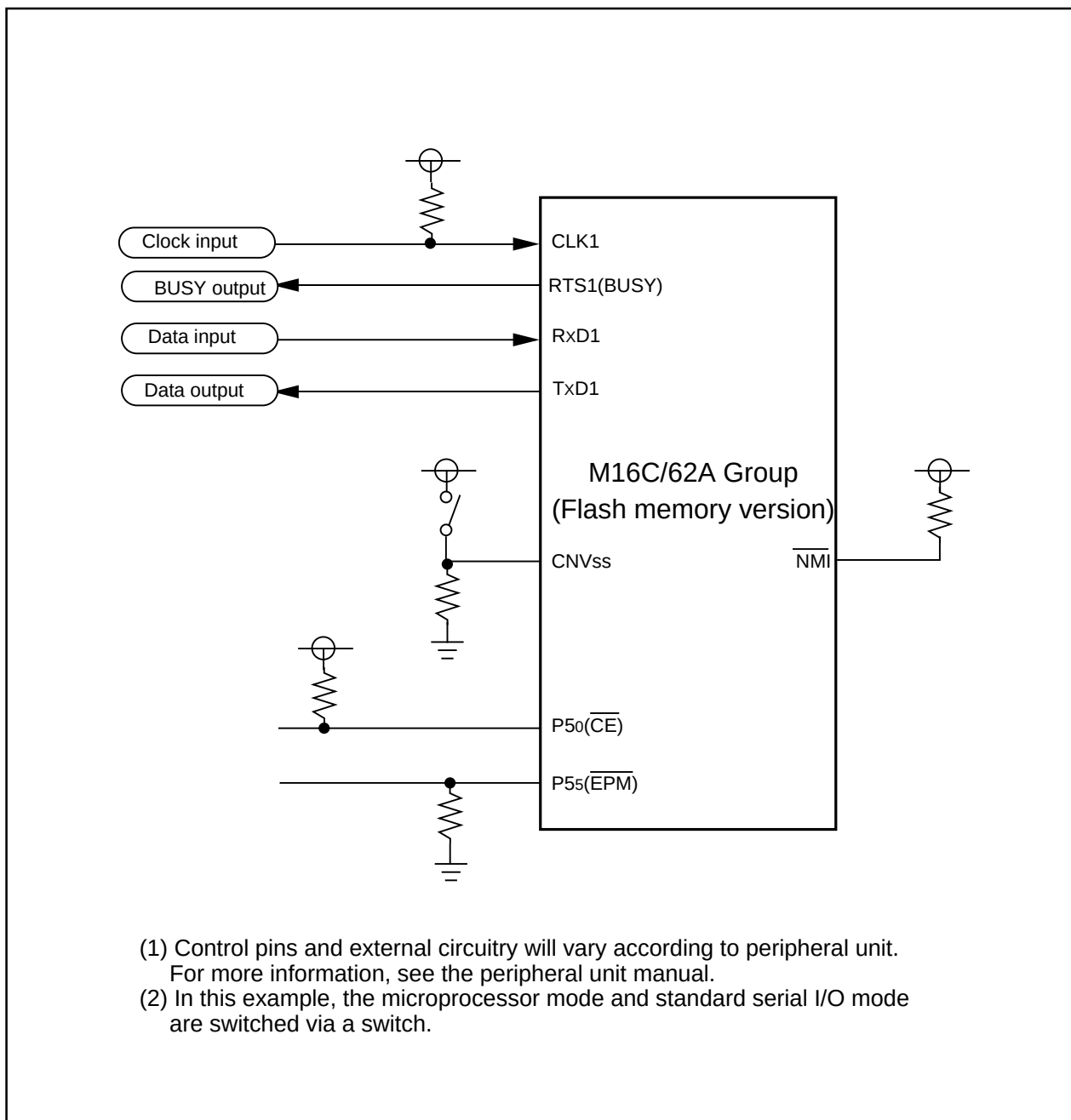


Figure 1.29.21. Example circuit application for the standard serial I/O mode 1

Overview of standard serial I/O mode 2 (clock asynchronized)

In standard serial I/O mode 2, software commands, addresses and data are input and output between the MCU and peripheral units (serial programmer, etc.) using 2-wire clock-asynchronized serial I/O (UART1). Standard serial I/O mode 2 is engaged by releasing the reset with the P65 (CLK1) pin "L" level.

The TxD1 pin is for CMOS output. Data transfer is in 8-bit units with LSB first, 1 stop bit and parity OFF. After the reset is released, connections can be established at 9,600 bps when initial communications (Figure 1.29.22) are made with a peripheral unit. However, this requires a main clock with a minimum 2 MHz input oscillation frequency. Baud rate can also be changed from 9,600 bps to 19,200, 38,400 or 57,600 bps by executing software commands. However, communication errors may occur because of the oscillation frequency of the main clock. If errors occur, change the main clock's oscillation frequency and the baud rate.

After executing commands from a peripheral unit that requires time to erase and write data, as with erase and program commands, allow a sufficient time interval or execute the read status command and check how processing ended, before executing the next command.

Data and status registers in memory can be read after transmitting software commands. Status, such as the operating state of the flash memory or whether a program or erase operation ended successfully or not, can be checked by reading the status register. Here following are explained initial communications with peripheral units, how frequency is identified and software commands.

Initial communications with peripheral units

After the reset is released, the bit rate generator is adjusted to 9,600 bps to match the oscillation frequency of the main clock, by sending the code as prescribed by the protocol for initial communications with peripheral units (Figure 1.29.22).

- (1) Transmit "B016" from a peripheral unit. If the oscillation frequency input by the main clock is 10 or 16 MHz, the MCU with internal flash memory outputs the "B016" check code. If the oscillation frequency is anything other than 10 or 16 MHz, the MCU does not output anything.
- (2) Transmit "0016" 16 times. (The MCU with internal flash memory sets the bit rate generator so that "0016" can be successfully received.)
- (3) The MCU with internal flash memory outputs the "B016" check code and initial communications end successfully *1. Initial communications must be transmitted at a speed of 9,600 bps and a transfer interval of a minimum 15 ms. Also, the baud rate at the end of initial communications is 9,600 bps.

*1. If the peripheral unit cannot receive "B016" successfully, change the oscillation frequency of the main clock.

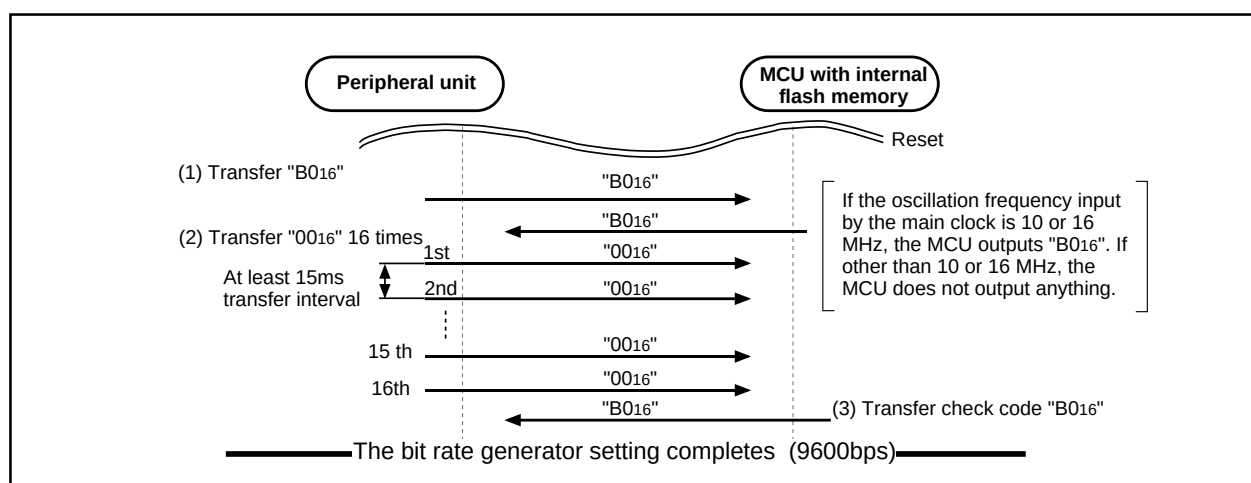


Figure 1.29.22. Peripheral unit and initial communication

How frequency is identified

When "0016" data is received 16 times from a peripheral unit at a baud rate of 9,600 bps, the value of the bit rate generator is set to match the operating frequency (2 - 16 MHz). The highest speed is taken from the first 8 transmissions and the lowest from the last 8. These values are then used to calculate the bit rate generator value for a baud rate of 9,600 bps.

Baud rate cannot be attained with some operating frequencies. Table 1.29.4 gives the operation frequency and the baud rate that can be attained for.

Table 1.29.4 Operation frequency and the baud rate

Operation frequency (MHz)	Baud rate 9,600bps	Baud rate 19,200bps	Baud rate 38,400bps	Baud rate 57,600bps
16MHz	√	√	√	√
12MHz	√	√	√	—
11MHz	√	√	√	—
10MHz	√	√	—	√
8MHz	√	√	—	√
7.3728MHz	√	√	√	√
6MHz	√	√	√	—
5MHz	√	√	—	—
4.5MHz	√	√	—	√
4.194304MHz	√	√	√	—
4MHz	√	√	—	—
3.58MHz	√	√	√	√
3MHz	√	√	√	—
2MHz	√	—	—	—

√ : Communications possible

— : Communications not possible

Appendix Standard Serial I/O Mode 2 (Flash Memory Version)

Software Commands

Table 1.29.5 lists software commands. In the standard serial I/O mode 2, erase operations, programs and reading are controlled by transferring software commands via the RxD1 pin. Standard serial I/O mode 2 adds four transmission speed commands - 9,600, 19,200, 38,400 and 57,600 bps - to the software commands of standard serial I/O mode 1. Software commands are explained here below.

Table 1.29.5. Software commands (Standard serial I/O mode 2)

	Control command	1st byte transfer	2nd byte	3rd byte	4th byte	5th byte	6th byte		When ID is not verified
1	Page read	FF ₁₆	Address (middle)	Address (high)	Data output	Data output	Data output	Data output to 259th byte	Not acceptable
2	Page program	41 ₁₆	Address (middle)	Address (high)	Data input	Data input	Data input	Data input to 259th byte	Not acceptable
3	Block erase	20 ₁₆	Address (middle)	Address (high)	D0 ₁₆				Not acceptable
4	Erase all unlocked blocks	A7 ₁₆	D0 ₁₆						Not acceptable
5	Read status register	70 ₁₆	SRD output	SRD1 output					Acceptable
6	Clear status register	50 ₁₆							Not acceptable
7	Read lock bit status	71 ₁₆	Address (middle)	Address (high)	Lock bit data output				Not acceptable
8	Lock bit program	77 ₁₆	Address (middle)	Address (high)	D0 ₁₆				Not acceptable
9	Lock bit enable	7A ₁₆							Not acceptable
10	Lock bit disable	75 ₁₆							Not acceptable
11	ID check function	F5 ₁₆	Address (low)	Address (middle)	Address (high)	ID size	ID1	To ID7	Acceptable
12	Download function	FA ₁₆	Size (low)	Size (high)	Check-sum	Data input	To required number of times		Not acceptable
13	Version data output function	FB ₁₆	Version data output	Version data output	Version data output	Version data output	Version data output	Version data output to 9th byte	Acceptable
14	Boot ROM area output function	FC ₁₆	Address (middle)	Address (high)	Data output	Data output	Data output	Data output to 259th byte	Not acceptable
15	Read check data	FD ₁₆	Check data (low)	Check data (high)					Not acceptable
16	Baud rate 9600	B0 ₁₆	B0 ₁₆						Acceptable
17	Baud rate 19200	B1 ₁₆	B1 ₁₆						Acceptable
18	Baud rate 38400	B2 ₁₆	B2 ₁₆						Acceptable
19	Baud rate 57600	B3 ₁₆	B3 ₁₆						Acceptable

Note 1: Shading indicates transfer from flash memory microcomputer to peripheral unit. All other data is transferred from the peripheral unit to the flash memory microcomputer.

Note 2: SRD refers to status register data. SRD1 refers to status register 1 data.

Note 3: All commands can be accepted when the flash memory is totally blank.

Page Read Command

This command reads the specified page (256 bytes) in the flash memory sequentially one byte at a time. Execute the page read command as explained here following.

- (1) Transfer the "FF₁₆" command code with the 1st byte.
- (2) Transfer addresses A₈ to A₁₅ and A₁₆ to A₂₃ with the 2nd and 3rd bytes respectively.
- (3) From the 4th byte onward, data (D₀–D₇) for the page (256 bytes) specified with addresses A₈ to A₂₃ will be output sequentially from the smallest address first.

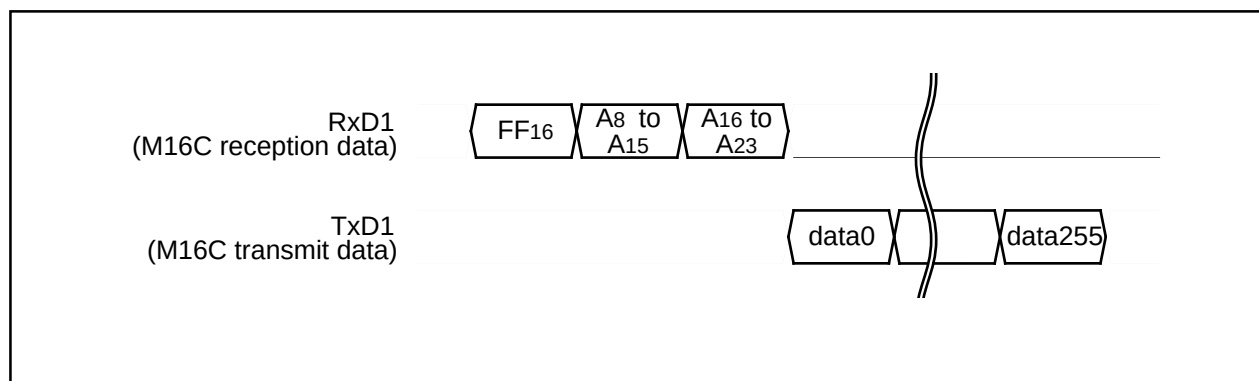


Figure 1.29.23. Timing for page read

Read Status Register Command

This command reads status information. When the "70₁₆" command code is sent with the 1st byte, the contents of the status register (SRD) specified with the 2nd byte and the contents of status register 1 (SRD1) specified with the 3rd byte are read.

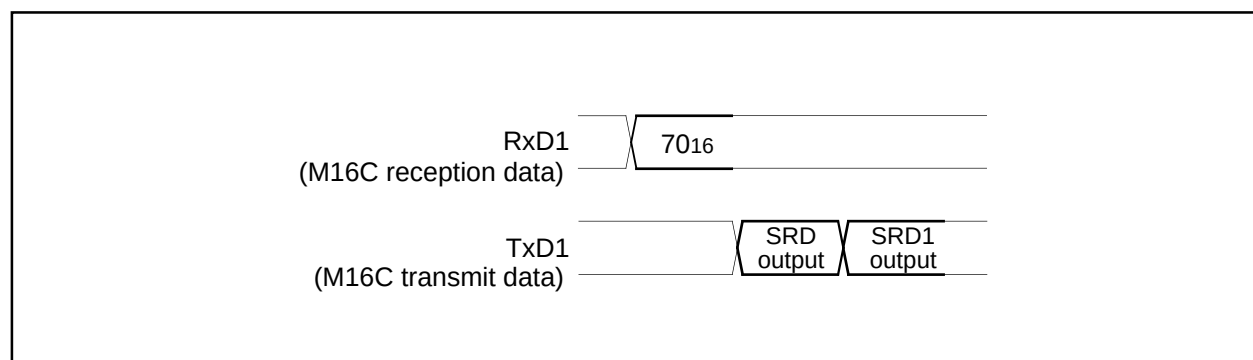


Figure 1.29.24. Timing for reading the status register

Clear Status Register Command

This command clears the bits (SR3–SR5) which are set when the status register operation ends in error. When the “50₁₆” command code is sent with the 1st byte, the aforementioned bits are cleared.

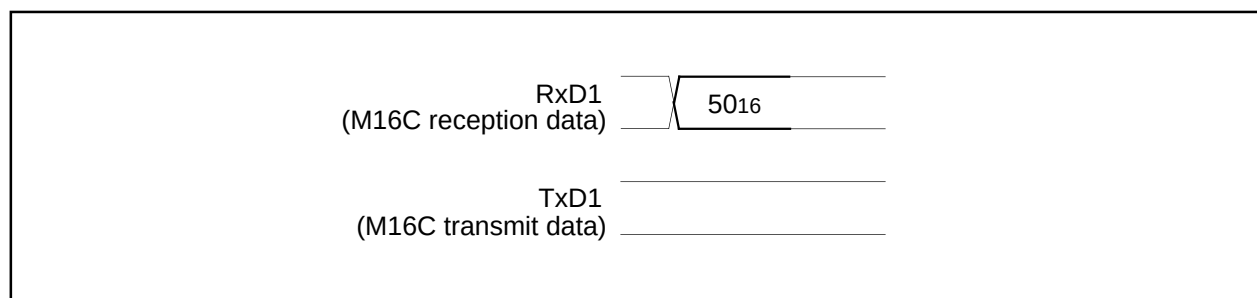


Figure 1.29.25. Timing for clearing the status register

Page Program Command

This command writes the specified page (256 bytes) in the flash memory sequentially one byte at a time. Execute the page program command as explained here following.

- (1) Transfer the “41₁₆” command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) From the 4th byte onward, as write data (D₀–D₇) for the page (256 bytes) specified with addresses A8 to A23 is input sequentially from the smallest address first, that page is automatically written.

The result of the page program can be known by reading the status register. For more information, see the section on the status register.

Each block can be write-protected with the lock bit. For more information, see the section on the data protection function. Additional writing is not allowed with already programmed pages.

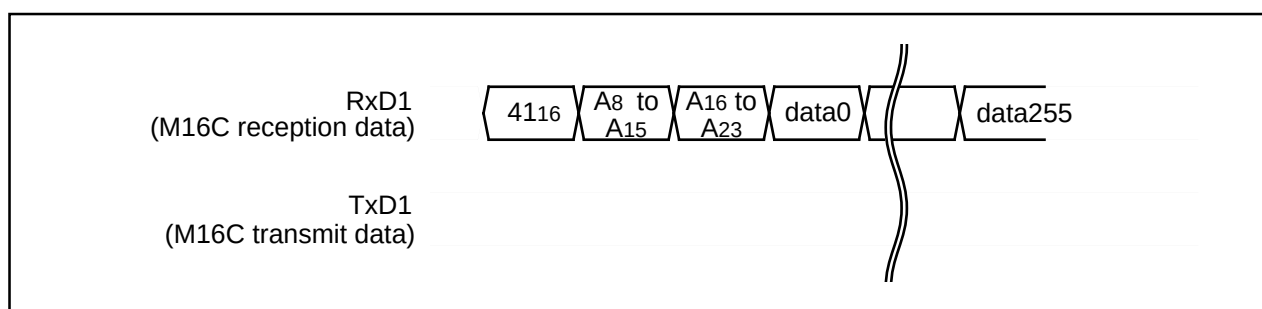


Figure 1.29.26. Timing for the page program

Block Erase Command

This command erases the data in the specified block. Execute the block erase command as explained here following.

- (1) Transfer the "20₁₆" command code with the 1st byte.
- (2) Transfer addresses A₈ to A₁₅ and A₁₆ to A₂₃ with the 2nd and 3rd bytes respectively.
- (3) Transfer the verify command code "D0₁₆" with the 4th byte. With the verify command code, the erase operation will start for the specified block in the flash memory. Write the highest address of the specified block for addresses A₈ to A₂₃.

After block erase ends, the result of the block erase operation can be known by reading the status register. For more information, see the section on the status register.

Each block can be erase-protected with the lock bit. For more information, see the section on the data protection function.

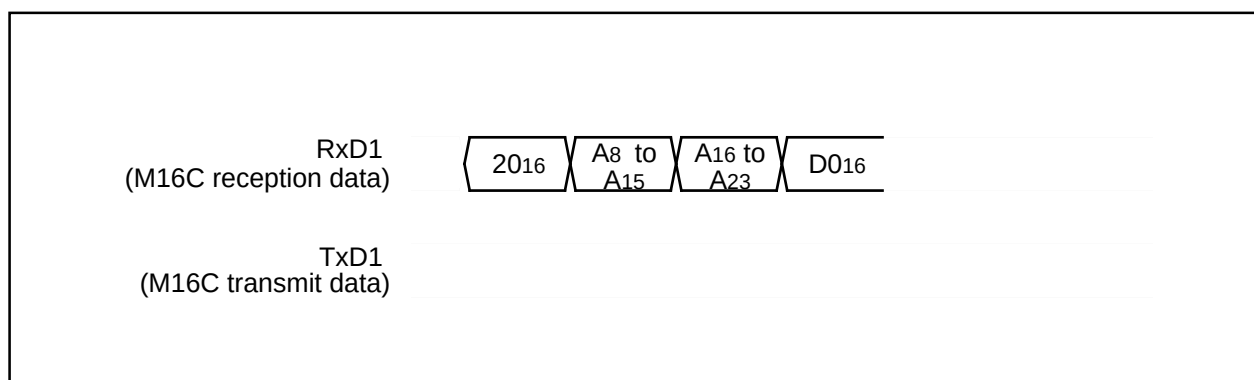


Figure 1.29.7. Timing for block erasing

Appendix Standard Serial I/O Mode 2 (Flash Memory Version)

Erase All Unlocked Blocks Command

This command erases the content of all blocks. Execute the erase all unlocked blocks command as explained here following.

- (1) Transfer the "A7₁₆" command code with the 1st byte.
- (2) Transfer the verify command code "D0₁₆" with the 2nd byte. With the verify command code, the erase operation will start and continue for all blocks in the flash memory.

The result of the erase operation can be known by reading the status register. Each block can be erase-protected with the lock bit. For more information, see the section on the data protection function.

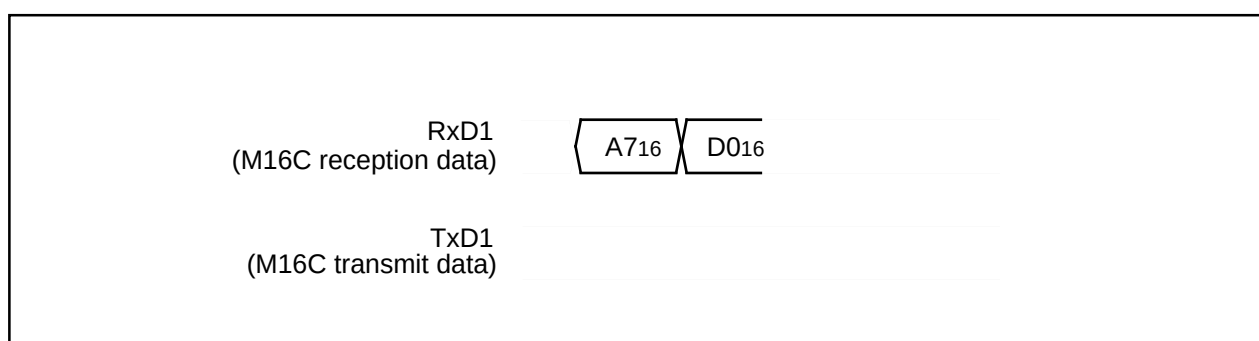


Figure 1.29.28. Timing for erasing all unlocked blocks

Lock Bit Program Command

This command writes "0" (lock) for the lock bit of the specified block. Execute the lock bit program command as explained here following.

- (1) Transfer the "77₁₆" command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) Transfer the verify command code "D0₁₆" with the 4th byte. With the verify command code, "0" is written for the lock bit of the specified block. Write the highest address of the specified block for addresses A8 to A23.

Lock bit status can be read with the read lock bit status command. For information on the lock bit function, reset procedure and so on, see the section on the data protection function.

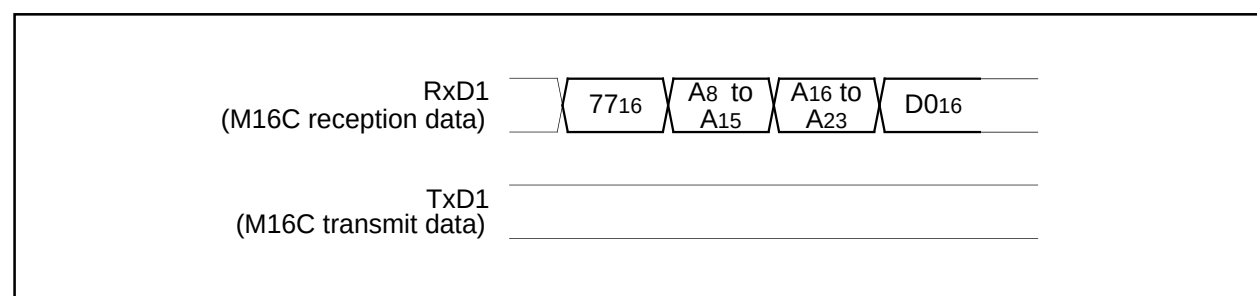


Figure 1.29.29. Timing for the lock bit program

Read Lock Bit Status Command

This command reads the lock bit status of the specified block. Execute the read lock bit status command as explained here following.

- (1) Transfer the "7116" command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) The lock bit data of the specified block is output with the 4th byte. The lock bit data is the 6th bit(D6) of the output data. Write the highest address of the specified block for addresses A8 to A23.

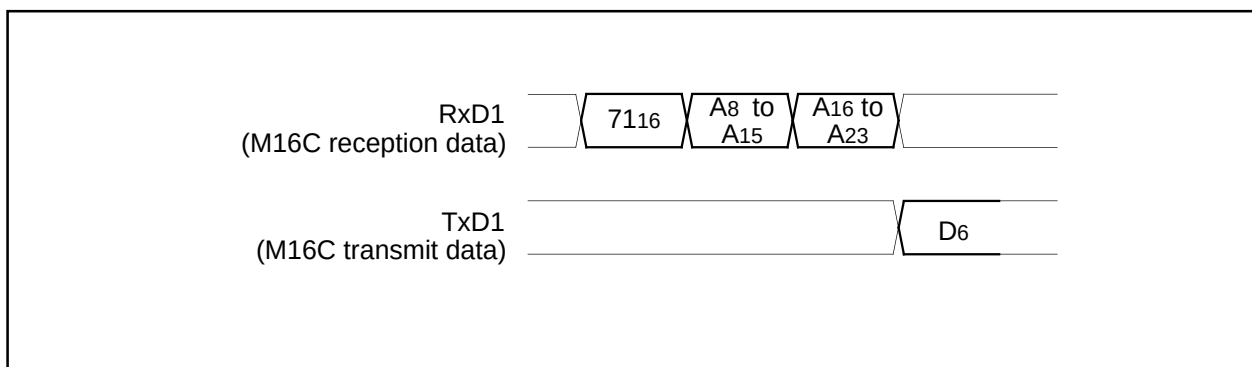


Figure 1.29.30. Timing for reading lock bit status

Lock Bit Enable Command

This command enables the lock bit in blocks whose bit was disabled with the lock bit disable command. The command code "7A16" is sent with the 1st byte of the serial transmission. This command only enables the lock bit function; it does not set the lock bit itself.

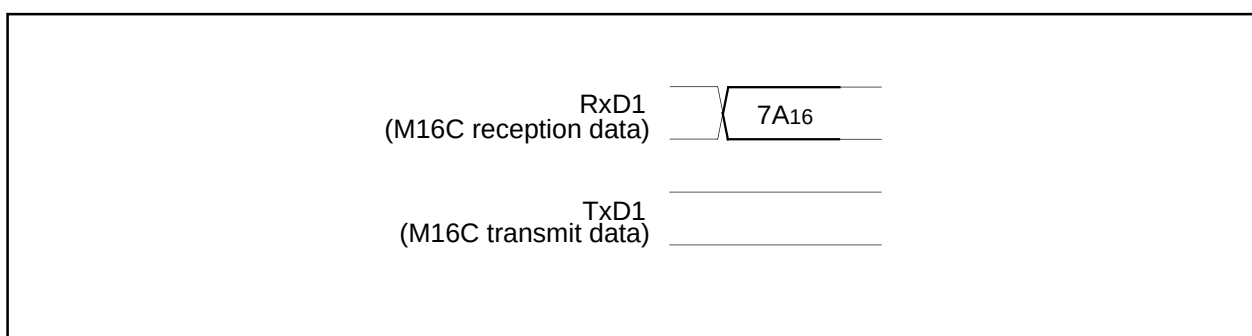


Figure 1.29.31. Timing for enabling the lock bit

Lock Bit Disable Command

This command disables the lock bit. The command code “7516” is sent with the 1st byte of the serial transmission. This command only disables the lock bit function; it does not set the lock bit itself. However, if an erase command is executed after executing the lock bit disable command, “0” (locked) lock bit data is set to “1” (unlocked) after the erase operation ends. In any case, after the reset is cancelled, the lock bit is enabled.

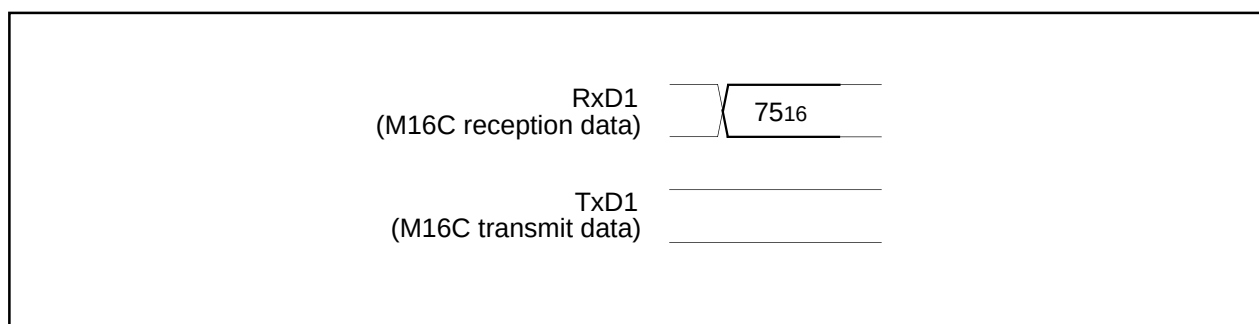


Figure 1.29.32. Timing for disabling the lock bit

Download Command

This command downloads a program to the RAM for execution. Execute the download command as explained here following.

- (1) Transfer the “FA16” command code with the 1st byte.
- (2) Transfer the program size with the 2nd and 3rd bytes.
- (3) Transfer the check sum with the 4th byte. The check sum is added to all data sent with the 5th byte onward.
- (4) The program to execute is sent with the 5th byte onward.

When all data has been transmitted, if the check sum matches, the downloaded program is executed. The size of the program will vary according to the internal RAM.

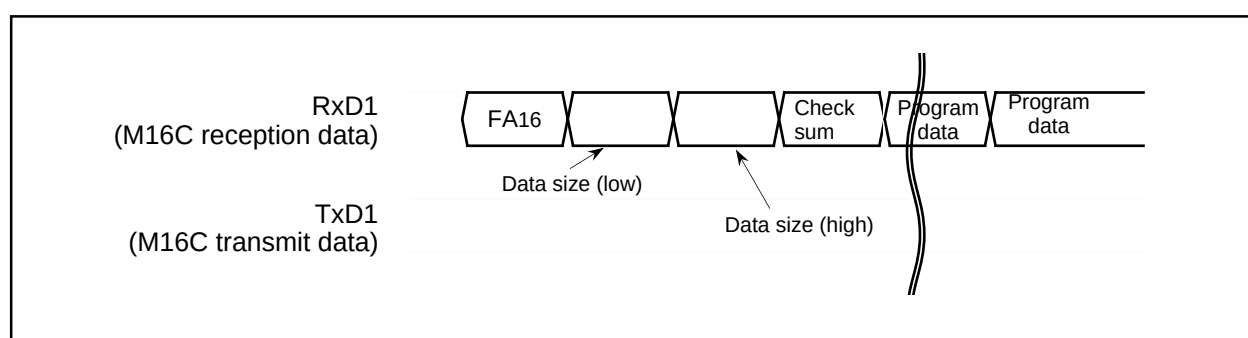


Figure 1.29.33. Timing for download

Version Information Output Command

This command outputs the version information of the control program stored in the boot area. Execute the version information output command as explained here following.

- (1) Transfer the "FB16" command code with the 1st byte.
- (2) The version information will be output from the 2nd byte onward. This data is composed of 8 ASCII code characters.

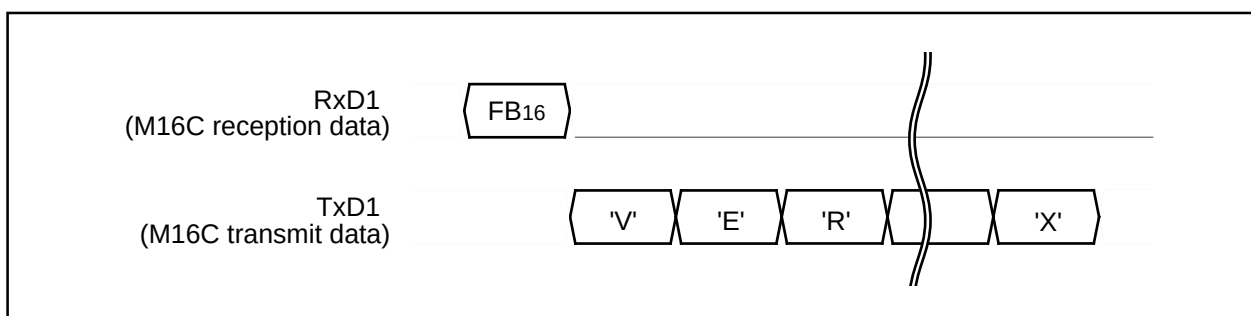


Figure 1.29.34. Timing for version information output

Boot ROM Area Output Command

This command outputs the control program stored in the boot ROM area in one page blocks (256 bytes). Execute the boot ROM area output command as explained here following.

- (1) Transfer the "FC16" command code with the 1st byte.
- (2) Transfer addresses A8 to A15 and A16 to A23 with the 2nd and 3rd bytes respectively.
- (3) From the 4th byte onward, data (D0–D7) for the page (256 bytes) specified with addresses A8 to A23 will be output sequentially from the smallest address first.

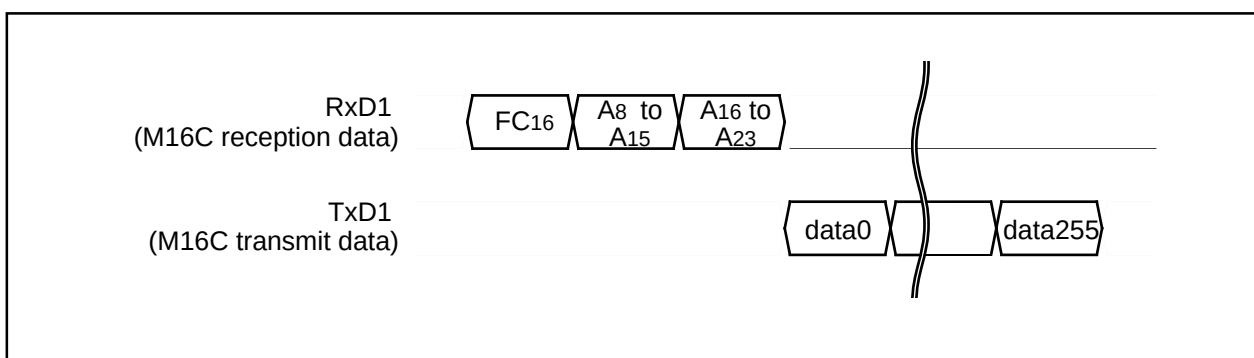


Figure 1.29.35. Timing for boot ROM area output

Appendix Standard Serial I/O Mode 2 (Flash Memory Version)

ID Check

This command checks the ID code. Execute the boot ID check command as explained here following.

- (1) Transfer the "F5₁₆" command code with the 1st byte.
- (2) Transfer addresses A0 to A7, A8 to A15 and A16 to A23 of the 1st byte of the ID code with the 2nd, 3rd and 4th bytes respectively.
- (3) Transfer the number of data sets of the ID code with the 5th byte.
- (4) The ID code is sent with the 6th byte onward, starting with the 1st byte of the code.

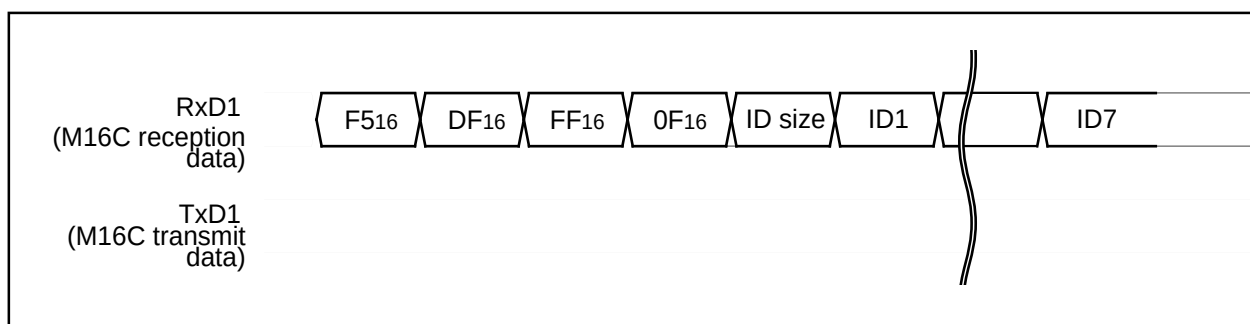


Figure 1.29.36. Timing for the ID check

ID Code

When the flash memory is not blank, the ID code sent from the peripheral units and the ID code written in the flash memory are compared to see if they match. If the codes do not match, the command sent from the peripheral units is not accepted. An ID code contains 8 bits of data. Area is, from the 1st byte, addresses 0FFFD₁₆, 0FFFE₃₁₆, 0FFFE_{B16}, 0FFFE_{F16}, 0FFFF₃₁₆, 0FFFF₇₁₆ and 0FFFF_{B16}. Write a program into the flash memory, which already has the ID code set for these addresses.

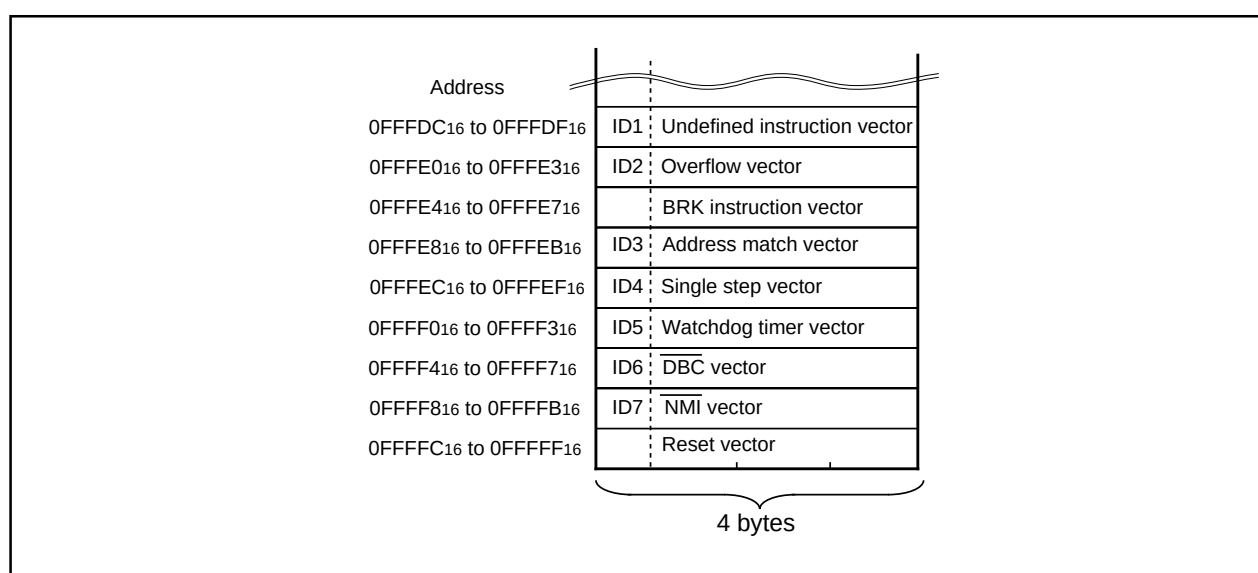


Figure 1.29.37. ID code storage addresses

Appendix Standard Serial I/O Mode 2 (Flash Memory Version)

Read Check Data

This command reads the check data that confirms that the write data, which was sent with the page program command, was successfully received.

- (1) Transfer the "FD16" command code with the 1st byte.
- (2) The check data (low) is received with the 2nd byte and the check data (high) with the 3rd.

To use this read check data command, first execute the command and then initialize the check data. Next, execute the page program command the required number of times. After that, when the read check command is executed again, the check data for all of the read data that was sent with the page program command during this time is read. The check data is the result of CRC operation of write data.

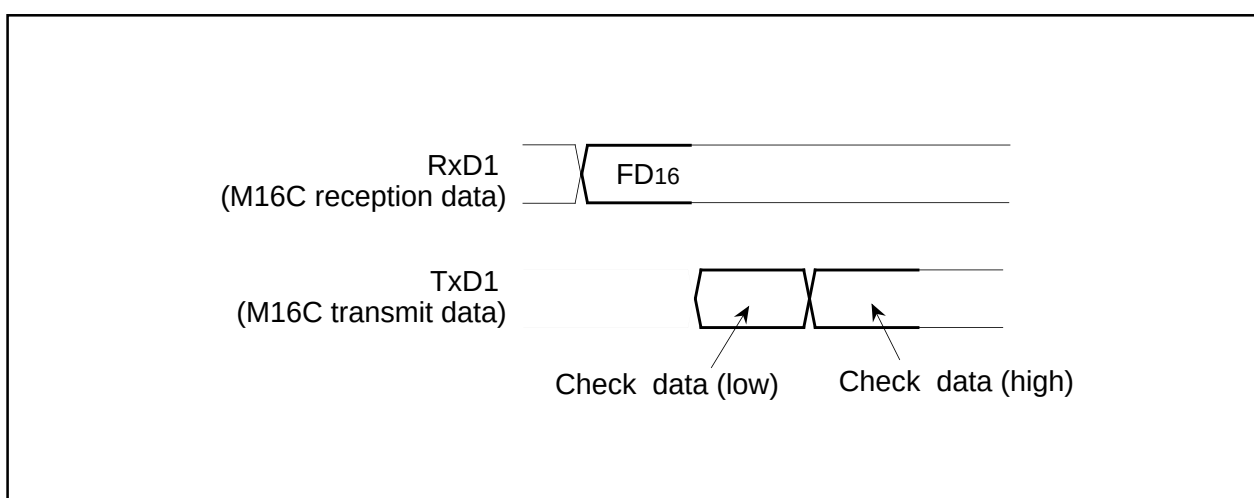


Figure 1.29.38. Timing for the read check data

Baud Rate 9600

This command changes baud rate to 9,600 bps. Execute it as follows.

- (1) Transfer the "B016" command code with the 1st byte.
- (2) After the "B016" check code is output with the 2nd byte, change the baud rate to 9,600 bps.

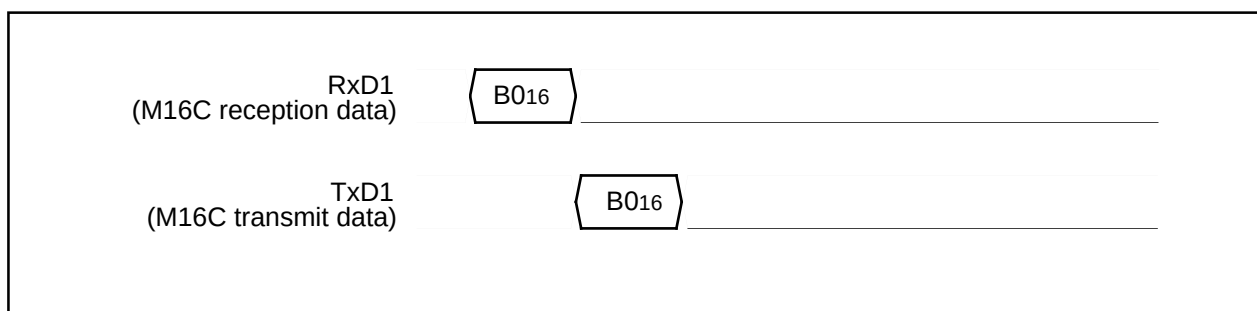


Figure 1.29.39. Timing of baud rate 9600

Baud Rate 19200

This command changes baud rate to 19,200 bps. Execute it as follows.

- (1) Transfer the "B116" command code with the 1st byte.
- (2) After the "B116" check code is output with the 2nd byte, change the baud rate to 19,200 bps.



Figure 1.29.40. Timing of baud rate 19200

Baud Rate 38400

This command changes baud rate to 38,400 bps. Execute it as follows.

- (1) Transfer the "B216" command code with the 1st byte.
- (2) After the "B216" check code is output with the 2nd byte, change the baud rate to 38,400 bps.

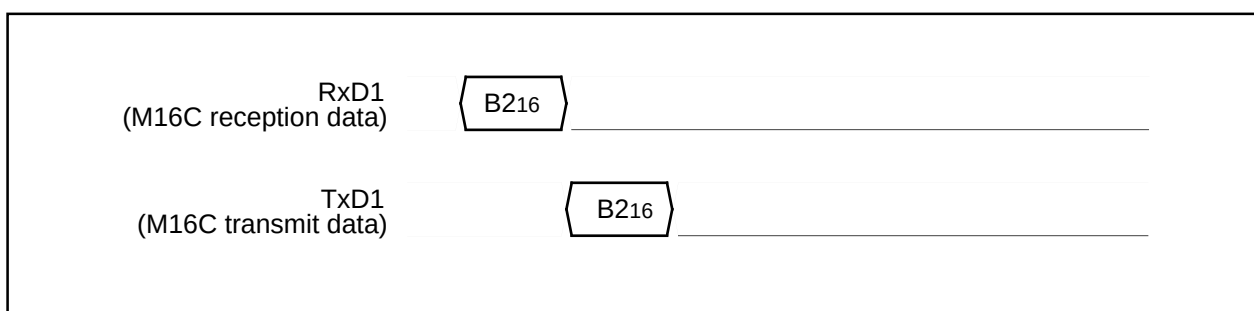


Figure 1.29.41. Timing of baud rate 38400

Baud Rate 57600

This command changes baud rate to 57,600 bps. Execute it as follows.

- (1) Transfer the "B316" command code with the 1st byte.
- (2) After the "B316" check code is output with the 2nd byte, change the baud rate to 57,600 bps.

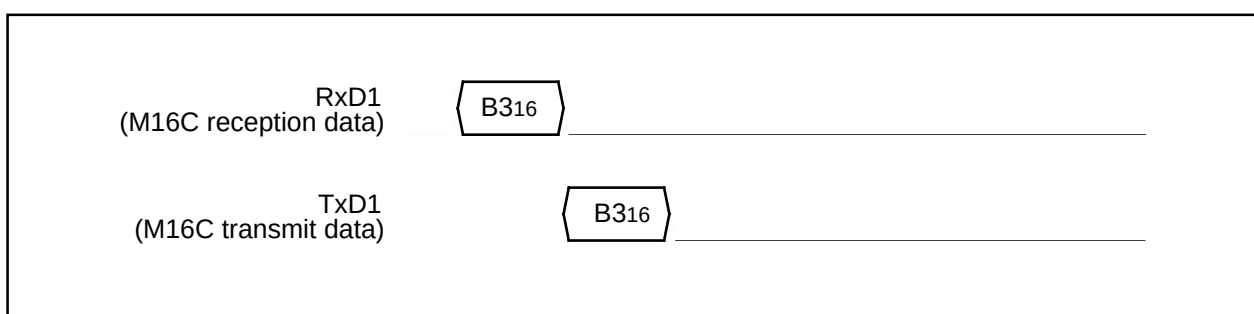


Figure 1.29.42. Timing of baud rate 57600

Example Circuit Application for The Standard Serial I/O Mode 2

The below figure shows a circuit application for the standard serial I/O mode 2.

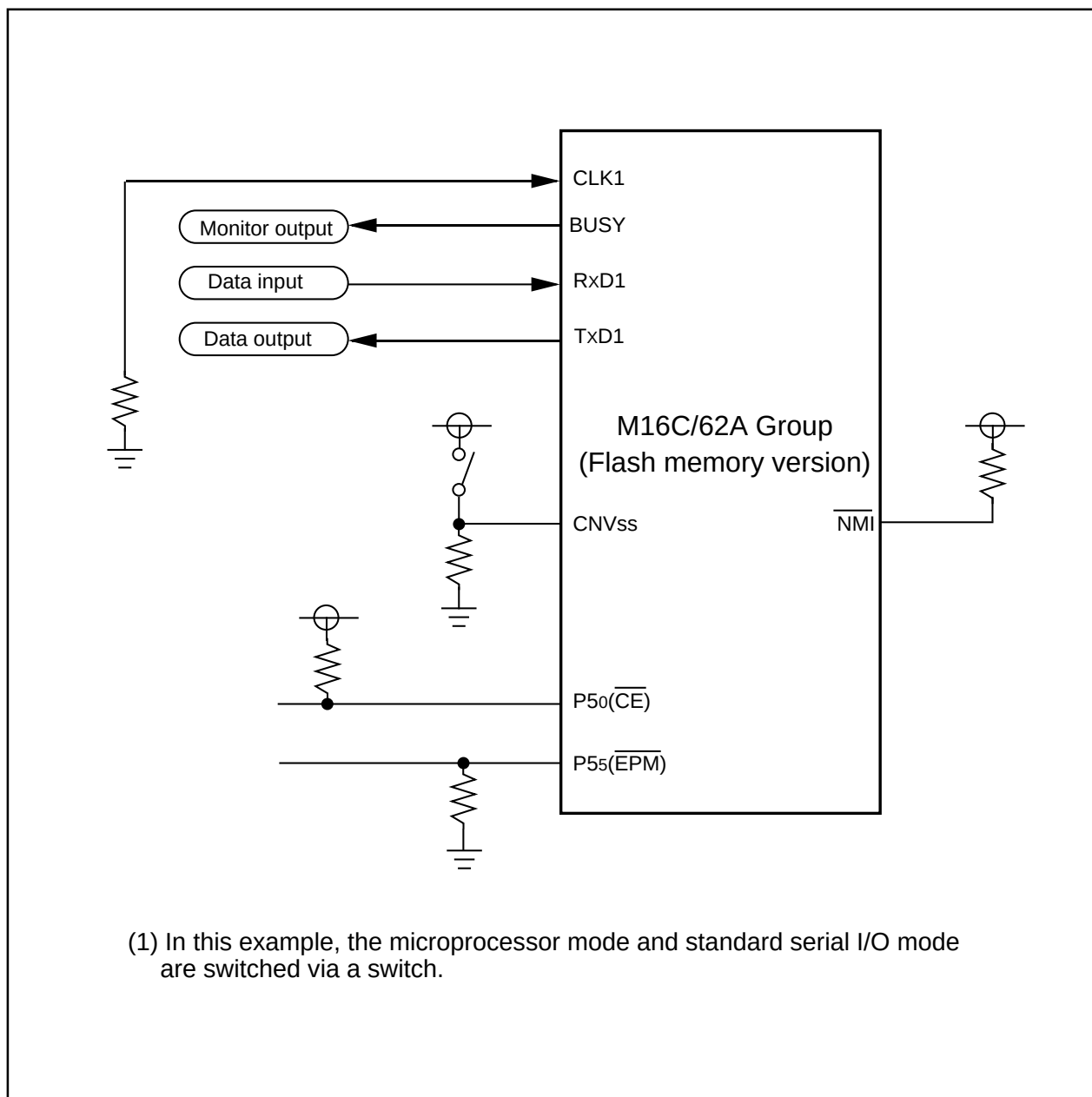


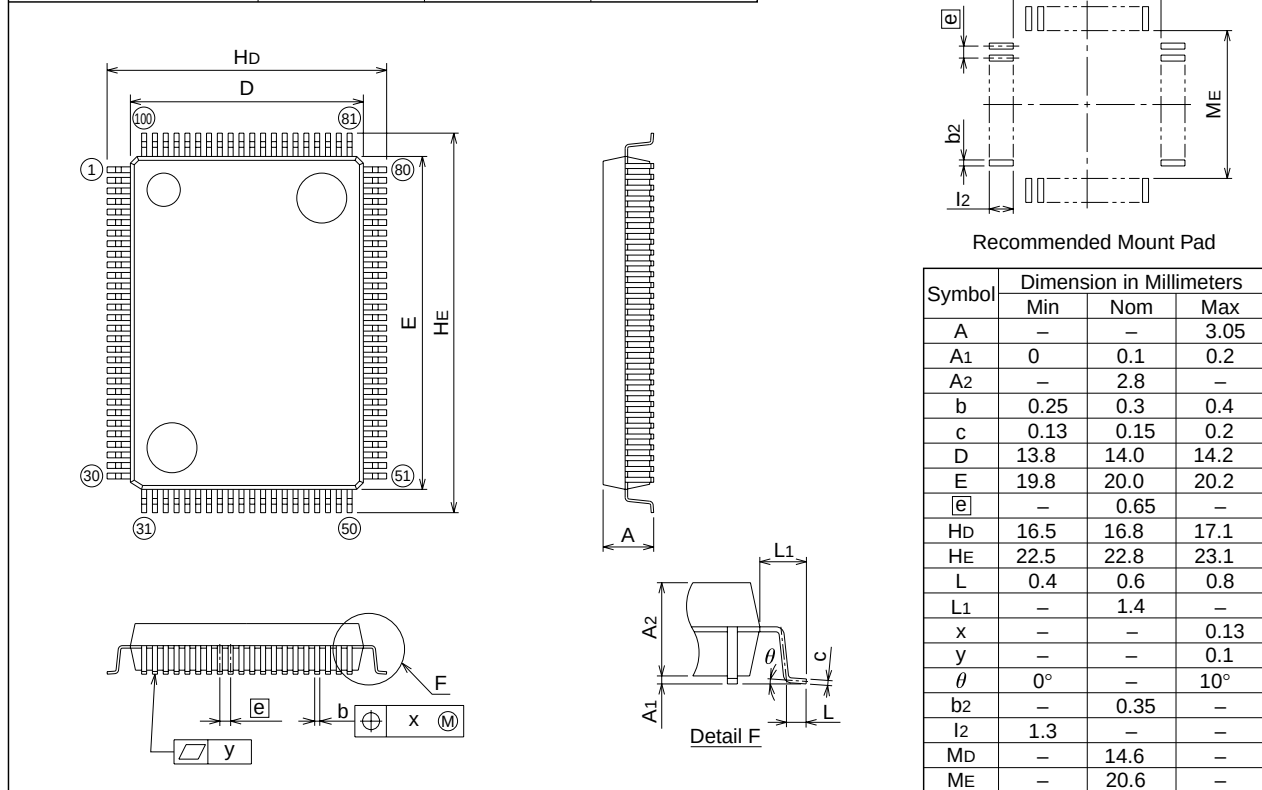
Figure 1.29.43. Example circuit application for the standard serial I/O mode 2

100P6S-A

(MMP)

Plastic 100pin 14X20mm body QFP

EIAJ Package Code	JEDEC Code	Weight(g)	Lead Material
QFP100-P-1420-0.65	—	1.58	Alloy 42

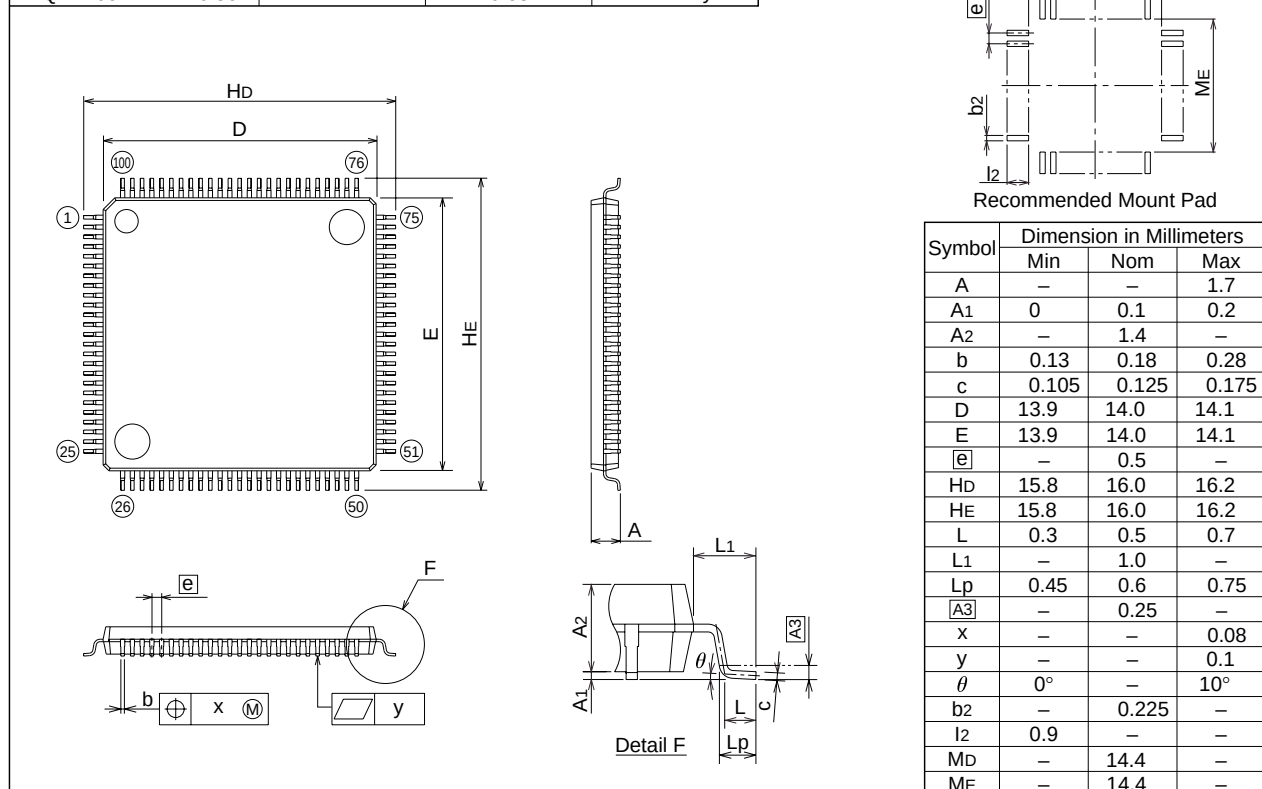


100P6Q-A

(MMP)

Plastic 100pin 14X14mm body LQFP

EIAJ Package Code	JEDEC Code	Weight(g)	Lead Material
LQFP100-P-1414-0.50	—	0.63	Cu Alloy



Differences between M16C/62A and M16C/62

Item	M16C/62A	M16C/62
Memory area	1 Mbyte fixed	Memory expansion 1.2 Mbytes mode 4 Mbytes mode
Serial I/O	No CTS/RTS separate function	CTS/RTS separate function
IIC bus mode	Analog or digital delay is selected as SDA delay	Only analog delay is selected as SDA delay
EPROM / one time PROM version	None	Have
Flash memory version	Standard serial I/O mode (clock asynchronous) is supported	Clock synchronized only

Differences in SFR between M16C/62A and M16C/62

Address	Register name	M16C/62A	M16C/62
0005 ₁₆	Processor mode register 1 (PM1)	b5,b4 Reserved bits	b5,b4 Memory area expansion bits
000B ₁₆	Data bank register (DBR)	Reserved register	Have
03B0 ₁₆	UART transmit/receive register 2 (UCON)	b6 Reserved bit	b6 CTS/RTS separation bit
0375 ₁₆	UART2 special mode register 3 (U2SMR3)	Have	None
0377 ₁₆	UART2 special mode register (U2SMR)	b7 SDA digital delay select bit	b7 Reserved bit

Description

Description

The M16C/62M group of single-chip microcomputers are built using the high-performance silicon gate CMOS process using a M16C/60 Series CPU core and are packaged in a 100-pin plastic molded QFP. These single-chip microcomputers operate using sophisticated instructions featuring a high level of instruction efficiency. With 1M bytes of address space, low voltage (2.2V to 3.6V), they are capable of executing instructions at high speed. They also feature a built-in multiplier and DMAC, making them ideal for controlling office, communications, industrial equipment, and other high-speed processing applications.

The M16C/62M group includes a wide range of products with different internal memory types and sizes and various package types.

Features

- Memory capacity ROM (See Figure 1.30.4. ROM Expansion)
RAM 10K to 20K bytes
- Shortest instruction execution time 100ns ($f(X_{IN})=10\text{MHz}$, $V_{CC}=2.7\text{V}$ to 3.6V)
142.9ns ($f(X_{IN})=7\text{MHz}$, $V_{CC}=2.2\text{V}$ to 3.6V with software one-wait)
- Supply voltage 2.7V to 3.6V ($f(X_{IN})=10\text{MHz}$, without software wait)
2.4V to 2.7V ($f(X_{IN})=7\text{MHz}$, without software wait)
2.2V to 2.4V ($f(X_{IN})=7\text{MHz}$ with software one-wait)
- Low power consumption 28.5mW ($V_{CC} = 3\text{V}$, $f(X_{IN})=10\text{MHz}$, without software wait)
- Interrupts 25 internal and 8 external interrupt sources, 4 software
interrupt sources; 7 levels (including key input interrupt)
- Multifunction 16-bit timer 5 output timers + 6 input timers
- Serial I/O 5 channels
(3 for UART or clock synchronous, 2 for clock synchronous)
- DMAC 2 channels (trigger: 24 sources)
- A-D converter 10 bits X 8 channels (Expandable up to 10 channels)
- D-A converter 8 bits X 2 channels
- CRC calculation circuit 1 circuit
- Watchdog timer 1 line
- Programmable I/O 87 lines
- Input port 1 line (P85 shared with $\overline{\text{NMI}}$ pin)
- Memory expansion Available (to a maximum of 1M bytes)
- Chip select output 4 lines
- Clock generating circuit 2 built-in clock generation circuits
(built-in feedback resistor, and external ceramic or quartz oscillator)

Applications

Audio, cameras, office equipment, communications equipment, portable equipment

Description

Pin Configuration

Figures 1.30.1 and 1.30.2 show the pin configurations (top view).

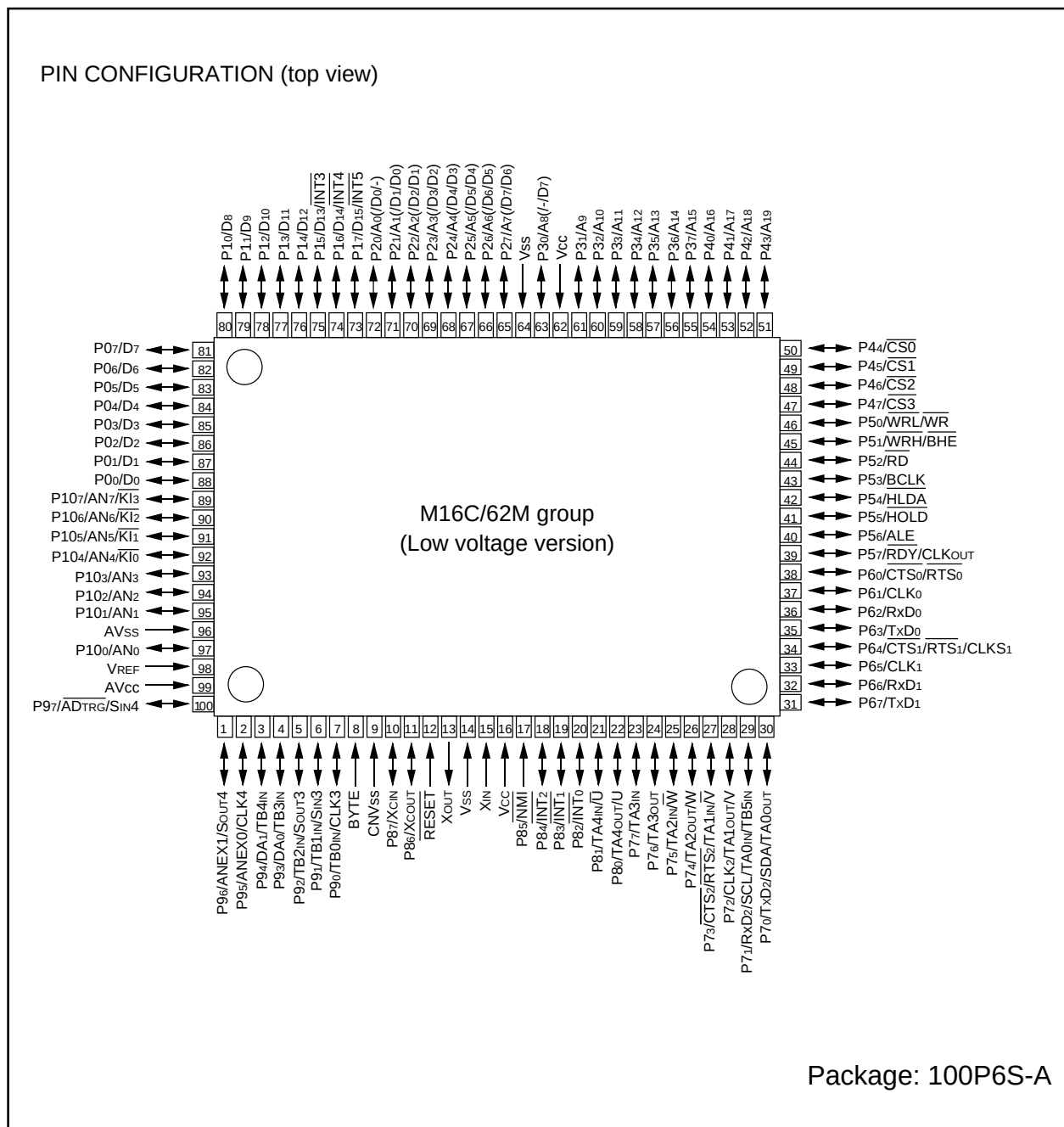


Figure 1.30.1. Pin configuration (top view)

Description

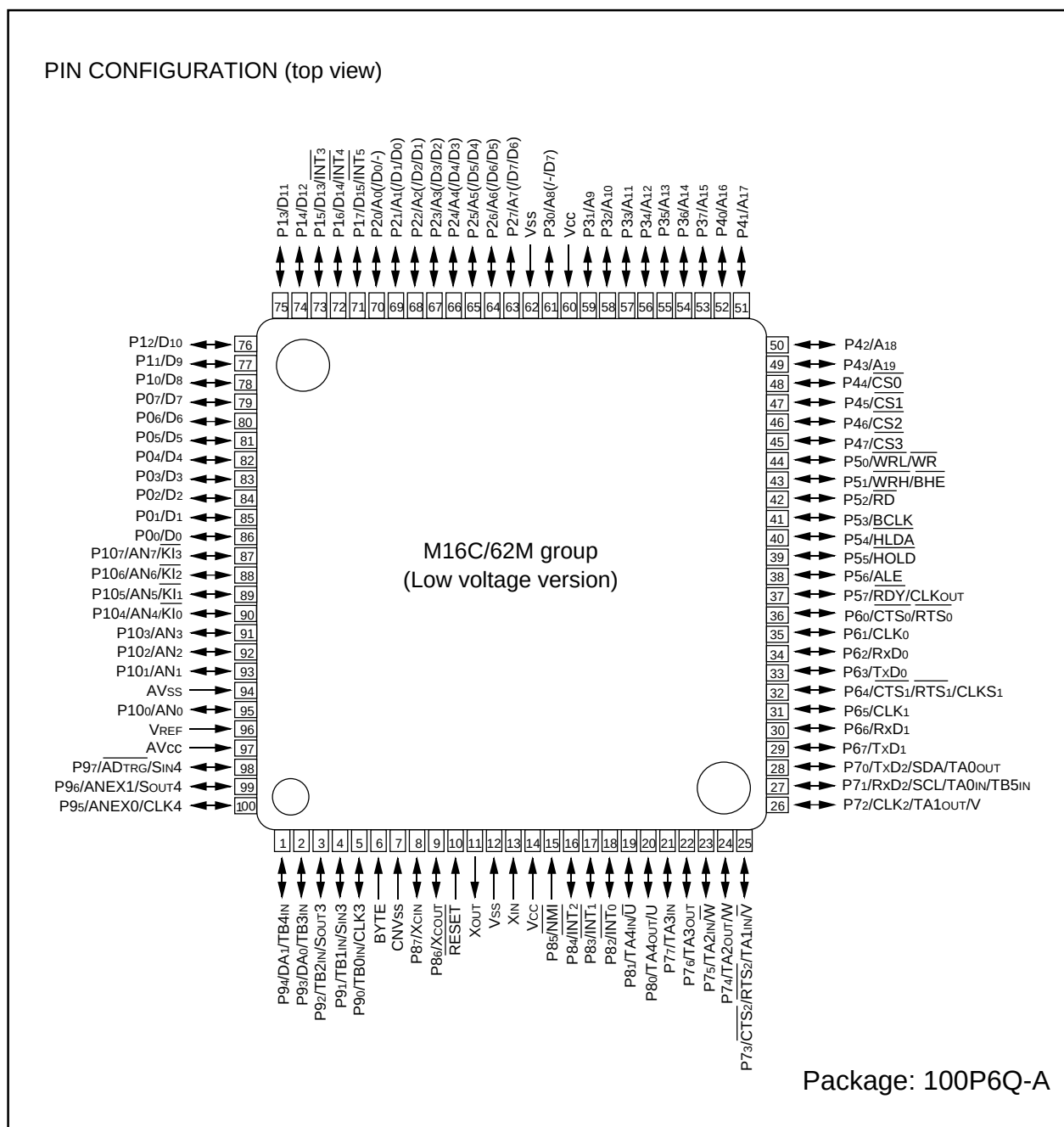


Figure 1.30.2. Pin configuration (top view)

Description

SINGLE-CHIP 16-BIT CMOS MICROCOMPUTER

Block Diagram

Figure 1.30.3 is a block diagram of the M16C/62M group.

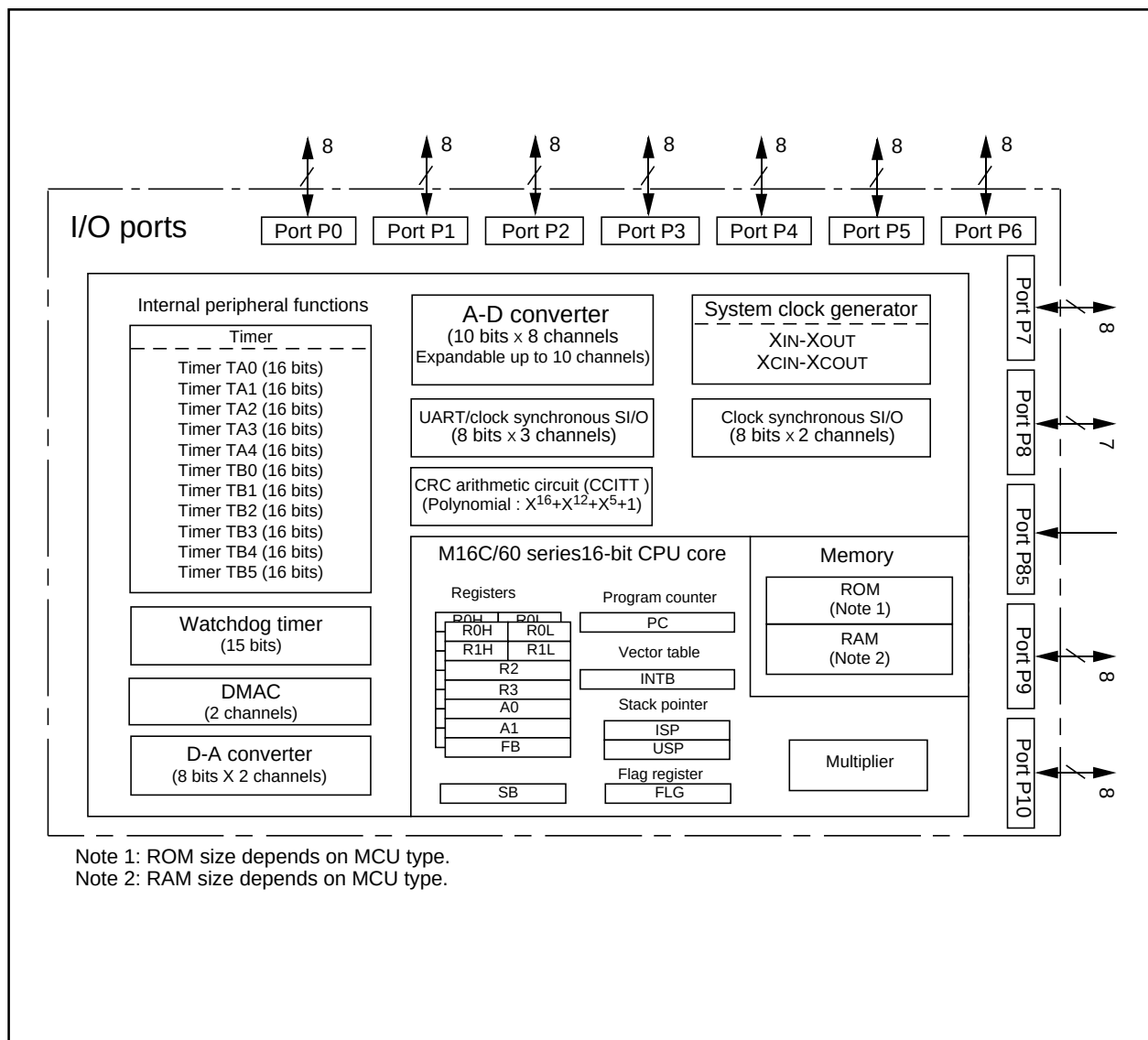


Figure 1.30.3. Block diagram of M16C/62M group

Description

Performance Outline

Table 1.30.1 is a performance outline of M16C/62M group.

Table 1.30.1. Performance outline of M16C/62M group

Item		Performance
Number of basic instructions		91 instructions
Shortest instruction execution time		100ns($f(X_{IN})=10\text{MHz}$, $V_{CC}=2.7\text{V}$ to 3.6V) 142.9ns ($f(X_{IN})=7\text{MHz}$, $V_{CC}=2.2\text{V}$ to 3.6V with software one-wait)
Memory capacity	ROM	(See the figure 1.30.4. ROM Expansion)
	RAM	10K to 20K bytes
I/O port	P0 to P10 (except P85)	8 bits x 10, 7 bits x 1
Input port	P85	1 bit x 1
Multifunction timer	TA0, TA1, TA2, TA3, TA4	16 bits x 5
	TB0, TB1, TB2, TB3, TB4, TB5	16 bits x 6
Serial I/O	UART0, UART1, UART2	(UART or clock synchronous) x 3
	SI/O3, SI/O4	(Clock synchronous) x 2
A-D converter		10 bits x (8 + 2) channels
D-A converter		8 bits x 2
DMAC		2 channels (trigger: 24 sources)
CRC calculation circuit		CRC-CCITT
Watchdog timer		15 bits x 1 (with prescaler)
Interrupt		25 internal and 8 external sources, 4 software sources, 7 levels
Clock generating circuit		2 built-in clock generation circuits (built-in feedback resistor, and external ceramic or quartz oscillator)
Supply voltage		2.7V to 3.6V ($f(X_{IN})=10\text{MHz}$, without software wait) 2.4V to 2.7V ($f(X_{IN})=7\text{MHz}$, without software wait) 2.2V to 2.4V ($f(X_{IN})=7\text{MHz}$ with software one-wait)
Power consumption		28.5mW ($f(X_{IN})=10\text{MHz}$, $V_{CC}=3\text{V}$ without software wait)
I/O characteristics	I/O withstand voltage	3V
	Output current	1mA
Memory expansion		Available (to a maximum of 1M bytes)
Device configuration		CMOS high performance silicon gate
Package		100-pin plastic mold QFP

Description

SINGLE-CHIP 16-BIT CMOS MICROCOMPUTER

Mitsubishi plans to release the following products in the M16C/62M group:

(1) Support for mask ROM version and Flash memory version

(2) ROM capacity

(3) Package

100P6S-A : Plastic molded QFP (mask ROM and flash memory versions)

100P6Q-A : Plastic molded QFP (mask ROM and flash memory versions)

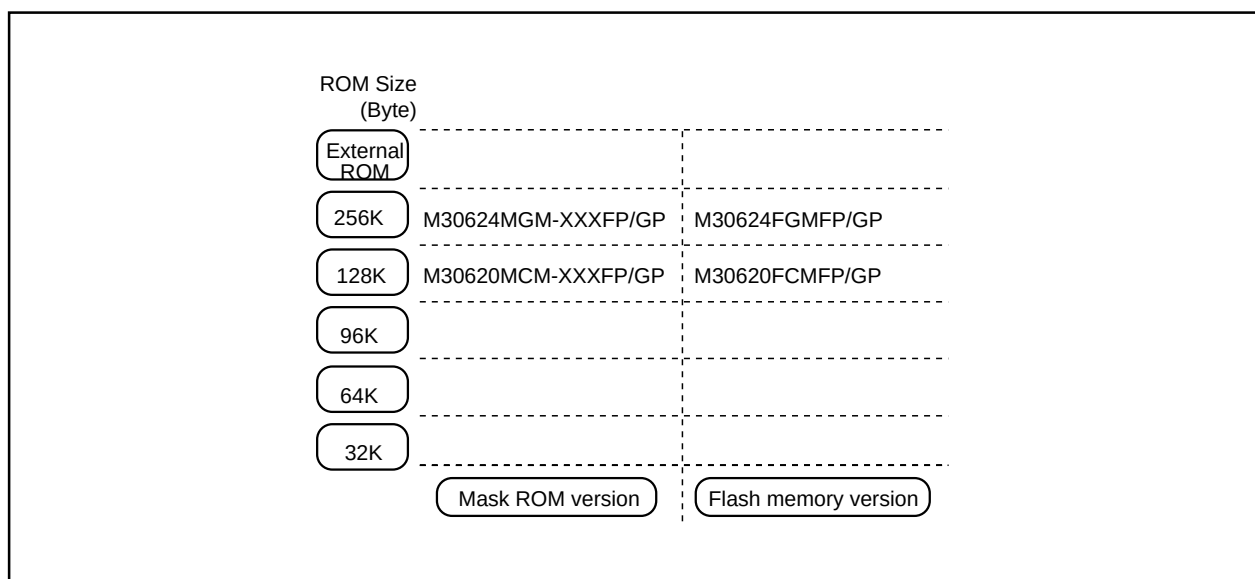


Figure 1.30.4. ROM expansion

The M16C/62M group products currently supported are listed in Table 1.30.2.

Table 1.30.2. M16C/62M group

June, 2001

Type No	ROM capacity	RAM capacity	Package type	Remarks
M30620MCM-XXXFP	128K byte	10K byte	100P6S-A	mask ROM version
M30620MCM-XXXGP			100P6Q-A	
M30624MGM-XXXFP	256K byte	20K byte	100P6S-A	
M30624MGM-XXXGP			100P6Q-A	
M30620FCMFP	128K byte	10K byte	100P6S-A	Flash memory 3V version
M30620FCMGP			100P6Q-A	
M30624FGMFP	256K byte	20K byte	100P6S-A	
M30624FGMGP			100P6Q-A	

Description

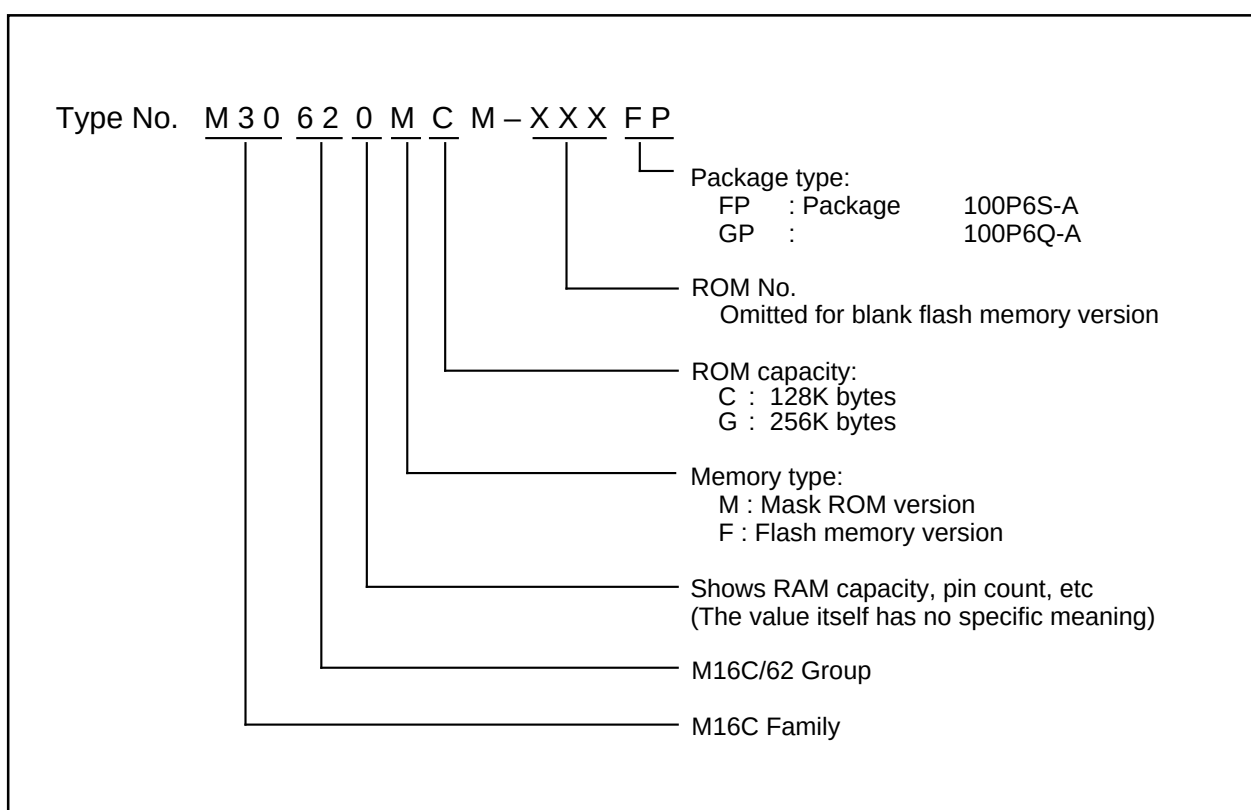


Figure 1.30.5. Type No., memory size, and package

Electrical characteristics

Table 1.31.1. Absolute maximum ratings

Symbol	Parameter		Condition	Rated value	Unit
V _{cc}	Supply voltage		V _{cc} =AV _{cc}	- 0.3 to 4.6	V
AV _{cc}	Analog supply voltage		V _{cc} =AV _{cc}	- 0.3 to 4.6	V
V _i	Input voltage	RESET, CNV _{ss} , BYTE, 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 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇ , V _{REF} , X _{IN}		- 0.3 to V _{cc} + 0.3	V
		P7 ₀ , P7 ₁		- 0.3 to 4.6	V
V _o	Output voltage	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 , X _{OUT}		- 0.3 to V _{cc} + 0.3	V
		P7 ₀ , P7 ₁		- 0.3 to 4.6	V
P _d	Power dissipation		T _{opr} =25 °C	300	mW
T _{opr}	Operating ambient temperature			- 20 to 85 / -40 to 85 (Note)	°C
T _{stg}	Storage temperature			- 65 to 150	°C

Note : Specify a product of -40°C to 85°C to use it.

Electrical characteristics

Table 1.31.2. Recommended operating conditions (referenced to $V_{CC} = 2.2V$ to $3.6V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (Note 3) unless otherwise specified)

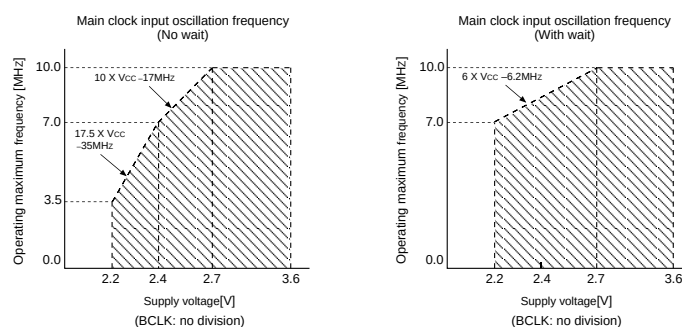
Symbol	Parameter		Standard			Unit	
			Min.	Typ.	Max.		
V _{CC}	Supply voltage		2.2	3.0	3.6	V	
AV _{CC}	Analog supply voltage			V _{CC}		V	
V _{SS}	Supply voltage			0		V	
AV _{SS}	Analog supply voltage			0		V	
V _{IH}	HIGH input voltage	P31 to P37, P40 to P47, P50 to P57, P60 to P67, P72 to P77, P80 to P87, P90 to P97, P100 to P107, X _{IN} , RESET, CNV _{SS} , BYTE	0.8V _{CC}		V _{CC}	V	
		P70, P71	0.8V _{CC}		4.6	V	
		P00 to P07, P10 to P17, P20 to P27, P30 (during single-chip mode)	0.8V _{CC}		V _{CC}	V	
		P00 to P07, P10 to P17, P20 to P27, P30 (data input function during memory expansion and microprocessor modes)	0.5V _{CC}		V _{CC}	V	
V _{IL}	LOW input voltage	P31 to P37, P40 to P47, P50 to P57, P60 to P67, P70 to P77, P80 to P87, P90 to P97, P100 to P107, X _{IN} , RESET, CNV _{SS} , BYTE	0		0.2V _{CC}	V	
		P00 to P07, P10 to P17, P20 to P27, P30 (during single-chip mode)	0		0.2V _{CC}	V	
		P00 to P07, P10 to P17, P20 to P27, P30 (data input function during memory expansion and microprocessor modes)	0		0.16V _{CC}	V	
I _{OH} (peak)	HIGH peak output current	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P47, P50 to P57, P60 to P67, P72 to P77, P80 to P84, P86, P87, P90 to P97, P100 to P107			- 10.0	mA	
I _{OH} (avg)	HIGH average output current	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P47, P50 to P57, P60 to P67, P72 to P77, P80 to P84, P86, P87, P90 to P97, P100 to P107			- 5.0	mA	
I _{OL} (peak)	LOW peak output current	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P47, P50 to P57, P60 to P67, P70 to P77, P80 to P84, P86, P87, P90 to P97, P100 to P107			10.0	mA	
I _{OL} (avg)	LOW average output current	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P47, P50 to P57, P60 to P67, P70 to P77, P80 to P84, P86, P87, P90 to P97, P100 to P107			5.0	mA	
f (X _{IN})	Main clock input oscillation frequency	No wait	V _{CC} =2.7V to 3.6V	0		10	MHz
			V _{CC} =2.4V to 2.7V	0		10 X V _{CC} - 17	MHz
			V _{CC} =2.2V to 2.4V	0		17.5 X V _{CC} - 35	MHz
		with wait	V _{CC} =2.7V to 3.6V	0		10	MHz
			V _{CC} =2.2V to 2.7V	0		6 X V _{CC} - 6.2	MHz
f (X _{CIN})	Subclock oscillation frequency			32.768	50	kHz	

Note 1: The mean output current is the mean value within 100ms.

Note 2: The total $I_{OL} (peak)$ for ports P0, P1, P2, P86, P87, P9, and P10 must be 80mA max. The total $I_{OH} (peak)$ for ports P0, P1, P2, P86, P87, P9, and P10 must be 80mA max. The total $I_{OL} (peak)$ for ports P3, P4, P5, P6, P7, and P80 to P84 must be 80mA max. The total $I_{OH} (peak)$ for ports P3, P4, P5, P6, P72 to P77, and P80 to P84 must be 80mA max.

Note 3: Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Note 4: Relationship between main clock oscillation frequency and supply voltage.



Flash memory version program voltage and read operation voltage characteristics

Flash program voltage	Flash read operation voltage
$V_{CC}=2.7V$ to $3.6V$	$V_{CC}=2.4V$ to $3.6V$
$V_{CC}=2.7V$ to $3.4V$	$V_{CC}=2.2V$ to $2.4V$

Note 5: Execute case without wait, program / erase of flash memory by $V_{CC}=2.7V$ to $3.6V$ and $f(BCLK) \leq 6.25$ MHz. Execute case with wait, program / erase of flash memory by $V_{CC}=2.7V$ to $3.6V$ and $f(BCLK) \leq 10.0$ MHz.

Electrical characteristics

Table 1.31.3. Electrical characteristics (referenced to $V_{CC} = 2.7V$ to $3.6V$, $V_{SS} = 0V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (Note 1), $f(X_{IN}) = 10MHz$ without wait unless otherwise specified)

Symbol	Parameter		Measuring condition	Standard			Unit	
				Min	Typ.	Max.		
V _{OH}	HIGH output voltage	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	I _{OH} =−1mA	2.5			V	
V _{OH}	HIGH output voltage	X _{OUT}	HIGHPOWER	I _{OH} =−0.1mA	2.5		V	
			LOWPOWER	I _{OH} =−50μA	2.5			
	HIGH output voltage	X _{COUT}	HIGHPOWER	With no load applied		3.0	V	
			LOWPOWER	With no load applied		1.6		
V _{OL}	LOW output voltage	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 ₄ , P8 ₆ ,P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	I _{OL} =1mA			0.5	V	
V _{OL}	LOW output voltage	X _{OUT}	HIGHPOWER	I _{OL} =0.1mA		0.5	V	
			LOWPOWER	I _{OL} =50μA		0.5		
	LOW output voltage	X _{COUT}	HIGHPOWER	With no load applied		0	V	
			LOWPOWER	With no load applied		0		
V _{T+} −V _{T−}	Hysteresis	HOLD, RDY, TA0 _{IN} to TA4 _{IN} , TB0 _{IN} to TB5 _{IN} , INT ₀ to INT ₅ , NMI, ADTRG, CTS ₀ to CTS ₂ , SCL, SDA, CLK ₀ to CLK ₄ , TA2 _{OUT} to TA4 _{OUT} , KI ₀ to KI ₃ , RxD ₀ to RxD ₂ , S _{IN3} , S _{IN4}		0.2		0.8	V	
V _{T+} −V _{T−}	Hysteresis	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 , X _{IN} , RESET, CNVss, BYTE	V _I =3V			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 , X _{IN} , RESET, CNVss, BYTE	V _I =0V			−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 =0V	20	75	330	kΩ	
R _{fXIN}	Feedback resistance	X _{IN}			3.0		MΩ	
R _{fXCIN}	Feedback resistance	X _{CIN}			10.0		MΩ	
V _{RAM}	RAM retention voltage		When clock is stopped	2.0			V	
I _{CC}	Power supply current	In single-chip mode, the output pins are open and other pins are Vss	Mask ROM version	f(X _{IN})=10MHz Square wave, no division		9.5	21.25	mA
			Flash memory 3V version	f(X _{IN})=10MHz Square wave, no division		12.0	21.25	mA
			Mask ROM version, flash memory 3V version	f(X _{CIN})=32kHz Square wave		45.0		μA
			Flash memory 3V version program	f(X _{IN})=10MHz Square wave, division by 2		14.0		mA
			Flash memory 3V version erase	f(X _{IN})=10MHz Square wave, division by 2		17.0		mA
			Mask ROM version, flash memory 3V version	f(X _{CIN})=32kHz When a WAIT instruction is executed. Oscillation capacity High (Note 2)		2.8		μA
				f(X _{CIN})=32kHz When a WAIT instruction is executed. Oscillation capacity Low (Note 2)		0.9		μA
			When clock is stopped T _{opr} =25°C				1.0	μA
			When clock is stopped T _{opr} =85°C				20.0	

Note 1: Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Note 2: With one timer operated using fc32.

Electrical characteristics

Table 1.31.4. A-D conversion characteristics (referenced to $V_{CC} = AV_{CC} = V_{REF} = 2.4V$ to $3.6V$, $V_{SS} = AV_{SS} = 0V$, at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (Note 2), $f(X_{IN})=10MHz$ unless otherwise specified)

Symbol	Parameter		Measuring condition	Standard			Unit
				Min.	Typ.	Max	
—	Resolution		$V_{REF} = V_{CC}$			10	Bits
—	Absolute accuracy	Sample & hold function not available (8 bit)	$V_{REF} = V_{CC} = 3V$, $f_{AD} = f_{AD}/2$			± 2	LSB
R_{LADDER}	Ladder resistance		$V_{REF} = V_{CC}$	10		40	k Ω
t_{CONV}	Conversion time(8bit)			9.8			μs
V_{REF}	Reference voltage			2.4		V_{CC}	V
V_{IA}	Analog input voltage			0		V_{REF}	V

Note 1: Connect AV_{CC} pin to V_{CC} pin and apply the same electric potential.

Note 2: Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Table 1.31.5. D-A conversion characteristics (referenced to $V_{CC} = 2.4V$ to $3.6V$, $V_{SS} = AV_{SS} = 0V$, $V_{REF}=3V$, at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (Note 2), $f(X_{IN})=10MHz$ unless otherwise specified)

Symbol	Parameter	Measuring condition	Standard			Unit
			Min.	Typ.	Max	
—	Resolution				8	Bits
—	Absolute accuracy				1.0	%
t_{su}	Setup time				3	μs
R_o	Output resistance		4	10	20	k Ω
I_{VREF}	Reference power supply input current	(Note1)			1.0	mA

Note 1: This applies when using one D-A converter, with the D-A register for the unused D-A converter set to "0016".
The A-D converter's ladder resistance is not included.

Also, when D-A register contents are not "0016", the current I_{VREF} always flows even though V_{ref} may have been set to be "unconnected" by the A-D control register.

Note 2: Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Table 1.31.6. Flash memory version electrical characteristics

(referenced to $V_{CC} = 2.7V$ to $3.6V$, at $T_{opr} = 0^{\circ}C$ to $60^{\circ}C$ unless otherwise specified)

Parameter	Standard			Unit
	Min.	Typ.	Max	
Page program time		6	120	ms
Block erase time		50	600	ms
Erase all unlocked blocks time		50 X n (Note)	600 X n (Note)	ms
Lock bit program time		6	120	ms

Note : n denotes the number of block erases.

Table 1.31.7. Flash memory version program voltage and read operation voltage characteristics
($T_{opr} = 0^{\circ}C$ to $60^{\circ}C$)

Flash program voltage	Flash read operation voltage
$V_{CC}=2.7V$ to $3.6V$	$V_{CC}=2.4V$ to $3.6V$
$V_{CC}=2.7V$ to $3.4V$	$V_{CC}=2.2V$ to $2.4V$

Timing

Timing requirements

(referenced to $V_{CC} = 3V$, $V_{SS} = 0V$, at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (*) unless otherwise specified)* : Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Table 1.31.8. External clock input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t_c	External clock input cycle time	100		ns
$t_{w(H)}$	External clock input HIGH pulse width	40		ns
$t_{w(L)}$	External clock input LOW pulse width	40		ns
t_r	External clock rise time		18	ns
t_f	External clock fall time		18	ns

Table 1.31.9. Memory expansion and microprocessor modes

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{ac1(RD-DB)}$	Data input access time (no wait)		(Note)	ns
$t_{ac2(RD-DB)}$	Data input access time (with wait)		(Note)	ns
$t_{ac3(RD-DB)}$	Data input access time (when accessing multiplex bus area)		(Note)	ns
$t_{su(DB-RD)}$	Data input setup time	80		ns
$t_{su(RDY-BCLK)}$	RDY input setup time	60		ns
$t_{su(HOLD-BCLK)}$	HOLD input setup time	80		ns
$t_h(RD-DB)$	Data input hold time	0		ns
$t_h(BCLK-RDY)$	RDY input hold time	0		ns
$t_h(BCLK-HOLD)$	HOLD input hold time	0		ns
$t_d(BCLK-HLDA)$	HLDA output delay time		100	ns

Note: Calculated according to the BCLK frequency as follows:

$$t_{ac1(RD-DB)} = \frac{10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

$$t_{ac2(RD-DB)} = \frac{3 \times 10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

$$t_{ac3(RD-DB)} = \frac{3 \times 10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

Timing

Timing requirements

(referenced to $V_{CC} = 3V$, $V_{SS} = 0V$, at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (*) unless otherwise specified)

* : Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Table 1.31.10. Timer A input (counter input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiN input cycle time	150		ns
$t_{w(TAH)}$	TAiN input HIGH pulse width	60		ns
$t_{w(TAL)}$	TAiN input LOW pulse width	60		ns

Table 1.31.11. Timer A input (gating input in timer mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiN input cycle time	600		ns
$t_{w(TAH)}$	TAiN input HIGH pulse width	300		ns
$t_{w(TAL)}$	TAiN input LOW pulse width	300		ns

Table 1.31.12. Timer A input (external trigger input in one-shot timer mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiN input cycle time	300		ns
$t_{w(TAH)}$	TAiN input HIGH pulse width	150		ns
$t_{w(TAL)}$	TAiN input LOW pulse width	150		ns

Table 1.31.13. Timer A input (external trigger input in pulse width modulation mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(TAH)}$	TAiN input HIGH pulse width	150		ns
$t_{w(TAL)}$	TAiN input LOW pulse width	150		ns

Table 1.31.14. Timer A input (up/down input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(UP)}$	TAiOUT input cycle time	3000		ns
$t_{w(UPH)}$	TAiOUT input HIGH pulse width	1500		ns
$t_{w(UPL)}$	TAiOUT input LOW pulse width	1500		ns
$t_{su(UP-TIN)}$	TAiOUT input setup time	600		ns
$t_{h(TIN-UP)}$	TAiOUT input hold time	600		ns

Timing

Timing requirements

(referenced to $V_{CC} = 3V$, $V_{SS} = 0V$, at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (*) unless otherwise specified)

* : Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Table 1.31.15. 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)	160		ns
$t_{w(TBL)}$	TBiIn input LOW pulse width (counted on both edges)	160		ns

Table 1.31.16. 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 1.31.17. 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

Table 1.31.18. A-D trigger input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(AD)}$	ADTRG input cycle time (trigger able minimum)	1500		ns
$t_{w(ADL)}$	ADTRG input LOW pulse width	200		ns

Table 1.31.19. Serial I/O

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	50		ns
$t_{h(C-D)}$	RxDi input hold time	90		ns

Table 1.31.20. External interrupt INTi inputs

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(INH)}$	INTi input HIGH pulse width	380		ns
$t_{w(INL)}$	INTi input LOW pulse width	380		ns

Timing

Switching characteristics (referenced to $V_{CC} = 3V$, $V_{SS} = 0V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (Note 3), CM15 = "1" unless otherwise specified)

Table 1.31.21. Memory expansion and microprocessor modes (with no wait)

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
$t_d(BCLK-AD)$	Address output delay time	Figure 1.31.1		60	ns
$t_h(BCLK-AD)$	Address output hold time (BCLK standard)		4		ns
$t_h(RD-AD)$	Address output hold time (RD standard)		0		ns
$t_h(WR-AD)$	Address output hold time (WR standard)		0		ns
$t_d(BCLK-CS)$	Chip select output delay time			60	ns
$t_h(BCLK-CS)$	Chip select output hold time (BCLK standard)		4		ns
$t_d(BCLK-ALE)$	ALE signal output delay time			60	ns
$t_h(BCLK-ALE)$	ALE signal output hold time		-4		ns
$t_d(BCLK-RD)$	RD signal output delay time			60	ns
$t_h(BCLK-RD)$	RD signal output hold time		0		ns
$t_d(BCLK-WR)$	WR signal output delay time			60	ns
$t_h(BCLK-WR)$	WR signal output hold time		0		ns
$t_d(BCLK-DB)$	Data output delay time (BCLK standard)			80	ns
$t_h(BCLK-DB)$	Data output hold time (BCLK standard)		4		ns
$t_d(DB-WR)$	Data output delay time (WR standard)		(Note1)		ns
$t_h(WR-DB)$	Data output hold time (WR standard)(Note2)		0		ns

Note 1: Calculated according to the BCLK frequency as follows:

$$t_d(DB-WR) = \frac{10^9}{f(BCLK) \times 2} - 80 \quad [ns]$$

Note 2: This is standard value shows the timing when the output is off, and doesn't show hold time of data bus.

Hold time of data bus is different by capacitor volume and pull-up (pull-down) resistance value.

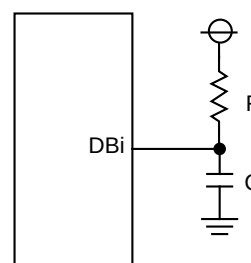
Hold time of data bus is expressed in

$$t = -CR \times \ln(1 - V_{OL} / V_{CC})$$

by a circuit of the right figure.

For example, when $V_{OL} = 0.2V_{CC}$, $C = 30pF$, $R = 1k\Omega$, hold time of output "L" level is

$$t = -30pF \times 1k\Omega \times \ln(1 - 0.2V_{CC} / V_{CC}) \\ = 6.7ns.$$



Note 3: Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

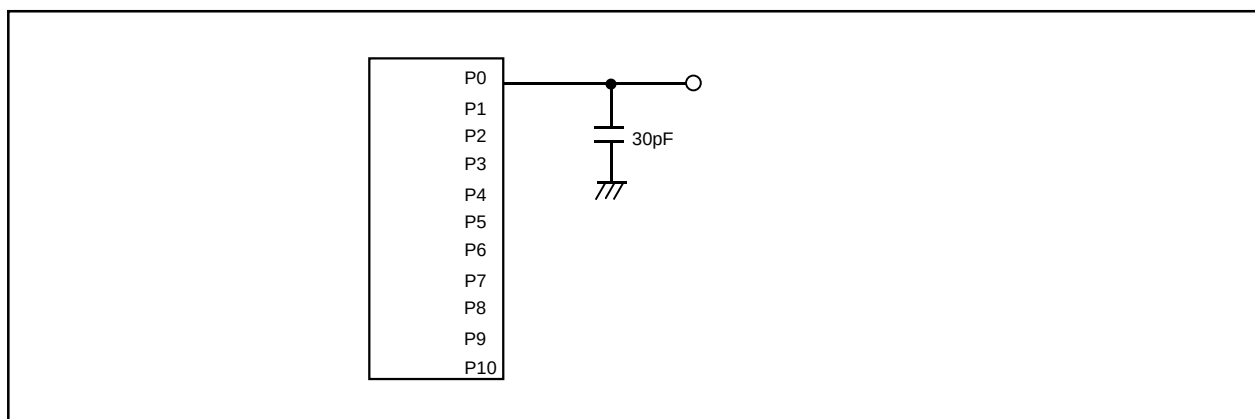


Figure 1.31.1. Port P0 to P10 measurement circuit

Switching characteristics (referenced to $V_{CC} = 3V$, $V_{SS} = 0V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (Note 3), CM15 = "1" unless otherwise specified)

Table 1.31.22. Memory expansion and microprocessor modes
(when accessing external memory area with wait)

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	Figure 1.31.1		60	ns
$t_{h(BCLK-AD)}$	Address output hold time (BCLK standard)		4		ns
$t_{h(RD-AD)}$	Address output hold time (RD standard)		0		ns
$t_{h(WR-AD)}$	Address output hold time (WR standard)		0		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			60	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (BCLK standard)		4		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			60	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		-4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			60	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			60	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (BCLK standard)			80	ns
$t_{h(BCLK-DB)}$	Data output hold time (BCLK standard)		4		ns
$t_{d(DB-WR)}$	Data output delay time (WR standard)		(Note1)		ns
$t_{h(WR-DB)}$	Data output hold time (WR standard)(Note2)		0		ns

Note 1: Calculated according to the BCLK frequency as follows:

$$t_{d(DB-WR)} = \frac{10^9}{f(BCLK)} - 80 \quad [ns]$$

Note 2: This is standard value shows the timing when the output is off, and doesn't show hold time of data bus.
Hold time of data bus is different by capacitor volume and pull-up (pull-down) resistance value.

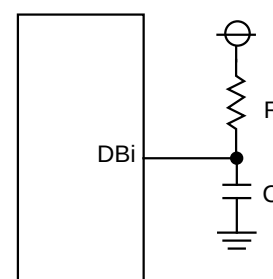
Hold time of data bus is expressed in

$$t = -CR \times \ln(1 - V_{OL} / V_{CC})$$

by a circuit of the right figure.

For example, when $V_{OL} = 0.2V_{CC}$, $C = 30pF$, $R = 1k\Omega$, hold time of output "L" level is

$$\begin{aligned} t &= -30pF \times 1k\Omega \times \ln(1 - 0.2V_{CC} / V_{CC}) \\ &= 6.7ns. \end{aligned}$$



Note 3: Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Switching characteristics (referenced to $V_{CC} = 3V$, $V_{SS} = 0V$ at $T_{opr} = -20^{\circ}C$ to $85^{\circ}C$ / $-40^{\circ}C$ to $85^{\circ}C$ (Note 2), CM15 = "1" unless otherwise specified)

Table 1.31.23. Memory expansion and microprocessor modes
(when accessing external memory area with wait, and select multiplexed bus)

Symbol	Parameter	Measuring condition	Standard		Unit
			Min.	Max.	
$t_d(BCLK-AD)$	Address output delay time	Figure 1.31.1		60	ns
$t_h(BCLK-AD)$	Address output hold time (BCLK standard)		4		ns
$t_h(RD-AD)$	Address output hold time (RD standard)		(Note 1)		ns
$t_h(WR-AD)$	Address output hold time (WR standard)		(Note 1)		ns
$t_d(BCLK-CS)$	Chip select output delay time			60	ns
$t_h(BCLK-CS)$	Chip select output hold time (BCLK standard)		4		ns
$t_h(RD-CS)$	Chip select output hold time (RD standard)		(Note 1)		ns
$t_h(WR-CS)$	Chip select output hold time (WR standard)		(Note 1)		ns
$t_d(BCLK-RD)$	RD signal output delay time			60	ns
$t_h(BCLK-RD)$	RD signal output hold time		0		ns
$t_d(BCLK-WR)$	WR signal output delay time			60	ns
$t_h(BCLK-WR)$	WR signal output hold time		0		ns
$t_d(BCLK-DB)$	Data output delay time (BCLK standard)			80	ns
$t_h(BCLK-DB)$	Data output hold time (BCLK standard)		4		ns
$t_d(DB-WR)$	Data output delay time (WR standard)		(Note 1)		ns
$t_h(WR-DB)$	Data output hold time (WR standard)		(Note 1)		ns
$t_d(BCLK-ALE)$	ALE signal output delay time (BCLK standard)			60	ns
$t_h(BCLK-ALE)$	ALE signal output hold time (BCLK standard)		-4		ns
$t_d(AD-ALE)$	ALE signal output delay time (Address standard)		(Note 1)		ns
$t_h(ALE-AD)$	ALE signal output hold time (Address standard)		40		ns
$t_d(AD-RD)$	Post-address RD signal output delay time		0		ns
$t_d(AD-WR)$	Post-address WR signal output delay time		0		ns
$t_{dZ}(RD-AD)$	Address output floating start time			8	ns

Note 1: Calculated according to the BCLK frequency as follows:

$$t_h(RD - AD) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$t_h(WR - AD) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$t_h(RD - CS) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$t_h(WR - CS) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

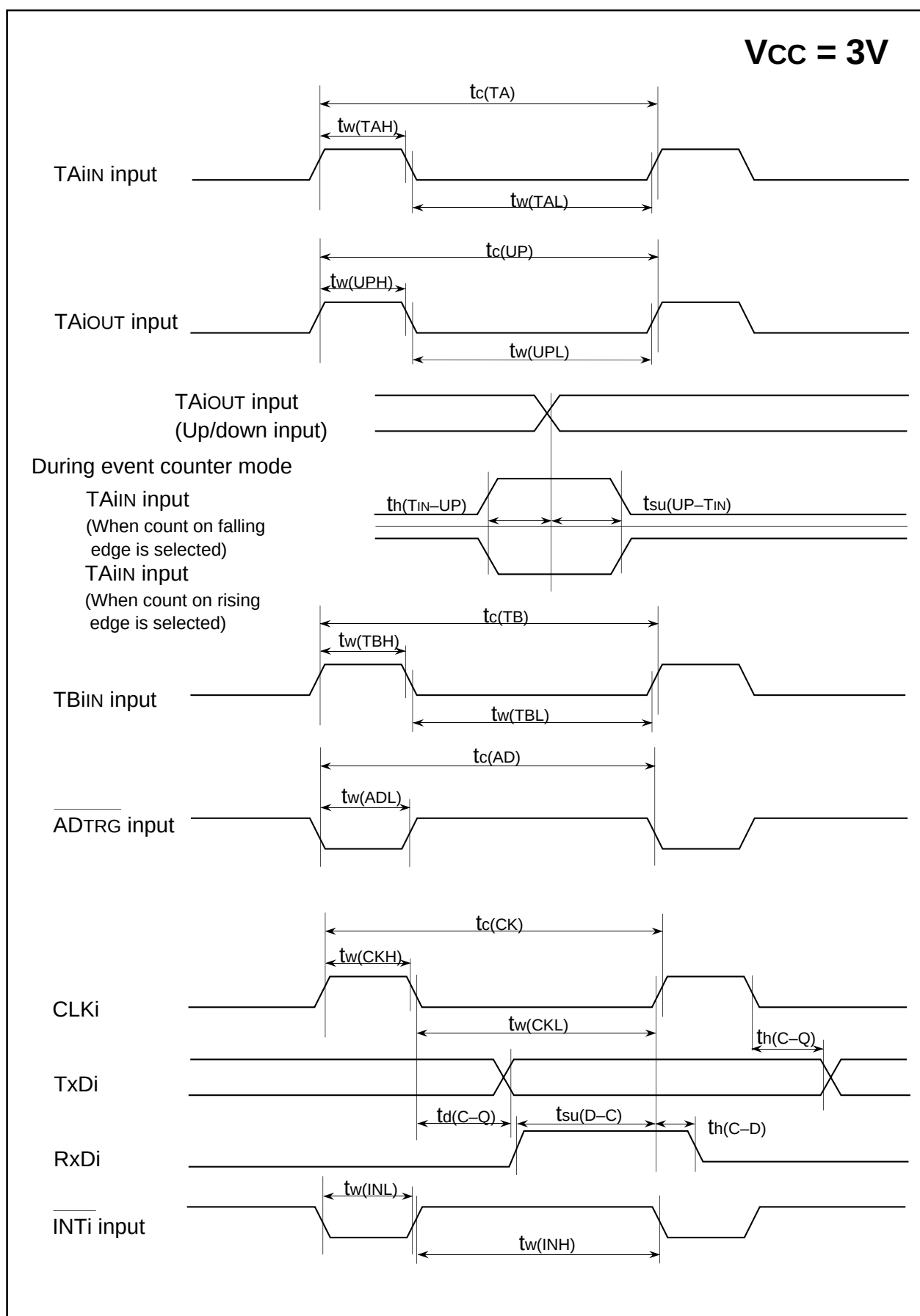
$$t_d(DB - WR) = \frac{10^9 \times 3}{f(BCLK) \times 2} - 80 \quad [ns]$$

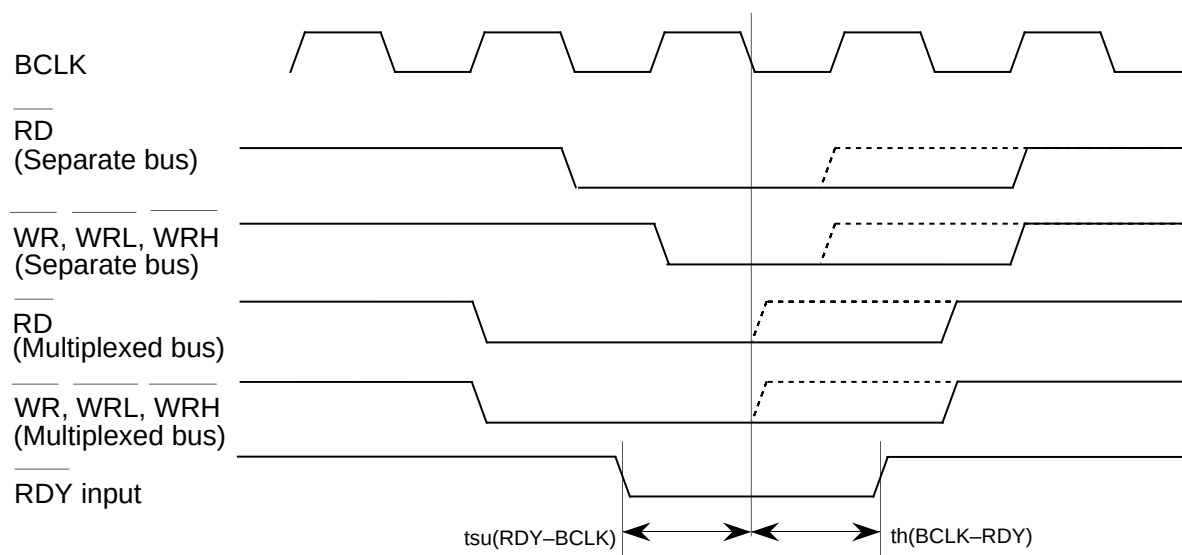
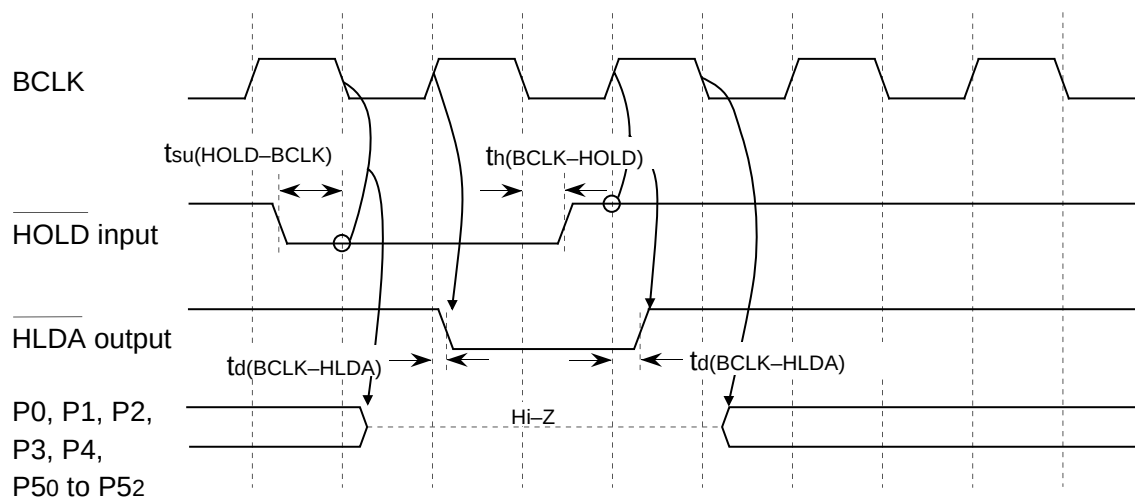
$$t_h(WR - DB) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$t_d(AD - ALE) = \frac{10^9}{f(BCLK) \times 2} - 45 \quad [ns]$$

Note 2: Specify a product of $-40^{\circ}C$ to $85^{\circ}C$ to use it.

Timing

Figure 1.31.2. V_{CC}=3V timing diagram (1)

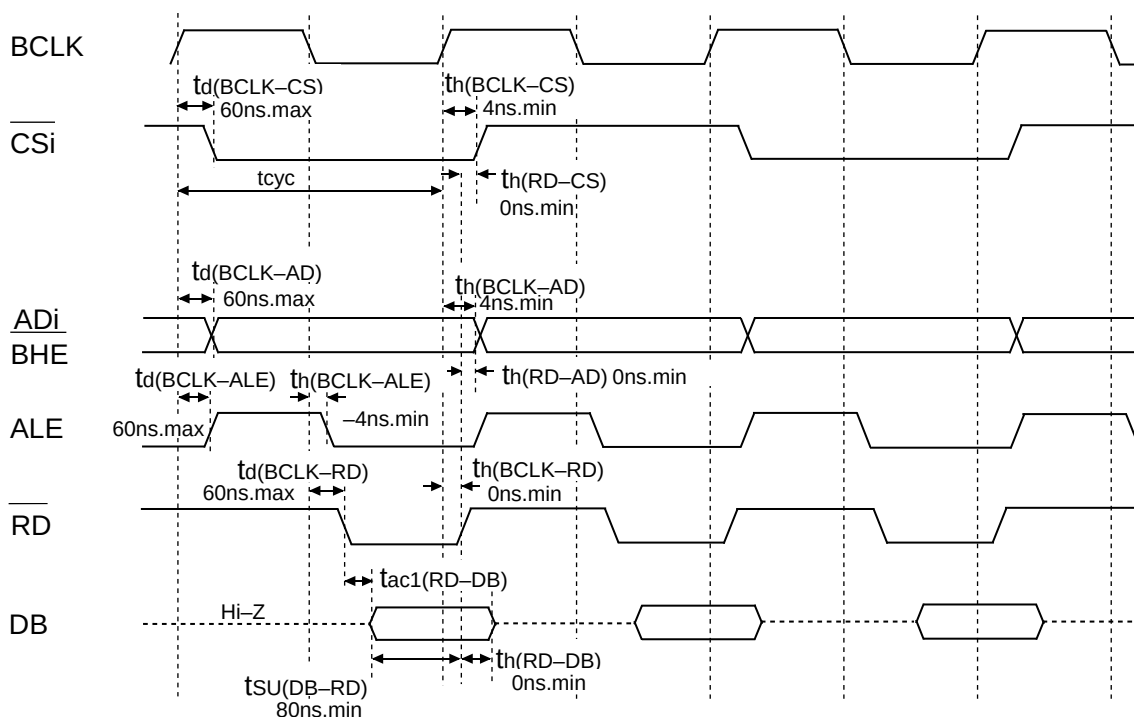
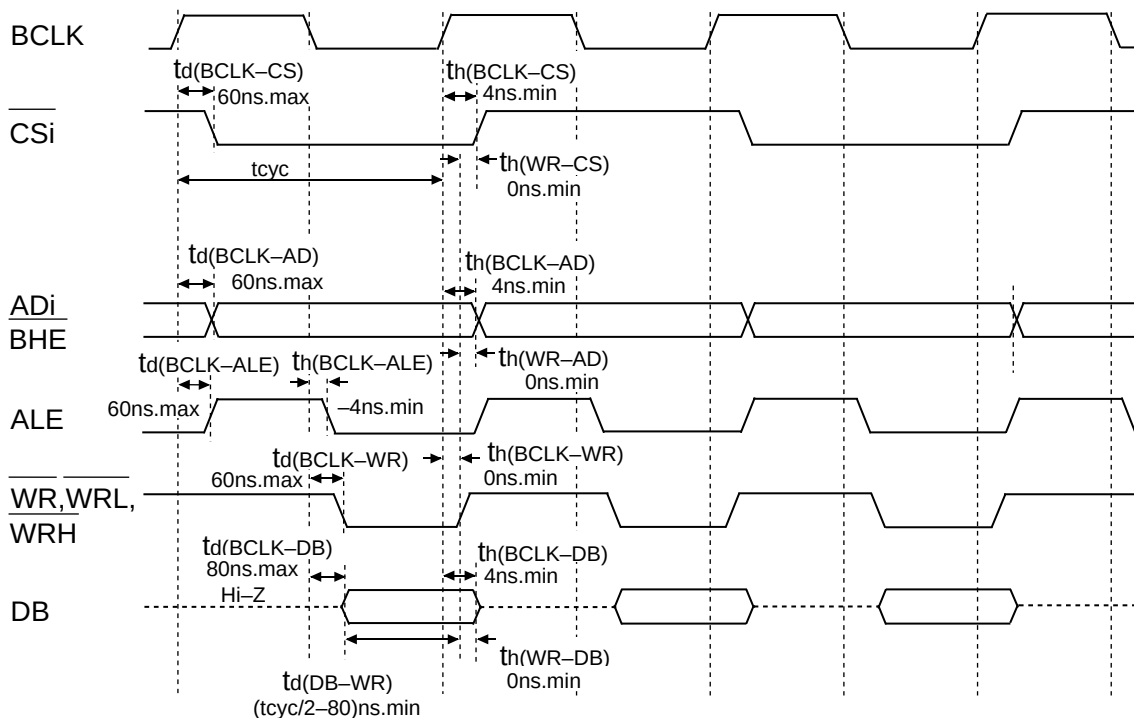
V_{CC} = 3V**Memory Expansion Mode and Microprocessor Mode****(Valid only with wait)****(Valid with or without wait)**

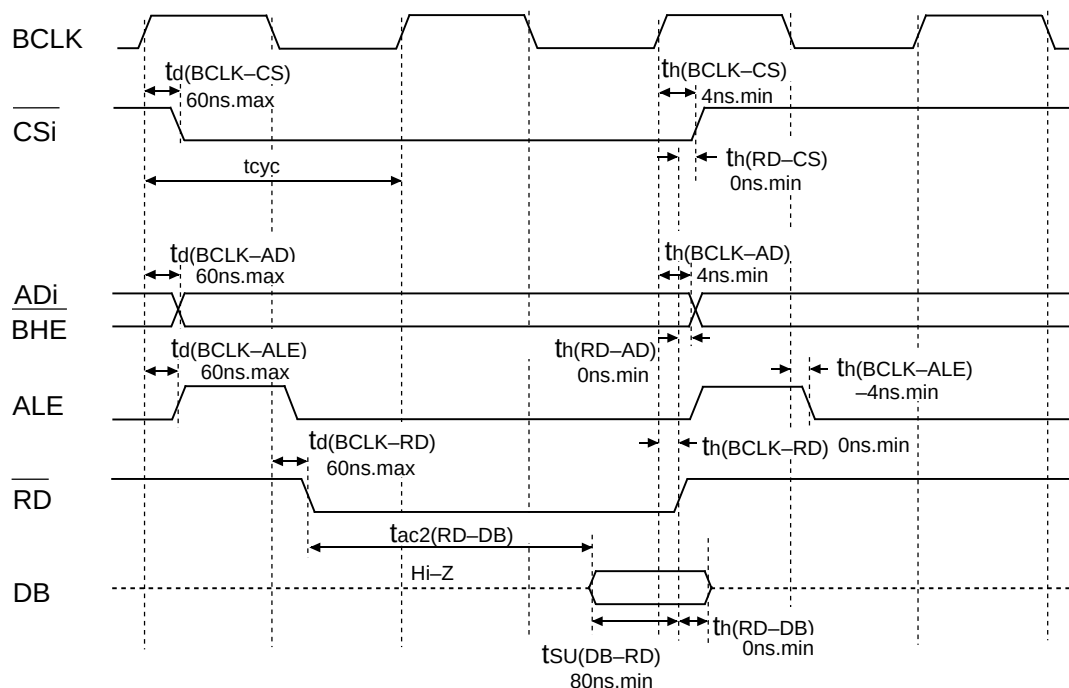
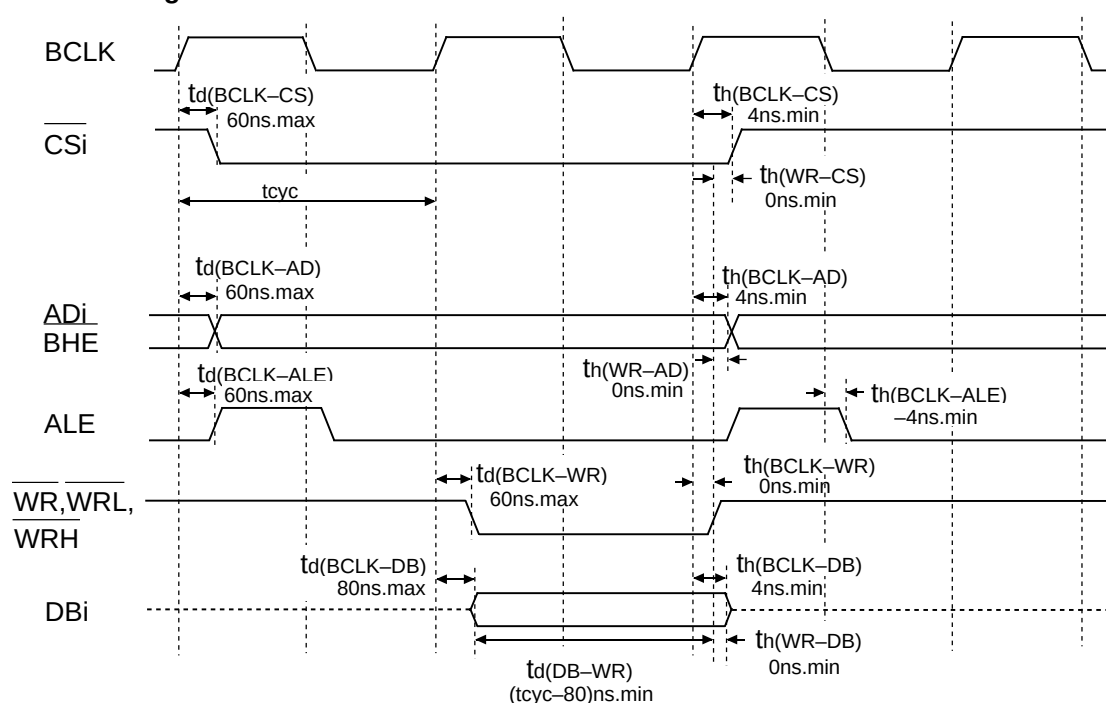
Note: The above pins are set to high-impedance regardless of the input level of the BYTE pin and bit (PM06) of processor mode register 0 selects the function of ports P40 to P43.

Measuring conditions :

- V_{CC}=3V
- Input timing voltage : Determined with V_{IL}=0.6V, V_{IH}=2.4V
- Output timing voltage : Determined with V_{OL}=1.5V, V_{OH}=1.5V

Figure 1.31.3. V_{CC}=3V timing diagram (2)

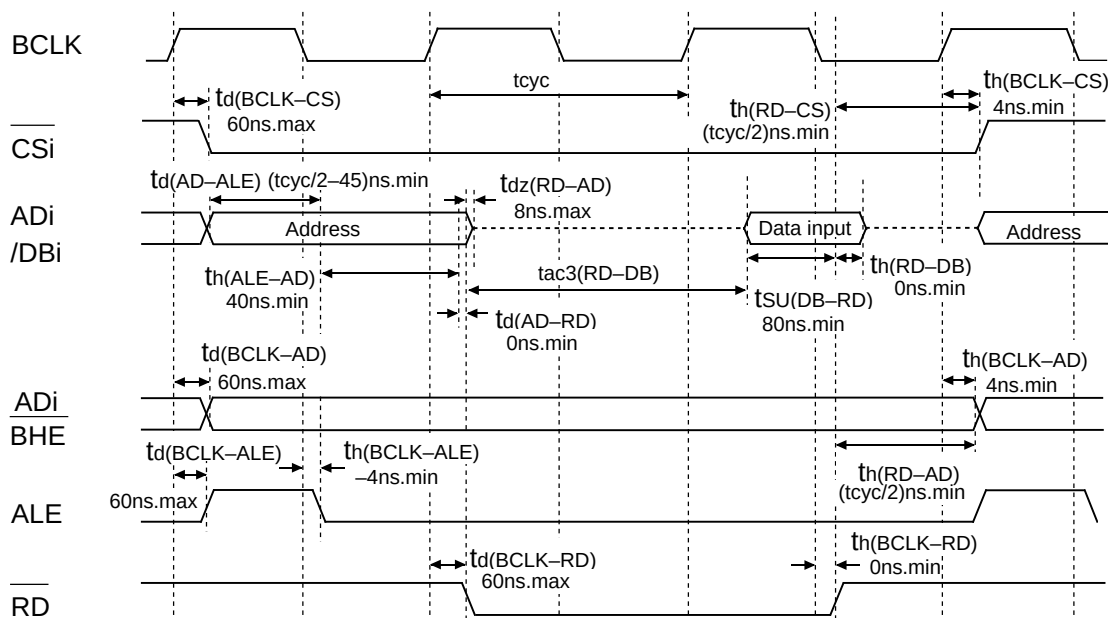
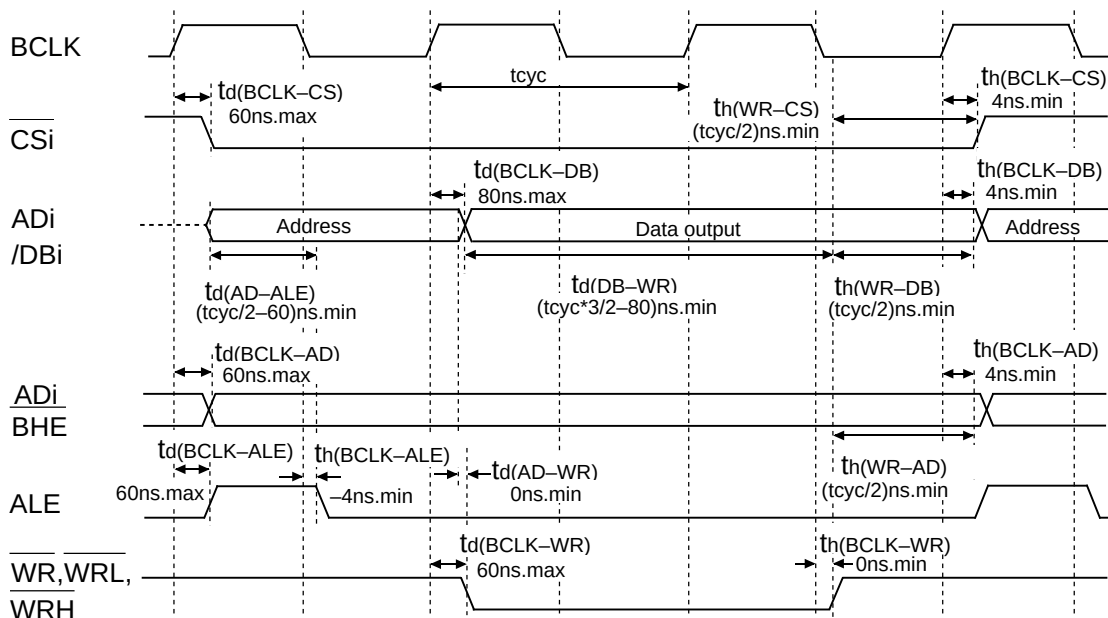
V_{CC} = 3V**Memory Expansion Mode and Microprocessor Mode****(With no wait)****Read timing****Write timing****Figure 1.31.4. V_{CC}=3V timing diagram (3)**

V_{CC} = 3V**Memory Expansion Mode and Microprocessor Mode****(When accessing external memory area with wait)****Read timing****Write timing**

Measuring conditions :

- V_{CC}=3V
- Input timing voltage : Determined with V_{IL}=0.48V, V_{IH}=1.5V
- Output timing voltage : Determined with V_{OL}=1.5V, V_{OH}=1.5V

Figure 1.31.5. V_{CC}=3V timing diagram (4)

V_{CC} = 3V**Memory Expansion Mode and Microprocessor Mode****(When accessing external memory area with wait, and select multiplexed bus)****Read timing****Write timing**

Measuring conditions :

- V_{CC}=3V
- Input timing voltage : Determined with V_{IL}=0.48V, V_{IH}=1.5V
- Output timing voltage : Determined with V_{OL}=1.5V, V_{OH}=1.5V

Figure 1.31.6. V_{CC}=3V timing diagram (5)

GZZ-SH13-95B<02A0>

**MITSUBISHI ELECTRIC-CHIP 16-BIT
MICROCOMPUTER M30620MCM-XXXFP/GP
MASK ROM CONFIRMATION FORM**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

*	Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
		Date issued	Date :			

*1. Check sheet

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30620MCM-XXXFP ☐ M30620MCM-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

*2. Mark specification

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30620MCM-XXXFP, submit the 100P6S mark specification sheet. For the M30620MCM-XXXGP, submit the 100P6Q mark specification sheet.

*3. Usage Conditions

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of X_{IN}-X_{OUT} oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(X_{IN}) =

 MHz

GZZ-SH13-95B<02A0>

Mask ROM number

**MITSUBISHI ELECTRIC-CHIP 16-BIT
MICROCOMPUTER M30620MCM-XXXFP/GP
MASK ROM CONFIRMATION FORM**

(2) Which kind of XCIN-XCOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

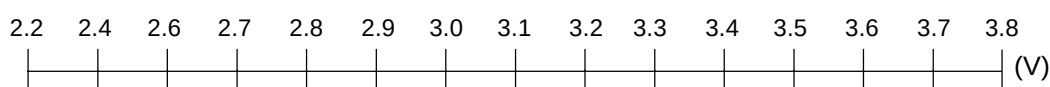
$f(XCIN) =$ kHz

(3) Which operation mode do you use?

- ☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

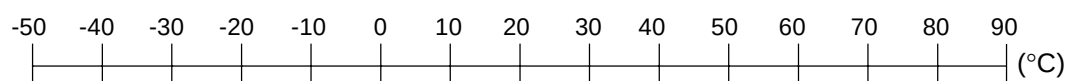
(4) Which operating supply voltage do you use?

(Circle the operating voltage range of use)



(5) Which operating ambient temperature do you use?

(Circle the operating temperature range of use)



(6) Do you use I²C (Inter IC) bus function?

- ☐ Not use ☐ Use

(7) Do you use IE (Inter Equipment) bus function?

- ☐ Not use ☐ Use

Thank you cooperation.

※4. Special item (Indicate none if there is not specified item)

GZZ-SH13-48B<98A1>

**mitsubishi electric-chip 16-bit
microcomputer M30624MGM-XXXFP/GP
mask ROM confirmation form**

Mask ROM number	

Receipt	Date :	
	Section head signature	Supervisor signature

Note : Please complete all items marked * .

*	Customer	Company name	TEL ()	Issuance signature	Submitted by	Supervisor
		Date issued	Date :			

*1. Check sheet

Mitsubishi processes the mask files generated by the mask file generation utilities out of those held on the floppy disks you give in to us, and forms them into masks. Hence, we assume liability provided that there is any discrepancy between the contents of these mask files and the ROM data to be burned into products we produce. Check thoroughly the contents of the mask files you give in.

Prepare 3.5 inches 2HD (IBM format) floppy disks. And store only one mask file in a floppy disk.

Microcomputer type No. : ☐ M30624MGM-XXXFP ☐ M30624MGM-XXXGP

File code :

 (hex)

Mask file name :

 .MSK (alpha-numeric 8-digit)

*2. Mark specification

The mark specification differs according to the type of package. After entering the mark specification on the separate mark specification sheet (for each package), attach that sheet to this masking check sheet for submission to Mitsubishi.

For the M30624MGM-XXXFP, submit the 100P6S mark specification sheet. For the M30624MGM-XXXGP, submit the 100P6Q mark specification sheet.

*3. Usage Conditions

For our reference when of testing our products, please reply to the following questions about the usage of the products you ordered.

(1) Which kind of X_{IN}-X_{OUT} oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

f(X_{IN}) =

 MHz

GZZ-SH13-48B<98A1>

Mask ROM number

**MITSUBISHI ELECTRIC-CHIP 16-BIT
MICROCOMPUTER M30624MGM-XXXFP/GP
MASK ROM CONFIRMATION FORM**

(2) Which kind of XCIN-XCOUT oscillation circuit is used?

- ☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ()

What frequency do not use?

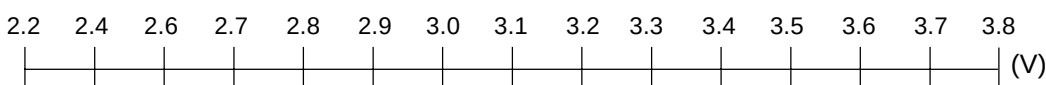
$f(XCIN) =$ kHz

(3) Which operation mode do you use?

- ☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

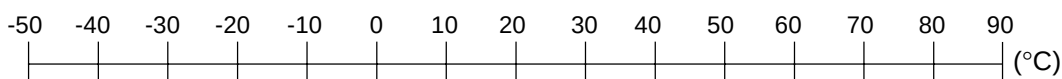
(4) Which operating supply voltage do you use?

(Circle the operating voltage range of use)



(5) Which operating ambient temperature do you use?

(Circle the operating temperature range of use)



(6) Do you use I²C (Inter IC) bus function?

- ☐ Not use ☐ Use

(7) Do you use IE (Inter Equipment) bus function?

- ☐ Not use ☐ Use

Thank you cooperation.

※4. Special item (Indicate none if there is not specified item)

[MEMO]

Chapter 2

Peripheral Functions Usage

2.1 Protect Usage

2.1.1 Overview of the protect usage

'Protect' is a function that causes a value held in a register to be unchanged even when a program runs away. The following is an overview of the protect usage:

(1) Registers affected by the protect function

The registers affected by the protect function are:

- (a) System clock control registers 0, 1 (addresses 0006₁₆ and 0007₁₆)
- (b) Processor mode registers 0, 1 (addresses 0004₁₆ and 0005₁₆)
- (c) Port P9 direction register (address 03F3₁₆), SI/Oi control register (i=3,4)(addresses 0362₁₆ and 0366₁₆)

The values in registers (1) through (3) cannot be changed in write-protect state. To change values in the registers, put the individual registers in write-enabled state.

(2) Protect register

Figure 2.1.1 shows protect register.

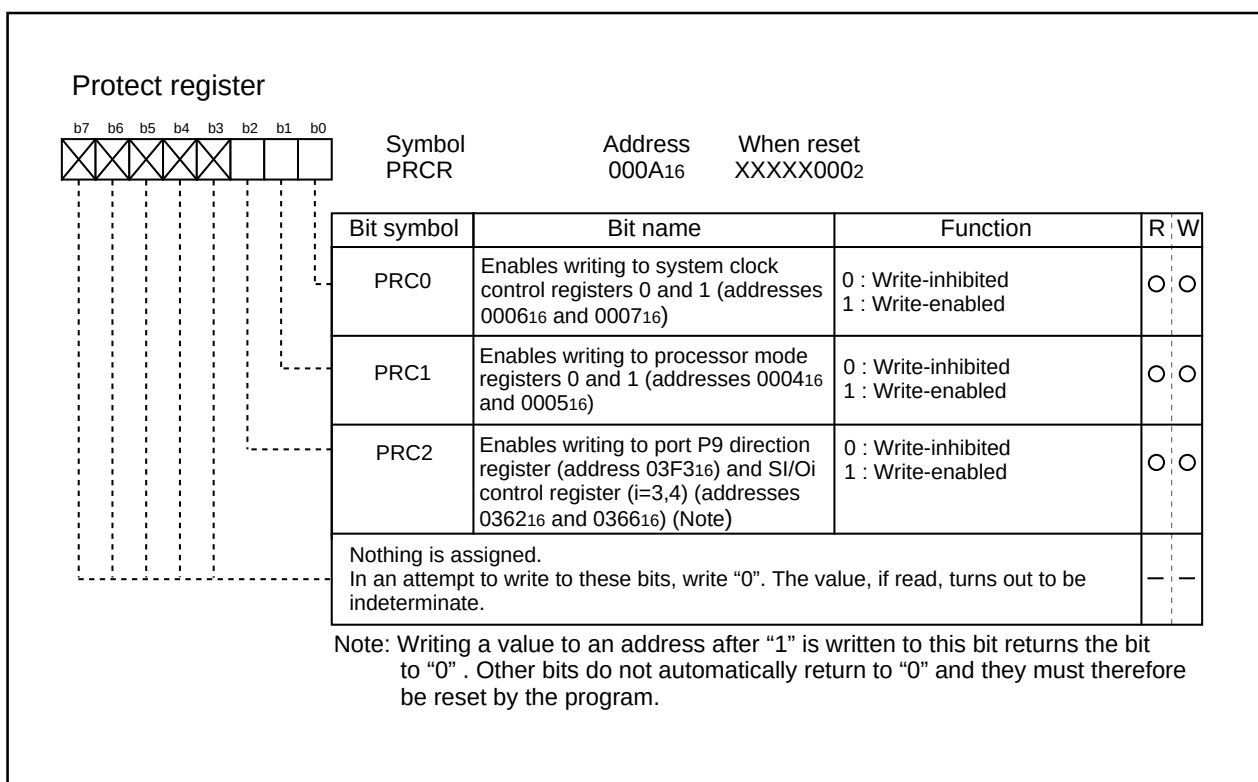


Figure 2.1.1. Protect register

2.1.2 Protect Operation

The following explains the protect operation. Figure 2.1.2 shows the set-up procedure.

- Operation
- (1) Setting "1" in the write-enable bit of system clock control registers 0 and 1 causes system clock control register 0 and system clock control register 1 to be in write-enabled state.
 - (2) The contents of system clock control register 0 and that of system clock control register 1 are changed.
 - (3) Setting "0" in the write-enable bit of system control registers 0 and 1 causes system clock control register 0 and system control register 1 to be in write-inhibited state.
 - (4) To change the contents of processor mode register 0 and that of processor mode register 1, follow the same steps as in dealing with system clock control registers.
 - (5) The write-enable bit of port 9 direction register and SI/Oi control register (i=3,4) goes to "0" when the next write instruction is executed after write-enabled state is readied. Make changes in input/output and SI/Oi control register (i=3,4) immediately after the instruction that sets "1" in the write-enable bit of port P9 direction register and SI/Oi control register (i=3,4) (avoid causing an interrupt). Also take measures to prevent DMA transfer from being executed.

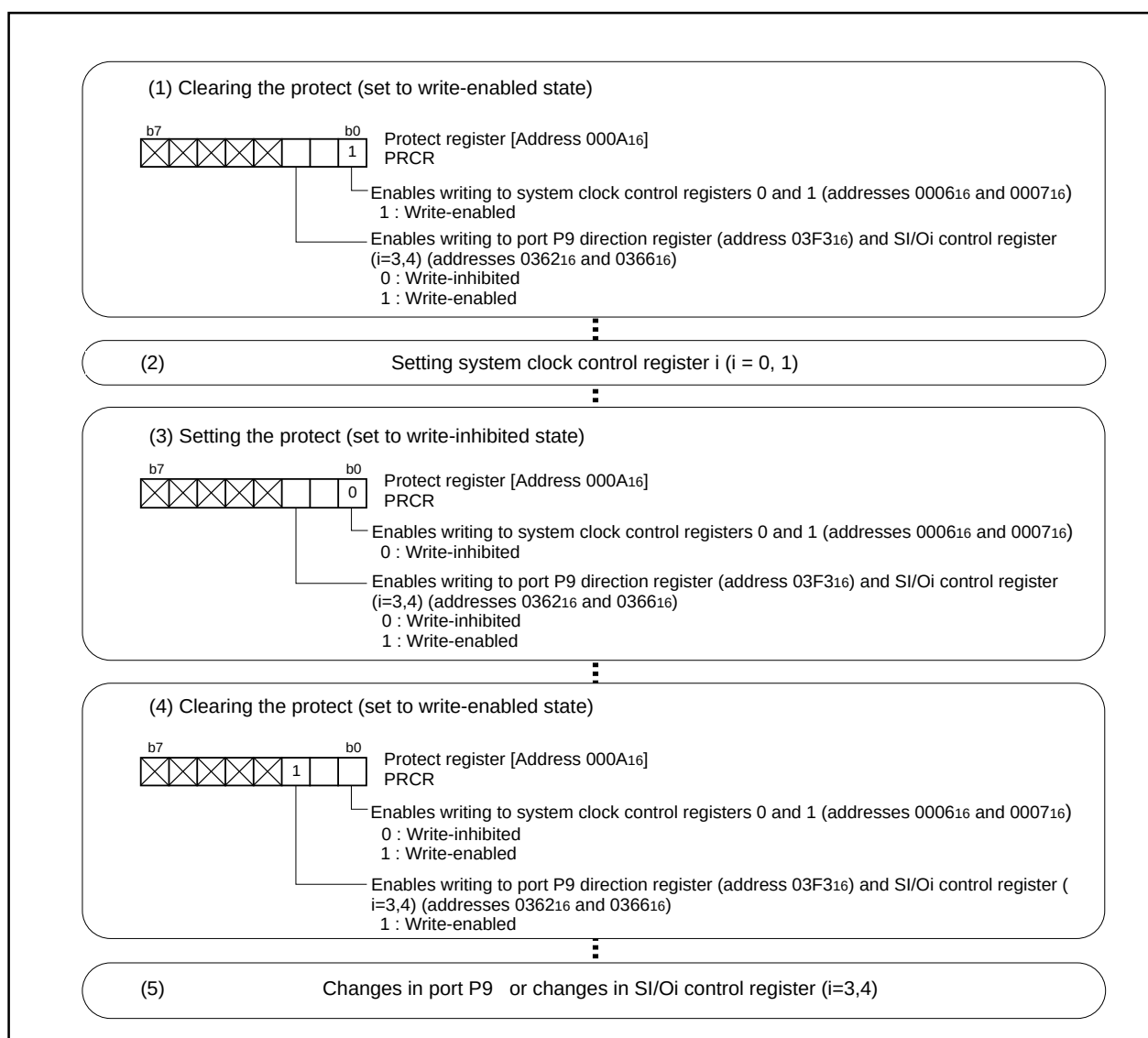


Figure 2.1.2. Set-up procedure for protect function

2.1.3 Precaution for Protect

- (1) The write-enable bit of port 9 direction register and SI/Oi control register (i=3,4) goes to "0" when the next write instruction is executed after write-enabled state is readied. Make changes in input/output and SI/Oi control register (i=3,4) immediately after the instruction that sets "1" in the write-enable bit of port P9 direction register and SI/Oi control register (i=3,4) (avoid causing an interrupt). Also take measures to prevent DMA transfer from being executed.

2.2 Timer A Usage

2.2.1 Overview of the timer A usage

Timer A is a 16-bit timer. The following is an overview of the timer A usage.

(1) Mode

Timer A operates in one of the four modes:

(a) Timer mode

In this mode, the internal count source is counted. Two functions can be selected: the pulse output function that reverses output from a port every time an overflow occurs, or the gate function which controls the count start/stop according to the input signal from a port.

- Timer mode operation P2-12
- Timer mode, gate function operation P2-14
- Timer mode, pulse output function operation P2-16

(b) Event counter mode

This mode counts the pulses from the outside and the number of overflows in other timers. The free-run type, in which nothing is reloaded from the reload register, can be selected when an underflow occurs. The pulse output function can also be selected. Please refer to the timer mode explanation for details, as the operation is identical.

- Event counter mode operation P2-18
- Event counter mode, free run type operation P2-20

Furthermore, Timer A has a 2-phase pulse signal processing function which generates an up count or down count in the event counter mode, depending on the phase of the two input signals.

- Operation of the 2-phase pulse signal processing function in normal event counter mode P2-22
- Operation of the 2-phase pulse signal processing function in 4-multiplication mode P2-24

(c) One-shot timer mode

In this mode, the timer is started by the trigger and stops when the timer goes to "0". The trigger can be selected from the following 3 types: an external input signal, an overflow of the timer, or a software trigger. The pulse output function can also be selected. Please refer to the timer mode explanation for details, as the operation is identical.

- Operation in one-shot timer mode effected by software P2-26
- Operation in one-shot timer mode effected by an external trigger P2-28

(d) Pulse width modulation (PWM) mode

In this mode, the arbitrary pulses are successively output. Either a 16-bit fixed-period PWM mode or 8-bit variable-period mode can be selected. The trigger for initiating output can also be selected. Please refer to the one-shot timer mode explanation for details, as the operation is identical.

- 16-bit PWM mode operation P2-30
- 8-bit PWM mode operation P2-32

(2) Count source

The internal count source can be selected from f1, f8, f32, and fc32. Clocks f1, f8, and f32 are derived by dividing the CPU's main clock by 1, 8, and 32 respectively. Clock fc32 is derived by dividing the CPU's secondary clock by 32.

(3) Count value

In timer mode or pulse width modulation mode, [the value set in the timer register + 1] becomes the count value. In event counter mode, [the set value + 1] becomes the count value when a down count is performed, or [FFFF16 - the set value + 1] becomes the count value when an up count is performed. In one-shot timer mode, the value set in the timer register becomes the count value.

The counter overflows (or underflows) when a count source equal to a count value is input, and an interrupt occurs. For the pulse output function, the output from the port varies (the value in the port register does not vary).

(4) Reading the timer

Either in timer mode or in event counter mode, reading the timer register takes out the count at that moment. Read it in 16-bit units. The data either in one-shot timer mode or in pulse width modulation mode is indeterminate.

(5) Writing to the timer

To write to the timer register when a count is in progress, the value is written only to the reload register. When writing to the timer register when a count is stopped, the value is written both to the reload register and to the counter. Write a value in 16-bit units.

(6) Relation between the input/output to/from the timer and the direction register

With the output function of the timer, pulses are output regardless of the direction register of the relevant port. To input an external signal to the timer, set the direction register of the relevant port to input.

(7) Pins related to timer A

(a) TA0IN, TA1IN, TA2IN, TA3IN, TA4IN	Input pins to timer A.
(b) TA0OUT, TA1OUT, TA2OUT, TA3OUT, TA4OUT	Output pins from timer A. They become input pins to timer A when event counter mode is active.

(8) Registers related to timer A

Figure 2.2.1 shows the memory map of timer A-related registers. Figures 2.2.2 through 2.2.5 show timer A-related registers.

Timer A

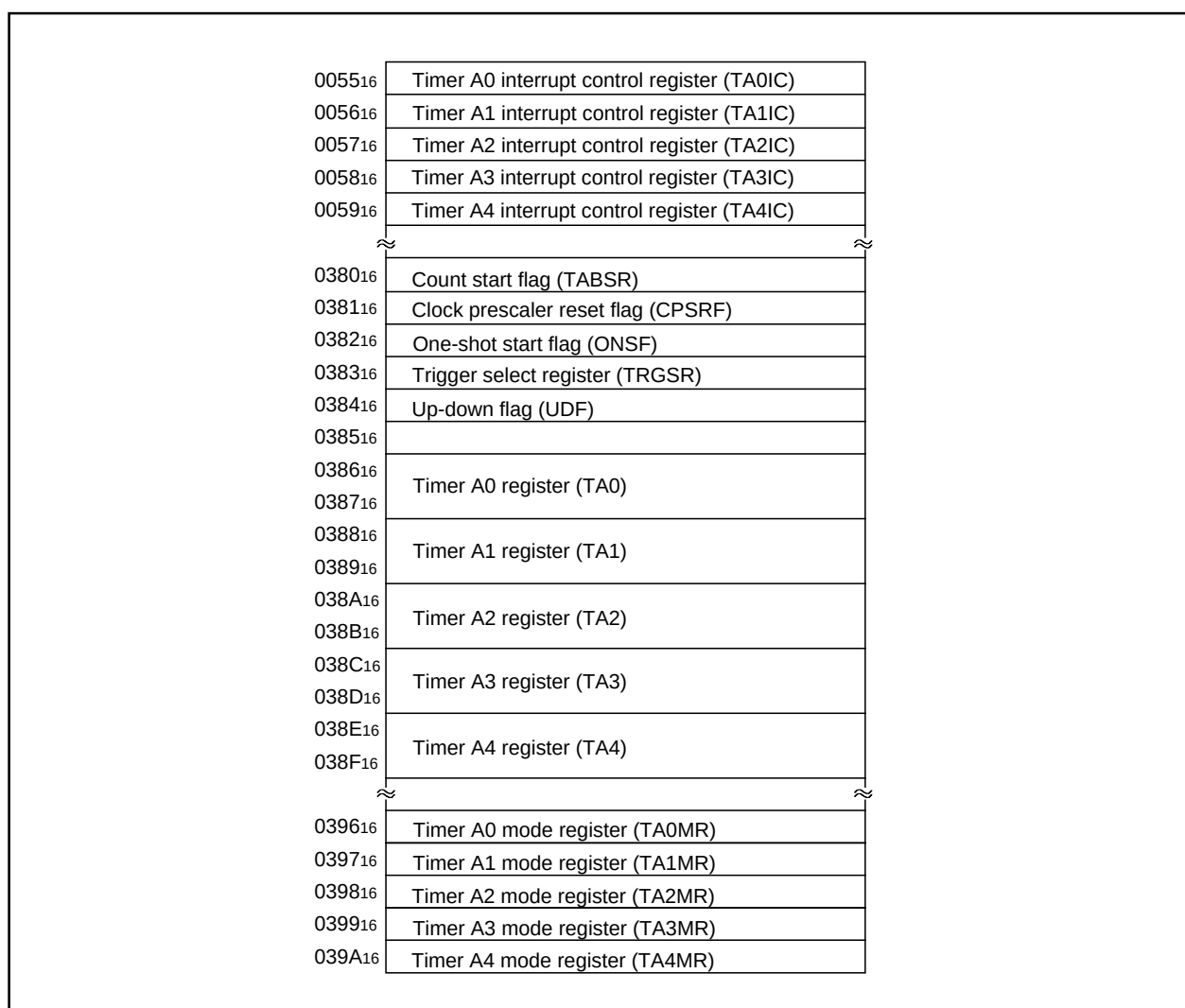


Figure 2.2.1. Memory map of timer A-related registers

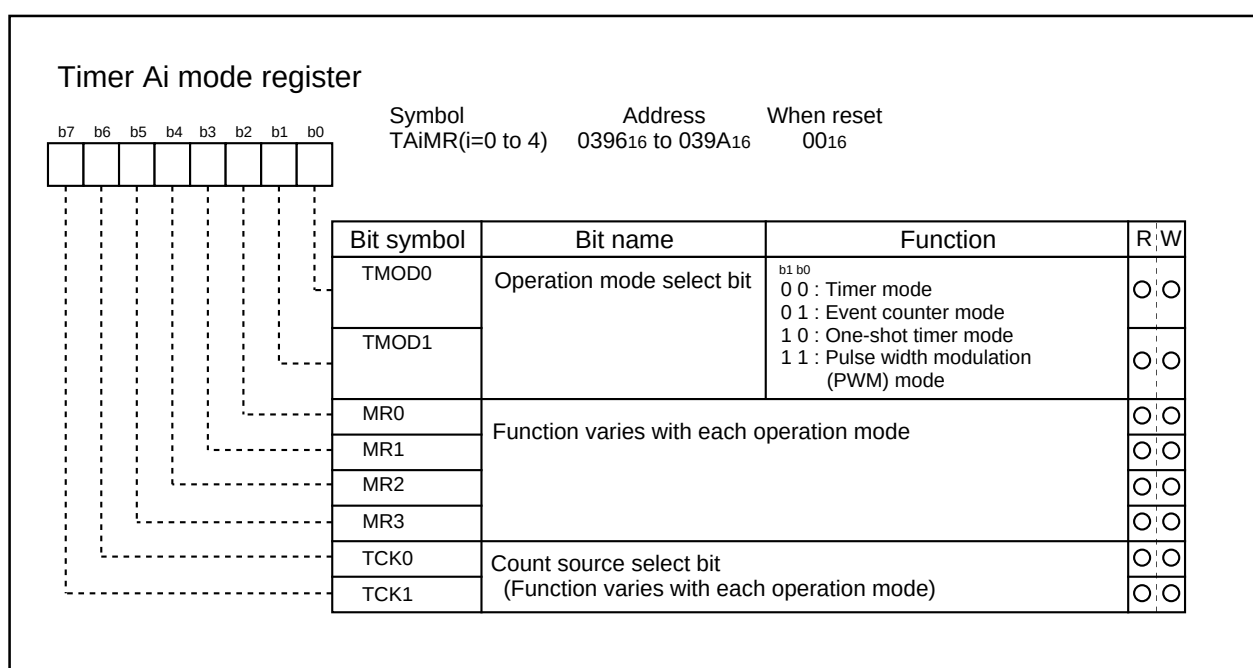


Figure 2.2.2. Timer A-related registers (1)

Timer Ai register (Note 1)

(b15) b7	(b8) b0 b7	b0	Symbol	Address	When reset
			TA0	0387 ₁₆ , 0386 ₁₆	Indeterminate
			TA1	0389 ₁₆ , 0388 ₁₆	Indeterminate
			TA2	038B ₁₆ , 038A ₁₆	Indeterminate
			TA3	038D ₁₆ , 038C ₁₆	Indeterminate
			TA4	038F ₁₆ , 038E ₁₆	Indeterminate
Function			Values that can be set	R	W
• Timer mode Counts an internal count source			0000 ₁₆ to FFFF ₁₆	○	○
• Event counter mode Counts pulses from an external source or timer overflow			0000 ₁₆ to FFFF ₁₆	○	○
• One-shot timer mode Counts a one shot width			0000 ₁₆ to FFFF ₁₆ (Note 2,4)	×	○
• Pulse width modulation mode (16-bit PWM) Functions as a 16-bit pulse width modulator			0000 ₁₆ to FFFE ₁₆ (Note 3,4)	×	○
• Pulse width modulation mode (8-bit PWM) Timer low-order address functions as an 8-bit prescaler and high-order address functions as an 8-bit pulse width modulator			00 ₁₆ to FE ₁₆ (High-order address) 00 ₁₆ to FF ₁₆ (Low-order address) (Note 3,4)	×	○

Note 1: Read and write data in 16-bit units.

Note 2: When the timer Ai register is set to "0000₁₆", the counter does not operate and the timer Ai interrupt request is not generated. When the pulse is set to output, the pulse does not output from the TAIOUT pin.Note 3: When the timer Ai register is set to "0000₁₆", the pulse width modulator does not operate and the output level of the TAIOUT pin remains "L" level, therefore the timer Ai interrupt request is not generated. This also occurs in the 8-bit pulse width modulator mode when the significant 8 high-order bits in the timer Ai register are set to "00₁₆".

Note 4: Use MOV instruction to write to this register.

Count start flag

Count start flag								Symbol	Address	When reset
b7	b6	b5	b4	b3	b2	b1	b0	TABSR	0380 ₁₆	00 ₁₆
Bit symbol		Bit name		Function		R/W				
TA0S		Timer A0 count start flag		0 : Stops counting 1 : Starts counting		○/○				
TA1S		Timer A1 count start flag				○/○				
TA2S		Timer A2 count start flag				○/○				
TA3S		Timer A3 count start flag				○/○				
TA4S		Timer A4 count start flag				○/○				
TB0S		Timer B0 count start flag				○/○				
TB1S		Timer B1 count start flag				○/○				
TB2S		Timer B2 count start flag				○/○				

Figure 2.2.3. Timer A-related registers (2)

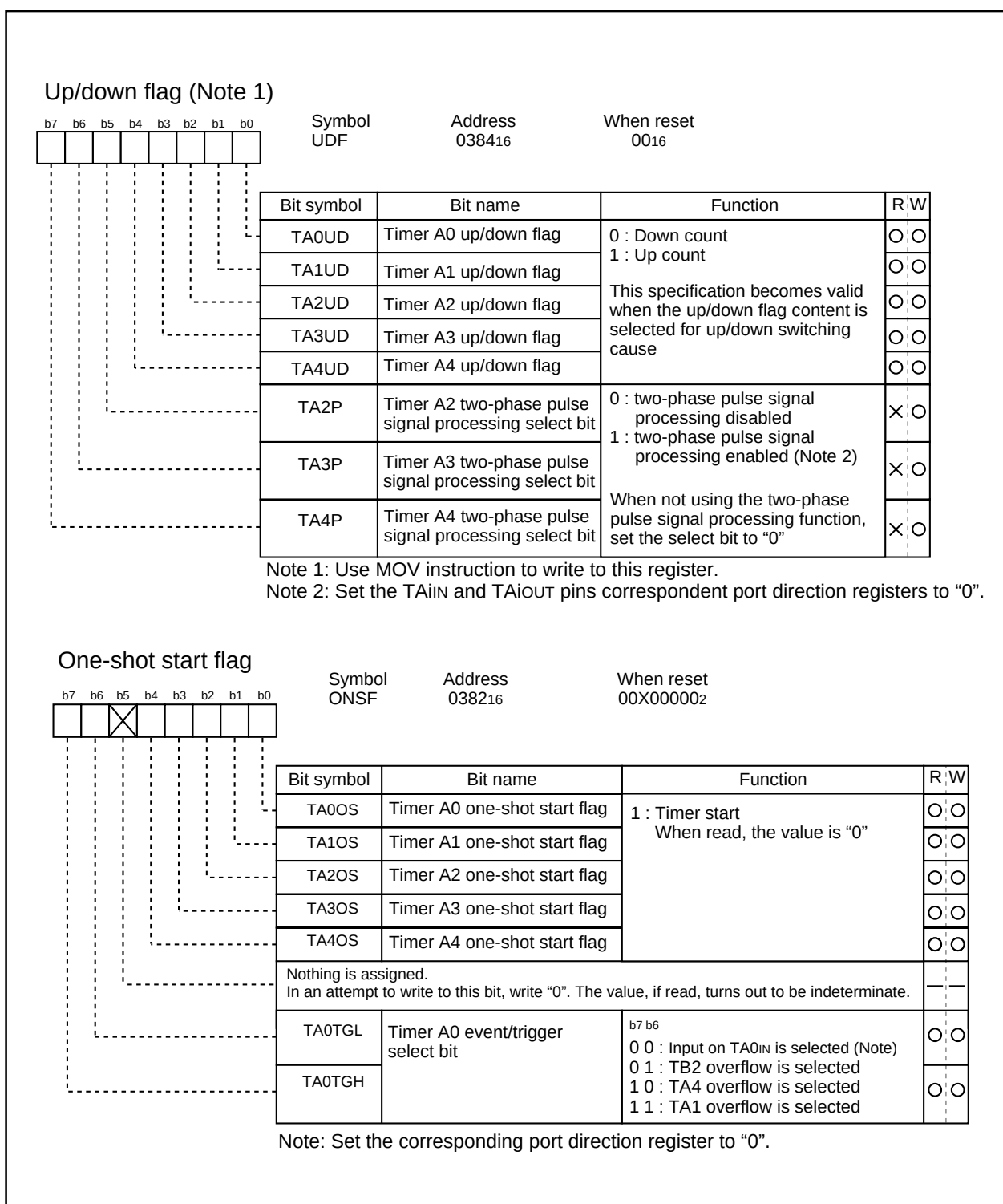


Figure 2.2.4. Timer A-related registers (3)

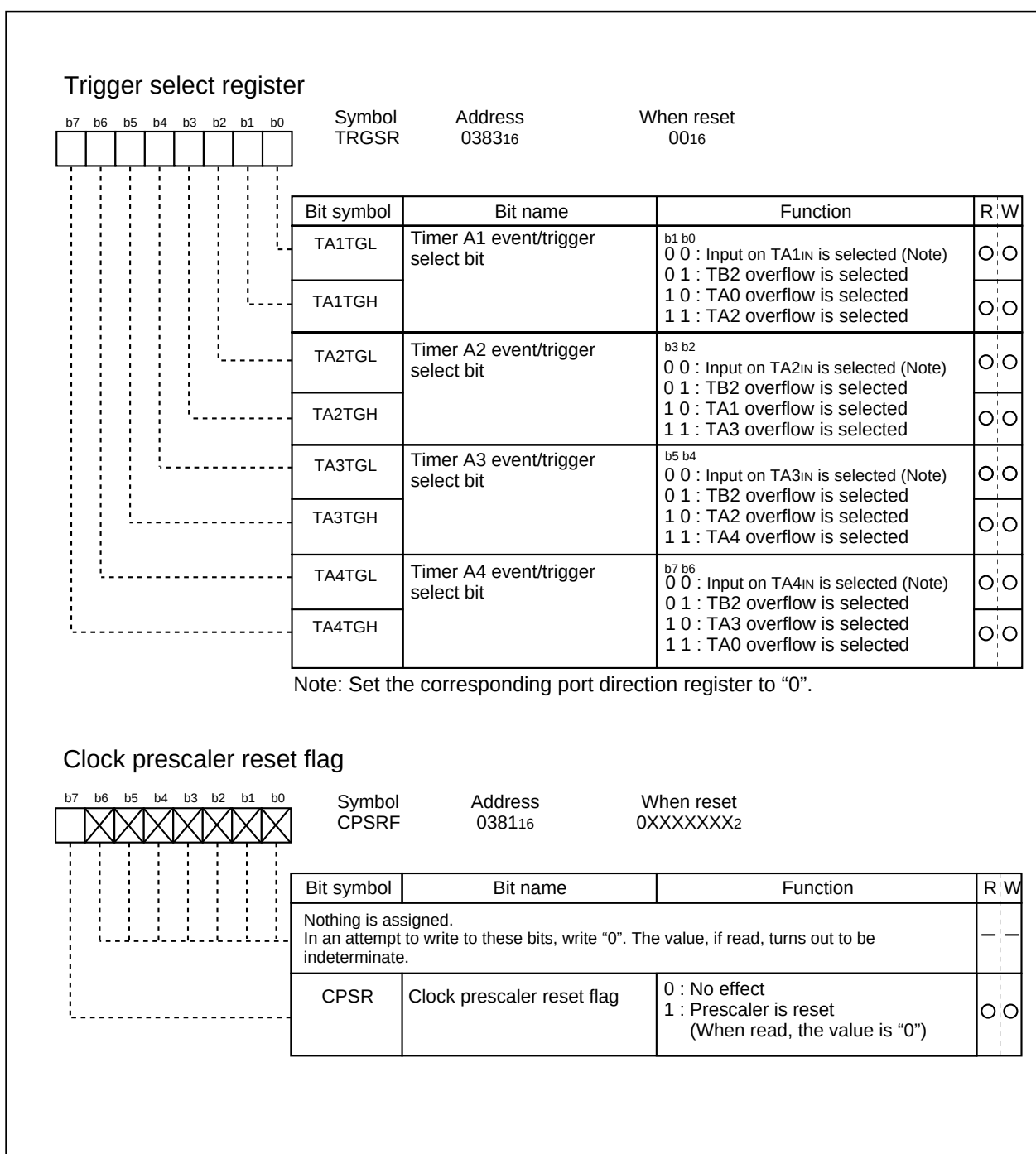


Figure 2.2.5. Timer A-related registers (4)

2.2.2 Operation of Timer A (timer mode)

In timer mode, choose functions from those listed in Table 2.2.1. Operations of the circled items are described below. Figure 2.2.6 shows the operation timing, and Figure 2.2.7 shows the set-up procedure.

Table 2.2.1. Chosen functions

Item	Set-up
Count source	☐ Internal count source ($f_1 / f_8 / f_{32} / f_{c32}$)
Pulse output function	☐ No pulses output
	☐ Pulses output
Gate function	☐ No gate function
	☐ Performs count only for the period in which the TAIN pin is at "L" level
	☐ Performs count only for the period in which the TAIN pin is at "H" level

- Operation
- (1) Setting the count start flag to "1" causes the counter to perform a down count on the count source.
 - (2) If an underflow occurs, the content of the reload register is reloaded, and the count continues. At this time, the timer Ai interrupt request bit goes to "1".
 - (3) Setting the count start flag to "0" causes the counter to hold its value and to stop.

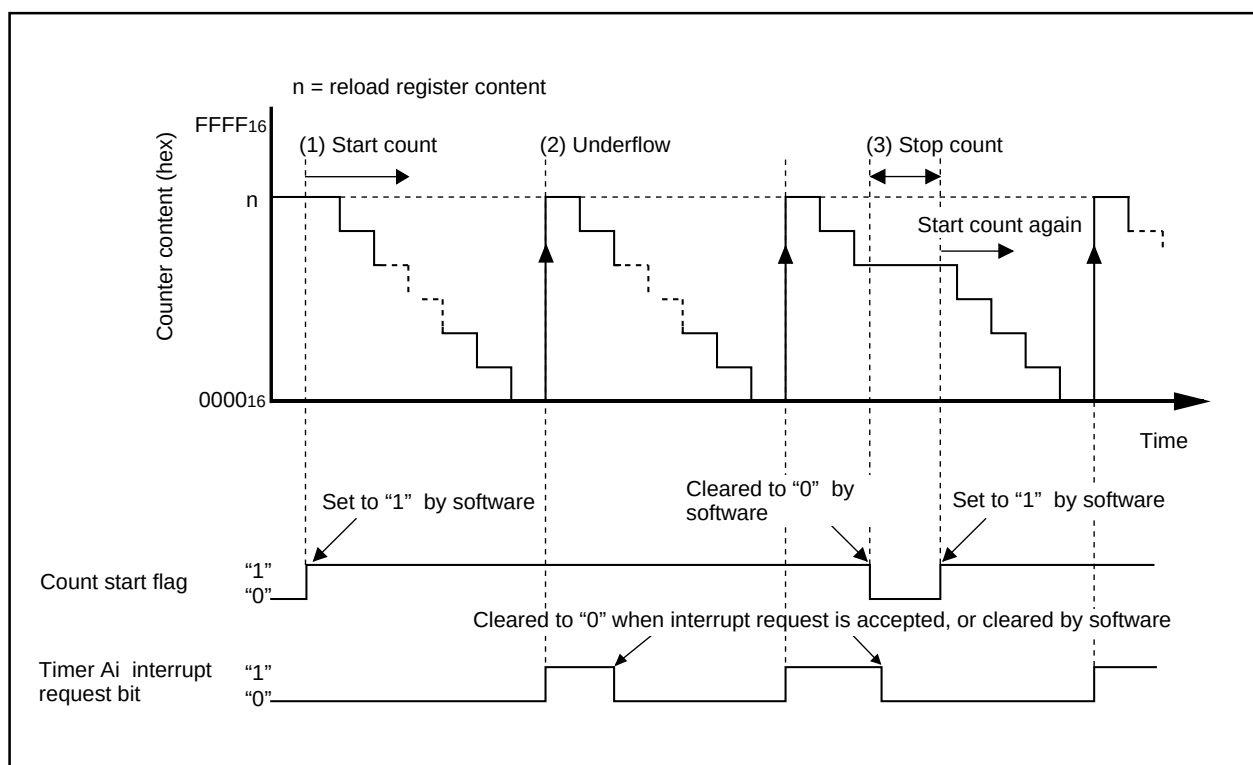
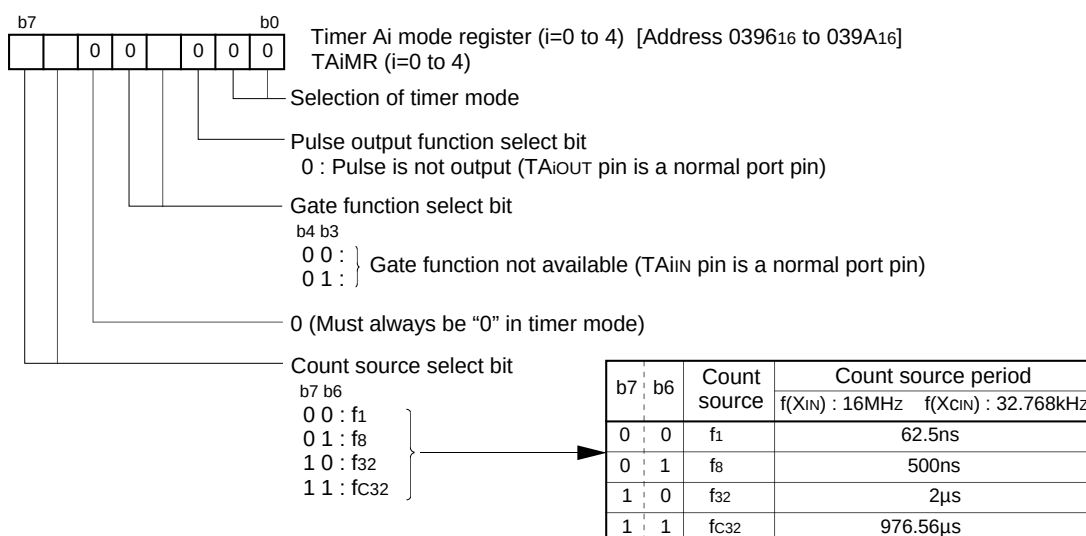
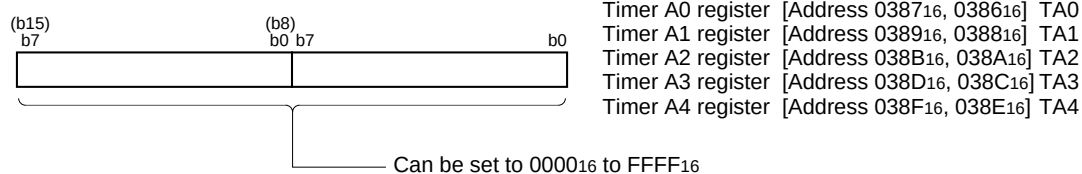


Figure 2.2.6. Operation timing of timer mode

Selecting timer mode and functions

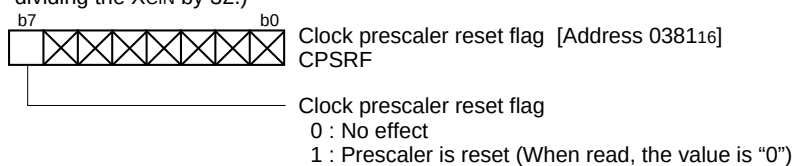


Setting counter value

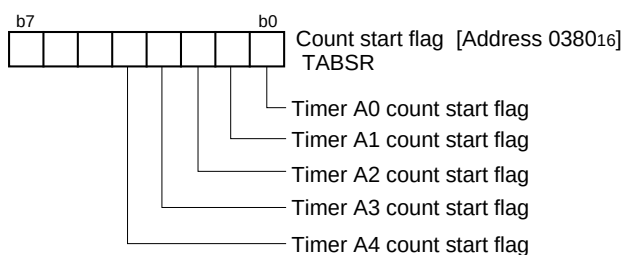


Setting clock prescaler reset flag

(This function is effective when f₃₂ is selected as the count source. Reset the prescaler for generating f₃₂ by dividing the X_{CIN} by 32.)



Setting count start flag



Start count

Figure 2.2.7. Set-up procedure of timer mode

2.2.3 Operation of Timer A (timer mode, gate function selected)

In timer mode, choose functions from those listed in Table 2.2.2. Operations of the circled items are described below. Figure 2.2.8 shows the operation timing, and Figure 2.2.9 shows the set-up procedure.

Table 2.2.2. Chooosed functions

Item	Set-up	
Count source	☐	Internal count source(f_1 / f_8 / f_{32} / f_{c32})
Pulse output function	☐	No pulses output
	☐	Pulses output
Gate function	☐	No gate function
	☐	Performs count only for the period in which the TAI _{IN} pin is at "L" level
	☐	Performs count only for the period in which the TAI _{IN} pin is at "H" level

- Operation
- (1) When the count start flag is set to "1" and the TAI_{IN} pin inputs at "H" level, the counter performs a down count on the count source.
 - (2) When the TAI_{IN} pin inputs at "L" level, the counter holds its value and stops.
 - (3) If an underflow occurs, the content of the reload register is reloaded and the count continues. At this time, the timer Ai interrupt request bit goes to "1".
 - (4) Setting the count start flag to "0" causes the counter to hold its value and to stop.

Note

- Make the pulse width of the signal input to the TAI_{IN} pin not less than two cycles of the count source.

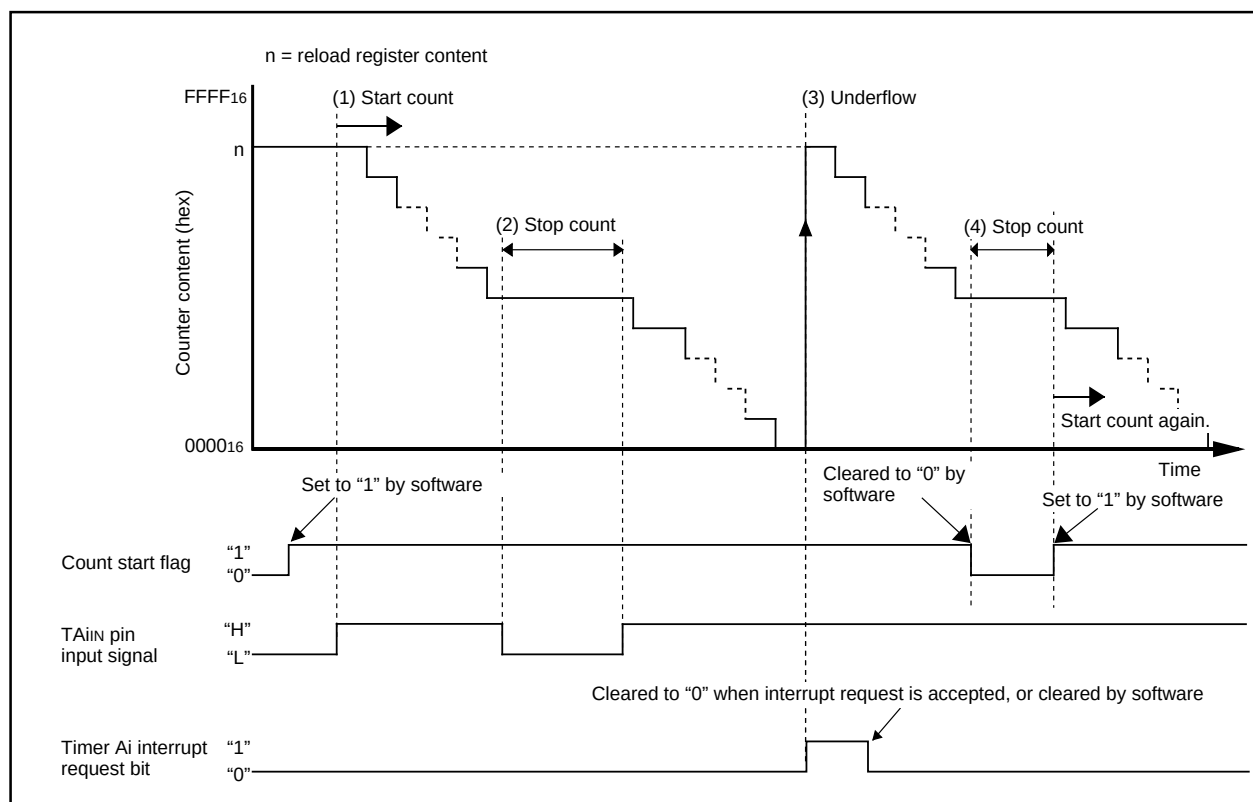
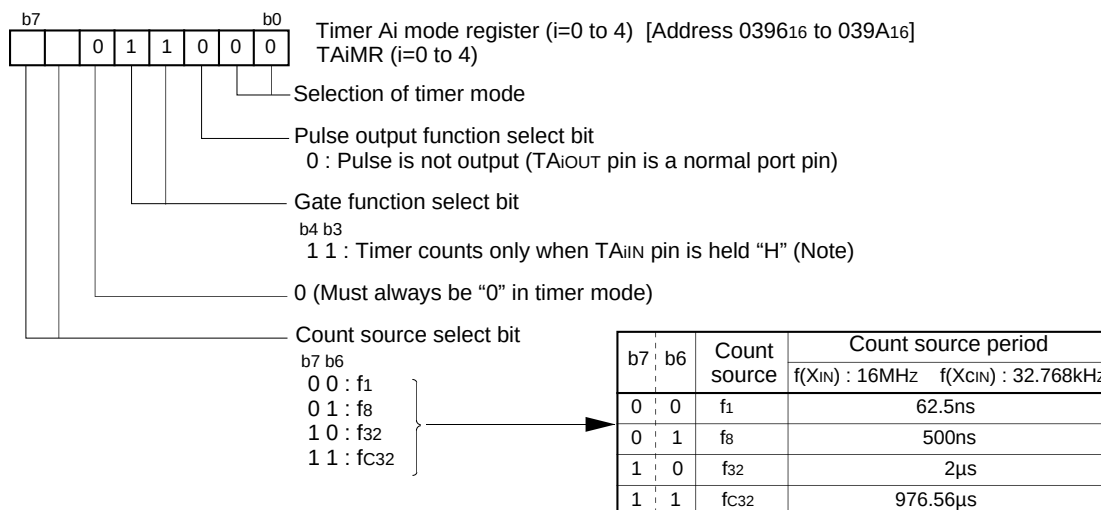


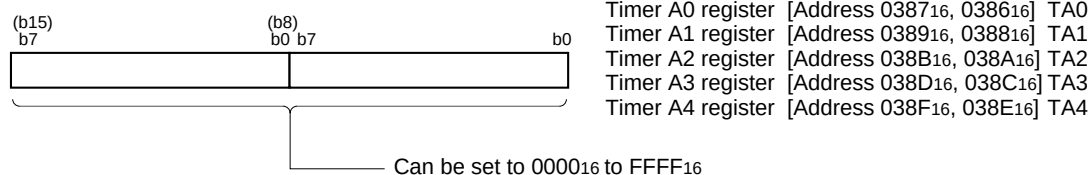
Figure 2.2.8. Operation timing of timer mode, gate function selected

Selecting timer mode and functions



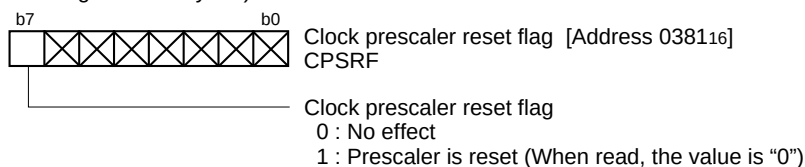
Note: Set the corresponding port direction register to "0".

Setting counter value

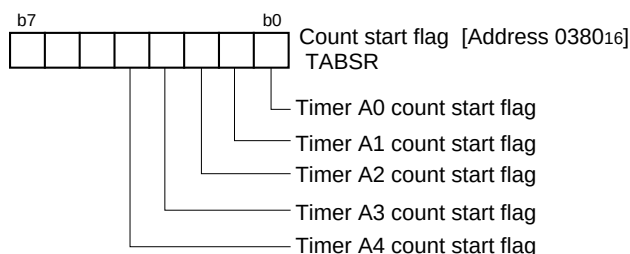


Setting clock prescaler reset flag

(This function is effective when f_{c32} is selected as the count source. Reset the prescaler for generating f_{c32} by dividing the X_{CIN} by 32.)



Setting count start flag



Start count

Figure 2.2.9. Set-up procedure of timer mode, gate function selected

2.2.4 Operation of Timer A (timer mode, pulse output function selected)

In timer mode, choose functions from those listed in Table 2.2.3. Operations of the circled items are described below. Figure 2.2.10 shows the operation timing, and Figure 2.2.11 shows the set-up procedure.

Table 2.2.3. Chosed functions

Item	Set-up	
Count source	O	Internal count source(f_1 / f_8 / f_{32} / f_{c32})
Pulse output function		No pulses output
	O	Pulses output
Gate function	O	No gate function
		Performs count only for the period in which the TAI _{IN} pin is at "L" level
		Performs count only for the period in which the TAI _{IN} pin is at "H" level

- Operation
- (1) Setting the count start flag to "1" causes the counter to perform a down count on the count source.
 - (2) If an underflow occurs, the content of the reload register is reloaded and the count continues. At this time, the timer Ai interrupt request bit goes to "1". Also, the output polarity of the TAI_{OUT} pin reverses.
 - (3) Setting the count start flag to "0" causes the counter to hold its value and to stop. Also, the TAI_{OUT} pin outputs an "L" level.

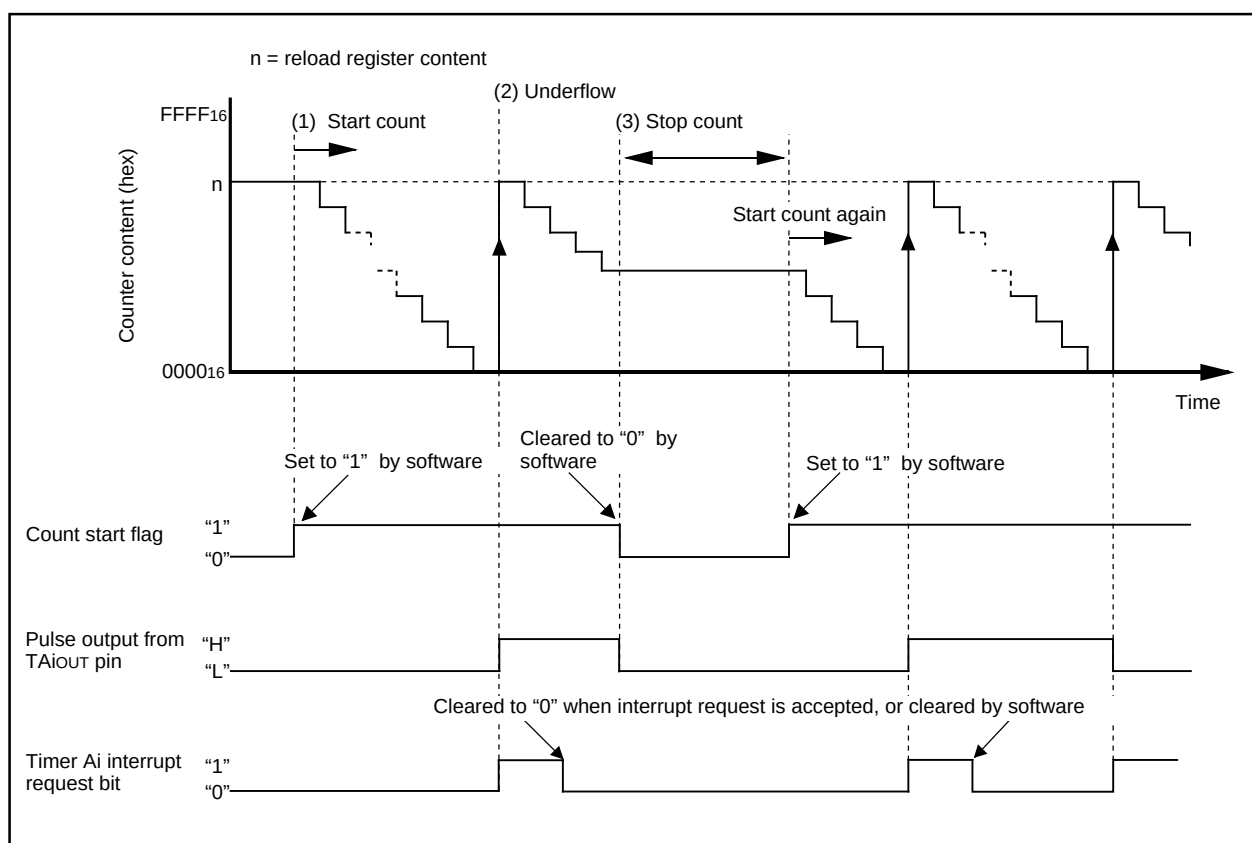
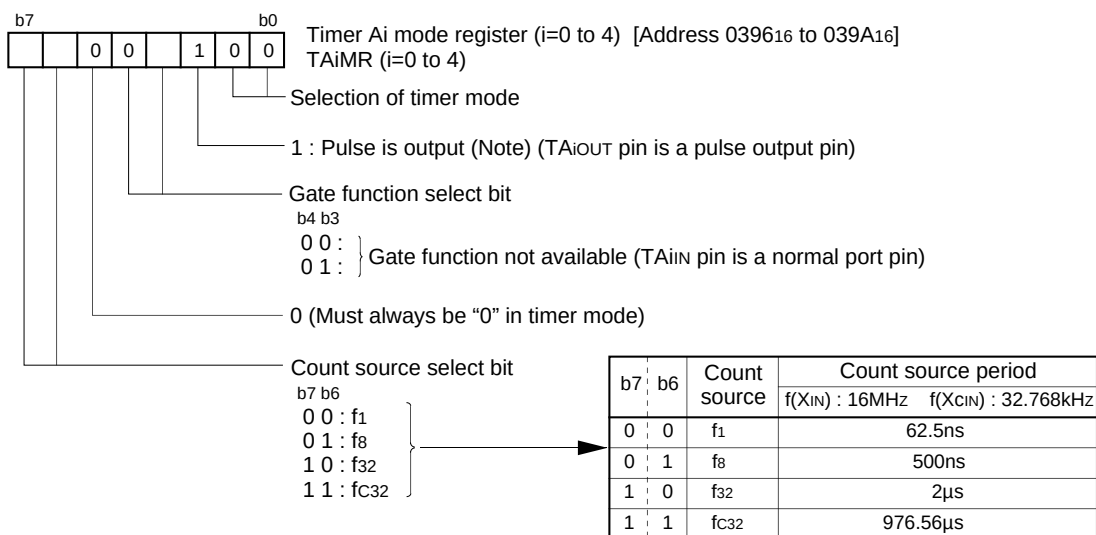


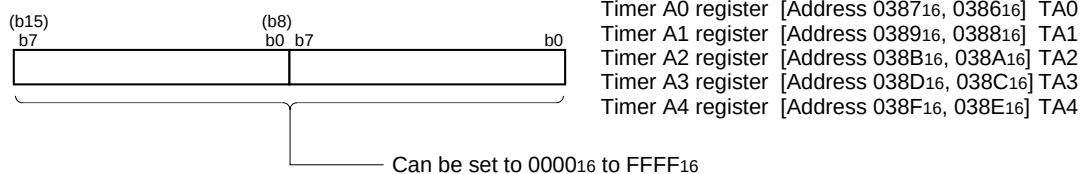
Figure 2.2.10. Operation timing of timer mode, pulse output function selected

Selecting timer mode and functions



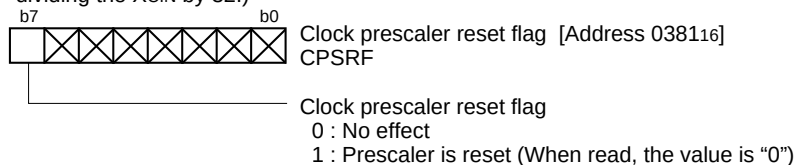
Note: The settings of the corresponding port register and port direction register are invalid.

Setting counter value

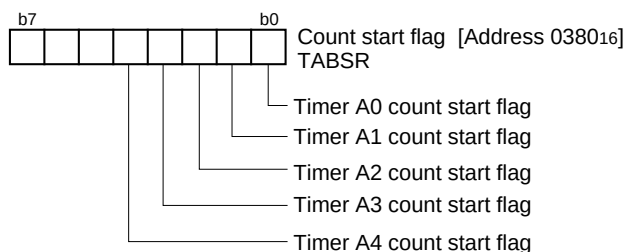


Setting clock prescaler reset flag

(This function is effective when f_{C32} is selected as the count source. Reset the prescaler for generating f_{C32} by dividing the X_{CIN} by 32.)



Setting count start flag



Start count

Figure 2.2.11. Set-up procedure of timer mode, pulse output function selected

2.2.5 Operation of Timer A (event counter mode, reload type selected)

In event counter mode, choose functions from those listed in Table 2.2.4. Operations of the circled items are described below. Figure 2.2.12 shows the operation timing, and Figure 2.2.13 shows the set-up procedure.

Table 2.2.4. Chosen functions

Item	Set-up		Item	Set-up	
Count source	○	Input signal to TAI _{IN} (counting falling edges)	Pulse output function	○	No pulses output
					Pulses output
		Input signal to TAI _{IN} (counting rising edges)	Count operation type	○	Reload type
					Free-run type
		Timer overflow (TB2/TA _j overflow)	Factor for switching between up and down	○	Content of up/down flag
					Input signal to TAI _{OUT}

Note: $j = i - 1$, but $j = 4$ when $i = 0$.

- Operation
- (1) Setting the count start flag to "1" causes the counter to count the falling edges of the count source.
 - (2) If an underflow occurs, the content of the reload register is reloaded, and the count continues. At this time, the timer Ai interrupt request bit goes to "1".
 - (3) If switching from an up count to a down count or vice versa while a count is in progress, the switch takes effect from the next effective edge of the count source.
 - (4) Setting the count start flag to "0" causes the counter to hold its value and to stop.
 - (5) If an overflow occurs, the content of the reload register is reloaded, and the count continues. At this time, the timer Ai interrupt request bit goes to "1".

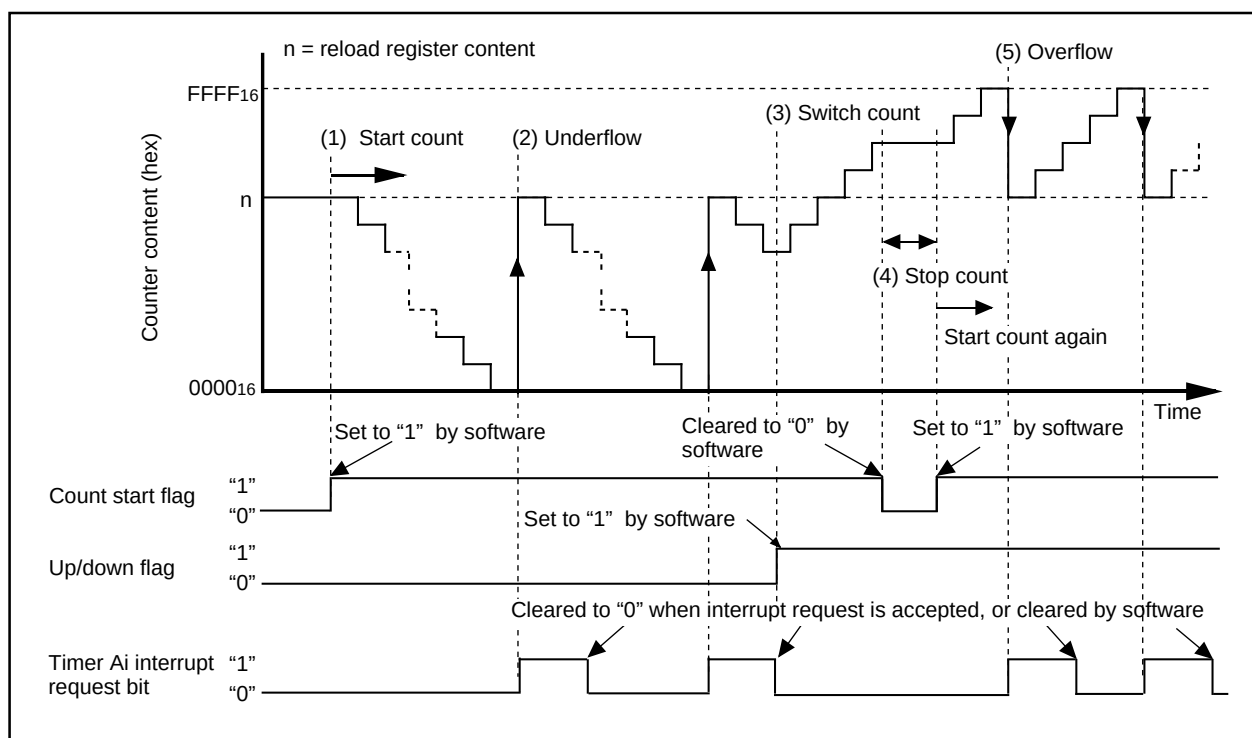


Figure 2.2.12. Operation timing of event counter mode, reload type selected

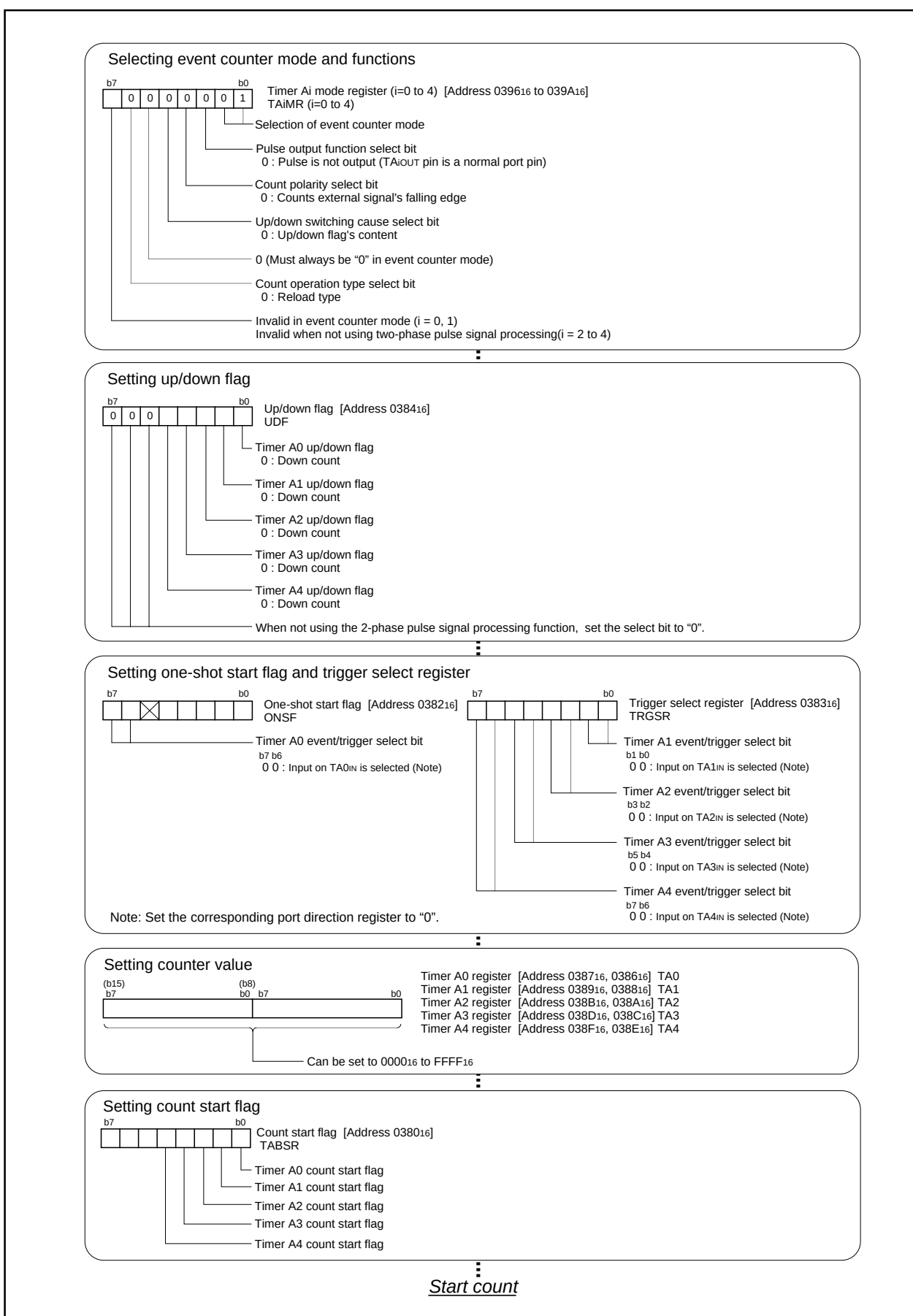


Figure 2.2.13. Set-up procedure of event counter mode, reload type selected

2.2.6 Operation of Timer A (event counter mode, free run type selected)

In event counter mode, choose functions from those listed in Table 2.2.5. Operations of the circled items are described below. Figure 2.2.14 shows the operation timing, and Figure 2.2.15 shows the set-up procedure.

Table 2.2.5. Chosed functions

Item	Set-up		Item	Set-up	
Count source	○	Input signal to TAI _{IN} (counting falling edges)	Pulse output function	○	No pulses output
		Input signal to TAI _{IN} (counting rising edges)			Pulses output
		Timer overflow (TB2/TA _j overflow)	Count operation type		Reload type
				○	Free-run type
			Factor for switching between up and down	○	Content of up/down flag
					Input signal to TAI _{OUT}

Note: $j = i - 1$, but $j = 4$ when $i = 0$

- Operation
- (1) Setting the count start flag to "1" causes the counter to count the falling edges of the count source.
 - (2) Even if an underflow occurs, the content of the reload register is not reloaded, but the count continues. At this time, the timer Ai interrupt request bit goes to "1".
 - (3) If switching from an up count to a down count or vice versa while a count is in progress, the switch takes effect from the next effective edge of the count source.
 - (4) Even if an overflow occurs, the content of the reload register is not reloaded, but the count continues. At this time, the timer Ai interrupt request bit goes to "1".

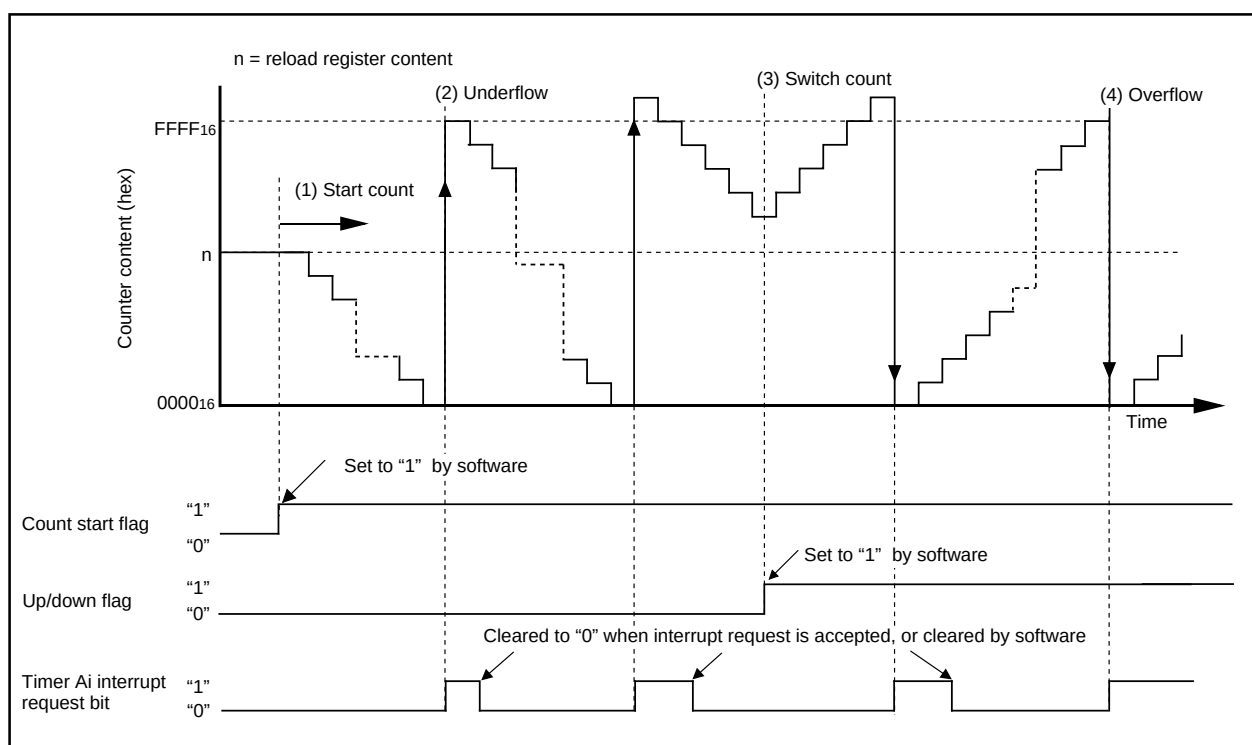


Figure 2.2.14. Operation timing of event counter mode, free run type selected

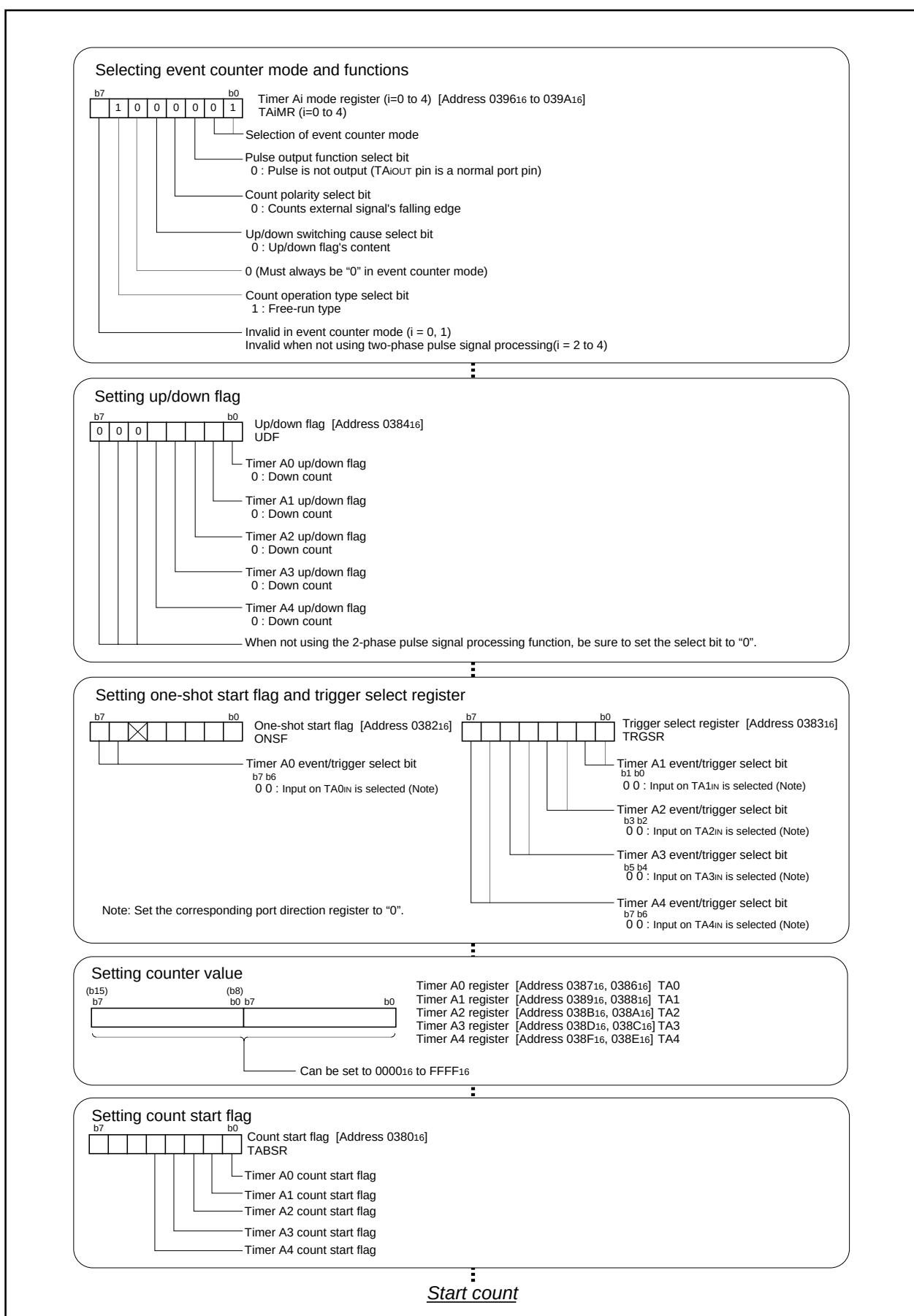


Figure 2.2.15. Set-up procedure of event counter mode, free run type selected

2.2.7 Operation of timer A (2-phase pulse signal process in event counter mode, normal mode selected)

In processing 2-phase pulse signals in event counter mode, choose functions from those listed in Table 2.2.6. Operations of the circled items are described below. Figure 2.2.16 shows the operation timing, and Figure 2.2.17 shows the set-up procedure.

Table 2.2.6. Chosen functions

Item	Set-up
Count operation type	Reload type
	☐ Free run type
2-phase pulses process (Note)	☐ Normal processing
	4-multiplication processing

Note: Timer A3 alone can be selected. Timer A2 is solely used for normal processes, and timer A4 is solely used for 4 multiplication processes.

- Operation
- (1) Setting the count start flag to "1" causes the counter to count effective edges of the count source.
 - (2) Even if an underflow occurs, the content of the reload register is not reloaded, but the count continues. At this time, the timer Ai interrupt request bit goes to "1".
 - (3) Even if an overflow occurs, the content of the reload register is not reloaded, but the count continues. At this time, the timer Ai interrupt request bit goes to "1".

- Note
- The up count or down count conditions are as follows:
If a rising edge is present at the TAIIN pin when the input signal level to the TAIOUT pin is "H", an up count is performed.
If a falling edge is present at the TAIIN pin when the input signal level to the TAIOUT pin is "H", a down count is performed.

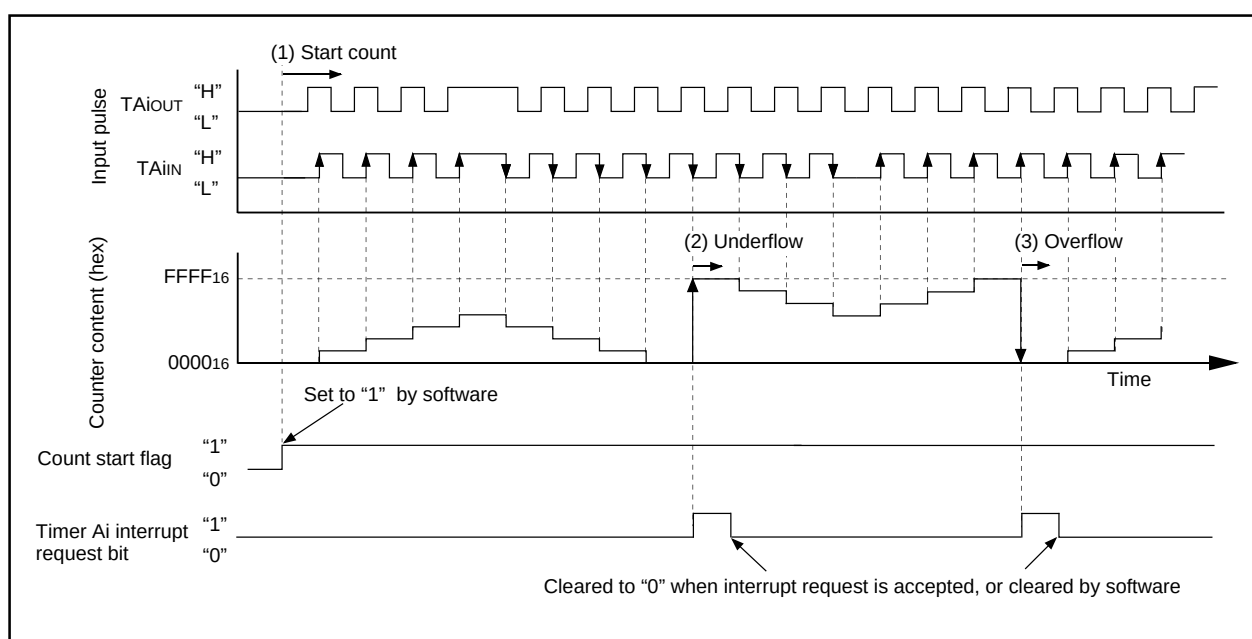
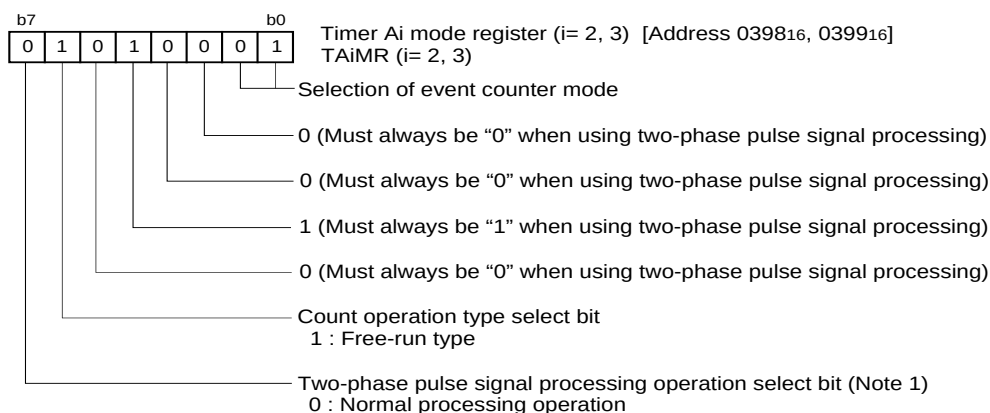


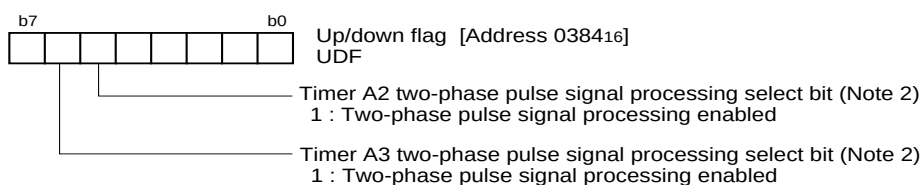
Figure 2.2.16. Operation timing of 2-phase pulse signal process in event counter mode, normal mode selected

Selecting event counter mode and functions



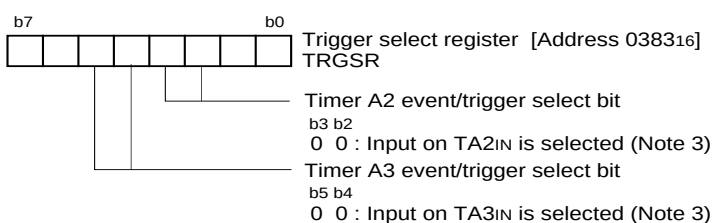
Note 1: This bit is valid for timer A3 mode register. For timer A2 mode register, this bit can be "0" or "1".

Setting two-phase pulse signal processing select bit



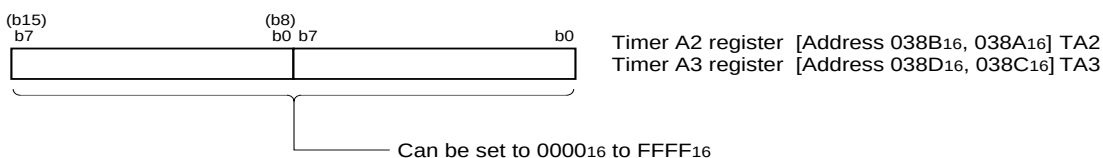
Note 2: Set the TAIIN, TAIOUT corresponding port direction register to "0".

Setting trigger select register

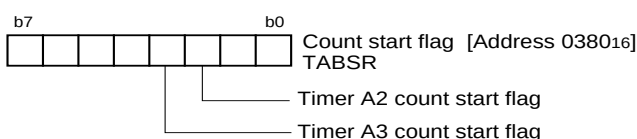


Note 3: Set the corresponding port direction register to "0".

Setting counter value



Setting count start flag



Start count

Figure 2.2.17. Set-up procedure of 2-phase pulse signal process in event counter mode, normal mode selected

2.2.8 Operation of timer A (2-phase pulse signal process in event counter mode, multiply-by-4 mode selected)

In processing 2-phase pulse signals in event counter mode, choose functions from those listed in Table 2.2.7. Operations of the circled items are described below. Figure 2.2.18 shows the operation timing, and Figure 2.2.19 shows the set-up procedure.

Table 2.2.7. Chosed functions

Item	Set-up		Item	Set-up	
Count operation type		Reload type	Processing 2 phase pulses (Note)		Normal processing
	○	Free run type		○	4-multiplication processing

Note: Timer A3 alone can be selected. Timer A2 is solely used for normal processes, and timer A4 is solely used for 4-multiplication processes.

- Operation
- (1) Setting the count start flag to "1" causes the counter to count effective edges of the count source.
 - (2) Even if an underflow occurs, the content of the reload register is not reloaded, but the count continues. At this time, the interrupt request bit goes to "1".
 - (3) Even if an overflow occurs, the content of the reload register is not reloaded, but the count continues. At this time, the interrupt request bit goes to "1".

Note • The up count or down count conditions are as follows:

Table 2.2.8. The up count or down count conditions

	Input signal to the TAIOUT pin	Input signal to the TAIIN pin		Input signal to the TAIOUT pin	Input signal to the TAIIN pin
Up count	"H" level	Rising	Down count	"H" level	Falling
	"L" level	Falling		"L" level	Rising
	Rising	"L" level		Rising	"H" level
	Falling	"H" level		Falling	"L" level

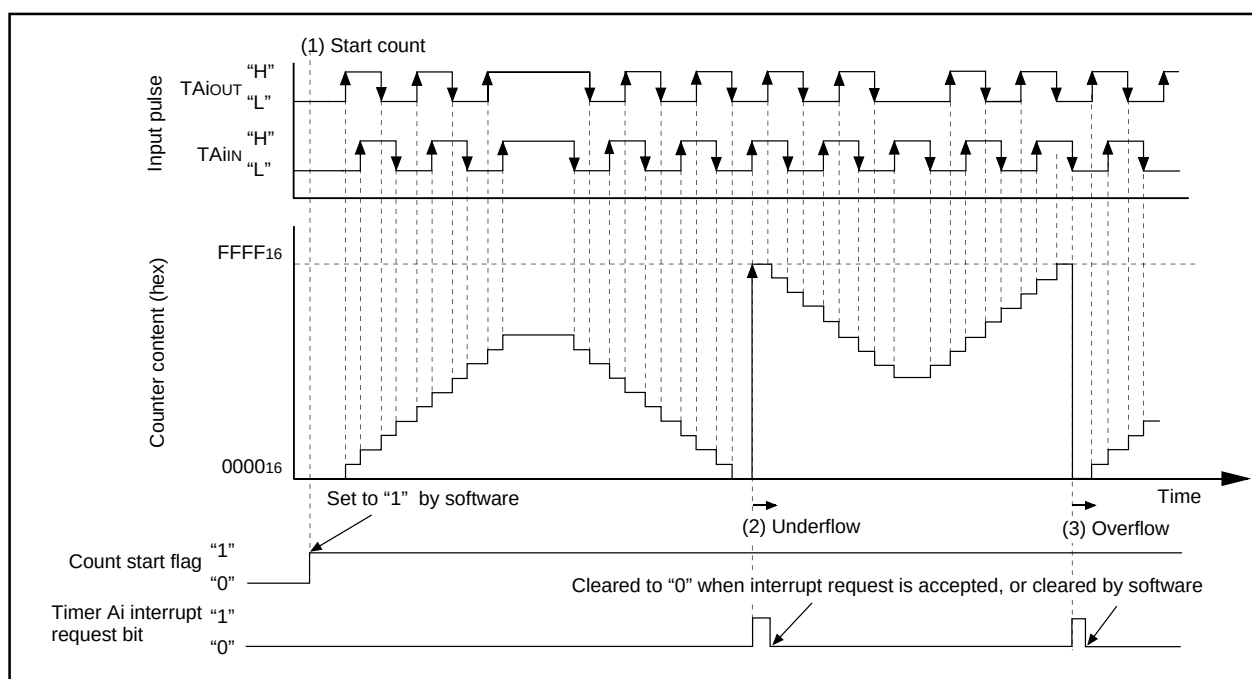
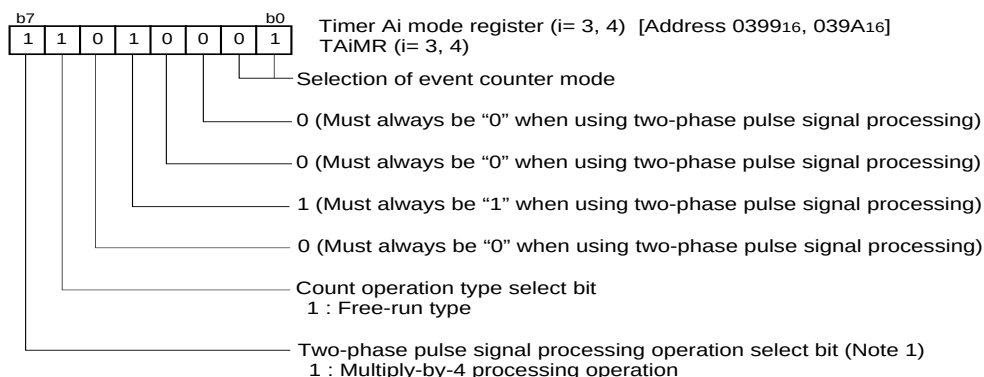


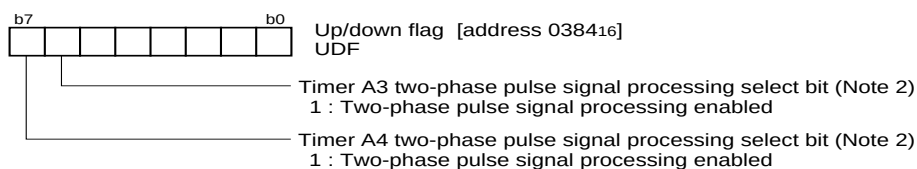
Figure 2.2.18. Operation timing of 2-phase pulse signal process in event counter mode, multiply-by-4 mode selected

Selecting event counter mode and functions



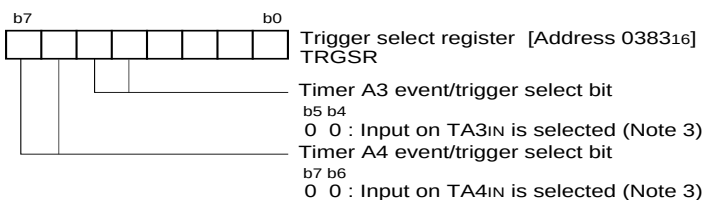
Note 1: This bit is valid for timer A3 mode register. For timer A4 mode register, this bit can be "0" or "1".

Setting two-phase pulse signal processing select bit



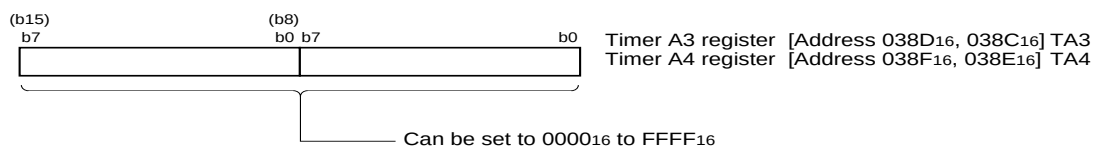
Note 2: Set the TAIIN, TAIOUT corresponding port direction register to "0".

Setting trigger select register

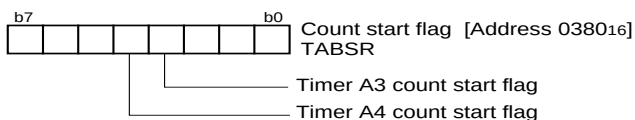


Note 3: Set the corresponding port direction register to "0".

Setting counter value



Setting count start flag



Start count

Figure 2.2.19. Set-up procedure of 2-phase pulse signal process in event counter mode, multiply-by-4 mode selected

2.2.9 Operation of Timer A (one-shot timer mode)

In one-shot timer mode, choose functions from those listed in Table 2.2.9. Operations of the circled items are described below. Figure 2.2.20 shows the operation timing, and Figure 2.2.21 shows the set-up procedure.

Table 2.2.9. Chosed functions

Item	Set-up
Count source	○ Internal count source ($f_1 / f_8 / f_{32} / f_{c32}$)
Pulse output function	No pulses output
	○ Pulses output
Count start condition	External trigger input (falling edge of input signal to the TAIIN pin)
	External trigger input (rising edge of input signal to the TAIIN pin)
	Timer overflow (TB2/TAj/TAK overflow)
	○ Writing "1" to the one-shot start flag

Note: $j = i - 1$, but $j = 4$ when $i = 0$; $k = i + 1$, but $k = 0$ when $i = 4$.

- Operation
- (1) Setting the one-shot start flag to "1" with the count start flag set to "1" causes the counter to perform a down count on the count source. At this time, the TAIOUT pin outputs an "H" level.
 - (2) The instant the value of the counter becomes "0000₁₆", the TAIOUT pin outputs an "L" level, and the counter reloads the content of the reload register and stops counting. At this time, the timer Ai interrupt request bit goes to "1".
 - (3) If a trigger occurs while a count is in progress, the counter reloads the value in the reload register again and continues counting. The reload timing is in step with the next count source input after the trigger.
 - (4) Setting the count start flag to "0" causes the counter to stop and to reload the content of the reload register. Also, the TAIOUT pin outputs an "L" level. At this time, the timer Ai interrupt request bit goes to "1".

- Note
- When the timer Ai register is set to "0000₁₆", the counter does not operate and the timer Ai interrupt request is not generated. When the pulse is set to output, the pulse does not output from the TAIOUT pin.

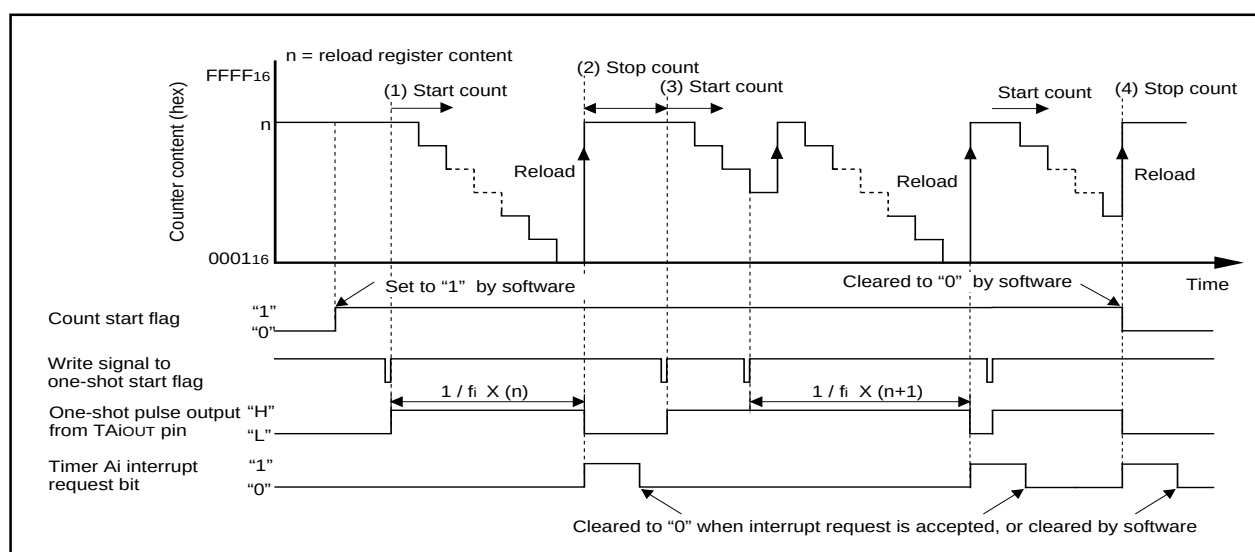


Figure 2.2.20. Operation timing of one-shot mode

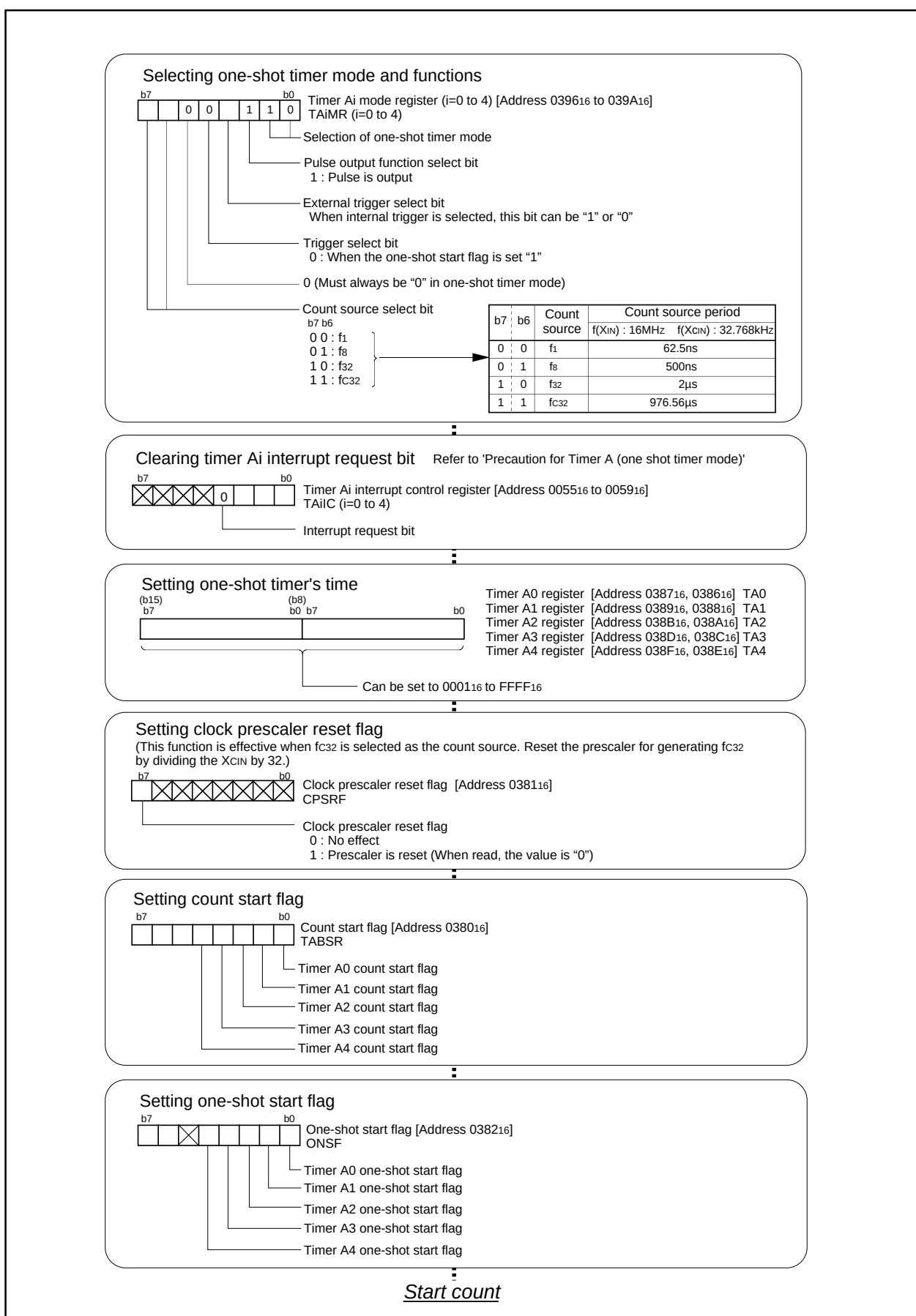


Figure 2.2.21. Set-up procedure of one-shot mode

2.2.10 Operation of Timer A (one-shot timer mode, external trigger selected)

In one-shot timer mode, choose functions from those listed in Table 2.2.10. Operations of the circled items are described below. Figure 2.2.22 shows the operation timing, and Figure 2.2.23 shows the set-up procedure.

Table 2.2.10. Chosed functions

Item	Set-up
Count source	○ Internal count source ($f_1 / f_8 / f_{32} / f_{c32}$)
Pulse output function	No pulses output
	○ Pulses output
Count start condition	External trigger input (falling edge of input signal to the TAI _{IN} pin)
	○ External trigger input (rising edge of input signal to the TAI _{IN} pin)
	Timer overflow (TB2/TA _j /TA _k overflow)
	Writing "1" to the one-shot start flag

Note: $j = i - 1$, but $j = 4$ when $i = 0$; $k = i + 1$, but $k = 0$ when $i = 4$.

- Operation
- (1) If the TAI_{IN} pin input level changes from "L" to "H" with the count start flag set to "1", the counter performs a down count on the count source. At this time, the TAI_{OUT} pin output level goes to "H" level.
 - (2) If the value of the counter becomes "0000₁₆", the TAI_{OUT} pin outputs an "L" level, and the counter reloads the content of the reload register and stops counting. At this time, the timer Ai interrupt request bit goes to "1".
 - (3) If a trigger occurs while a count is in progress, the counter reloads the value of the reload register again and continues counting. The reload timing is in step with the next count source input after the trigger.
 - (4) Setting the count start flag to "0" causes the counter to stop and to reload the content of the reload register. Also, the TAI_{OUT} pin outputs an "L" level. At this time, the timer Ai interrupt request bit goes to "1".

- Note
- When the timer Ai register is set to "0000₁₆", the counter does not operate and the timer Ai interrupt request is not generated. When the pulse is set to output, the pulse does not output from the TAI_{OUT} pin.

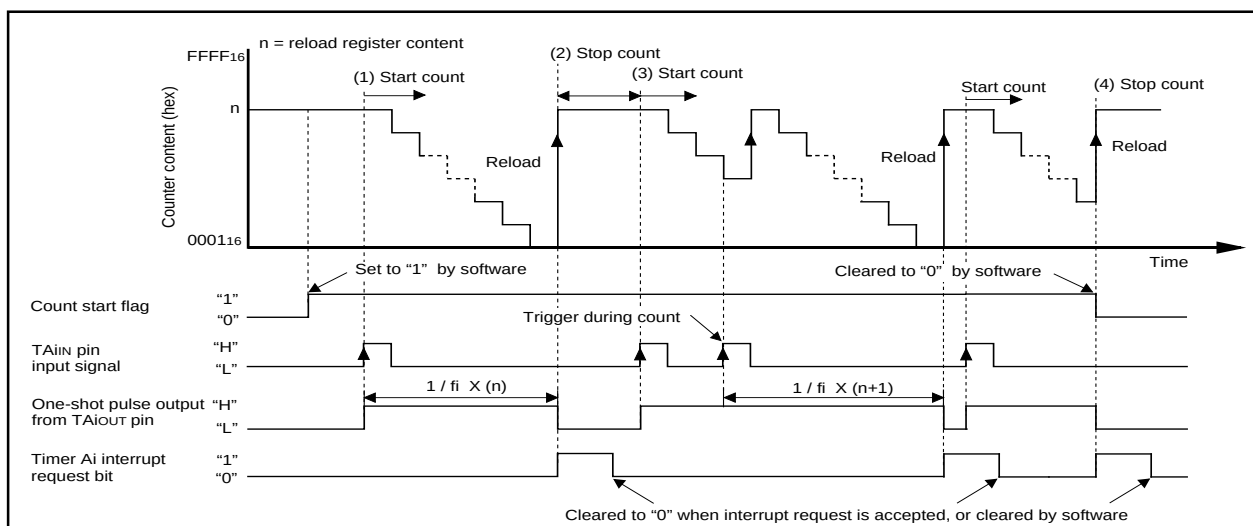


Figure 2.2.22. Operation timing of one-shot mode, external trigger selected

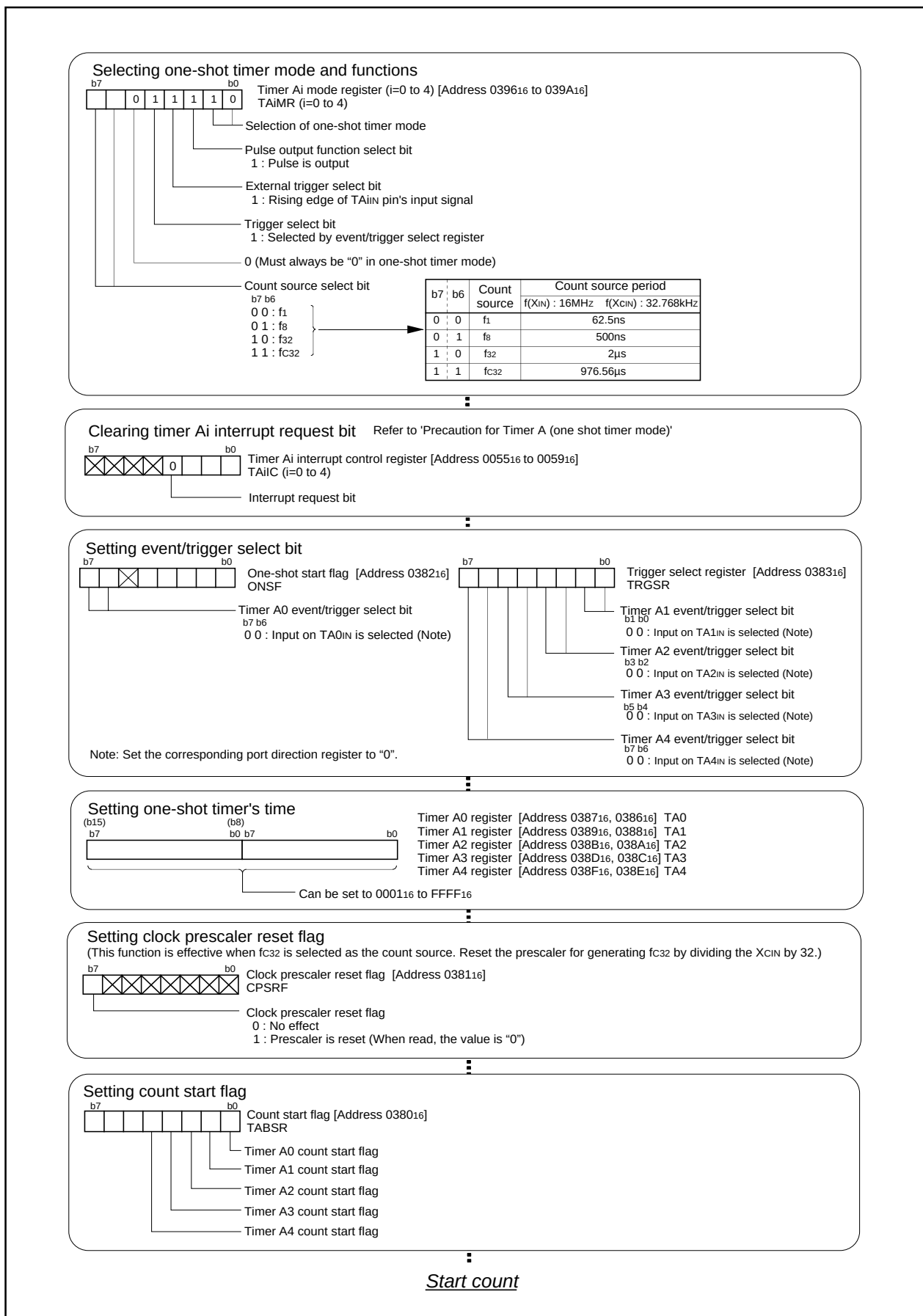


Figure 2.2.23. Set-up procedure of one-shot mode, external trigger selected

2.2.11 Operation of Timer A (pulse width modulation mode, 16-bit PWM mode selected)

In pulse width modulation mode, choose functions from those listed in Table 2.2.11. Operations of the circled items are described below. Figure 2.2.24 shows the operation timing, and Figure 2.2.25 shows the set-up procedure.

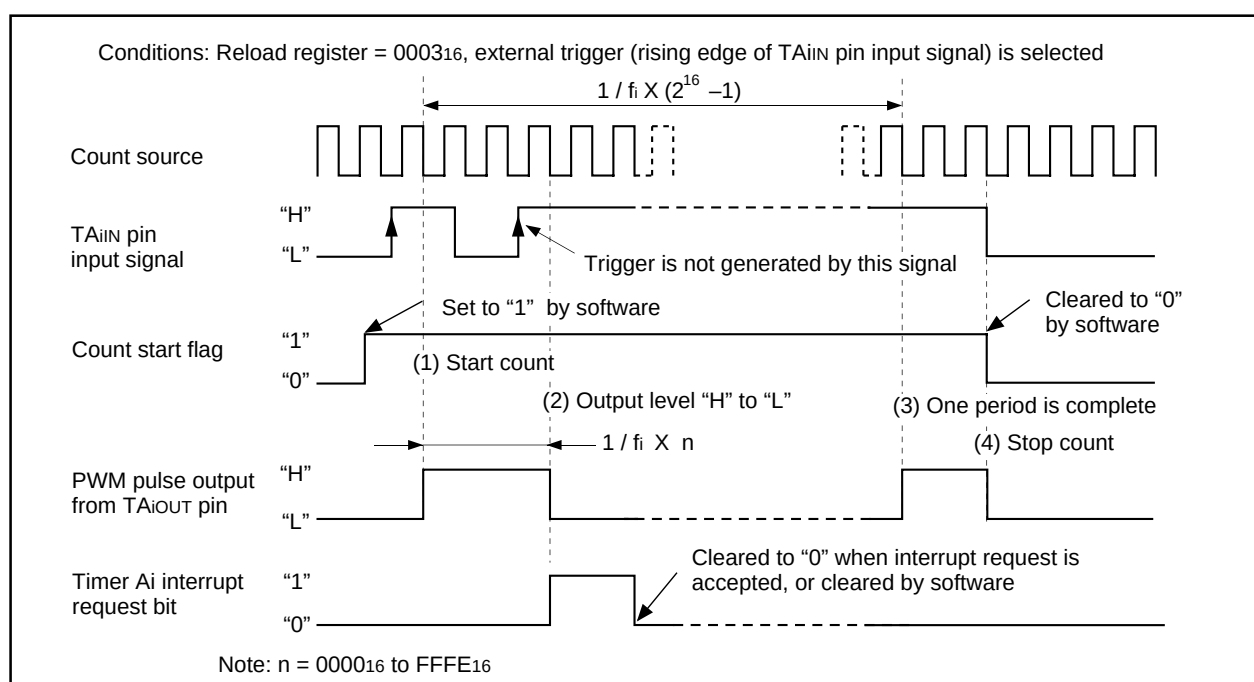
Table 2.2.11. Chosed functions

Item	Set-up	
Count source	☐	Internal count source (f_1 / f_8 / f_{32} / f_{c32})
PWM mode	☐	16-bit PWM
	☐	8-bit PWM
Count start condition	☐	External trigger input (falling edge of input signal to the TAIIN pin)
	☐	External trigger input (rising edge of input signal to the TAIIN pin)
	☐	Timer overflow (TB2/TAJ/TAK overflow)

Note: $j = i - 1$, but $j = 4$ when $i = 0$; $k = i + 1$, but $k = 0$ when $i = 4$.

- Operation
- (1) If the TAIIN pin input level changes from "L" to "H" with the count start flag set to "1", the counter performs a down count on the count source. Also, the TAIOUT pin outputs an "H" level.
 - (2) The TAIOUT pin output level changes from "H" to "L" when a set time period elapses. At this time, the timer Ai interrupt request bit goes to "1".
 - (3) The counter reloads the content of the reload register every time PWM pulses are output for one cycle, and continues counting.
 - (4) Setting the count start flag to "0" causes the counter to hold its value and to stop. Also, the TAIOUT outputs an "L" level.

- Note
- The period of PWM pulses becomes $(2^{16} - 1)/f_i$, and the "H" level pulse width becomes n/f_i . If the timer Ai register is set to "0000₁₆", the pulse width modulator does not work, and the TAIOUT pin outputs "L" level, therefore the timer Ai interrupt request is not generated.
(f_i : frequency of the count source $f_1, f_8, f_{32}, f_{c32}$; n : value of the timer)

**Figure 2.2.24. Operation timing of pulse width modulation mode, 16-bit PWM mode selected**

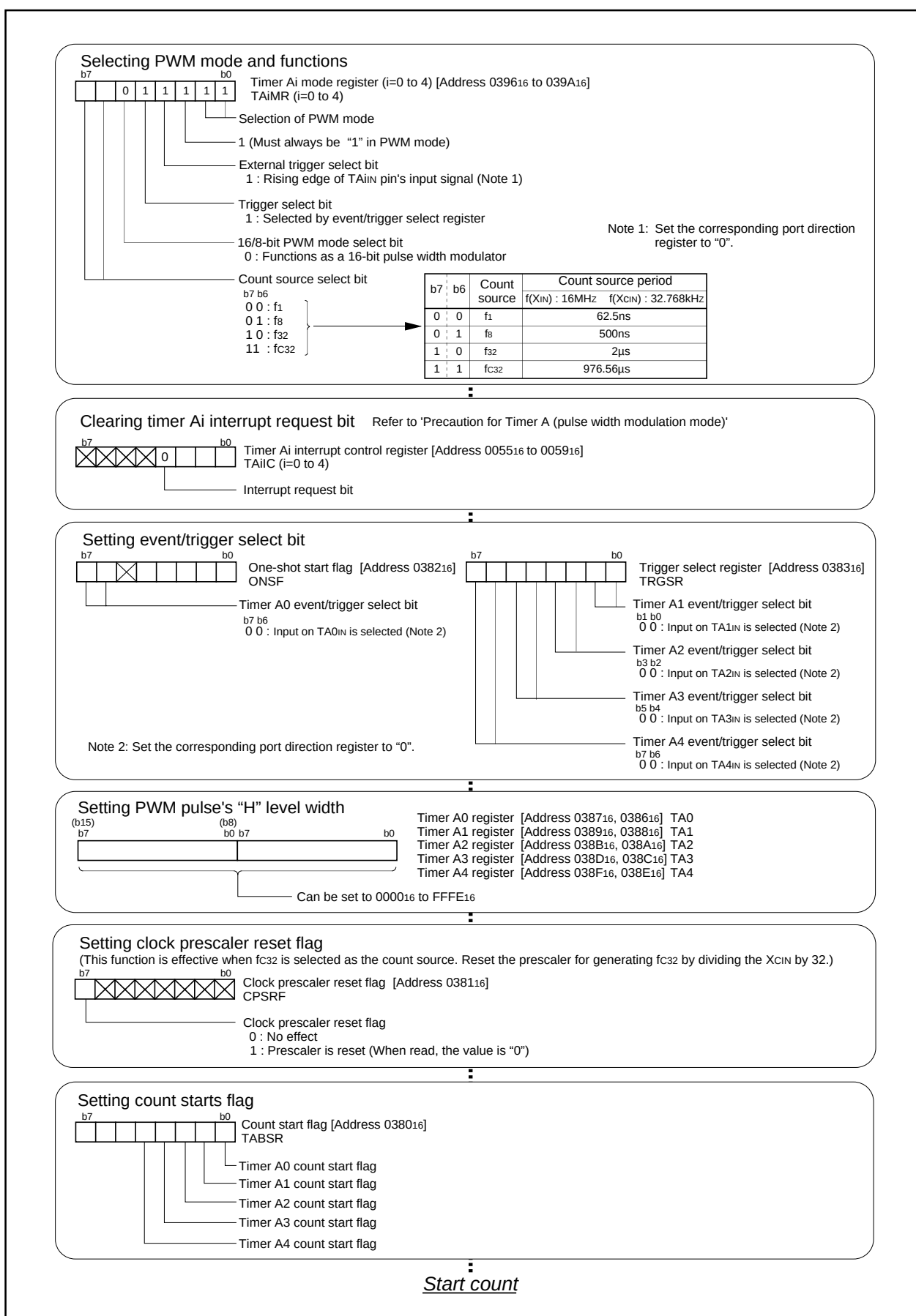


Figure 2.2.25. Set-up procedure of pulse width modulation mode, 16-bit PWM mode selected

2.2.12 Operation of Timer A (pulse width modulation mode, 8-bit PWM mode selected)

In pulse width modulation mode, choose functions from those listed in Table 2.2.12. Operations of the circled items are described below. Figure 2.2.26 shows the operation timing, and Figure 2.2.27 shows the set-up procedure.

Table 2.2.12. Chooosed functions

Item	Set-up
Count source	○ Internal count source (f_1 / f_8 / f_{32} / f_{c32})
PWM mode	16-bit PWM
	○ 8-bit PWM
Count start condition	○ External trigger input (falling edge of input signal to the TAI _{IN} pin)
	External trigger input (rising edge of input signal to the TAI _{IN} pin)
	Timer overflow (TB2/TAJ/TAK overflow)

Note: $j = i - 1$, but $j = 4$ when $i = 0$; $k = i + 1$, but $k = 0$ when $i = 4$.

- Operation
- (1) If the TAI_{IN} pin input level changes from "H" to "L" with the count start flag set to "1", the counter performs a down count on the count source. Also, the TAI_{OUT} pin outputs an "H" level.
 - (2) The TAI_{OUT} pin output level changes from "H" to "L" when a set time period elapses. At this time, the timer Ai interrupt request bit goes to "1".
 - (3) The counter reloads the content of the reload register every time PWM pulses are output for one cycle, and continues counting.
 - (4) Setting the count start flag to "0" causes the counter to hold its value and to stop. Also, the TAI_{OUT} pin outputs an "L" level.

- Note
- The period of PWM pulses becomes $(m + 1) \times (2^8 - 1) / f_i$, and the "H" level pulse width becomes $n \times (m + 1) / f_i$. If "0016" is set in the eight higher-order bits of the timer Ai register, the pulse width modulator does not work, and the TAI_{OUT} pin outputs "L" level, therefore the timer Ai interrupt request is not generated.
(f_i : frequency of the count source $f_1, f_8, f_{32}, f_{c32}$; n : value of the timer)
 - When a trigger is generated, the TAI_{OUT} pin outputs "L" level of same amplitude as "H" level of the set PWM pulse, after which it starts PWM pulse output.

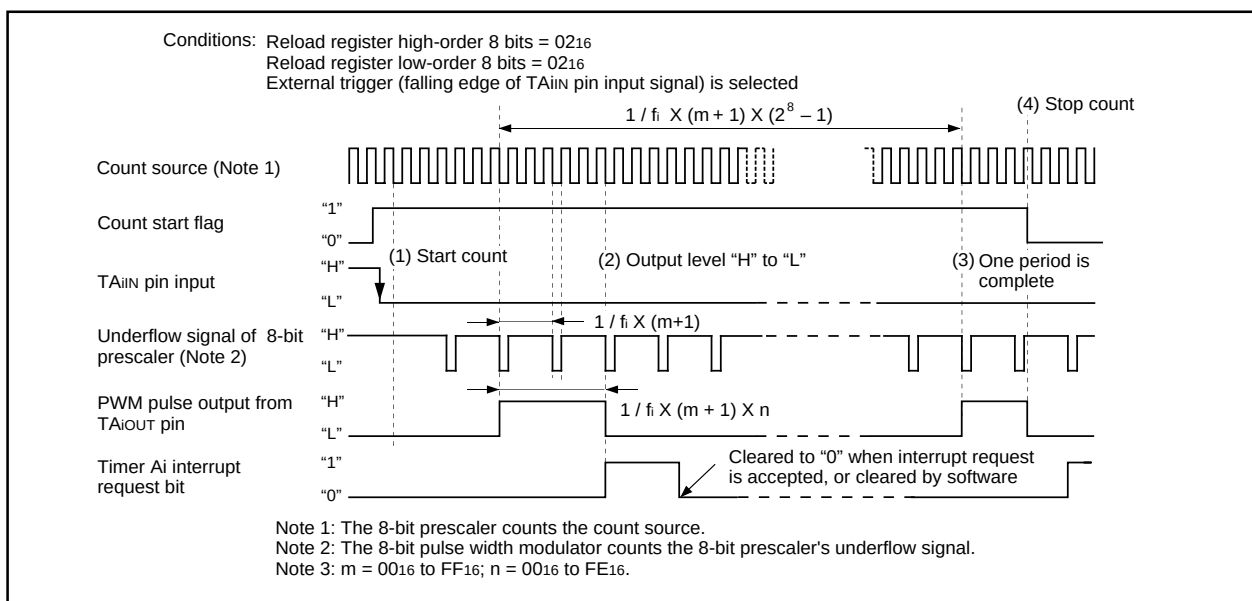


Figure 2.2.26. Operation timing of pulse width modulation mode, with 8-bit PWM mode selected

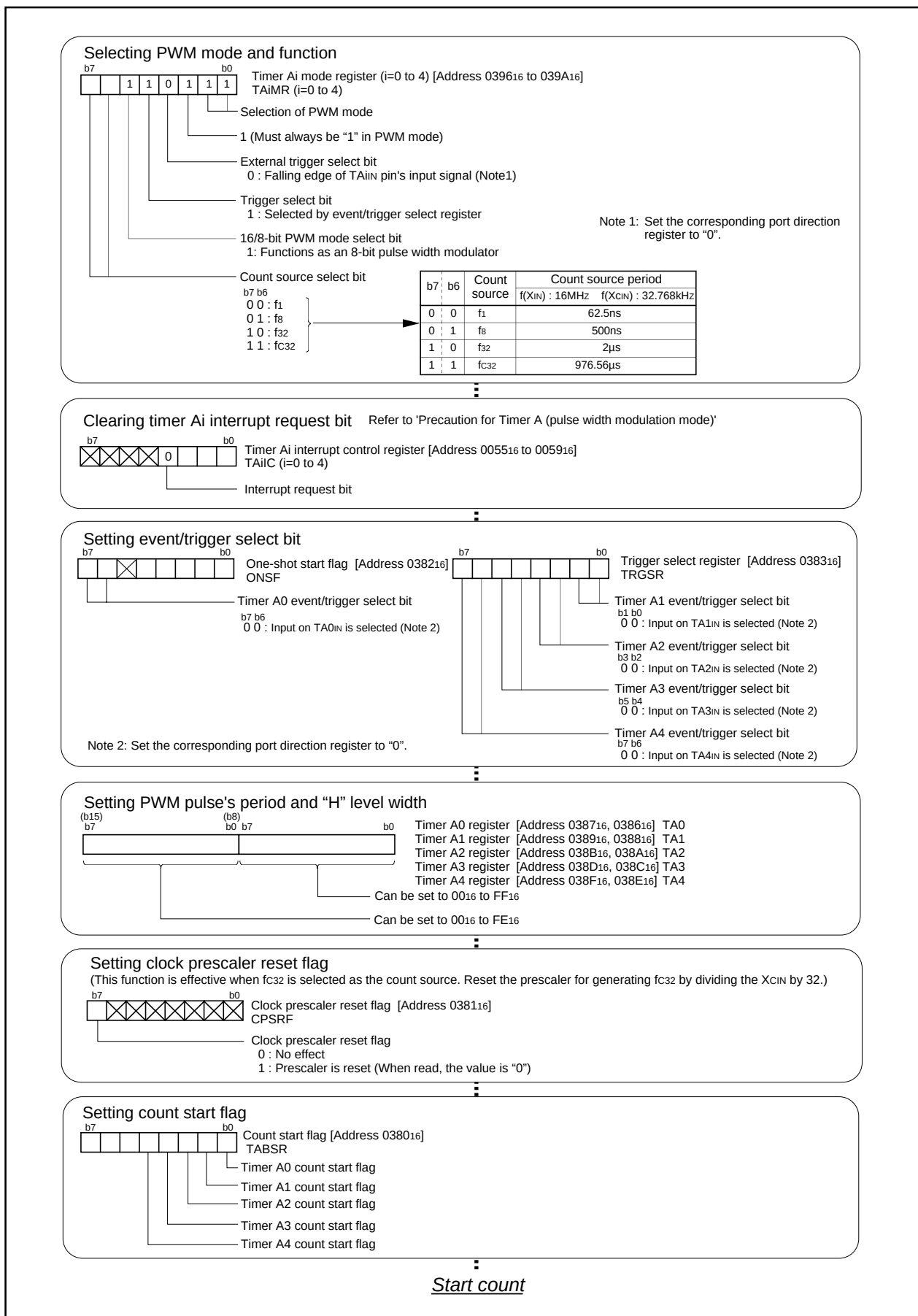
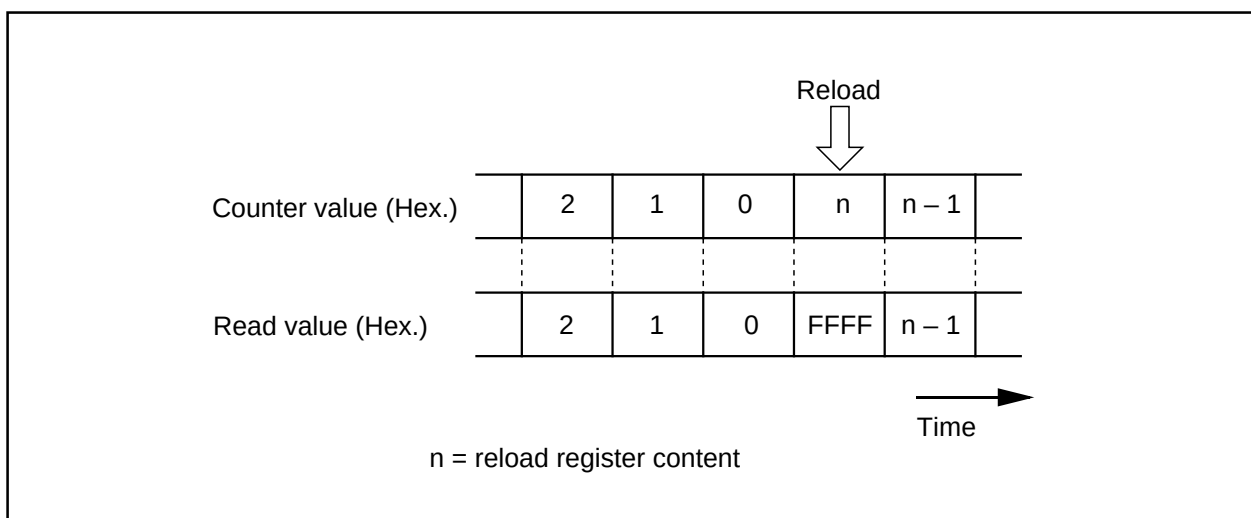


Figure 2.2.27. Set-up procedure of pulse width modulation mode, 8-bit PWM mode selected

2.2.13 Precautions for Timer A (timer mode)

- (1) To clear reset, the count start flag is set to "0". Set a value in the timer Ai register, then set the flag to "1".
- (2) Reading the timer Ai register while a count is in progress allows reading, with arbitrary timing, the value of the counter. Reading the timer Ai register with the reload timing shown in Figure 2.2.28 gets "FFFF₁₆". Reading the timer Ai register after setting a value in the timer Ai register with a count halted but before the counter starts counting gets a proper value.

**Figure 2.2.28. Reading timer Ai register**

2.2.14 Precautions for Timer A (event counter mode)

- (1) To clear reset, the count start flag is set to "0". Set a value in the timer Ai register, then set the flag to "1".
- (2) Reading the timer Ai register while a count is in progress allows reading, with arbitrary timing, the value of the counter. Reading the timer Ai register with the reload timing shown in Figure 2.2.29 gets "FFFF₁₆" by underflow or "0000₁₆" by overflow. Reading the timer Ai register after setting a value in the timer Ai register with a count halted but before the counter starts counting gets a proper value.
- (3) Please note the standards for the differences between the 2 pulses used in the 2-phase pulse signals input signals to the TAIN pin and TAIOUT pin (i = 2, 3, 4), as shown in Figure 2.2.30.
- (4) When free run type is selected, if count is stopped, set a value in the timer Ai register again.

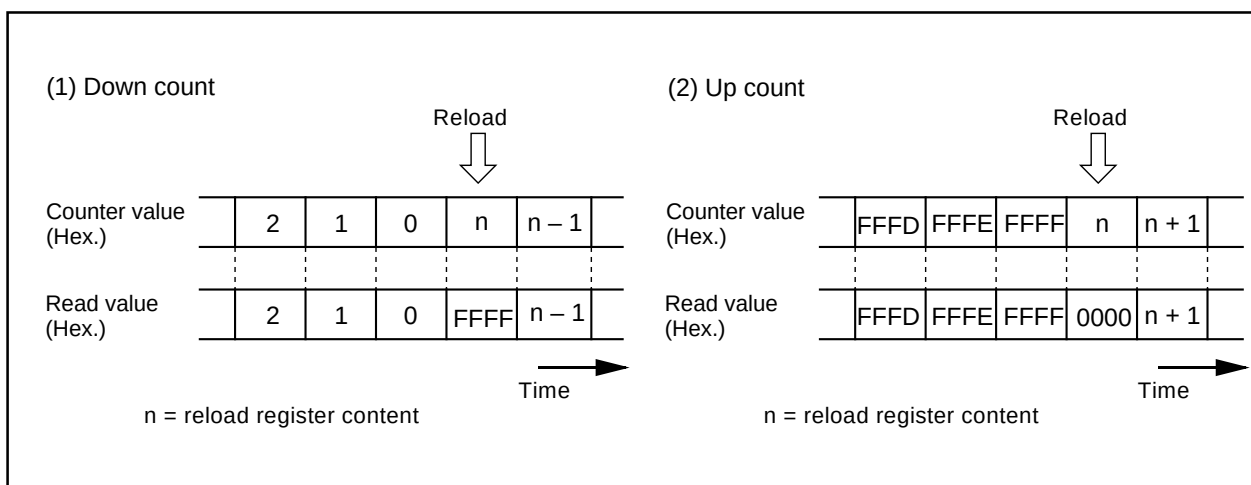


Figure 2.2.29. Reading timer Ai register

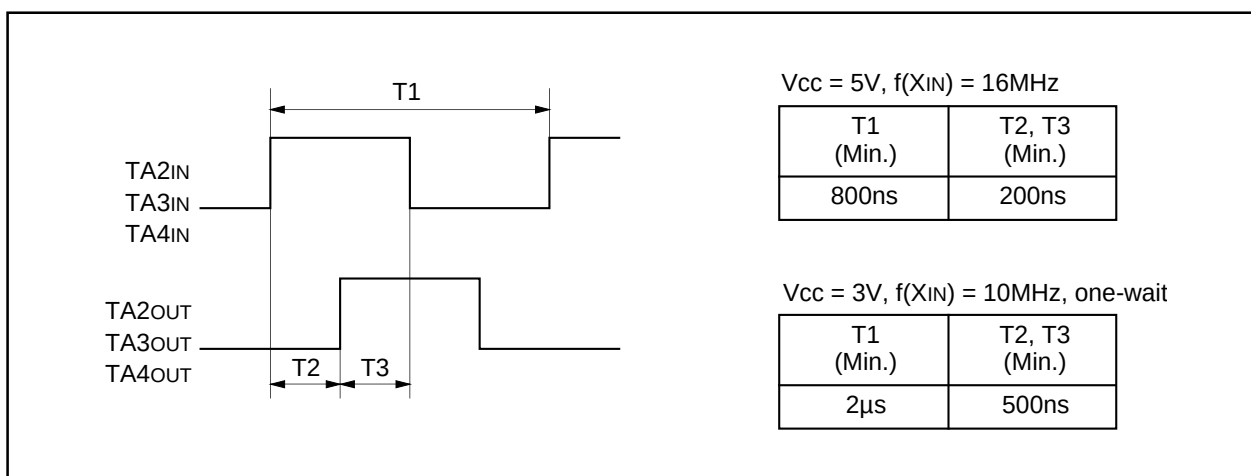


Figure 2.2.30. Standard of 2-phase pulses

2.2.15 Precautions for Timer A (one-shot timer mode)

- (1) At reset, the count start flag is set to "0". Set a value in the timer Ai register, then set the flag to "1".
- (2) Setting the count start flag to "0" while a count is in progress causes as follows:
 - The counter stops counting and a content of reload register is reloaded.
 - The TAIOUT pin outputs "L" level.
 - The interrupt request generated and the timer Ai interrupt request bit goes to "1".
- (3) The output from the one-shot timer synchronizes with the count source generated internally. Therefore, when an external trigger has been selected, a delay of one cycle of the maximum count source occurs between the trigger input to the TAIIN pin and the one-shot timer output.
- (4) The timer Ai interrupt request bit goes to "1" if the timer's operation mode is set using any of the following procedures:
 - Selecting one-shot timer mode after reset.
 - Changing operation mode from timer mode to one-shot timer mode.
 - Changing operation mode from event counter mode to one-shot timer mode.
 Therefore, to use timer Ai interrupt (interrupt request bit), set timer Ai interrupt request bit to "0" after the above listed changes have been made.
- (5) If a trigger occurs while a count is in progress, after the counter performs one down count following the reoccurrence of a trigger, the reload register contents are reloaded, and the count continues. To generate a trigger while a count is in progress, generate the second trigger after an elapse longer than one cycle of the timer's count source after the previous trigger occurred.

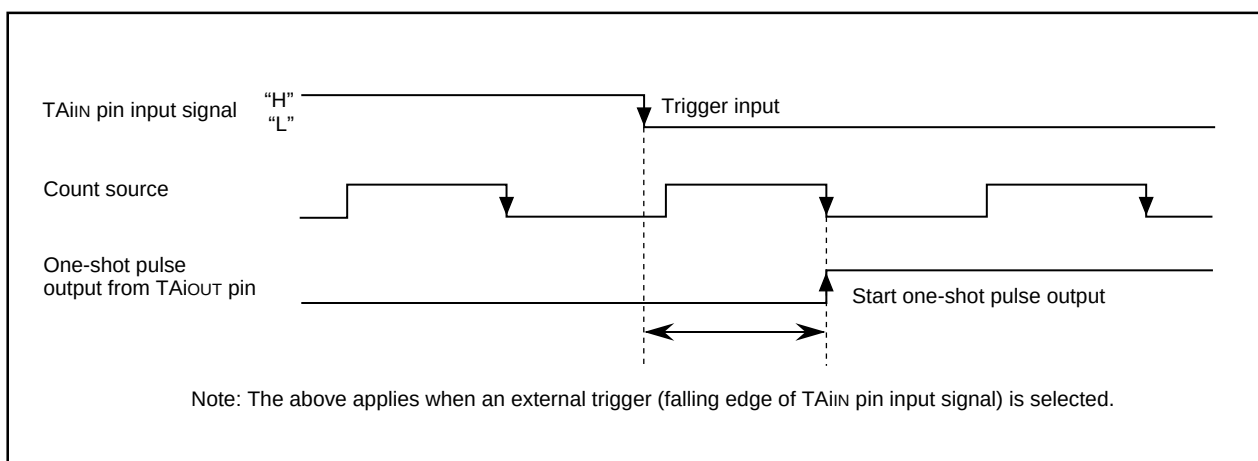


Figure 2.2.31. One-shot timer delay

2.2.16 Precautions for Timer A (pulse width modulation mode)

- (1) To clear reset, the count start flag is set to "0". Set a value in the timer Ai register, then set the flag to "1".
- (2) The timer Ai interrupt request bit becomes "1" if setting operation mode of the timer in compliance with any of the following procedures:
 - Selecting PWM mode after reset.
 - Changing operation mode from timer mode to PWM mode.
 - Changing operation mode from event counter mode to PWM mode.Therefore, to use timer Ai interrupt (interrupt request bit), set timer Ai interrupt request bit to "0" after the above listed changes have been made.
- (3) Setting the count start flag to "0" while PWM pulses are being output causes the counter to stop counting. If the TAIOUT pin is outputting an "H" level in this instance, the output level goes to "L", and the timer Ai interrupt request bit goes to "1". If the TAIOUT pin is outputting an "L" level in this instance, the level does not change, and the timer Ai interrupt request bit does not become "1".

2.3 Timer B Usage

2.3.1 Overview of the timer B usage

Timer B is a 16-bit timer. The following is an overview of the timer B usage.

(1) Mode

Timer B operates in one of three modes:

(a) Timer mode

The internal count source is counted.

- Operation in timer mode P2-42

(b) Event counter mode

The number of pulses coming from outside and the number of the timer overflows are counted.

- Operation in event counter mode P2-44

(c) Pulse period measurement/pulse width measurement mode

External pulse period or external pulse widths are measured. If pulse period measurement mode is selected, the periods of input pulses are continuously measured. If pulse width measurement mode is selected, widths of "H" level pulses and those of "L" level pulses are continuously measured.

- Operation in pulse period measurement mode P2-46
- Operation in pulse width measurement mode P2-48

(2) Count source

An internal count source can be selected from f1, f8, f32, and fc32. f1, f8, and f32 are clocks obtained by dividing the CPU main clock by 1, 8, and 32 respectively. fc32 is the clock obtained by dividing the CPU secondary clock by 32.

(3) Count value

The count value equals [the value set in the timer register + 1]. The counter underflows when a count source equal to a count value is input, and an interrupt request occurs.

(4) Reading the timer

In timer mode or event counter mode, the count value at the time of reading the timer register will be read. Read the register in 16-bit increments. In both the pulse period measurement mode and pulse width measurement mode, an indeterminate value is read until the second effective edge is input after a count is started, otherwise, the measurement results are read.

(5) Writing to the timer

When writing to the timer register while a count is in progress, the value is written only to the reload register. When writing to the timer register while a count has stopped, the value is written both to the reload register and the count. Write the value in 16-bit increments. The timer register cannot be written to in either the pulse period measurement mode or the pulse width measurement mode.

(6) Input to the timer and the direction register

To input an external signal to the timer, set the direction register of the relevant port to input.

(7) Pins related to timer B

(a) TB0IN, TB1IN, TB2IN, TB3IN, TB4IN, TB5IN: Input pins to timer B.

(8) Registers related to timer B

Figure 2.3.1 shows the memory map of timer B-related registers. Figures 2.3.2 and 2.3.3 show timer B-related registers.

0045 ₁₆	Timer B5 interrupt control register (TB5IC)
0045 ₁₆	Timer B4 interrupt control register (TB4IC)
0047 ₁₆	Timer B3 interrupt control register (TB3IC)
≈	≈
0340 ₁₆	Timer B3,4,5 count start flag (TBSR)
≈	≈
005A ₁₆	Timer B0 interrupt control register (TB0IC)
005B ₁₆	Timer B1 interrupt control register (TB1IC)
005C ₁₆	Timer B2 interrupt control register (TB2IC)
≈	≈
0350 ₁₆	Timer B3 register (TB3)
0351 ₁₆	
0352 ₁₆	Timer B4 register (TB4)
0353 ₁₆	
0354 ₁₆	Timer B5 register (TB5)
0355 ₁₆	
≈	≈
035B ₁₆	Timer B3 mode register (TB3MR)
035C ₁₆	Timer B4 mode register (TB4MR)
035D ₁₆	Timer B5 mode register (TB5MR)
≈	≈
0380 ₁₆	Count start flag (TABSR)
0381 ₁₆	Clock prescaler reset flag (CPSRF)
≈	≈
0390 ₁₆	Timer B0 register (TB0)
0391 ₁₆	
0392 ₁₆	Timer B1 register (TB1)
0393 ₁₆	
0394 ₁₆	Timer B2 register (TB2)
0395 ₁₆	
≈	≈
039B ₁₆	Timer B0 mode register (TB0MR)
039C ₁₆	Timer B1 mode register (TB1MR)
039D ₁₆	Timer B2 mode register (TB2MR)

Figure 2.3.1. Memory map of timer B-related registers

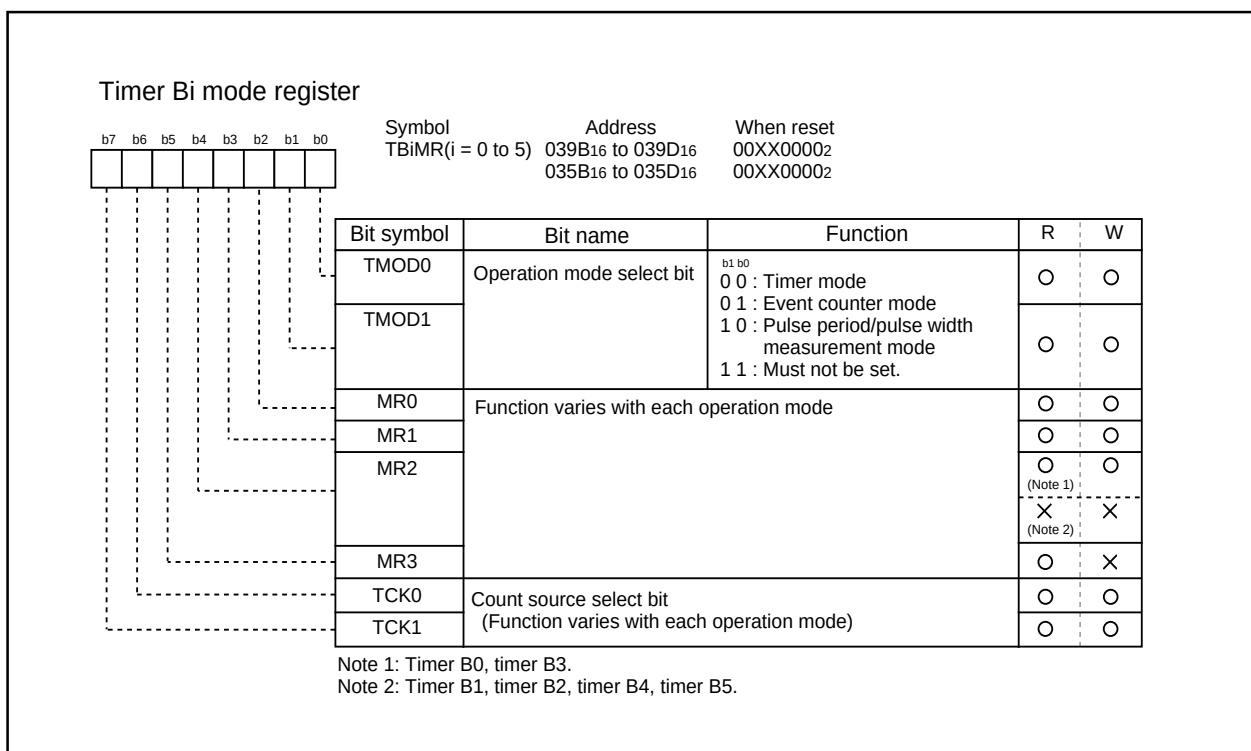


Figure 2.3.2. Timer B-related registers (1)

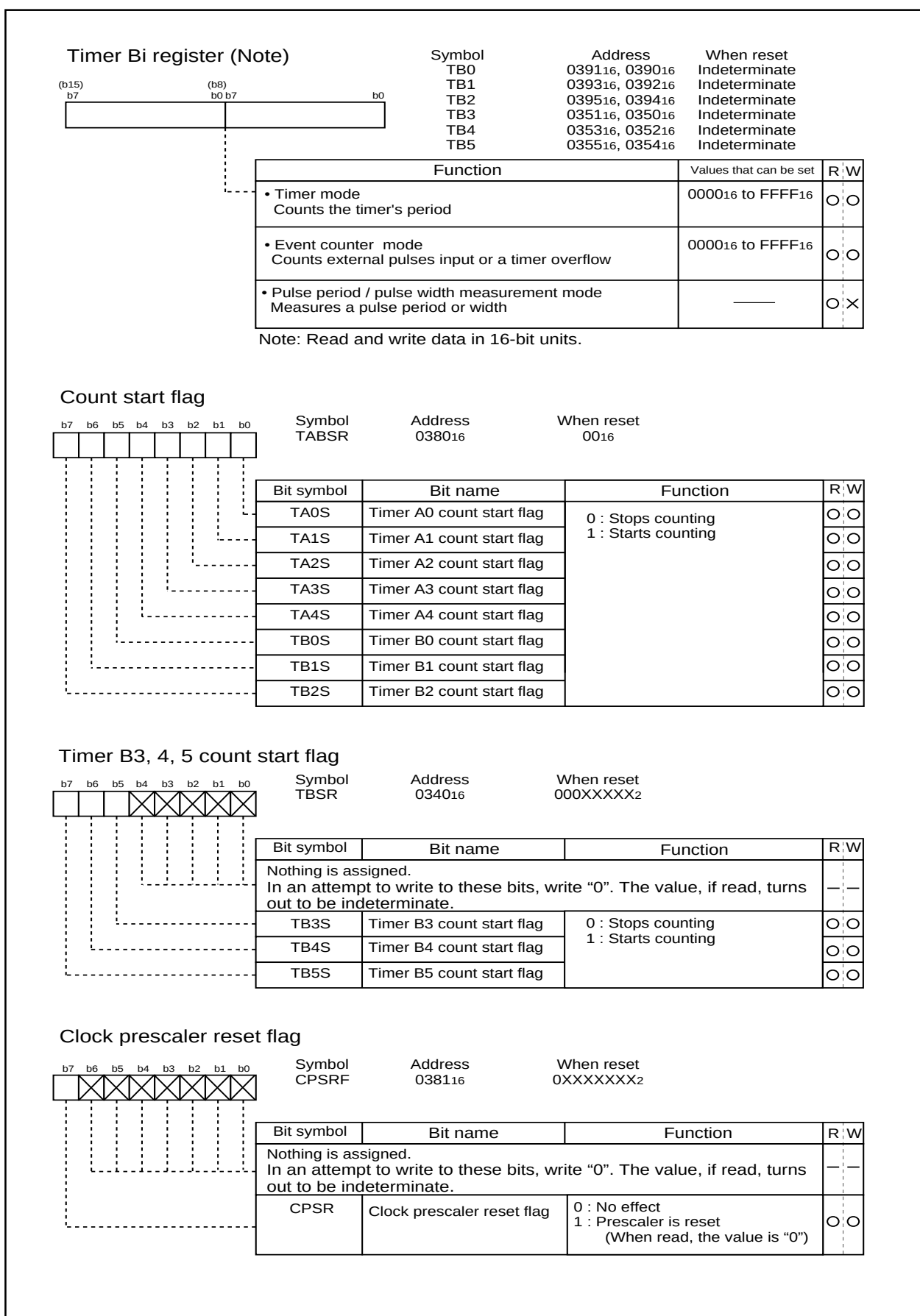


Figure 2.3.3. Timer B-related registers (2)

2.3.2 Operation of Timer B (timer mode)

In timer mode, choose functions from those listed in Table 2.3.1. Operations of the circled items are described below. Figure 2.3.4 shows the operation timing, and Figure 2.3.5 shows the set-up procedure.

Table 2.3.1. Chosed functions

Item	Set-up
Count source	0 Internal count source (f ₁ / f ₈ / f ₃₂ / f _{c32})

- Operation
- (1) Setting the count start flag to "1" causes the counter to perform a down count on the count source.
 - (2) If an underflow occurs, the content of the reload register is reloaded, and the counter continues counting. At this time, the timer Bi interrupt request bit goes to "1".
 - (3) Setting the count start flag to "0" causes the counter to hold its value and to stop.

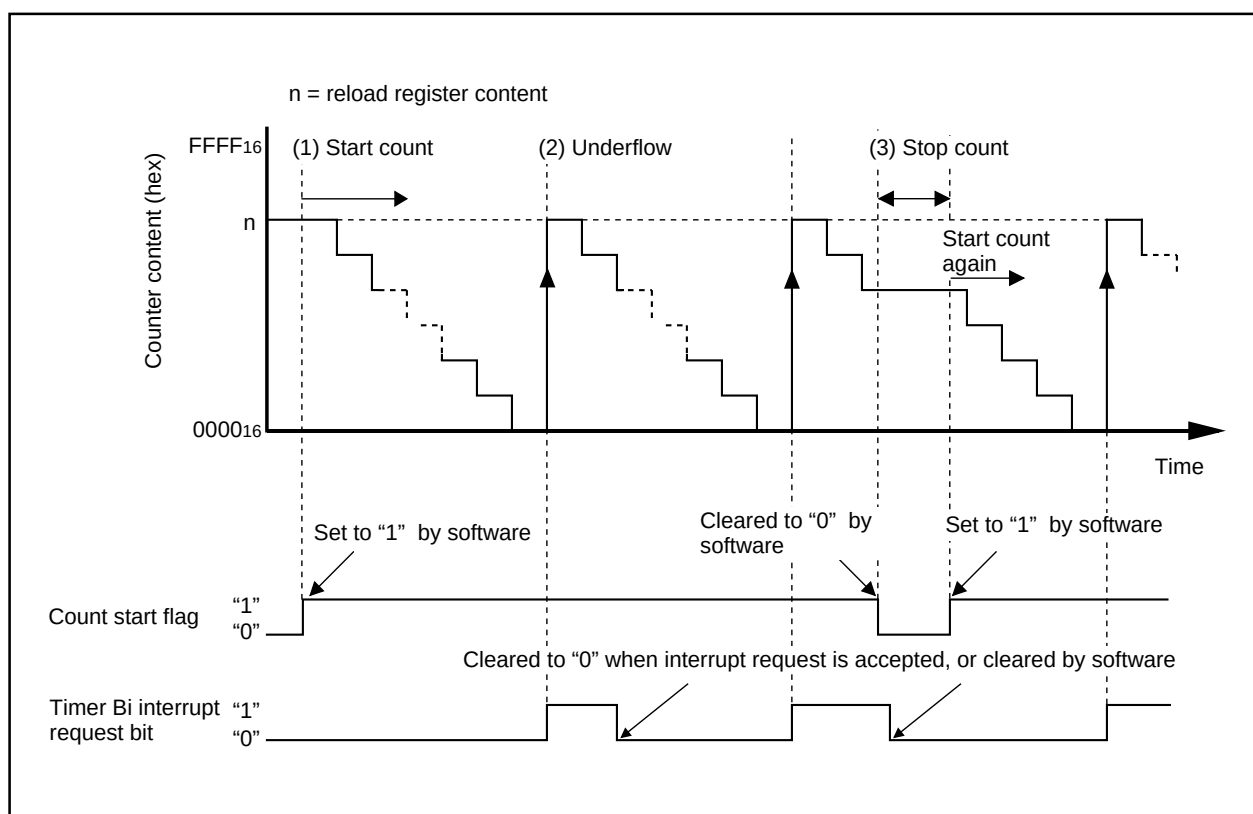
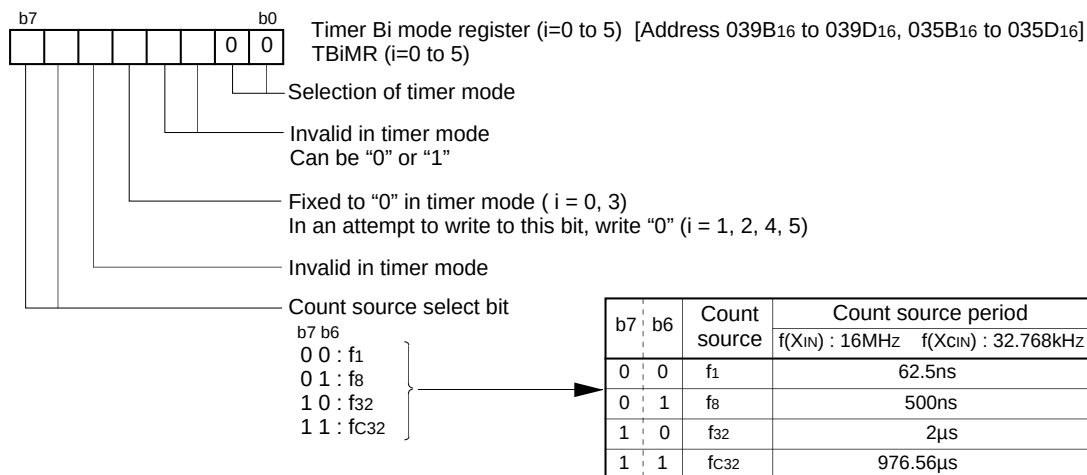
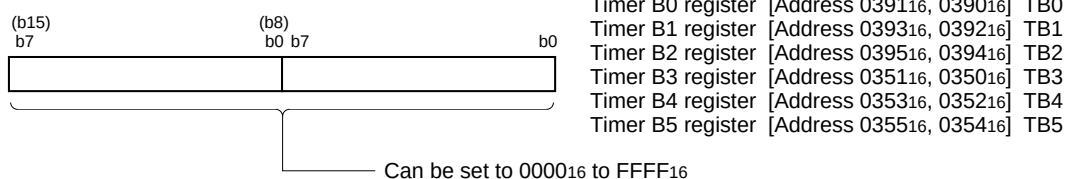


Figure 2.3.4. Operation timing of timer mode

Selecting timer mode and functions

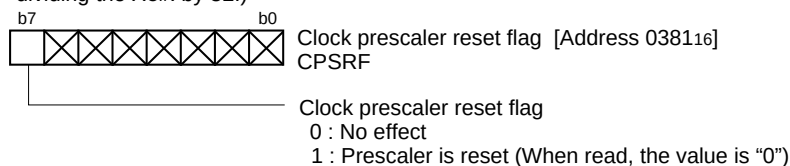


Setting counter value

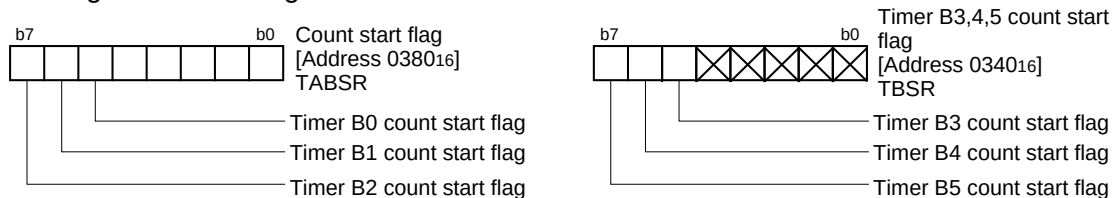


Setting clock prescaler reset flag

(This function is effective when f_{c32} is selected as the count source. Reset the prescaler for generating f_{c32} by dividing the X_{CIN} by 32.)



Setting count start flag



Start count

Figure 2.3.5. Set-up procedure of timer mode

2.3.3 Operation of Timer B (event counter mode)

In event counter mode, choose functions from those listed in Table 2.3.2. Operations of the circled items are described below. Figure 2.3.6 shows the operation timing, and Figure 2.3.7 shows the set-up procedure.

Table 2.3.2. Chosen functions

Item	Set-up
Count source	0 Input signal to the TB _{IN} pin (counting falling edges)
	Input signal to the TB _{IN} pin (counting rising edges)
	Input signal to the TB _{IN} pin (counting rising edges and falling edges)
	Timer overflow(TB _j overflow)

Note: $j = i - 1$, but $j = 2$ when $i = 0$, $j = 5$ when $i = 3$

- Operation
- (1) Setting the count start flag to "1" causes the counter to count the falling edges of the count source.
 - (2) If an underflow occurs, the content of the reload register is reloaded, and the count continues. At this time, the timer Bi interrupt request bit goes to "1".
 - (3) Setting the count start flag to "0" causes the counter to hold its value and to stop.

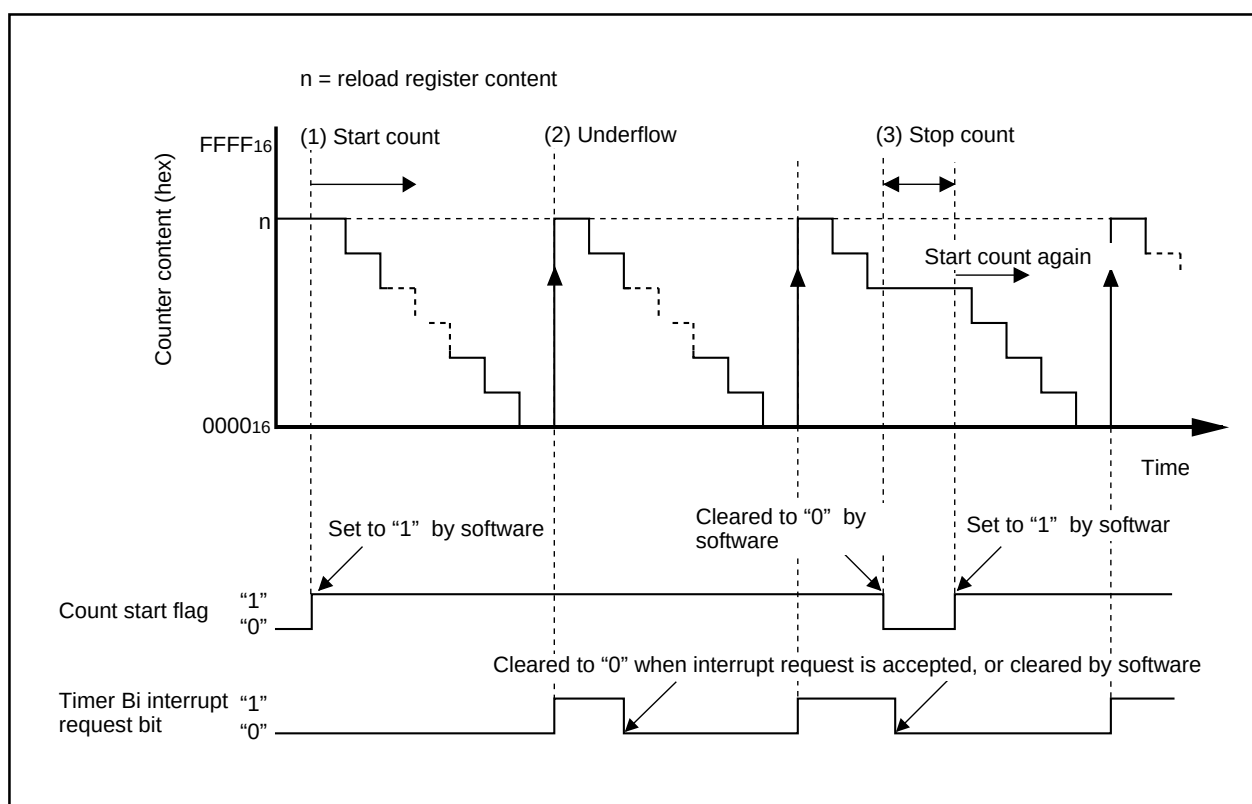


Figure 2.3.6. Operation timing of event counter mode

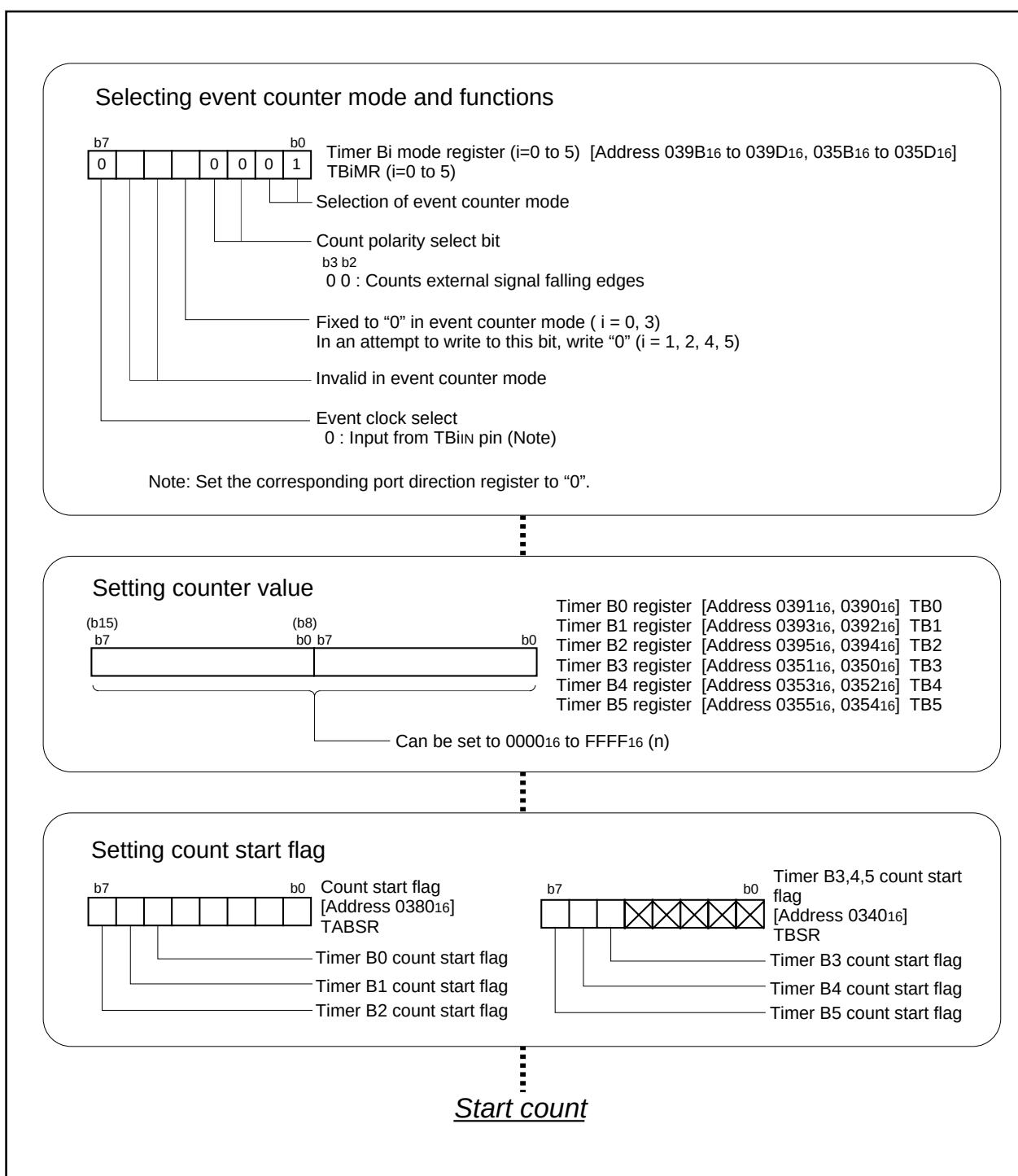


Figure 2.3.7. Set-up procedure of event counter mode

2.3.4 Operation of Timer B (pulse period measurement mode)

In pulse period/pulse width measurement mode, choose functions from those listed in Table 2.3.3. Operations of the circled items are described below. Figure 2.3.8 shows the operation timing, and Figure 2.3.9 shows the set-up procedure.

Table 2.3.3. Chosed functions

Item	Set-up
Count source	○ Internal count source ($f_1 / f_8 / f_{32} / f_{c32}$)
Measurement mode	○ Pulse period measurement (interval between measurement pulse falling edge to falling edge)
	Pulse period measurement (interval between measurement pulse rising edge to rising edge)
	Pulse width measurement (interval between measurement pulse falling edge to rising edge, and between rising edge to falling edge)

- Operation
- (1) Setting the count start flag to "1" causes the counter to start counting the count source.
 - (2) If a measurement pulse changes from "H" to "L", the value of the counter goes to "0000₁₆", and measurement is started. In this instance, an indeterminate value is transferred to the reload register. The timer Bi interrupt request does not generate.
 - (3) If a measurement pulse changes from "H" to "L" again, the value of the counter is transferred to the reload register, and the timer Bi interrupt request bit goes to "1". Then the value of the counter becomes "0000₁₆", and the measurement is started again.

- Note
- The timer Bi interrupt request bit goes to "1" when an effective edge of a measurement pulse is input or timer Bi is overflowed. The factor of interrupt request can be determined by use of the timer Bi overflow flag within the interrupt routine.
 - The value of the counter at the beginning of a count is indeterminate. Therefore, the timer Bi overflow flag may go to "1" and timer Bi interrupt request may be generated during the interval between a count start and an effective edge input.
 - The timer Bi overflow flag is indeterminate after reset. The timer Bi overflow flag goes to "0" if timer Bi mode register is written to when the count start flag is "1". This flag cannot be set to "1" by software.

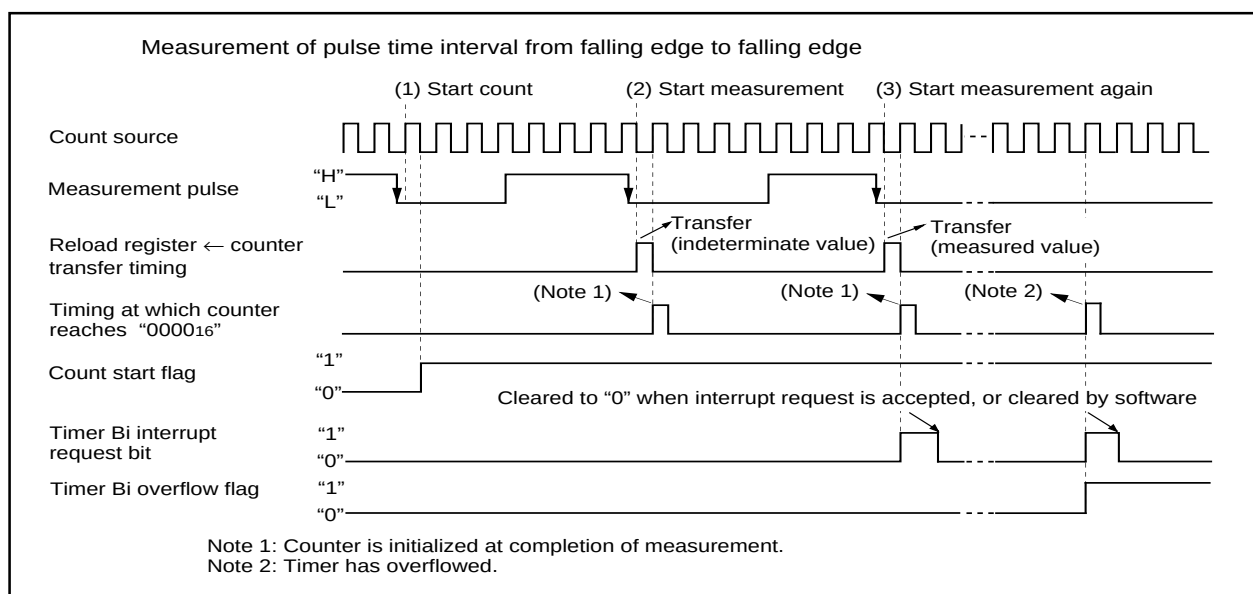


Figure 2.3.8. Operation timing of pulse period measurement mode

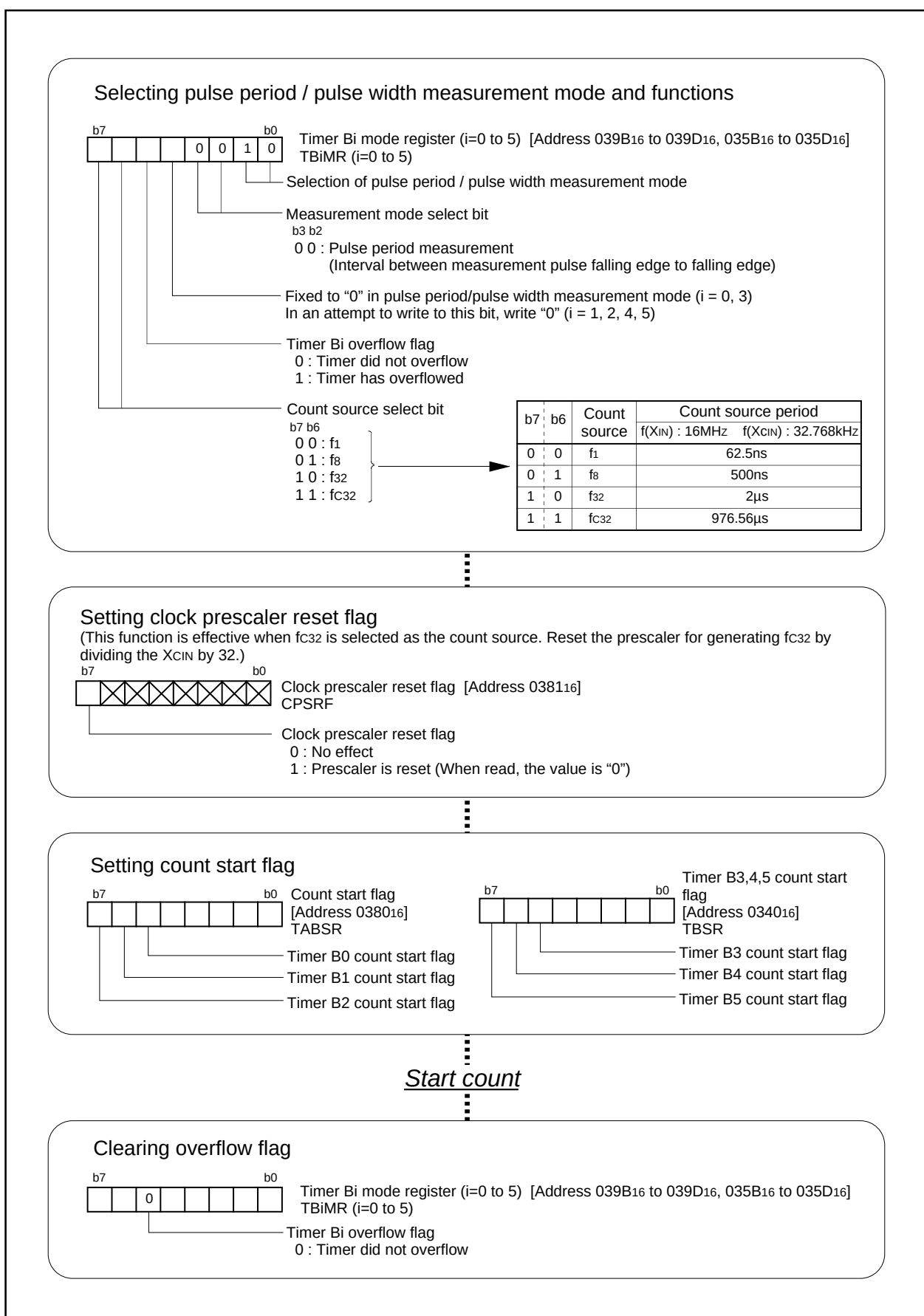


Figure 2.3.9. Set-up procedure of pulse period measurement mode

2.3.5 Operation of Timer B (pulse width measurement mode)

In pulse period/pulse width measurement mode, choose functions from those listed in Table 2.3.4. Operations of the circled items are described below. Figure 2.3.10 shows the operation timing, and Figure 2.3.11 shows the set-up procedure.

Table 2.3.4. Chosed functions

Item	Set-up	
Count source	○	Internal count source ($f_1 / f_8 / f_{32} / f_{c32}$)
Measurement mode		Pulse period measurement (interval between measurement pulse falling edge to falling edge)
		Pulse period measurement (interval between measurement pulse rising edge to rising edge)
	○	Pulse width measurement (interval between measurement pulse falling edge to rising edge, and between rising edge to falling edge)

- Operation
- (1) Setting the count start flag to "1" causes the counter to start counting the count source.
 - (2) If an effective edge of a pulse to be measured is input, the value of the counter goes to "0000₁₆", and measurement is started. In this instance, an indeterminate value is transferred to the reload register. The timer Bi interrupt request does not generate.
 - (3) If an effective edge of a pulse to be measured is input again, the value of the counter is transferred to the reload register, and the timer Bi interrupt request bit goes to "1". Then the value of the counter becomes "0000₁₆", and measurement is started again.

- Note
- The timer Bi interrupt request bit goes to "1" when an effective edge of a pulse to be measured is input or timer Bi is overflows. The factor of interrupt request can be determined by use of the timer Bi overflow flag within the interrupt routine.
 - The value of the counter at the beginning of a count is indeterminate. Therefore, the timer Bi overflow flag may go to "1" and timer Bi interrupt request may be generated during the interval between a count start and an effective edge input.
 - The timer Bi overflow flag is indeterminate after reset. The timer Bi overflow flag goes to "0" if timer Bi mode register is written to when the count start flag is "1". This flag cannot be set to "1" by software.

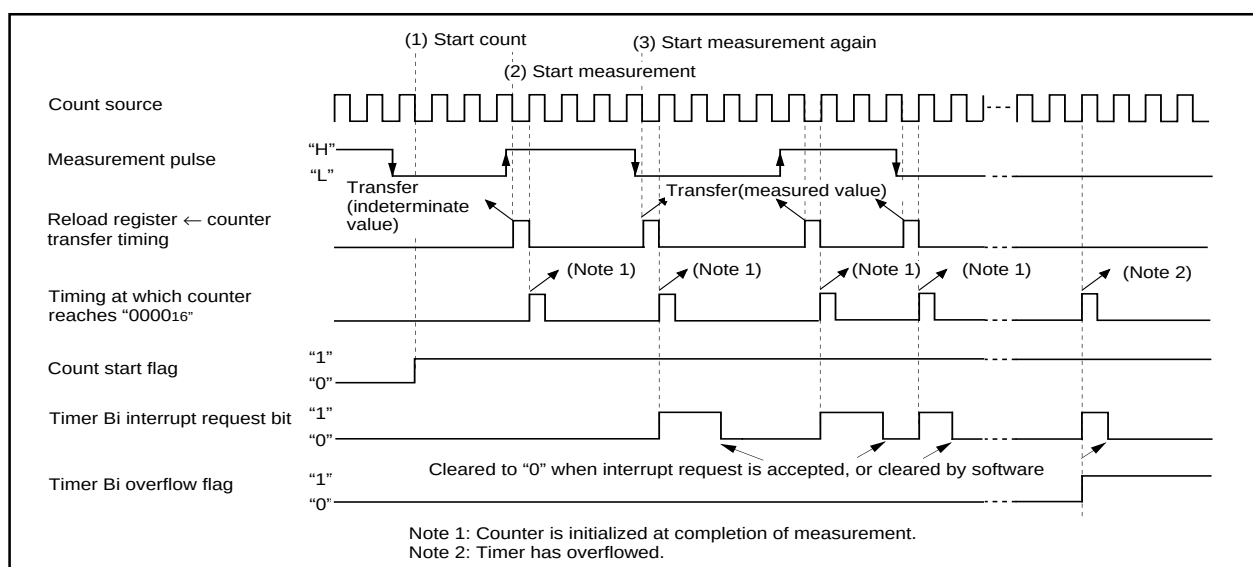
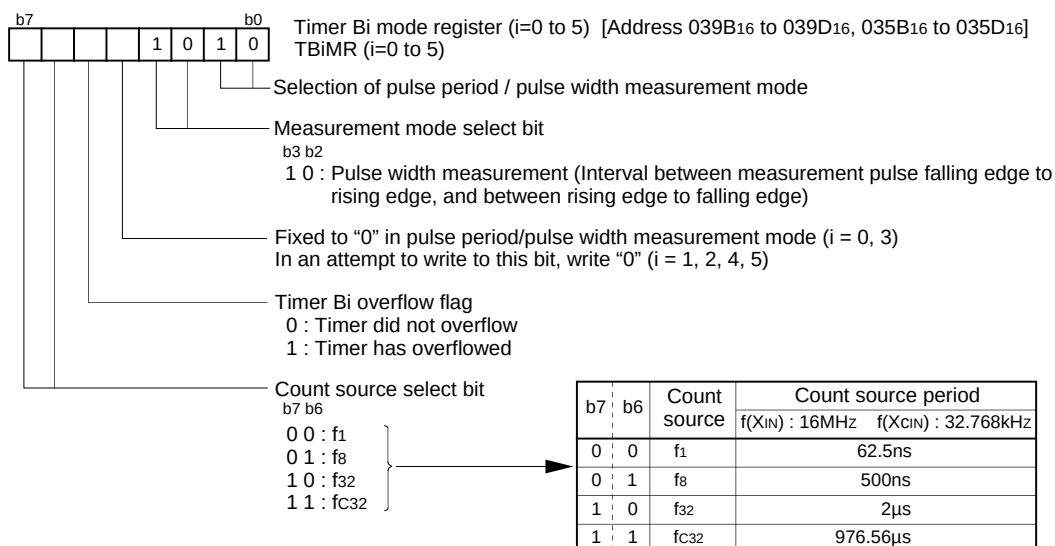


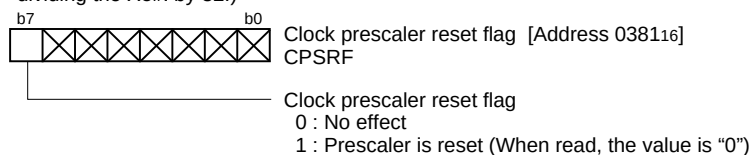
Figure 2.3.10. Operation timing of pulse width measurement mode

Selecting pulse period / pulse width measurement mode and functions

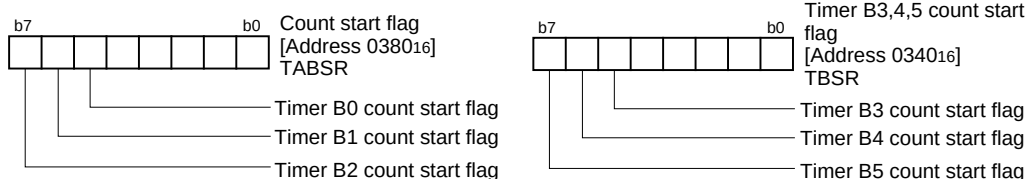


Setting clock prescaler reset flag

(This function is effective when f_{c32} is selected as the count source. Reset the prescaler for generating f_{c32} by dividing the X_{CIN} by 32.)



Setting count start flag



Start count

Clearing overflow flag

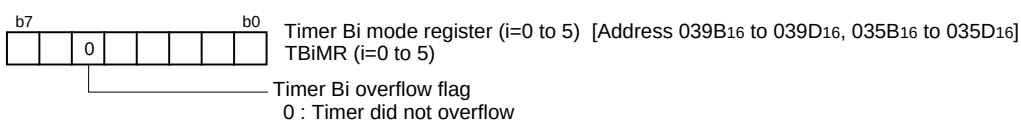
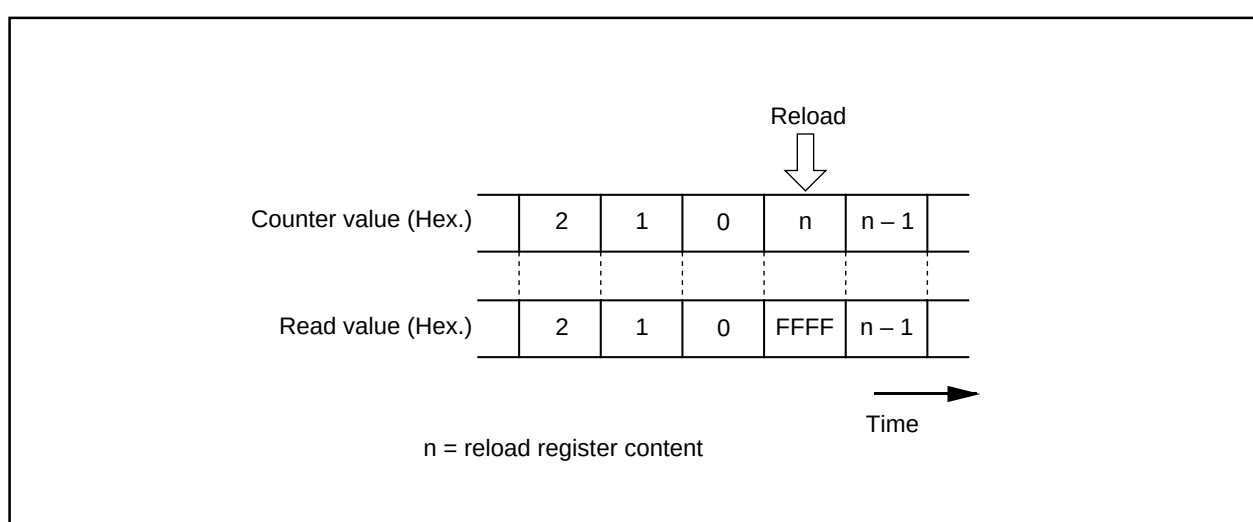


Figure 2.3.11. Set-up procedure of pulse width measurement mode

2.3.6 Precautions for Timer B (timer mode, event counter mode)

- (1) To clear reset, the count start flag is set to "0". Set a value in the timer Bi register, then set the flag to "1".
- (2) Reading the timer Bi register while a count is in progress allows reading, with arbitrary timing, the value of the counter. Reading the timer Bi register with the reload timing shown in Figure 2.3.12 gets "FFFF₁₆". Reading the timer Bi register after setting a value in the timer Bi register with a count halted but before the counter starts counting gets a proper value.

**Figure 2.3.12. Reading timer Bi register**

2.3.7 Precautions for Timer B (pulse period/pulse width measurement mode)

- (1) The timer Bi interrupt request bit goes to "1" when an effective edge of a measurement pulse is input or timer Bi is overflowed. The factor of interrupt request can be determined by use of the timer Bi overflow flag within the interrupt routine.
- (2) If the timer overflow occurs simultaneously with the input of a measurement pulse, and if the interrupt factor cannot be determined from the timer Bi overflow flag, connect the timers and count the number of overflows.
- (3) When reset, the timer Bi overflow flag goes to "1". This flag can be set to "0" by writing to the timer Bi mode register when the count start flag is "1".
- (4) Use the timer Bi interrupt request bit to detect only overflows. Use the timer Bi overflow flag only to determine the interrupt factor within the interrupt routine.
- (5) When the first effective edge is input after a count is started, an indeterminate value is transferred to the reload register. At this time, timer Bi interrupt request is not generated.
- (6) The value of the counter is indeterminate at the beginning of a count. Therefore, the timer Bi overflow flag may go to "1" and timer Bi interrupt request may be generated during the interval between a count start and an effective edge input.
- (7) If changing the measurement mode select bits are set after a count is started, the timer Bi interrupt request bit goes to "1". Note that the timer Bi interrupt request bit does not change if the same value as before is written to the measurement mode select bits.
- (8) If the input signal to the TBiIN pin is affected by noise, precise measurement may not be performed in some cases. It is recommended to see that measurements fall within a specific range by use of software.
- (9) For pulse width measurement, pulse widths are successively measured. Use software to check whether the measurement result is an "H" level width or an "L" level width.

2.4 Clock-Synchronous Serial I/O Usage

2.4.1 Overview of the clock-synchronous serial I/O usage

Clock-synchronous serial I/O carries out 8-bit data communications in synchronization with the clock. The following is an overview of the clock-synchronous serial I/O usage.

(1) Transmission/reception format

8-bit data

(2) Transfer rate

If the internal clock is selected as the transfer clock, the divide-by-2 frequency, resulting from the bit rate generator division, becomes the transfer rate. The bit rate generator count source can be selected from the following: f₁, f₈, and f₃₂. Clocks f₁, f₈, and f₃₂ are derived by dividing the CPU's main clock by 1, 8, and 32 respectively.

Furthermore, if an external clock is selected as the transfer clock, the clock frequency input to the CLK pin becomes the transfer rate.

(3) Error detection

Only overrun error can be detected. Overrun error is an error that occurs when the next data is made ready before the reception buffer register is read.

(4) How to deal with an error

When receiving data, read an error flag and reception data simultaneously to determine which error has occurred. If the data read is erroneous, initialize the error flag and the UARTi receive buffer register, then receive the data again.

To initialize the UARTi receive buffer register

1. Set the receive enable bit to "0" (disable reception).
2. Set the serial I/O mode select bit to "0002" (invalid serial I/O).
3. Set the serial I/O mode select bit.
4. Set the receive enable bit to "1" again (enable reception).

To transmit data again due to an error on the reception side, set the UARTi transmit buffer register again, then transmit the data again.

To set the UARTi transmit buffer register again

1. Set the serial I/O mode select bits to "0002" (invalidate serial I/O).
2. Set the serial I/O mode select bits again.
3. Set the transmit enable bit to "1" (enable transmission), then set transmission data in the UARTi transmit buffer register.

(5) Function selection

For clock-synchronous serial I/O, the following functions can be selected:

(a) CTS/RTS function

In the $\overline{\text{CTS}}$ function, an external IC can start transmission/reception by inputting an "H" level to the $\overline{\text{CTS}}$ pin. The $\overline{\text{CTS}}$ pin input level is detected when transmission/reception starts. Therefore, if the level is set to "L" during transmission/reception, it will stop from the next data.

The $\overline{\text{RTS}}$ function informs an external IC that $\overline{\text{RTS}}$ is reception-ready and has changed to "L". $\overline{\text{RTS}}$ goes to "H" at the falling edge of the transfer clock.

The clock-synchronous serial I/O has three types of $\overline{\text{CTS}}/\overline{\text{RTS}}$ functions to choose from:

• $\overline{\text{CTS}}/\overline{\text{RTS}}$ functions disabled	$\overline{\text{CTS}}/\overline{\text{RTS}}$ pin is a programmable I/O port.
• $\overline{\text{CTS}}$ function only enabled	$\overline{\text{CTS}}/\overline{\text{RTS}}$ pin performs the $\overline{\text{CTS}}$ function.
• $\overline{\text{RTS}}$ function only enabled	$\overline{\text{CTS}}/\overline{\text{RTS}}$ pin performs the $\overline{\text{RTS}}$ function.

(b) Function for choosing polarity

This function switches the polarity of the transfer clock. The following operations are available:

- Data is input at the falling edge of the transfer clock, and is output at the rising edge.
- Data is input at the rising edge of the transfer clock, and is output at the falling edge.

(c) Function for choosing which bit to transmit first

This function is to choose whether to transmit data from bit 0 or from bit 7. Choose either of the following:

- LSB first Data is transmitted from bit 0.
- MSB first Data is transmitted from bit 7.

(d) Function for choosing successive reception mode

Successive reception mode is a mode in which reading the receive buffer register makes the reception-enabled status ready. In this mode, there is no need to write dummy data to the transmit buffer register so as to make the reception-enabled status ready. But at the time of starting reception, read the receive buffer register into a dummy manner.

- Normal mode Writing dummy data to the transmit buffer register makes the reception enabled status ready.
- Successive reception mode Reading the reception buffer register makes the reception-enabled status ready.

(e) Function for outputting transfer clock to multiple pins

This function is to switch among pins to output the transfer clock. This function is effective only when selecting the internal clock. Switching among pins for outputting the transfer clock allows data transmission to two external ICs in a time-sharing manner.

(f) Data logic select function

This function is to reserve data when writing to transmit buffer register or reading from receive buffer register.

(g) Function for choosing a transmission interrupt factor

The timing to generate a transmission interrupt can be selected from the following: the instant the transmission buffer is emptied or the instant the transmission register is emptied. When transmission buffer empty timing is selected, an interrupt occurs when transmitted data is moved from the transmission buffer to the transmission register. Therefore, data can be transmitted in succession. When transmission register empty timing is selected, an interrupt occurs when data transmission is complete.

(h) TxD, RxD I/O polarity reverse function

This function is to reserve a polarity of TxD port output level and a polarity of RxD port input level.

Following are some examples in which various functions (a) through (g) are selected:

- Transmission Operation WITH: $\overline{CTS}$ function, transmission at falling edge of transfer clock, LSB First, interrupt at instant transmission buffer is emptied; WITHOUT transfer clock output to multiple pins function P2-60
- Transmission Operation WITH: $\overline{CTS}/\overline{RTS}$ function disabled, transmission at falling edge of transfer clock, LSB First, interrupt at instant transmission is completed; WITH transfer clock output to multiple pins function (UART0 selection available) P2-64
- Reception WITH: $\overline{RTS}$ function, reception at falling edge of transfer clock, LSB First, successive reception mode disabled; WITHOUT transfer clock output to multiple pins function P2-68

(6) Input to the serial I/O and the direction register

To input an external signal to the serial I/O, set the direction register of the relevant port to input.

(7) Pins related to the serial I/O

- $\overline{CTS}_0$, $\overline{CTS}_1$, $\overline{CTS}_2$ pins Input pins for the $\overline{CTS}$ function
- $\overline{RTS}_0$, $\overline{RTS}_1$, $\overline{RTS}_2$ pins Output pins for the $\overline{RTS}$ function
- CLK0, CLK1, CLK2 pins Input/output pins for the transfer clock
- Rx0, Rx1, Rx2 pins Input pins for data
- Tx0, Tx1, Tx2 pins Output pins for data (Since Tx2 pin is N-channel open drain, this pin needs pull-up resistor.)
- CLKS1 pin Output pin for transfer clock. Can be used as transfer clock output pin in the transfer clock output to multiple pins function.

(8) Registers related to the serial I/O

Figure 2.4.1 shows the memory map of serial I/O-related registers, and Figures 2.4.2 to 2.4.6 show serial I/O-related registers.

004F ₁₆	UART2 transmit interrupt control register (S2TIC)
0050 ₁₆	UART2 receive interrupt control register (S2RIC)
0051 ₁₆	UART0 transmit interrupt control register (S0TIC)
0052 ₁₆	UART0 receive interrupt control register (S0RIC)
0053 ₁₆	UART1 transmit interrupt control register(S1TIC)
0054 ₁₆	UART1 receive interrupt control register(S1RIC)
⋮	
0378 ₁₆	UART2 transmit/receive mode register (U2MR)
0379 ₁₆	UART2 bit rate generator (U2BRG)
037A ₁₆	UART2 transmit buffer register (U2TB)
037B ₁₆	
037C ₁₆	UART2 transmit/receive control register 0 (U2C0)
037D ₁₆	UART2 transmit/receive control register 1 (U2C1)
037E ₁₆	UART2 receive buffer register (U2RB)
037F ₁₆	
⋮	
03A0 ₁₆	UART0 transmit/receive mode register (U0MR)
03A1 ₁₆	UART0 bit rate generator (U0BRG)
03A2 ₁₆	UART0 transmit buffer register (U0TB)
03A3 ₁₆	
03A4 ₁₆	UART0 transmit/receive control register 0 (U0C0)
03A5 ₁₆	UART0 transmit/receive control register 1 (U0C1)
03A6 ₁₆	UART0 receive buffer register (U0RB)
03A7 ₁₆	
03A8 ₁₆	UART1 transmit/receive mode register (U1MR)
03A9 ₁₆	UART1 bit rate generator (U1BRG)
03AA ₁₆	UART1 transmit buffer register (U1TB)
03AB ₁₆	
03AC ₁₆	UART1 transmit/receive control register 0 (U1C0)
03AD ₁₆	UART1 transmit/receive control register 1 (U1C1)
03AE ₁₆	UART1 receive buffer register (U1RB)
03AF ₁₆	
03B0 ₁₆	UART transmit/receive control register 2 (UCON)
03B1 ₁₆	

Figure 2.4.1. Memory map of serial I/O-related registers

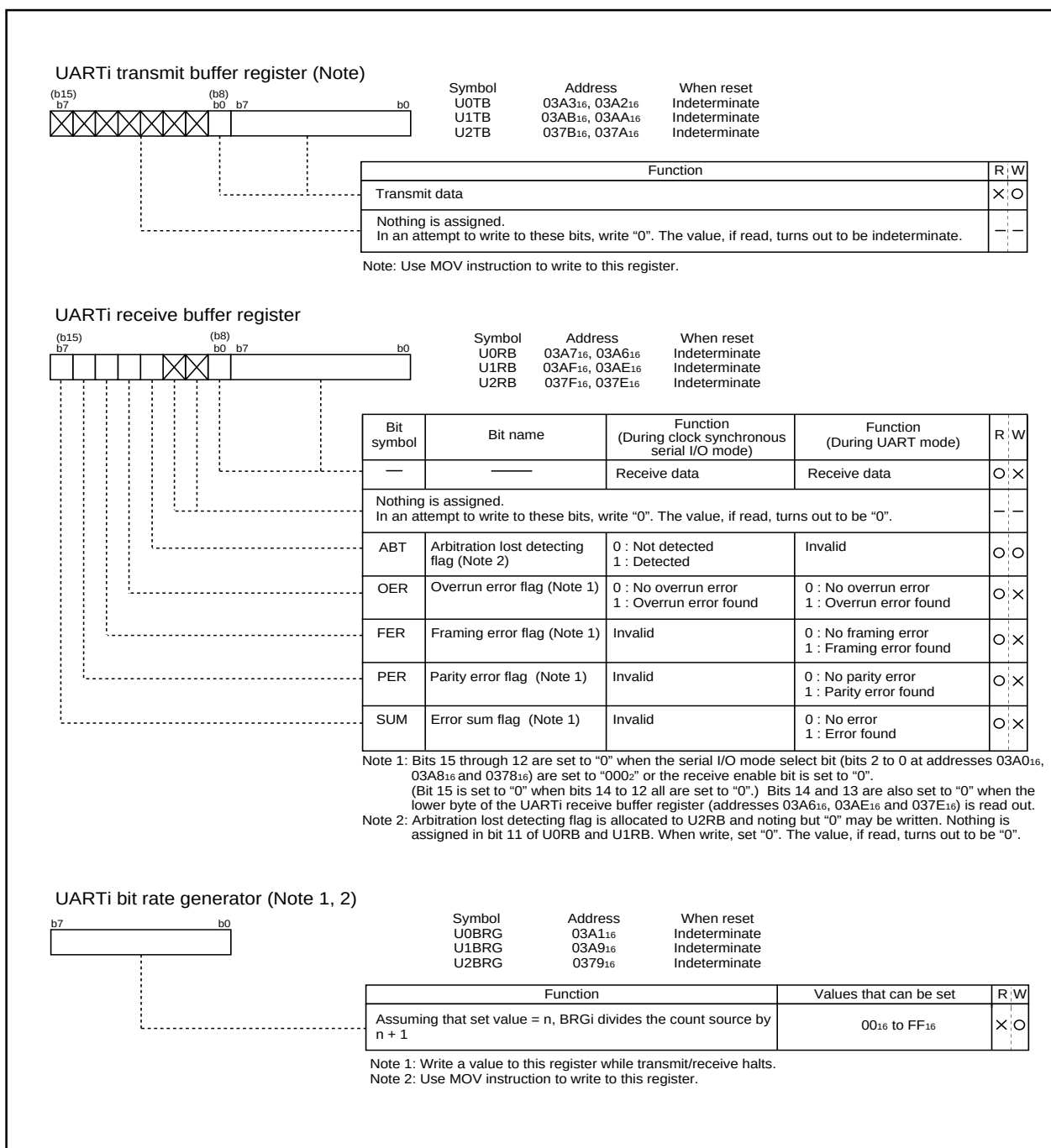


Figure 2.4.2. Serial I/O-related registers (1)

UARTi transmit/receive mode register

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
b7	SMD0	Must be fixed to 001 b2 b1 b0 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	b2 b1 b0 1 0 0 : Transfer data 7 bits long 1 0 1 : Transfer data 8 bits long 1 1 0 : Transfer data 9 bits long 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	○	○
b6	SMD1			○	○
b5	SMD2			○	○
b4	CKDIR	0 : Internal clock 1 : External clock (Note)	0 : Internal clock 1 : External clock (Note)	○	○
b3	STPS	Invalid	0 : One stop bit 1 : Two stop bits	○	○
b2	PRY	Invalid	Valid when bit 6 = "1" 0 : Odd parity 1 : Even parity	○	○
b1	PRYE	Invalid	0 : Parity disabled 1 : Parity enabled	○	○
b0	SLEP	Must always be "0"	0 : Sleep mode deselected 1 : Sleep mode selected	○	○

Note : Set the corresponding port direction register to "0".

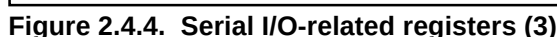
UART2 transmit/receive mode register

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
b7	SMD0	Must be fixed to 001 b2 b1 b0 0 0 0 : Serial I/O invalid 0 1 0 : (Note 1) 0 1 1 : Must not be set. 1 1 1 : Must not be set.	b2 b1 b0 1 0 0 : Transfer data 7 bits long 1 0 1 : Transfer data 8 bits long 1 1 0 : Transfer data 9 bits long 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	○	○
b6	SMD1			○	○
b5	SMD2			○	○
b4	CKDIR	0 : Internal clock 1 : External clock (Note 2)	Must always be "0"	○	○
b3	STPS	Invalid	0 : One stop bit 1 : Two stop bits	○	○
b2	PRY	Invalid	Valid when bit 6 = "1" 0 : Odd parity 1 : Even parity	○	○
b1	PRYE	Invalid	0 : Parity disabled 1 : Parity enabled	○	○
b0	IOPOL	0 : No reverse 1 : Reverse Usually set to "0"	0 : No reverse 1 : Reverse Usually set to "0"	○	○

Note 1: Bit 2 to bit 0 are set to "0102" when I²C mode is used.

Note 2: Set the corresponding port direction register to "0".

Figure 2.4.3. Serial I/O-related registers (2)



UARTi transmit/receive control register 1

Bit	Symbol	Address	When reset
b7	UIC1(i=0,1)	03A5 ₁₆ , 03AD ₁₆	02 ₁₆
b6			
b5			
b4			
b3			
b2			
b1			
b0			

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
TE	Transmit enable bit	0 : Transmission disabled 1 : Transmission enabled	0 : Transmission disabled 1 : Transmission enabled	○	○
TI	Transmit buffer empty flag	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	○	×
RE	Receive enable bit	0 : Reception disabled 1 : Reception enabled	0 : Reception disabled 1 : Reception enabled	○	○
RI	Receive complete flag	0 : No data present in receive buffer register 1 : Data present in receive buffer register	0 : No data present in receive buffer register 1 : Data present in receive buffer register	○	×
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".					—

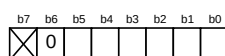
UART2 transmit/receive control register 1

Bit	Symbol	Address	When reset
b7	U2C1	037D ₁₆	02 ₁₆
b6			
b5			
b4			
b3			
b2			
b1			
b0			

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
TE	Transmit enable bit	0 : Transmission disabled 1 : Transmission enabled	0 : Transmission disabled 1 : Transmission enabled	○	○
TI	Transmit buffer empty flag	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	○	×
RE	Receive enable bit	0 : Reception disabled 1 : Reception enabled	0 : Reception disabled 1 : Reception enabled	○	○
RI	Receive complete flag	0 : No data present in receive buffer register 1 : Data present in receive buffer register	0 : No data present in receive buffer register 1 : Data present in receive buffer register	○	×
U2IRS	UART2 transmit interrupt cause select bit	0 : Transmit buffer empty (TI = 1) 1 : Transmit is completed (TXEPT = 1)	0 : Transmit buffer empty (TI = 1) 1 : Transmit is completed (TXEPT = 1)	○	○
U2RRM	UART2 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enabled	Must always be "0"	○	○
U2LCH	Data logic select bit	0 : No reverse 1 : Reverse	0 : No reverse 1 : Reverse	○	○
U2ERE	Error signal output enable bit	Must be fixed to "0"	0 : Output disabled 1 : Output enabled	○	○

Figure 2.4.5. Serial I/O-related registers (4)

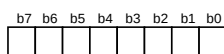
UART transmit/receive control register 2

Symbol
UCONAddress
03B0₁₆When reset
X0000000₂

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
U0IRS	UART0 transmit interrupt cause select bit	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	○	○
U1IRS	UART1 transmit interrupt cause select bit	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	○	○
U0RRM	UART0 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enable	Must always be "0"	○	○
U1RRM	UART1 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enable	Must always be "0"	○	○
CLKMD0	CLK/CLKS select bit 0	Valid when bit 5 = "1" 0 : Clock output to CLK1 1 : Clock output to CLKS1	Invalid	○	○
CLKMD1	CLK/CLKS select bit 1 (Note)	0 : Normal mode (CLK output is CLK1 only) 1 : Transfer clock output from multiple pins function selected	Must always be "0"	○	○
Reserved bit		Must always be set to "0"		○	○
Nothing is assigned. In an attempt to write to this bit, write "0". The value, if read, turns out to be indeterminate.				—	—

Note: When using multiple pins to output the transfer clock, the following requirements must be met:
 • UART1 internal/external clock select bit (bit 3 at address 03A8₁₆) = "0".

UART2 special mode register

Symbol
U2SMRAddress
0377₁₆When reset
00₁₆

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
IICM	I ² C mode select bit	0 : Normal mode 1 : I ² C mode	Must always be "0"	○	○
ABC	Arbitration lost detecting flag control bit	0 : Update per bit 1 : Update per byte	Must always be "0"	○	○
BBS	Bus busy flag	0 : STOP condition detected 1 : START condition detected	Must always be "0"	○	○ (Note1)
LSYN	SCLL sync output enable bit	0 : Disabled 1 : Enabled	Must always be "0"	○	○
ABSCS	Bus collision detect sampling clock select bit	Must always be "0"	0 : Rising edge of transfer clock 1 : Underflow signal of timer A0	○	○
ACSE	Auto clear function select bit of transmit enable bit	Must always be "0"	0 : No auto clear function 1 : Auto clear at occurrence of bus collision	○	○
SSS	Transmit start condition select bit	Must always be "0"	0 : Ordinary 1 : Falling edge of RxD2	○	○
SDDS	SDA digital delay select bit (Note 2, Note 3)	0 : Analog delay output is selected 1 : Digital delay output is selected (must always be "0" when not using I ² C mode)	Must always be "0"	○	○

Note 1: Nothing but "0" may be written.

Note 2: When not in I²C mode, do not set this bit by writing a "1". During normal mode, fix it to "0". When this bit = "0", UART2 special mode register 3 (U2SMR3 at address 0375₁₆) bits 7 to 5 (DL2 to DL0 = SDA digital delay setup bits) are initialized to "000", with the analog delay circuit selected. Also, when SDDS = "0", the U2SMR3 register cannot be read or written to.

Note 3: When analog delay is selected, only the analog delay value is effective; when digital delay is selected, only the digital delay value is effective.

Figure 2.4.6. Serial I/O-related registers (5)

2.4.2 Operation of Serial I/O (transmission in clock-synchronous serial I/O mode)

In transmitting data in clock-synchronous serial I/O mode, choose functions from those listed in Table 2.4.1. Operations of the circled items are described below. Figure 2.4.7 shows the operation timing, and Figures 2.4.8 and 2.4.9 show the set-up procedures.

Table 2.4.1. Chooosed functions

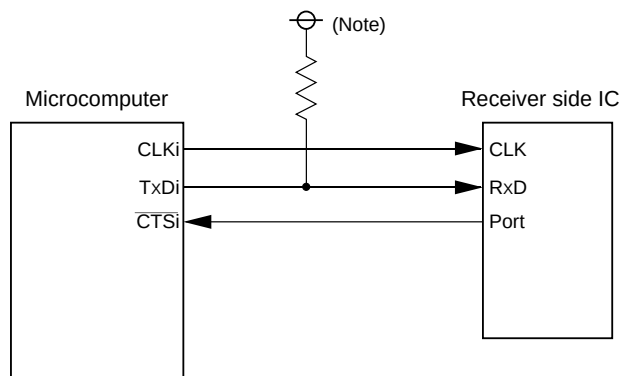
Item	Set-up		Item	Set-up	
Transfer clock source	☐	Internal clock ($f_1 / f_8 / f_{32}$)	Transmission interrupt factor	☐	Transmission buffer empty
		External clock (CLKi pin)			Transmission complete
$\overline{\text{CTS}}$ function	☐	$\overline{\text{CTS}}$ function enabled	Output transfer clock to multiple pins (Note 1)	☐	Not selected
		$\overline{\text{CTS}}$ function disabled			Selected
CLK polarity	☐	Output transmission data at the falling edge of the transfer clock	Data logic select function (Note 2)	☐	No reverse
		Output transmission data at the rising edge of the transfer clock			Reverse
Transfer clock	☐	LSB first	Tx/D, Rx/D I/O polarity reverse bit (Note 2)	☐	No reverse
		MSB first			Reverse

Note 1: This can be selected only when UART1 is used in combination with the internal clock. When this function is selected, UART1 $\overline{\text{CTS}}$ /RTS function can not be utilized. Set the UART1 CTS/RTS disable bit to "1".

Note 2: UART2 only.

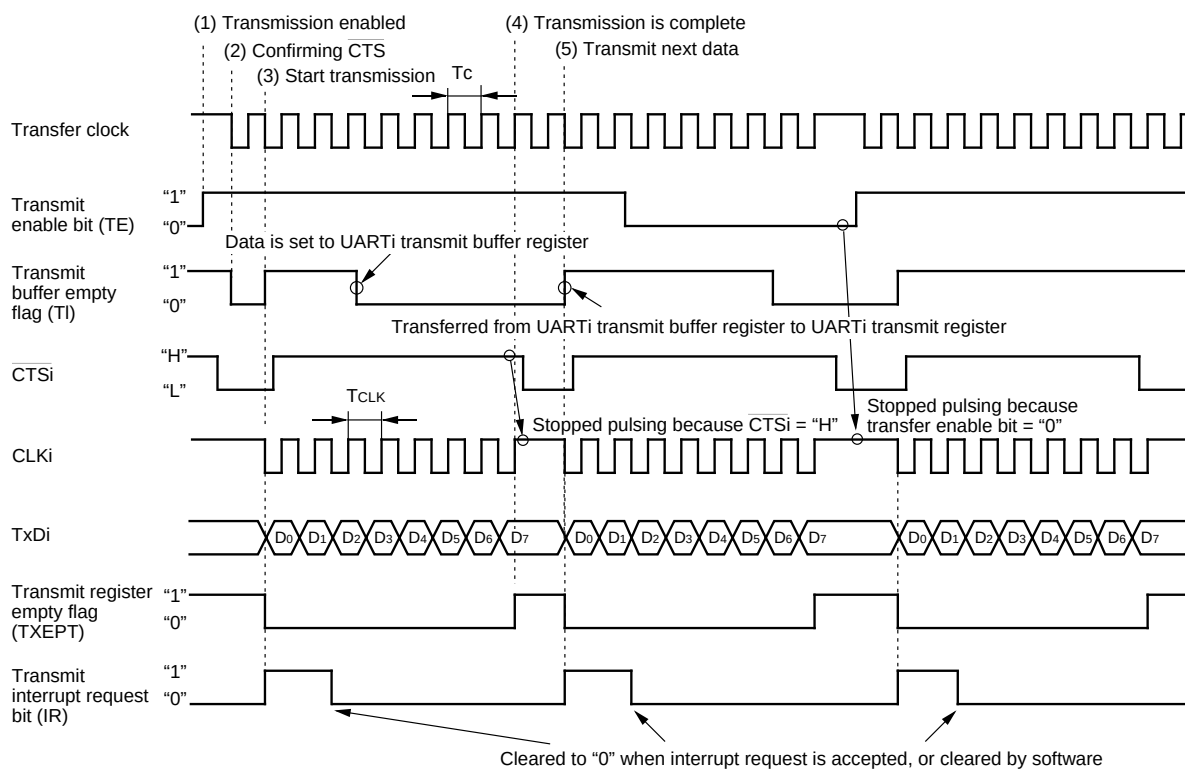
- Operation
- (1) Setting the transmit enable bit to "1" and writing transmission data to the UARTi transmit buffer register makes data transmissible status ready.
 - (2) When input to the $\overline{\text{CTS}}_i$ pin goes to "L" level, transmission starts (the $\overline{\text{CTS}}_i$ pin must be controlled on the reception side).
 - (3) In synchronization with the first falling edge of the transfer clock, transmission data held in the UARTi transmit buffer register is transmitted to the UARTi transmit register. At this time, the UARTi transmit interrupt request bit goes to "1". Also, the first bit of the transmission data is transmitted from the TxDi pin. Then the data is transmitted bit by bit from the lower order in synchronization with the falling edges.
 - (4) When transmission of 1-byte data is completed, the transmit register empty flag goes to "1", which indicates that transmission is completed. The transfer clock stops at "H" level.
 - (5) If the next transmission data is set in the UARTi transmit buffer register while transmission is in progress (before the eighth bit has been transmitted), the data is transmitted in succession.

Example of wiring



Note : Since TxD2 pin is N-channel open drain, this pin needs pull-up resistor.

Example of operation



Shown in () are bit symbols.
The above timing applies to the following settings:

- Internal clock is selected.
- CTS function is selected.
- CLK polarity select bit = "0".
- Transmit interrupt cause select bit = "0".

$$T_c = T_{\text{CLK}} = 2(n + 1) / f_i$$

f_i : frequency of BRGi count source (f_1, f_8, f_{32})
 n : value set to BRGi

Figure 2.4.7. Operation timing of transmission in clock-synchronous serial I/O mode

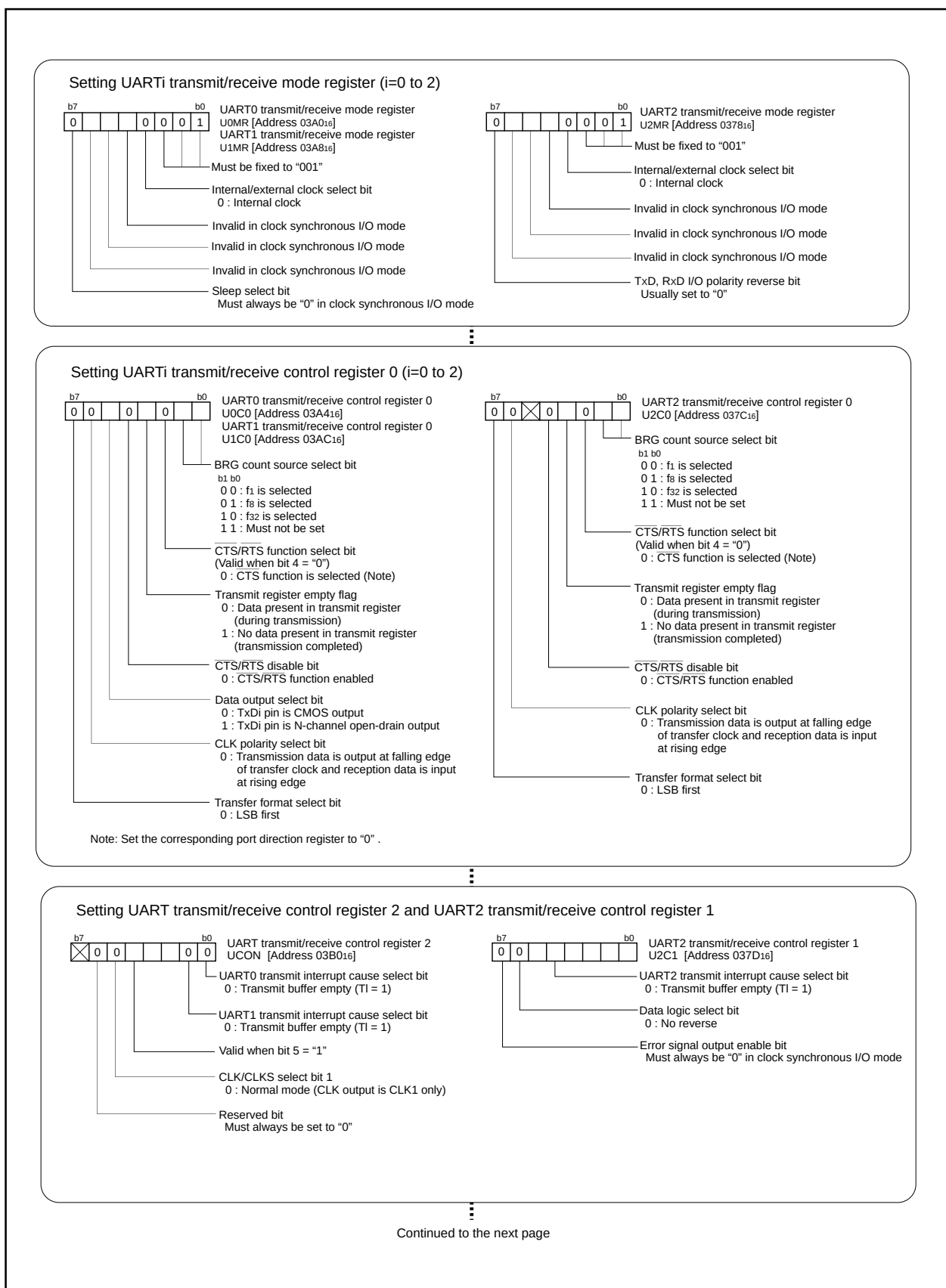


Figure 2.4.8. Set-up procedure of transmission in clock-synchronous serial I/O mode (1)

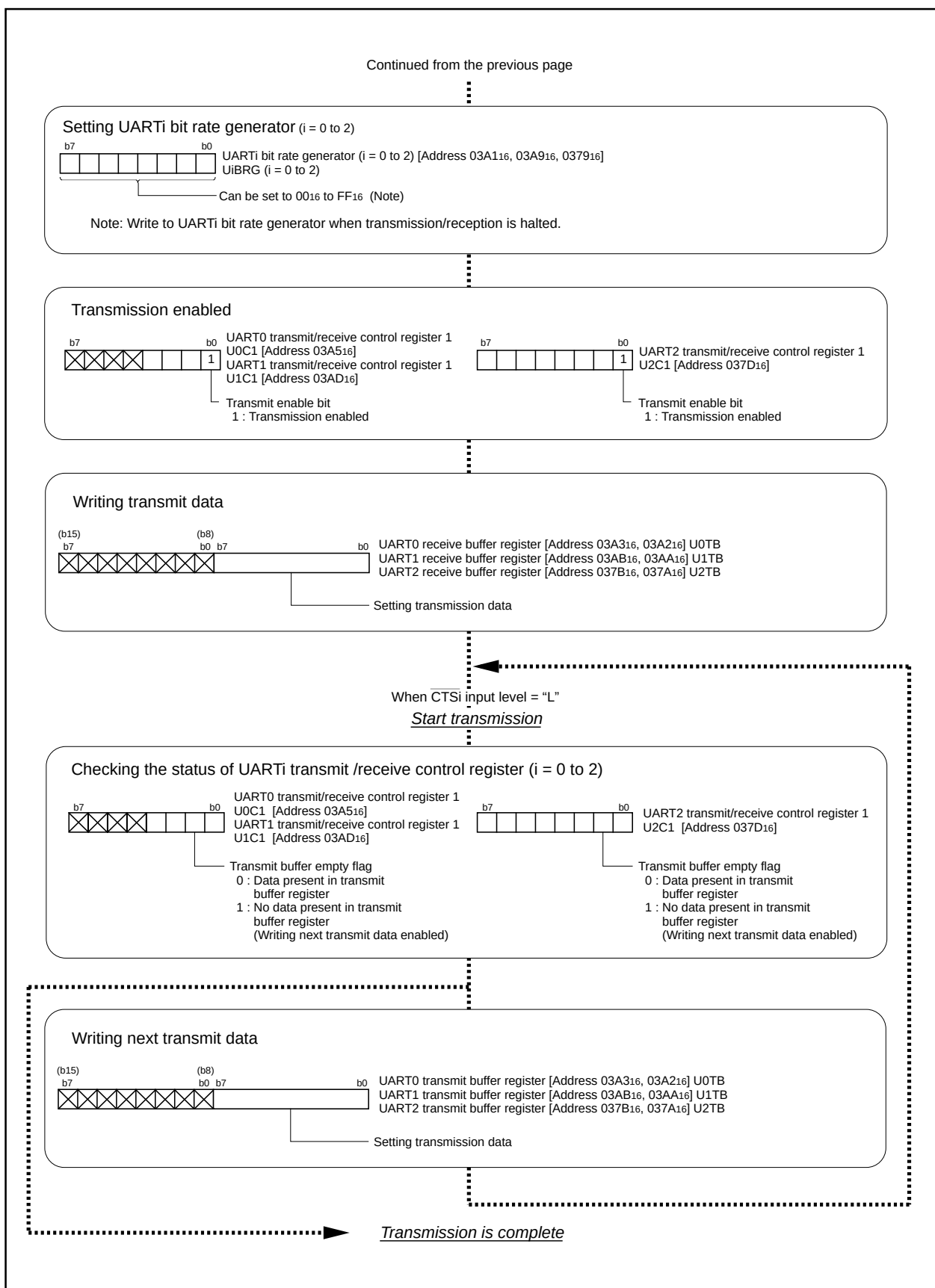


Figure 2.4.9. Set-up procedure of transmission in clock-synchronous serial I/O mode (2)

2.4.3 Operation of the Serial I/O (transmission in clock-synchronous serial I/O mode, transfer clock output from multiple pins function selected)

In transmitting data in clock-synchronous serial I/O mode, choose functions from those listed in Table 2.4.2. Operations of the circled items are described below. Figure 2.4.10 shows the operation timing, and Figures 2.4.11 and 2.4.12 show the set-up procedures.

Table 2.4.2. Chosed functions

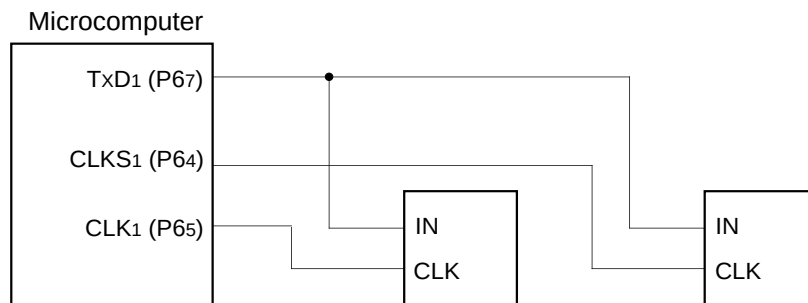
Item	Set-up		Item	Set-up	
Transfer clock source	☐	Internal clock (f ₁ / f ₈ / f ₃₂)	Transmission interrupt factor		Transmission buffer empty
		External clock (CLKi pin)		☐	Transmission complete
CTS function		CTS function enabled	Output transfer clock to multiple pins (Note 1)		Not selected
	☐	CTS function disabled		☐	Selected
CLK polarity	☐	Output transmission data at the falling edge of the transfer clock	Data logic select function (Note 2)	☐	No reverse
		Output transmission data at the rising edge of the transfer clock			Reverse
Transfer clock	☐	LSB first	Tx/D, Rx/D I/O polarity reverse bit (Note 2)	☐	No reverse
		MSB first			Reverse

Note 1: This can be selected only when UART1 is used in combination with the internal clock. When this function is selected, UART1 CTS/RTS function can not be utilized. Set the UART1 CTS/RTS disable bit to "1".

Note 2: UART2 only.

- Operation
- (1) Setting the transmit enable bit to "1" makes data transmissible status ready.
 - (2) When transmission data is written to the UART1 transmit buffer register, transmission data held in the UART1 transmit buffer register is transmitted to the UART1 transmit register in synchronization with the first falling edge of the transfer clock. At this time, the first bit of the transmission data is transmitted from the TxD1 pin. Then the data is transmitted bit by bit from the lower order in synchronization with the falling edges of the transfer clock.
 - (3) When transmission of 1-byte data is completed, the transmit register empty flag goes to "1", which indicates that the transmission is completed. The transfer clock stops at "H" level. At this time, the UART1 transmit interrupt request bit goes to "1".
 - (4) Setting CLK/CLKS select bit 1 to "1" and setting CLK/CLKS select bit 0 to "1" causes the CLKS1 pin to go to the transfer clock output pin. Change the transfer clock output pin when transmission is halted.

Example of wiring



Note: This applies when performing only transmission with an internal clock selected in the clock synchronous serial I/O mode.

Example of operation

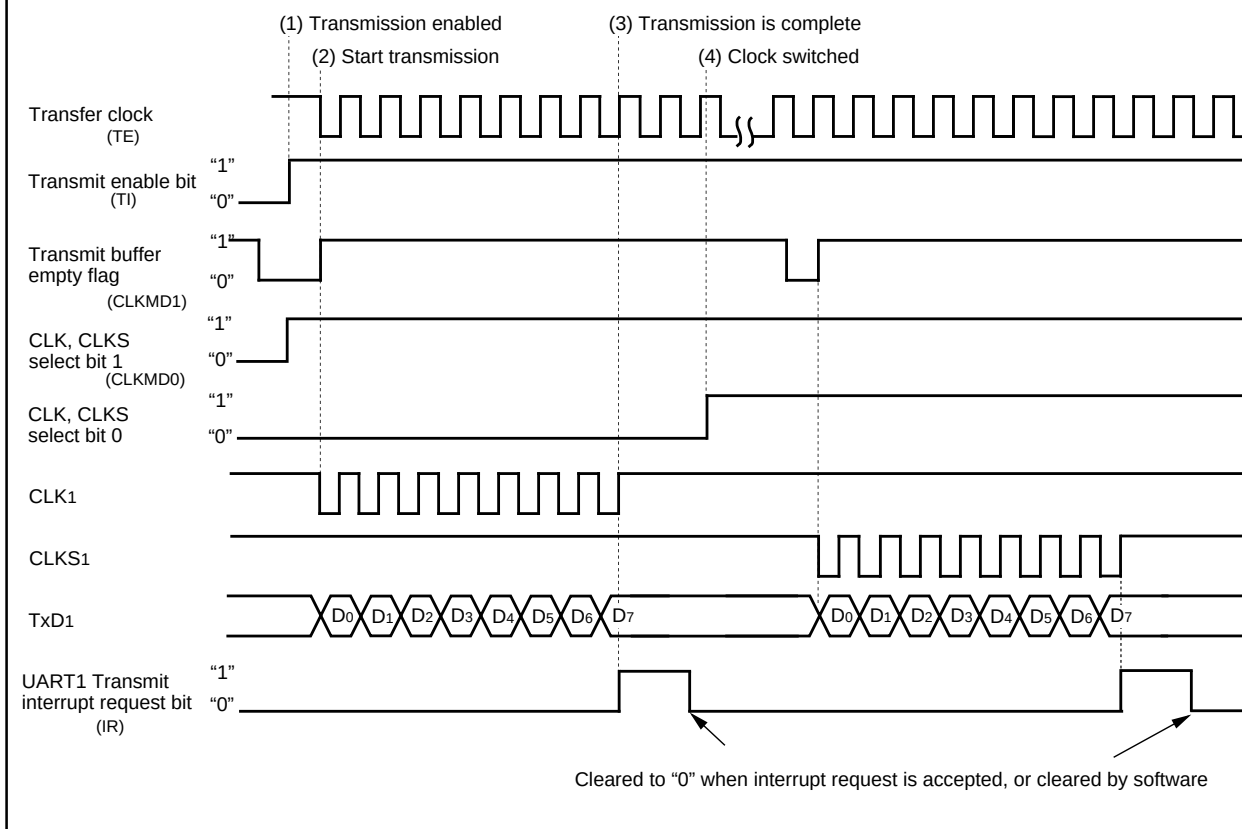
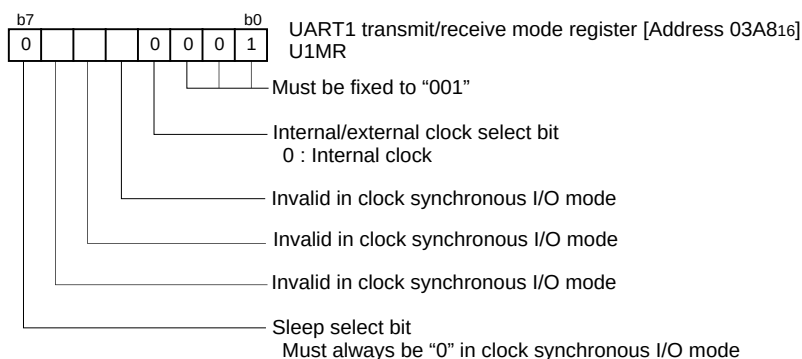


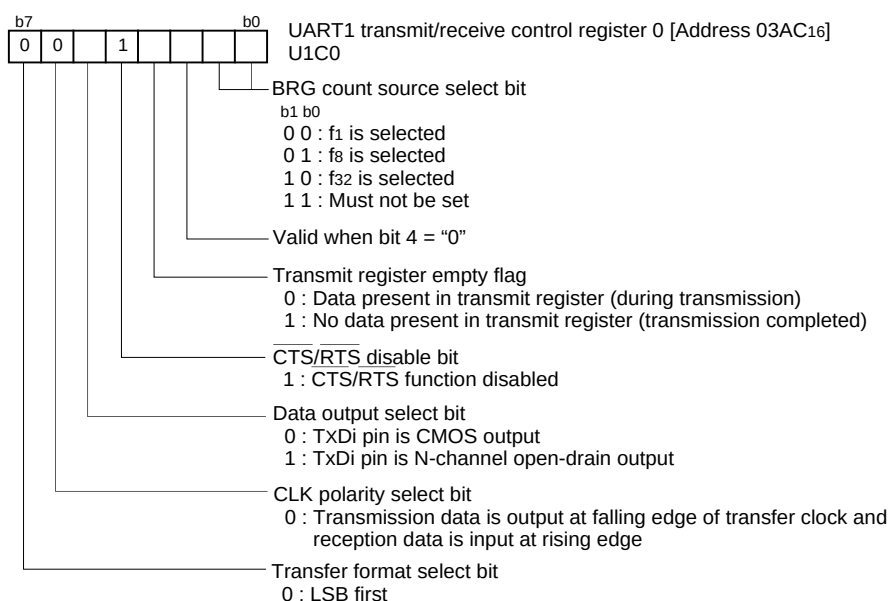
Figure 2.4.10. Operation timing of transmission in clock-synchronous serial I/O mode, transfer clock output from multiple pins function selected

Setting UART1 transmit/receive mode register



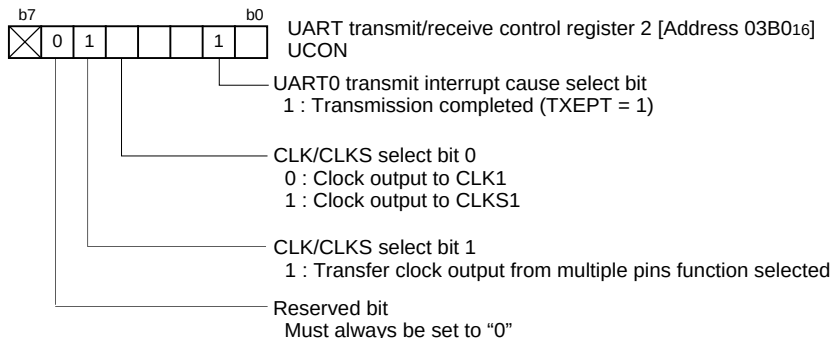
⋮

Setting UART1 transmit/receive control register 0



⋮

Setting UART transmit/receive control register 2



⋮

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Figure 2.4.11. Set-up procedure of transmission in clock-synchronous serial I/O mode, transfer clock output from multiple pins function selected (1)

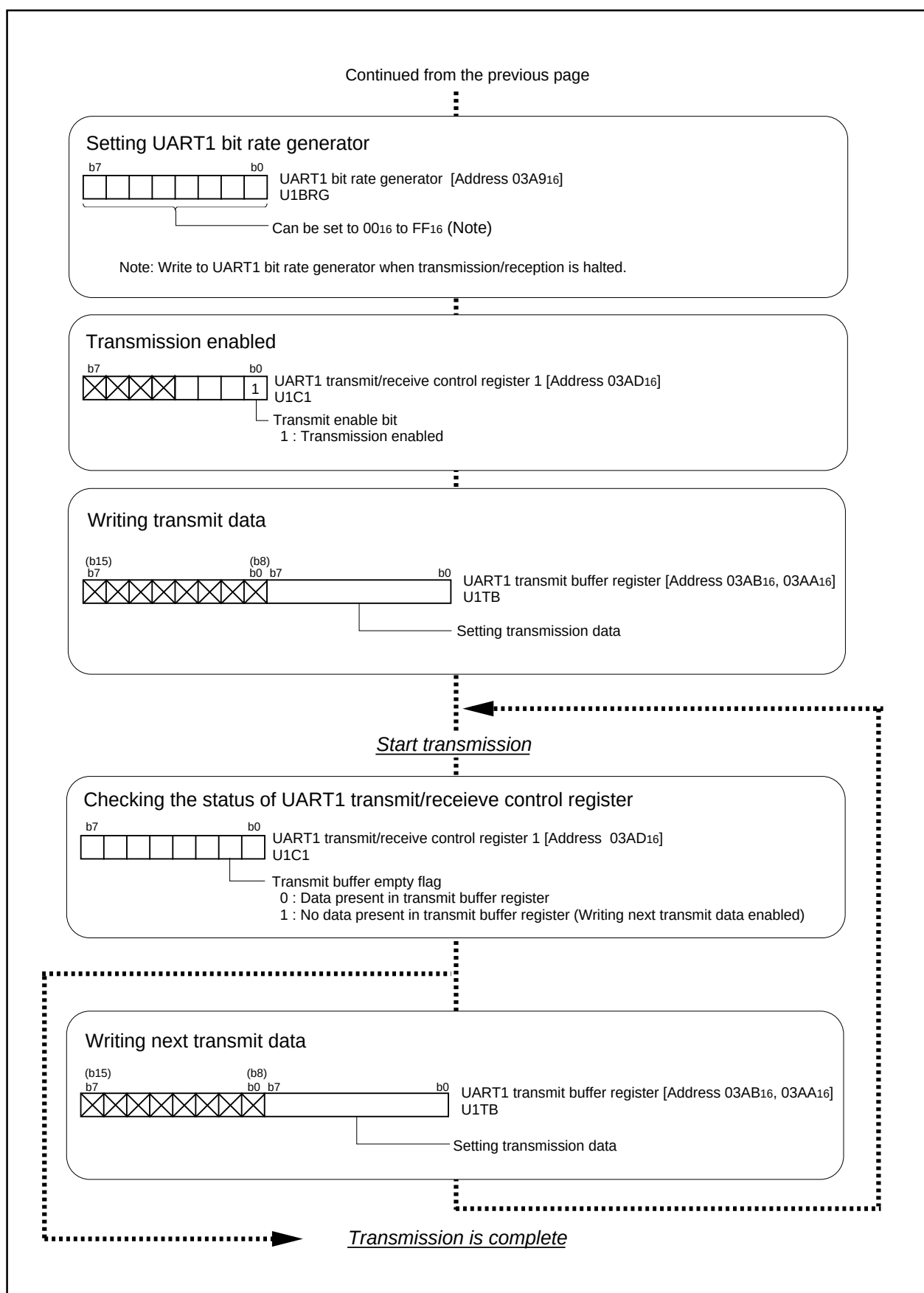


Figure 2.4.12. Set-up procedure of transmission in clock-synchronous serial I/O mode, transfer clock output from multiple pins function selected (2)

2.4.4 Operation of Serial I/O (reception in clock-synchronous serial I/O mode)

In receiving data in clock-synchronous serial I/O mode, choose functions from those listed in Table 2.4.3. Operations of the circled items are described below. Figure 2.4.13 shows the operation timing, and Figures 2.4.14 and 2.4.15 show the set-up procedures.

Table 2.4.3. Chooed functions

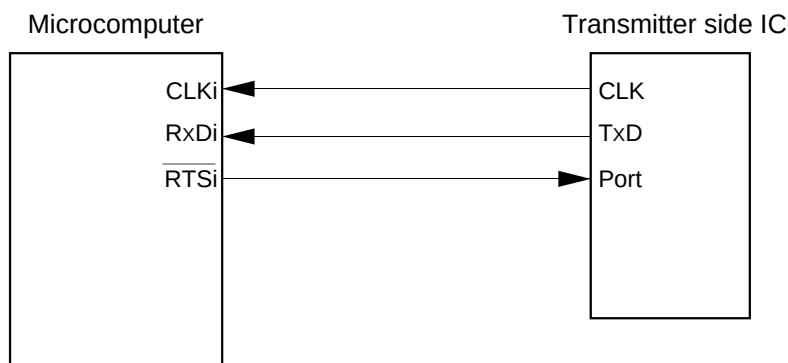
Item	Set-up	Item	Set-up
Transfer clock source	Internal clock (f ₁ / f ₈ / f ₃₂)	Continuous receive mode	☐ Disabled
	☐ External clock (CLKi pin)		☐ Enabled
RTS function	☐ RTS function enabled	Output transfer clock to multiple pins (Note 1)	☐ Not selected
	RTS function disabled		☐ Selected
CLK polarity	☐ Input reception data at the rising edge of the transfer clock	Data logic select function (Note 2)	☐ No reverse
	Input reception data at the falling edge of the transfer clock		☐ Reverse
Transfer clock	☐ LSB first	TxD, RxD I/O polarity reverse bit (Note 2)	☐ No reverse
	MSB first		☐ Reverse

Note 1: This can be selected only when UART1 is used in combination with the internal clock. When this function is selected, UART1 CTS/RTS function can not be utilized. Set the UART1 CTS/RTS disable bit to "1".

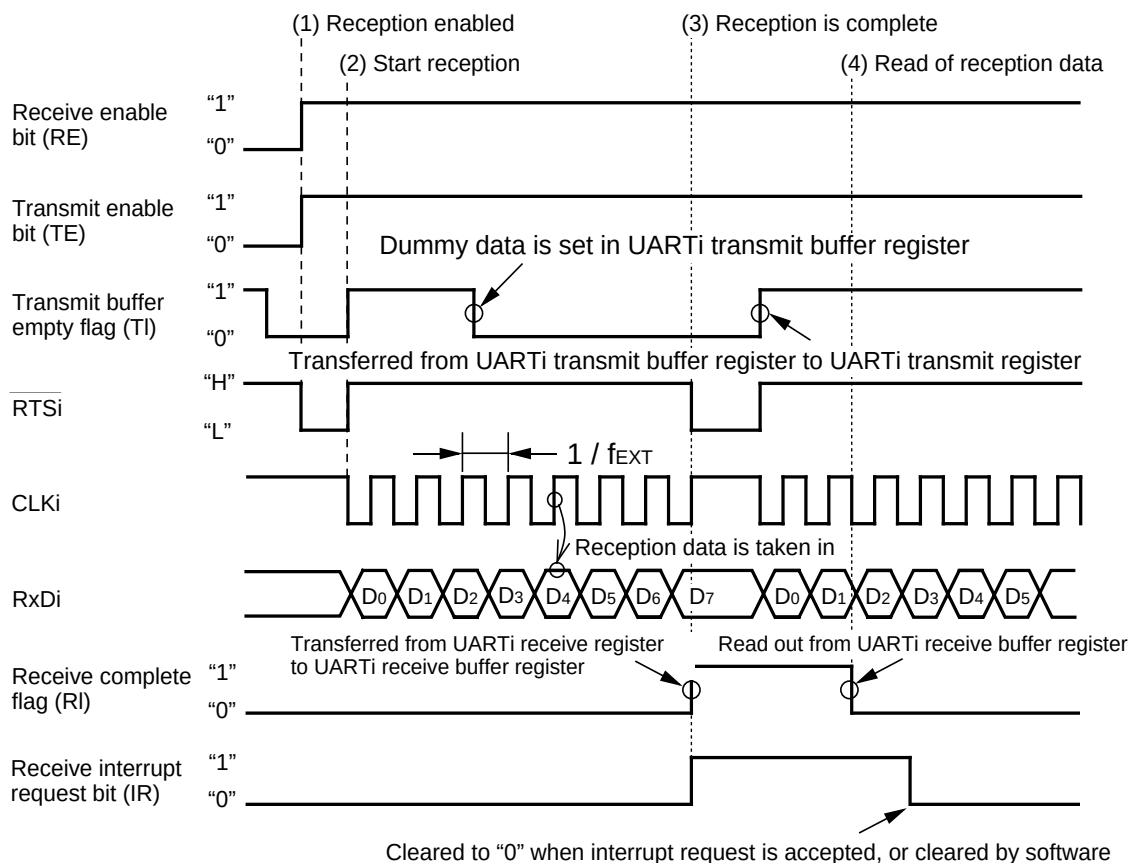
Note 2: UART2 only.

- Operation
- (1) Writing dummy data to the UARTi transmit buffer register, setting the receive enable bit to "1", and the transmit enable bit to "1", makes the data receivable status ready. At this time, the output from the $\overline{\text{RTSi}}$ pin goes to "L" level, which informs the transmission side that the data receivable status is ready (output the transfer clock from the IC on the transmission side after checking that the $\overline{\text{RTS}}$ output has gone to "L" level).
 - (2) In synchronization with the first rising edge of the transfer clock, the input signal to the RxDi pin is stored in the highest bit of the UARTi receive register. Then, data is taken in by shifting right the content of the UARTi reception data in synchronization with the rising edges of the transfer clock.
 - (3) When 1-byte data lines up in the UARTi receive register, the content of the UARTi receive register is transmitted to the UARTi receive buffer register. The transfer clock stops at "H" level. At this time, the receive complete flag and the UARTi receive interrupt request bit goes to "1".
 - (4) The receive complete flag goes to "0" when the lower-order byte of the UARTi buffer register is read.

Example of wiring



Example of operation



Shown in () are bit symbols.

The above timing applies to the following settings:

- External clock is selected.
- RTS function is selected.
- CLK polarity select bit = "0".

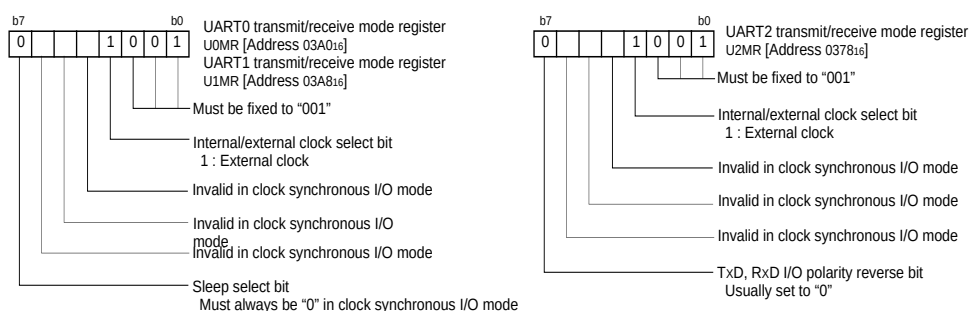
f_{EXT} : frequency of external clock

Make sure that the following conditions are met when the CLKi pin input = "H" before data reception

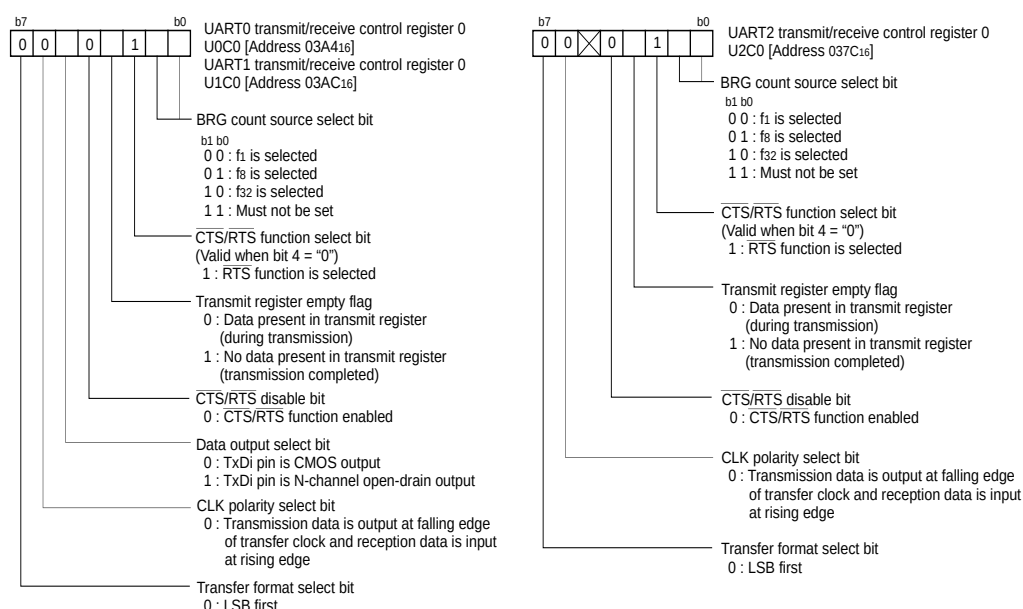
- Transmit enable bit → "1"
- Receive enable bit → "1"
- Dummy data write to UARTi transmit buffer register

Figure 2.4.13. Operation timing of reception in clock-synchronous serial I/O mode

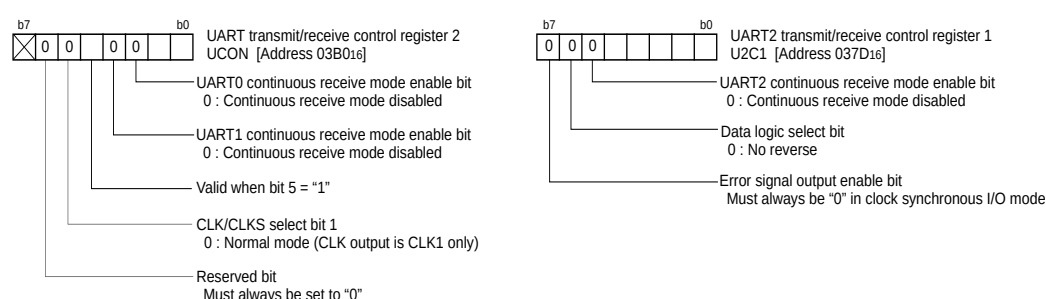
Setting UARTi transmit/receive mode register (i=0 to 2)



Setting UARTi transmit/receive control register 0 (i=0 to 2)



Setting UART transmit/receive control register 2 and UART2 transmit/receive control register 1



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Figure 2.4.14. Set-up procedure of reception in clock-synchronous serial I/O mode (1)

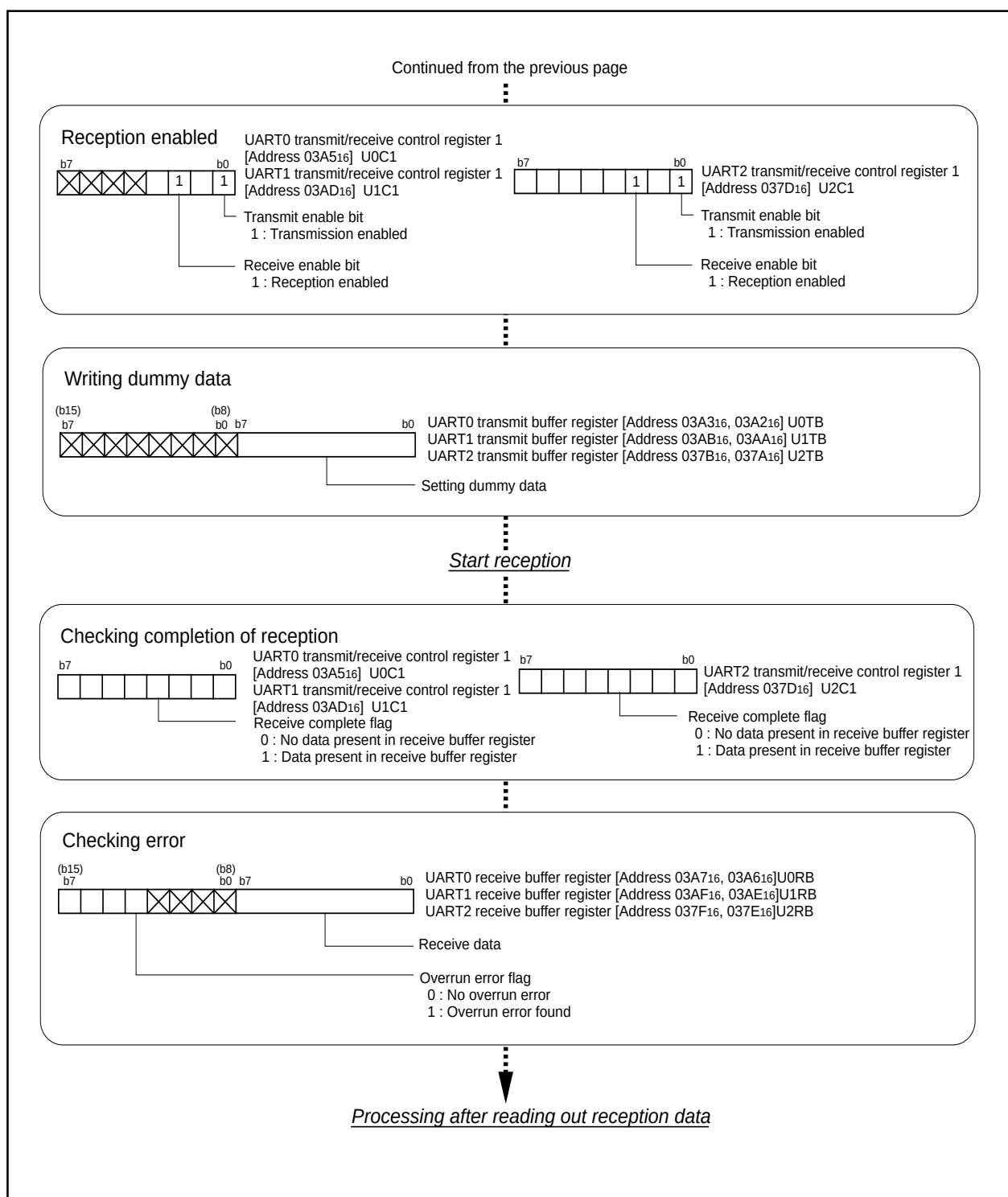


Figure 2.4.15. Set-up procedure of reception in clock-synchronous serial I/O mode (2)

2.4.5 Precautions for Serial I/O (in clock-synchronous serial I/O)

Transmission/reception

- (1) With an external clock selected, and choosing the $\overline{\text{RTS}}$ function, the output level of the $\overline{\text{RTSi}}$ pin goes to "L" when the data-receivable status becomes ready, which informs the transmission side that the reception has become ready. The output level of the $\overline{\text{RTSi}}$ pin goes to "H" when reception starts. So if the $\overline{\text{RTSi}}$ pin is connected to the $\overline{\text{CTSi}}$ pin on the transmission side, the circuit can transmission and reception data with consistent timing. With the internal clock, the $\overline{\text{RTS}}$ function has no effect. Figure 2.4.16 shows an example of wiring.

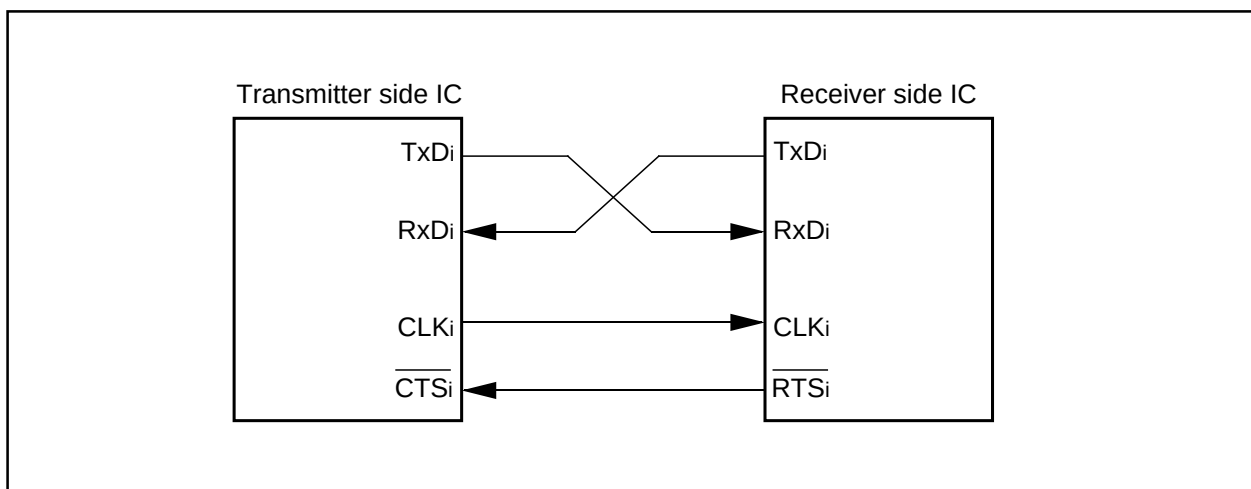


Figure 2.4.16. Example of wiring

Transmission

- (1) With an external clock selected, perform the following set-up procedure with the CLKi pin input level = "H" if the CLK polarity select bit = "0" or with the CLKi pin input level = "L" if the CLK polarity select bit = "1":
 1. Set the transmit enable bit (to "1")
 2. Write transmission data to the UARTi transmit buffer register
 3. "L" level input to the $\overline{\text{CTS}}_i$ pin (when the $\overline{\text{CTS}}$ function is selected)

Reception (1) In operating the clock-synchronous serial I/O, operating a transmitter generates a shift clock. Fix settings for transmission even when using the device only for reception. Dummy data is output to the outside from the TxDi pin (transmission pin) when receiving data.

- (2) With the internal clock selected, setting the transmit enable bit to "1" (transmission-enabled status) and setting dummy data in the UARTi transmission buffer register generates a shift clock.

With the external clock selected, a shift clock is generated when the transmit enable bit is set to "1", dummy data is set in the UARTi transmit buffer register, and the external clock is input to the CLKi pin.

- (3) In receiving data in succession, an overrun error occurs when the next reception data is made ready in the UARTi receive register with the receive complete flag set to "1" (before the content of the UARTi receive buffer register is read), and overrun error flag is set to "1". In this instance, the next data is written to the UARTi receive buffer register, so handle with this problem by writing programs on transmission side and reception side so that the previous data is transmitted again.

If an overrun error occurs, the UARTi receive interrupt request bit does not change.

- (4) To receive data in succession, set dummy data in the lower-order byte of the UARTi transmit buffer register every time reception is made.

- (5) With an external clock selected, perform the following set-up procedure with the CLKi pin input level = "H" if the CLK polarity select bit = "0" or with the CLKi pin input level = "L" if the CLK polarity select bit = "1":

1. Set receive enable bit (to "1")
2. Set transmit enable bit (to "1")
3. Write dummy data to the UARTi transmit buffer register

- (6) Output from the $\overline{\text{RTS}}$ pin goes to "L" level as soon as the receive enable bit is set to "1". This is not related to the content of the transmit buffer empty flag or the content of the transmit enable bit.

Output from the $\overline{\text{RTS}}$ pin goes to "H" level when reception starts, and goes to "L" level when reception is completed. This is not related to the content of the transmit buffer empty flag or the content of the receive complete flag.

2.5.1 Overview of the clock-asynchronous serial I/O usage

(1) Transmission/reception format

The diagram illustrates the bit sequence for different transfer data lengths. It is organized into three main sections, each corresponding to a specific transfer data length. Each section lists the components of the bit sequence (Start bit, Data bits, Parity bit, and Stop bits) and the total number of stop bits (SP).

- Transfer data length : 7 bits**
 - 1ST – 7DATA ——— 1SP
 - 1ST – 7DATA ——— 2SP
 - 1ST – 7DATA – 1PAR – 1SP
 - 1ST – 7DATA – 1PAR – 2SP
- Transfer data length : 8 bits**
 - 1ST – 8DATA ——— 1SP
 - 1ST – 8DATA ——— 2SP
 - 1ST – 8DATA – 1PAR – 1SP
 - 1ST – 8DATA – 1PAR – 2SP
- Transfer data length : 9 bits**
 - 1ST – 9DATA ——— 1SP
 - 1ST – 9DATA ——— 2SP
 - 1ST – 9DATA – 1PAR – 1SP
 - 1ST – 9DATA – 1PAR – 2SP

Legend:

- ST : Start bit
- DATA : Character bit (Transfer data)
- PAR : Parity bit
- SP : Stop bit

Table 2.5.1. Transmission data names and functions

Name	Function
ST (start bit)	A 1-bit “L” signal to be added immediately before character bits. This bit signals the start of data transmission.
DATA (character bits)	Transmission data set in the UARTi transmit buffer register.
PAR (parity bit)	A signal to be added immediately after character bits so as to increase data reliability. The level of this signal so varies that the total number of 1's in character bits and this bit always becomes even or odd depending on which parity is chosen, even or odd.
SP (stop bit)	Either 1-bit or 2-bit “H” signal to be added immediately after character bits (after the parity bit if parity is checked). This / they signals the end of data transmission.

(2) Transfer rate

The divide-by-16 frequency, resulting from division in the bit rate generator (BRG), becomes the transfer rate. The count source for the transfer rate register can be selected from f₁, f₈, f₃₂, and the input from the CLK pin. Clocks f₁, f₈, f₃₂ are derived by dividing the CPU's main clock by 1, 8, and 32 respectively.

Table 2.5.2. Example of baud rate setting

Baud rate (bps)	BRG's count source	System clock : 16MHz		System clock : 7.3728MHz	
		BRG's set value : n	Actual time (bps)	BRG's set value : n	Actual time (bps)
600	f ₈	207 (CF ₁₆)	601	95 (5F ₁₆)	600
1200	f ₈	103 (67 ₁₆)	1202	47 (2F ₁₆)	1200
2400	f ₈	51 (33 ₁₆)	2404	23 (17 ₁₆)	2400
4800	f ₁	207 (CF ₁₆)	4808	95 (5F ₁₆)	4800
9600	f ₁	103 (67 ₁₆)	9615	47 (2F ₁₆)	9600
14400	f ₁	68 (44 ₁₆)	14493	31 (1F ₁₆)	14400
19200	f ₁	51 (33 ₁₆)	19231	23 (17 ₁₆)	19200
28800	f ₁	34 (22 ₁₆)	28571	15 (F ₁₆)	28800
31250	f ₁	33 (21 ₁₆)	31250		

(3) An error detection

In clock-asynchronous serial I/O mode, detect errors are shown in Table 2.5.3.

Table 2.5.3. Error detection

Type of error	Description	When the flag turns on	How to clear the flag
Overrun error	- This error occurs when the next data lines up before the content of the UARTi receive buffer register is read. - The next data is written to the UARTi receive buffer register. - The UARTi receive interrupt request bit does not change.	The error is detected when data is transferred from the UARTi receive register to the UARTi receive buffer register.	- Set the serial I/O mode select bits to "000₂". - Set the receive enable bit to "0".
Framing error	This error occurs when the stop bit falls short of the set number of stop bits.		- Set the serial I/O mode select bits to "000₂". - Set the receive enable bit to "0". - Read the lower-order byte of the UARTi receive buffer register.
Parity error	With parity enabled, this error occurs when the total number of 1's in character bits and the parity bit is different from the specified number.		
Error-sum flag	This flag turns on when any error (overrun, framing, or parity) is detected.		When all error (overrun, framing, and parity) are removed, the flag is cleared.

(4) How to deal with an error

When receiving data, read an error flag and reception data simultaneously to determine which error has occurred. If the data read is erroneous, initialize the error flag and the UARTi receive buffer register, then receive the data again.

To initialize the UARTi receive buffer register

1. Set the receive enable bit to "0" (disable reception).
2. Set the receive enable bit to "1" again (enable reception).

To transmit data again due to an error on the reception side, set the UARTi transmit buffer register again, then transmit the data again.

To set the UARTi transmit buffer register again

1. Set the serial I/O mode select bits to "0002" (invalidate serial I/O).
2. Set the serial I/O mode select bits again.
3. Set the transmit enable bit to "1" (enable transmission), then set transmission data in the UARTi transmit buffer register.

(5) Functions selection

In operating UART, the following functions can be used:

(a) CTS/RTS function

$\overline{\text{CTS}}$ function is a function in which an external IC can start transmission/reception by means of inputting an "L" level to the $\overline{\text{CTS}}$ pin. The $\overline{\text{CTS}}$ pin input level is detected when transmission/reception starts, so if the level is gone to "H" while transmission/reception is in progress, transmission/reception stops at the next data.

$\overline{\text{RTS}}$ function is a function to inform an external IC that $\overline{\text{RTS}}$ pin output level has changed to "L" when reception is ready. $\overline{\text{RTS}}$ regoes to "H" at the falling edge of the transfer clock.

When using clock-asynchronous serial I/O, choose one of three types of $\overline{\text{CTS}}/\overline{\text{RTS}}$ functions.

• $\overline{\text{CTS}}/\overline{\text{RTS}}$ functions disabled	$\overline{\text{CTS}}/\overline{\text{RTS}}$ pin is a programmable I/O port.
• $\overline{\text{CTS}}$ function only enabled	$\overline{\text{CTS}}/\overline{\text{RTS}}$ pin performs the $\overline{\text{CTS}}$ function.
• $\overline{\text{RTS}}$ function only enabled	$\overline{\text{CTS}}/\overline{\text{RTS}}$ pin performs the $\overline{\text{RTS}}$ function.

(b) Sleep mode

Sleep mode is a mode in which data is transferred to a particular microcomputer among those connected by use of clock-asynchronous serial I/O devices.

(c) Data logic select function

This function is to reserve data when writing to transmit buffer register or reading from receive buffer register.

(d) TxD, RxD I/O polarity reverse function

This function receive a polarity of TxD port output level and a polarity of RxD port input level.

(e) Bus collision detection function

This function is to sample the output level of the TxD pin and the input level of the RxD pin at the rising edge of the transfer clock; if their values are different, then an interrupt request occurs.

The following are examples in which functions (a) to (e) are chosen:

- Transmission WITH: $\overline{\text{CTS}}$ function, WITHOUT: other functions P2-84
- Reception WITH: $\overline{\text{RTS}}$ function, WITHOUT: other functions P2-88

Also, the SIM interface is used by adding some extra settings in UART2's clock-asynchronous serial I/O mode. Direct or inverse format is selected by connecting SIM card.

- Transmission WITH: direct format P2-92
- Reception WITH: direct format P2-96

(6) Input to the serial I/O and the direction register

To input an external signal to the serial I/O, set the direction register of the relevant port to input.

(7) Pins related to the serial I/O

- $\overline{\text{CTS0}}$, $\overline{\text{CTS1}}$, $\overline{\text{CTS2}}$ pins :Input pins for the $\overline{\text{CTS}}$ function
- $\overline{\text{RTS0}}$, $\overline{\text{RTS1}}$, $\overline{\text{RTS2}}$ pins :Output pins for the $\overline{\text{RTS}}$ function
- CLK0, CLK1 pins :Input pins for the transfer clock
- RxD0, RxD1, RxD2 pins :Input pins for data
- TxD0, TxD1, TxD2 pins :Output pins for data

Since TxD2 pin is N-channel open drain, this pin needs pull-up resistor.

(8) Registers related to the serial I/O

Figure 2.5.2 shows the memory map of serial I/O-related registers, and Figures 2.5.3 to 2.5.7 show UARTi-related registers.

004A ₁₆	Bus collision detection interrupt control register (BCNIC)
≈	
004F ₁₆	UART2 transmit interrupt control register (S2TIC)
0050 ₁₆	UART2 receive interrupt control register (S2RIC)
0051 ₁₆	UART0 transmit interrupt control register (S0TIC)
0052 ₁₆	UART0 receive interrupt control register (S0RIC)
0053 ₁₆	UART1 transmit interrupt control register(S1TIC)
0054 ₁₆	UART1 receive interrupt control register(S1RIC)
≈	
0378 ₁₆	UART2 transmit/receive mode register (U2MR)
0379 ₁₆	UART2 bit rate generator (U2BRG)
037A ₁₆	UART2 transmit buffer register (U2TB)
037B ₁₆	
037C ₁₆	UART2 transmit/receive control register 0 (U2C0)
037D ₁₆	UART2 transmit/receive control register 1 (U2C1)
037E ₁₆	UART2 receive buffer register (U2RB)
037F ₁₆	
≈	
03A0 ₁₆	UART0 transmit/receive mode register (U0MR)
03A1 ₁₆	UART0 bit rate generator (U0BRG)
03A2 ₁₆	UART0 transmit buffer register (U0TB)
03A3 ₁₆	
03A4 ₁₆	UART0 transmit/receive control register 0 (U0C0)
03A5 ₁₆	UART0 transmit/receive control register 1 (U0C1)
03A6 ₁₆	UART0 receive buffer register (U0RB)
03A7 ₁₆	
03A8 ₁₆	UART1 transmit/receive mode register (U1MR)
03A9 ₁₆	UART1 bit rate generator (U1BRG)
03AA ₁₆	UART1 transmit buffer register (U1TB)
03AB ₁₆	
03AC ₁₆	UART1 transmit/receive control register 0 (U1C0)
03AD ₁₆	UART1 transmit/receive control register 1 (U1C1)
03AE ₁₆	UART1 receive buffer register (U1RB)
03AF ₁₆	
03B0 ₁₆	UART transmit/receive control register 2 (UCON)

Figure 2.5.2. Memory map of UARTi-related registers

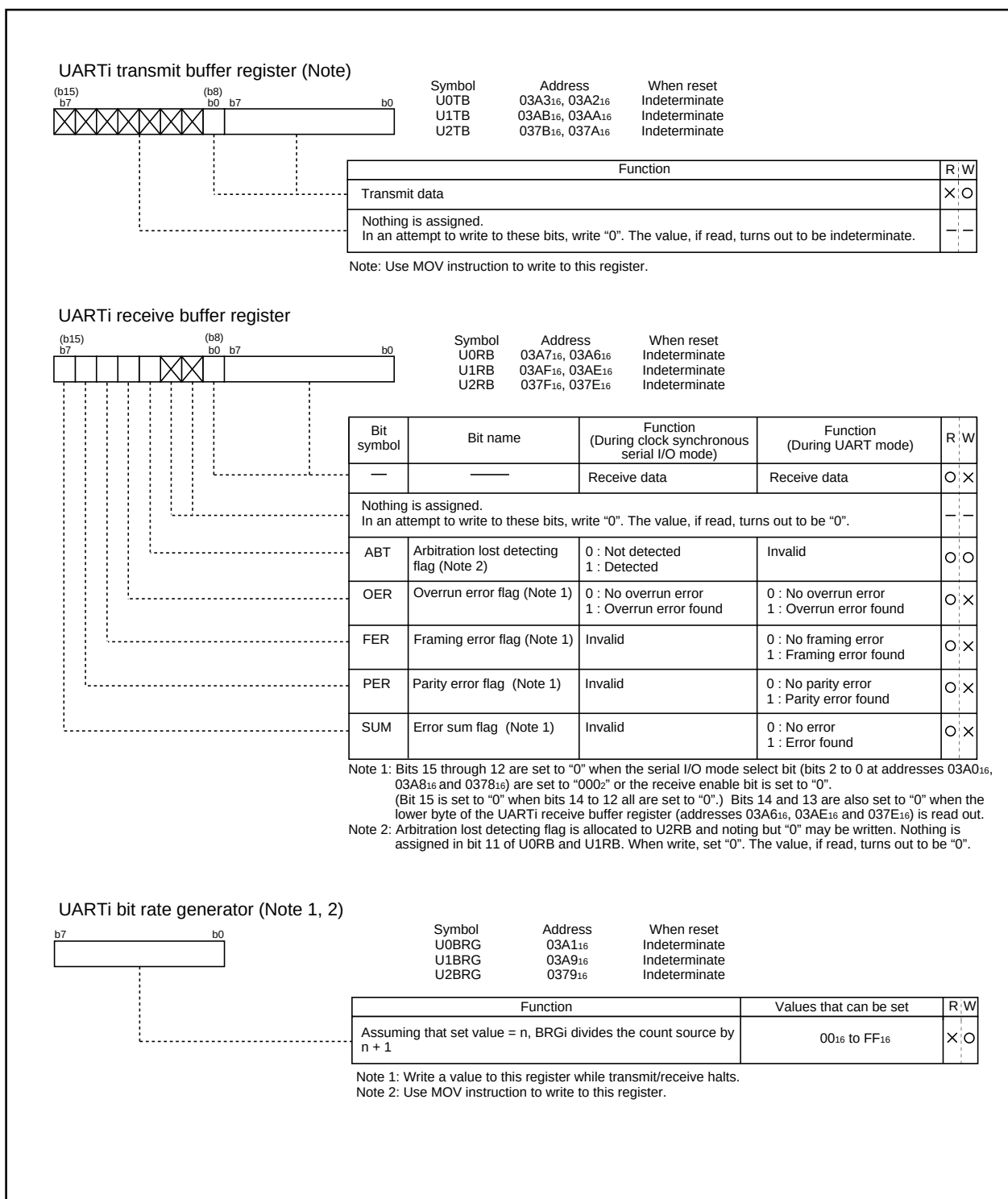


Figure 2.5.3. UARTi-related registers (1)

UARTi transmit/receive mode register

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
b7	SMD0	Must be fixed to 001 b2 b1 b0 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	b2 b1 b0 1 0 0 : Transfer data 7 bits long 1 0 1 : Transfer data 8 bits long 1 1 0 : Transfer data 9 bits long 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	○	○
b6	SMD1			○	○
b5	SMD2			○	○
b4	CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock (Note)	○	○
b3	STPS	Stop bit length select bit	Invalid	○	○
b2	PRY	Odd/even parity select bit	Invalid	○	○
b1	PRYE	Parity enable bit	Invalid	○	○
b0	SLEP	Sleep select bit	Must always be "0"	○	○

Note : Set the corresponding port direction register to "0".

UART2 transmit/receive mode register

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
b7	SMD0	Must be fixed to 001 b2 b1 b0 0 0 0 : Serial I/O invalid 0 1 0 : (Note 1) 0 1 1 : Must not be set. 1 1 1 : Must not be set.	b2 b1 b0 1 0 0 : Transfer data 7 bits long 1 0 1 : Transfer data 8 bits long 1 1 0 : Transfer data 9 bits long 0 0 0 : Serial I/O invalid 0 1 0 : Must not be set. 0 1 1 : Must not be set. 1 1 1 : Must not be set.	○	○
b6	SMD1			○	○
b5	SMD2			○	○
b4	CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock (Note 2)	○	○
b3	STPS	Stop bit length select bit	Invalid	○	○
b2	PRY	Odd/even parity select bit	Invalid	○	○
b1	PRYE	Parity enable bit	Invalid	○	○
b0	IOPOL	TxD, RxD I/O polarity reverse bit	0 : No reverse 1 : Reverse Usually set to "0"	○	○

Note 1: Bit 2 to bit 0 are set to "0102" when I²C mode is used.

Note 2: Set the corresponding port direction register to "0".

Figure 2.5.4. UARTi-related registers (2)

UARTi transmit/receive control register 0

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
CLK0	BRG count source select bit	b1 b0 0 0 : f1 is selected 0 1 : f8 is selected 1 0 : f32 is selected 1 1 : Must not be set.	b1 b0 0 0 : f1 is selected 0 1 : f8 is selected 1 0 : f32 is selected 1 1 : Must not be set.	○	○
CLK1				○	○
CRS	CTS/RTS function select bit	Valid when bit 4 = "0" 0 : CTS function is selected (Note 1) 1 : RTS function is selected (Note 2)	Valid when bit 4 = "0" 0 : CTS function is selected (Note 1) 1 : RTS function is selected (Note 2)	○	○
TXEPT	Transmit register empty flag	0 : Data present in transmit register (during transmission) 1 : No data present in transmit register (transmission completed)	0 : Data present in transmit register (during transmission) 1 : No data present in transmit register (transmission completed)	○	×
CRD	CTS/RTS disable bit	0 : CTS/RTS function enabled 1 : CTS/RTS function disabled (P60 and P64 function as programmable I/O port)	0 : CTS/RTS function enabled 1 : CTS/RTS function disabled (P60 and P64 function as programmable I/O port)	○	○
NCH	Data output select bit	0 : TxDi pin is CMOS output 1 : TxDi pin is N-channel open-drain output	0 : TxDi pin is CMOS output 1 : TxDi pin is N-channel open-drain output	○	○
CKPOL	CLK polarity select bit	0 : Transmit data is output at falling edge of transfer clock and receive data is input at rising edge 1 : Transmit data is output at rising edge of transfer clock and receive data is input at falling edge	Must always be "0"	○	○
UFORM	Transfer format select bit	0 : LSB first 1 : MSB first	Must always be "0"	○	○

Note 1: Set the corresponding port direction register to "0".

Note 2: The settings of the corresponding port register and port direction register are invalid.

UART2 transmit/receive control register 0

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
CLK0	BRG count source select bit	b1 b0 0 0 : f1 is selected 0 1 : f8 is selected 1 0 : f32 is selected 1 1 : Must not be set.	b1 b0 0 0 : f1 is selected 0 1 : f8 is selected 1 0 : f32 is selected 1 1 : Must not be set.	○	○
CLK1				○	○
CRS	CTS/RTS function select bit	Valid when bit 4 = "0" 0 : CTS function is selected (Note 1) 1 : RTS function is selected (Note 2)	Valid when bit 4 = "0" 0 : CTS function is selected (Note 1) 1 : RTS function is selected (Note 2)	○	○
TXEPT	Transmit register empty flag	0 : Data present in transmit register (during transmission) 1 : No data present in transmit register (transmission completed)	0 : Data present in transmit register (during transmission) 1 : No data present in transmit register (transmission completed)	○	×
CRD	CTS/RTS disable bit	0 : CTS/RTS function enabled 1 : CTS/RTS function disabled (P73 functions programmable I/O port)	0 : CTS/RTS function enabled 1 : CTS/RTS function disabled (P73 functions programmable I/O port)	○	○
Nothing is assigned. In an attempt to write to this bit, write "0". The value, if read, turns out to be "0".				—	—
CKPOL	CLK polarity select bit	0 : Transmit data is output at falling edge of transfer clock and receive data is input at rising edge 1 : Transmit data is output at rising edge of transfer clock and receive data is input at falling edge	Must always be "0"	○	○
UFORM	Transfer format select bit (Note 3)	0 : LSB first 1 : MSB first	0 : LSB first 1 : MSB first	○	○

Note 1: Set the corresponding port direction register to "0".

Note 2: The settings of the corresponding port register and port direction register are invalid.

Note 3: Only clock synchronous serial I/O mode and 8-bit UART mode are valid.

Figure 2.5.5. UARTi-related registers (3)

UARTi transmit/receive control register 1

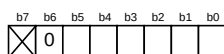
b7 b6 b5 b4 b3 b2 b1 b0								Symbol UIC1(i=0,1)	Address 03A5 ₁₆ ,03AD ₁₆	When reset 02 ₁₆
Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W					
TE	Transmit enable bit	0 : Transmission disabled 1 : Transmission enabled	0 : Transmission disabled 1 : Transmission enabled	○	○					
TI	Transmit buffer empty flag	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	0 : Data present in transmit buffer register 1 : No data present in transmit buffer register	○	×					
RE	Receive enable bit	0 : Reception disabled 1 : Reception enabled	0 : Reception disabled 1 : Reception enabled	○	○					
RI	Receive complete flag	0 : No data present in receive buffer register 1 : Data present in receive buffer register	0 : No data present in receive buffer register 1 : Data present in receive buffer register	○	×					
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".				—	—					

UART2 transmit/receive control register 1

b7	b6	b5	b4	b3	b2	b1	b0	Symbol	Address	When reset
								U2C1	037D ₁₆	02 ₁₆

Figure 2.5.6. UARTi-related registers (4)

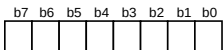
UART transmit/receive control register 2

Symbol
UCONAddress
03B0₁₆When reset
X0000002

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
U0IRS	UART0 transmit interrupt cause select bit	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	○	○
U1IRS	UART1 transmit interrupt cause select bit	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	○	○
U0RRM	UART0 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enable	Must always be "0"	○	○
U1RRM	UART1 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enable	Must always be "0"	○	○
CLKMD0	CLK/CLKS select bit 0	Valid when bit 5 = "1" 0 : Clock output to CLK1 1 : Clock output to CLKS1	Invalid	○	○
CLKMD1	CLK/CLKS select bit 1 (Note)	0 : Normal mode (CLK output is CLK1 only) 1 : Transfer clock output from multiple pins function selected	Must always be "0"	○	○
Reserved bit		Must always be set to "0"		○	○
Nothing is assigned. In an attempt to write to this bit, write "0". The value, if read, turns out to be indeterminate.				—	—

Note: When using multiple pins to output the transfer clock, the following requirements must be met:
• UART1 internal/external clock select bit (bit 3 at address 03A8₁₆) = "0".

UART2 special mode register

Symbol
U2SMRAddress
0377₁₆When reset
00₁₆

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
IICM	I ² C mode select bit	0 : Normal mode 1 : I ² C mode	Must always be "0"	○	○
ABC	Arbitration lost detecting flag control bit	0 : Update per bit 1 : Update per byte	Must always be "0"	○	○
BBS	Bus busy flag	0 : STOP condition detected 1 : START condition detected	Must always be "0"	○	○ (Note1)
LSYN	SCLL sync output enable bit	0 : Disabled 1 : Enabled	Must always be "0"	○	○
ABSCS	Bus collision detect sampling clock select bit	Must always be "0"	0 : Rising edge of transfer clock 1 : Underflow signal of timer A0	○	○
ACSE	Auto clear function select bit of transmit enable bit	Must always be "0"	0 : No auto clear function 1 : Auto clear at occurrence of bus collision	○	○
SSS	Transmit start condition select bit	Must always be "0"	0 : Ordinary 1 : Falling edge of Rx _{D2}	○	○
SDDS	SDA digital delay select bit (Note 2, Note 3)	0 : Analog delay output is selected 1 : Digital delay output is selected (must always be "0" when not using I ² C mode)	Must always be "0"	○	○

Note 1: Nothing but "0" may be written.

Note 2: When not in I²C mode, do not set this bit by writing a "1". During normal mode, fix it to "0". When this bit = "0", UART2 special mode register 3 (U2SMR3 at address 0375₁₆) bits 7 to 5 (DL2 to DL0 = SDA digital delay setup bits) are initialized to "000", with the analog delay circuit selected. Also, when SDDS = "0", the U2SMR3 register cannot be read or written to.

Note 3: When analog delay is selected, only the analog delay value is effective; when digital delay is selected, only the digital delay value is effective.

Figure 2.5.7. UARTi-related registers (5)

2.5.2 Operation of Serial I/O (transmission in UART mode)

In transmitting data in UART mode, choose functions from those listed in Table 2.5.4. Operations of the circled items are described below. Figure 2.5.8 shows the operation timing, and Figures 2.5.9 and 2.5.10 show the set-up procedures.

Table 2.5.4. Chosed functions

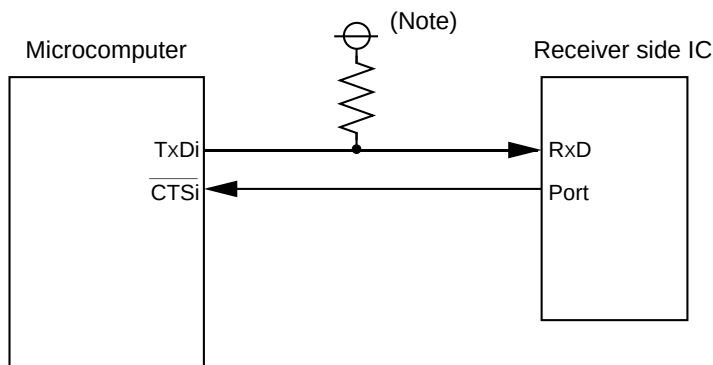
Item	Set-up		Item	Set-up	
Transfer clock source (Note 1)	○	Internal clock ($f_1 / f_8 / f_{32}$)	Sleep mode (Note 1)	○	Sleep mode off
		External clock (CLKi pin)			Sleep mode selected
CTS function	○	CTS function enabled	Data logic select function (Note 2)	○	No reverse
		CTS function disabled			Reverse
Transmission interrupt factor	○	Transmission buffer empty	TxD, RxD I/O polarity reverse bit (Note 2)	○	No reverse
					Reverse
		Transmission complete	Bus collision detection function (Note 2)	○	Not selected
					Selected

Note 1: UART0, UART1 only.

Note 2: UART2 only.

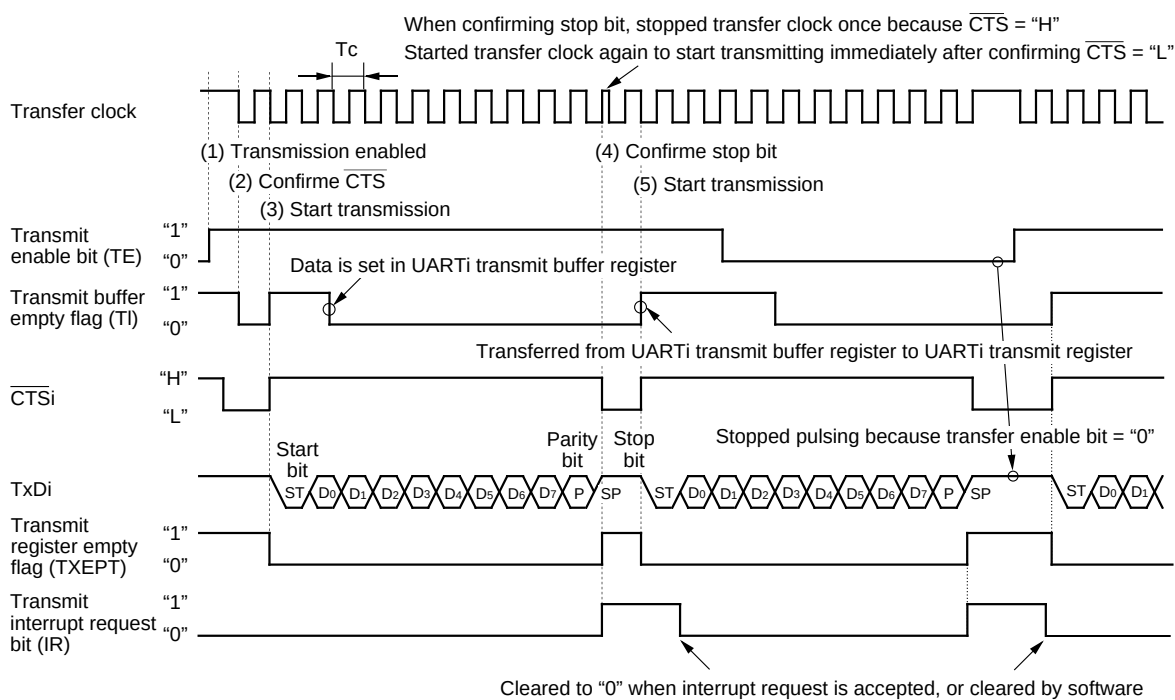
- Operation
- (1) Setting the transmit enable bit to "1" and writing transmission data to the UARTi transmit buffer register readies the data transmissible status.
 - (2) When input to the $\overline{\text{CTS}}_i$ pin goes to "L", transmission starts (the $\overline{\text{CTS}}_i$ pin needs to be controlled on the reception side).
 - (3) Transmission data held in the UARTi transmit buffer register is transmitted to the UARTi transmit register. At this time, the first bit (the start bit) of the transmission data is transmitted from the TxDi pin. Then, data is transmitted, bit by bit, in sequence: LSB, ..., MSB, parity bit, and stop bit(s).
 - (4) When the stop bit(s) is (are) transmitted, the transmit register empty flag goes to "1", which indicates that transmission is completed. At this time, the UARTi transmit interrupt request bit goes to "1". The transfer clock stops at "H" level.
 - (5) If the transmission condition of the next data is ready when transmission is completed, a start bit is generated following to stop bit(s), and the next data is transmitted.

Example of wiring



Note: Since TxD2 pin is N-channel open drain, this pin needs pull-up resistor.

Example of operation



Shown in () are bit symbols.

The above timing applies to the following settings :

- Parity is enabled.
- One stop bit.
- CTS function is selected.
- Transmit interrupt cause select bit = "1".

$$T_c = 16(n + 1) / f_i \text{ or } 16(n + 1) / f_{EXT}$$

f_i : frequency of BRGi count source (f_1, f_8, f_{32})
 f_{EXT} : frequency of BRGi count source (external clock)
 n : value set to BRGi

Figure 2.5.8. Operation timing of transmission in UART mode

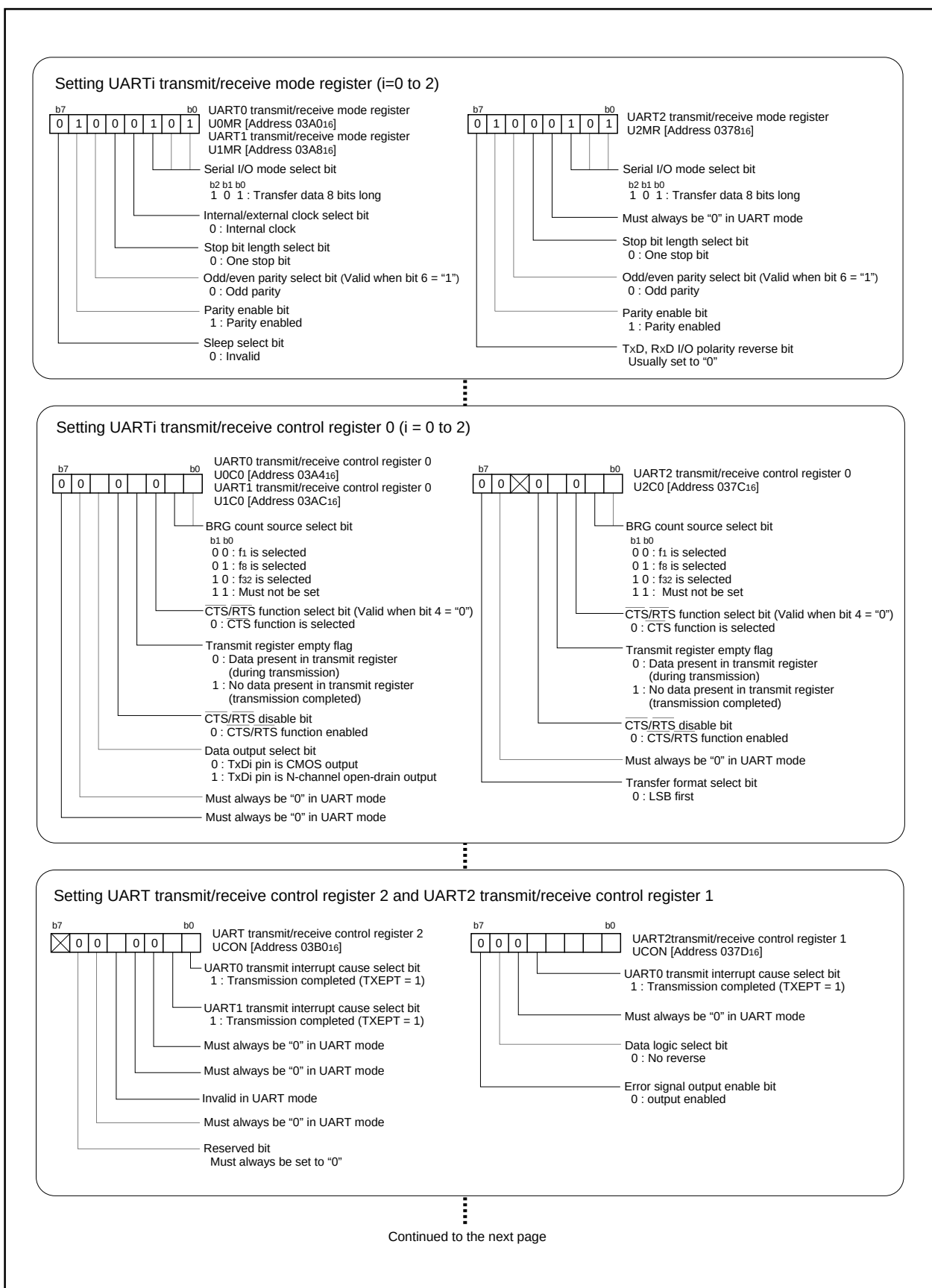


Figure 2.5.9. Set-up procedure of transmission in UART mode (1)

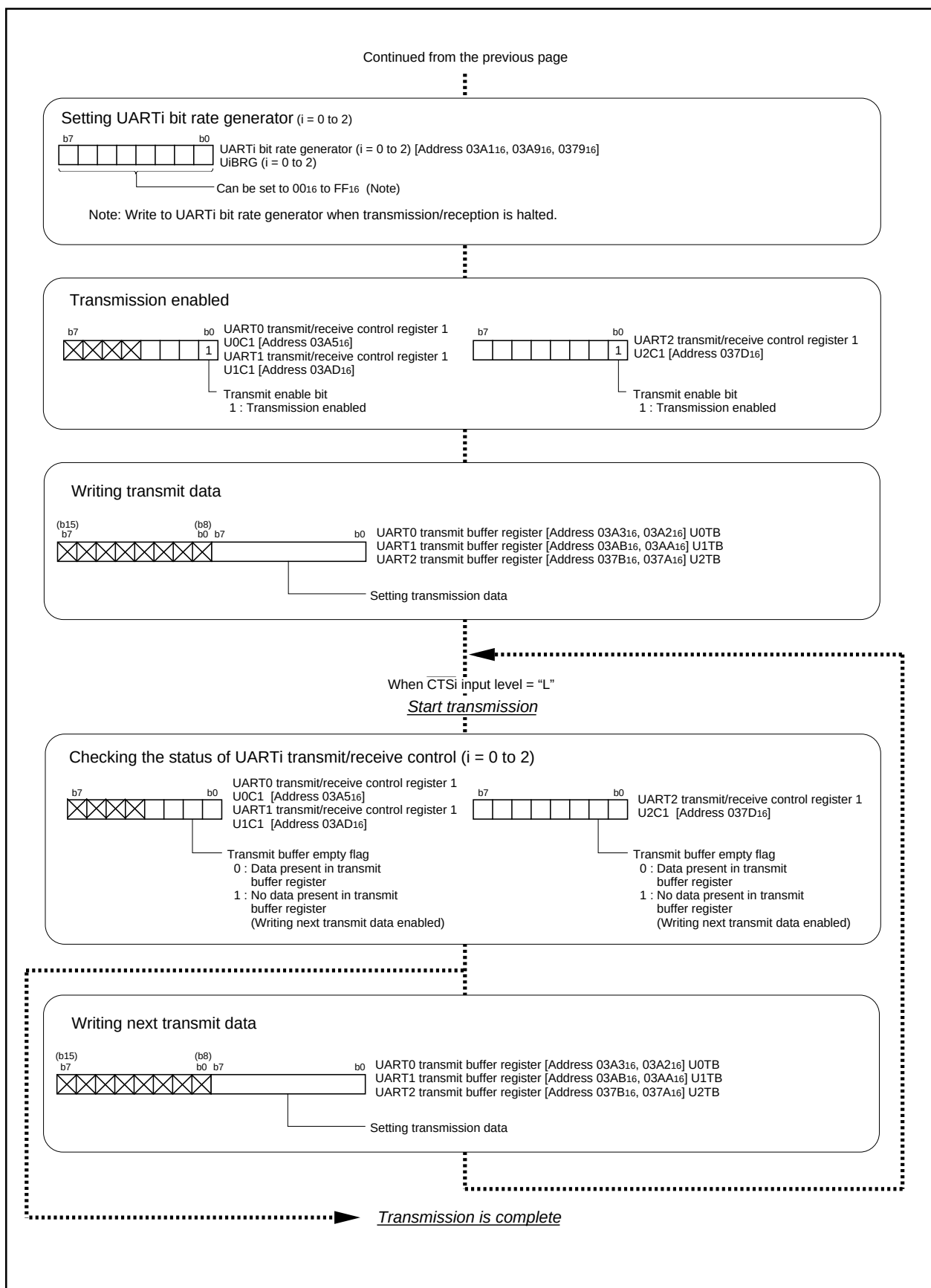


Figure 2.5.10. Set-up procedure of transmission in UART mode (2)

2.5.3 Operation of Serial I/O (reception in UART mode)

In receiving data in UART mode, choose functions from those listed in Table 2.5.5. Operations of the circled items are described below. Figure 2.5.11 shows the operation timing, and Figures 2.5.12 and 2.5.13 show the set-up procedures.

Table 2.5.5. Chosed functions

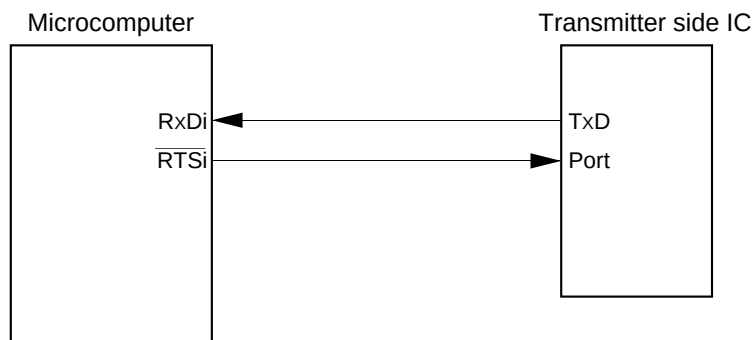
Item	Set-up		Item	Set-up	
Transfer clock source (Note 1)	☐	Internal clock (f_1 / f_8 / f_{32})	Data logic select function (Note 2)	☐	No reverse
		External clock (CLKi pin)			Reverse
RTS function	☐	RTS function enabled	Tx/D, Rx/D I/O polarity reverse bit (Note 2)	☐	No reverse
		RTS function disabled			Reverse
Sleep mode (Note 1)	☐	Sleep mode off	Bus collision detection function (Note 2)	☐	Not selected
		Sleep mode selected			Selected

Note 1: UART0, UART1 only.

Note 2: UART2 only.

- Operation
- (1) Setting the receive enable bit to "1" readies data-receivable status. At this time, output from the $\overline{\text{RTSi}}$ pin goes to "L" level to inform the transmission side that the receivable status is ready.
 - (2) When the first bit (the start bit) of reception data is received from the RxDi pin, output from the $\overline{\text{RTS}}$ goes to "H" level. Then, data is received, bit by bit, in sequence: LSB, ..., MSB, and stop bit(s).
 - (3) When the stop bit(s) is (are) received, the content of the UARTi receive register is transmitted to the UARTi receive buffer register.
At this time, the receive complete flag goes to "1" to indicate that the reception is completed, the UARTi receive interrupt request bit goes to "1", and output from the $\overline{\text{RTS}}$ pin goes to "H" level.
 - (4) The receive complete flag goes to "0" when the lower-order byte of the UARTi buffer register is read.

Example of wiring



Example of operation

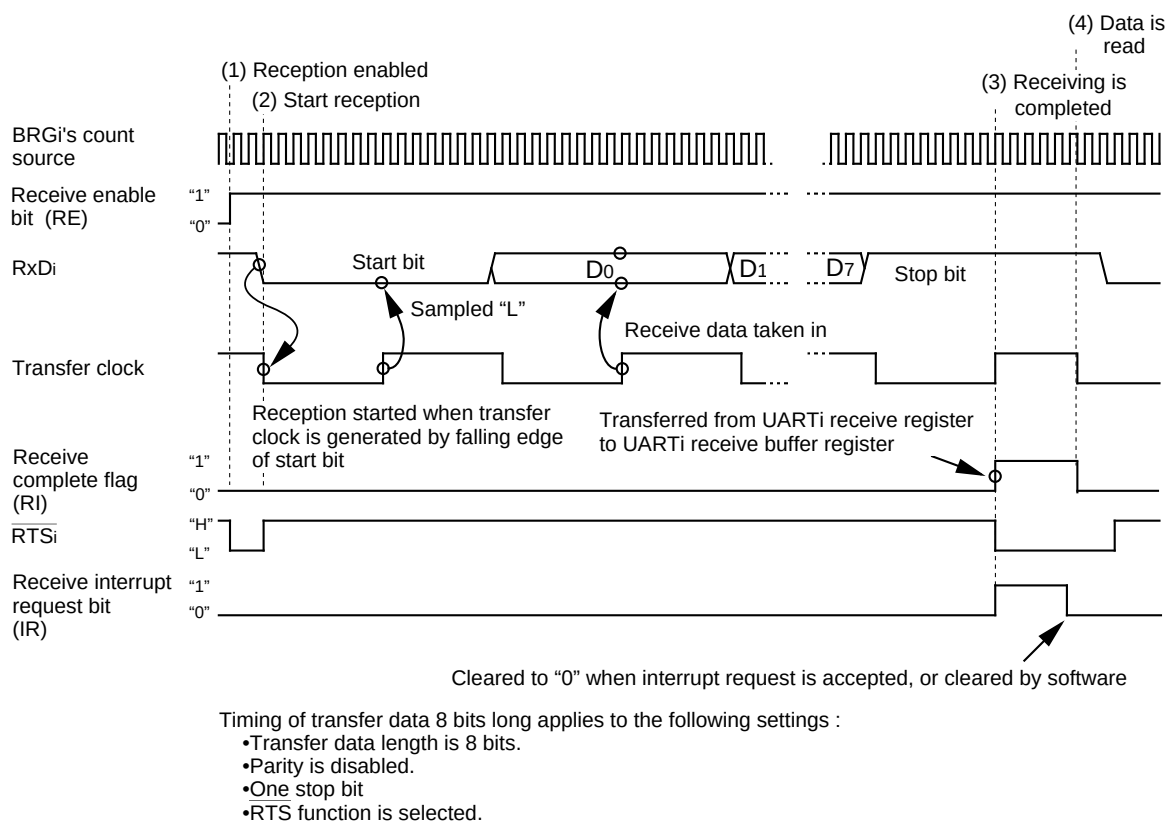


Figure 2.5.11. Operation timing of reception in UART mode

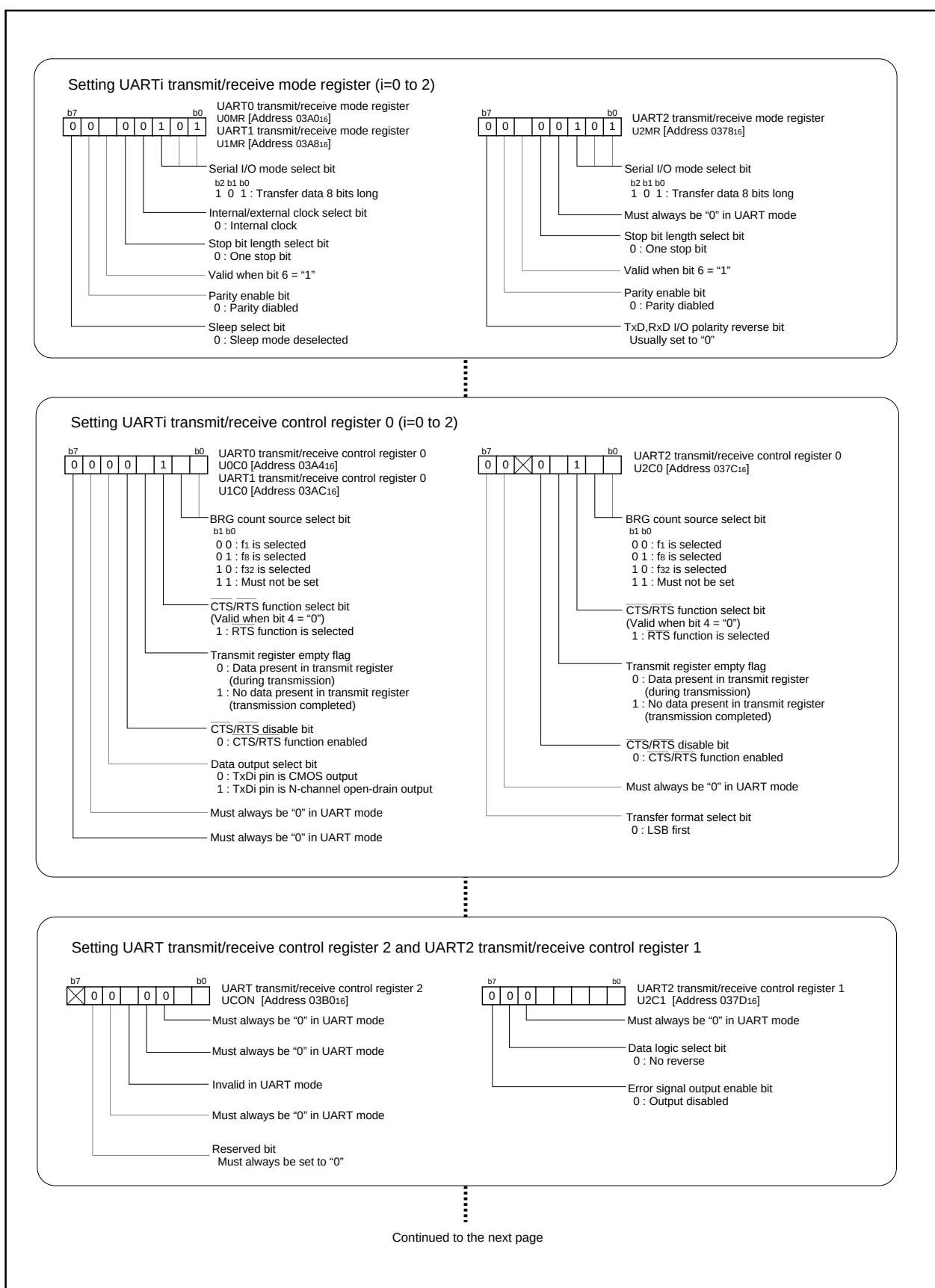


Figure 2.5.12. Set-up procedure of reception in UART mode (1)

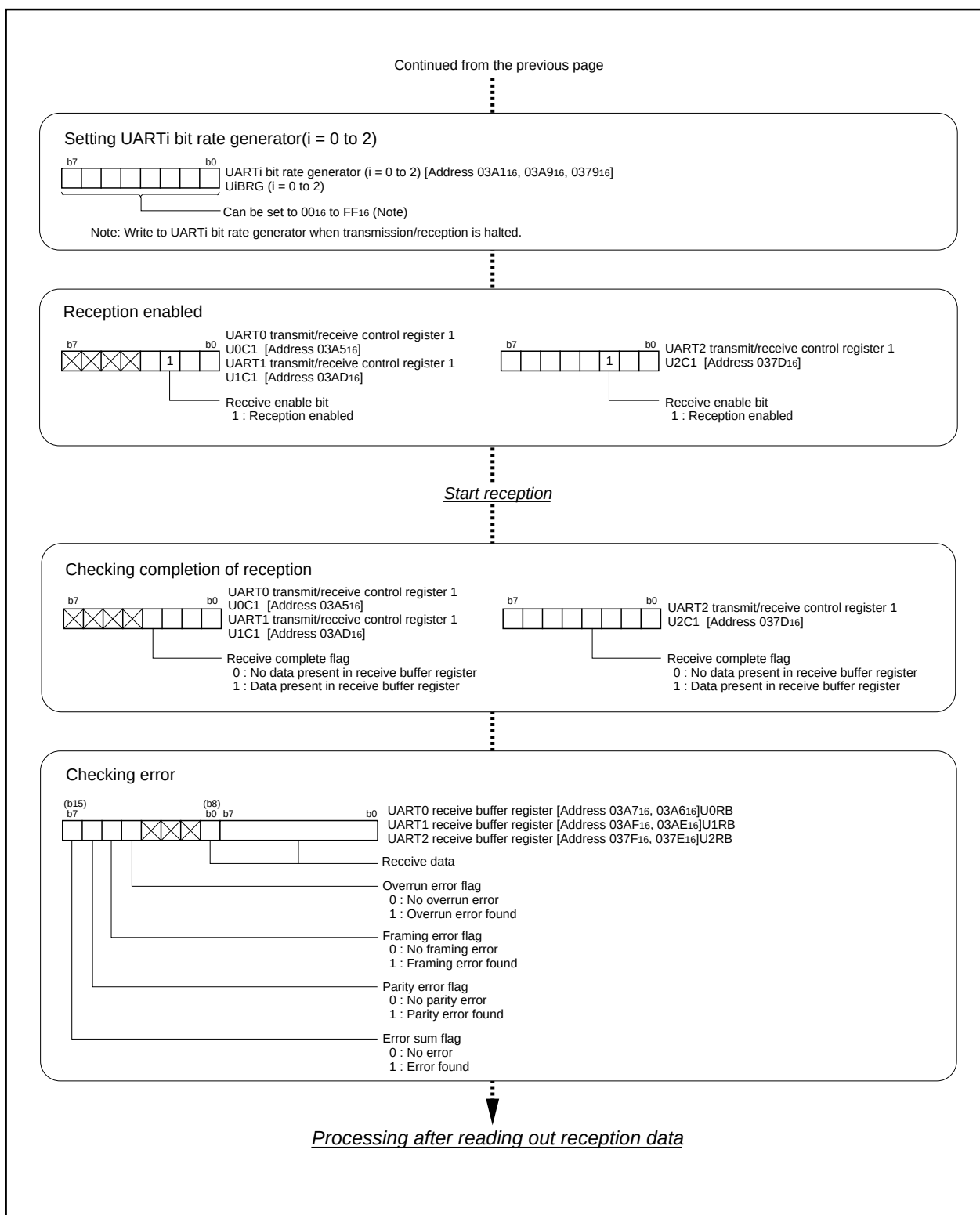


Figure 2.5.13. Set-up procedure of reception in UART mode (2)

2.5.4 Operation of Serial I/O (transmission used for SIM interface)

In transmitting data in UART mode (used for SIM interface), choose functions from those listed in Table 2.5.6. Operations of the circled items are described below. Figure 2.5.14 shows the operation timing, and Figures 2.5.15 and 2.5.16 show the set-up procedures.

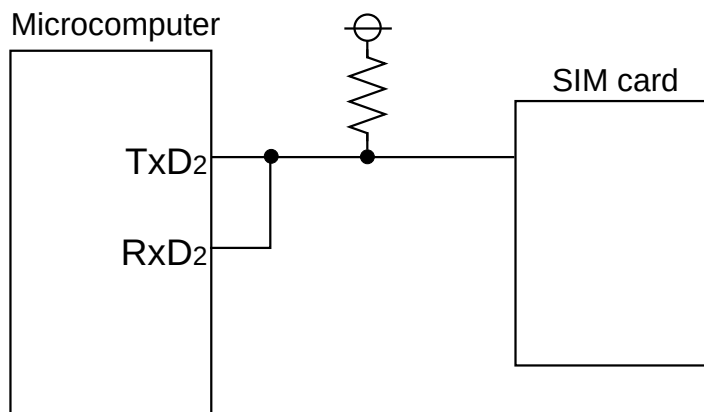
Table 2.5.6. Chooed functions

Item	Set-up	
Transfer data format	☐	Direct format
	☐	Inverse format

- Operation (1) Setting the transmit enable bit and receive enable bit to "1" and writing transmission data to the UART2 transmit buffer register readies the data transmissible status. Set UART2 transfer interrupt is enabled.
- (2) Transmission data held in the UART2 transmit buffer register is transmitted to the UART2 transmit register. At this time, the first bit (the start bit) of the transmission data is transmitted from the TxD2 pin. Then, data is transmitted, bit by bit, in sequence: LSB, ..., MSB, parity bit, and stop bit(s).
- (3) When the stop bit(s) is (are) transmitted, the transmit register empty flag goes to "1", which indicates that transmission is completed. At this time, the UART2 transmit interrupt request bit goes to "1". The transfer clock stops at "H" level.
- (4) If the transmission condition of the next data is ready when transmission is completed, a start bit is generated following to stop bit(s), and the next data is transmitted.
- (5) If a parity error occurs, an L is output from the SIM card, and the RxD2 terminal turns to the "L" level. Check the RxD2 terminal's level within the UART2 transmission interrupt routine, and if it is found to be at the "L" level, then handle the error.

- Note
- The parity error level is determined within a UART2 transmission interrupt. When a transmission interrupt request occurs, set the priority level of the transmission interrupt higher than those of other interrupts so that the interrupt routine can be immediately carried out. Either in the main routine or in an interrupt routine, the interrupt inhibition time has to be made as short as possible.
 - Set the RxD2 terminal's direction register to input.

Example of wiring



Example of operation (when direct format)

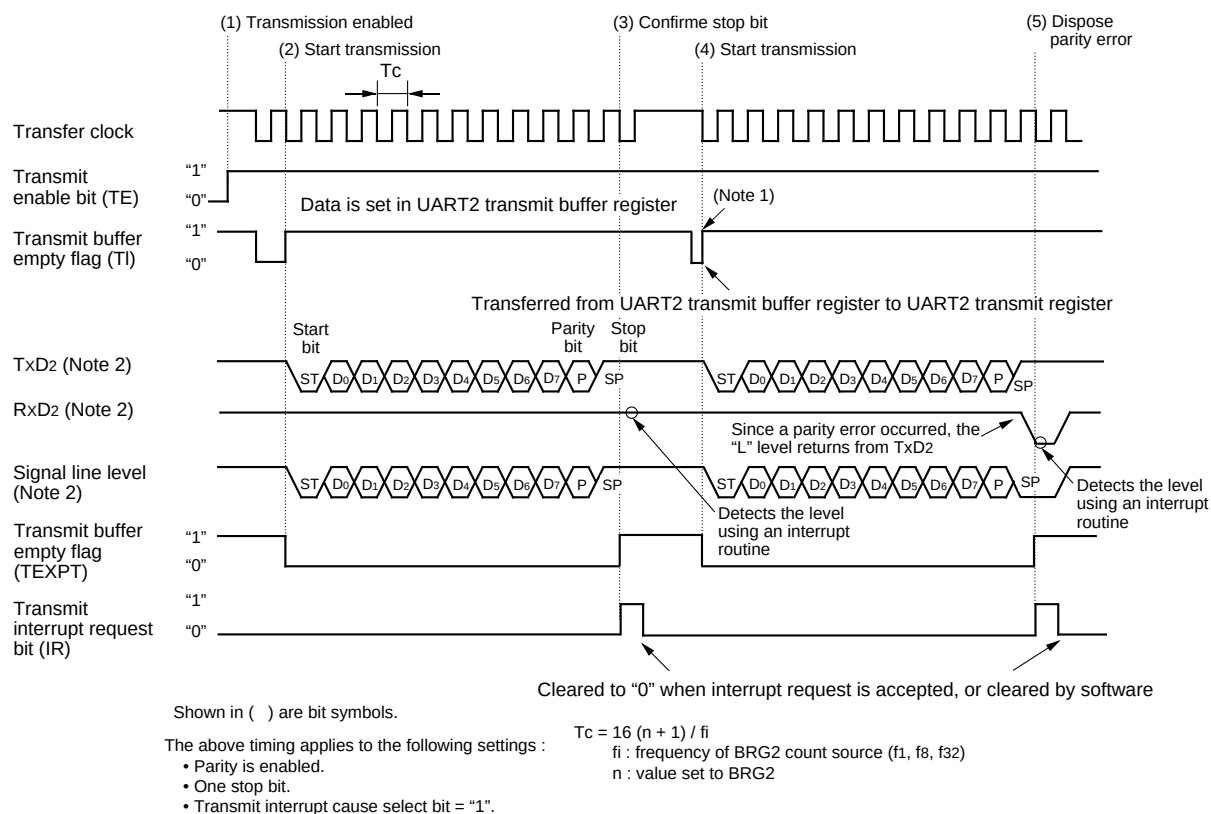


Figure 2.5.14. Operation timing of transmission in UART mode (used for SIM interface)

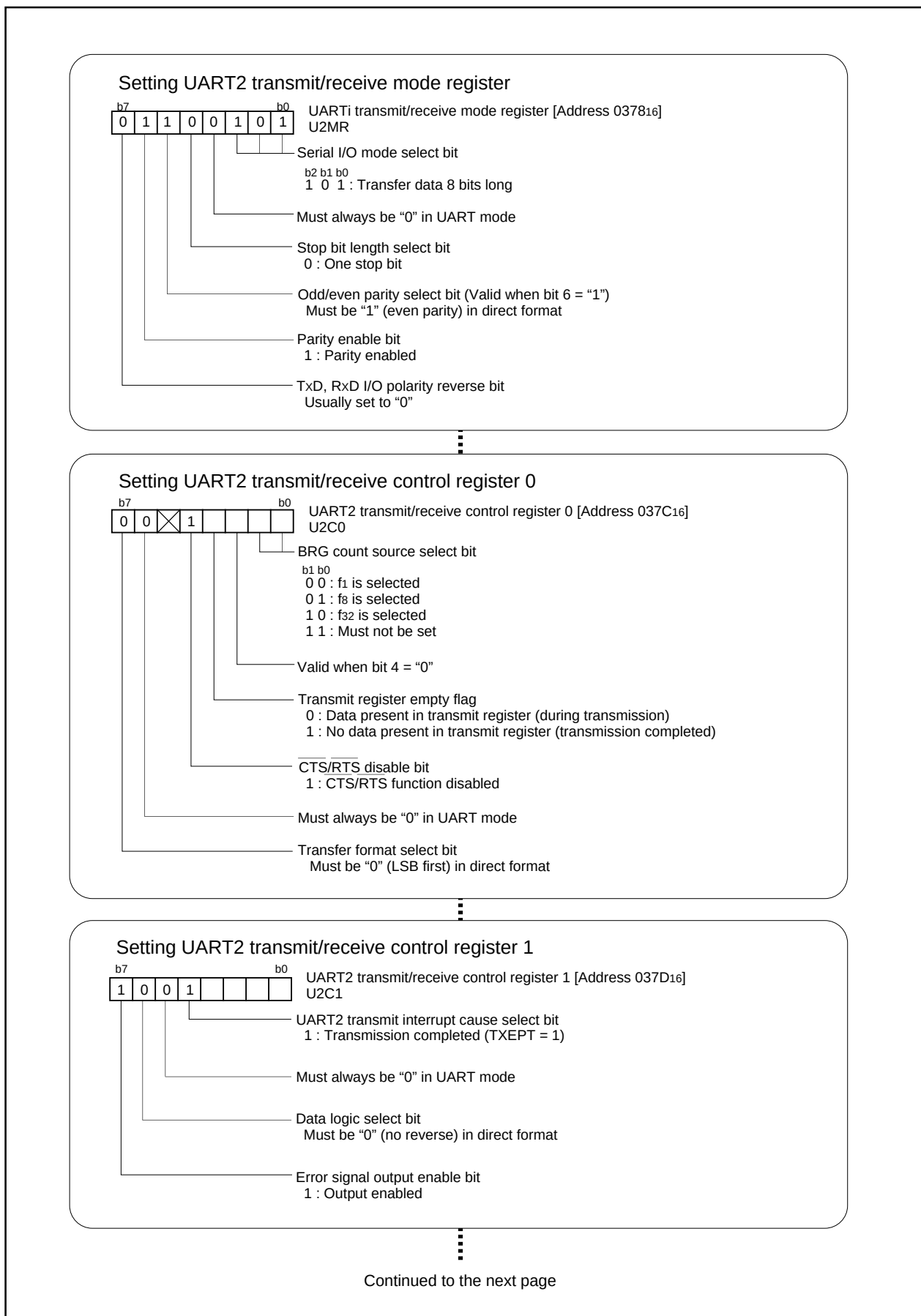


Figure 2.5.15. Set-up procedure of transmission in UART mode (used for SIM interface) (1)

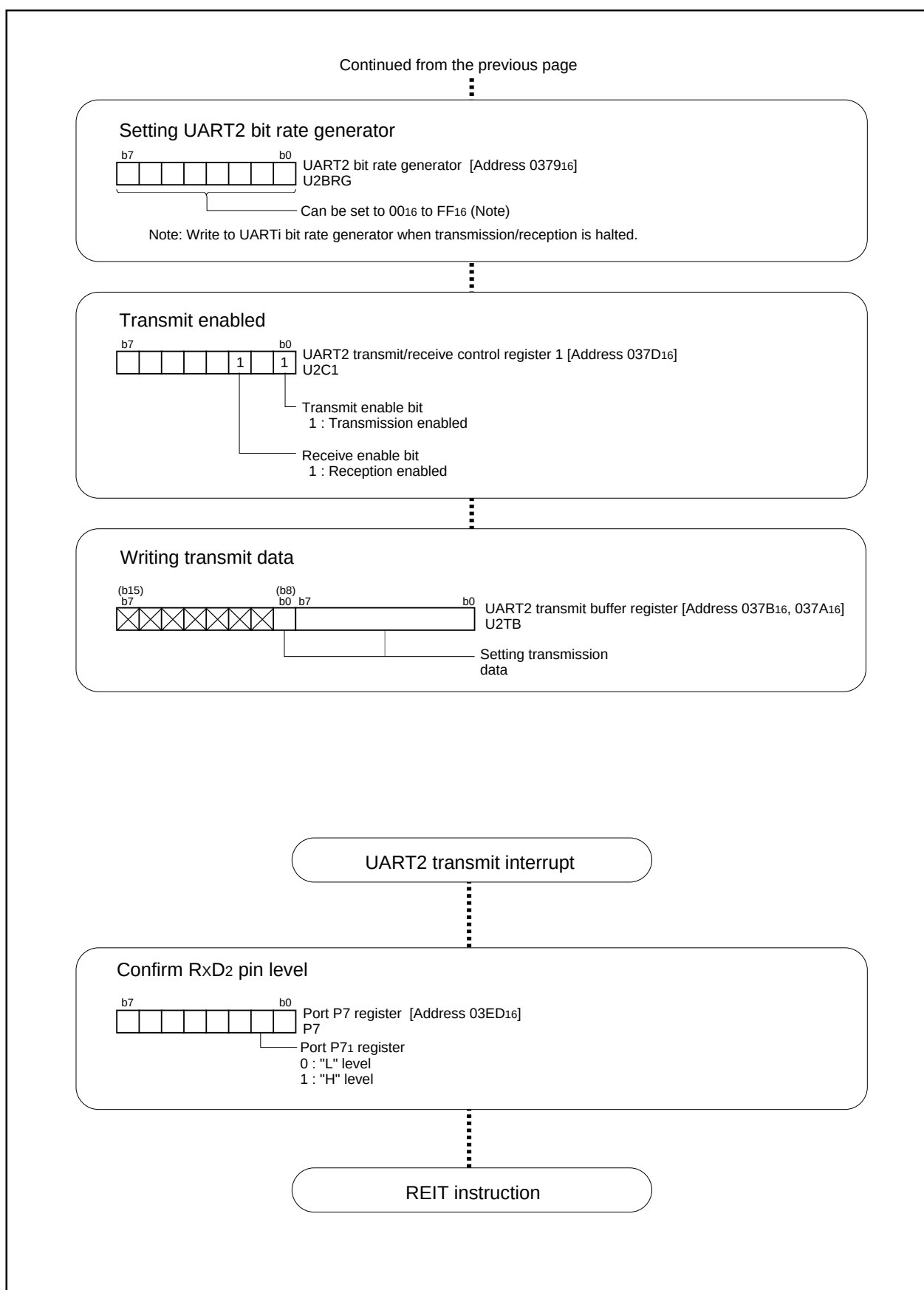


Figure 2.5.16. Set-up procedure of transmission in UART mode (used for SIM interface) (2)

2.5.5 Operation of Serial I/O (reception used for SIM interface)

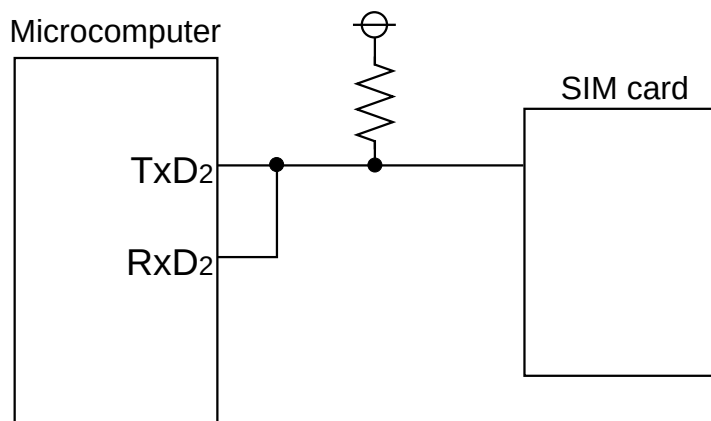
In receiving data in UART mode (used for SIM interface), choose functions from those listed in Table 2.5.7. Operations of the circled items are described below. Figure 2.5.17 shows the operation timing, and Figures 2.5.18 and 2.5.19 show the set-up procedures.

Figure 2.5.7. Chooosed functions

Item	Set-up	
Transfer data format	0	Direct format
		Inverse format

- Operation (1) Setting the transmit enable bit and receive enable bit to “1” readies data-receivable status.
- (2) When the first bit (the start bit) of reception data is received from the RxD2 pin, data is received, bit by bit, in sequence: LSB, ..., MSB, and stop bit(s).
- (3) When the stop bit(s) is (are) received, the content of the UART2 receive register is transmitted to the UART2 receive buffer register.
- At this time, the receive complete flag goes to “1” to indicate that the reception is completed, the UART2 receive interrupt request bit goes to “1”, and output from the RTS pin goes to “H” level.
- (4) The receive complete flag goes to “0” when the lower-order byte of the UART2 buffer register is read.
- (5) When the parity error is occurred, TxD2 pin goes to “L” level.

Example of wiring



Example of operation (when direct format)

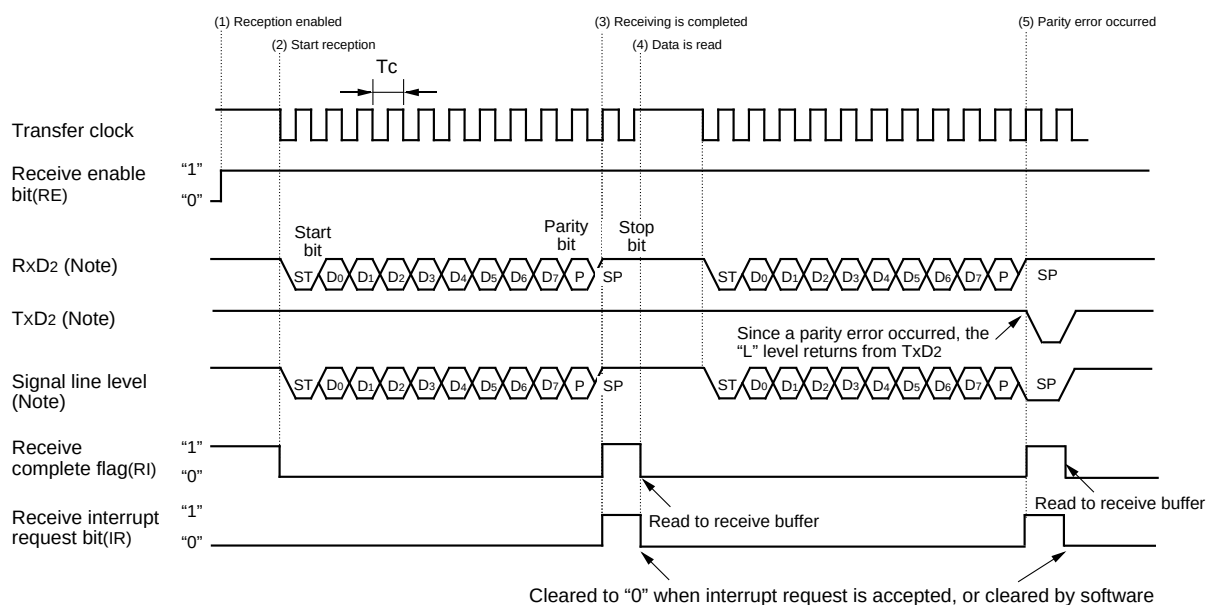
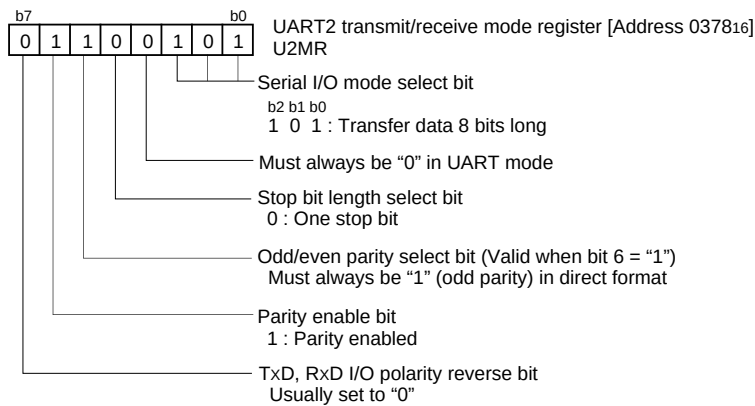


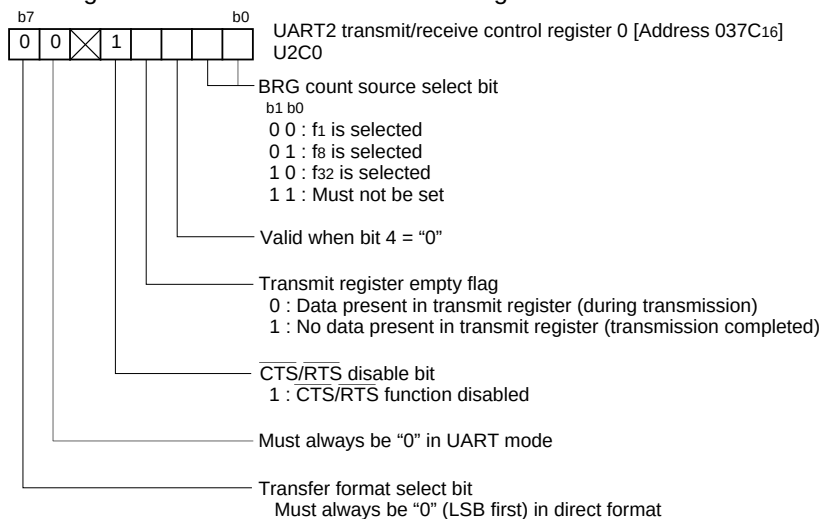
Figure 2.5.17. Operation timing of reception in UART mode (used for SIM interface)

Setting UART2 transmit/receive mode register



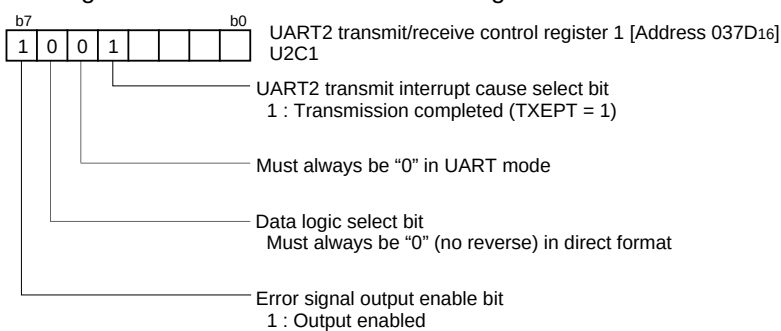
⋮

Setting UART2 transmit/receive control register 0



⋮

Setting UART2 transmit/receive control register 1



⋮

Continued to the next page

Figure 2.5.18. Set-up procedure of reception in UART mode (used for SIM interface) (1)

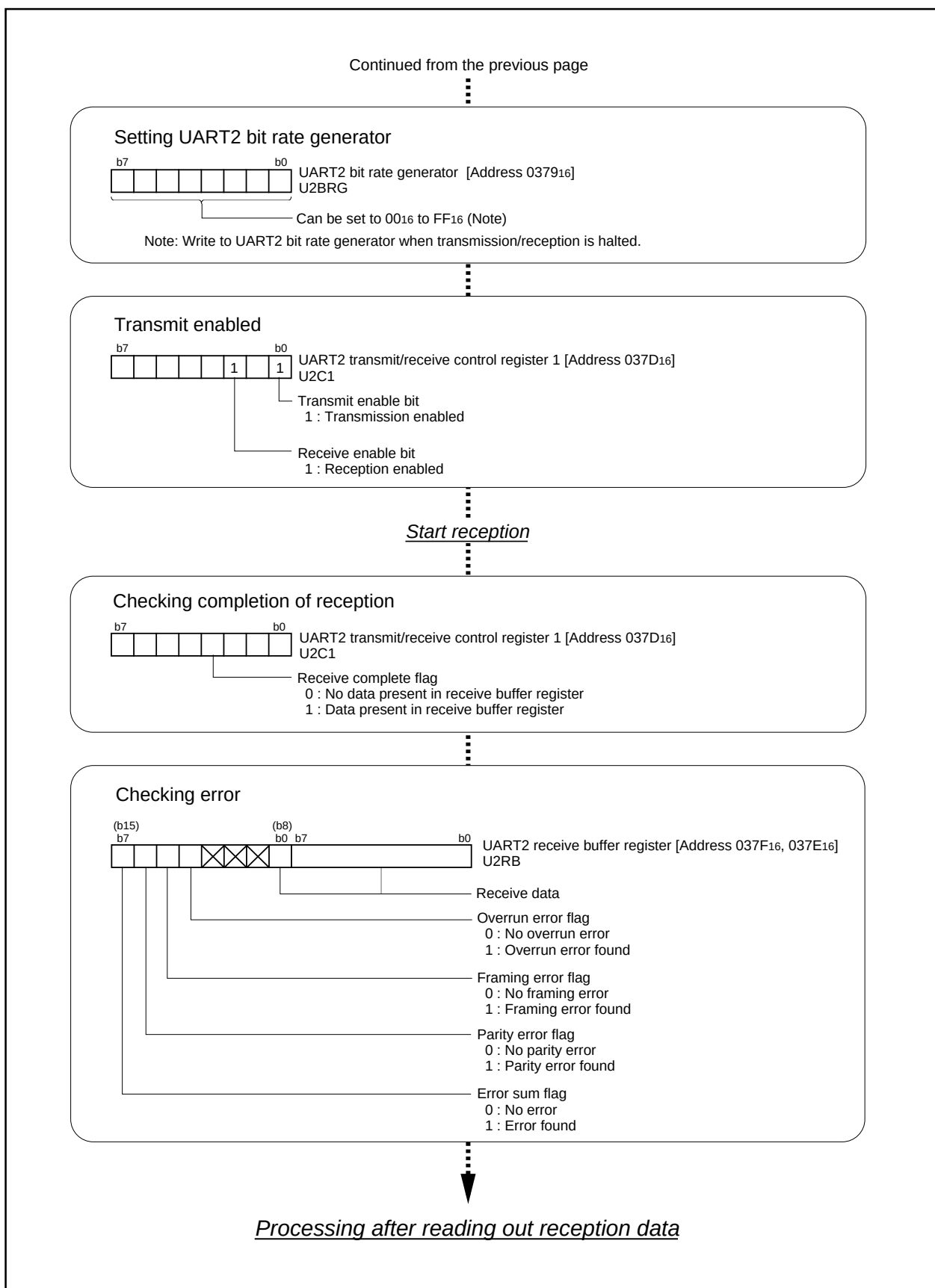


Figure 2.5.19. Set-up procedure of reception in UART mode (used for SIM interface)(2)

2.5.6 Clock Signals in used for the SIM Interface

In conforming to the SIM interface, the UART clock signal within the SIM card needs to conform to the UART2 clock signal within the microprocessor. Two examples are given here as means of generating a UART2 clock signal within the microprocessor.

- * In the case of setting a value equal to or less than $(1/256 \times 1/16)$ in the division rate of UART2 clock
Choose f_1 for the UART's source clock signal and set an optional value in the bit rate generator.
- * In the case of setting a value equal to or greater than $(1/256 \times 1/16)$ in the division rate of UART2 clock
Set the bit rate generator to "0", turn the source clock signal to timer output and set an optional value in the timer. In order to maintain the synchronization, the serial I/O mode select bits must be reset to "0002", then the UART2 transmit/receive mode register is set back to the original setting at every one byte transmission.

Let F be the clock signal within the SIM card and D be the bit rate adjustment factor, then the formula for the UART clock signal becomes as follows. Figure 2.5.20 shows an example of connection.

- In the case of setting a value equal to or less than $(1/256 \times 1/16)$ in the division rate of UART2 clock
UART2 clock signal within microprocessor = UART clock within SIM card

$$f_1 \times \frac{1}{\text{Bit rate generator} + 1} \times \frac{1}{16} = f_1 \times \frac{1}{\text{Timer Ai counter} + 1} \times \text{flip-flop} \times \frac{1}{F/D}$$

Let $X_{IN} = 16 \text{ MHz}$, timer Ai counter = 1, $F = 372$, and $D = 1$, then the value to be set in the bit rate generator becomes

$$16 \times \frac{1}{\text{Bit rate generator} + 1} \times \frac{1}{16} = 16 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{372/1}$$

Bit rate generator = 92

Table 2.5.8 shows an example of setting in the UART2 bit rate generator.

- In the case of setting a value equal to or greater than $(1/256 \times 1/16)$ in the division rate of UART2 clock
UART2 clock signal within microprocessor = UART clock within SIM card

$$f_1 \times \frac{1}{\text{Timer Aj counter} + 1} \times \text{flip-flop} \times \frac{1}{\text{Bit rate generator} + 1} \times \frac{1}{16} \\ = f_1 \times \frac{1}{\text{Bit rate generator} + 1} \times \text{flip-flop} \times \frac{1}{F/D}$$

Let $X_{IN} = 16 \text{ MHz}$, timer Ai counter = 3, bit rate generator = 0, $F = 1860$, and $D = 1$, then the value to be set in the timer Aj counter becomes

$$16 \times \frac{1}{\text{Timer Aj counter} + 1} \times \frac{1}{2} \times \frac{1}{0 + 1} \times \frac{1}{16} = 16 \times \frac{1}{3 + 1} \times \frac{1}{2} \times \frac{1}{1860/1}$$

Timer Aj counter = 464

Table 2.5.9 shows an example of setting in the timer Aj counter.

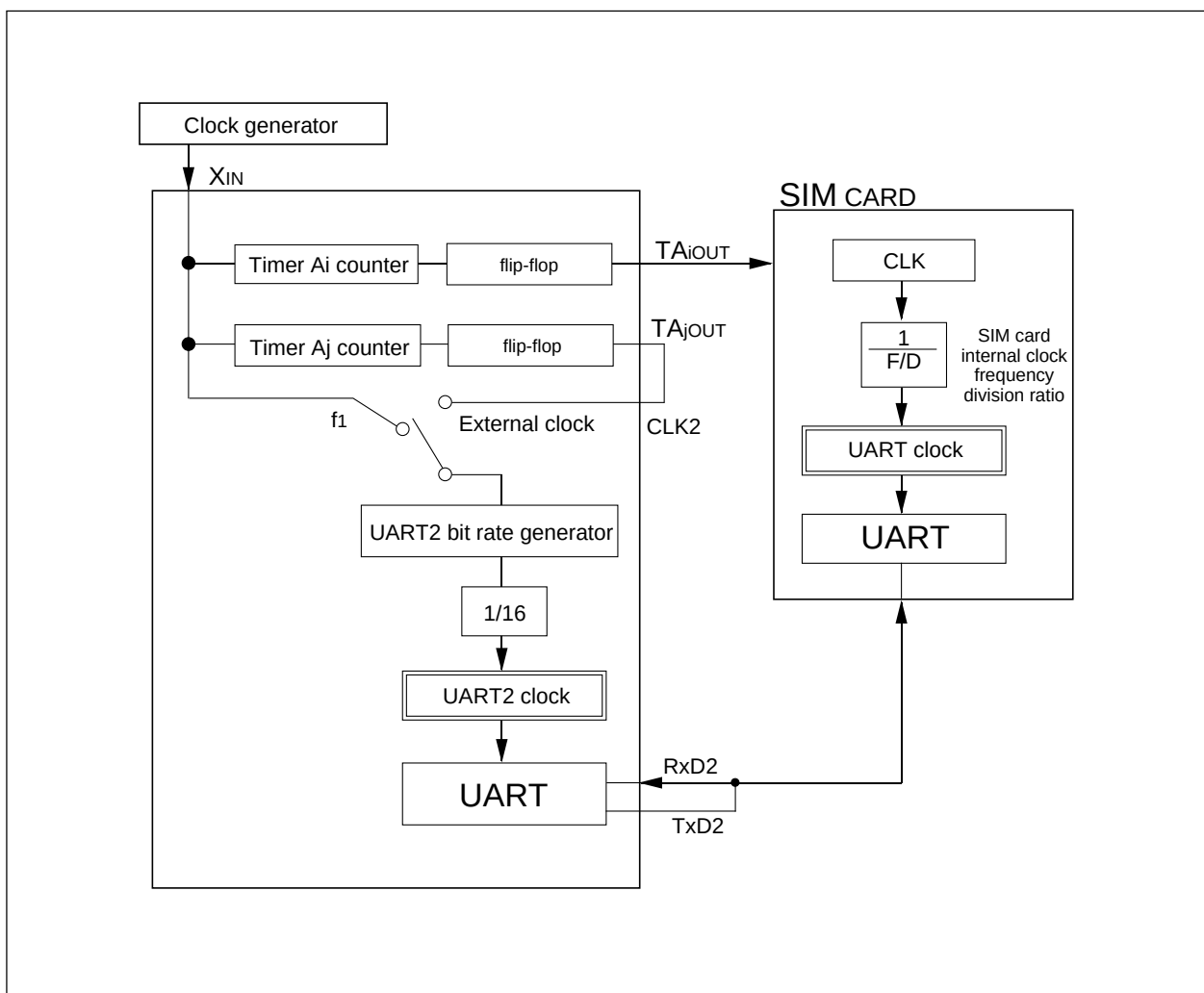


Figure 2.5.20. Example of connection

Table 2.5.8. UART2 bit rate adjustment factor

SIM card internal clock F(Hz)	Bit rate D	F/D	UART2 bit rate generator set value	SIM card internal clock F(Hz)	Bit rate D	F/D	UART2 bit rate generator set value
372	1	372	92	1116	1	1116	
	2	186			2	558	
	4	93			4	279	
	8				8		
	16				16		
	1/2	744	185		1/2	2232	
	1/4	1488			1/4	4464	
	1/8	2976			1/8	8928	
	1/16	5952			1/16	17856	
	1/32	11904			1/32	35712	
	1/64	23808			1/64	71424	
558	1	558		1488	1	1488	
	2	279			2	744	185
	4				4	372	92
	8				8	186	
	16				16	93	
	1/2	1116			1/2	2976	
	1/4	2232			1/4	5952	
	1/8	4464			1/8	11904	
	1/16	8928			1/16	23808	
	1/32	17856			1/32	47616	
	1/64	35712			1/64	95232	
744	1	744	185	1860	1	1860	
	2	372	92		2	930	
	4	186			4	465	
	8	93			8		
	16				16		
	1/2	1488			1/2	3720	
	1/4	2976			1/4	7440	
	1/8	5952			1/8	14880	
	1/16	11904			1/16	29760	
	1/32	23808			1/32	59520	
	1/64	47616			1/64	119040	

 Combination impossible

 Combination in which the F/D itself does not become an integer

Setting example under the following conditions.

$f(X_{IN})=16\text{MHz}$

Timer Ai counter set value = 1

Table 2.5.9. TimerAi register adjustment factor

SIM card internal clock F(Hz)	Bit rate D	F/D	Timer Ai value	SIM card internal clock F(Hz)	Bit rate D	F/D	Timer Aj value
372	1	372	92	1116	1	1116	278
	2	186			2	558	
	4	93			4	279	
	8				8		
	16				16		
	1/2	744	185		1/2	2232	557
	1/4	1488	371		1/4	4464	1115
	1/8	2976	743		1/8	8928	2231
	1/16	5952	1487		1/16	17856	4463
	1/32	11904	2975		1/32	35712	8927
	1/64	23808	5951		1/64	71424	17855
558	1	558		1488	1	1488	371
	2	279			2	744	185
	4				4	372	92
	8				8	186	
	16				16	93	
	1/2	1116	278		1/2	2976	743
	1/4	2232	557		1/4	5952	1487
	1/8	4464	1115		1/8	11904	2975
	1/16	8928	2231		1/16	23808	5951
	1/32	17856	4463		1/32	47616	11903
	1/64	35712	8927		1/64	95232	23807
744	1	744	185	1860	1	1860	464
	2	372	92		2	930	
	4	186			4	465	
	8	93			8		
	16				16		
	1/2	1488	371		1/2	3720	929
	1/4	2976	743		1/4	7440	1859
	1/8	5952	1487		1/8	14880	3719
	1/16	11904	2975		1/16	29760	7439
	1/32	23808	5951		1/32	59520	14879
	1/64	47616	11903		1/64	119040	29759



Combination impossible



Combination in which the F/D itself does not become an integer

Setting example under the following conditions.

f(XIN)=16MHz

Timer Ai counter set value = 3, UART2 bit rate generator set value = 0

2.5.7 Error-permitted range range of transfer baud

During reception, the receive data input to the RxDi pin is taken at the rising edge of the transfer clock. Accordingly, in order to receive data correctly, the stop bit must be input when the transfer clock of one-set receive data rises last. Figure 2.5.21 shows the relationship between the transfer clock and receive data.

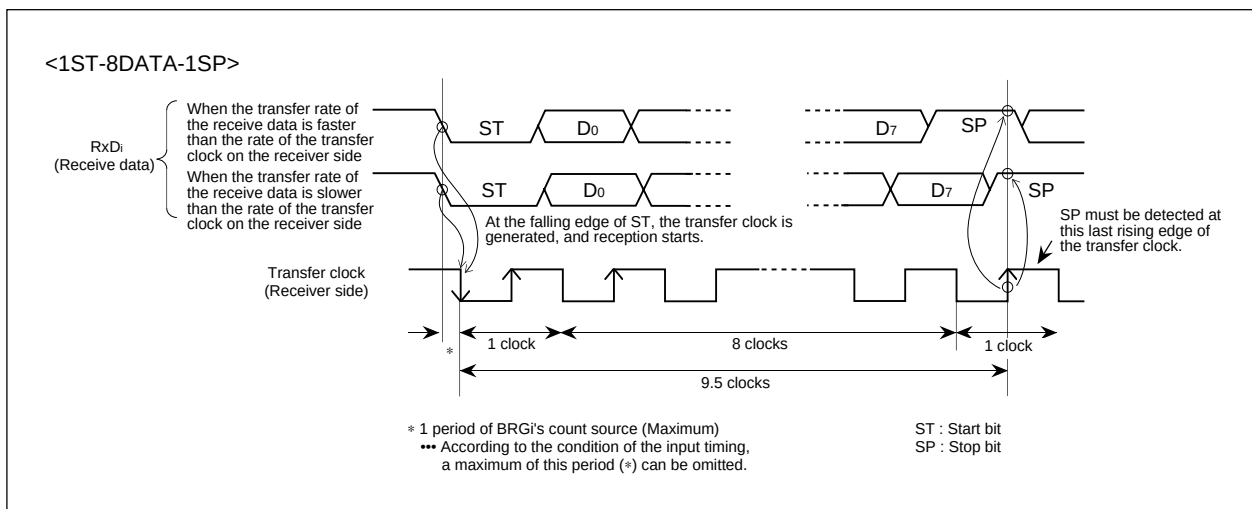


Figure 2.5.21 Relationship between transfer clock and receive data

Accordingly, the transfer rate of the receiver and transmitter sides must satisfy the following formula in order to receive data correctly.

$$\left(\frac{1}{B_t} \times (b - 1) + \frac{1}{F} \right) < \left(\frac{1}{B_r} \times (b - 0.5) + \frac{1}{F} \right) < \left(\frac{1}{B_t} \times b \right)$$

Br : Transfer rate on receiver side (bps)

Bt : Transfer rate on transmitter side (bps)

F : BRGi's count source frequency on receiver side (Hz)

b : Entire bit number of one-set data

(ex : 12 bits in the case of 1ST-8DATA-1PAR-2SP; See Figure 2.5.1)

Be sure to satisfy the above formula, and set the timing with enough margin. Also, the user shall make sufficient evaluation before actually using it.

2.6 SI/O3, 4 Usage

2.6.1 Overview of the SI/O3,4 usage

SI/O3, 4 carries out 8-bit data communications in synchronization with the clock. The following is an overview of the SI/O3, 4 usage.

(1) Transmission/reception format

8-bit data

(2) Transfer rate

If the internal clock is selected as the transfer clock, the divide-by-2 frequency, resulting from the bit rate generator division, becomes the transfer rate. The bit rate generator count source can be selected from the following: f₁, f₈, and f₃₂. Clocks f₁, f₈, and f₃₂ are derived by dividing the CPU's main clock by 1, 8, and 32 respectively.

Furthermore, if an external clock is selected as the transfer clock, the clock frequency input to the CLK pin becomes the transfer rate.

(3) Function selection

For SI/O3, 4, the following functions can be selected:

(a) Function for choosing which bit to transmit first

This function is to choose whether to transmit data from bit 0 or from bit 7. Choose either of the following:

- LSB first Data is transmitted from bit 0.
- MSB first Data is transmitted from bit 7.

(b) Choosing output level when not transferring

- Internal clock High-impedance output.
- External clock "H" or "L" output level is selected.

(6) Input to the serial I/O and the direction register

To input an external signal to the serial I/O, set the direction register of the relevant port to input.

(7) Pins related to the SI/O3, 4

- CLK3, CLK4 pins Input/output pins for the transfer clock
- SIN3, SIN4 pins Input pins for data
- SOUT3, SOUT4 pins Output pins for data

(8) Registers related to the SI/O3, 4

Figure 2.6.1 shows the memory map of SI/O3, 4-related registers, and Figures 2.6.2 show SI/O3, 4-related registers.

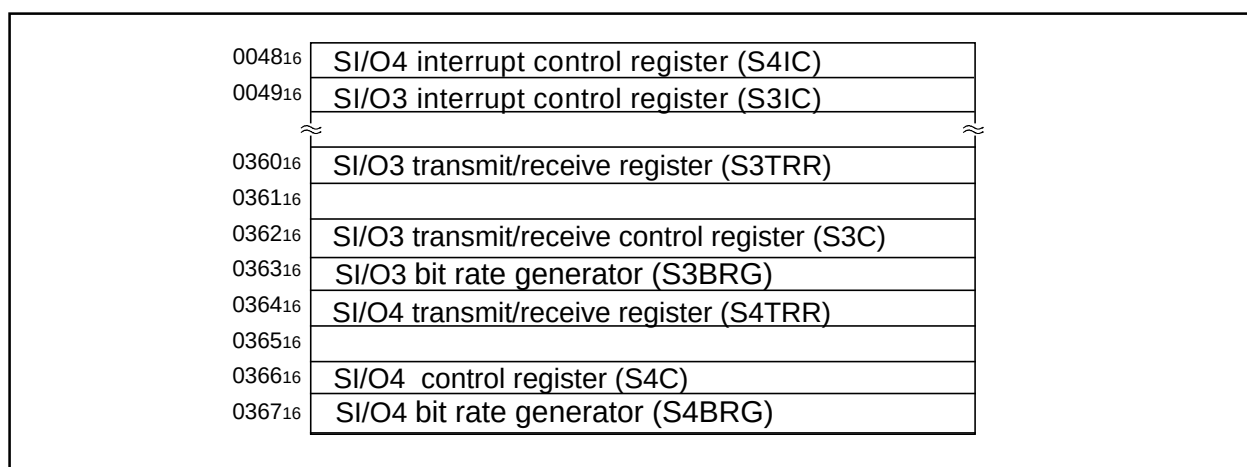
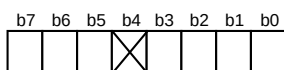


Figure 2.6.1. Memory map of serial I/O3, 4-related registers

S I/Oi control register (i = 3, 4) (Note 1)



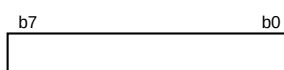
Symbol Address When reset
SiC 0362₁₆, 0366₁₆ 40₁₆

Bit symbol	Bit name	Description	R	W
SMi0	Internal synchronous clock select bit	b1 b0 : Selecting f ₁ 0 0 : Selecting f ₈ 0 1 : Selecting f ₃₂ 1 0 : Selecting f ₃₂ 1 1 : Must not be set.	○	○
SMi1			○	○
SMi2		0 : Souti output 1 : Souti output disable(high impedance)	○	○
SMi3		0 : Input-output port 1 : Souti output, CLK function	○	○
	Nothing is assigned. In an attempt to write to this bit, write "0". The value, if read, turns out to be "0".		—	—
SMi5	Transfer direction select bit	0 : LSB first 1 : MSB first	○	○
SMi6	Synchronous clock select bit (Note 2)	0 : External clock 1 : Internal clock	○	○
SMi7	Souti initial value set bit	Effective when SMi3 = 0 0 : L output 1 : H output	○	○

Note 1: Set "1" in bit 2 of the protection register (000A₁₆) in advance to write to the S I/Oi control register (i = 3, 4).

Note 2: When using the port as an input/output port by setting the SI/Oi port select bit (i = 3, 4) to "0", be sure to set the sync clock select bit to "1".

SI/Oi bit rate generator (Note 1, 2)



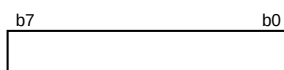
Symbol Address When reset
S3BRG 0363₁₆ Indeterminate
S4BRG 0367₁₆ Indeterminate

Indeterminate	Values that can be set	R	W
Assuming that set value = n, BRGi divides the count source by n + 1	00 ₁₆ to FF ₁₆		○

Note 1: Write a value to this register while transmit/receive halts.

Note 2: Use MOV instruction to write to this register.

SI/Oi transmit/receive register (Note)



Symbol Address When reset
S3TRR 0360₁₆ Indeterminate
S4TRR 0364₁₆ Indeterminate

Indeterminate	R	W
Transmission/reception starts by writing data to this register. After transmission/reception finishes, reception data is input.	○	○

Note: Write a value to this register while transmit/receive halts.

Figure 2.6.2. Serial I/O3, 4-related registers

2.6.2 Operation of SI/O3,4

In transmitting data in this mode, choose functions from those listed in Table 2.6.1. Operations of the circled items are described below. Figure 2.6.3 shows the operation timing, and Figures 2.6.4 and 2.6.5 show the set-up procedures.

Table 2.6.1. Chosed functions

Item	Set-up		Item	Set-up	
Transfer clock source	☐	Internal clock (f_1 / f_8 / f_{32})	SOUTi initial value set function	☐	Not used
		External clock (CLKi pin)			Used
Transfer clock	☐	LSB first			
		MSB first			

- Operation
- (1) Transfer begins upon writing the SI/Oi transmit data.
The transmit data is sent out from the SOUTi pin synchronously with falling edges of the transfer clock.
 - (2) When SOUT finishes sending one byte of data, the interrupt request bit is set to 1.
 - (3) After the transfer is completed, SOUT holds the last data for a 1/2 transfer clock period before going to a high-impedance state.

- Note
- Do not write data to the SI/Oi transmit/receive register ($i = 3, 4$; addresses 0360₁₆, 0364₁₆) during a transfer.
 - Data can only be written to the SI/Oi transmit/receive register when the device is idle neither sending nor receiving data.

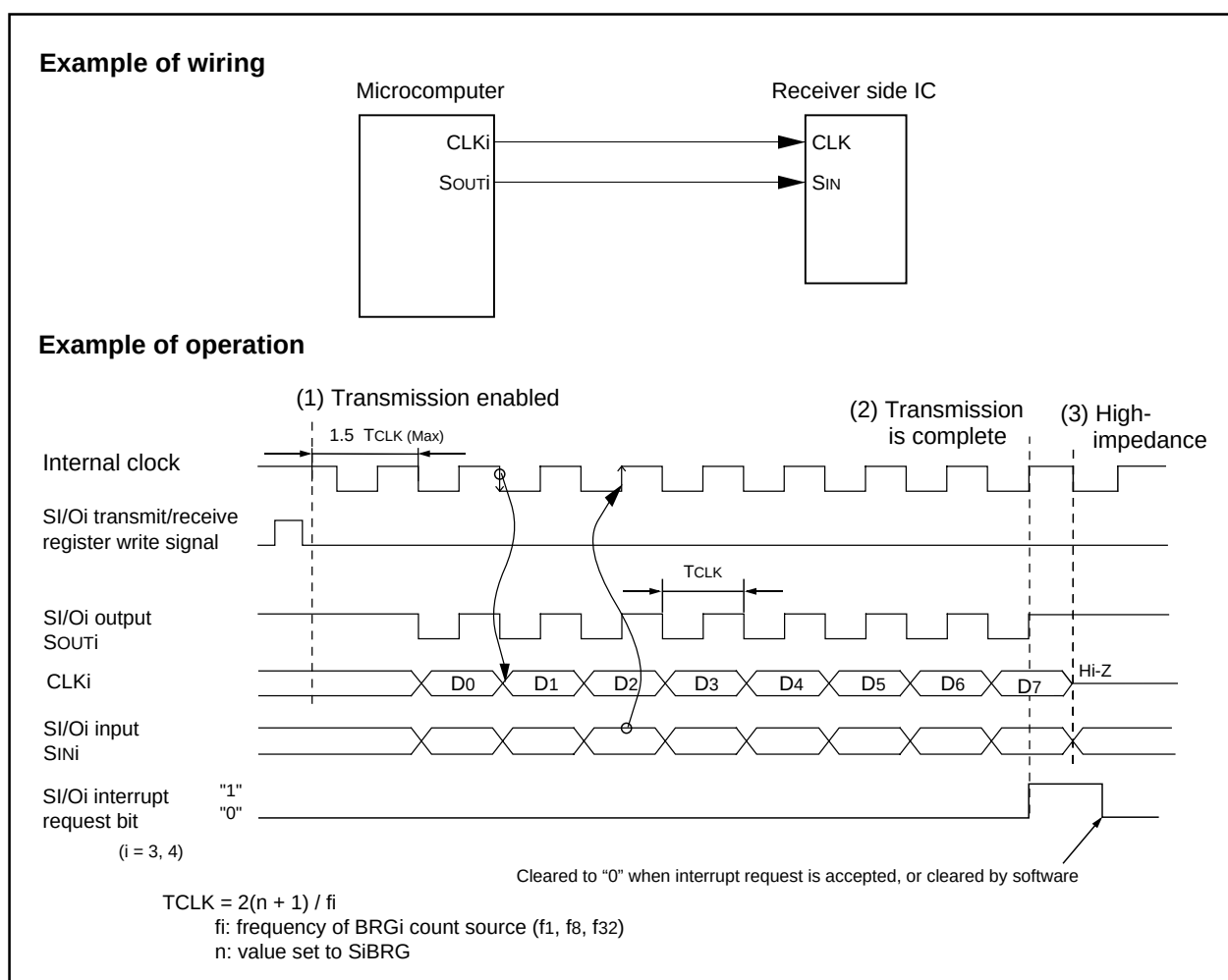


Figure 2.6.3. Operation timing of transmission in SI/O3, 4 mode

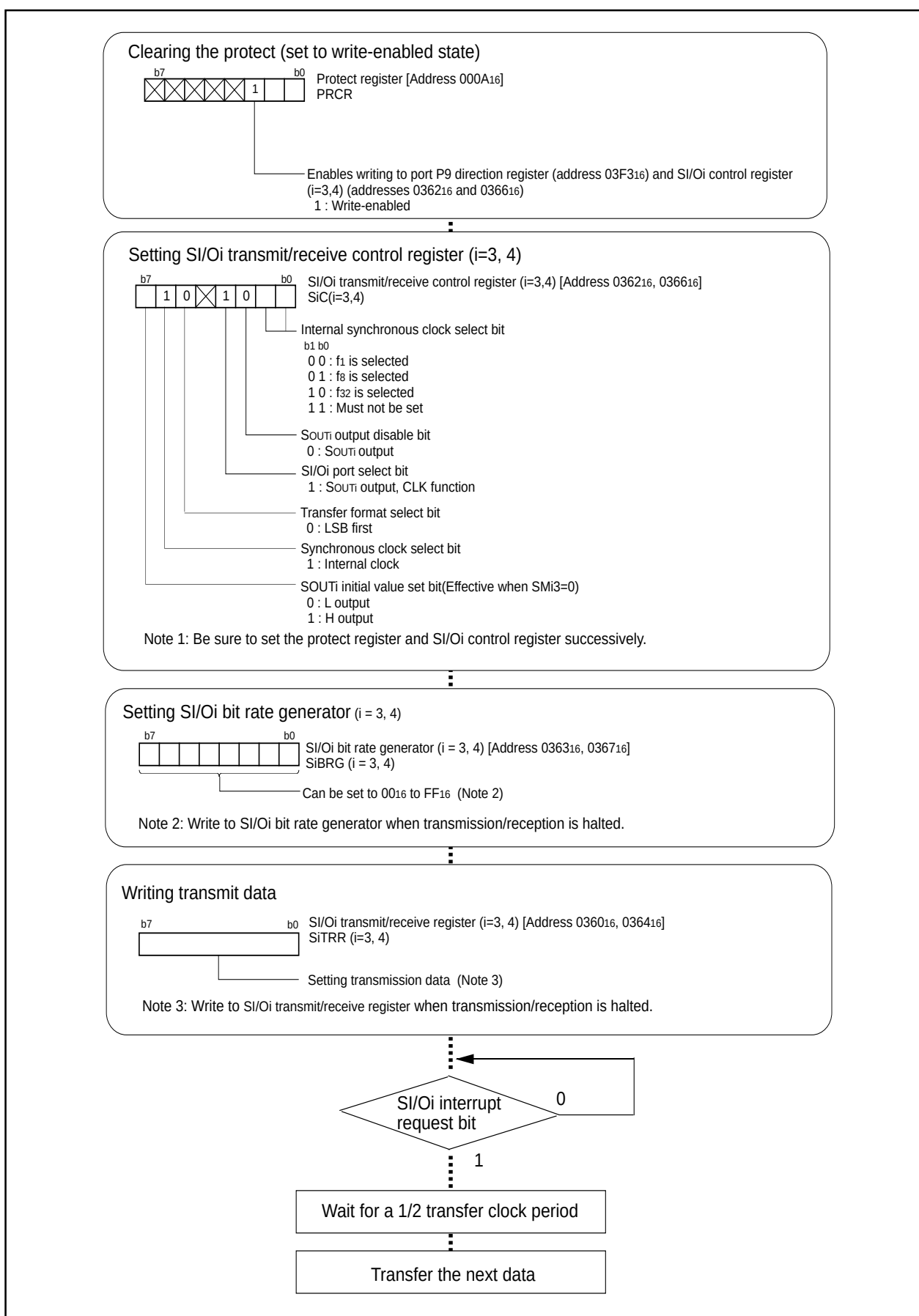


Figure 2.6.4. Set-up procedure of transmission in SI/O3, 4 mode

2.7 A-D Converter Usage

2.7.1 Overview of the A-D converter usage

The A-D converter used in the M16C/62A group operates on a successive conversion basis. The following is an overview of the A-D converter usage.

(1) Mode

The A-D converter operates in one of five modes:

(a) One-shot mode

Carries out A-D conversion on input level of one specified pin only once.

(b) Repetition mode

Repeatedly carries out A-D conversion on input level of one specified pin.

(c) One-shot sweep mode

Carries out A-D conversion on input level of two or more specified pins only once.

(d) Repeated sweep mode 0

Repeatedly carries out A-D conversion on input level of two or more pins.

(e) Repeated sweep mode 1

Repeatedly carries out A-D conversion on input level of two or more pins. This mode is different from the repeated sweep mode 0 in that weights can be assigned to specifying pins control the number of conversion times.

(2) Operation clock

The operation clock in 5 V operation can be selected from the following: f_{AD} , divide-by-2 f_{AD} , and divide-by-4 f_{AD} . In 3 V operation, the selection is divide-by-2 f_{AD} or divide-by-4. The f_{AD} frequency is equal to that of the CPU's main clock.

(3) Conversion time

Number of conversion for A-D convertor varies depending on resolution as given. Table 2.7.1 shows relation between the A-D converter operation clock and conversion time.

Sample & Hold function selected:

33 ϕ_{AD} cycles for 10-bit resolution, or 28 ϕ_{AD} cycles for 8-bit resolution

No Sample & Hold function:

59 ϕ_{AD} cycles for 10-bit resolution, or 49 ϕ_{AD} cycles for 8-bit resolution

Table 2.7.1. Conversion time every operation clock

Frequency selection bit 1		0		1
Frequency selection bit 0		0	1	Invalid
A-D converter's operation clock		$\phi_{AD} = \frac{f_{AD}}{4}$	$\phi_{AD} = \frac{f_{AD}}{2}$	$\phi_{AD} = f_{AD}$
Min. conversion cycles (Note 1)	8-bit mode	28 X ϕ_{AD}		
	10-bit mode	33 X ϕ_{AD}		
Min. conversion time (Note 2)	8-bit mode	11.2 μ s	5.6 μ s	2.8 μ s
	10-bit mode	13.2 μ s	6.6 μ s	3.3 μ s

Note 1: The number of conversion cycles per one analog input pin.

Note 2: The conversion time per one analog input pin (when $f_{AD} = f(XIN) = 10$ MHz)

(4) Functions selection**(a) Sample & Hold function**

Sample & Hold function samples input voltage when A-D conversion starts and carries out A-D conversion on the voltage sampled. When A-D conversion starts, input voltage is sampled for 3 cycles of the operation clock. When the Sample & Hold function is selected, set the operation clock for A-D conversion to 1 MHz or higher.

(b) 8-bit A-D to 10-bit A-D switching function

Either 8-bit resolution or 10-bit resolution can be selected. When 8-bit resolution is selected, the 8 higher-order bits of the 10-bit A-D are subjected to A-D conversion. The equations for 10-bit resolution and 8-bit resolution are given below:

$$\text{10-bit resolution} \quad (V_{\text{ref}} \times n / 2^{10}) - (V_{\text{ref}} \times 0.5 / 2^{10}) \quad (n = 1 \text{ to } 1023), 0 (n = 0)$$

$$\text{8-bit resolution} \quad (V_{\text{ref}} \times n / 2^8) - (V_{\text{ref}} \times 0.5 / 2^{10}) \quad (n = 1 \text{ to } 255), 0 (n = 0)$$

(c) A-D conversion by external trigger

The user can select software or an external pin input to start A-D conversion.

(d) External operation amplifier connection function

The selected A-D converter pin input voltage can be output from the ANEX0 pin. By connecting an operation amplifier between the ANEX1 pin and ANEX0 pin when using this function, the input voltage to all A-D conversion pins can be amplified with one operation amplifier.

(e) Expanded analog input pins function

A-D conversion can be done for voltage input from either the ANEX0 pin or the ANEX1 pin.

(f) Connecting or cutting Vref

Cutting Vref allows decrease of the current flowing into the A-D converter. To decrease the microcomputer's power consumption, cut Vref. To carry out A-D conversion, start A-D conversion 1 μ s or longer after connecting Vref.

The following are examples in which functions (a) through (f) are selected:

- One-shot mode P2-116
- One-shot mode, trigger by $\overline{\text{ADTRG}}$ P2-118
- One-shot mode, software trigger, expanded analog input P2-120
- One-shot mode, software trigger, external operation amplifier connected P2-122
- Repeat mode, software trigger P2-124
- One-shot sweep mode, software trigger P2-126
- Repeated sweep mode 0, software trigger P2-128
- Repeated sweep mode 1, software trigger P2-130

(5) Input to A-D converter and direction register

To use the A-D converter, set the direction register of the relevant port to input.

(6) Pins related to A-D converter

(a) AN ₀ pin through AN ₇ pin	Input pins of the A-D converter
(b) AV _{cc} pin	Power source pin of the analog section
(c) V _{REF} pin	Input pin of reference voltage
(d) AV _{ss} pin	GND pin of the analog section
(e) ANEX ₀ pin and ANEX ₁ pin	Expanded input pins of the A-D converter
(f) $\overline{\text{ADTRG}}$ pin	Trigger input pin of the A-D converter

(7) A-D converter and related registers

Figure 2.7.1 shows the memory map of A-D converter-related registers, and Figures 2.7.2 through 2.7.4 show A-D converter-related registers.

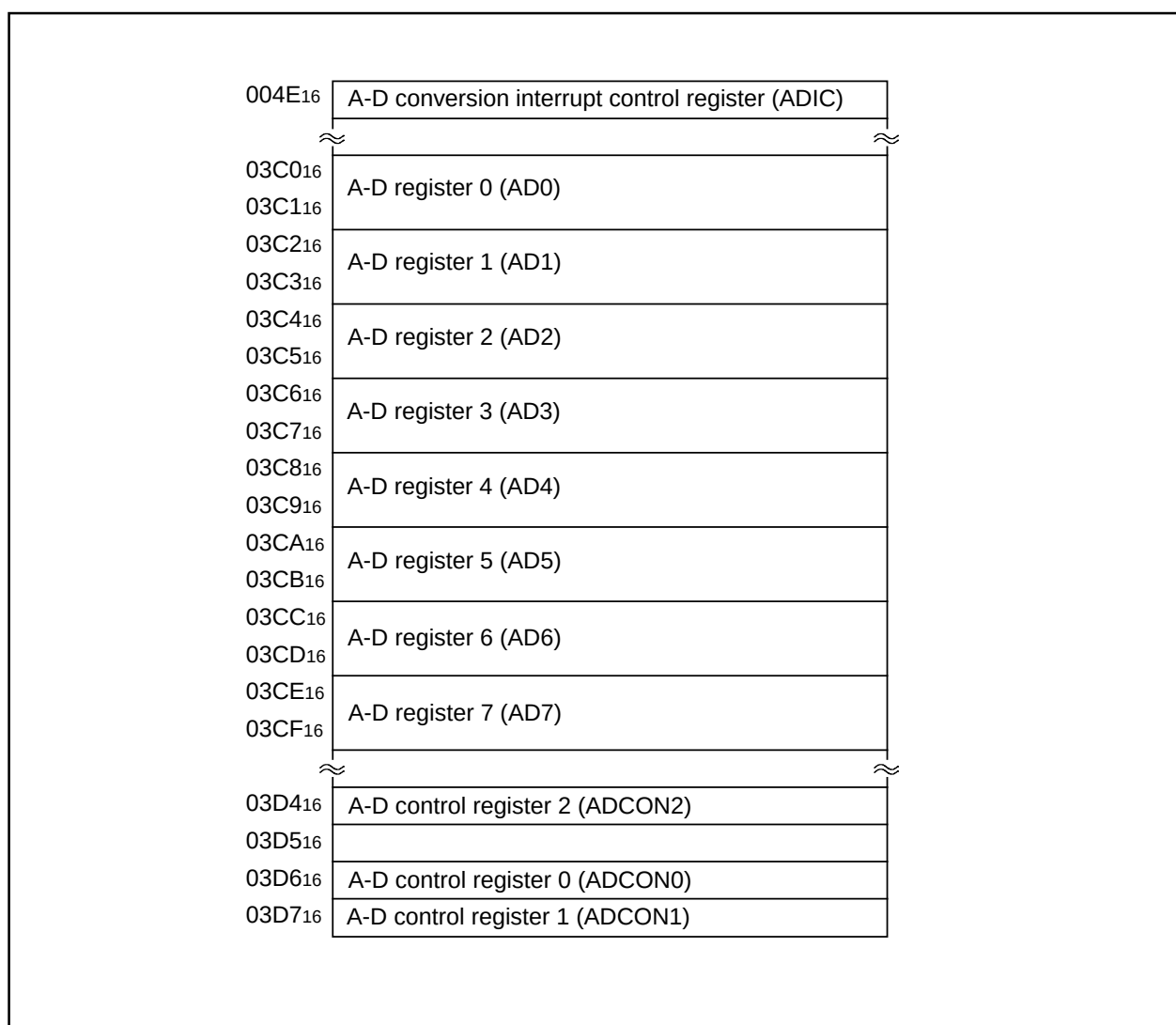


Figure 2.7.1. Memory map of A-D converter-related registers

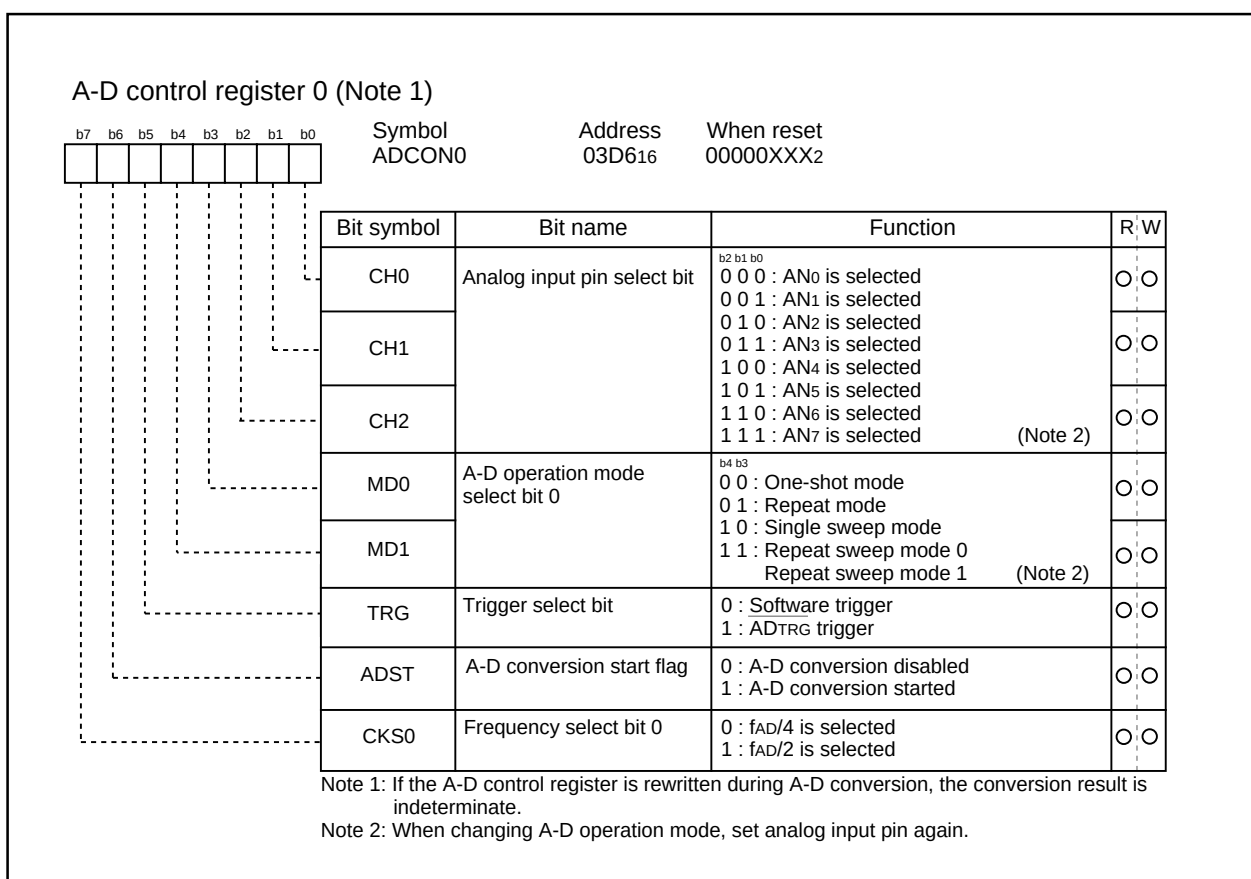


Figure 2.7.2. A-D converter-related registers (1)

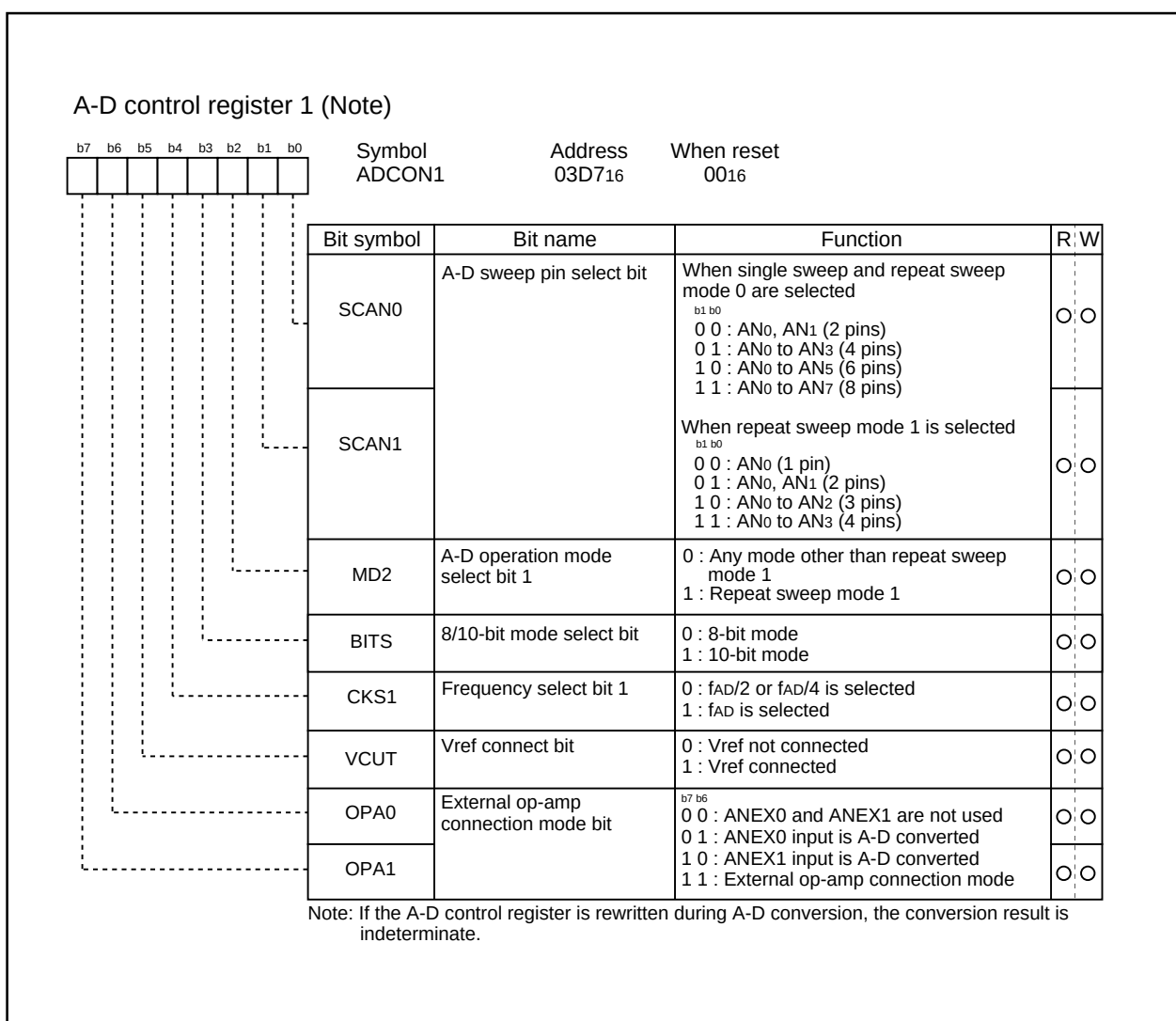
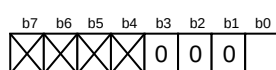


Figure 2.7.3. A-D converter-related registers (2)

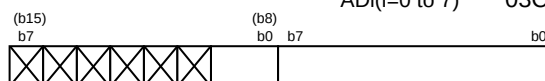
A-D control register 2 (Note)

Symbol
ADCON2Address
03D4₁₆When reset
0000XXX0₂

Bit symbol	Bit name	Function	R	W
SMP	A-D conversion method select bit	0 : Without sample and hold 1 : With sample and hold	○	○
Reserved bit		Must always be set to "0"	○	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".			—	—

Note: If the A-D control register is rewritten during A-D conversion, the conversion result is indeterminate.

A-D register i

Symbol
ADi(i=0 to 7)Address
03C0₁₆ to 03CF₁₆When reset
Indeterminate

Function	R	W
Eight low-order bits of A-D conversion result	○	×
• During 10-bit mode Two high-order bits of A-D conversion result	○	×
• During 8-bit mode When read, the content is indeterminate	×	×
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".	—	—

Figure 2.7.4. A-D converter-related registers (3)

2.7.2 Operation of A-D converter (one-shot mode)

In one-shot mode, choose functions from those listed in Table 2.7.2. Operations of the circled items are described below. Figure 2.7.5 shows the operation timing, and Figure 2.7.6 shows the set-up procedure.

Table 2.7.2. Chosen functions

Item	Set-up	Item	Set-up
Operation clock ϕ_{AD}	☐ Divided-by-4 f_{AD} / divided-by-2 f_{AD} / f_{AD}	Expanded analog input pin	☐ Not used
Resolution	☐ 8-bit / 10-bit		Either ANEX0 pin or ANEX1 pin
Analog input pin	☐ One of AN0 pin to AN7 pin		External operation amplifier connection mode
Trigger for starting A-D conversion	☐ Software trigger	Sample & Hold	Not activated
	Trigger by $\overline{ADTRG}$		☐ Activated

- Operation (1) Setting the A-D conversion start flag to "1" causes the A-D converter to begin operating.
- (2) After A-D conversion is completed, the content of the successive comparison register (conversion result) is transmitted to A-D register i. At this time, the A-D conversion interrupt request bit goes to "1". Also, the A-D conversion start flag goes to "0", and the A-D converter stops operating.

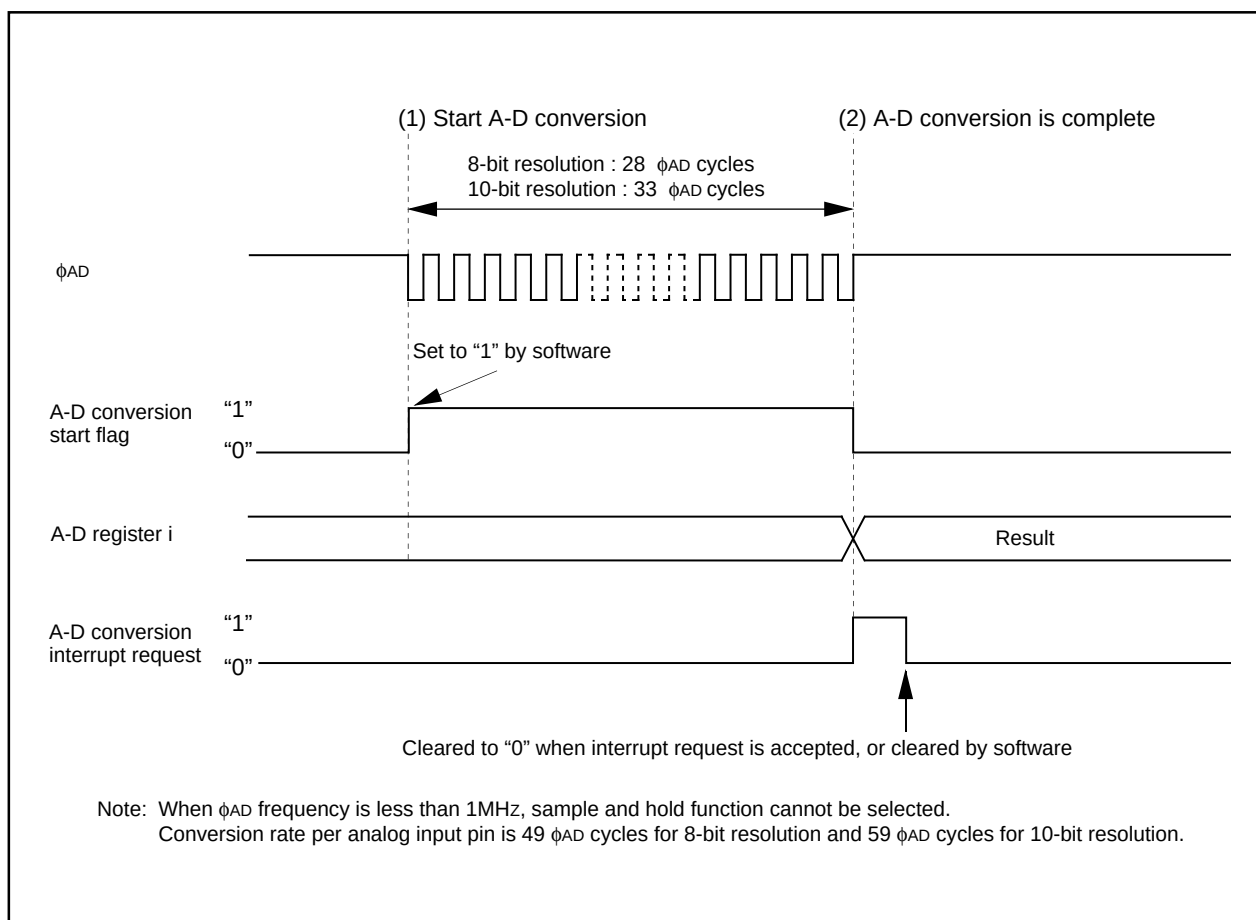


Figure 2.7.5. Operation timing of one-shot mode

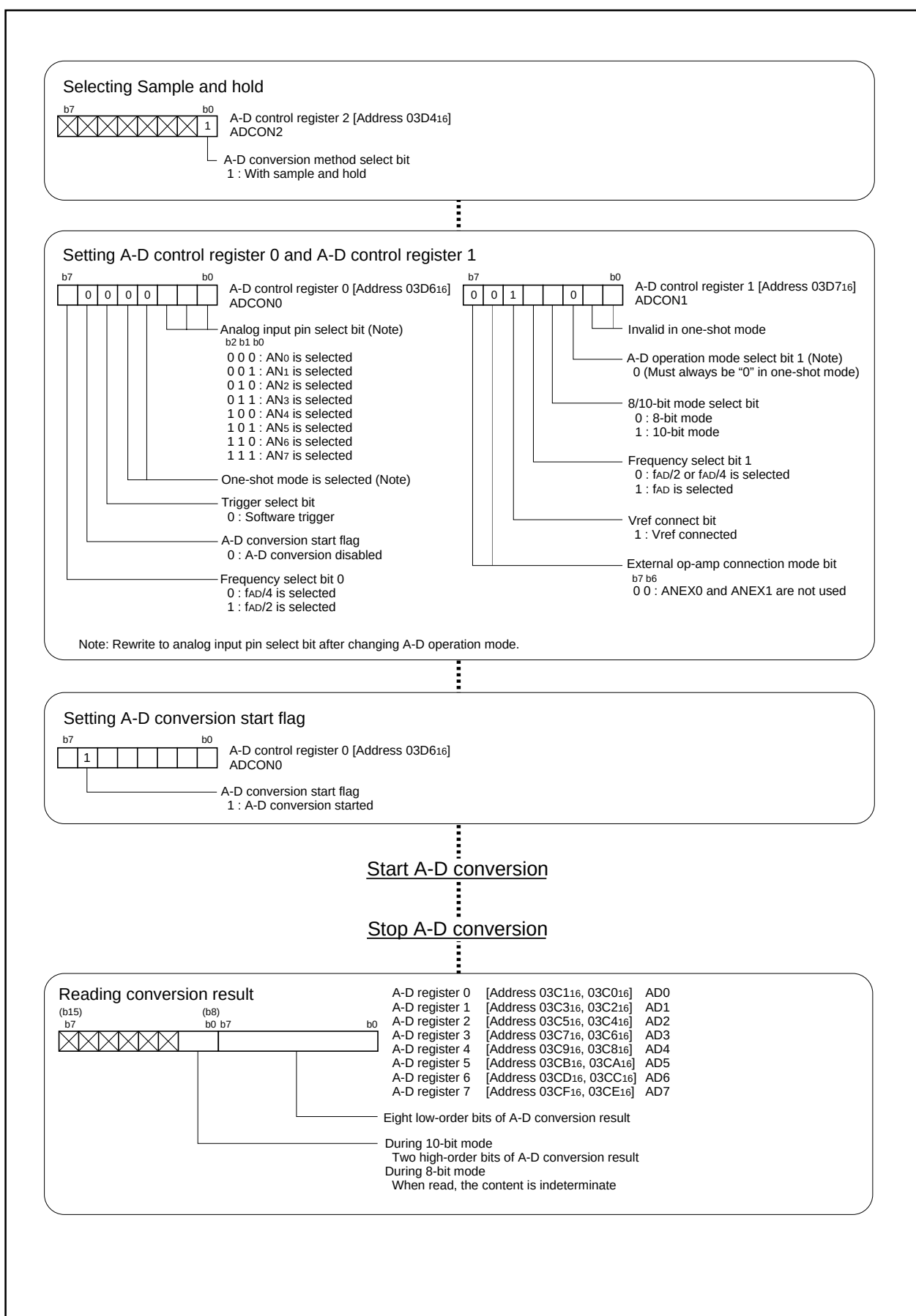


Figure 2.7.6. Set-up procedure of one-shot mode

2.7.3 Operation of A-D Converter (in one-shot mode, an external trigger selected)

In one-shot mode, choose functions from those listed in Table 2.7.3. Operations of the circled items are described below. Figure 2.7.7 shows timing chart, and Figure 2.7.8 shows the set-up procedure.

Table 2.7.3. Chosen functions

Item	Set-up	Item	Set-up
Operation clock ϕ_{AD}	☐ Divided-by-4 f_{AD} / divided-by-2 f_{AD} / f_{AD}	Expanded analog input pin	☐ Not used
Resolution	☐ 8-bit / 10-bit		Either ANEX0 pin or ANEX1 pin
Analog input pin	☐ One of AN ₀ pin to AN ₇ pin		External operation amplifier connection mode
Trigger for starting A-D conversion	Software trigger	Sample & Hold	Not activated
	☐ Trigger by $\overline{ADTRG}$		☐ Activated

- Operation
- (1) If the level of the $\overline{ADTRG}$ changes from "H" to "L" with the A-D conversion start flag set to "1", the A-D converter begins operating.
 - (2) After A-D conversion is completed, the content of the successive comparison register (conversion result) is transmitted to A-D register i. At this time, the A-D conversion interrupt request bit goes to "1". Also the A-D converter stops operating.
 - (3) If the level of the $\overline{ADTRG}$ pin changes from "H" to "L", the A-D converter carries out conversion from step (1) again. If the level of the $\overline{ADTRG}$ pin changes from "H" to "L" while conversion is in progress, the A-D converter stops the A-D conversion in process, and carries out conversion from step (1) again.

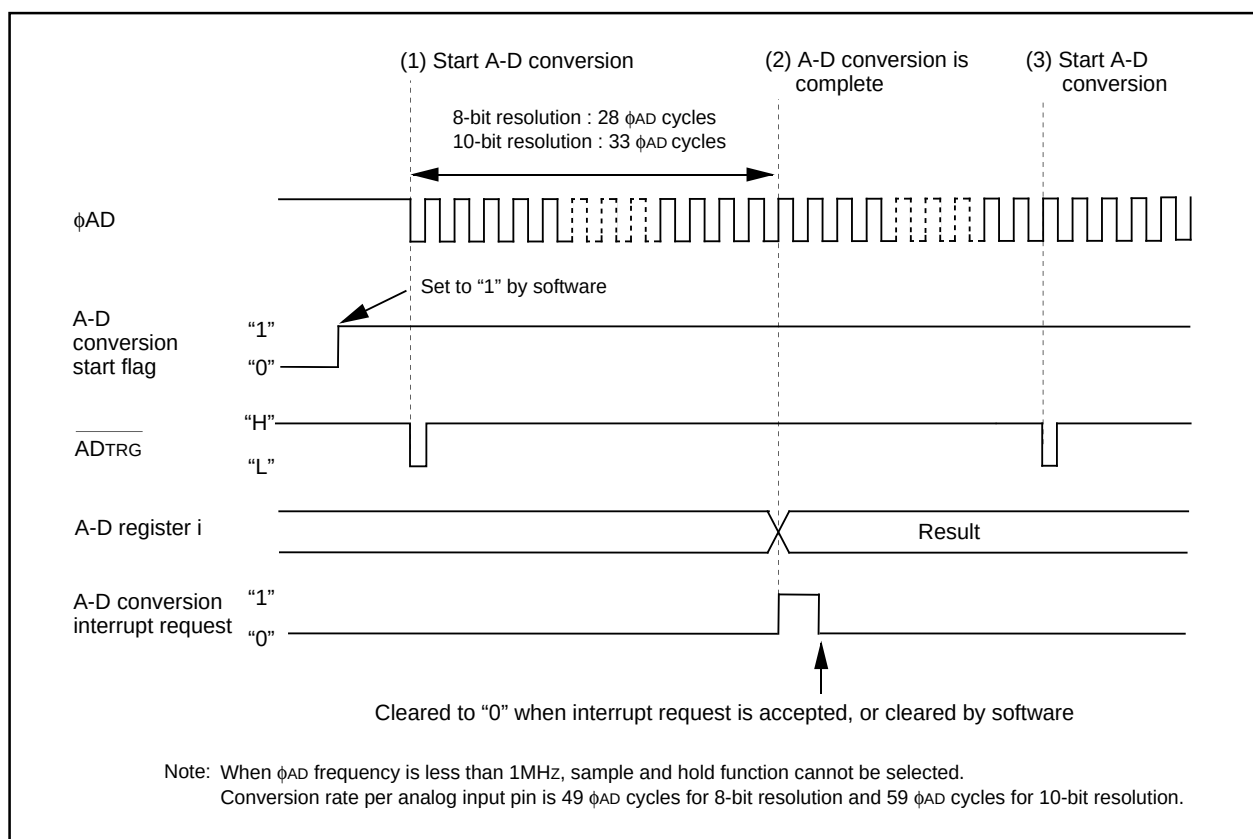


Figure 2.7.7. Operation timing of one-shot mode, with an external trigger selected

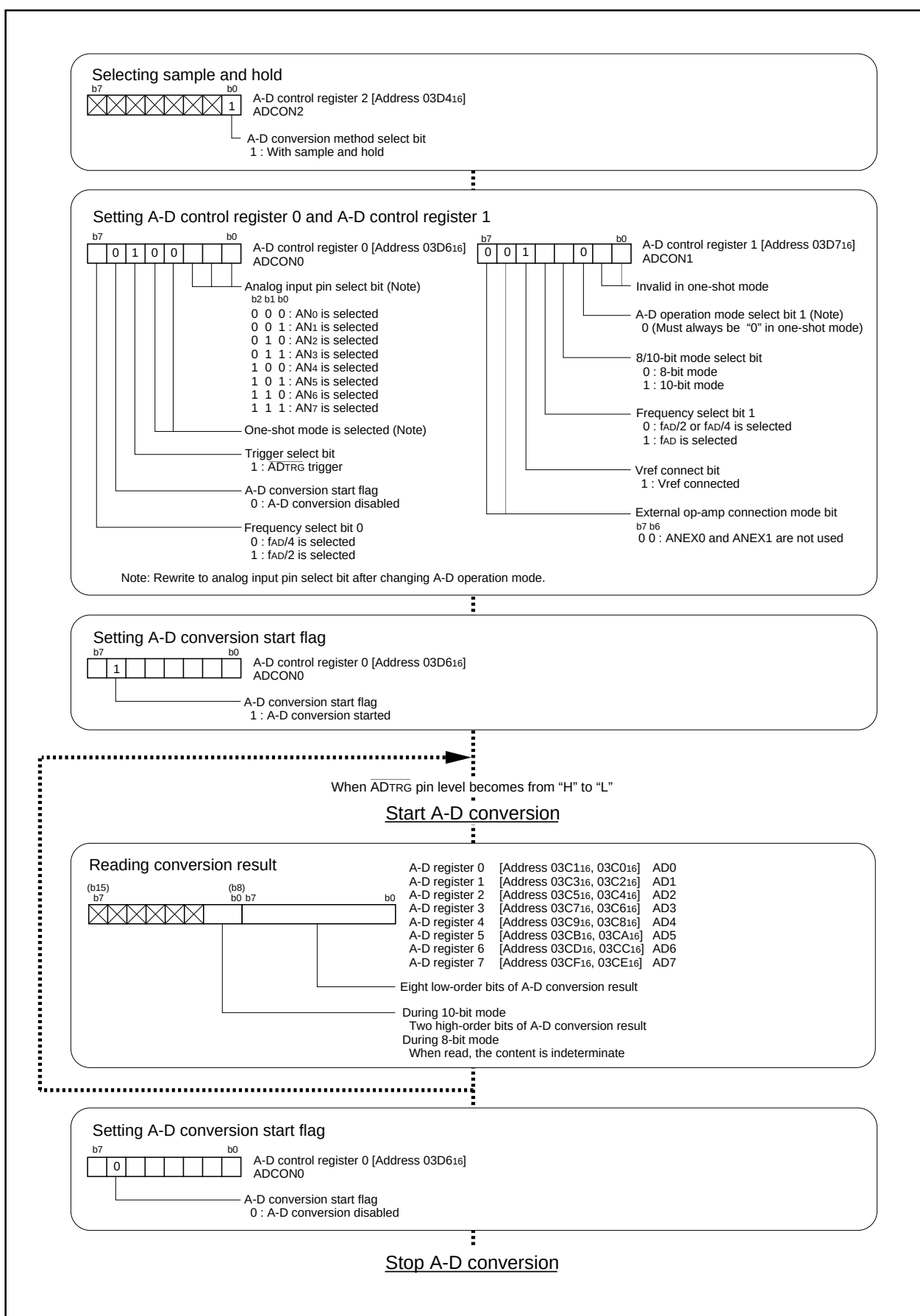


Figure 2.7.8. Set-up procedure of one-shot mode, with an external trigger selected

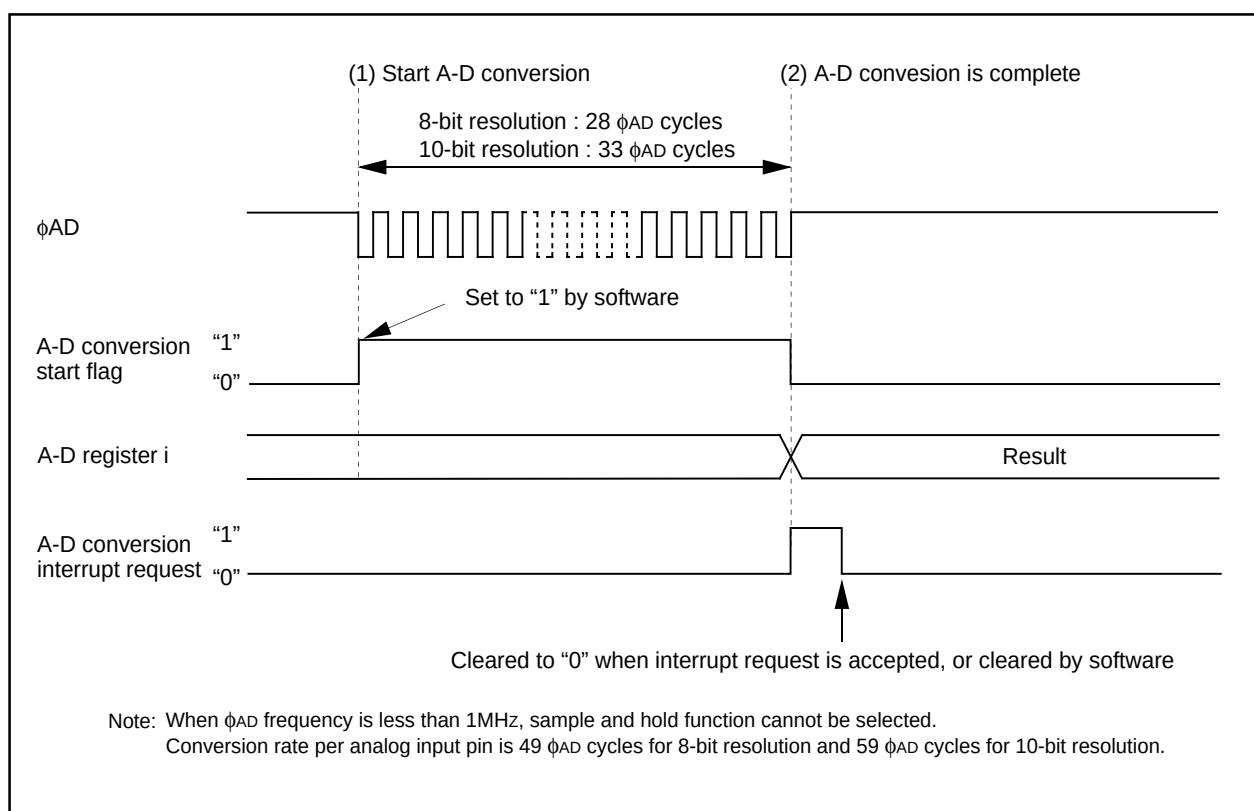
2.7.4 Operation of A-D Converter (in one-shot mode, expanded analog input pin selected)

In one-shot mode, choose functions from those listed in Table 2.7.4. Operations of the circled items are described below. Figure 2.7.9 shows timing chart, and Figure 2.7.10 shows the set-up procedure.

Table 2.7.4. Chosen functions

Item	Set-up		Item	Set-up	
Operation clock ϕ_{AD}	☐	Divided-by-4 f_{AD} / divided-by-2 f_{AD} / f_{AD}	Expanded analog input pin	☐	Not used
Resolution	☐	8-bit / 10-bit		☐	Either ANEX0 pin or ANEX1 pin
Analog input pin	☐	One of AN0 pin to AN7 pin		☐	External operation amplifier connection mode
Trigger for starting A-D conversion	☐	Software trigger	Sample & Hold	☐	Not activated
	☐	Trigger by AD_{TRG}		☐	Activated

- Operation (1) Setting the A-D conversion start flag to "1" causes the A-D converter to start the conversion on voltage input to the ANEXi pin.
- (2) After the A-D conversion of voltage input to the ANEXi pin is completed, the content of the successive comparison register (conversion result) is transmitted to the A-D register. At the same time, the A-D conversion interrupt request bit goes to "1". Also, the A-D conversion start flag goes to "0", and the A-D converter stops operating.

**Figure 2.7.9. Operation timing of one-shot mode, with expanded analog input pin selected**

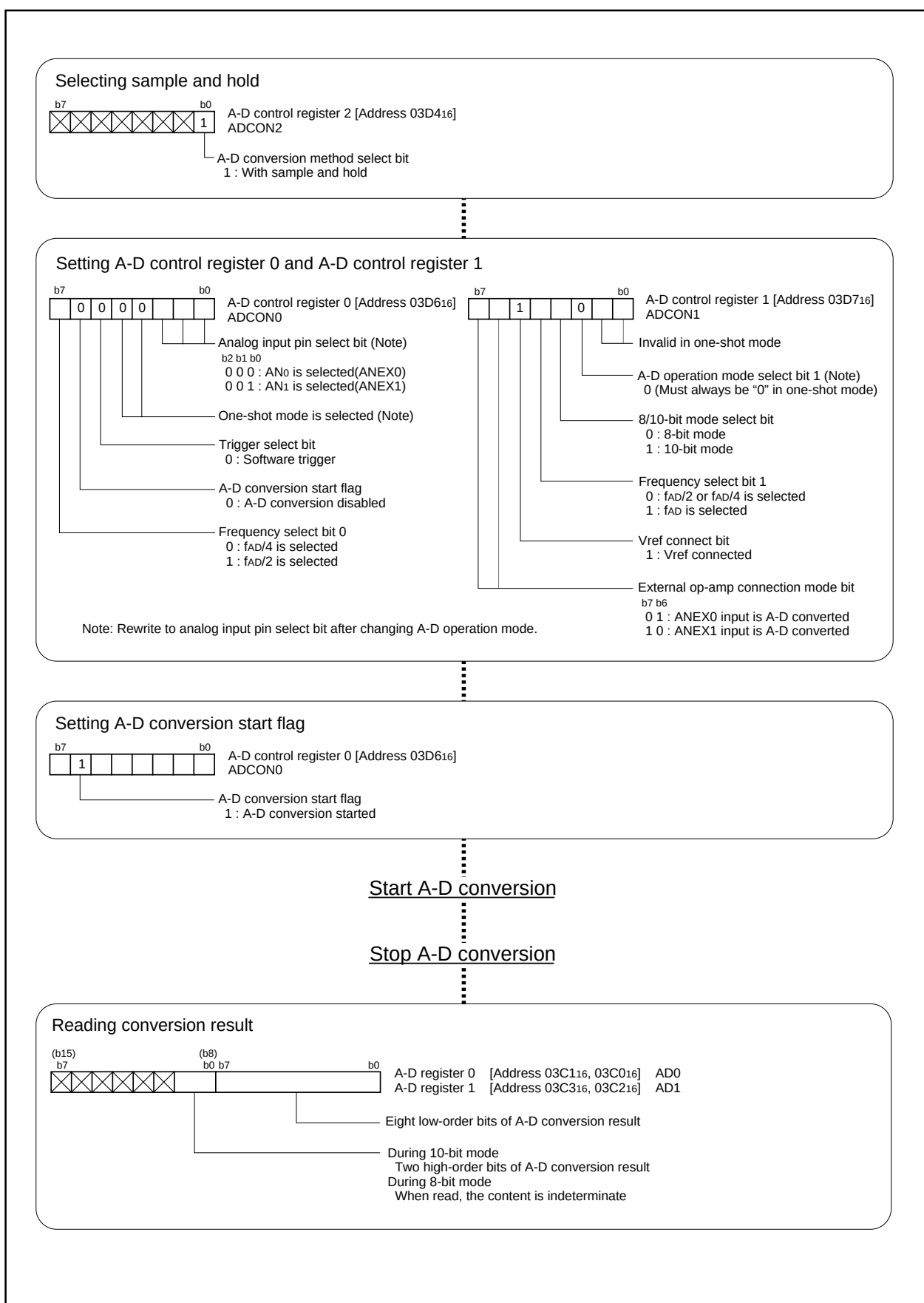


Figure 2.7.10. Set-up procedure of one-shot mode, with expanded analog input pin selected

2.7.5 Operation of A-D Converter (in one-shot mode, external op-amp connection mode selected)

In one-shot mode, choose functions from those listed in Table 2.7.5. Operations of the circled items are described below. Figure 2.7.11 shows timing chart, and Figure 2.7.12 shows the set-up procedure.

Table 2.7.5. Chosen functions

Item	Set-up	Item	Set-up
Operation clock ϕ_{AD}	☐ Divided-by-4 f_{AD} / divided-by-2 f_{AD} / f_{AD}	Expanded analog input pin	☐ Not used
Resolution	☐ 8-bit / 10-bit		☐ Either ANEX0 pin or ANEX1 pin
Analog input pin	☐ One of AN0 pin to AN7 pin		☐ External operation amplifier connection mode
Trigger for starting A-D conversion	☐ Software trigger	Sample & Hold	☐ Not activated
	☐ Trigger by $\overline{ADTRG}$		☐ Activated

- Operation (1) Setting the A-D conversion start flag to "1" causes voltage input to the ANi pin to be output from the ANEX0 pin. The A-D conversion is carried out on voltage input to the ANEX1 pin (connect an operation amplifier between the ANEX0 pin and the ANEX1 pin).
- (2) After the A-D conversion is completed, the content of the successive comparison register (conversion result) is transmitted to A-D register i corresponding to the ANi pin. At this time, the A-D conversion interrupt request bit goes to "1".

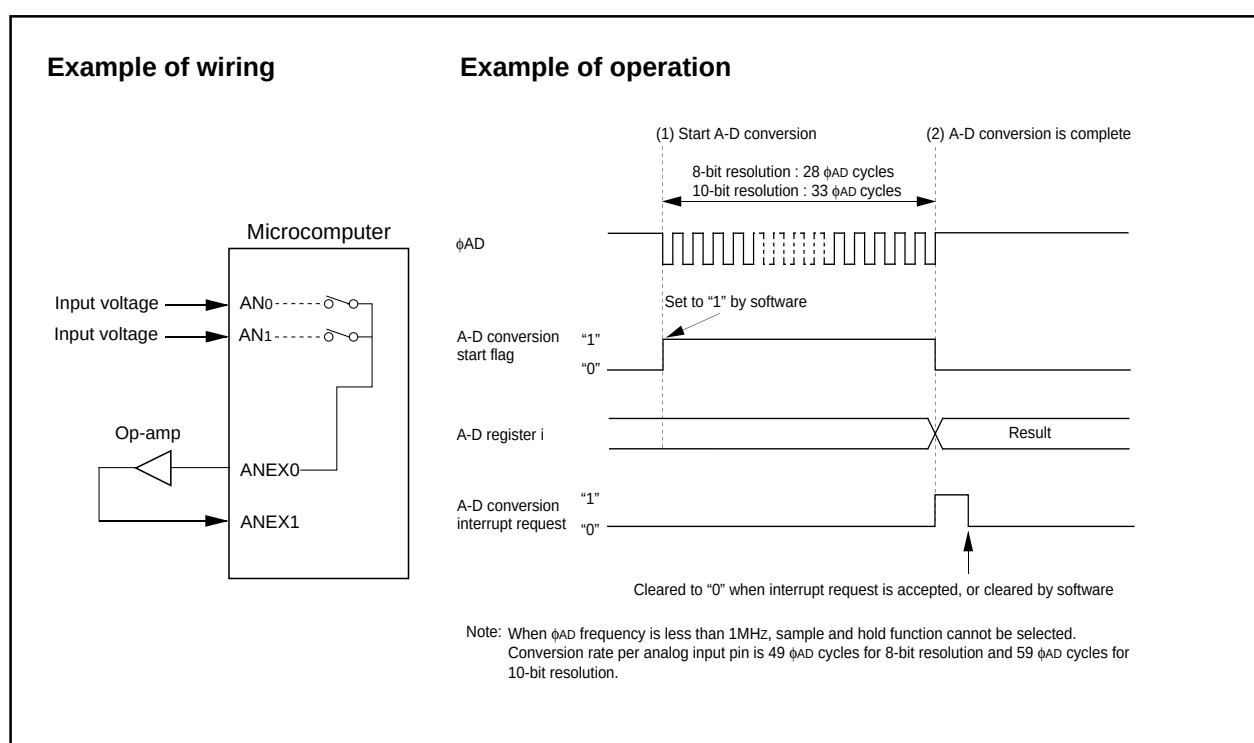


Figure 2.7.11. Operation timing of one-shot mode, with external op-amp connection mode selected

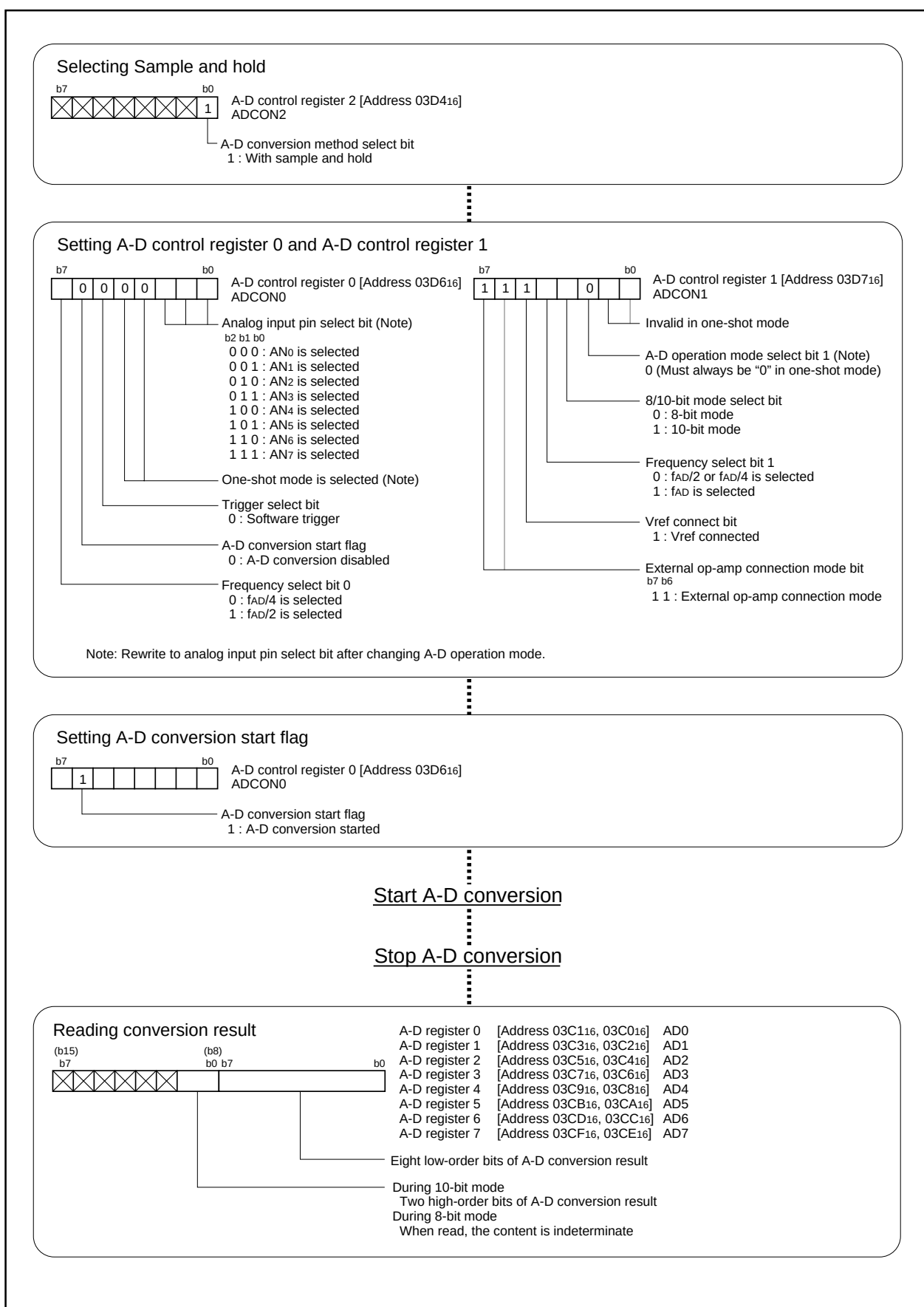


Figure 2.7.12. Set-up procedure of one-shot mode, with external op-amp connection mode selected

2.7.6 Operation of A-D Converter (in repeat mode)

In repeat mode, choose functions from those listed in Table 2.7.6. Operations of the circled items are described below. Figure 2.7.13 shows timing chart, and Figure 2.7.14 shows the set-up procedure.

Table 2.7.6. Chosen functions

Item	Set-up		Item	Set-up	
Operation clock ϕ_{AD}	☐	Divided-by-4 f_{AD} / divided-by-2 f_{AD} / f_{AD}	Expanded analog input pin	☐	Not used
Resolution	☐	8-bit / 10-bit			Either ANEX0 pin or ANEX1 pin
Analog input pin	☐	One of AN ₀ pin to AN ₇ pin			External operation amplifier connection mode
Trigger for starting A-D conversion	☐	Software trigger	Sample & Hold		Not activated
		Trigger by $\overline{ADTRG}$		☐	Activated

- Operation
- (1) Setting the A-D conversion start flag to “1” causes the A-D converter to start operating.
 - (2) After the first conversion is completed, the content of the successive comparison register (conversion result) is transmitted to A-D register i. The A-D conversion interrupt request bit does not go to “1”.
 - (3) The A-D converter continues operating until the A-D conversion start flag is set to “0” by software. The conversion result is transmitted to A-D register i every time a conversion is completed.

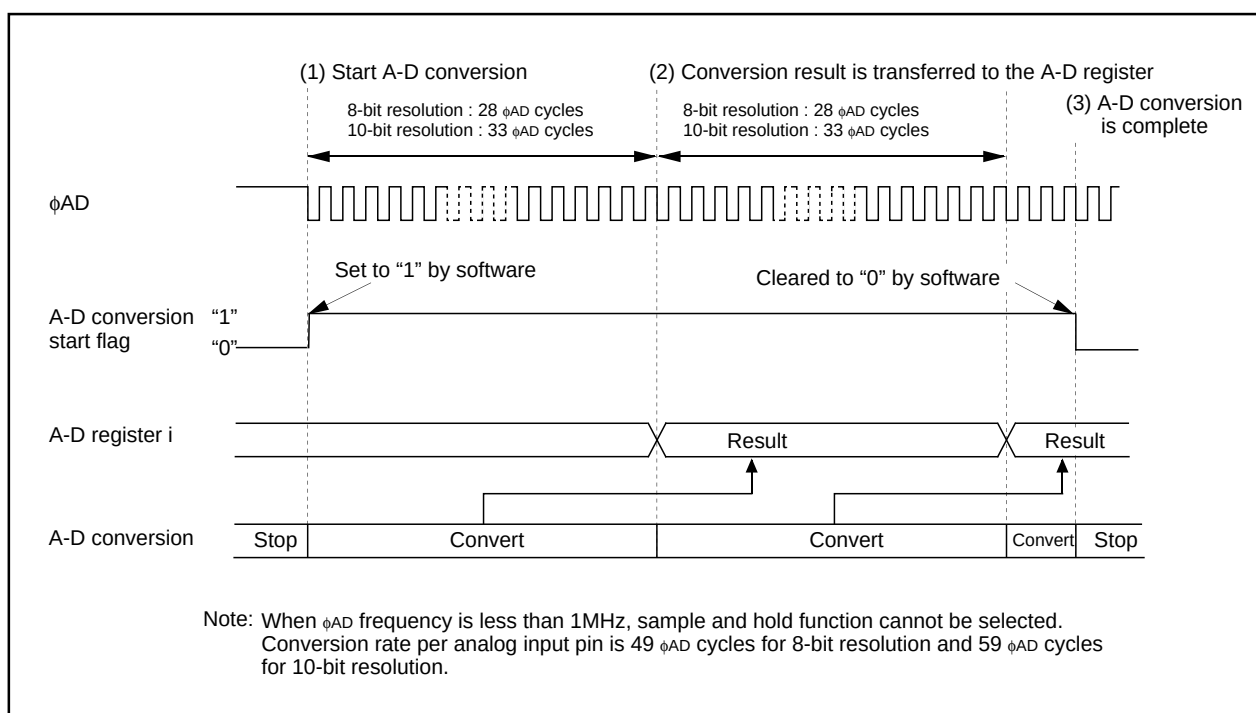


Figure 2.7.13. Operation timing of repeat mode

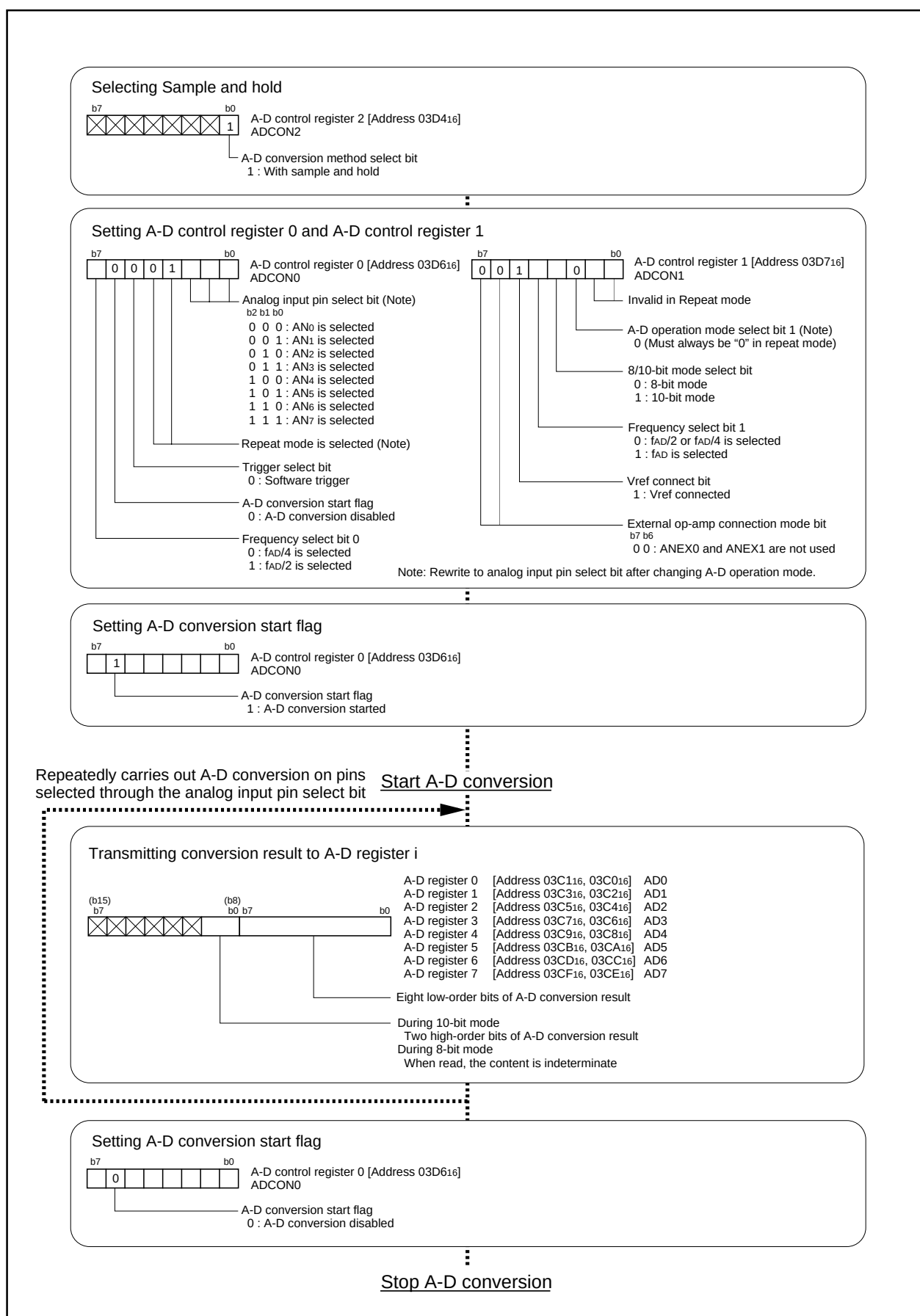


Figure 2.7.14. Set-up procedure of repeat mode

2.7.7 Operation of A-D Converter (in single sweep mode)

In single sweep mode, choose functions from those listed in Table 2.7.7. Operations of the circled items are described below. Figure 2.7.15 shows timing chart, and Figure 2.7.16 shows the set-up procedure.

Table 2.7.7. Chooed functions

Item	Set-up		Item	Set-up	
Operation clock AD	☐	Divided-by-4 f_{AD} / divided-by-2 f_{AD} / f_{AD}	Trigger for starting A-D conversion	☐	Software trigger
Resolution	☐	8-bit / 10-bit			Trigger by $\overline{ADTRG}$
Analog input pin	☐	AN ₀ and AN ₁ (2 pins) / AN ₀ to AN ₃ (4 pins) / AN ₀ to AN ₅ (6 pins) / AN ₀ to AN ₇ (8 pins)	Expanded analog input pin	☐	Not used
					External ope-amp connection mode
			Sample & Hold		Not activated
				☐	Activated

- Operation
- (1) Setting the A-D conversion start flag to "1" causes the A-D converter to start the conversion on voltage input to the AN₀ pin.
 - (2) After the A-D conversion of voltage input to the AN₀ pin is completed, the content of the successive comparison register (conversion result) is transmitted to A-D register 0. The A-D converter converts all analog input pins selected by the user. The conversion result is transmitted to A-D register i corresponding to each pin, every time conversion on one pin is completed.
 - (3) When the A-D conversion on all the analog input pins selected is completed, the A-D conversion interrupt request bit goes to "1". At this time, the A-D conversion start flag goes to "0". The A-D converter stops operating.

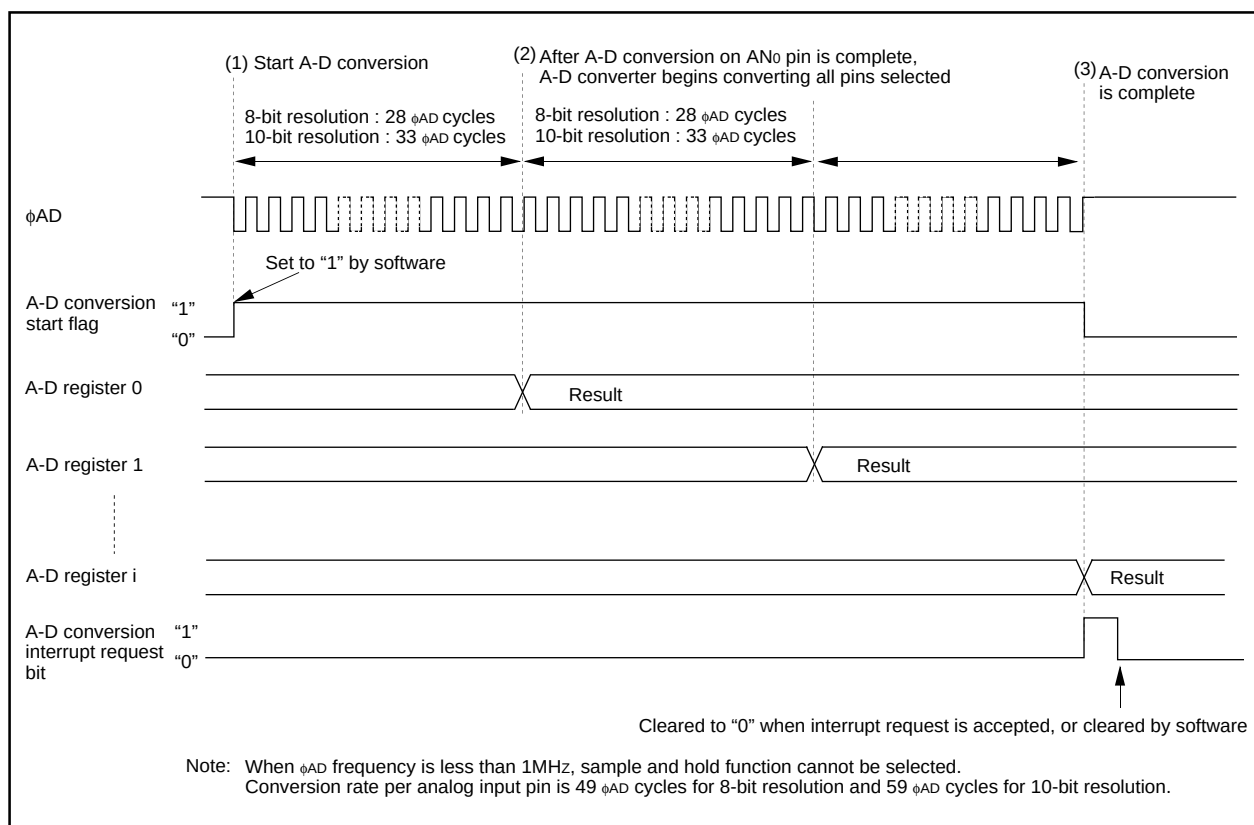


Figure 2.7.15. Operation timing of single sweep mode

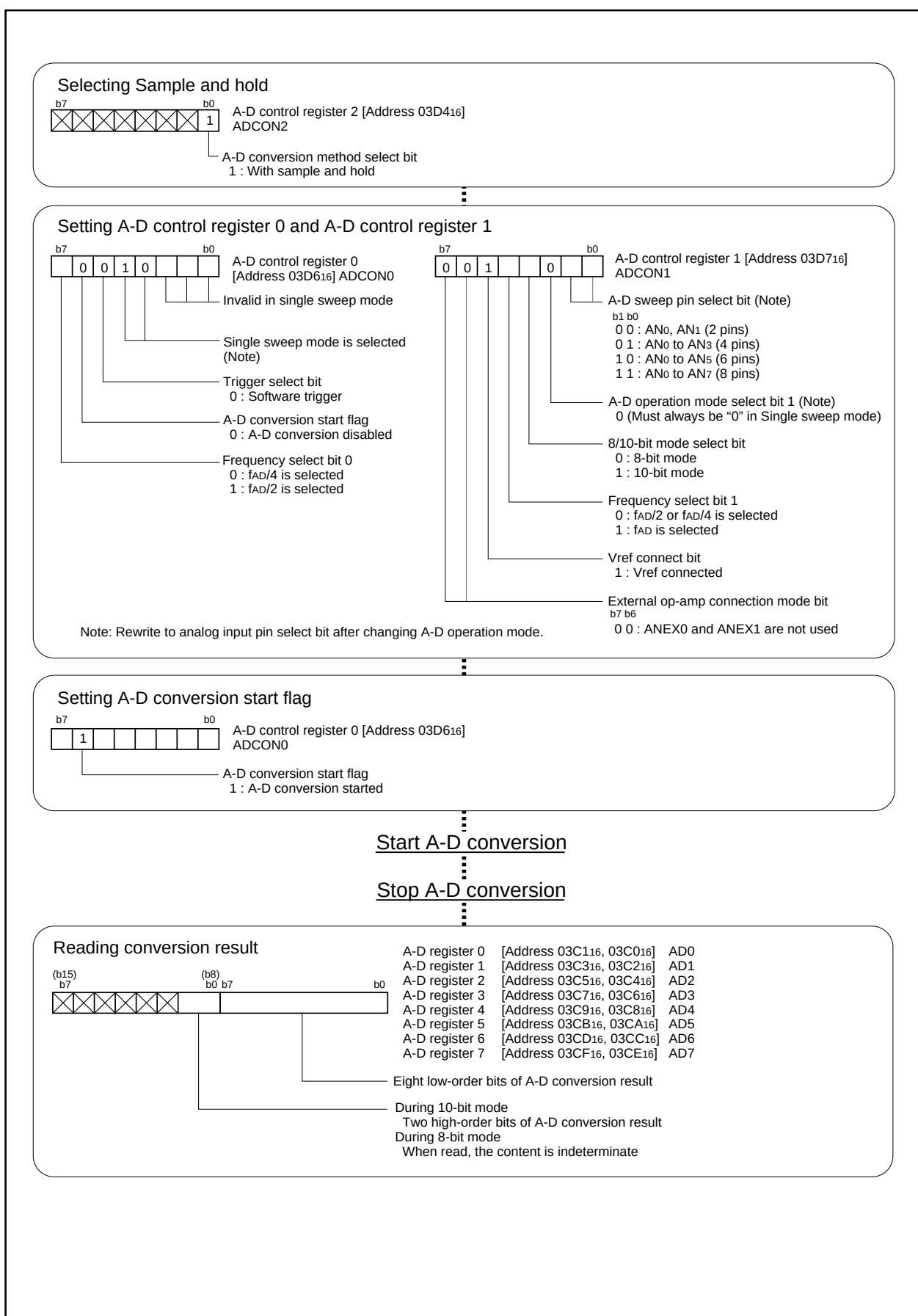


Figure 2.7.16. Set-up procedure of single sweep mode

2.7.8 Operation of A-D Converter (in repeat sweep mode 0)

In repeat sweep 0 mode, choose functions from those listed in Table 2.7.8. Operations of the circled items are described below. Figure 2.7.17 shows timing chart, and Figure 2.7.18 shows the set-up procedure.

Table 2.7.8. Chosed functions

Item	Set-up	Item	Set-up
Operation clock ϕ_{AD}	☐ Divided-by-4 f_{AD} / divided-by-2 f_{AD} / f_{AD}	Trigger for starting A-D conversion	☐ Software trigger
Resolution	☐ 8-bit / 10-bit		Trigger by $\overline{ADTRG}$
Analog input pin	☐ AN_0 and AN_1 (2 pins) / AN_0 to AN_3 (4 pins) / AN_0 to AN_5 (6 pins) / AN_0 to AN_7 (8 pins)	Expanded analog input pin	☐ Not used
			External ope-amp connection mode
		Sample & Hold	Not activated
			☐ Activated

- Operation
- (1) Setting the A-D conversion start flag to "1" causes the A-D converter to start the conversion on voltage input to the AN_0 pin.
 - (2) After the A-D conversion of voltage input to the AN_0 pin is completed, the content of the successive comparison register (conversion result) is transmitted to A-D register 0.
 - (3) The A-D converter converts all pins selected by the user. The conversion result is transmitted to A-D register i corresponding to each pin every time A-D conversion on the pin is completed. The A-D conversion interrupt request bit does not go to "1".
 - (4) The A-D converter continues operating until the A-D conversion start flag is set to "0" by software.

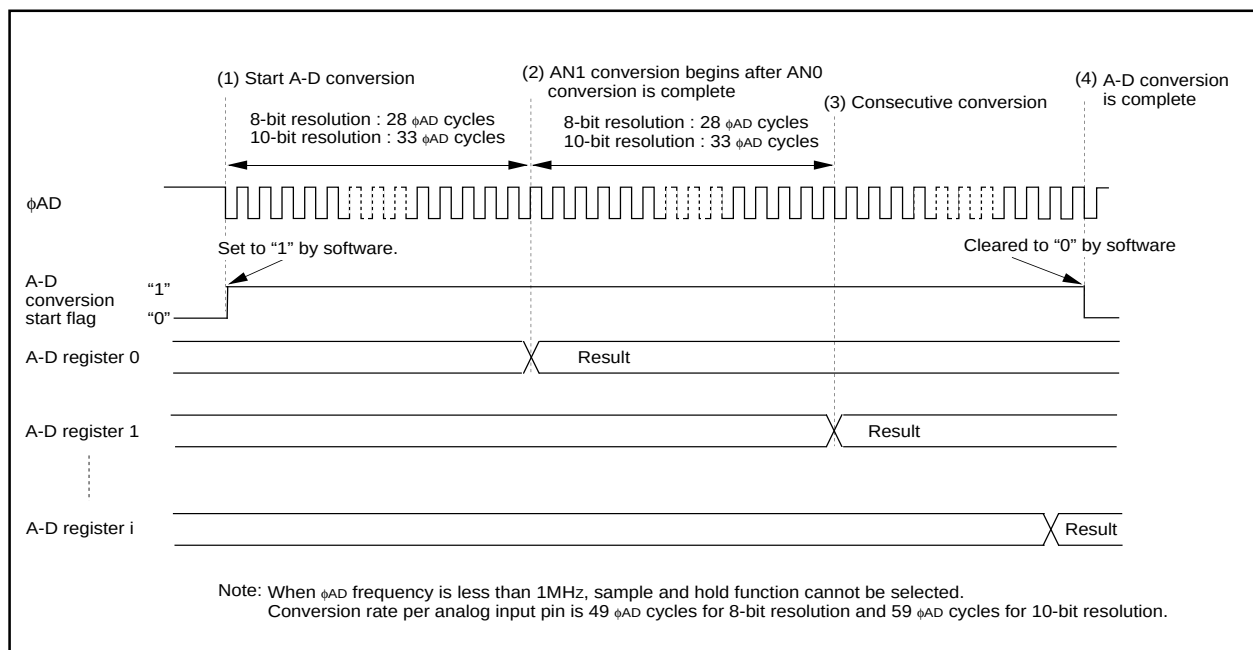


Figure 2.7.17. Operation timing of repeat sweep 0 mode

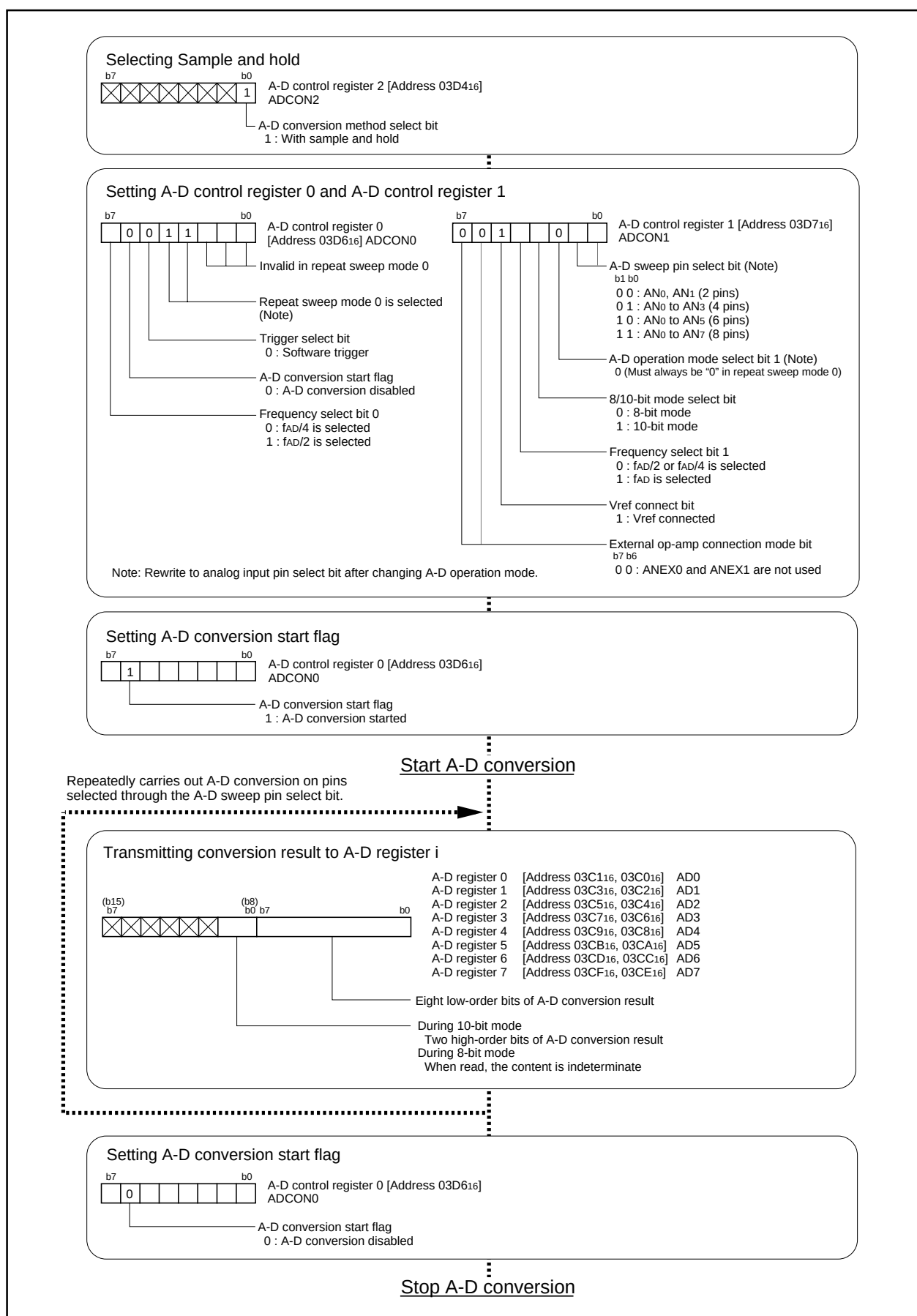


Figure 2.7.18. Set-up procedure of repeat sweep 0 mode

2.7.9 Operation of A-D Converter (in repeat sweep mode 1)

In repeat sweep 1 mode, choose functions from those listed in Table 2.7.9. Operations of the circled items are described below. Figure 2.7.19 shows ANi pin's sweep sequence, Figure 2.7.20 shows timing chart, and Figure 2.7.21 shows the set-up procedure.

Table 2.7.9. Chooed functions

Item	Set-up	Item	Set-up
Operation clock ϕ_{AD}	☐ Divided-by-4 f_{AD} / divided-by-2 f_{AD} / f_{AD}	Trigger for starting A-D conversion	☐ Software trigger
Resolution	☐ 8-bit / 10-bit		Trigger by AD_{TRG}
Analog input pin	☐ AN0 (1 pin) / AN0 and AN1 (2 pins) / AN0 to AN2 (3 pins) / AN0 to AN3 (4 pins)	Expanded analog input pin	☐ Not used
			External ope-amp connection mode
		Sample & Hold	Not activated
			☐ Activated

- Operation
- (1) Setting the A-D conversion start flag to "1" causes the A-D converter to start the conversion on voltage input to the AN0 pin.
 - (2) After the A-D conversion on voltage input to the AN0 pin is completed, the content of the successive comparison register (conversion result) is transmitted to A-D register 0.
 - (3) Every time the A-D converter carries out A-D conversion on a selected analog input pin, the A-D converter carries out A-D conversion on only one unselected pin, and then the A-D converter carries out A-D conversion from the AN0 pin again. (See Figure 2.7.19.) The conversion result is transmitted to A-D register i every time conversion on a pin is completed. The A-D conversion interrupt request bit does not go to "1".
 - (4) The A-D converter continues operating until software goes the A-D conversion start flag to "0".

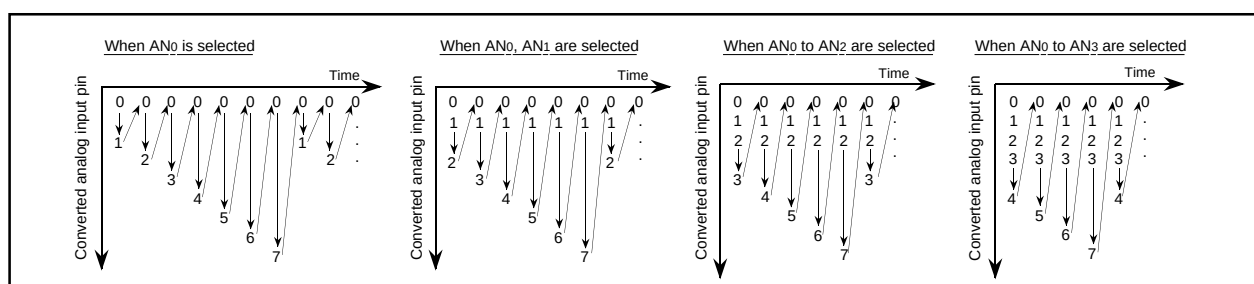


Figure 2.7.19. ANi pin's sweep sequence in repeat sweep mode

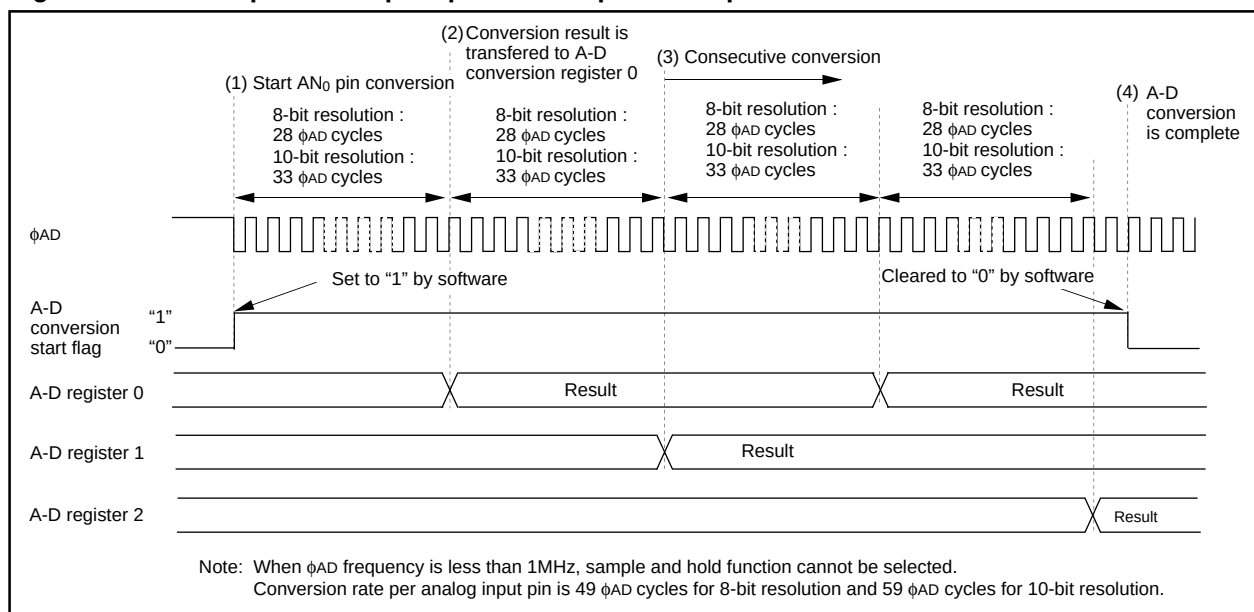


Figure 2.7.20. Operation timing of repeat sweep 1 mode

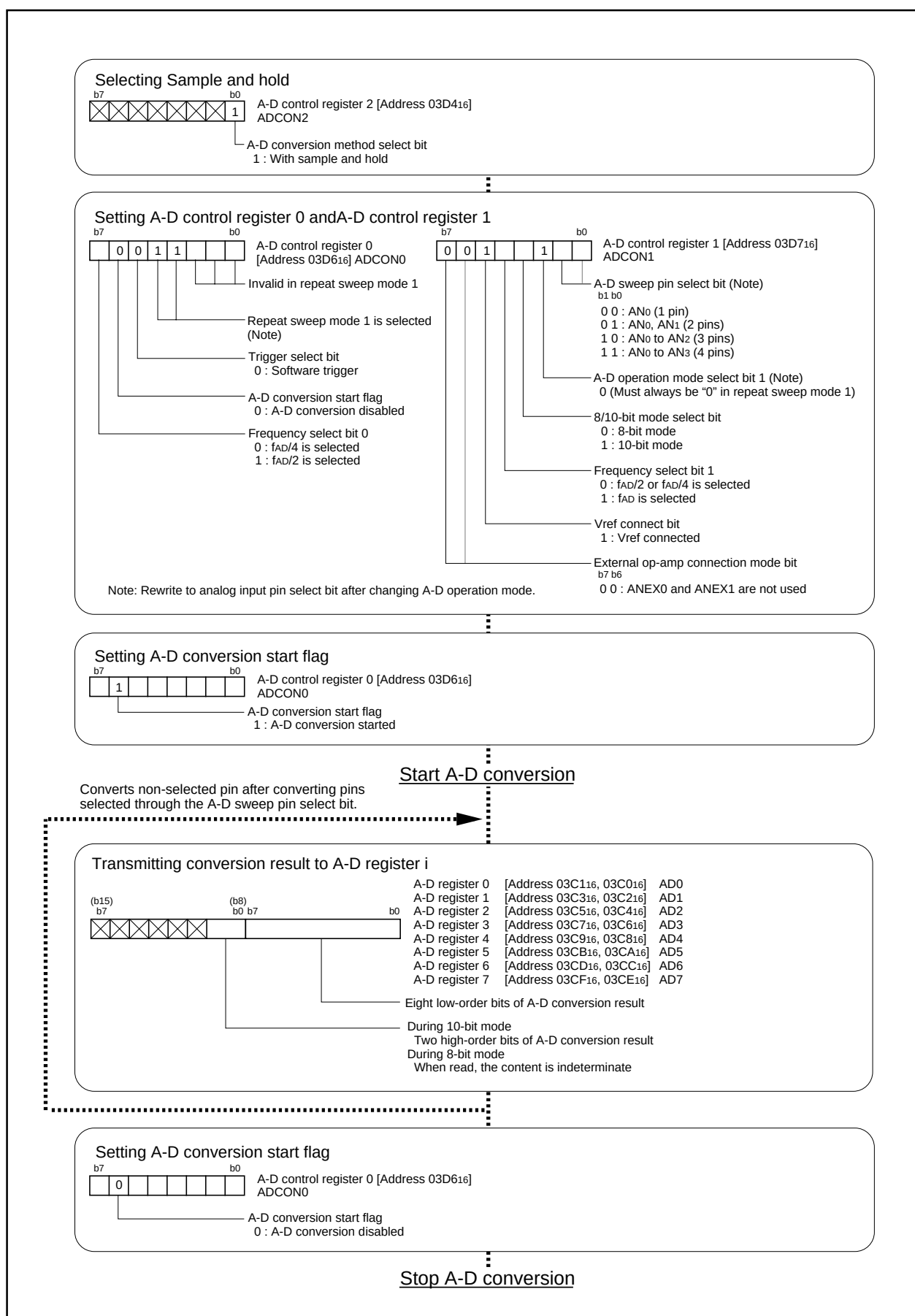


Figure 2.7.21. Set-up procedure of repeat sweep 1 mode

2.7.10 Precautions for A-D Converter

- (1) Write to each bit (except bit 6) of A-D control register 0, to each bit of A-D control register 1, and to bit 0 of A-D control register 2 when A-D conversion is stopped (before a trigger occurs). In particular, when the Vref connection bit is changed from 0 to 1, start A-D conversion after an elapse of 1 μ s or longer.
- (2) To reduce conversion error due to noise, connect a voltage to the AVcc pin and to the Vref pin from an independent source. It is recommended to connect a capacitor between the AVss pin and the AVcc pin, between the AVss pin and the Vref pin, and between the AVss pin and the analog input pin (ANi). Figure 2.7.22 shows the an example of connecting the capacitors to these pins.

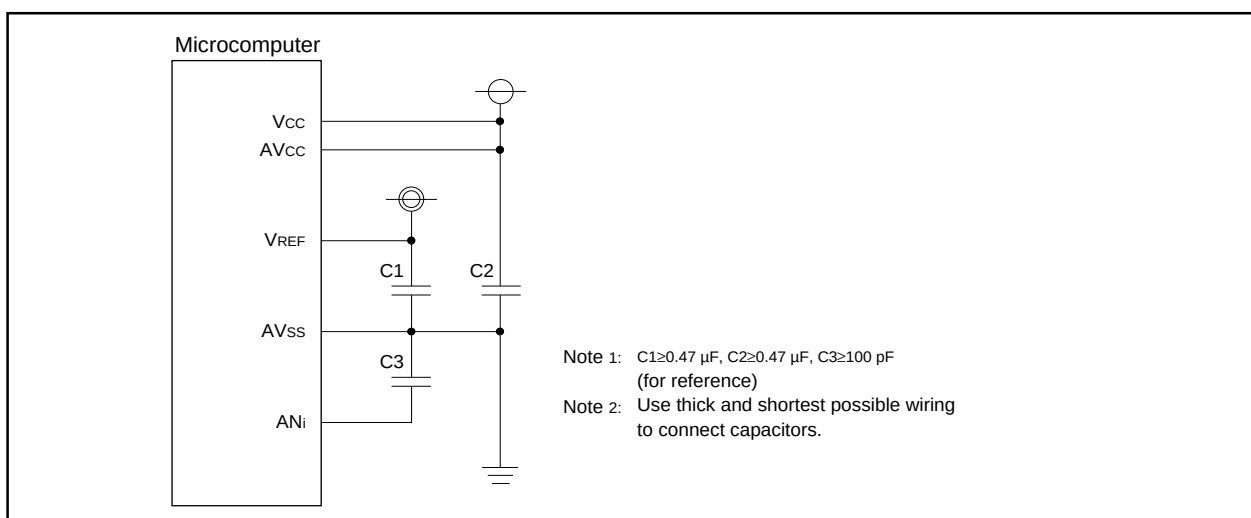


Figure 2.7.22. Use of capacitors to reduce noise

- (3) Set the direction register of the following ports to input: the port corresponding to a pin to be used as an analog input pin and external trigger input pin (P97).
- (4) In using a key-input interrupt, none of the 4 pins (AN4 through AN7) can be used as an A-D conversion port (if the A-D input voltage goes to "L" level, a key-input interrupt occurs).
- (5) If using the A-D converter with $V_{cc} = 2.7\text{V}$ to 4.0V :
Use only a divided frequency for f_{AD} (undivided f_{AD} is not allowed).
Select without the Sample & Hold feature.
Select 8-bit mode.
- (6) Rewrite to analog input pin select bits after changing A-D operation mode.
- (7) When using the one-shot or single sweep mode
Confirm that A-D conversion is complete before reading the A-D register.
(Note: When A-D conversion interrupt request bit is set, it shows that A-D conversion is completed.)
- (8) When using the repeat mode or repeat sweep mode 0 or 1
Use the undivided main clock as the internal CPU clock.
- (9) Use ϕ_{AD} under 10 MHz. When X_{IN} is over 10 MHz, divide it.

2.7.11 Method of A-D Conversion (10-bit mode)

(1) The A-D converter compares the reference voltage (Vref) generated internally based on the contents of the successive comparison register with the analog input voltage (VIN) input from the analog input pin. Each bit of the comparison result is stored in the successive comparison register until analog-to-digital conversion (successive comparison method) is complete. If a trigger occurs, the A-D converter carries out the following:

1. Fixes bit 9 of the successive comparison register.

Compares Vref with VIN: [In this instance, the contents of the successive comparison register are "10000000002" (default).]

Bit 9 of the successive comparison register varies depending on the comparison result as follows.

If $V_{ref} < V_{IN}$, then "1" is assigned to bit 9.

If $V_{ref} > V_{IN}$, then "0" is assigned to bit 9.

2. Fixes bit 8 of the successive comparison register.

Sets bit 8 of the successive comparison register to "1", then compares Vref with VIN.

Bit 8 of the successive comparison register varies depending on the comparison result as follows:

If $V_{ref} < V_{IN}$, then "1" is assigned to bit 8.

If $V_{ref} > V_{IN}$, then "0" is assigned to bit 8.

3. Fixes bit 7 through bit 0 of the successive comparison register.

Carries out step 2 above on bit 7 through bit 0.

After bit 0 is fixed, the contents of the successive comparison register (conversion result) are transmitted to A-D register i.

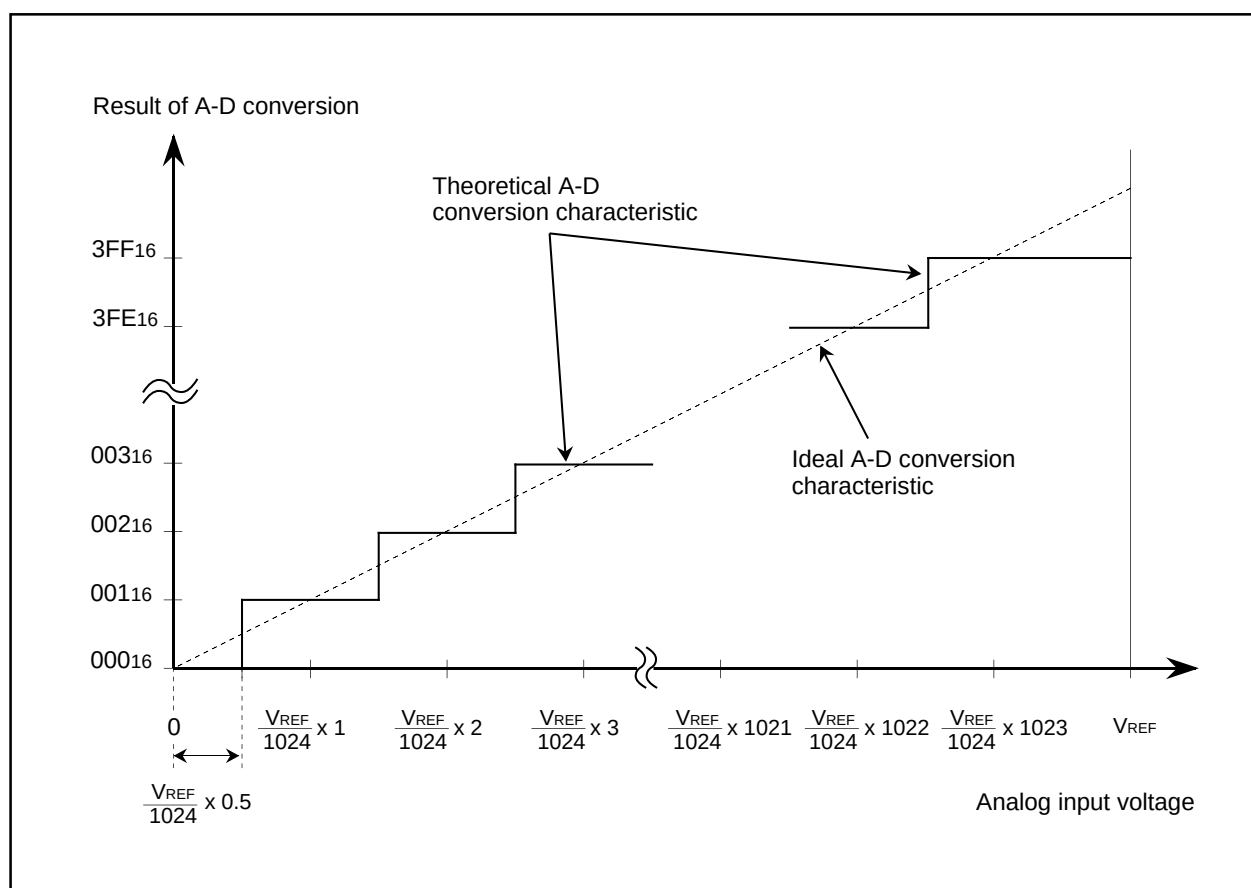
Vref is generated based on the latest content of the successive comparison register. Table 2.7.10 shows the relationship of the successive comparison register contents and Vref. Table 2.7.11 shows how the successive comparison register and Vref vary while A-D conversion is in progress. Figure 2.7.23 shows theoretical A-D conversion characteristics.

Table 2.7.10. Relationship of the successive comparison register contents and Vref

Successive approximation register : n	Vref (V)
0	0
1 to 1023	$\frac{V_{REF}}{1024} \times n - \frac{V_{REF}}{2048}$

Table 2.7.11. Variation of the successive comparison register and Vref while A-D conversion is in progress (10-bit mode)

	Successive approximation register	Vref change
A-D converter stopped	b9 b0 1 0 0 0 0 0 0 0 0 0	$\frac{V_{REF}}{2} [M]$
1st comparison	1 0 0 0 0 0 0 0 0 0	$\frac{V_{REF}}{2} - \frac{V_{REF}}{2048} [M]$
2nd comparison	n9 1 0 0 0 0 0 0 0 0	$\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4} - \frac{V_{REF}}{2048} [M]$
3rd comparison	n9 n8 1 0 0 0 0 0 0 0	$\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4} \pm \frac{V_{REF}}{8} - \frac{V_{REF}}{2048} [M]$
10th comparison	n9 n8 n7 n6 n5 n4 n3 n2 n1 0	$\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4} \pm \frac{V_{REF}}{8} \pm \dots \pm \frac{V_{REF}}{1024} - \frac{V_{REF}}{2048} [M]$
Conversion complete	n9 n8 n7 n6 n5 n4 n3 n2 n1 n0 This data transfers to the bit 0 to bit 9 of A-D register i.	

**Figure 2.7.23. Theoretical A-D conversion characteristics (10-bit mode)**

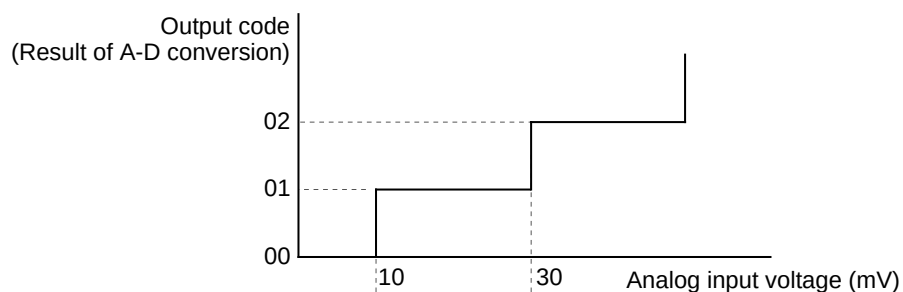
2.7.12 Method of A-D Conversion (8-bit mode)

- (1) In 8-bit mode, 8 higher-order bits of the 10-bit successive comparison register becomes A-D conversion result. Hence, if compared to a result obtained by using an 8-bit A-D converter, the voltage compared is different by $3 V_{REF}/2048$ (see what are underscored in Table 2.7.12), and differences in stepping points of output codes occur as shown in Figure 2.7.24.

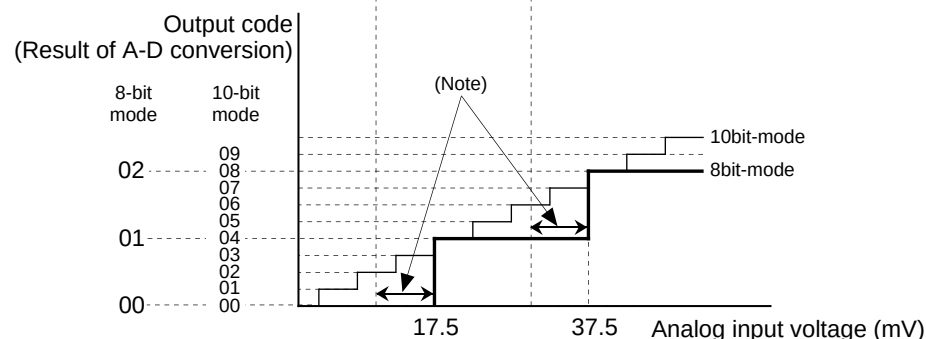
Table 2.7.12. The comparison voltage in 8-bit mode compared to 8-bit A-D converter

		8-bit mode	8-bit A-D converter
Comparison voltage V_{REF}	$n = 0$	0	0
	$n = 1 \text{ to } 255$	$\frac{V_{REF}}{2^8} \times n - \frac{V_{REF}}{2^{10}} \times 0.5$	$\frac{V_{REF}}{2^8} \times n - \frac{V_{REF}}{2^8} \times 0.5$

Optimal conversion characteristics of 8-bit A-D converter ($V_{REF} = 5.12 \text{ V}$)



Optimal conversion characteristics in 8-bit mode ($V_{REF} = 5.12 \text{ V}$)

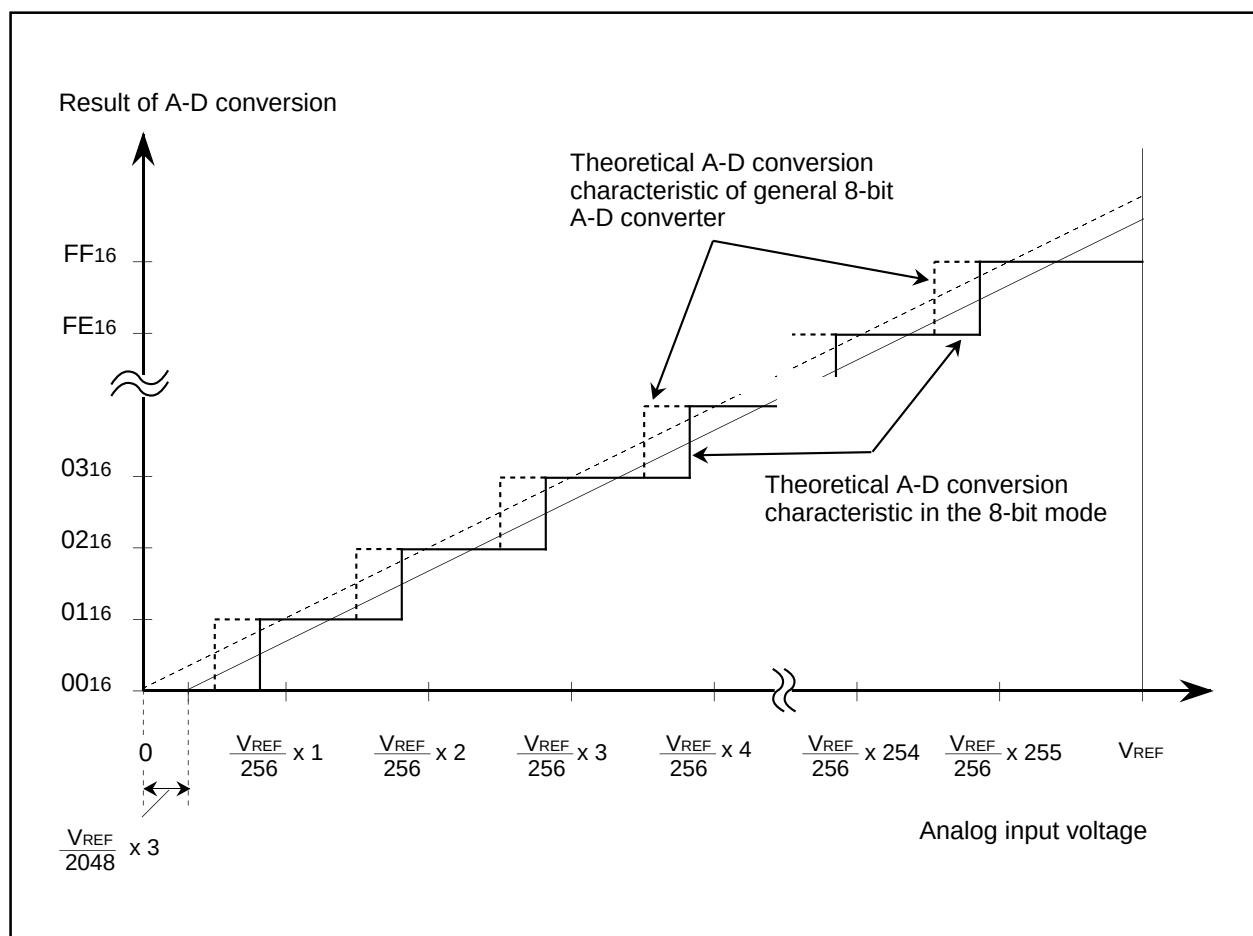


Note: Differences in stepping points of output code for analog input voltage.

Figure 2.7.24. The level conversion characteristics of 8-bit mode and 8-bit A-D converter

Table 2.7.13. Variation of the successive comparison register and Vref while A-D conversion is in progress (8-bit mode)

	Successive approximation register	Vref change
A-D converter stopped	b9 b0 1 0 0 0 0 0 0 0 0 0	$\frac{V_{REF}}{2} [V]$
1st comparison	1 0 0 0 0 0 0 0 0 0	$\frac{V_{REF}}{2} - \frac{V_{REF}}{2048} [V]$
2nd comparison	n9 1 0 0 0 0 0 0 0 0 ↑ 1st comparison result	$\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4} - \frac{V_{REF}}{2048} [V] \begin{cases} n9 = 1 & + \frac{V_{REF}}{4} \\ n9 = 0 & - \frac{V_{REF}}{4} \end{cases}$
3rd comparison	n9 n8 1 0 0 0 0 0 0 0 ↑ 2nd comparison result	$\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4} \pm \frac{V_{REF}}{8} - \frac{V_{REF}}{2048} [V] \begin{cases} n8 = 1 & + \frac{V_{REF}}{8} \\ n8 = 0 & - \frac{V_{REF}}{8} \end{cases}$
⋮	⋮	⋮
8th comparison	n9 n8 n7 n6 n5 n4 n3 1 0 0	$\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4} \pm \frac{V_{REF}}{8} \pm \dots \pm \frac{V_{REF}}{256} - \frac{V_{REF}}{2048} [V]$
Conversion complete	n9 n8 n7 n6 n5 n4 n3 n2 0 0 This data transfers to bit 0 to bit 7 of A-D register i.	

**Figure 2.7.25. Theoretical A-D conversion characteristics (8-bit mode)**

2.7.13 Absolute Accuracy and Differential Non-Linearity Error

• Absolute accuracy

Absolute accuracy is the difference between output code based on the theoretical A-D conversion characteristics, and actual A-D conversion result. When measuring absolute accuracy, the voltage at the middle point of the width of analog input voltage (1-LSB width), that can meet the expectation of outputting an equal code based on the theoretical A-D conversion characteristics, is used as an analog input voltage. For example, if 10-bit resolution is used and if V_{REF} (reference voltage) = 5.12 V, then 1-LSB width becomes 5 mV, and 0 mV, 5 mV, 10 mV, 15 mV, 20 mV, ... are used as analog input voltages. If analog input voltage is 25 mV, "absolute accuracy = $\pm 3\text{LSB}$ " refers to the fact that actual A-D conversion falls on a range from "002₁₆" to "008₁₆" though an output code, "005₁₆", can be expected from the theoretical A-D conversion characteristics. Zero error and full-scale error are included in absolute accuracy.

Also, all the output codes for analog input voltage between V_{REF} and V_{CC} becomes "3FF₁₆".

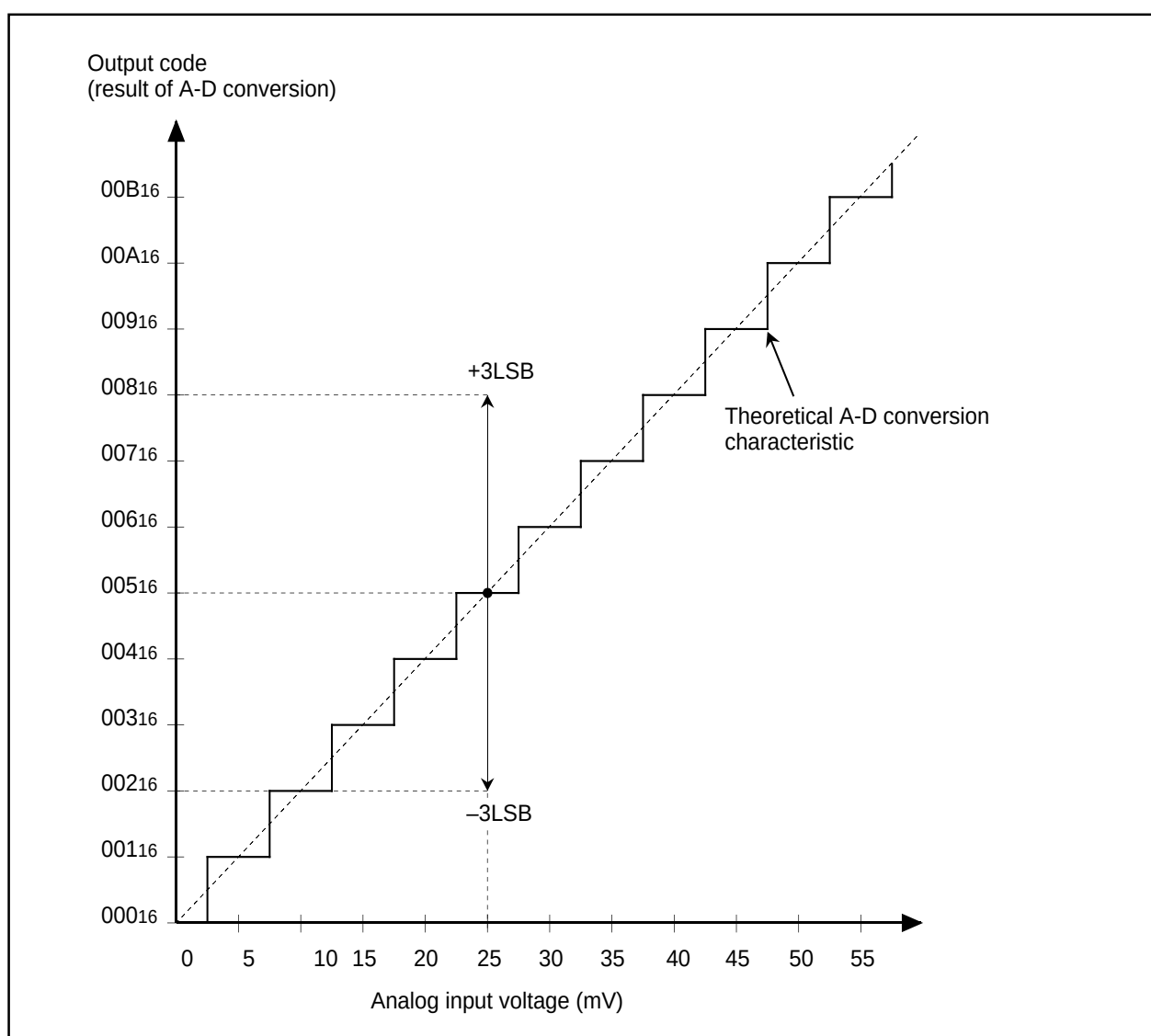


Figure 2.7.26. Absolute accuracy (10-bit resolution)

• Differential non-linearity error

Differential non-linearity error refers to the difference between 1-LSB width based on the theoretical A-D conversion characteristics (an analog input width that can meet the expectation of outputting an equal code) and an actually measured 1-LSB width (analog input voltage width that outputs an equal code). If 10-bit resolution is used and if V_{REF} (reference voltage) = 5.12 V, “differential non-linearity error = $\pm 1\text{LSB}$ ” refers to the fact that 1-LSB width actually measured falls on a range from 0 mV to 10 mV though 1-LSB width based on the theoretical A-D conversion characteristics is 5 mV.

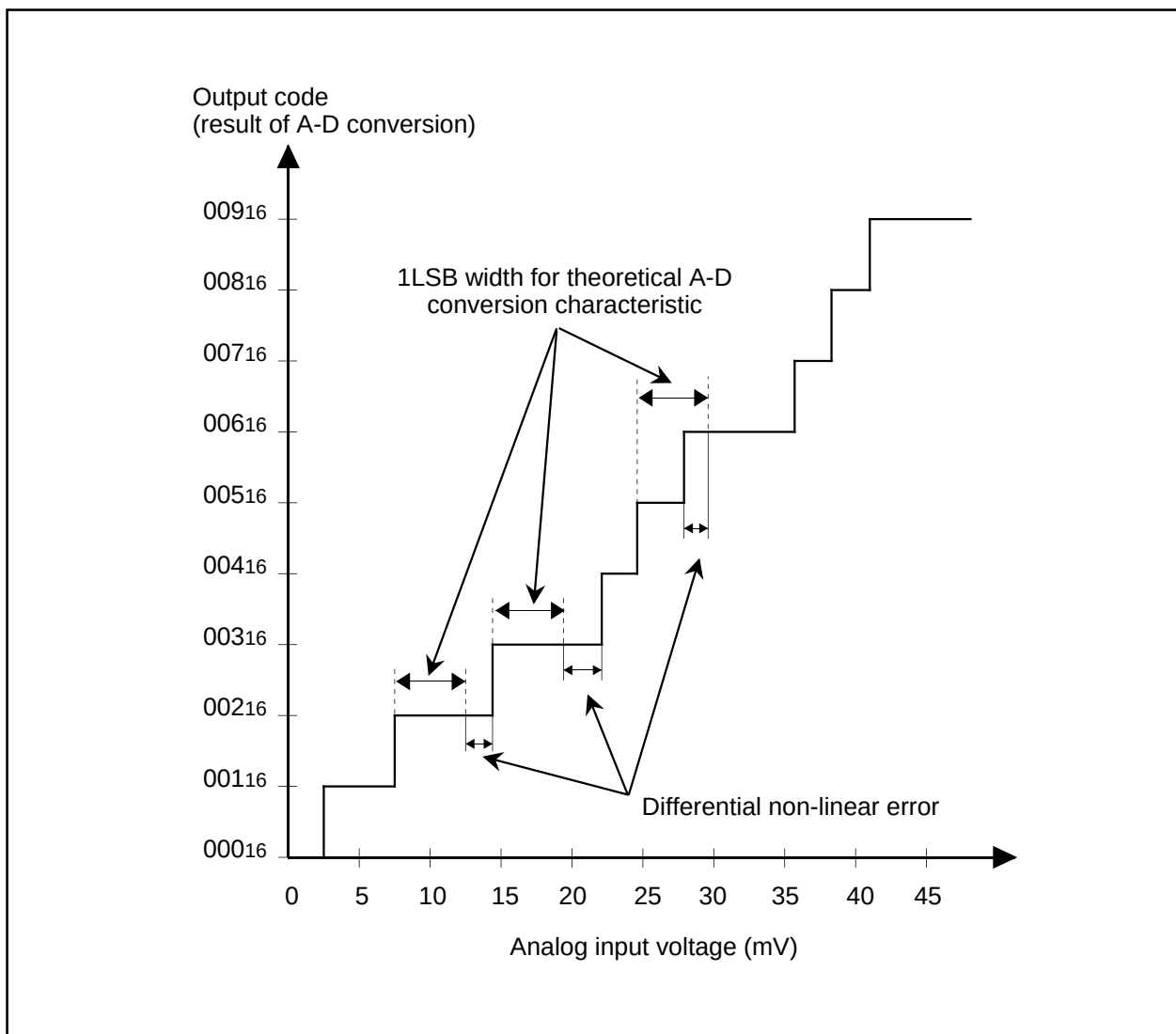


Figure 2.7.27. Differential non-linearity error (10-bit resolution)

2.7.14 Internal Equivalent Circuit of Analog Input

Figure 2.7.28 shows the internal equivalent circuit of analog input.

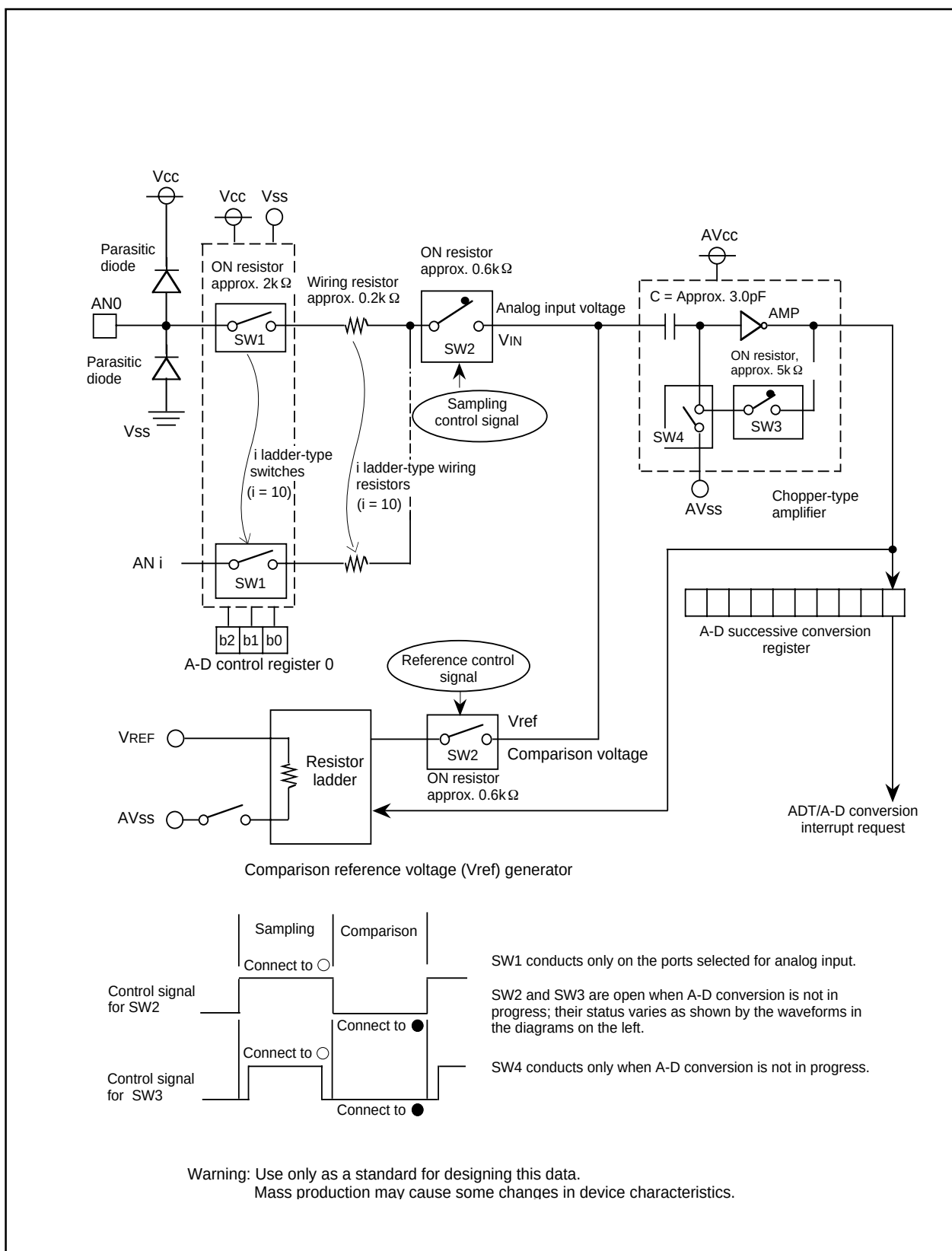


Figure 2.7.28. Internal equivalent circuit to analog input

2.7.15 Sensor's Output Impedance under A-D Conversion

To carry out A-D conversion properly, charging the internal capacitor C shown in Figure 2.7.29 has to be completed within a specified period of time. With T as the specified time, time T is the time that switches SW2 and SW3 are connected to O in Figure 2.7.28. Let output impedance of sensor equivalent circuit be R₀, microcomputer's internal resistance be R, precision (error) of the A-D converter be X, and the A-D converter's resolution be Y (Y is 1024 in the 10-bit mode, and 256 in the 8-bit mode).

$$V_c \text{ is generally } V_c = V_{IN} \left\{ 1 - e^{-\frac{t}{C(R_0 + R)}} \right\}$$

$$\text{And when } t = T, \quad V_c = V_{IN} - \frac{X}{Y} V_{IN} = V_{IN} \left(1 - \frac{X}{Y} \right)$$

$$e^{-\frac{T}{C(R_0 + R)}} = \frac{X}{Y}$$

$$-\frac{T}{C(R_0 + R)} = \ln \frac{X}{Y}$$

$$\text{Hence, } R_0 = -\frac{T}{C \cdot \ln \frac{X}{Y}} - R$$

With the model shown in Figure 2.7.29 as an example, when the difference between V_{IN} and V_c becomes 0.1LSB, we find impedance R₀ when voltage between pins V_c changes from 0 to $V_{IN} - (0.1/1024) V_{IN}$ in time T. (0.1/1024) means that A-D precision drop due to insufficient capacitor charge is held to 0.1LSB at time of A-D conversion in the 10-bit mode. Actual error however is the value of absolute precision added to 0.1LSB. When $f(X_{IN}) = 10 \text{ MHz}$, $T = 0.3 \mu\text{s}$ in the A-D conversion mode with sample & hold. Output impedance R₀ for sufficiently charging capacitor C within time T is determined as follows.

$T = 0.3 \mu\text{s}$, $R = 7.8 \text{ k}\Omega$, $C = 3 \text{ pF}$, $X = 0.1$, and $Y = 1024$. Hence,

$$R_0 = -\frac{0.3 \times 10^{-6}}{3.0 \times 10^{-12} \cdot \ln \frac{0.1}{1024}} - 7.8 \times 10^3 \approx 3.0 \times 10^3$$

Thus, the allowable output impedance of the sensor circuit capable of thoroughly driving the A-D converter turns out to be approximately 3.0 kΩ. Tables 2.7.14 and 2.7.15 show output impedance values based on the LSB values.

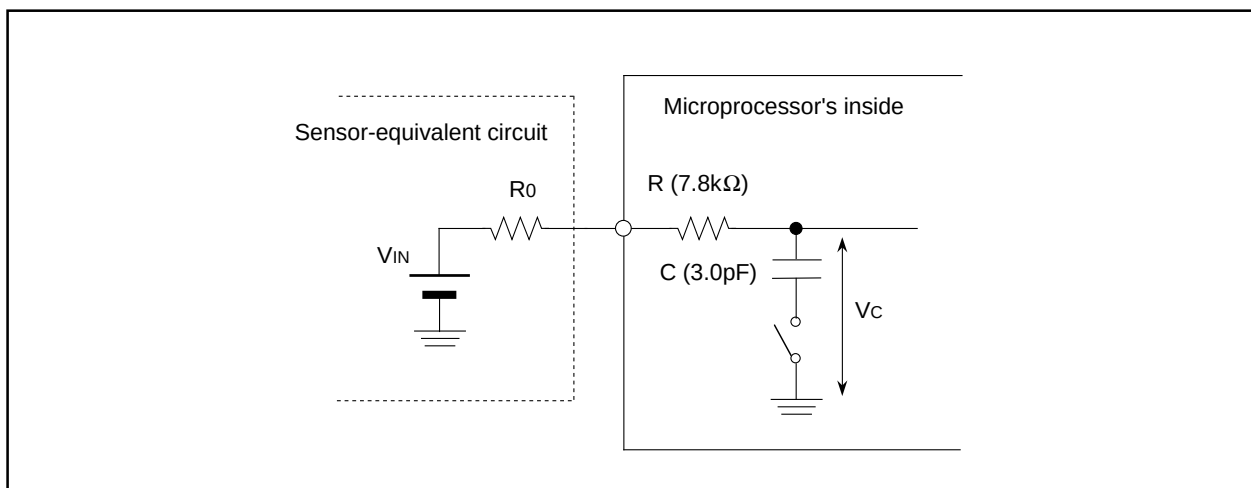


Figure 2.7.29 A circuit equivalent to the A-D conversion terminal

Tables 2.7.14. Relation between output impedance and precision (error) of A-D converter (10-bit mode) Reference value

f(Xin) (MHz)	Cycle (μ s)	Sampling time (μ s)	R (k Ω)	C (pF)	Resolution (LSB)	R0 (k Ω)
10	0.1	0.3 (3 x cycle, Sample & hold bit is enabled)	7.8	3.0	0.1	3.0
					0.3	4.5
					0.5	5.3
					0.7	5.9
					0.9	6.4
					1.1	6.8
					1.3	7.2
					1.5	7.5
					1.7	7.8
					1.9	8.1
10	0.1	0.2 (2 x cycle, Sample & hold bit is disabled)	7.8	3.0	0.3	0.4
					0.5	0.9
					0.7	1.3
					0.9	1.7
					1.1	2.0
					1.3	2.2
					1.5	2.4
					1.7	2.6
					1.9	2.8

Tables 2.7.15. Relation between output impedance and precision (error) of A-D converter (8-bit mode) Reference value

f(Xin) (MHz)	Cycle (μ s)	Sampling time (μ s)	R (k Ω)	C (pF)	Resolution (LSB)	R0 (k Ω)
10	0.1	0.3 (3 x cycle, Sample & hold bit is enabled)	7.8	3.0	0.1	4.9
					0.3	7.0
					0.5	8.2
					0.7	9.1
					0.9	9.9
					1.1	10.5
					1.3	11.1
					1.5	11.7
					1.7	12.1
					1.9	12.6
10	0.1	0.2 (2 x cycle, Sample & hold bit is disabled)	7.8	3.0	0.1	0.7
					0.3	2.1
					0.5	2.9
					0.7	3.5
					0.9	4.0
					1.1	4.4
					1.3	4.8
					1.5	5.2
					1.7	5.5
					1.9	5.8

2.8 D-A Converter Usage

2.8.1 Overview of the D-A converter usage

The D-A converter used in the M16C/62A group is based on the 8-bit R-2R technique.

(1) Output voltage

The D-A converter outputs voltage within a range from 0 V to VREF. The output voltage is determined by $V_{REF}/(256) \times$ the D-A register contents.

The D-A converter is not effected by the Vref connection bit of the A-D converter.

(2) Conversion time

$t_{su} = 3 \mu s$

(3) Output from the D-A converter and the direction register

To use the D-A converter, do not set the direction register of the relevant port to output.

(4) Pins related to the D-A converter

- DA0 pin, DA1 pin Output pins of the D-A converter
- AVcc pin The power source pin of the analog section
- VREF pin Input pin of the reference voltage
- AVss pin The GND pin of the analog section

(5) Registers related to the D-A converter

Figure 2.8.1 shows the memory map of D-A converter-related registers, and Figure 2.8.2 shows D-A converter-related registers.

(6) Note

D-A output pins shared with P93 and P94. The two pins are input ports and floating at the reset.

03D8 ₁₆	D-A register 0 (DA0)
03D9 ₁₆	
03DA ₁₆	D-A register 1 (DA1)
03DB ₁₆	
03DC ₁₆	D-A control register (DACon)

Figure 2.8.1. Memory map of D-A converter-related registers

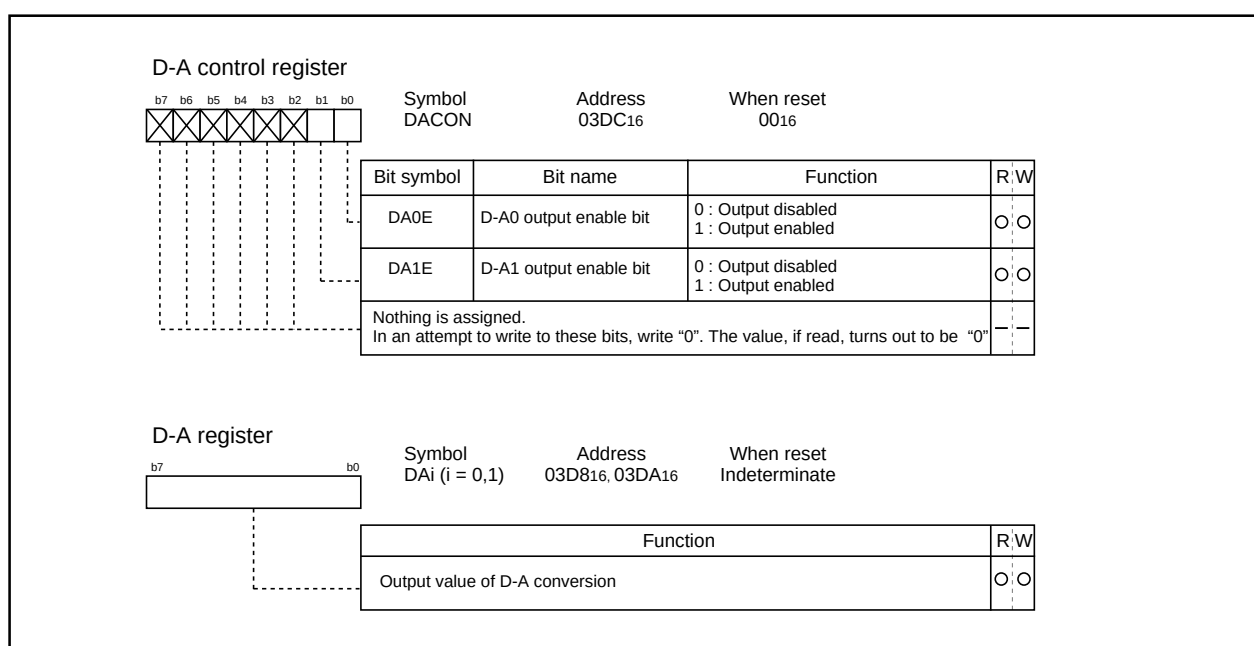


Figure 2.8.2. D-A converter-related registers

2.8.2 D-A Converter Operation

The following is the D-A converter operation. Figure 2.8.3 shows the set-up procedure.

- Operation
- (1) Writing a value to the D-A register starts D-A conversion.
 - (2) Setting the D-Ai output enable bit to "1" outputs an analog signal on the DAi pin.
 - (3) The D-A converter continues outputting an analog signal until the D-A output enable bit is set to "0".

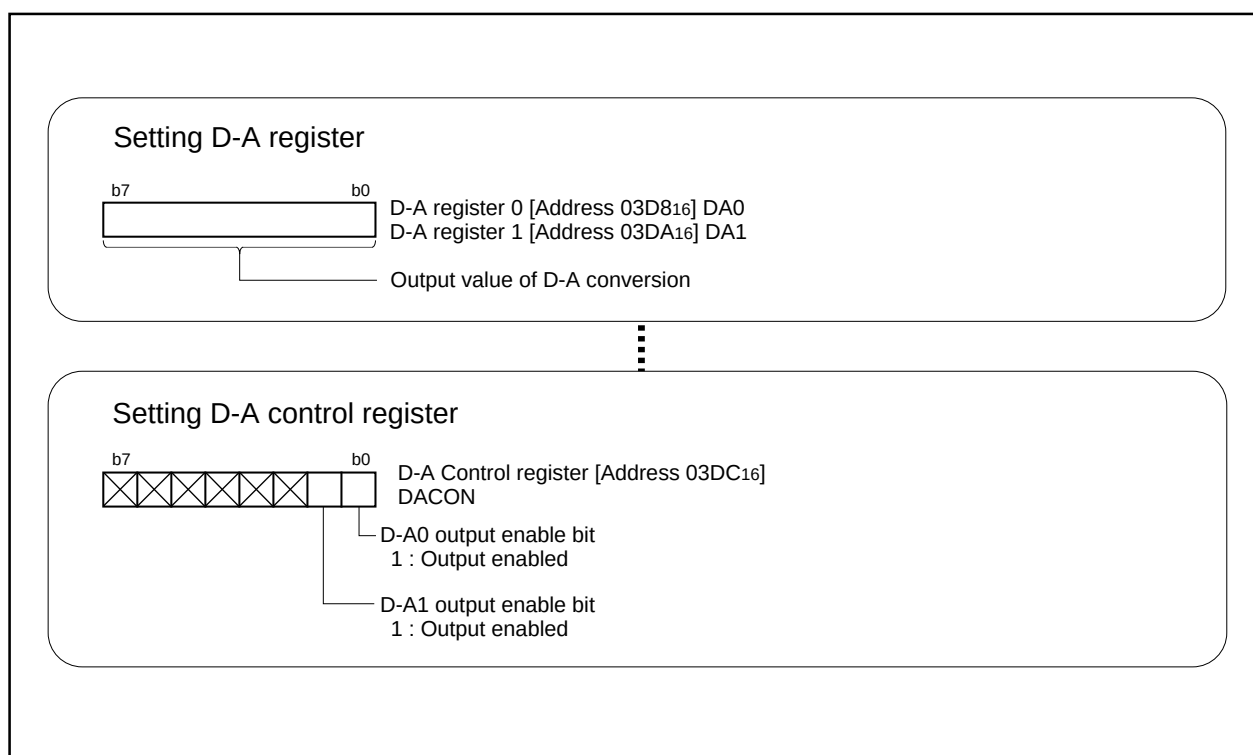


Figure 2.8.3. Set-up procedure of D-A converter

2.9 DMAC Usage

2.9.1 Overview of the DMAC usage

DMAC transfers one data item held in the source address to the destination address every time a transfer request is generated. The following is an overview of the DMAC usage.

(1) Source address and destination address

Both the register which indicates a source and the register which indicates a destination comprise of 24 bits, so that each can cover a 1M bytes space. After transfer of one bit of data is completed, the address in either the source register or the destination register can be incremented. However, both registers cannot be incremented. The links between the source and destination are as follows:

- (a) A fixed address from an arbitrary 1M bytes space
- (b) An arbitrary 1M bytes space from a fixed address
- (c) A fixed address from another fixed address

(2) The number of bits of data transferred

The number of bit of data indicated by the transfer counter is transferred. If a 16-bit transfer is selected, up to 128K bytes can be transferred. If an 8-bit transfer is selected, up to 64K bytes can be transferred. The transfer counter is decremented each time one bit of data is transferred, and a DMA interrupt request occurs when the transfer counter underflows.

(3) DMA transfer factor

The DMA transfer factor can be selected from the following 25 factors: falling edge/two edges of $\overline{INT0}$ / $\overline{INT1}$ pin, timer A0 interrupt request through timer A4 interrupt request, timer B0 interrupt request through timer B5 interrupt request, UART0 transmission interrupt request, UART0 reception interrupt request, UART1 transmission/UART1 reception interrupt request, UART2 transmission interrupt request, UART2 reception interrupt request, S/O 3, 4 interrupt request, A-D conversion interrupt request, and software trigger.

When software trigger is selected, DMA transfer is generated by writing "1" to software DMA interrupt request bit. When other factor is selected, DMA transfer is generated by generating corresponding interrupt request.

(4) Channel priority

If DMA0 transfer request and DMA1 transfer request occur simultaneously, priority is given to DMA0.

(5) Writing to a register

When writing to the source register or the destination register with DMA enabled, the content of the register with a fixed address will change at the time of writing. Therefore, the user should not write to a register with a fixed address when the DMA enable bit is set to "1". The contents of the register with 'forward direction' selected, and the transfer counter, are changed when reloaded. A reload occurs either when the transfer counter underflows, or when the DMA enable bit is re-enabled, after having been disabled.

The reload register can be written to, as in normal conditions.

(6) Reading to a register

The reload register can be read to, as in normal conditions.

(7) Switching function**(a) Switching between one-shot transfer and repeated transfer**

'One-shot transfer' refers to a mode in which DMA is disabled after the transfer counter underflows. 'Repeated transfer' refers to a mode in which a reload is carried out after the transfer counter underflows. The reload is carried out for the transfer counter and on the address pointer subjected to forward direction.

The following are examples of operation in which the options listed are selected.

- A fixed address from an arbitrary 1M byte space, one-shot transfer P2-148
- An arbitrary 1M byte space from a fixed address, repeated transfer P2-150

(8) Registers related to DMAC

Figure 2.9.1 shows the memory map of DMAC-related registers, and Figures 2.9.2 and 2.9.3 show DMAC-related registers.

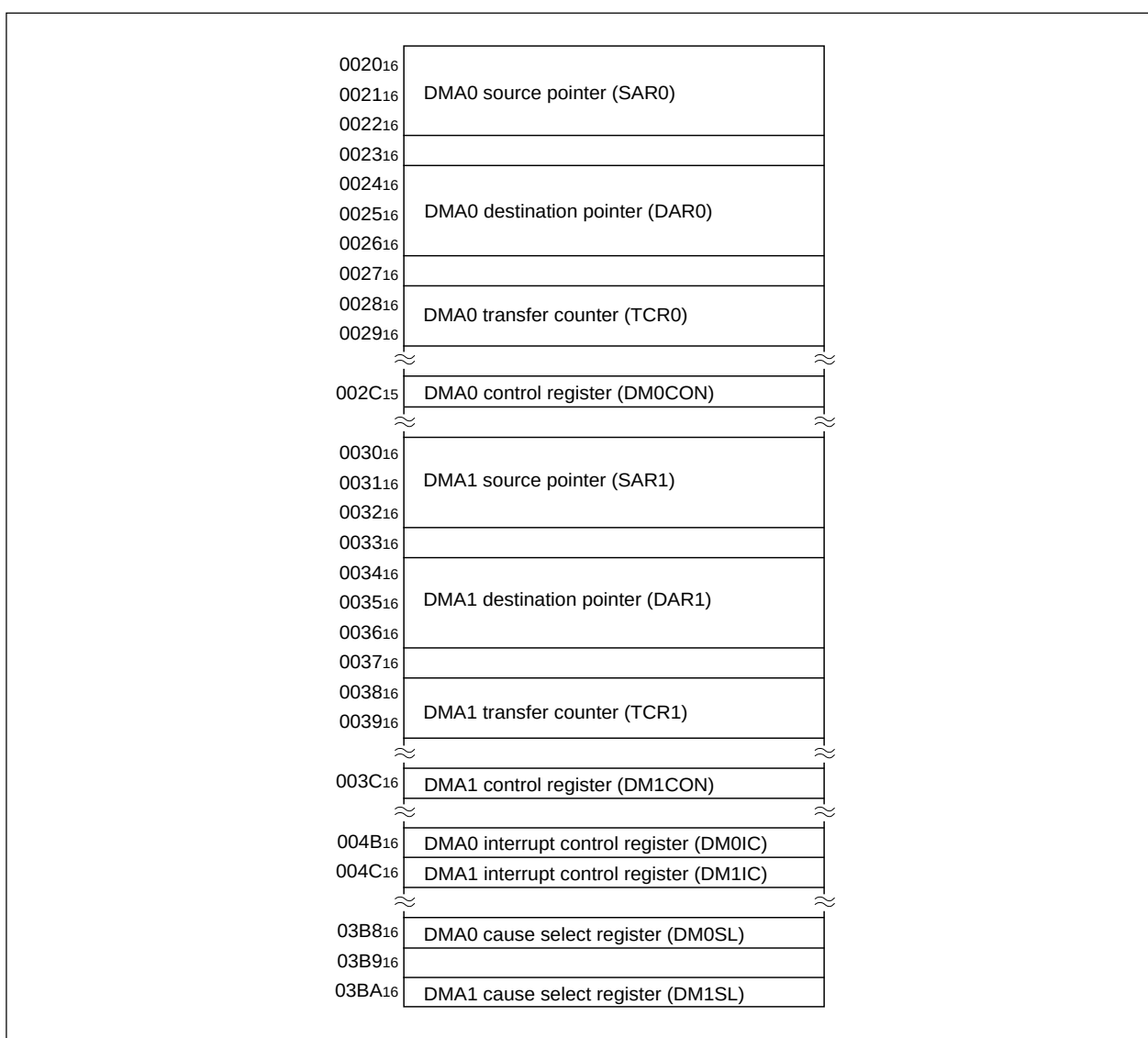


Figure 2.9.1. Memory map of DMAC-related registers

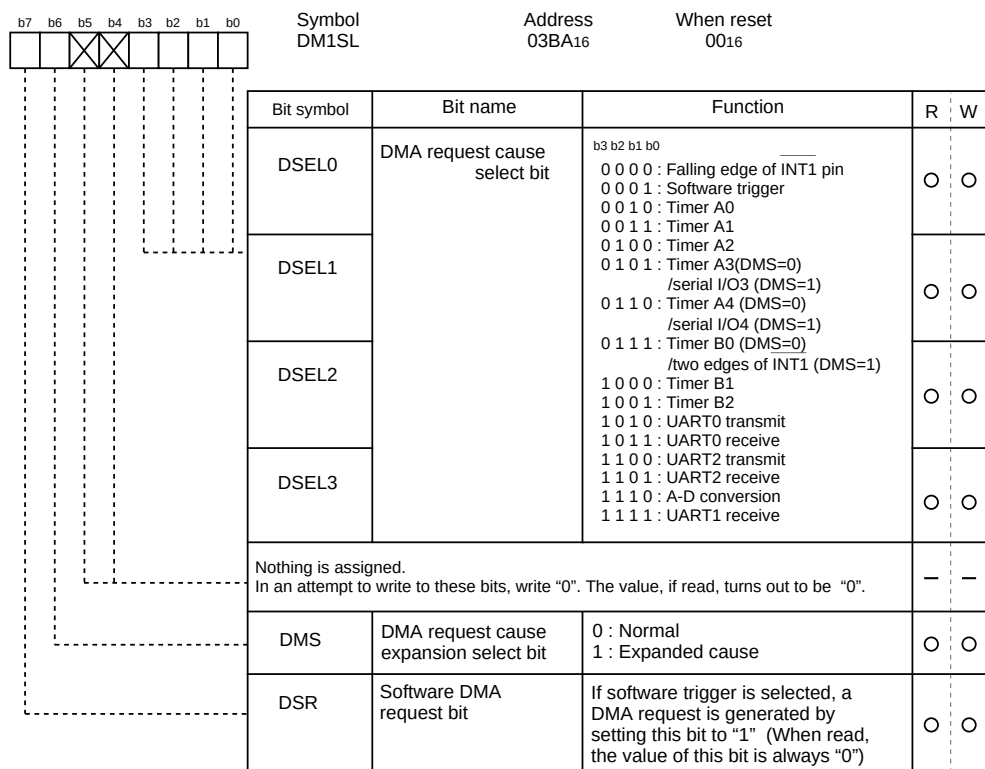
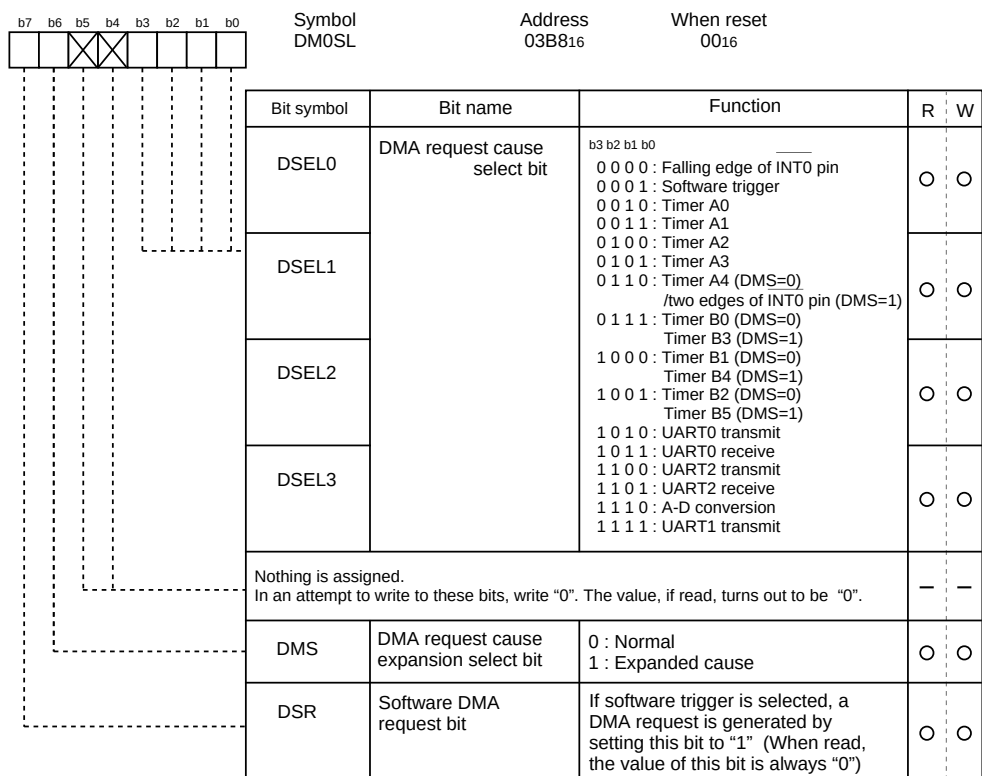
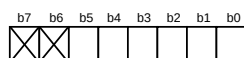


Figure 2.9.2. DMAC-related registers (1)

DMAi control register

Symbol
DMiCON(i=0,1)Address
002C₁₆, 003C₁₆When reset
00000X00₂

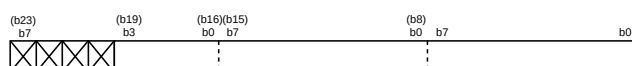
Bit symbol	Bit name	Function	R	W
DMBIT	Transfer unit bit select bit	0 : 16 bits 1 : 8 bits	○	○
DMASL	Repeat transfer mode select bit	0 : Single transfer 1 : Repeat transfer	○	○
DMAS	DMA request bit (Note 1)	0 : DMA not requested 1 : DMA requested	○	○ (Note 2)
DMAE	DMA enable bit	0 : Disabled 1 : Enabled	○	○
DSD	Source address direction select bit (Note 3)	0 : Fixed 1 : Forward	○	○
DAD	Destination address direction select bit (Note 3)	0 : Fixed 1 : Forward	○	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".			—	—

Note 1: DMA request can be cleared by resetting the bit.

Note 2: This bit can only be set to "0".

Note 3: Source address direction select bit and destination address direction select bit cannot be set to "1" simultaneously.

DMAi source pointer (i = 0, 1)

Symbol
SAR0
SAR1Address
0022₁₆ to 0020₁₆
0032₁₆ to 0030₁₆When reset
Indeterminate
Indeterminate

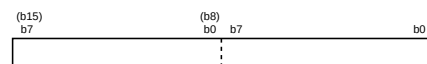
Function	Transfer address specification	R	W
• Source pointer Stores the source address	00000 ₁₆ to FFFFF ₁₆	○	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".		—	—

DMAi destination pointer (i = 0, 1)

Symbol
DAR0
DAR1Address
0026₁₆ to 0024₁₆
0036₁₆ to 0034₁₆When reset
Indeterminate
Indeterminate

Function	Transfer address specification	R	W
• Destination pointer Stores the destination address	00000 ₁₆ to FFFFF ₁₆	○	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".		—	—

DMAi transfer counter (i = 0, 1)

Symbol
TCR0
TCR1Address
0029₁₆, 0028₁₆
0039₁₆, 0038₁₆When reset
Indeterminate
Indeterminate

Function	Transfer count specification	R	W
• Transfer counter Set a value one less than the transfer count	0000 ₁₆ to FFFF ₁₆	○	○

Figure 2.9.3. DMAC-related registers (2)

2.9.2 Operation of DMAC (one-shot transfer mode)

In one-shot transfer mode, choose functions from the items shown in Table 2.9.1. Operations of the circled items are described below. Figure 2.9.4 shows an example of operation and Figure 2.9.5 shows the set-up procedure.

Table 2.9.1. Chooed functions

Item	Set-up	
Transfer space	☐	Fixed address from an arbitrary 1 M bytes space
	☐	Arbitrary 1 M bytes space from a fixed address
	☐	Fixed address from fixed address
Unit of transfer	☐	8 bits
	☐	16 bits

- Operation
- (1) When software trigger is selected, setting software DMA request bit to "1" generates a DMA transfer request signal.
 - (2) If DMAC is active, data transfer starts, and the contents of the address indicated by the DMAi forward-direction address pointer are transferred to the address indicated by the DMAi destination pointer. When data transfer starts directly after DMAC becomes active, the value of the DMAi transfer counter reload register is reloaded to the DMAi transfer counter, and the value of the DMAi source pointer is reloaded by the DMAi forward-direction address pointer. Each time a DMA transfer request signal is generated, 1 byte of data is transferred. The DMAi transfer counter is down counted, and the DMAi forward-direction address pointer is up counted.
 - (3) If the DMA transfer counter underflows, the DMA enable bit changes to "0" and DMA transfer is completed. The DMA interrupt request bit changes to "1" simultaneously.

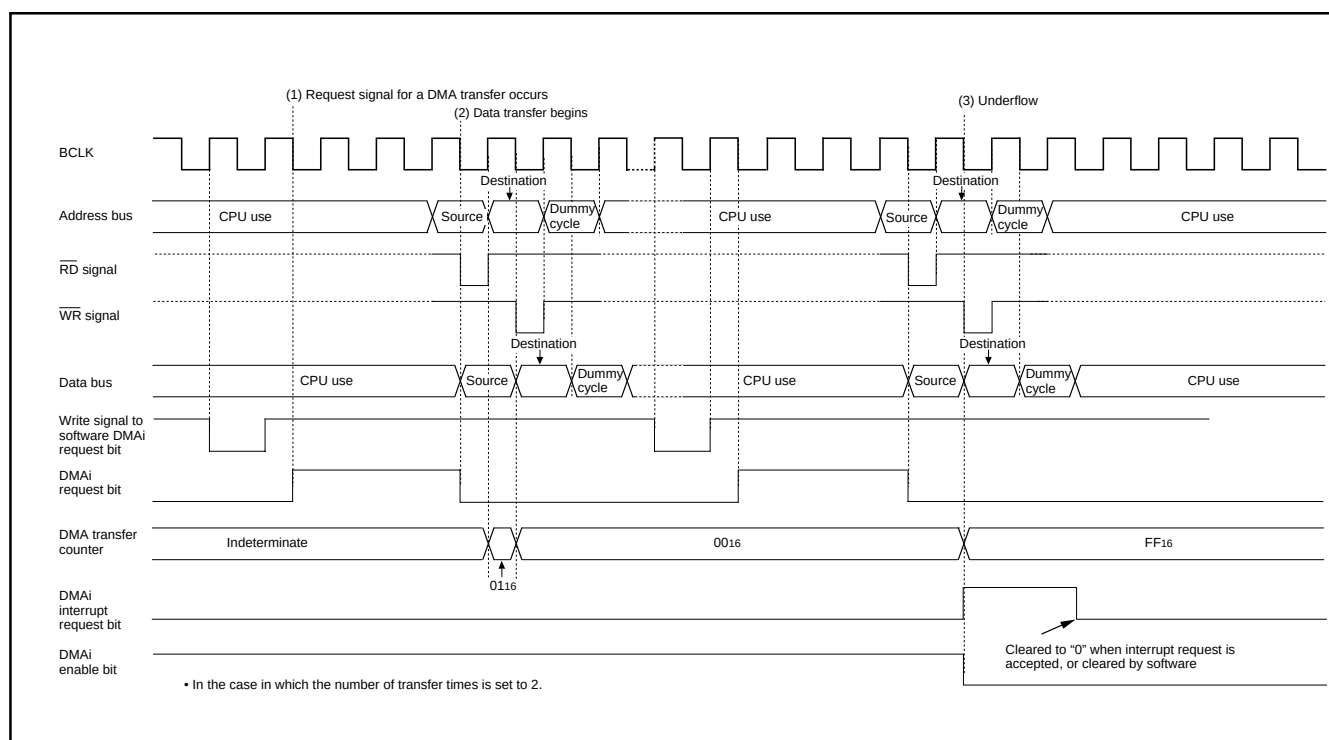


Figure 2.9.4. Example of operation of one-shot transfer mode

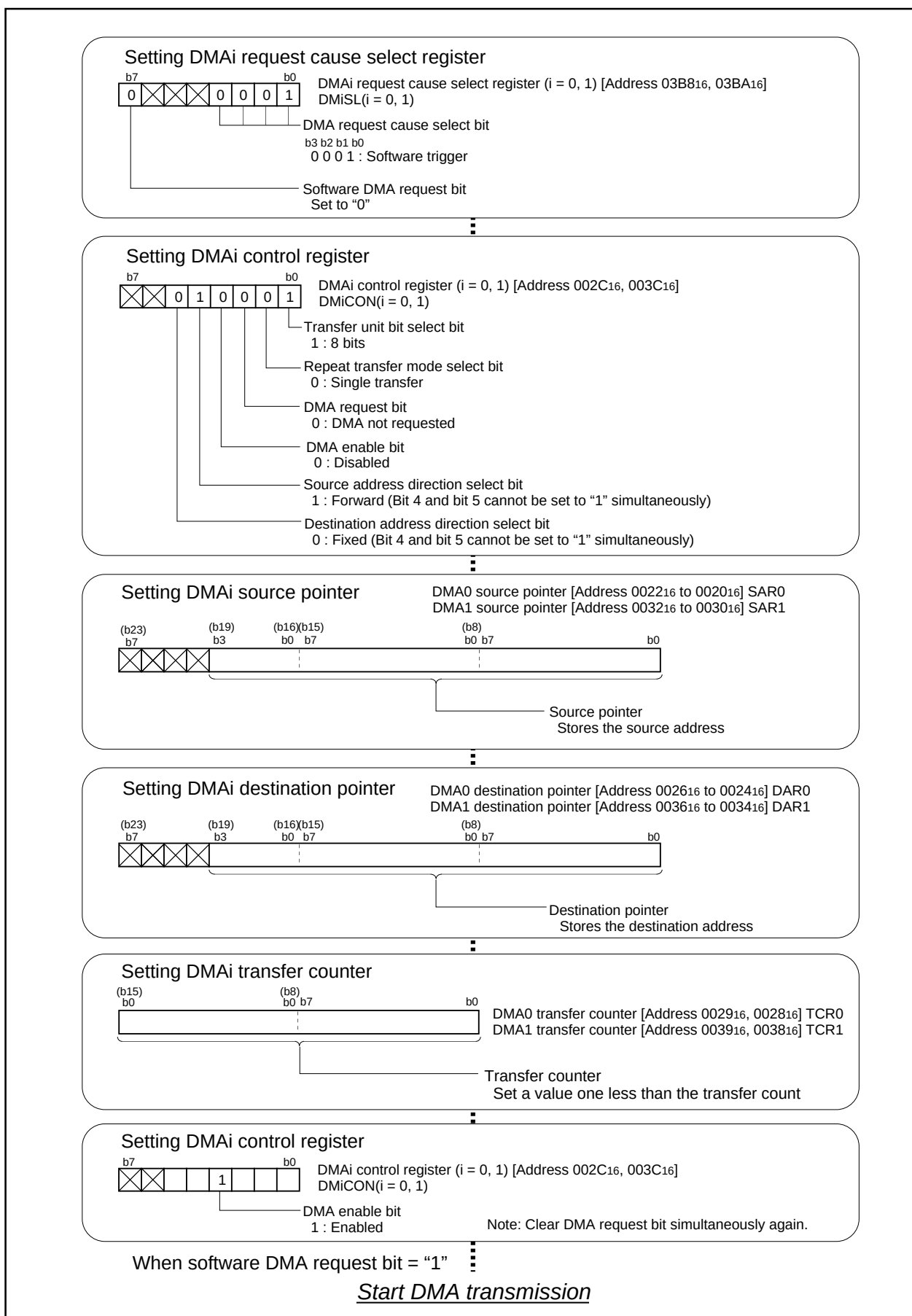


Figure 2.9.5. Set-up procedure of one-shot transfer mode

2.9.3 Operation of DMAC (repeated transfer mode)

In repeat transfer mode, choose functions from the items shown in Table 2.9.2. Operations of the circled items are described below. Figure 2.9.6 shows an example of operation and Figure 2.9.7 shows the set-up procedure.

Table 2.9.2. Chooosed functions

Item	Set-up
Transfer space	Fixed address from an arbitrary 1 M bytes space
	☐ Arbitrary 1 M bytes space from a fixed address
	Fixed address from fixed address
Unit of transfer	8 bits
	☐ 16 bits

- Operation
- (1) When software trigger is selected, setting software DMA request bit to “1” generates a DMA transfer request signal.
 - (2) If DMAC is active, data transfer starts, and the contents of the address indicated by the DMAi forward-direction address pointer are transferred to the address indicated by the DMAi destination pointer. When data transfer starts directly after DMAC becomes active, the value of the DMAi transfer counter reload register is reloaded to the DMAi transfer counter, and the value of the DMAi source pointer is reloaded by the DMAi forward-direction address pointer. Each time a DMA transfer request signal is generated, 2 byte of data is transferred. The DMAi transfer counter is down counted, and the DMAi forward-direction address pointer is up counted.
 - (3) Though DMAi transfer counter is underflowed, DMA enable bit is still “1”. The DMA interrupt request bit changes to “1” simultaneously.
 - (4) After DMAi transfer counter is underflowed, when the next DMA request is generated, DMA transfer is repeated from (1).

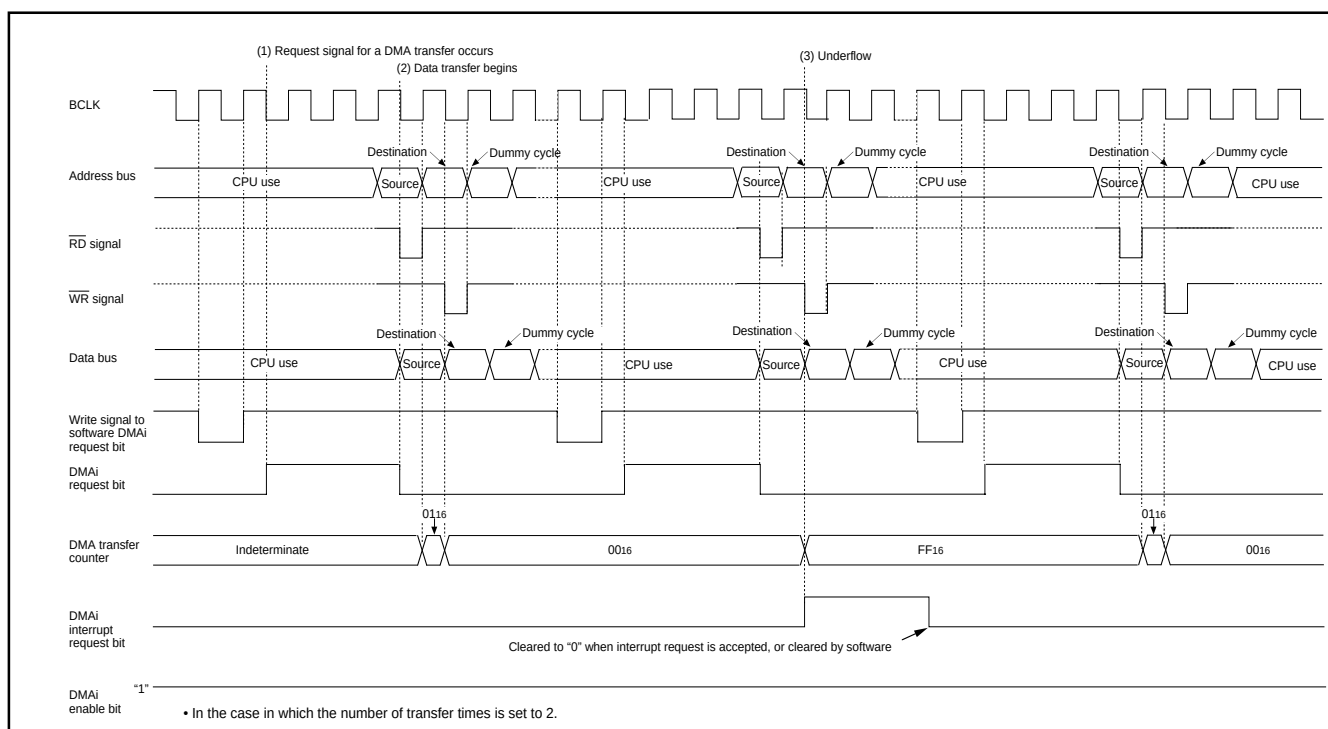


Figure 2.9.6. Example of operation of repeated transfer mode

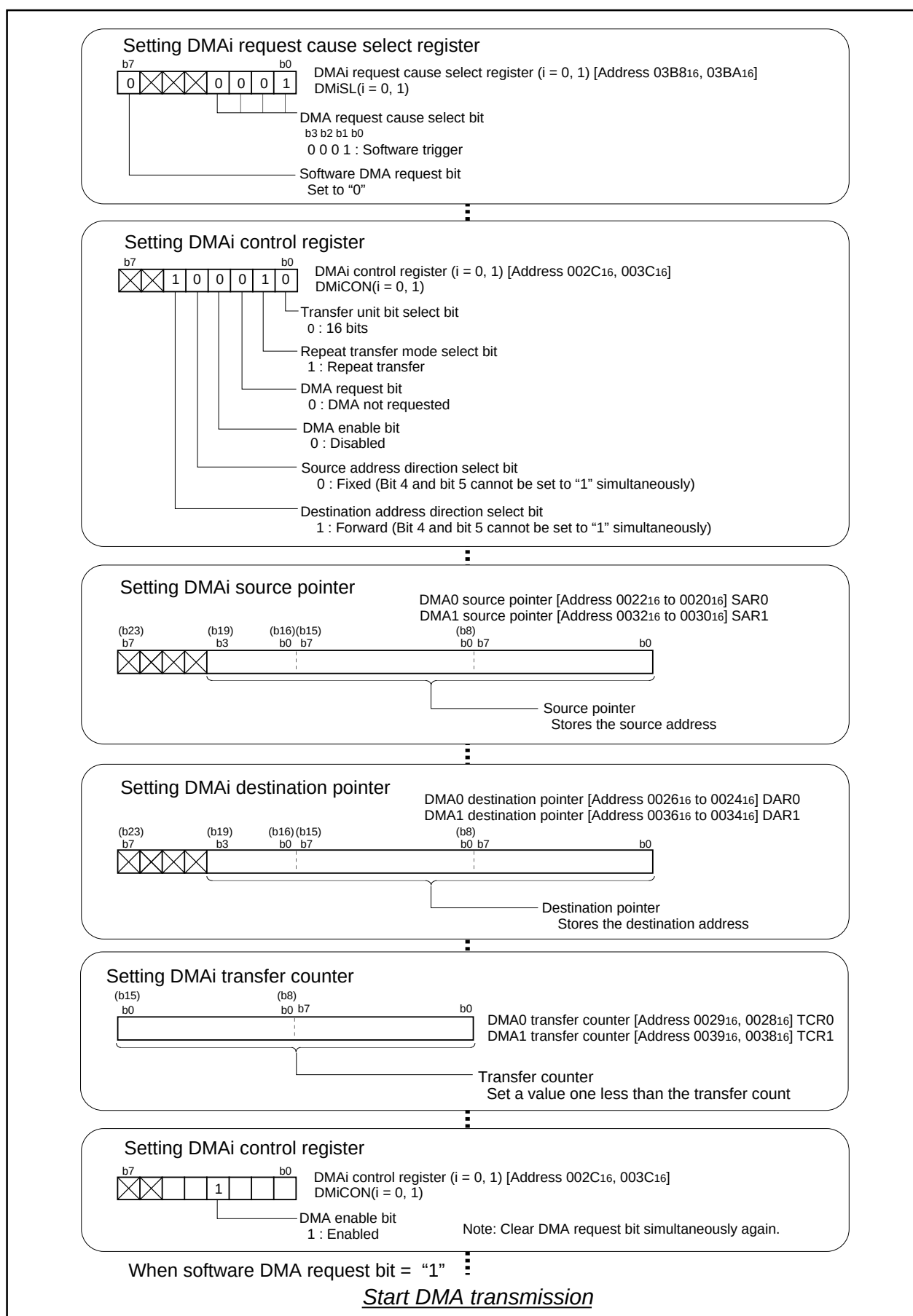


Figure 2.9.7. Set-up procedure of repeated transfer mode

2.10 CRC Calculation Circuit Usage

2.10.1 Overview of the CRC calculation circuit usage

Cyclic Redundancy Check (CRC) is a method that compares CRC code formed from transmission data by use of a polynomial generation with CRC check data so as to detect errors in transmission data. Using the CRC calculation circuit allows generation of CRC code. A polynomial counter is used for the polynomial generation of CRC_CCITT ($X^{16} + X^{12} + X^5 + 1$).

(1) Registers related to CRC calculation circuit

Figure 2.10.1 shows the memory map of CRC-related registers, and Figure 2.10.2 shows CRC-related registers.

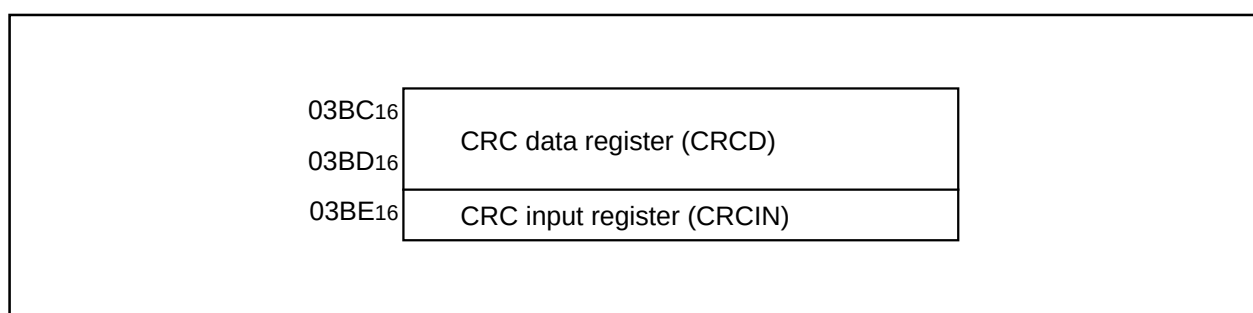


Figure 2.10.1. Memory map of CRC-related registers

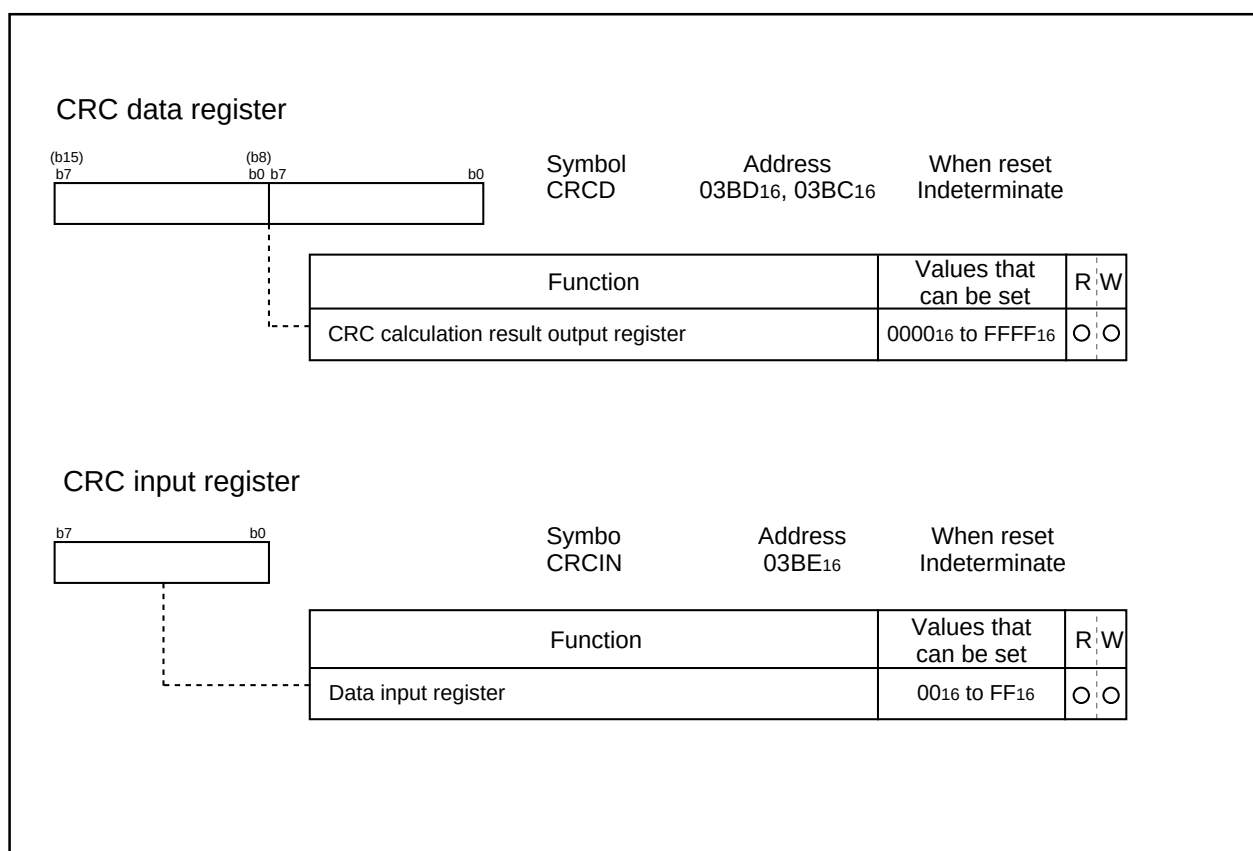


Figure 2.10.2. CRC-related registers

2.10.2 Operation of CRC Calculation Circuit

The following describes the operation of the CRC calculation. Figure 2.10.3 shows an example of calculation data 0123₁₆ using the CRC calculation circuit.

- Operation
- (1) The CRC calculation circuit sets an initial value in the CRC data register.
 - (2) Writing 1 byte data to the CRC input register generates CRC code based on the data register.
CRC code generation for 1 byte data finishes in two machine cycles.
 - (3) The CRC calculation circuit detects an error by means of comparing the CRC-checking data with the content of the CRC data register, after the next data is written to the CRC input register.
 - (4) The content of CRC data register after all data is written becomes CRC code.

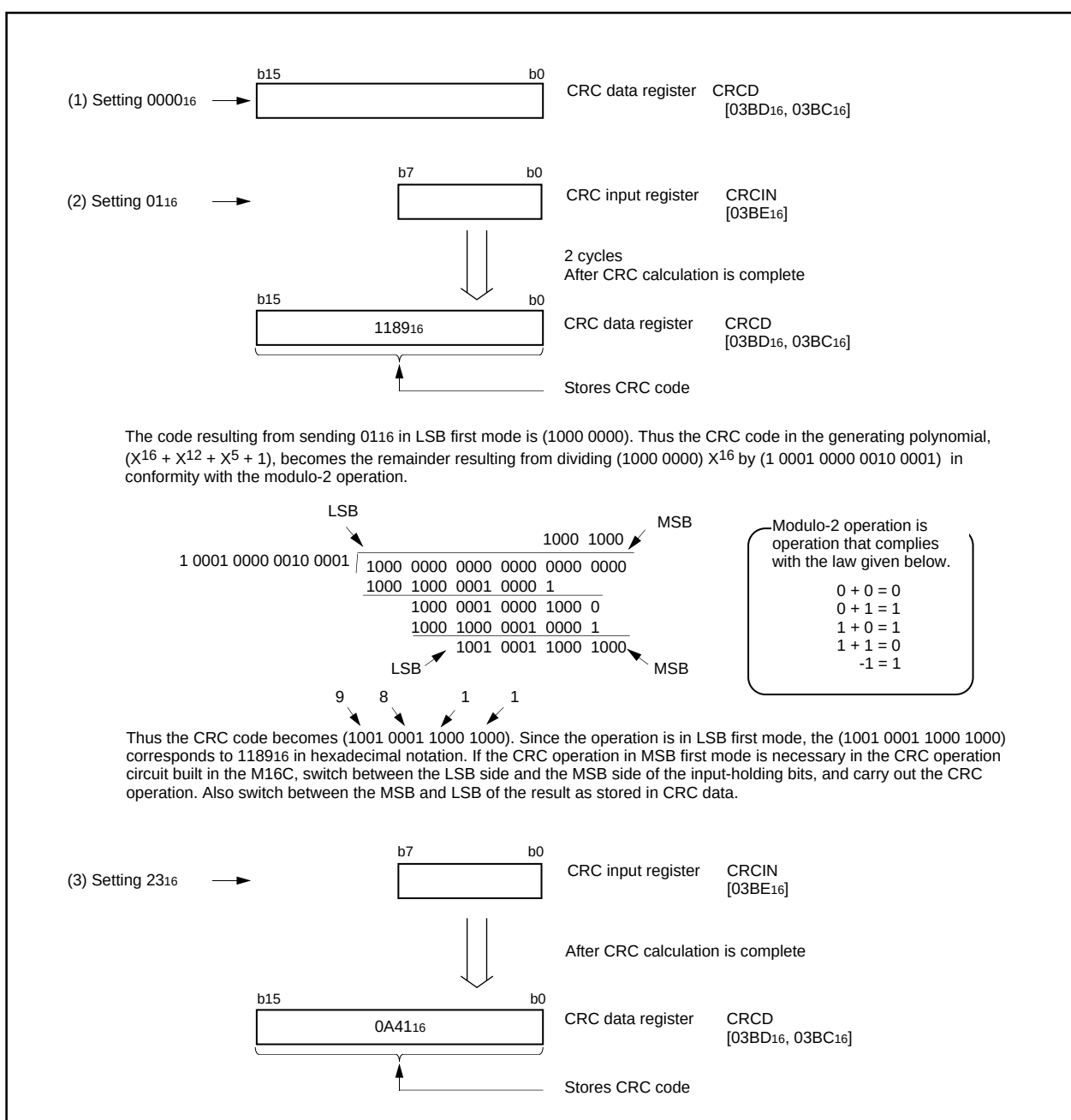


Figure 2.10.3. Calculation example using the CRC calculation circuit

2.11 Watchdog Timer Usage

2.11.1 Overview of the watchdog timer usage

The watchdog timer can detect a runaway program using its 15-bit timer prescaler. The following is an overview of the watchdog timer usage.

(1) Watchdog timer start procedure

When reset, the watchdog timer is in stopped state. Writing to the watchdog timer start register initializes the watchdog timer to 7FFF₁₆ and causes it to start performing a down count. The watchdog timer, once started operating, cannot be stopped by any means other than stopping conditions.

(2) Watchdog timer stop conditions

The watchdog timer stops in any one of the following states:

- (a) Period in which the CPU is in stopped state
- (b) Period in which the CPU is in waiting state
- (c) Period in which the microcomputer is in hold state

(3) Watchdog timer initialization

The watchdog timer is initialized to 7FFF₁₆ in the cases given below, and begins a down count.

- (a) When the watchdog timer writes to the watchdog timer start register while a count is in progress
- (b) When the watchdog timer underflows

(4) Runaway detection

When the watchdog timer underflows, a watchdog timer interrupt occurs. In writing a program, write to the watchdog timer start register before the watchdog timer underflows. The watchdog timer interrupt occurs regardless of the status of the interrupt enable flag (I flag). In processing a watchdog timer interrupt, set the software reset bit to "1" to reset software.

(5) Watchdog timer cycle

The watchdog timer cycle varies depending on the BCLK and the frequency division ratio of the prescaler selected.

Table 2.11.1. The watchdog timer cycle

CM07	CM06	CM17	CM16	BCLK	WDC7	Period
0	0	0	0	16MHz	0	Approx. 32.8ms (Note)
					1	Approx. 262.1ms (Note)
0	0	0	1	8MHz	0	Approx. 65.5ms (Note)
					1	Approx. 524.3ms (Note)
0	0	1	0	4MHz	0	Approx. 131.1ms (Note)
					1	Approx. 1.049s (Note)
0	0	1	1	1MHz	0	Approx. 524.3ms (Note)
					1	Approx. 4.194s (Note)
0	1	Invalid	Invalid	2MHz	0	Approx. 262.1ms (Note)
					1	Approx. 2.097s (Note)
1	Invalid	Invalid	Invalid	32kHz	Invalid	Approx. 2s (Note)

Note: An error due to the prescaler occurs.

(6) Registers related to the watchdog timer

Figure 2.11.1 shows the memory map of watchdog timer-related registers, and Figure 2.11.2 shows watchdog timer-related registers.

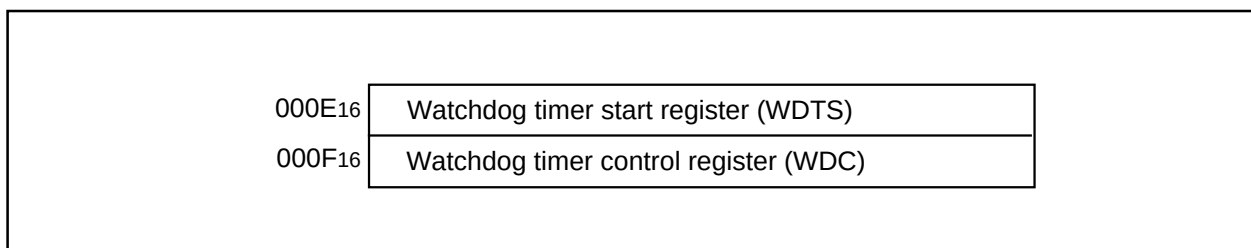


Figure 2.11.1. Memory map of watchdog timer-related registers

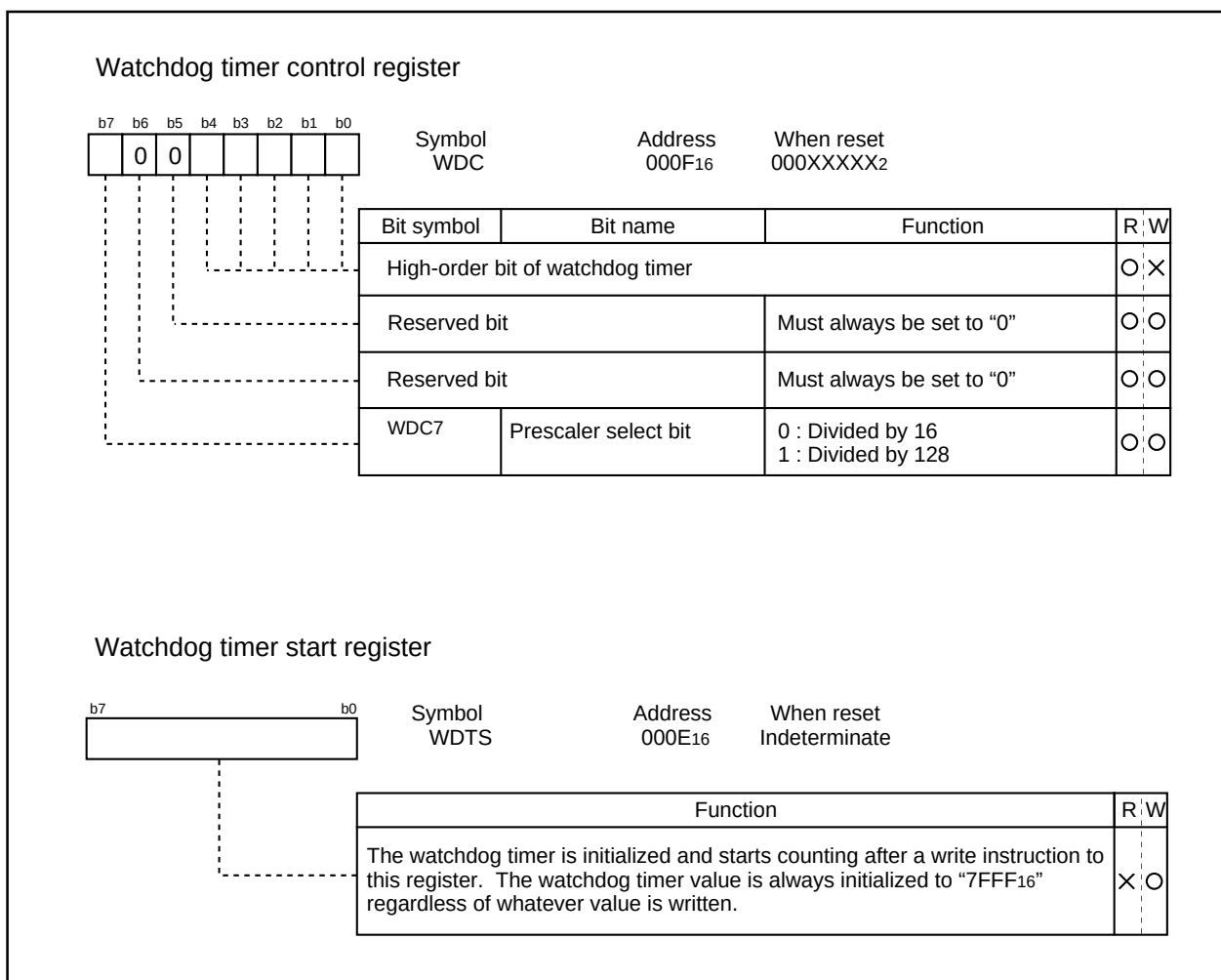


Figure 2.11.2. Watchdog timer-related registers

2.11.2 Operation of Watchdog Timer

The following is an operation of the watchdog timer. Figure 2.11.3 shows the operation timing, and Figure 2.11.4 shows the set-up procedure.

- Operation
- (1) Writing to the watchdog timer start register initializes the watchdog timer to $7FFF_{16}$ and causes it to start a down count.
 - (2) With a count in progress, writing to the watchdog timer start register again initializes the watchdog timer to $7FFF_{16}$ and causes it to resume counting.
 - (3) Either executing the WAIT instruction or going to the stopped state causes the watchdog timer to hold the count in progress and to stop counting. The watchdog timer resumes counting after returning from the execution of the WAIT instruction or from the stopped state.
 - (4) If the watchdog timer underflows, it is initialized to $7FFF_{16}$ and continues counting. At this time, a watchdog timer interrupt occurs.

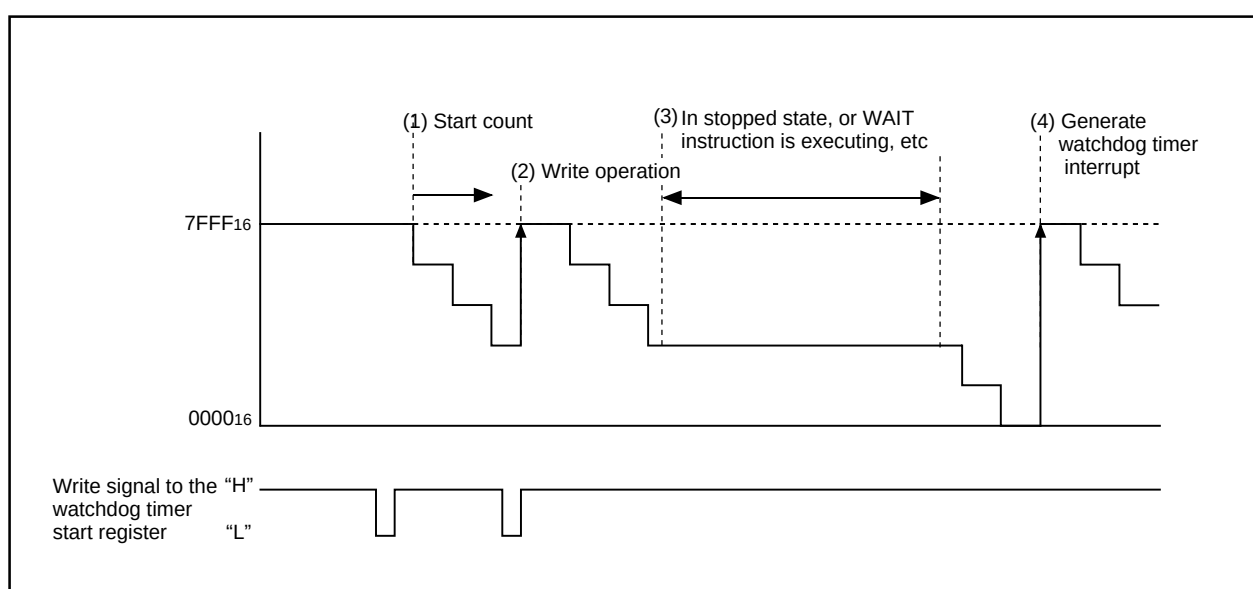


Figure 2.11.3. Operation timing of watchdog timer

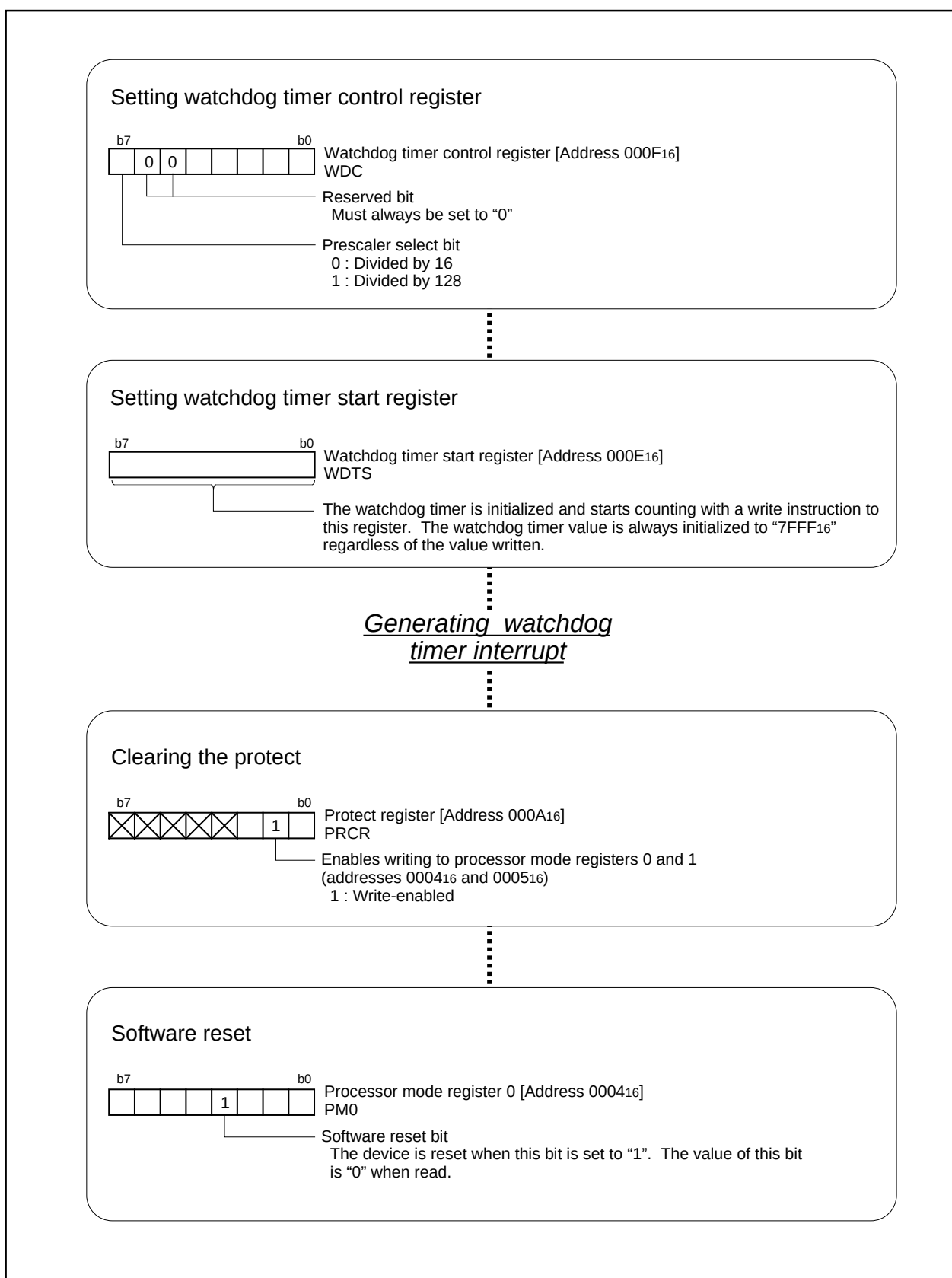


Figure 2.11.4. Set-up procedure of watchdog timer

2.12 Address Match Interrupt Usage

2.12.1 Overview of the address match interrupt usage

The address match interrupt is used for correcting a ROM or for a simplified debugging-purpose monitor. The following is an overview of the address match interrupt usage.

(1) Enabling/disabling the address match interrupt

The address match interrupt enable bit can be used to enable and disable an address match interrupt. It is affected neither by the processor interrupt priority level (IPL) nor the interrupt enable flag (I flag).

(2) Timing of the address match interrupt

An interrupt occurs immediately before executing the instruction in the address indicated by the address match interrupt register. Set the first address of the instruction in the address match interrupt register. Setting a half address of an instruction or an address of tabulated data does not generate an address match interrupt.

The first instruction of an interrupt routine does not generate an address match interrupt either.

(3) Returning from an address match interrupt

The address put in the stack when an address match interrupt occurs depends on the instruction not yet executed (the instruction the address match interrupt register indicates). The return address is not put in the stack. For this reason, to return from an address match interrupt, either rewrite the content of the stack and use the REIT instruction or use the POP instruction to restore the stack to the state as it was before the interrupt occurred and return by use of a jump instruction.

Figure 2.12.1 shows unexecuted instructions and corresponding the stacked addresses.

<Instructions whose address is added to by 2 when an address match interrupt occurs>

- 16-bit operation code instructions
- 8-bit operation code instructions given below

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.B:S	#IMM8,dest
STNZ.B:S	#IMM8,dest	STZX.B:S	#IMM81,#IMM82,dest		
CMP.B:S	#IMM8,dest	PUSHM	src	POPM	dest
JMPS	#IMM8	JSRS	#IMM8		
MOV.B:S	#IMM,dest	(However, dest = A0/A1)			

<Instructions whose address is added to by 1 when an address match interrupt occurs>

- Instructions other than those listed above

Figure 2.12.1. Unexecuted instructions and corresponding stacked addresses

(4) How to determine an address match interrupt

Address match interrupts can be set at two different locations. However, both location will have the same vector address. Therefore, it is necessary to determine which interrupt has occurred; address match interrupt 0 or address match interrupt 1. Using the content of the stack, etc., determine which interrupt has occurred according to the first part of the address match interrupt routine.

(5) Registers related to the address match interrupt

Figure 2.12.2 shows the memory map of address match interrupt-related registers, and Figure 2.12.3 shows address match interrupt-related registers.

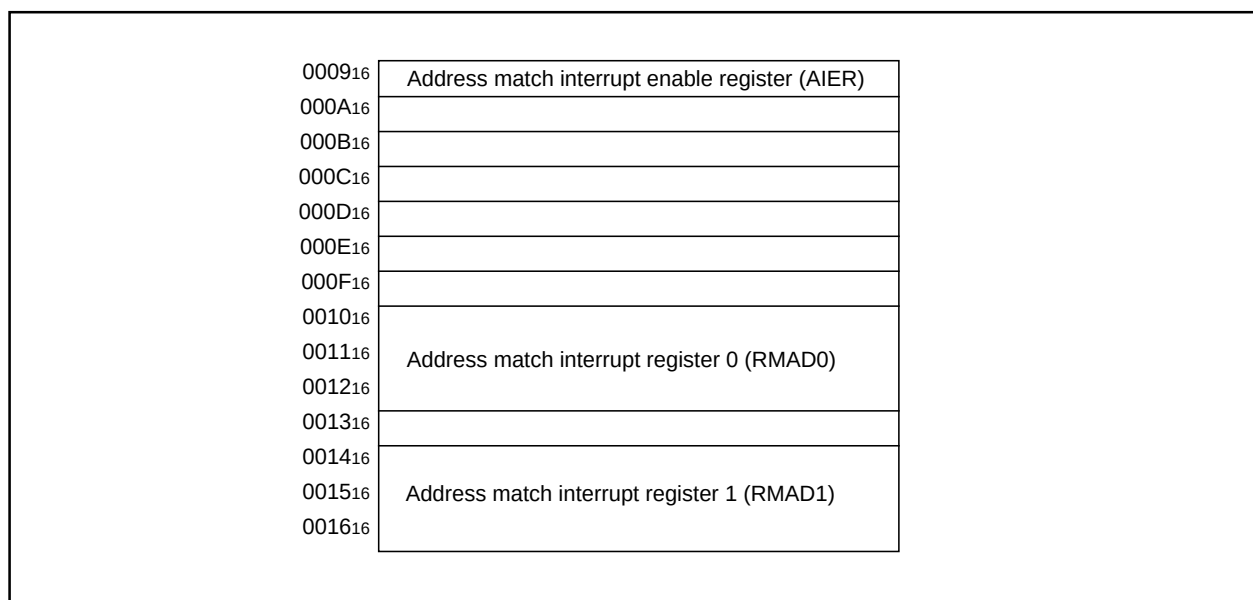


Figure 2.12.2. Memory map of address match interrupt-related registers

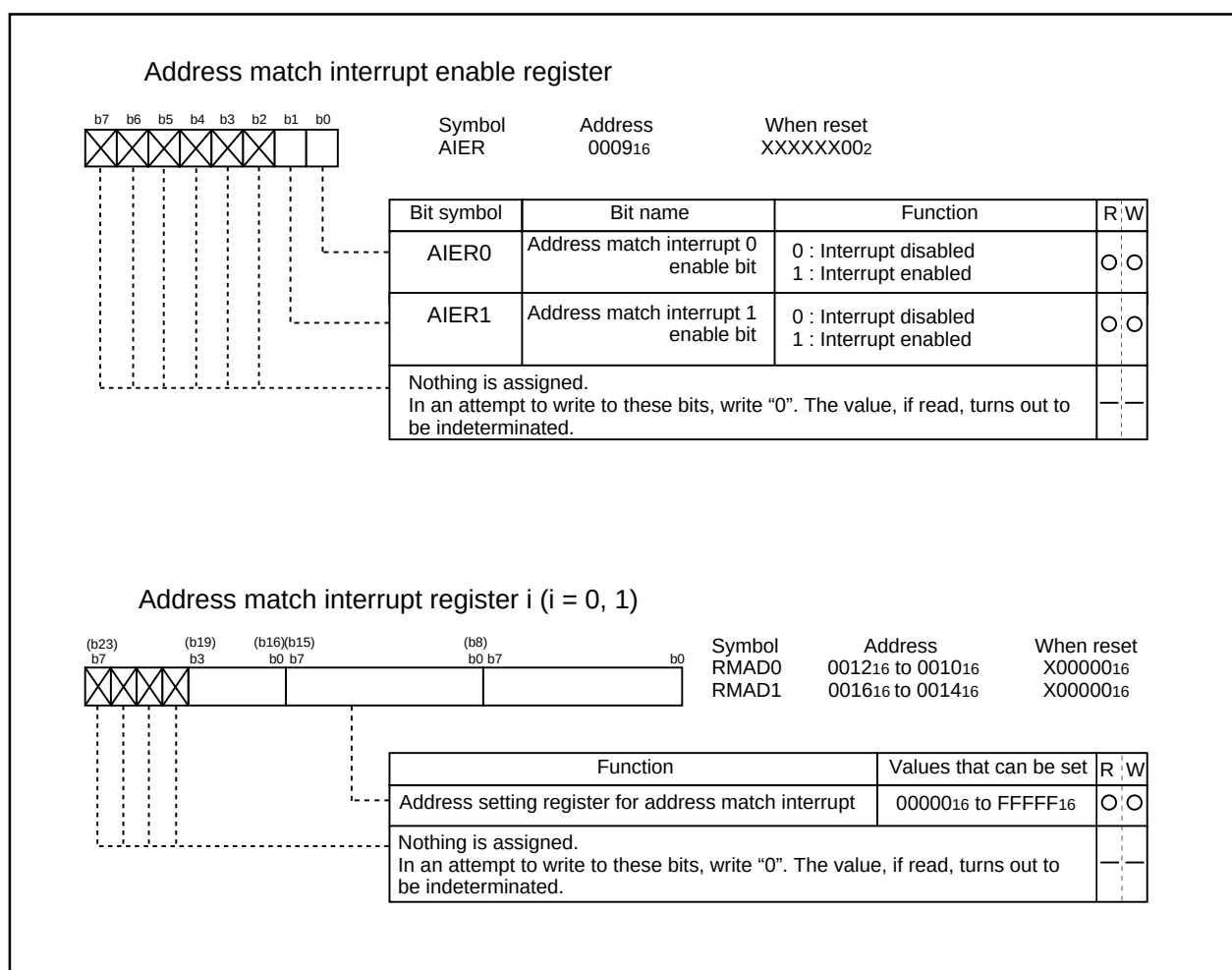


Figure 2.12.3. Address match interrupt-related registers

2.12.2 Operation of Address Match Interrupt

The following is an operation of address match interrupt. Figure 2.12.4 shows the set-up procedure of address match interrupt, and Figure 2.12.5 shows the overview of the address match interrupt handling routine.

- Operation
- (1) The address match interrupt handling routine sets an address to be used to cause the address match interrupt register to generate an interrupt.
 - (2) Setting the address match enable flag to "1" enables an interrupt to occur.
 - (3) An address match interrupt occurs immediately before the instruction in the address indicated by the address match interrupt register as a program is executed.

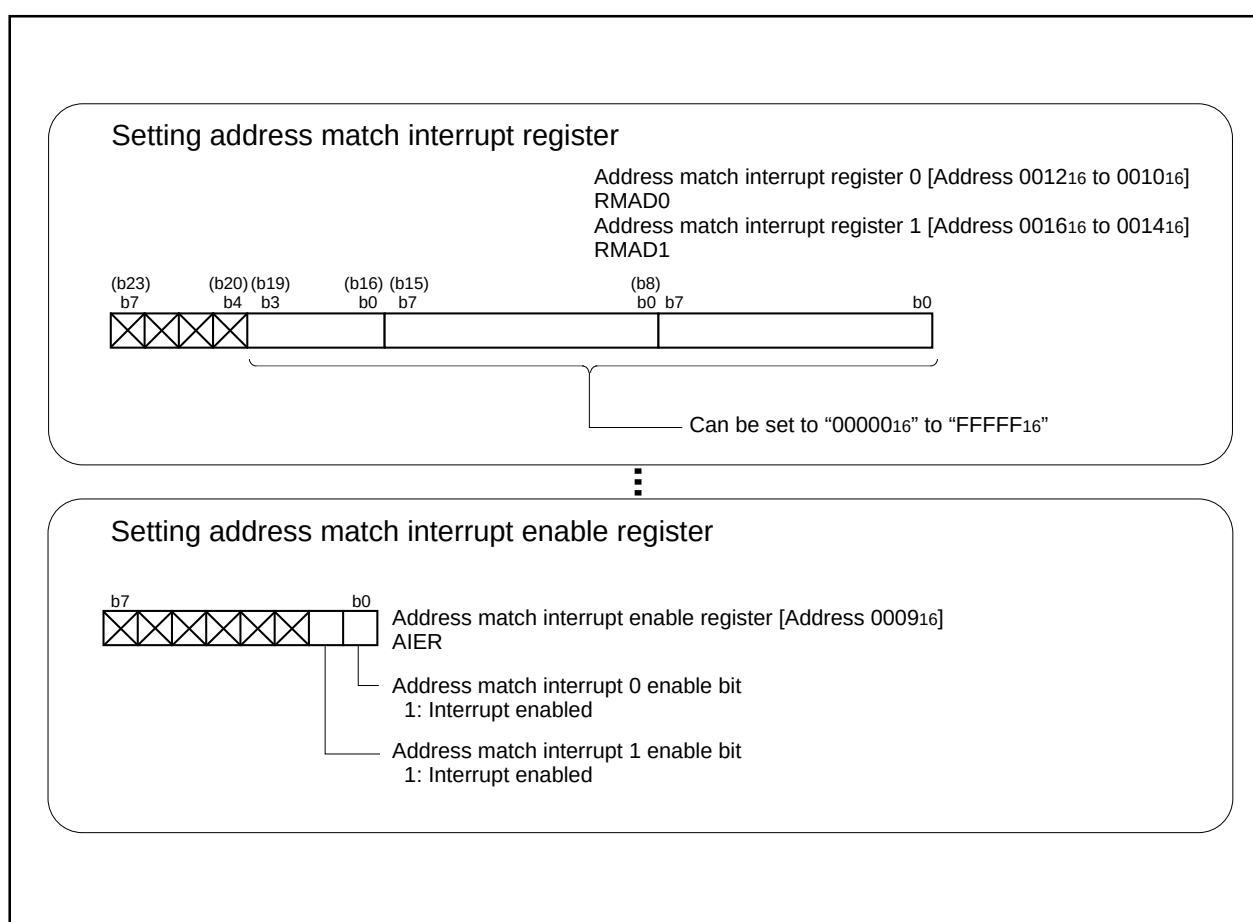


Figure 2.12.4. Set-up procedure of address match interrupt

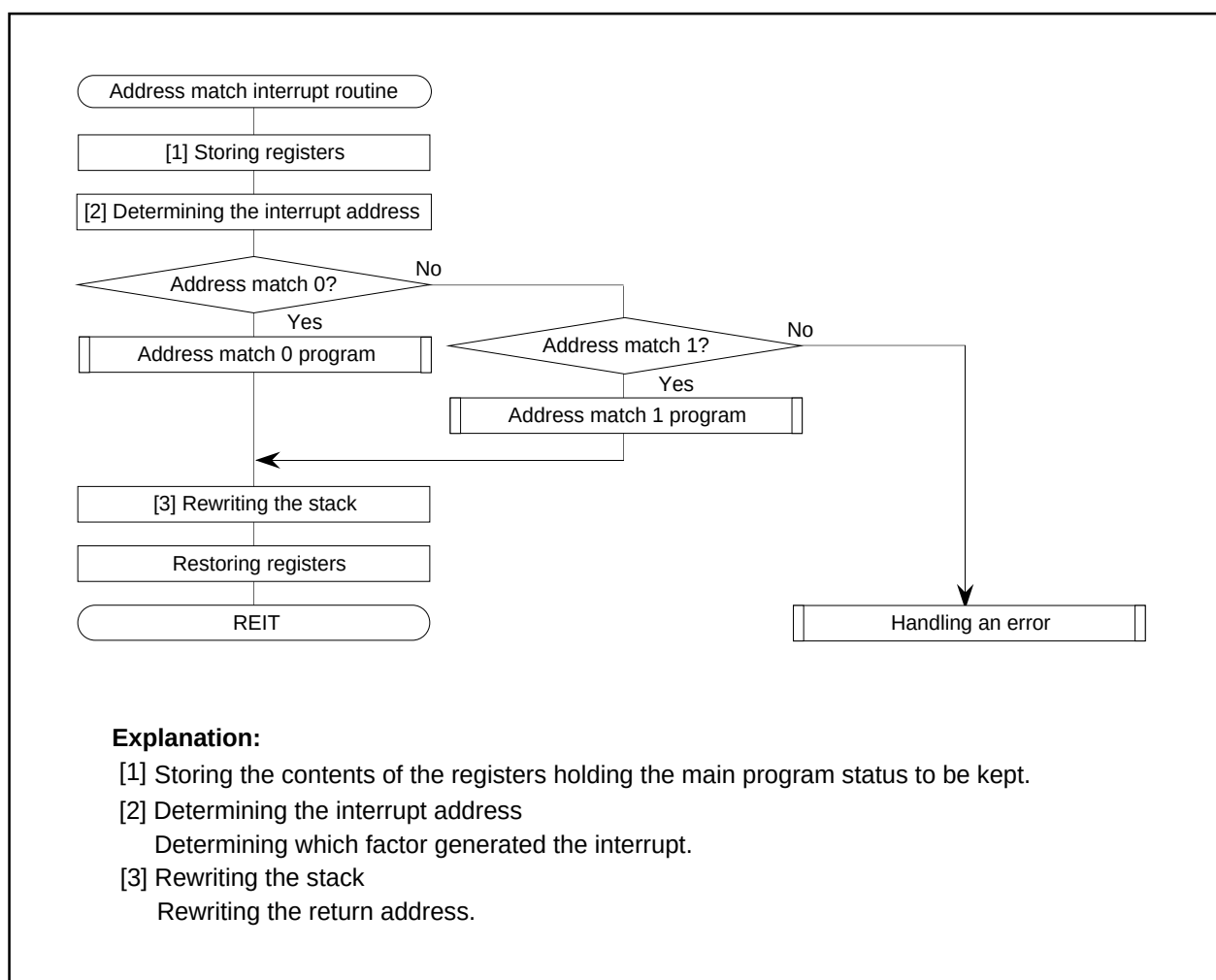


Figure 2.12.5. Overview of the address match interrupt handling routine

2.13 Key-Input Interrupt Usage

2.13.1 Overview of the key-input interrupt usage

Key-input interrupt occurs when a falling edge is input to P104 through P107. The following is an overview of the key-input interrupt usage:

(1) Enabling/disabling the key-input interrupt

The key-input interrupt can be enabled and disabled using the key-input interrupt register. The key-input interrupt is affected by the interrupt priority level (IPL) and the interrupt enable flag (I flag).

(2) Occurrence timing of the key-input interrupt

With key-input interrupt acceptance enabled, pins P104 through P107, which are set to input, become key-input interrupt pins ($\overline{KI0}$ through $\overline{KI3}$). A key-input interrupt occurs when a falling edge is input to a key-input interrupt pin. At this moment, the level of other key-input interrupt pins must be "H". No interrupt occurs when the level of other key-input interrupt pins is "L".

(3) How to determine a key-input interrupt

A key-input interrupt occurs when a falling edge is input to one of four pins, but each pin has the same vector address.

Therefore, read the input level of pins P104 through P107 in the key-input interrupt routine to determine the interrupted pin.

(4) Registers related to the key-input interrupt

Figure 2.13.1 shows the memory map of key-input interrupt-related registers, and Figure 2.13.2 shows key-input interrupt-related registers.

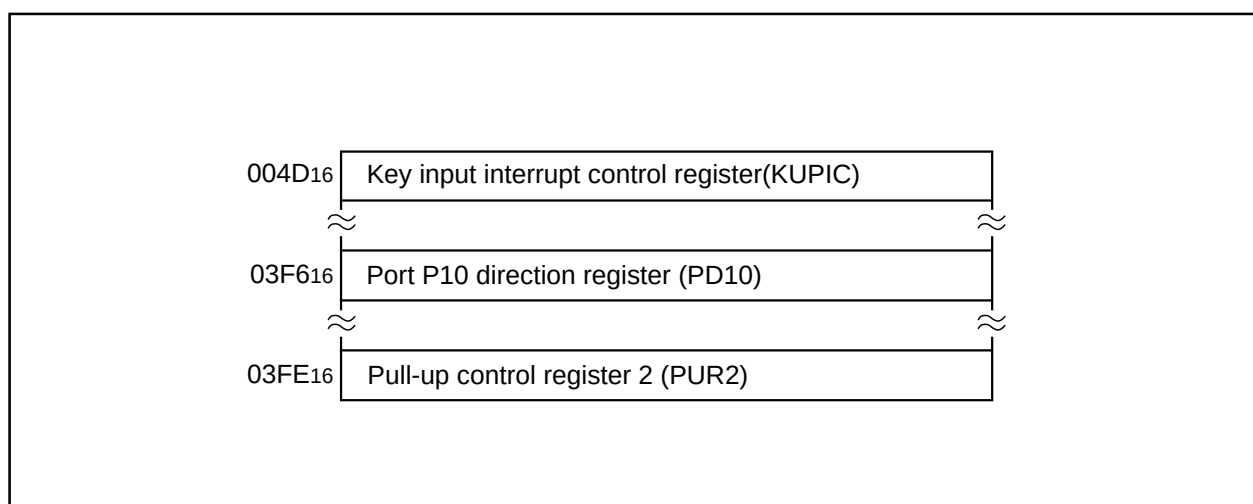


Figure 2.13.1. Memory map of key-input interrupt-related registers

Interrupt control register (Note 2)

b7b6b5b4b3b2b1b0	Symbol KUPIC	Address 004D ₁₆	When reset XXXX0000 ₂		
	Bit symbol	Bit name	Function	R	W
	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	☐	☐
	ILVL1			☐	☐
	ILVL2			☐	☐
	IR	Interrupt request bit	0 : Interrupt not requested 1 : Interrupt requested	☐	☐ (Note1)
	Nothing is assigned. These bits can neither be set nor reset. When read, their contents are indeterminate.			—	—

Note 1: This bit can only be accessed for reset (= 0), but cannot be accessed for set (= 1).

Note 2: To rewrite the interrupt control register, do so at a point that does not generate the interrupt request for that register. For details, see the precautions for interrupts.

Port P10 direction register

b7	b6	b5	b4	b3	b2	b1	b0	Symbol PD10	Address 03F6 ₁₆	When reset 00 ₁₆
Bit symbol		Bit symbol		Bit symbol		R		W		
PD10_0		Port P10 ₀ direction register		0 : Input mode (Functions as an input port) 1 : Output mode (Functions as an output port)		○		○		
PD10_1		Port P10 ₁ direction register				○		○		
PD10_2		Port P10 ₂ direction register				○		○		
PD10_3		Port P10 ₃ direction register				○		○		
PD10_4		Port P10 ₄ direction register				○		○		
PD10_5		Port P10 ₅ direction register				○		○		
PD10_6		Port P10 ₆ direction register				○		○		
PD10_7		Port P10 ₇ direction register				○		○		

Pull-up control register 2

b7	b6	b5	b4	b3	b2	b1	b0	Symbol PUR2	Address 03FE ₁₆	When reset 00 ₁₆		
								Bit symbol	Bit name	Function	R	W
								PU20	P80 to P83 pull-up	The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high	○	○
								PU21	P84 to P87 pull-up (Except P85)		○	○
								PU22	P90 to P93 pull-up		○	○
								PU23	P94 to P97 pull-up		○	○
								PU24	P100 to P103 pull-up		○	○
								PU25	P104 to P107 pull-up		○	○
								Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".			—	—
											—	—

Figure 2.13.2. key-input interrupt-related registers

2.13.2 Operation of Key-Input Interrupt

The following is an operation of key-input interrupt. Figure 2.13.3 shows an example of a circuit that uses the key-input interrupt, Figure 2.13.4 shows an example of operation of key-input interrupt, and Figure 2.13.5 shows the setting procedure of key-input interrupt.

- Operation
- (1) Set the direction register of the ports to be changed to key-input interrupt pins to input, and set the pull-up function.
 - (2) Setting the key-input interrupt control register and setting the interrupt enable flag makes the interrupt-enabled state ready.
 - (3) If a falling edge is input to either $\overline{KI0}$ through $\overline{KI3}$, the key-input interrupt request bit goes to "1".

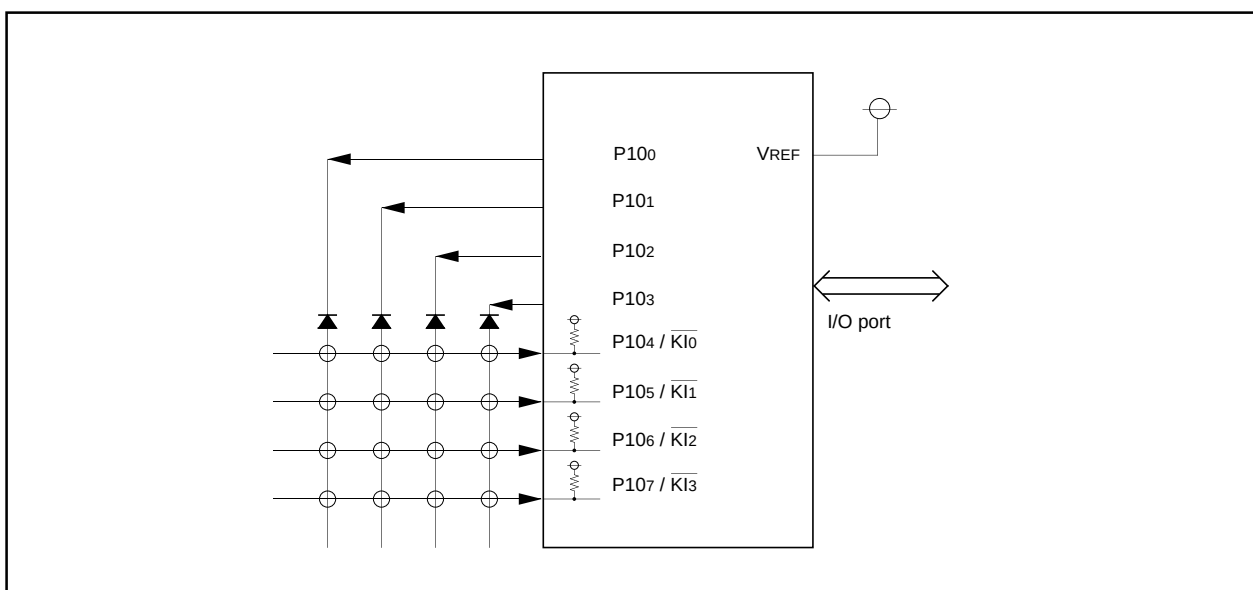


Figure 2.13.3. Example of circuit using the key-input interrupt

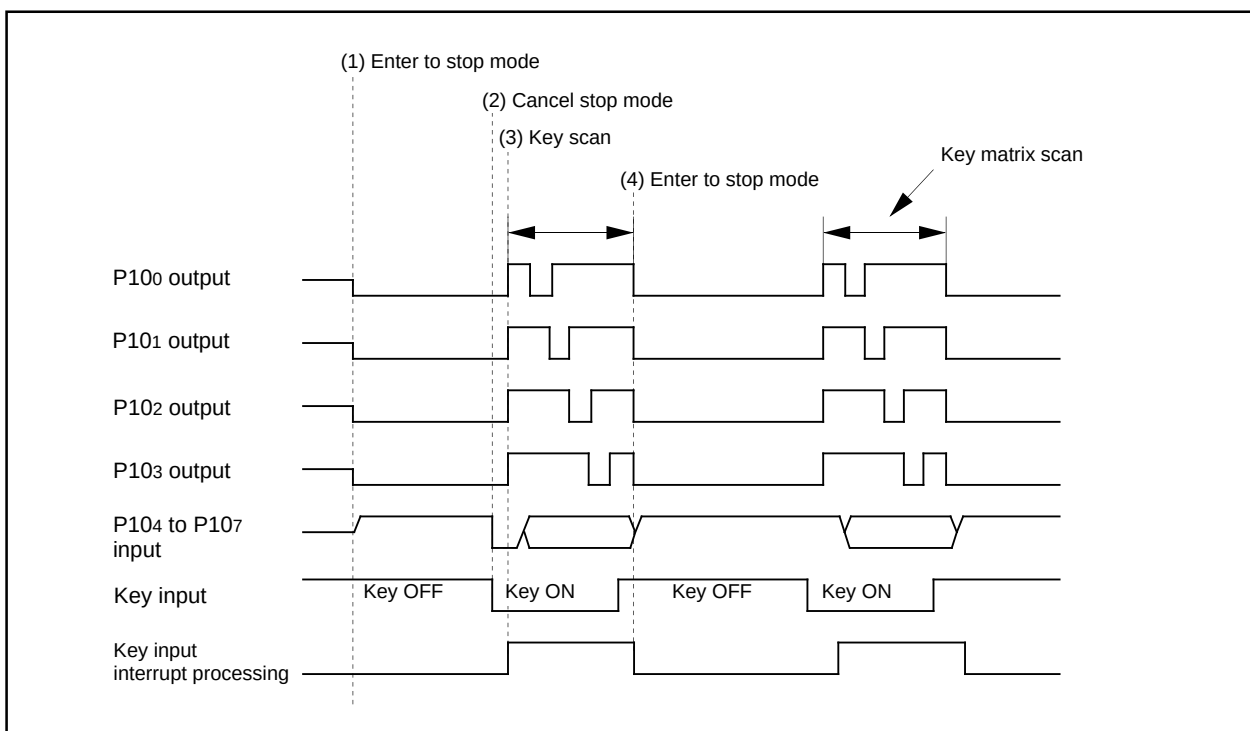


Figure 2.13.4. Example of operation of key-input interrupt

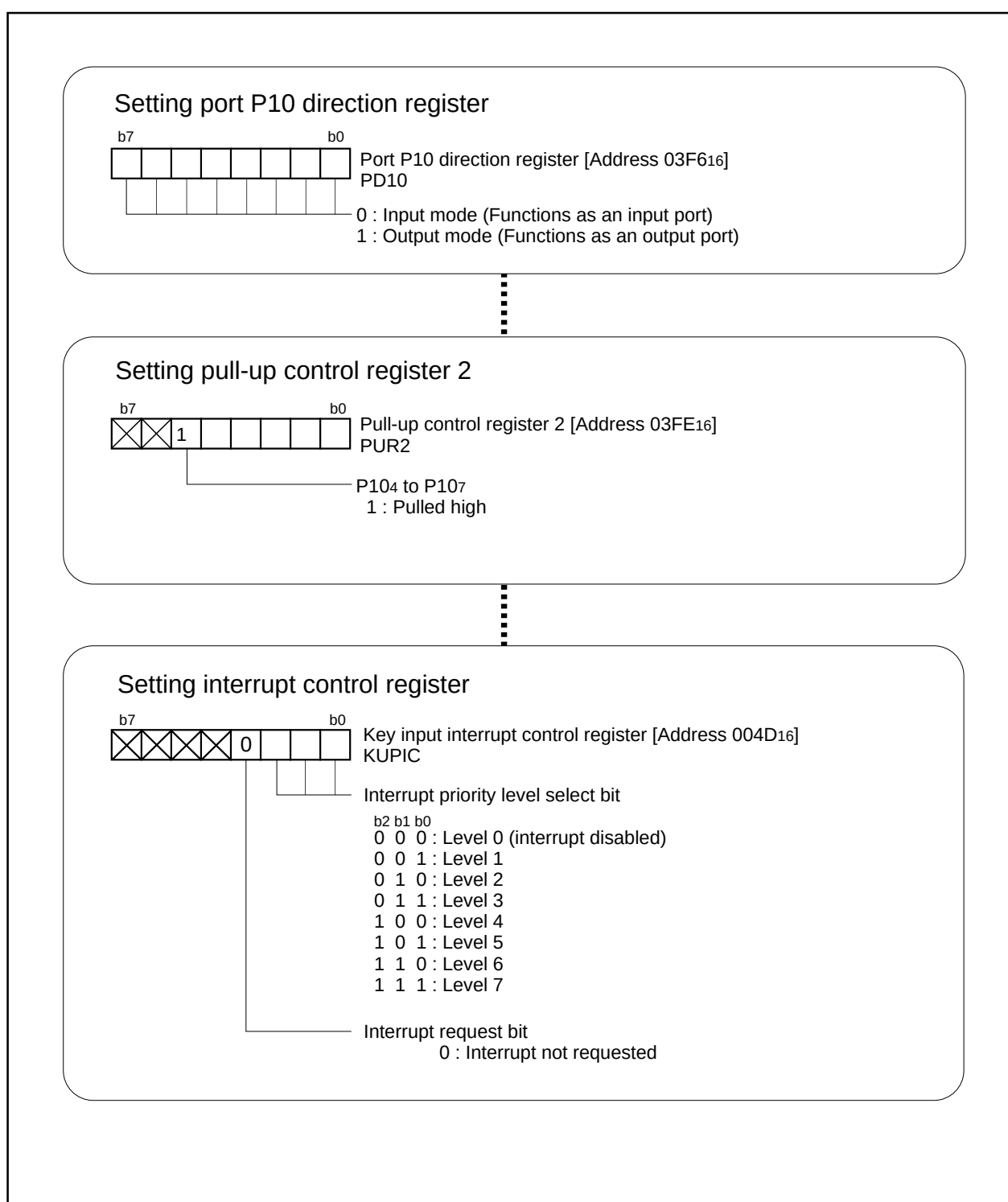


Figure 2.13.5. Set-up procedure of key-input interrupt

2.14 Multiple interrupts Usage

2.14.1 Overview of the Multiple interrupts usage

The following is an overview of the multiple interrupts usage.

(1) Interrupt control

Descriptions are given here regarding how to enable or disable maskable interrupts and how to set the priority to be accepted. What is described here does not apply to non-maskable interrupts.

Enable or disable a non-maskable interrupt using the interrupt enable flag (I flag), interrupt priority level selection bit, or processor interrupt priority level (IPL). Whether an interrupt request is present or absent is indicated by the interrupt request bit. The interrupt request bit and the interrupt priority level select bit are located in the interrupt control register of each interrupt. Also, the interrupt enable flag (I flag) and the IPL are located in the flag register (FLG).

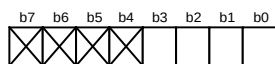
Figure 2.14.1 shows the memory map of the interrupt control registers, and Figure 2.14.2 shows the interrupt control registers.

0044 ₁₆	INT3 interrupt control register (INT3IC)
0045 ₁₆	Timer B5 interrupt control register (TB5IC)
0046 ₁₆	Timer B4 interrupt control register (TB4IC)
0047 ₁₆	Timer B3 interrupt control register (TB3IC)
0048 ₁₆	SI/O4 interrupt control register (S4IC) INT5 interrupt control register (INT5IC)
0049 ₁₆	SI/O3 interrupt control register (S4IC) INT4 interrupt control register (INT4IC)
004A ₁₆	Bus collision detection interrupt control register (BCNIC)
004B ₁₆	DMA0 interrupt control register (DM0IC)
004C ₁₆	DMA1 interrupt control register (DM1IC)
004D ₁₆	Key input interrupt control register (KUPIC)
004E ₁₆	A-D conversion interrupt control register (ADIC)
004F ₁₆	UART2 transmit interrupt control register (S2TIC)
0050 ₁₆	UART2 receive interrupt control register (S2RIC)
0051 ₁₆	UART0 transmit interrupt control register (S0TIC)
0052 ₁₆	UART0 receive interrupt control register (S0RIC)
0053 ₁₆	UART1 transmit interrupt control register (S1TIC)
0054 ₁₆	UART1 receive interrupt control register (S1RIC)
0055 ₁₆	Timer A0 interrupt control register (TA0IC)
0056 ₁₆	Timer A1 interrupt control register (TA1IC)
0057 ₁₆	Timer A2 interrupt control register (TA2IC)
0058 ₁₆	Timer A3 interrupt control register (TA3IC)
0059 ₁₆	Timer A4 interrupt control register (TA4IC)
005A ₁₆	Timer B0 interrupt control register (TB0IC)
005B ₁₆	Timer B1 interrupt control register (TB1IC)
005C ₁₆	Timer B2 interrupt control register (TB2IC)
005D ₁₆	INT0 interrupt control register (INT0IC)
005E ₁₆	INT1 interrupt control register (INT1IC)
005F ₁₆	INT2 interrupt control register (INT2IC)

Figure 2.14.1. Memory map of the interrupt control registers

Interrupt control register (Note 2)

Symbol	Address	When reset
TBiIC(i=3 to 5)	0045 ₁₆ to 0047 ₁₆	XXXXX0002
BCNiC	004A ₁₆	XXXXX0002
DMiIC(i=0, 1)	004B ₁₆ , 004C ₁₆	XXXXX0002
KUPiC	004D ₁₆	XXXXX0002
ADiC	004E ₁₆	XXXXX0002
SiTiC(i=0 to 2)	0051 ₁₆ , 0053 ₁₆ , 004F ₁₆	XXXXX0002
SiRiC(i=0 to 2)	0052 ₁₆ , 0054 ₁₆ , 0050 ₁₆	XXXXX0002
TAiIC(i=0 to 4)	0055 ₁₆ to 0059 ₁₆	XXXXX0002
TBiIC(i=0 to 2)	005A ₁₆ to 005C ₁₆	XXXXX0002

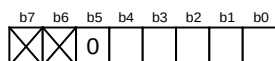


Bit symbol	Bit name	Function	R	W
ILVL0	Interrupt priority level select bit	b2 b1 b0 0 0 0 : Level 0 (interrupt disabled) 0 0 1 : Level 1 0 1 0 : Level 2 0 1 1 : Level 3 1 0 0 : Level 4 1 0 1 : Level 5 1 1 0 : Level 6 1 1 1 : Level 7	○	○
ILVL1			○	○
ILVL2			○	○
IR	Interrupt request bit	0 : Interrupt not requested 1 : Interrupt requested	○	○ (Note 1)
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be indeterminate.			—	—

Note 1: This bit can only be accessed for reset (= 0), but cannot be accessed for set (= 1).

Note 2: To rewrite the interrupt control register, do so at a point that does not generate the interrupt request for that register. For details, see the precautions for interrupts.

Symbol	Address	When reset
INTiIC(i=3)	0044 ₁₆	XX00X0002
SiIC/INTjIC (i=4, 3)	0048 ₁₆ , 0049 ₁₆	XX00X0002
(j=5, 4)	0048 ₁₆ , 0049 ₁₆	XX00X0002
INTiIC(i=0 to 2)	005D ₁₆ to 005F ₁₆	XX00X0002



Bit symbol	Bit name	Function	R	W
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	○	○
ILVL1			○	○
ILVL2			○	○
IR	Interrupt request bit	0 : Interrupt not requested 1 : Interrupt requested	○	○ (Note 1)
POL	Polarity select bit	0 : Selects falling edge 1 : Selects rising edge	○	○
Reserved bit		Must always be set to "0"	○	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be indeterminate.			—	—

Note 1: This bit can only be accessed for reset (= 0), but cannot be accessed for set (= 1).

Note 2: To rewrite the interrupt control register, do so at a point that does not generate the interrupt request for that register. For details, see the precautions for interrupts.

Figure 2.14.2. Interrupt control registers

(2) Interrupt Enable Flag (I flag)

The interrupt enable flag (I flag) controls the enabling and disabling of maskable interrupts. Setting this flag to "1" enables all maskable interrupts; setting it to "0" disables all maskable interrupts. This flag is set to "0" after reset.

The content is changed when the I flag is changed causes the acceptance of the interrupt request in the following timing:

- When changing the I flag using the REIT instruction, the acceptance of the interrupt takes effect as the REIT instruction is executed.
- When changing the I flag using one of the FCLR, FSET, POPC, and LDC instructions, the acceptance of the interrupt is effective as the next instruction is executed.

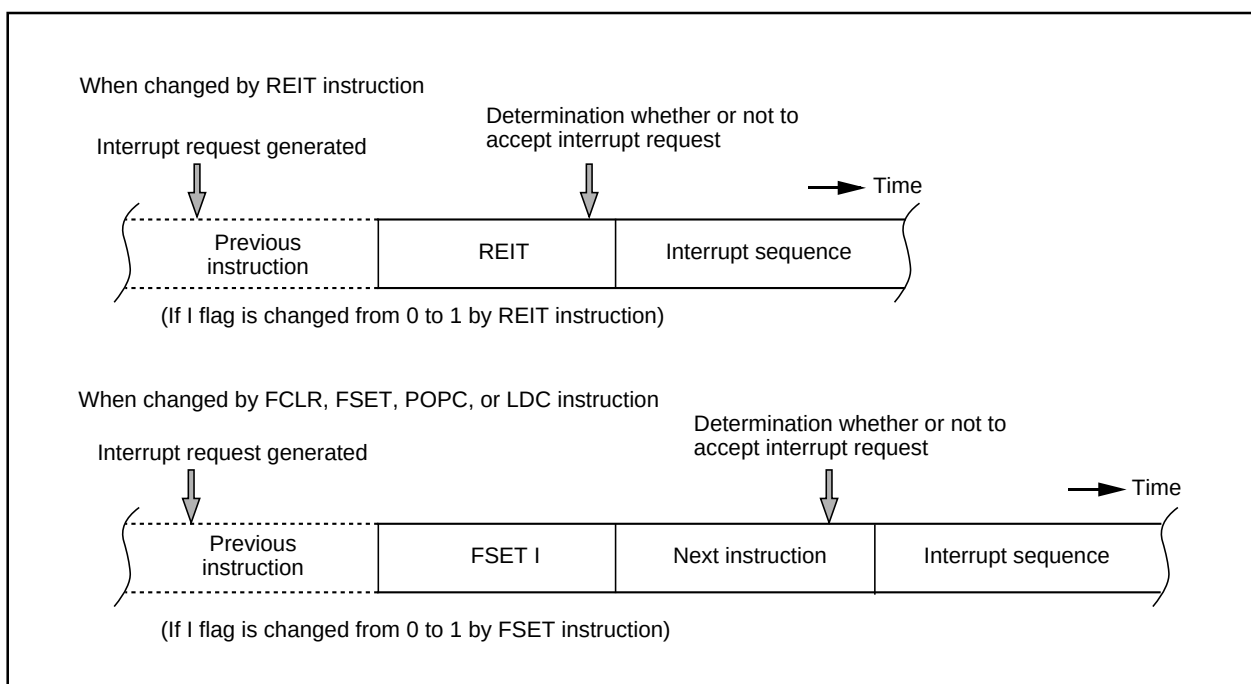


Figure 2.14.3. The timing of reflecting the change in the I flag to the interrupt

(3) Interrupt Request Bit

The interrupt request bit is set to "1" by hardware when an interrupt is requested. After the interrupt is accepted and jumps to the corresponding interrupt vector, the request bit is set to "0" by hardware. The interrupt request bit can also be set to "0" by software. (Do not set this bit to "1").

(4) Interrupt Priority Level Select Bit and Processor Interrupt Priority Level (IPL)

Set the interrupt priority level using the interrupt priority level select bit, which is one of the component bits of the interrupt control register. When an interrupt request occurs, the interrupt priority level is compared with the IPL. The interrupt is enabled only when the priority level of the interrupt is higher than the IPL. Therefore, setting the interrupt priority level to "0" disables the interrupt.

Table 2.14.1 shows the settings of interrupt priority levels and Table 2.14.2 shows the interrupt levels enabled, according to the contents of the IPL.

The following are conditions under which an interrupt is accepted:

- interrupt enable flag (I flag) = 1
- interrupt request bit = 1
- interrupt priority level > IPL

The interrupt enable flag (I flag), the interrupt request bit, the interrupt priority select bit, and the IPL are independent, and they are not affected by one another.

Table 2.14.1. Settings of interrupt priority levels

Interrupt priority level select bit	Interrupt priority level	Priority order
b2 b1 b0 0 0 0	Level 0 (interrupt disabled)	———
0 0 1	Level 1	Low ↓ High
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	

Table 2.14.2. Interrupt levels enabled according to the contents of the IPL

IPL	Enabled interrupt priority levels
IPL ₂ IPL ₁ IPL ₀ 0 0 0	Interrupt levels 1 and above are enabled
0 0 1	Interrupt levels 2 and above are enabled
0 1 0	Interrupt levels 3 and above are enabled
0 1 1	Interrupt levels 4 and above are enabled
1 0 0	Interrupt levels 5 and above are enabled
1 0 1	Interrupt levels 6 and above are enabled
1 1 0	Interrupt levels 7 and above are enabled
1 1 1	All maskable interrupts are disabled

When either the IPL or the interrupt priority level is changed, the new level is reflected to the interrupt in the following timing:

- When changing the IPL using the REIT instruction, the reflection takes effect as of the instruction that is executed in 2 clock cycles after the last clock cycle involved in the REIT instruction.
- When changing the IPL using either the POPC, LDC or LDIPIL instruction, the reflection takes effect as of the instruction that is executed in 3 cycles after the last clock cycle involved in the instruction used.
- When changing the interrupt priority level using the MOV or similar instruction, the reflection takes effect as of the instruction that is executed in 2 clock cycles after the last clock cycle involved in the instruction used.

(5) Interrupt Priority

If there are two or more interrupt requests occurring at a point in time within a single sampling (checking whether interrupt requests are made), the interrupt assigned a higher priority is accepted.

Assign an arbitrary priority to maskable interrupts (peripheral I/O interrupts) using the interrupt priority level select bit. If the same interrupt priority level is assigned, however, the interrupt assigned a higher hardware priority is accepted.

Priorities of the special interrupts, such as Reset (dealt with as an interrupt assigned the highest priority), watchdog timer interrupt, etc. are regulated by hardware.

Figure 2.14.4 shows the priorities of hardware interrupts.

Software interrupts are not affected by the interrupt priority. If an instruction is executed, control branches invariably to the interrupt routine.

Reset > $\overline{\text{NMI}}$ > $\overline{\text{DBC}}$ > Watchdog timer > Peripheral I/O > Single step > Address match

Figure 2.14.4. Hardware interrupts priorities

(6) Interrupt resolution circuit

When two or more interrupts are generated simultaneously, this circuit selects the interrupt with the highest priority level. Figure 2.14.5 shows the circuit that judges the interrupt priority level.

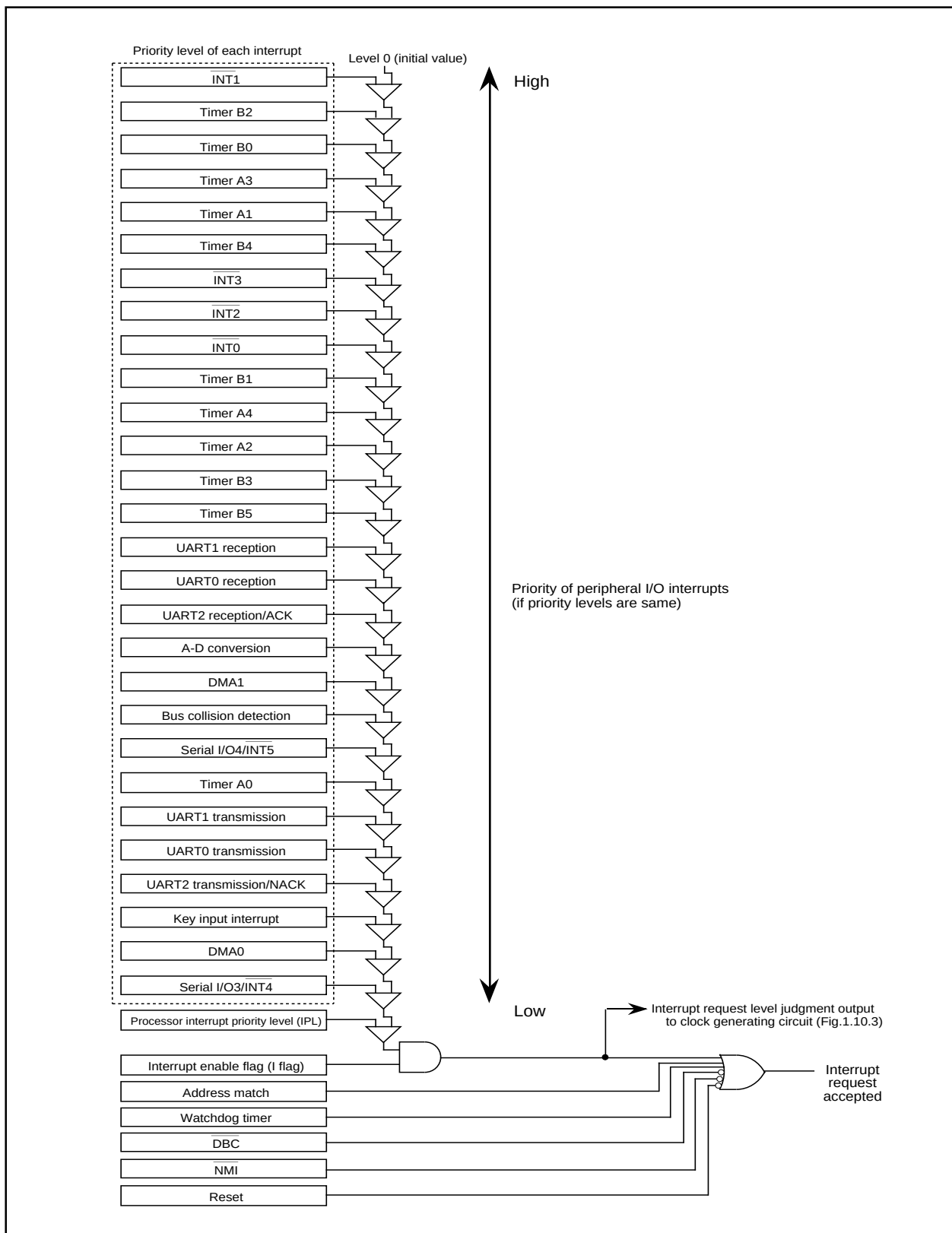


Figure 2.14.5. Interrupts resolution circuit

2.14.2 Multiple Interrupts Operation

The state when control branched to an interrupt routine is described below:

- The interrupt enable flag (I flag) is set to “0” (the interrupt is disabled).
- The interrupt request bit of the accepted interrupt is set to “0”.
- The processor interrupt priority level (IPL) is assigned to the same interrupt priority level as assigned to the accepted interrupt.

Setting the interrupt enable flag (I flag) to “1” within an interrupt routine allows an interrupt request assigned a priority higher than the IPL to be accepted.

An interrupt request that is not accepted because of low priority will be held. If the condition following is met when the REIT instruction returns the IPL and the interrupt priority is determined, then the interrupt request being held is accepted.

Interrupt priority level of the interrupt request being held > Returned the IPL

Figure 2.14.6 shows the example of the multiple interrupts operation.

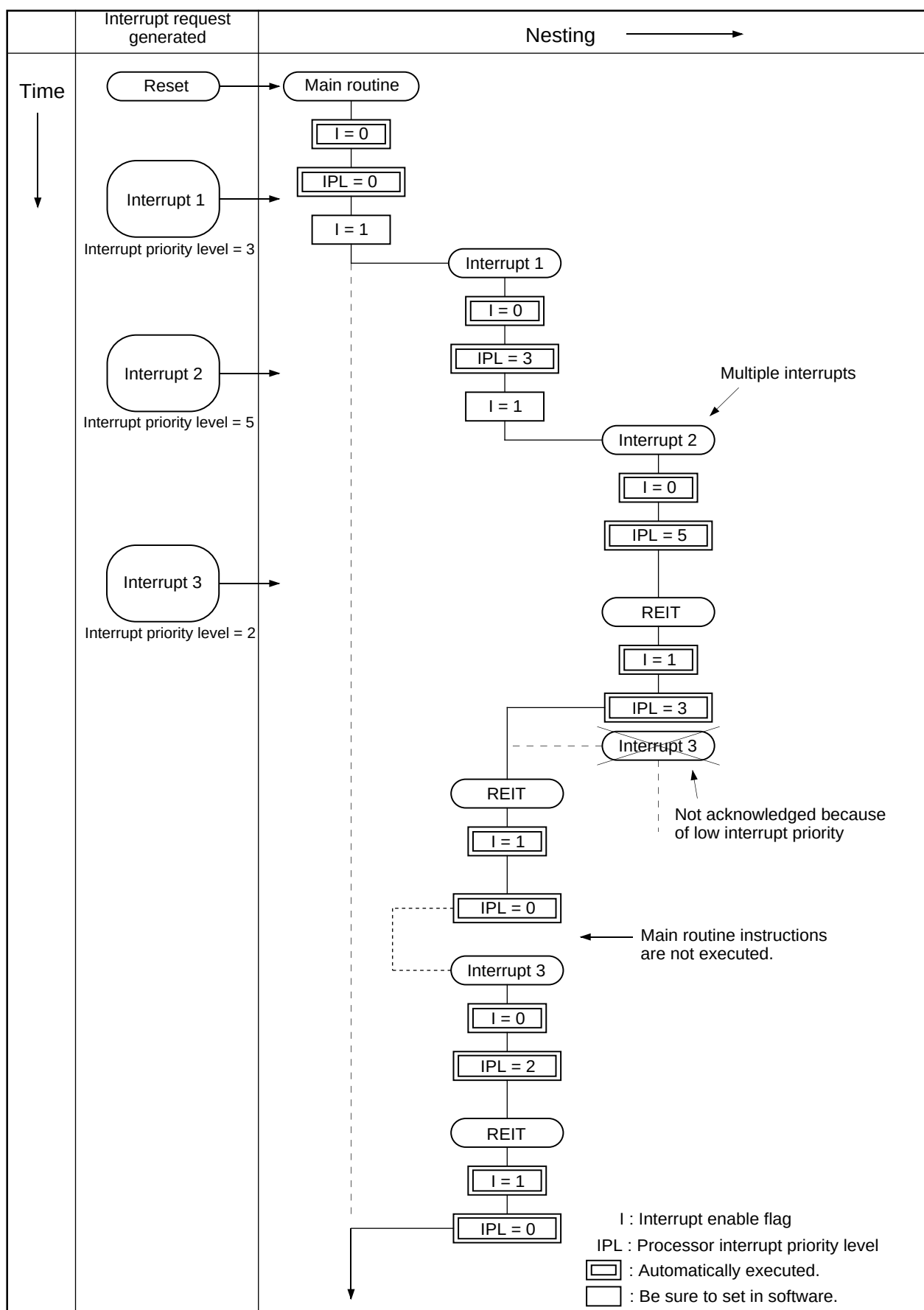


Figure 2.14.6. Example of the multiple interrupts operation

2.15 Power Control Usage

2.15.1 Overview of the power control usage

'Power Control' refers to the reduction of CPU power consumption by stopping the CPU and oscillators, or decreasing the operation clock. The following is a description of the three available power control modes:

(1) Modes

Power control is available in three modes.

(a) Normal operation mode

- **High-speed mode**

Divide-by-1 frequency of the main clock becomes the BCLK. The CPU operates with the BCLK selected. Each peripheral function operates according to its assigned clock.

- **Medium-speed mode**

Divide-by-2, divide-by-4, divide-by-8, or divide-by-16 frequency of the main clock becomes the BCLK. The CPU operates according to the BCLK selected. Each peripheral function operates according to its assigned clock.

- **Low-speed mode**

fc becomes the BCLK. The CPU operates according to the fc clock. The fc clock is supplied by the secondary clock. Each peripheral function operates according to its assigned clock.

- **Low power consumption mode**

The main clock operating in low-speed mode is stopped. The CPU operates according to the fc clock. The fc clock is supplied by the secondary clock. The only peripheral functions that operate are those with the sub-clock selected as the count source.

(b) Wait mode

The CPU operation is stopped. The oscillators do not stop.

(c) Stop mode

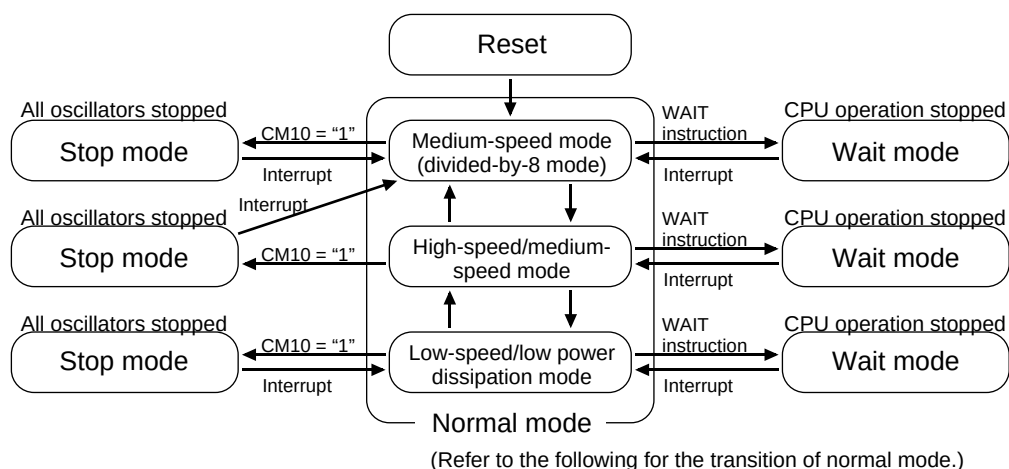
All oscillators stop. The CPU and all built-in peripheral functions stop. This mode, among the three modes listed here, is the most effective in decreasing power consumption.

Figure 2.15.1 is the state transition diagram of the above modes.

(2) Switching the driving capacity of the oscillation circuit

Both the main clock and the secondary clock have the ability to switch the driving capacity. Reducing the driving capacity after the oscillation stabilizes allows for further reduction in power consumption.

Transition of stop mode, wait mode



Transition of normal mode

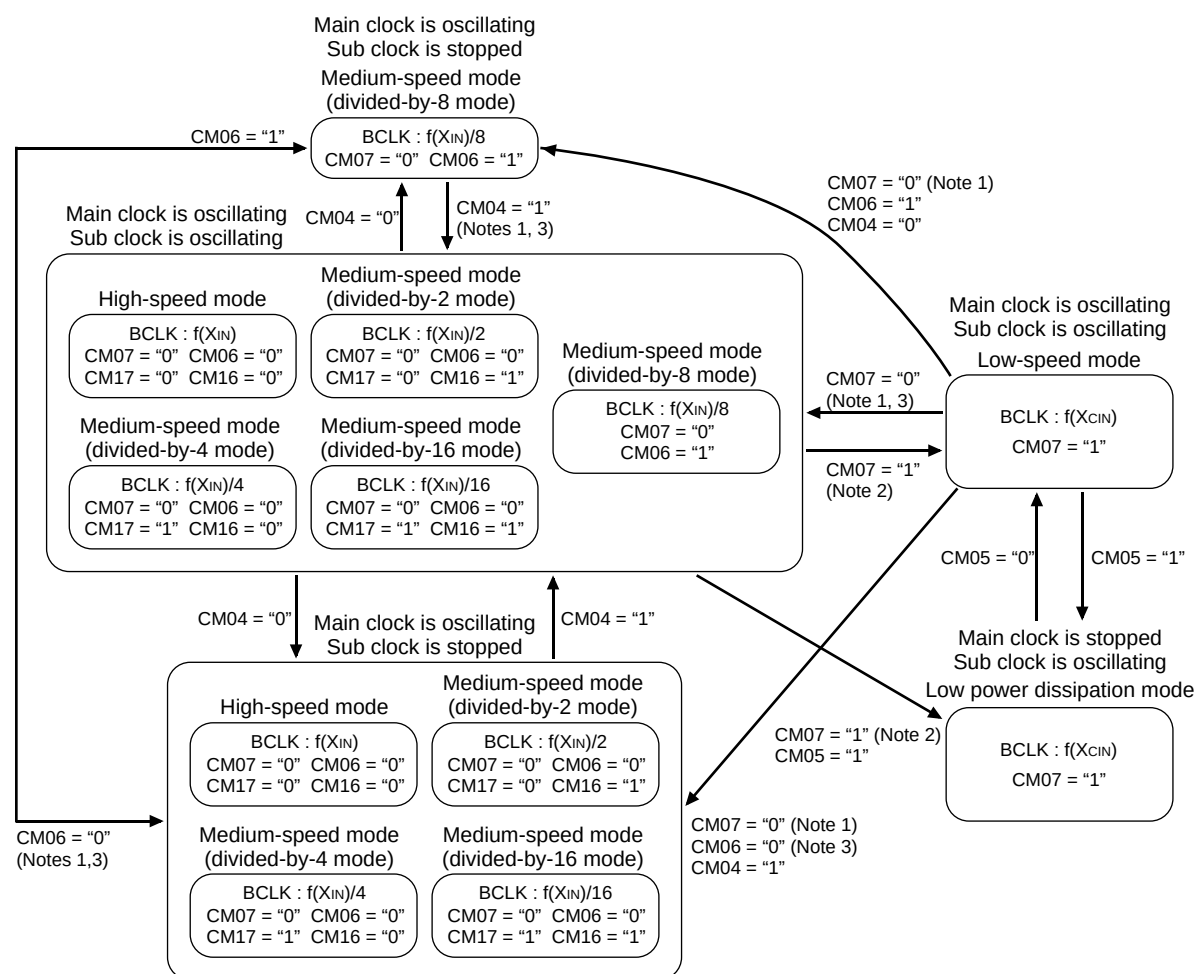


Figure 2.15.1. State transition diagram of power control mode

(3) Clearing stop mode and wait mode

The stop mode and wait mode can be cleared by generating an interrupt request, or by resetting hardware. Set the priority level of the interrupt to be used for clearing, higher than the processor interrupt priority level (IPL), set that of the interrupt to "0" not to be used for clearing, and enable the interrupt enable flag (I flag). When an interrupt clears a mode, that interrupt is processed. Table 2.15.1 shows the interrupts that can be used for clearing a stop mode and wait mode.

(4) BCLK in returning from wait mode or stop mode**(a) Returning from wait mode**

The processor immediately returns to the BCLK, which was in use before entering wait mode.

(b) Returning from stop mode

CM06 is set to "1" when the device enters stop mode after selecting the main clock for BCLK. CM17, CM16, and CM07 do not change state. In this case, when restored from stop mode, the device starts operating in divided-by-8 mode.

When the device enters stop mode after selecting the subclock for BCLK, CM06, CM17, CM16, and CM07 all do not change state. In this case, when restored from stop mode, the device starts operating in low-speed mode.

Table 2.15.1. Interrupts available for clearing stop mode and wait mode

Interrupt for clearing	Wait mode		Stop mode
	CM02 = 0	CM02 =1(Note 6), CM07 = 0, CM05 = 0	
Bus collision detection interrupt	Possible	Note 1	Note 1
DMA0 interrupt	Impossible	Impossible	Impossible
DMA1 interrupt	Impossible	Impossible	Impossible
Key input interrupt	Possible	Possible	Possible
A-D interrupt	Note 3	Impossible	Impossible
UART0 transmit interrupt	Possible	Note 1	Note 1
UART0 receive interrupt	Possible	Note 1	Note 1
UART1 transmit interrupt	Possible	Note 1	Note 1
UART1 receive interrupt	Possible	Note 1	Note 1
UART2 transmit interrupt	Possible	Note 1	Note 1
UART2 receive interrupt	Possible	Note 1	Note 1
SI/O3 interrupt	Possible	Note 4	Note 4
SI/O4 interrupt	Possible	Note 4	Note 4
Timer A0 interrupt	Possible	Note 2, Note 5	Note 2
Timer A1 interrupt	Possible	Note 2, Note 5	Note 2
Timer A2 interrupt	Possible	Note 2, Note 5	Note 2
Timer A3 interrupt	Possible	Note 2, Note 5	Note 2
Timer A4 interrupt	Possible	Note 2, Note 5	Note 2
Timer B0 interrupt	Possible	Note 2, Note 5	Note 2
Timer B1 interrupt	Possible	Note 2, Note 5	Note 2
Timer B2 interrupt	Possible	Note 2, Note 5	Note 2
Timer B3 interrupt	Possible	Note 2, Note 5	Note 2
Timer B4 interrupt	Possible	Note 2, Note 5	Note 2
Timer B5 interrupt	Possible	Note 2, Note 5	Note 2
INT0 interrupt	Possible	Possible	Possible
INT1 interrupt	Possible	Possible	Possible
INT2 interrupt	Possible	Possible	Possible
INT3 interrupt	Possible	Possible	Possible
INT4 interrupt	Possible	Possible	Possible
INT5 interrupt	Possible	Possible	Possible
NMI interrupt	Possible	Possible	Possible

Note 1: Can be used when an external clock is selected (UART0, UART1).

Can be used when an external clock in clock synchronous serial I/O mode is selected (UART2).

Note 2: Can be used when the external signal is being counted in event counter mode.

Note 3: Can be used in one-shot mode and one-shot sweep mode.

Note 4: Can be used when an external clock is selected.

Note 5: Can be used when count source is fc32.

Note 6: When the MCU running in low-speed or low power dissipation mode, do not enter wait mode with CM02 is set to "1".

(5) Sequence of returning from stop mode

Sequence of returning from stop mode is oscillation start-up time and interrupt sequence.

When interrupt is generated in stop mode, CM10 becomes "0" and clearing stop mode.

Starting oscillation and supplying BCLK execute the interrupt sequence as follow:

In the interrupt sequence, the processor carries out the following in sequence given:

- CPU gets the interrupt information (the interrupt number and interrupt request level) by reading address 00000₁₆. The interrupt request bit of the interrupt written in address 00000₁₆ will then be set to "0".
- Saves the content of the flag register (FLG) as it was immediately before the start of interrupt sequence in the temporary register (Note) within the CPU.
- Sets the interrupt enable flag (I flag), the debug flag (D flag), and the stack pointer assignment flag (U flag) to "0" (the U flag, however does not change if the INT instruction, in software interrupt numbers 32 through 63, is executed)
- Saves the content of the temporary register (Note) within the CPU in the stack area.
- Saves the content of the program counter (PC) in the stack area.
- Sets the interrupt priority level of the accepted instruction in the IPL.

Note: This register cannot be utilized by the user.

After the interrupt sequence is completed, the processor resumes executing instructions from the first address of the interrupt routine.

Figure 2.15.2 shows the sequence of returning from stop mode.

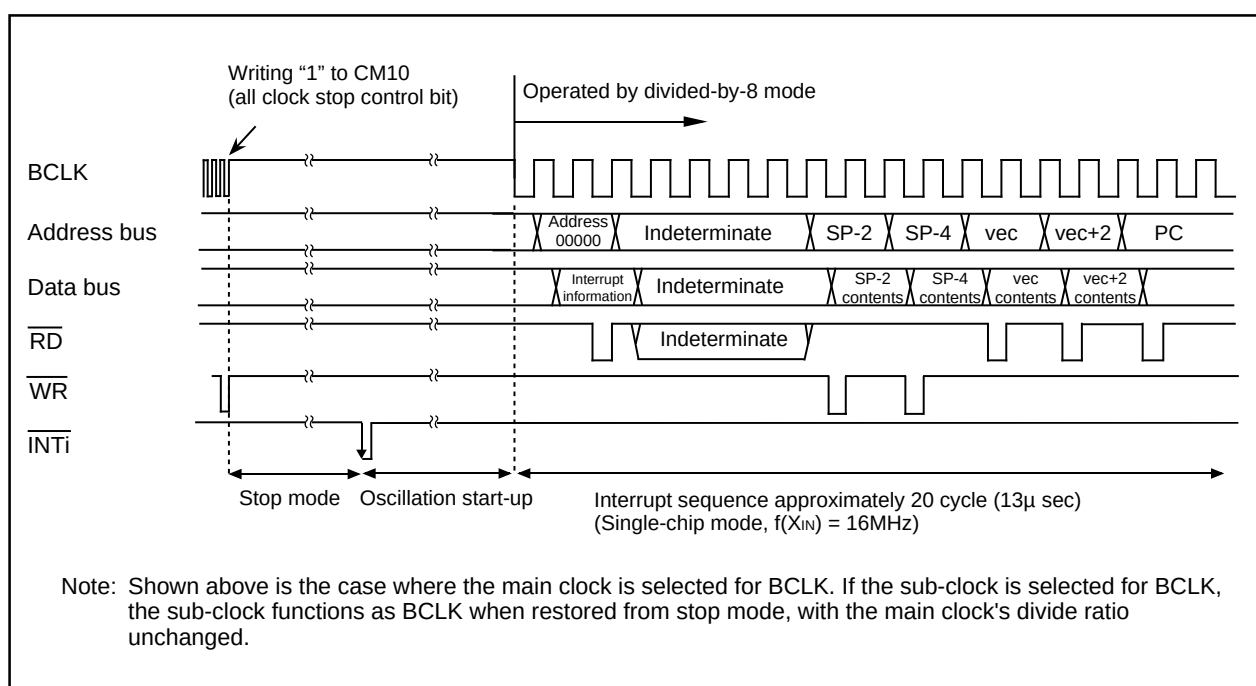


Figure 2.15.2. Sequence of returning from stop mode

(6) Registers related to power control

Figure 2.15.3 shows the memory map of power control-related registers, and Figure 2.15.4 shows power control-related registers.

0006 ₁₆	System clock control register 0 (CM0)
0007 ₁₆	System clock control register 1 (CM1)

Figure 2.15.3. Memory map of power control-related registers

System clock control register 0 (Note 1)

b7 b6 b5 b4 b3 b2 b1 b0								Symbol CM0	Address 000616	When reset 4816
</										

Note 1: Set bit 0 of the protect register (address 000A16) to "1" before writing to this register.

Note 2: Changes to "1" when shifting to stop mode and at a reset.

Note 3: When entering low power dissipation mode, main clock stops by using this bit. To stop the main clock, when the sub clock oscillation is stable, set system clock select bit (CM07) to "1" before setting this bit to "1".

Note 4: When inputting external clock, only clock oscillation buffer is stopped and clock input is acceptable.

Note 5: If this bit is set to "1", XOUT turns "H". The built-in feedback resistor remains being connected, so XIN turns pulled up to XOUT ("H") via the feedback resistor.

Note 6: Set port Xc select bit (CM04) to "1" and stabilize the sub-clock oscillating before setting this bit from "0" to "1". Do not write to both bits at the same time. And also, set the main clock stop bit (CM05) to "0" and stabilize the main clock oscillating before setting this bit from "1" to "0".

Note 7: This bit changes to "1" when shifting from high-speed/medium-speed mode to stop mode and at a reset. When shifting from low-speed/low power dissipation mode to stop mode, the value before stop mode is retained.

Note 8: fc32 is not included. Do not set to "1" when using low-speed or low power dissipation mode.

Note 9: When the XCIN/XCOUT is used, set ports P86 and P87 as the input ports without pull-up.

System clock control register 1 (Note 1)

b7	b6	b5	b4	b3	b2	b1	b0	Symbol CM1	Address 0007 ₁₆	When reset 20 ₁₆
			0	0	0	0				

Note 1: Set bit 0 of the protect register (address 000A16) to "1" before writing to this register.

Note 2: This bit changes to "1" when shifting from high-speed/medium-speed mode to stop mode and at a reset. When shifting from low-speed/low power dissipation mode to stop mode, the value before stop mode is retained.

Note 3: Can be selected when bit 6 of the system clock control register 0 (address 000616) is "0". If "1", division mode is fixed at 8.

Note 4: If this bit is set to "1", XOUT turns "H", and the built-in feedback resistor is cut off. XCIN and XCOUT turn high-impedance state.

Figure 2.15.4. Power control-related registers

2.15.2 Stop Mode Set-Up

Settings and operation for entering stop mode are described here.

Operation (1) Enables the interrupt used for returning from stop mode.

(2) Sets the interrupt enable flag (I flag) to "1".

(3) Clearing the protection and setting all clock stop control bit to "1" stops oscillation and causes the processor to go into stop mode.

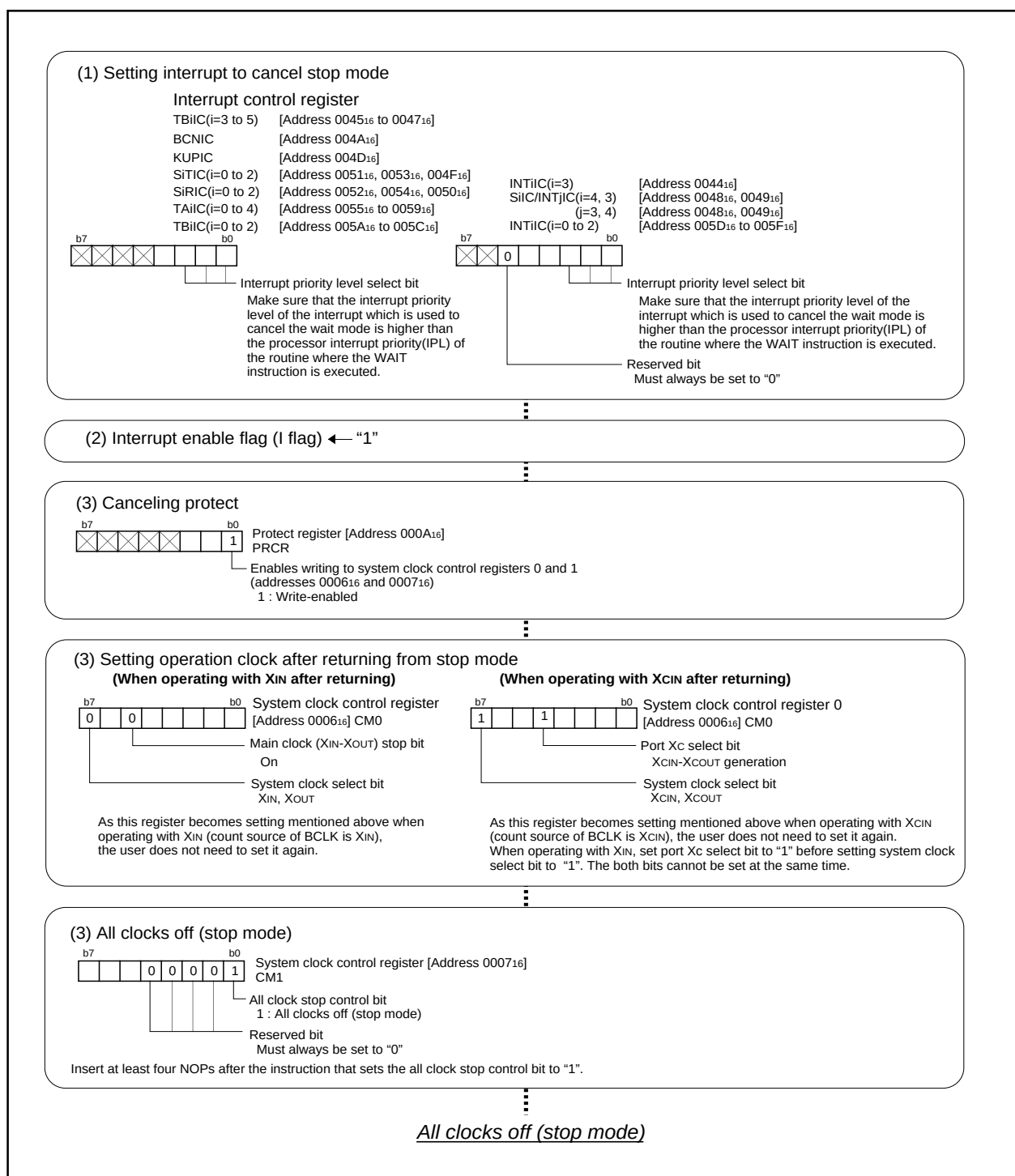


Figure 2.15.5. Example of stop mode set-up

2.15.3 Wait Mode Set-Up

Settings and operation for entering wait mode are described here.

- Operation
- (1) Enables the interrupt used for returning from wait mode.
 - (2) Sets the interrupt enable flag (I flag) to "1".
 - (3) Clears the protection and changes the content of the system clock control register.
 - (4) Executes the WAIT instruction.

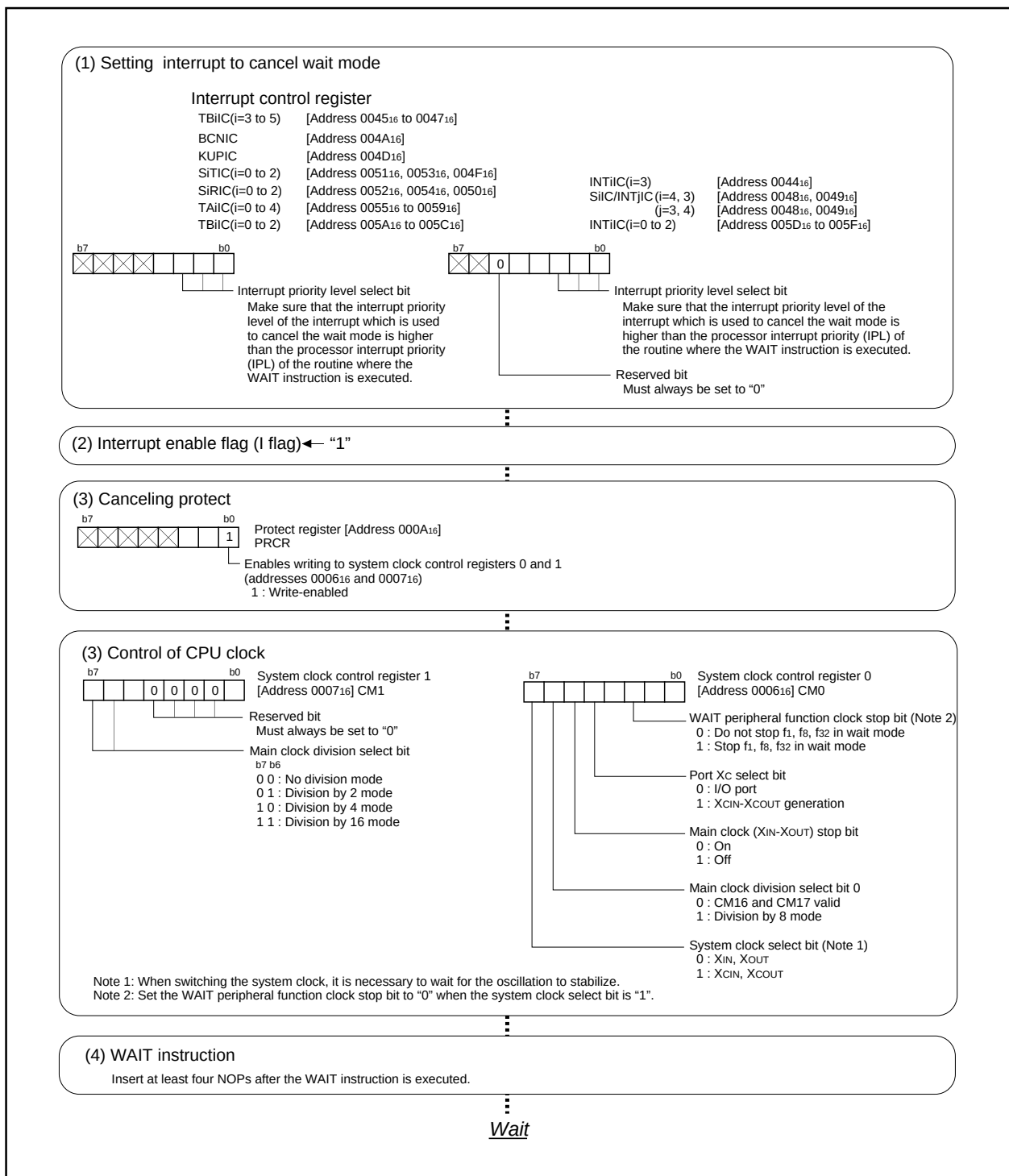


Figure 2.15.6. Example of wait mode set-up

2.15.4 Precautions in Power Control

- (1) The processor does not switch to stop mode when the $\overline{\text{NMI}}$ pin is at "L" level.
- (2) When returning from stop mode by hardware reset, $\overline{\text{RESET}}$ pin must be set to "L" level until main clock oscillation is stabilized.
- (3) When switching to either wait mode or stop mode, instructions occupying four bytes either from the WAIT instruction or from the instruction that sets the all clock stop control bit to "1" within the instruction queue are prefetched and then the program stops. So put at least four NOPs in succession either to the WAIT instruction or to the instruction that sets the all clock stop control bit to "1".
- (4) Before the count source for BCLK can be changed from X_{IN} to X_{CIN} or vice versa, the clock to which the count source is going to be switched must be oscillating stably. Allow a wait time in software for the oscillation to stabilize before switching over the clock.
- (5) Suggestions to reduce power consumption

(a) Ports

The processor retains the state of each programmable I/O port even when it goes to wait mode or to stop mode. A current flows in active I/O ports. A pass current flows in input ports that float. When entering wait mode or stop mode, set non-used ports to input and stabilize the potential.

(b) A-D converter

A current always flows in the V_{REF} pin. When entering wait mode or stop mode, set the V_{ref} connection bit to "0" so that no current flows into the V_{REF} pin.

(c) D-A converter

The processor retains the D-A state even when entering wait mode or stop mode. Disable the output from the D-A converter then work on the programmable I/O ports. Set D-A register to "0016".

(d) Stopping peripheral functions

In wait mode, stop non-used peripheral functions using the WAIT peripheral function clock stop bit. However, peripheral function clock fc_{32} does not stop so that the peripherals using fc_{32} do not contribute to the power saving. When the MCU running in low-speed or low power dissipation mode, do not enter WAIT mode with this bit set to "1".

(e) Switching the oscillation-driving capacity

Set the driving capacity to "LOW" when oscillation is stable.

(f) External clock

When using an external clock input for the CPU clock, set the main clock stop bit to "1". Setting the main clock stop bit to "1" causes the X_{OUT} pin not to operate and the power consumption goes down (when using an external clock input, the clock signal is input regardless of the content of the main clock stop bit).

2.16 Programmable I/O Ports Usage

2.16.1 Overview of the programmable I/O ports usage

Eighty-seven programmable I/O ports and one input-only port are available. I/O pins also serve as I/O pins for built-in peripheral functions.

Each port has a direction register that defines the I/O direction and also has a port register for I/O data. In addition, each port has a pull-up control register that defines pull-up in terms of 4 bits. The input-only port has neither direction register nor pull-up control bit.

The following is an overview of the programmable I/O ports usage:

(1) Writing to a port register

With the direction register set to output, the level of the written values from each relevant pin is output by writing to a port register. The output level conforms to CMOS output. Port P70 and P71 are N channel open drain. Writing to the port register, with the direction register set to input, inputs a value to the port register, but nothing is output to the relevant pins. The output level remains floating.

In memory expansion and microprocessor mode, the contents of corresponding port and direction registers of pins A0 to A19, D0 to D15, $\overline{CS0}$ to $\overline{CS3}$, $\overline{RD}$, $\overline{WRL/WR}$, $\overline{WRH/BHE}$, ALE, $\overline{RDY}$, $\overline{HOLD}$, $\overline{HLDA}$ and BCLK cannot be modified.

(2) Reading a port register

With the direction register set to output, reading a port register takes out the content of the port register, not the content of the pin. With the direction register set to input, reading the port register takes out the content of the pin.

(3) Effect of the protection register

Data written to the direction register of P9 is affected by the protection register. The direction register of P9 cannot be easily rewritten.

(4) Input-only port

P85 is used as the input-only port, it also serves as $\overline{NMI}$. P85 has no direction register. Pull-up cannot be set to this port. As $\overline{NMI}$ cannot be disabled, an $\overline{NMI}$ interrupt occurs if a falling edge is input to P85. Use P85 for reading the level input at this time only.

(5) Setting pull-up

The pull-up control bit allows setting of the pull-up, in terms of 4 bits, either in use or not in use. For the four bits chosen, pull-up is effective only in the ports whose direction register is set to input. Pull-up is not effective in ports whose direction register is set to output.

Do not set pull-up of corresponding pin when $\overline{XCIN/XCOUT}$ is set or a port is used as A-D input.

Pull-up can be set for P0 to P3, P40 to P43, P5 in only single-chip mode. Pull-up cannot be set for P0 to P3, P40 to P43, P5 in memory expansion and microprocessor modes. The contents of register can be changed, but the pull-up resistance is not connected.

(6) I/O functions of built-in peripheral devices

Table 2.16.1 shows relation between ports and I/O functions of built-in peripheral devices.

Table 2.16.1. Relation between ports and I/O functions of built-in peripheral devices

Port	Internal peripheral device I/O pins
P15 to P17	Input pins for external interrupt
P6	I/O pins for serial I/O communication
P70	I/O pins for serial I/O communication/Timer A I/O pin
P71	I/O pins for serial I/O communication/Timer A I/O pins/Timer B input pin
P72 to P73	I/O pins for serial I/O communication/Timer A I/O pins/Three-phase motor control output pins
P74 to P75	Timer A I/O pins/Three-phase motor control output pins
P76 to P77	Timer A I/O pins
P80, P81	Timer A I/O pins
P82 to P84	Input pins for external interrupt
P86, P87	Sub-clock oscillation circuit I/O pins
P90 to P92	Timer B input pins
P93, P94	D-A converter output pins
P95, P96	A-D converter extended input pins
P97	A-D trigger input pin
P100 to P103	A-D converter input pins
P104 to P107	A-D converter input pins / key-input interrupt function input pins

(7) Examples of working on non-used pins

Table 2.16.2 contains examples of working on non-used pins. There are shown here for mere examples. In practical use, make suitable changes and perform sufficient evaluation in compliance with you application.

(a) Single-chip mode

Table 2.16.2. Examples of working on unused pins in single-chip mode

Pin name	Connection
Ports P0 to P10 (excluding P85)	After setting for input mode, connect every pin to Vss or Vcc via a resistor; or after setting for output mode, leave these pins open. (Note 1, Note 3)
XOUT (Note 2)	Open
NMI	Connect to Vcc via a resistor
AVcc	Connect to Vcc
AVss, VREF, BYTE	Connect to Vss

Note 1: If setting these pins in output mode and opening them, ports are in input mode until switched into output mode by use of software after reset. Thus the voltage levels of the pins become unstable, and there can be instances in which the power source current increases while the ports are in input mode.

In view of an instance in which the contents of the direction registers change due to a runaway generated by noise or other causes, setting the contents of the direction registers periodically by use of software increases program reliability.

Note 2: When an external clock is input to the XIN pin.

Note 3: Output "L" if port P70 and P71 are set to output mode.
Port P70 and P71 are N channel open drain output.

(b) Memory expansion mode, microprocessor mode
Table 2.16.3. Examples of working on unused pins in memory expansion mode or microprocessor mode

Pin name	Connection
Ports P6 to P10 (excluding P85)	After setting for input mode, connect every pin to Vss or Vcc via a resistor; or after setting for output mode, leave these pins open. (Note 1, Note 2, Note 5)
$\overline{\text{BHE}}$, $\overline{\text{ALE}}$, $\overline{\text{HLDA}}$	Open (Note 3)
XOUT (Note 4), BCLK (Note 6)	Open
$\overline{\text{HOLD}}$, $\overline{\text{RDY}}$, $\overline{\text{NMI}}$	Connect via resistor to Vcc (pull-up)
AVcc	Connect to Vcc
AVss, VREF	Connect to Vss

Note 1: If setting these pins in output mode and opening them, ports are in input mode until switched into output mode by use of software after reset. Thus the voltage levels of the pins become unstable, and there can be instances in which the power source current increases while the ports are in input mode.

In view of an instance in which the contents of the direction registers change due to a runaway generated by noise or other causes, setting the contents of the direction registers periodically by use of software increases program reliability.

Note 2: Make wiring as short as possible (not more than 2 cm from the microcomputer's pins) in working on non-used pins.

Note 3: When a Vss level is connected to the CNVss pin, these pins are input ports until the processor mode is switched by use of software after reset. Thus the voltage levels of the pins destabilize, and there can be an increase in the power source current while these pins are input ports.

Note 4: When an external clock is input to the XIN pin.

Note 5: Output "L" if port P70 and P71 are set to output mode.
Port P70 and P71 are N channel open drain output.

Note 6: When the BCLK output disable bit (bit 7 at address 000416) is set to "1", connect to Vcc via a resistor (pull-up).

(8) Registers related to the programmable I/O ports

Figure 2.16.1 shows the memory map of programmable I/O ports-related registers, and Figures 2.16.2 to 2.16.4 show programmable I/O ports-related registers.

03E0 ₁₆	Port P0 register (P0)
03E1 ₁₆	Port P1 register (P1)
03E2 ₁₆	Port P0 direction register (PD0)
03E3 ₁₆	Port P1 direction register (PD1)
03E4 ₁₆	Port P2 register (P2)
03E5 ₁₆	Port P3 register (P3)
03E6 ₁₆	Port P2 direction register (PD2)
03E7 ₁₆	Port P3 direction register (PD3)
03E8 ₁₆	Port P4 register (P4)
03E9 ₁₆	Port P5 register (P5)
03EA ₁₆	Port P4 direction register (PD4)
03EB ₁₆	Port P5 direction register (PD5)
03EC ₁₆	Port P6 register (P6)
03ED ₁₆	Port P7 register (P7)
03EE ₁₆	Port P6 direction register (PD6)
03EF ₁₆	Port P7 direction register (PD7)
03F0 ₁₆	Port P8 register (P8)
03F1 ₁₆	Port P9 register (P9)
03F2 ₁₆	Port P8 direction register (PD8)
03F3 ₁₆	Port P9 direction register (PD9)
03F4 ₁₆	Port P10 register (P10)
03F5 ₁₆	
03F6 ₁₆	Port P10 direction register (PD10)
≈	≈
03FC ₁₆	Pull-up control register 0 (PUR0)
03FD ₁₆	Pull-up control register 1 (PUR1)
03FE ₁₆	Pull-up control register 2 (PUR2)
03FF ₁₆	Port control register (PCR)

Figure 2.16.1. Memory map of programmable I/O ports-related registers

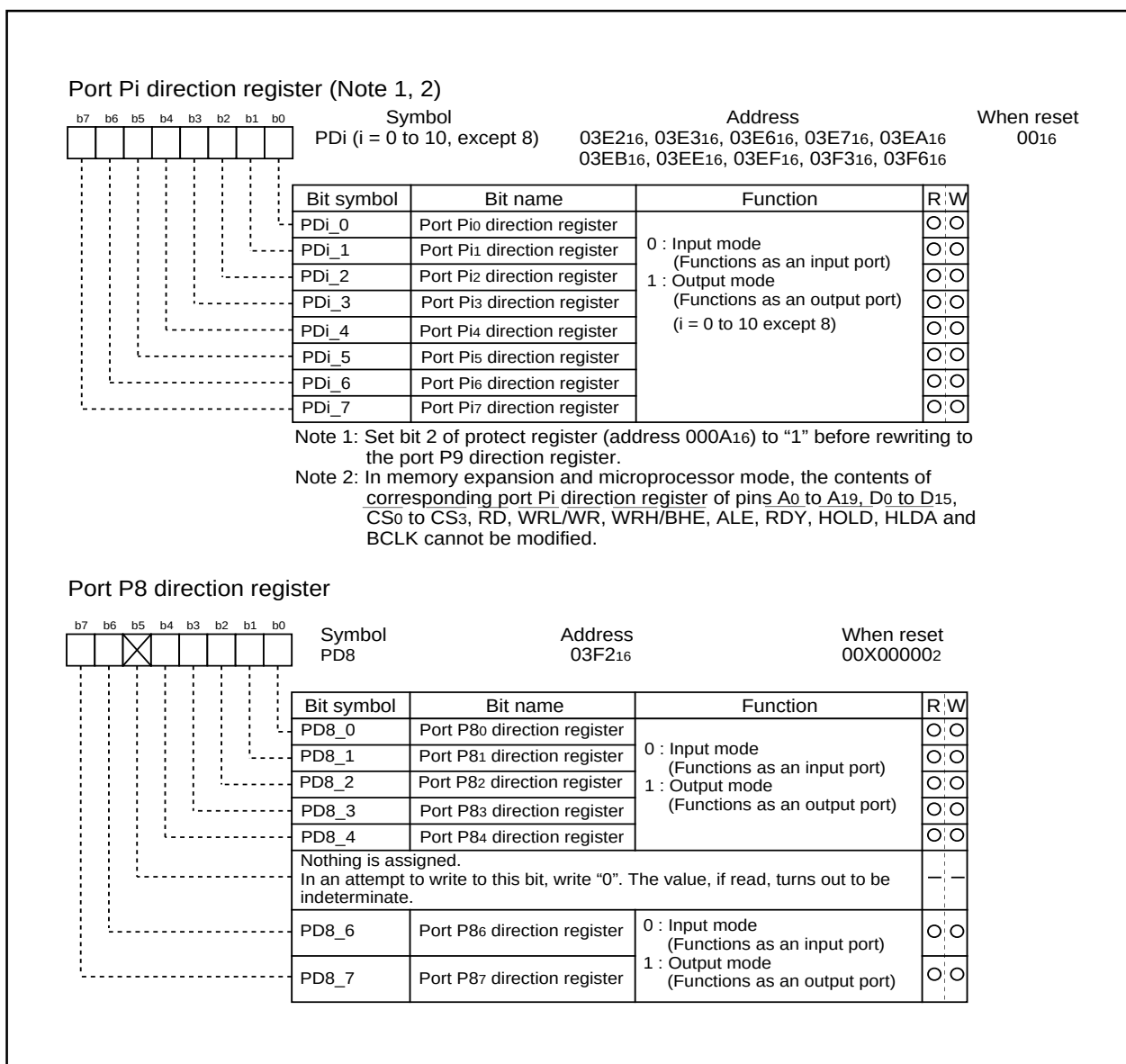


Figure 2.16.2. Programmable I/O ports-related registers (1)

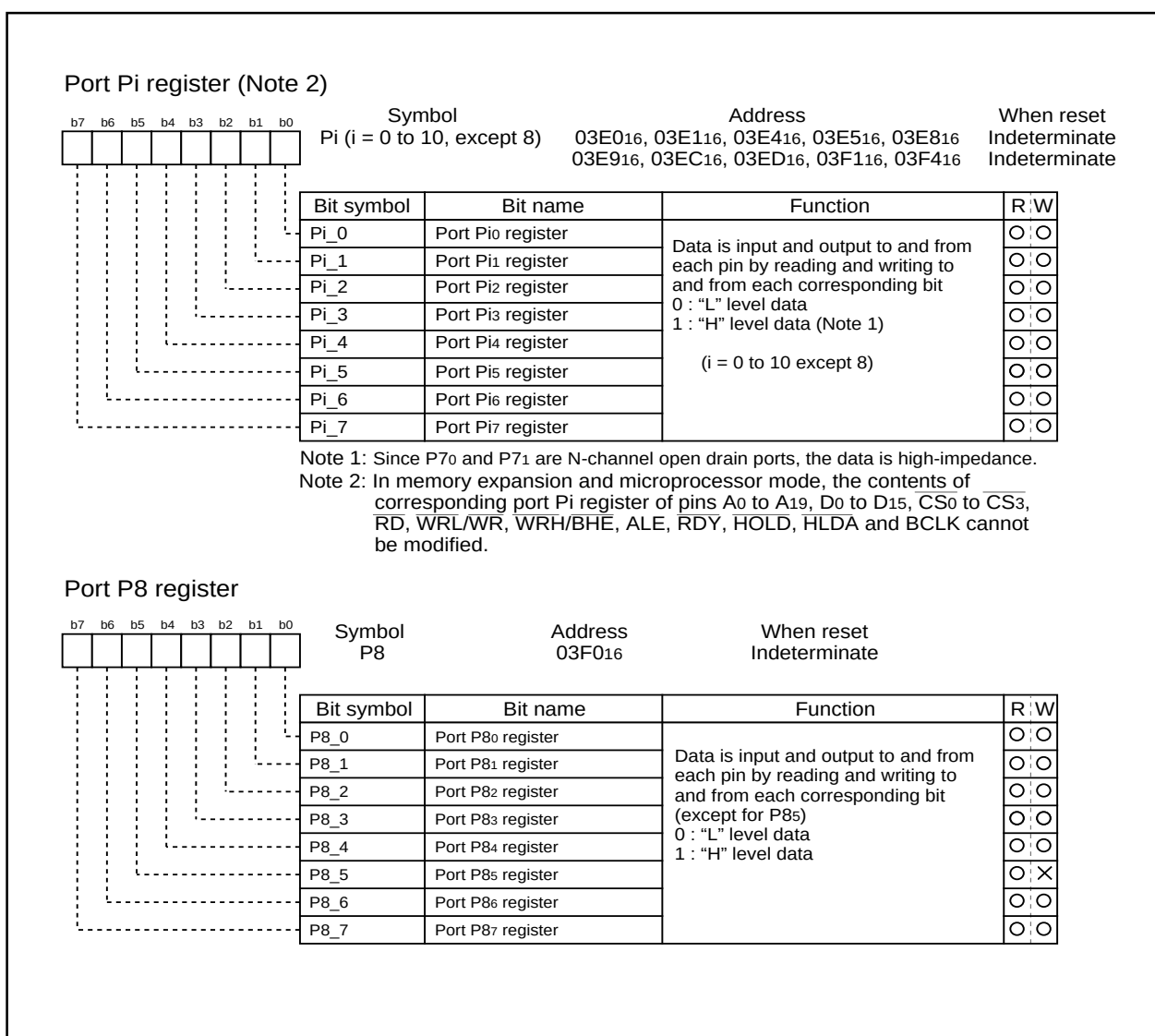


Figure 2.16.3. Programmable I/O ports-related registers (2)

Pull-up control register 0 (Note)

b7	b6	b5	b4	b3	b2	b1	b0	Symbol PUR0	Address 03FC ₁₆	When reset 00 ₁₆	
								Bit symbol	Bit name	Function	R/W
								PU00	P0 ₀ to P0 ₃ pull-up	The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high	
								PU01	P0 ₄ to P0 ₇ pull-up		
								PU02	P1 ₀ to P1 ₃ pull-up		
								PU03	P1 ₄ to P1 ₇ pull-up		
								PU04	P2 ₀ to P2 ₃ pull-up		
								PU05	P2 ₄ to P2 ₇ pull-up		
								PU06	P3 ₀ to P3 ₃ pull-up		
								PU07	P3 ₄ to P3 ₇ pull-up		

Note : In memory expansion and microprocessor mode, the content of this register can be changed, but the pull-up resistance is not connected.

Pull-up control register 1

b7	b6	b5	b4	b3	b2	b1	b0	Symbol PUR1	Address 03FD ₁₆	When reset 00 ₁₆ (Note 2)	
								Bit symbol	Bit name	Function	R:W
								PU10	P40 to P43 pull-up (Note 3)	The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high	
								PU11	P44 to P47 pull-up		
								PU12	P50 to P53 pull-up (Note 3)		
								PU13	P54 to P57 pull-up		
								PU14	P60 to P63 pull-up		
								PU15	P64 to P67 pull-up		
								PU16	P72 to P73 pull-up (Note 1)		
								PU17	P74 to P77 pull-up		

Note 1: Since P70 and P71 are N-channel open drain ports, pull-up is not available for them.

Note 2: When the Vcc level is being impressed to the CNVss terminal, this register becomes to 02₁₆ when reset (PU11 becomes to "1").

Note 3: In memory expansion and microprocessor mode, the content of these bits can be changed, but the pull-up resistance is not connected.

Pull-up control register 2

b7	b6	b5	b4	b3	b2	b1	b0	Symbol PUR2	Address 03FE ₁₆	When reset 00 ₁₆																										
								<table><tr><th>Bit symbol</th><th>Bit name</th><th>Function</th><th>R:W</th></tr><tr><td>PU20</td><td>P80 to P83 pull-up</td><td rowspan="6">The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high</td><td>☐ ☐</td></tr><tr><td>PU21</td><td>P84 to P87 pull-up (Except P85)</td><td>☐ ☐</td></tr><tr><td>PU22</td><td>P90 to P93 pull-up</td><td>☐ ☐</td></tr><tr><td>PU23</td><td>P94 to P97 pull-up</td><td>☐ ☐</td></tr><tr><td>PU24</td><td>P100 to P103 pull-up</td><td>☐ ☐</td></tr><tr><td>PU25</td><td>P104 to P107 pull-up</td><td>☐ ☐</td></tr><tr><td colspan="3">Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".</td><td>☐ ☐</td></tr></table>	Bit symbol	Bit name	Function	R:W	PU20	P80 to P83 pull-up	The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high	☐ ☐	PU21	P84 to P87 pull-up (Except P85)	☐ ☐	PU22	P90 to P93 pull-up	☐ ☐	PU23	P94 to P97 pull-up	☐ ☐	PU24	P100 to P103 pull-up	☐ ☐	PU25	P104 to P107 pull-up	☐ ☐	Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".			☐ ☐	
Bit symbol	Bit name	Function	R:W																																	
PU20	P80 to P83 pull-up	The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high	☐ ☐																																	
PU21	P84 to P87 pull-up (Except P85)		☐ ☐																																	
PU22	P90 to P93 pull-up		☐ ☐																																	
PU23	P94 to P97 pull-up		☐ ☐																																	
PU24	P100 to P103 pull-up		☐ ☐																																	
PU25	P104 to P107 pull-up		☐ ☐																																	
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be "0".			☐ ☐																																	

Figure 2.16.4. Programmable I/O ports-related registers (3)

[MEMO]

Chapter 3

Examples of Peripheral functions Applications

This chapter presents applications in which peripheral functions built in the M16C/62A are used. They are shown here as examples. In practical use, make suitable changes and perform sufficient evaluation. For basic use, see Chapter 2 Peripheral Functions Usage.

Here follows the list of applications that appear in this chapter.

- 3.1 Long-period timers P2-192
- 3.2 Variable-period variable-duty PWM output P2-196
- 3.3 Delayed one-shot output P2-200
- 3.4 Buzzer output P2-204
- 3.5 Solution for external interrupt pins shortage P2-206
- 3.6 Memory to memory DMA transfer P2-208
- 3.7 Controlling power using stop mode P2-212
- 3.8 Controlling power using wait mode P2-216

[MEMO]

3.1 Long-Period Timers

Overview In this process, Timer A0 and Timer A1 are connected to make a 16-bit timer with a 16-bit prescaler. Figure 3.1.1 shows the operation timing, Figure 3.1.2 shows the connection diagram, and Figures 3.1.3 and 3.1.4 show the set-up procedure.

Use the following peripheral functions:

- Timer mode of timer A
- Event counter mode of timer A

Specifications

- (1) Set timer A0 to timer mode, and set timer A1 to event counter mode.
- (2) Perform a count on count source f1 using timer A0 to count for 1 ms, and perform a count on timer A0 using timer A1 to count for 1 second.
- (3) Connect a 16-MHz oscillator to XIN.

- Operation**
- (1) Setting the count start flag to "1" causes the counter to begin counting. The counter of timer A0 performs a down count on count source f1.
 - (2) If the counter of timer A0 underflows, the counter reloads the content of the reload register and continues counting. At this time, the timer A0 interrupt request bit goes to "1". The counter of timer A1 performs a down count on underflows in timer A0.
 - (3) If the counter of timer A1 underflows, the counter reloads the content of the reload register and continues counting. At this time, the timer A1 interrupt request bit goes to "1".

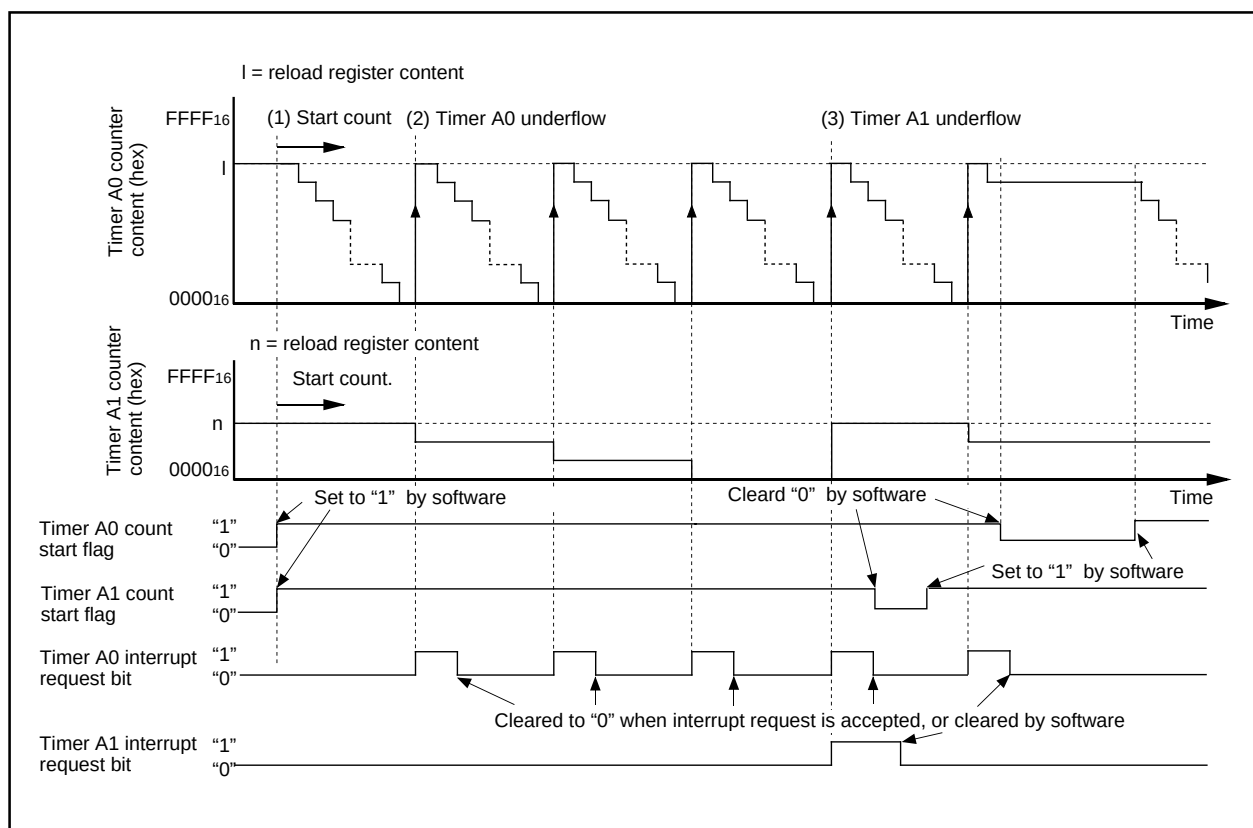


Figure 3.1.1. Operation timing of long-period timers

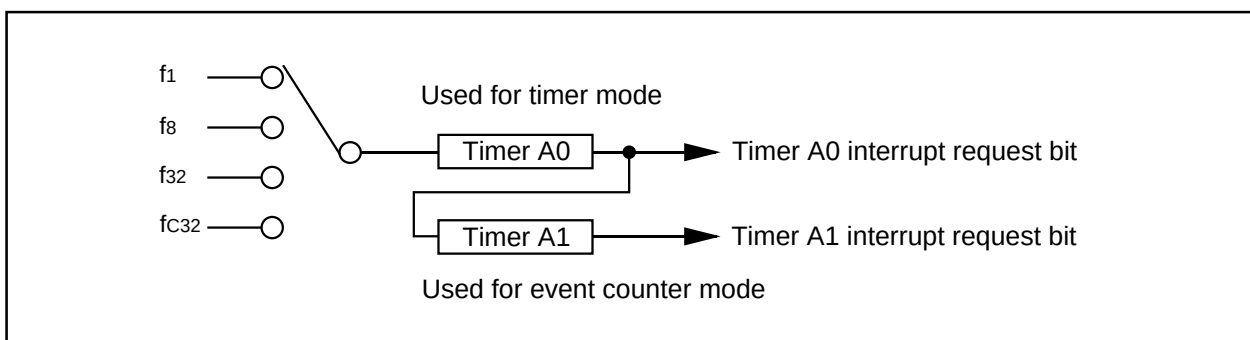
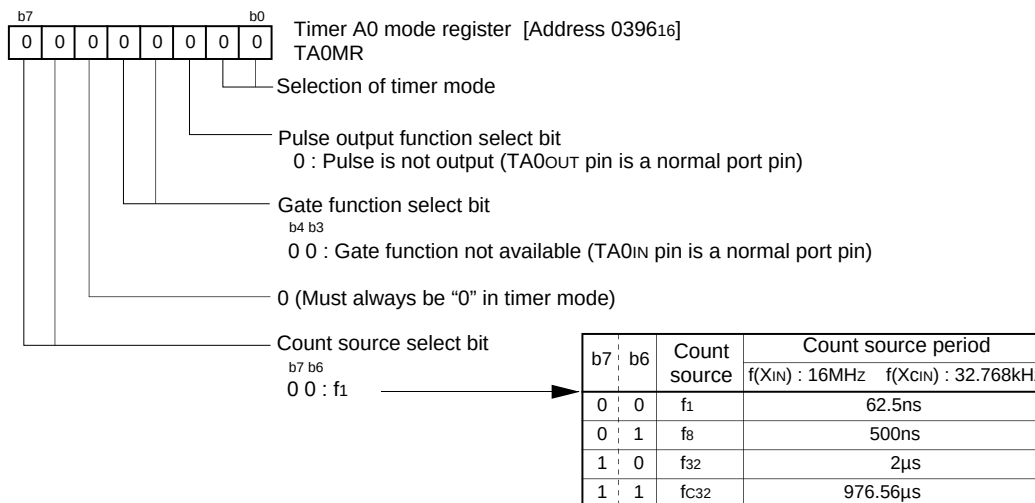


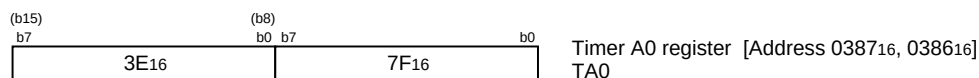
Figure 3.1.2. Connection diagram of long-period timers

Setting timer A0

Selecting timer mode and functions

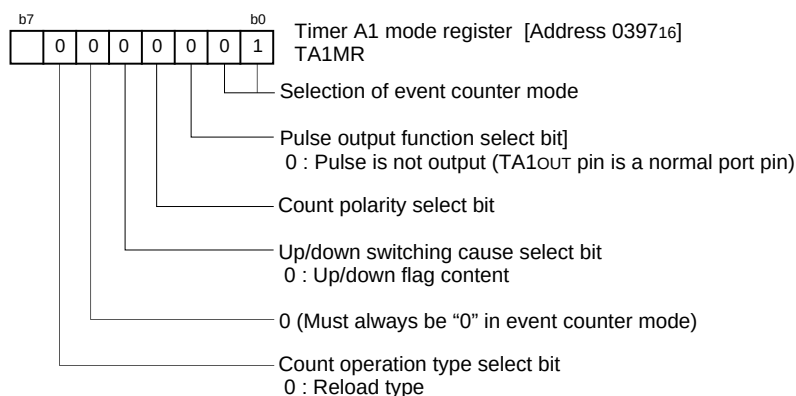


Setting counter value



Setting timer A1

Selecting event counter mode and each function



Continued to the next page

Figure 3.1.3. Set-up procedure of long-period timers (1)

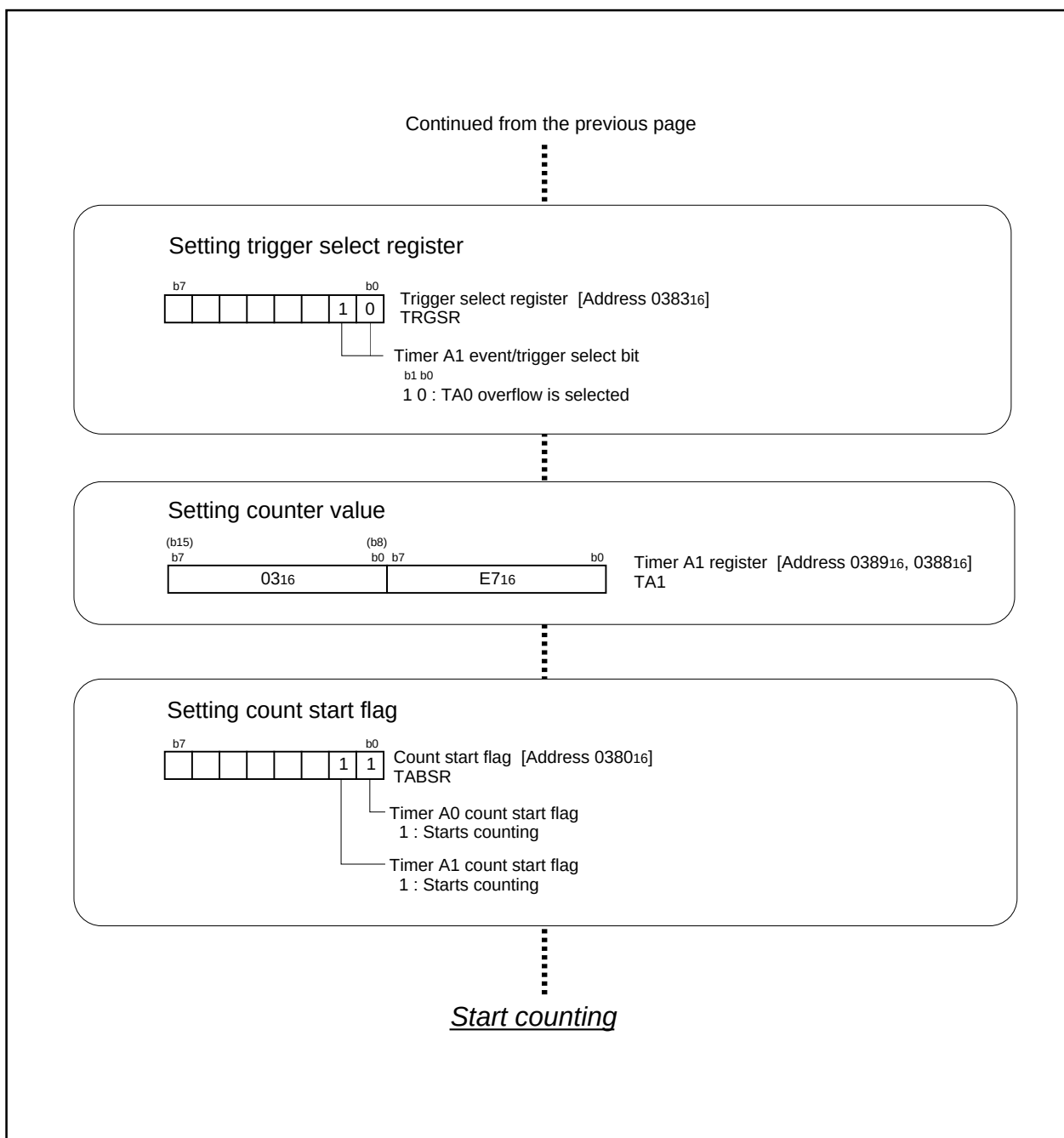


Figure 3.1.4. Set-up procedure of long-period timers (2)

3.2 Variable-Period Variable-Duty PWM Output

Overview In this process, Timer A0 and A1 are used to generate variable-period, variable-duty PWM output. Figure 3.2.1 shows the operation timing, Figure 3.2.2 shows the connection diagram, and Figures 3.2.3 and 3.2.4 show the set-up procedure.

Use the following peripheral functions:

- Timer mode of timer A
- One-shot timer mode of timer A

Specifications

- (1) Set timer A0 in timer mode, and set timer A1 in one-shot timer mode with pulse-output function.
- (2) Set 1 ms, the PWM period, to timer A0. Set 500 μ s, the width of PWM "H" pulse, to timer A1.
Both timer A0 and timer A1 use f1 for the count source.
- (3) Connect a 16-MHz oscillator to XIN.

- Operation**
- (1) Setting the count start flag to "1" causes the counter of timer A0 to begin counting. The counter of timer A0 performs a down count on count source f1.
 - (2) If the counter of timer A0 underflows, the counter reloads the content of the reload register and continues counting. At this time, the timer A0 interrupt request bit goes to "1".
 - (3) An underflow in timer A0 triggers the counter of timer A1 and causes it to begin counting. When the counter of timer A1 begins counting, the output level of the TA1OUT pin goes to "H".
 - (4) As soon as the count of the counter of timer A1 becomes "0000₁₆", the output level of TA1OUT pin goes to "L", and the counter reloads the content of the reload register and stops counting. At the same time, the timer A1 interrupt request bit goes to "1".

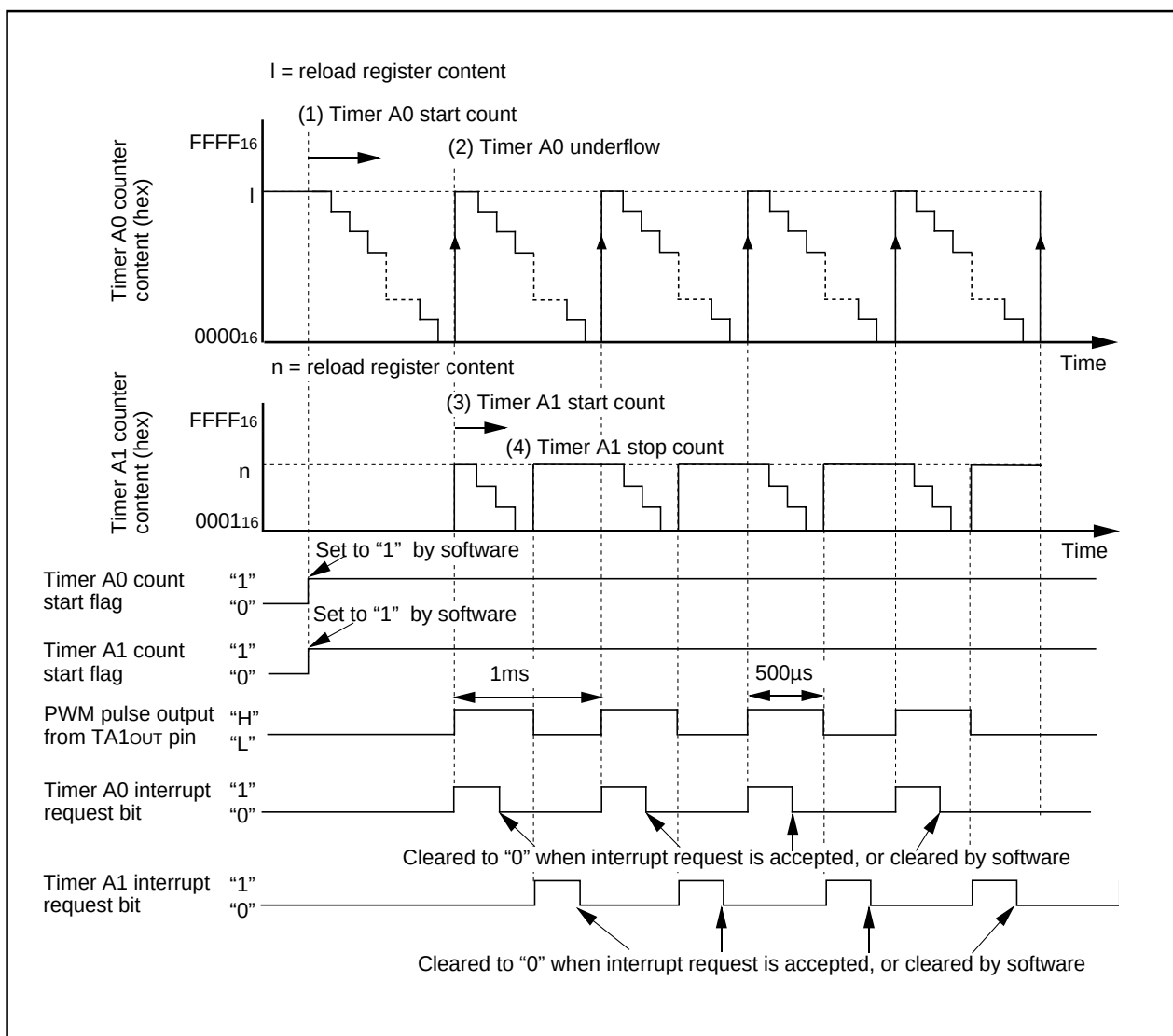


Figure 3.2.1. Operation timing of variable-period variable-duty PWM output

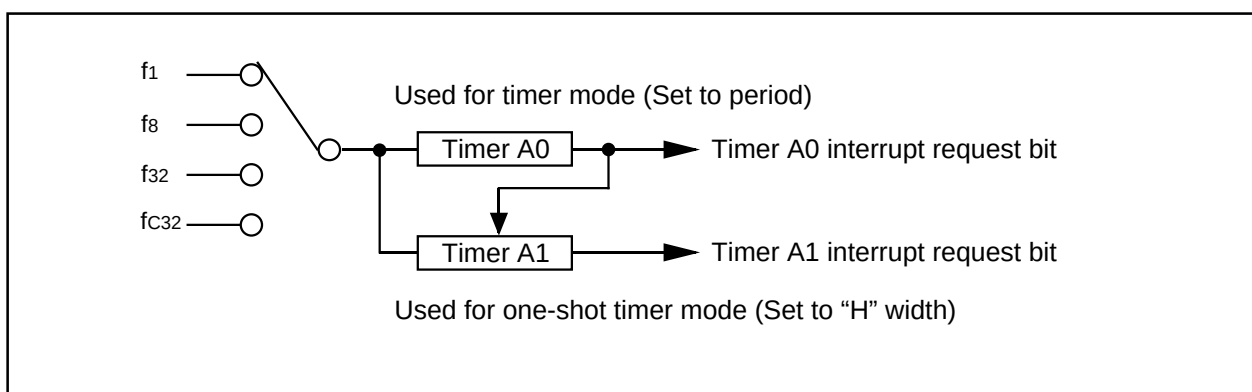
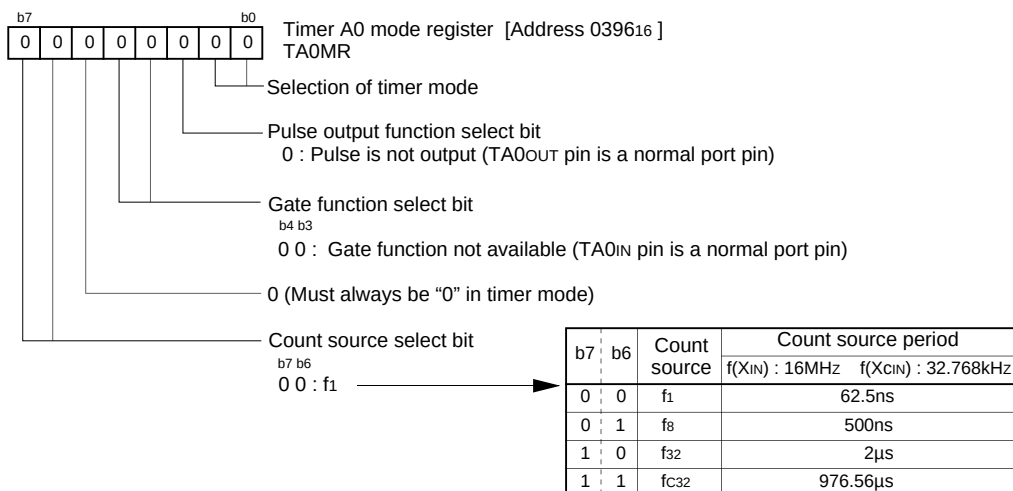


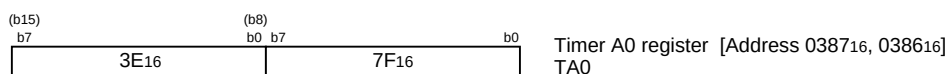
Figure 3.2.2. Connection diagram of variable-period variable-duty PWM output

Setting timer A0

Selecting timer mode and functions

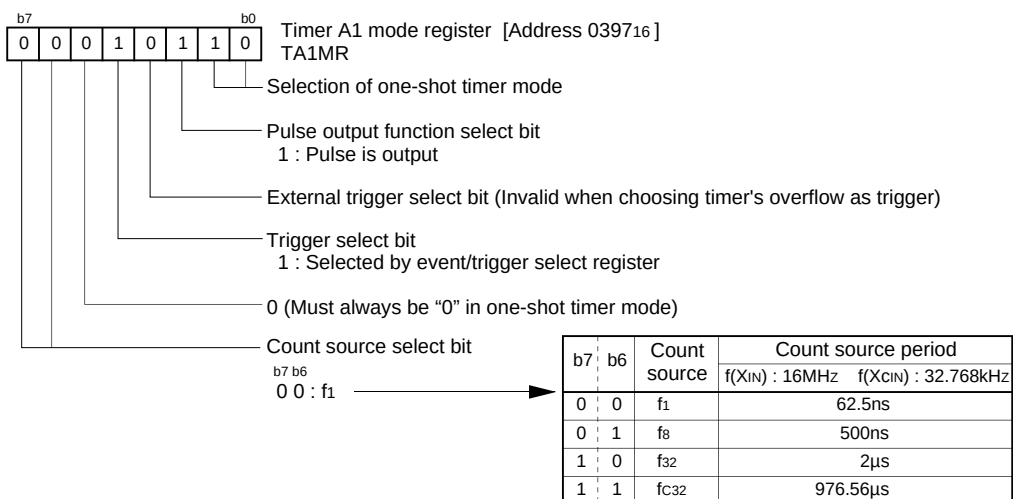


Setting counter value



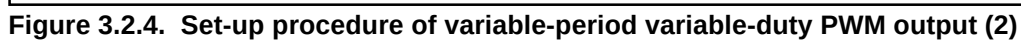
Setting timer A1

Selecting one-shot timer mode and functions



Continued to the next page

Figure 3.2.3. Set-up procedure of variable-period variable-duty PWM output (1)



3.3 Delayed One-Shot Output

Overview The following are steps of outputting a pulse only once after a specified elapse since an external trigger is input. Figure 3.3.1 shows the operation timing, Figure 3.3.2 shows the connection diagram, and Figures 3.3.3 and 3.3.4 show the set-up procedure.

Use the following peripheral function:

- One-shot timer mode of timer A

Specifications

- (1) Set timer A0 in one-shot timer mode, and set timer A1 in one-shot timer mode with pulse-output function.
- (2) Set 1 ms, an interval before a pulse is output, in timer A0; and set 50 μ s, a pulse width, in timer A1. Both timer A0 and timer A1 use f1 for the count source.
- (3) Connect a 16-MHz oscillator to XIN.

- Operation**
- (1) Setting the trigger select bit to "1" and setting the count start flag to "1" enables the counter of timer A0 to count.
 - (2) If an effective edge, selected by use of the external trigger select bit, is input to the TA0IN pin, the counter begins a down count. The counter of timer A0 performs a down count on count source f1.
 - (3) As soon as the counter of timer A0 becomes "0000₁₆", the counter reloads the content of the reload register and stops counting. At this time, the timer A0 interrupt request bit goes to "1".
 - (4) An underflow in timer A0 triggers the counter of timer A1 and causes it to begin counting. When timer A1 begins counting, the output level of the TA1OUT pin goes to "H".
 - (5) As soon as the counter of timer A1 becomes "0000₁₆", the output level of the TA1OUT pin goes to "L", the counter reloads the content of the reload register, and stops counting. At this time, timer A1 interrupt request bit goes to "1".

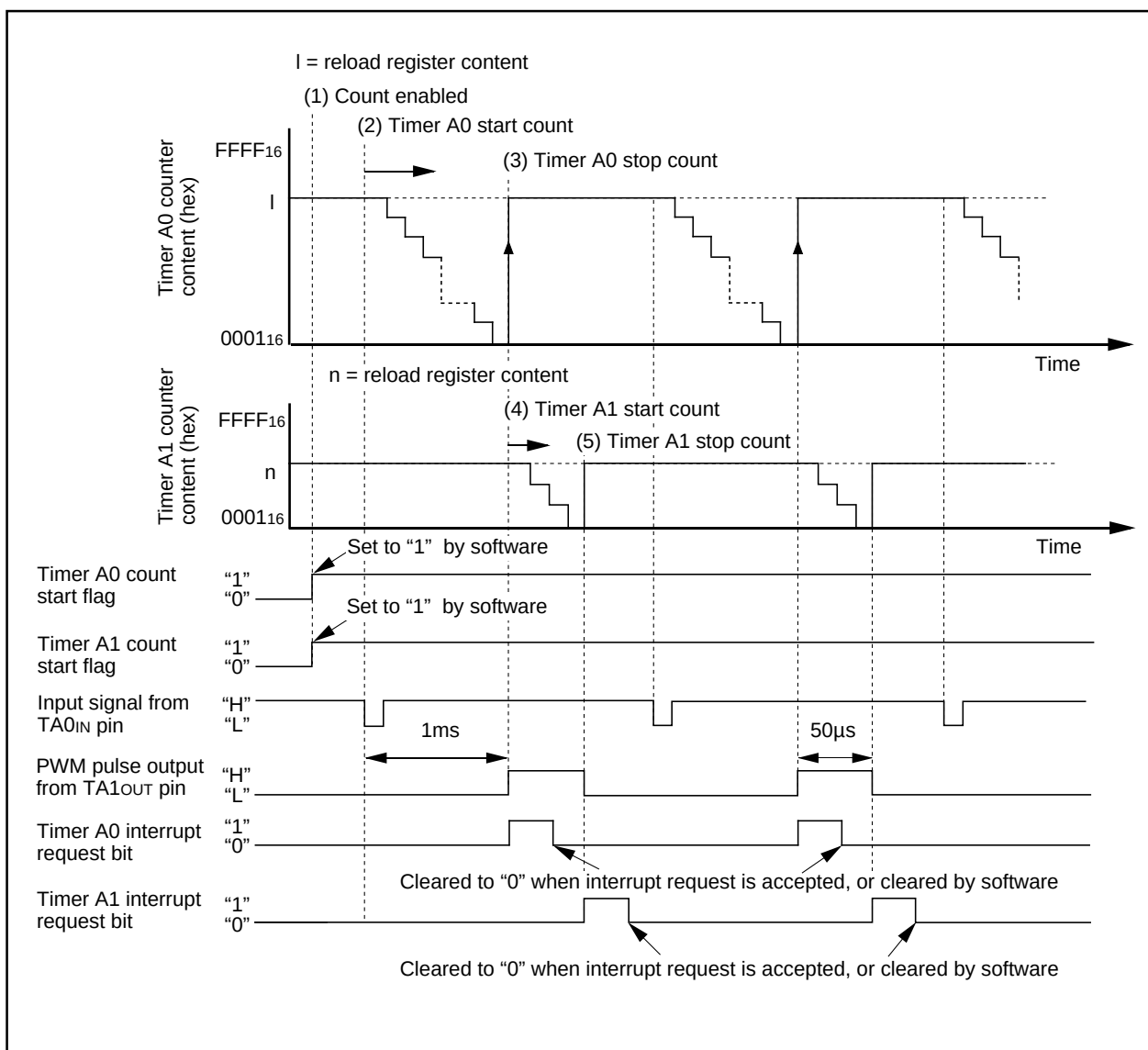


Figure 3.3.1. Operation timing of delayed one-shot output

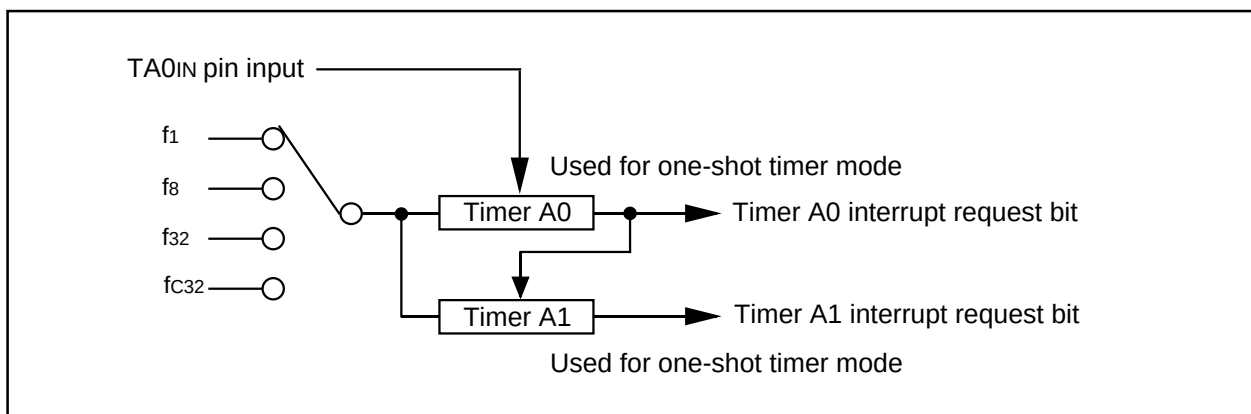
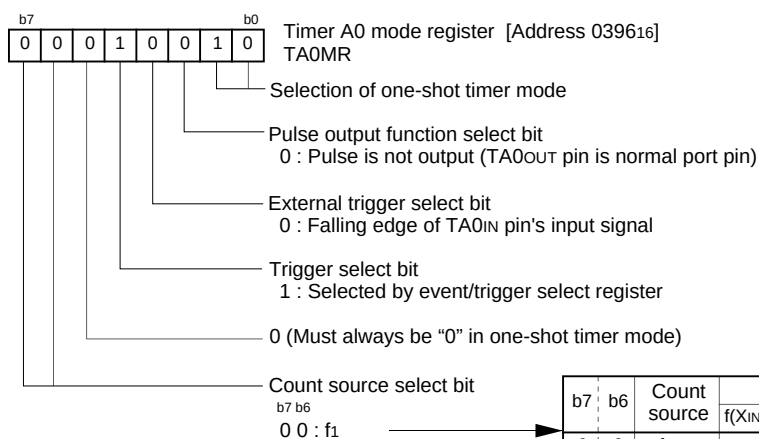


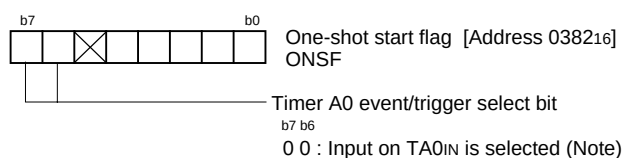
Figure 3.3.2. Connection diagram of delayed one-shot output

Setting timer A0

Selecting one-shot timer mode and functions

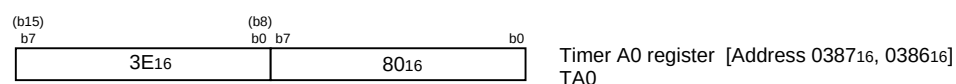


b7	b6	Count source	Count source period	
			f(X _{IN}) : 16MHz	f(X _{CIN}) : 32.768kHz
0	0	f ₁	62.5ns	
0	1	f ₈	500ns	
1	0	f ₃₂	2μs	
1	1	f _{C32}	976.56μs	

Setting one-shot start flag
(Select TA0IN pin to input TA0 trigger)

Note: Set the corresponding port direction register to "0".

Setting delay time



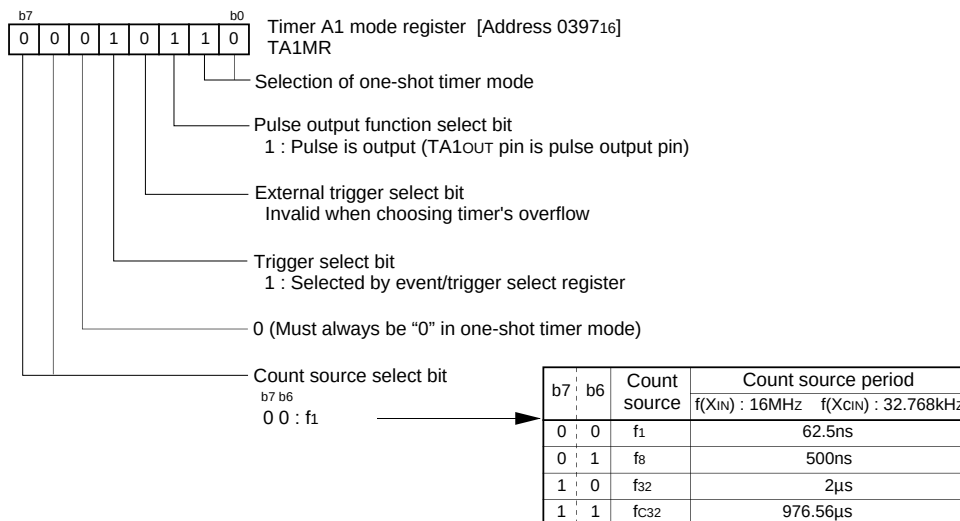
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Figure 3.3.3. Set-up procedure of delayed one-shot output (1)

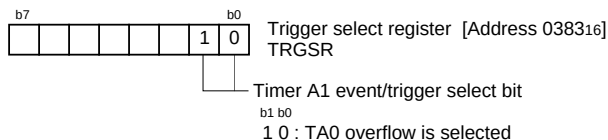
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Setting timer A1

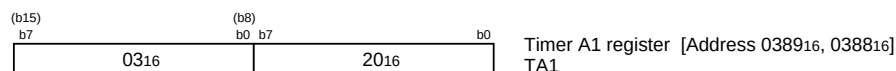
Selecting one-shot timer mode and functions



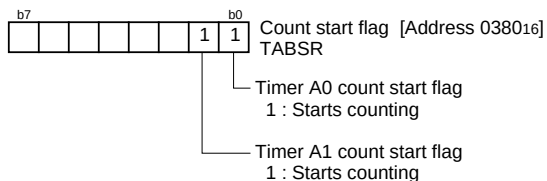
Setting trigger select register (Set timer A0 to trigger timer A1)



Setting one-shot timer's time



Setting count start flag



Start counting

Figure 3.3.4. Set-up procedure of delayed one-shot output (2)

3.4 Buzzer Output

Overview The timer mode is used to make the buzzer ring. Figure 3.4.1 shows the operation timing, and Figure 3.4.2 shows the set-up procedure.

Use the following peripheral function:

- The pulse-outputting function in timer mode of timer A.

Specifications

- (1) Sound a 2-kHz buzz beep by use of timer A0.
- (2) Effect pull-up in the relevant port by use of a pull-up resistor. When the buzzer is off, set the port high-impedance, and stabilize the potential resulting from pulling up.
- (3) Connect a 16-MHz oscillator to X_{IN}.

Operation

- (1) The microcomputer begins performing a count on timer A0. Timer A0 has disabled interrupts.
- (2) The microcomputer begins pulse output by setting the pulse output function select bit to "Pulse output effected". P7₀ changes into TA0_{OUT} pin and outputs 2-kHz pulses.
- (3) The microcomputer stops outputting pulses by setting the pulse output function select bit to "Pulse output not effected". P7₀ goes to an input pin, and the output from the pin becomes high-impedance.

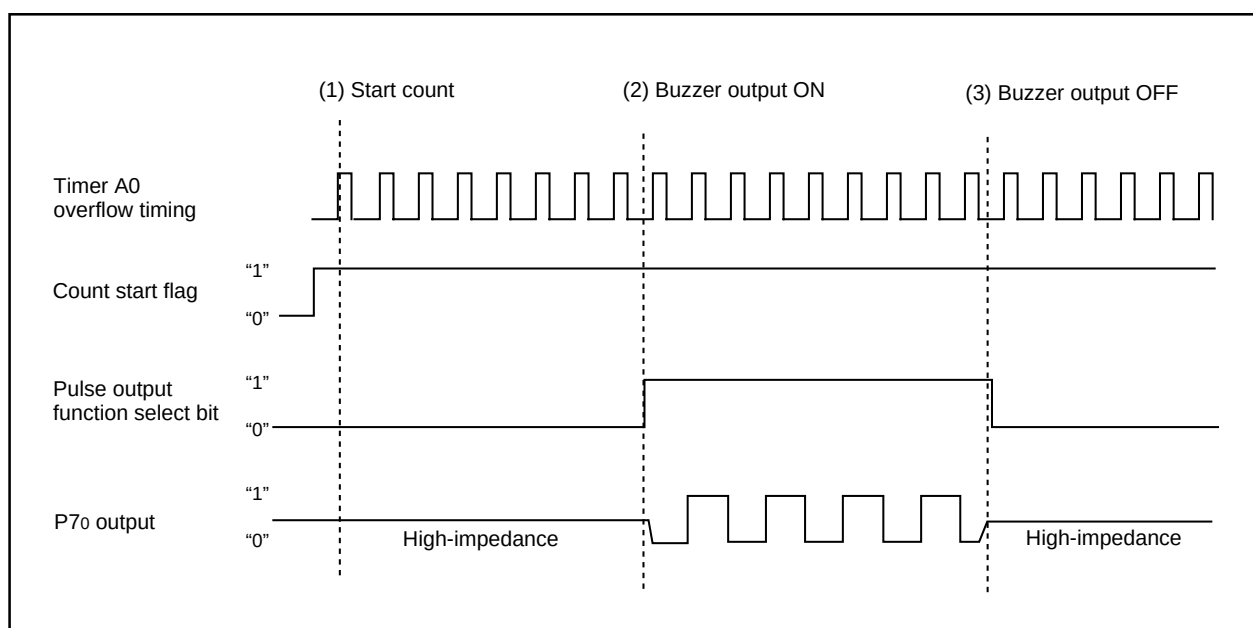


Figure 3.4.1. Operation timing of buzzer output

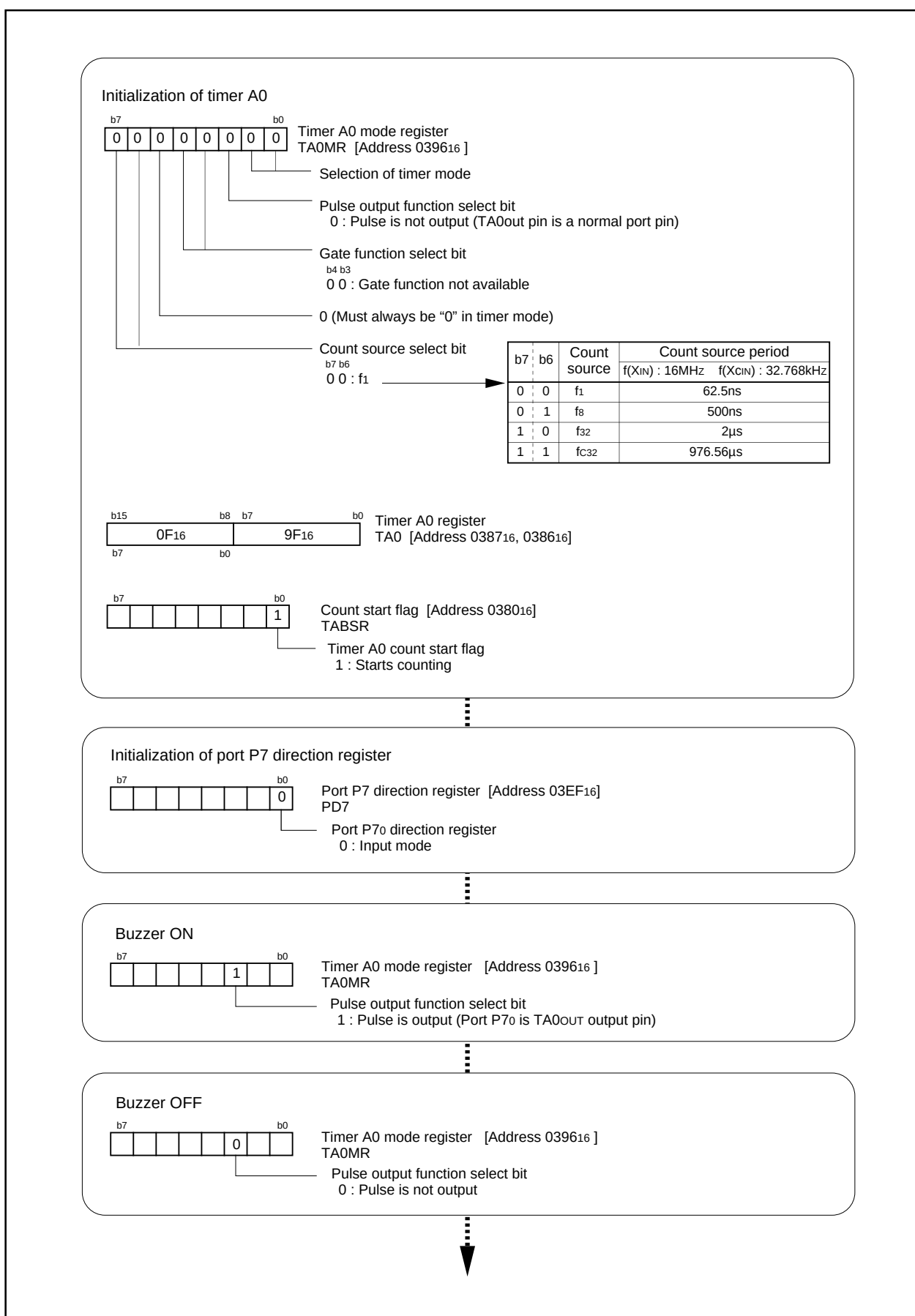


Figure 3.4.2. Set-up procedure of buzzer output

3.5 Solution for External Interrupt Pins Shortage

Overview The following are solution for external interrupt pins shortage. Figure 3.5.1 shows the set-up procedure.

Use the following peripheral function:

- Event counter mode of timer A

Specifications

(1) Inputting a falling edge to the TA0IN pin generates a timer A0 interrupt.

Operation (1) Set timer A0 to event counter mode, set timer to "0", and set interrupt priority levels in timer A0.
(2) Inputting a falling edge to the TA0IN pin generates a timer A0 interrupt.

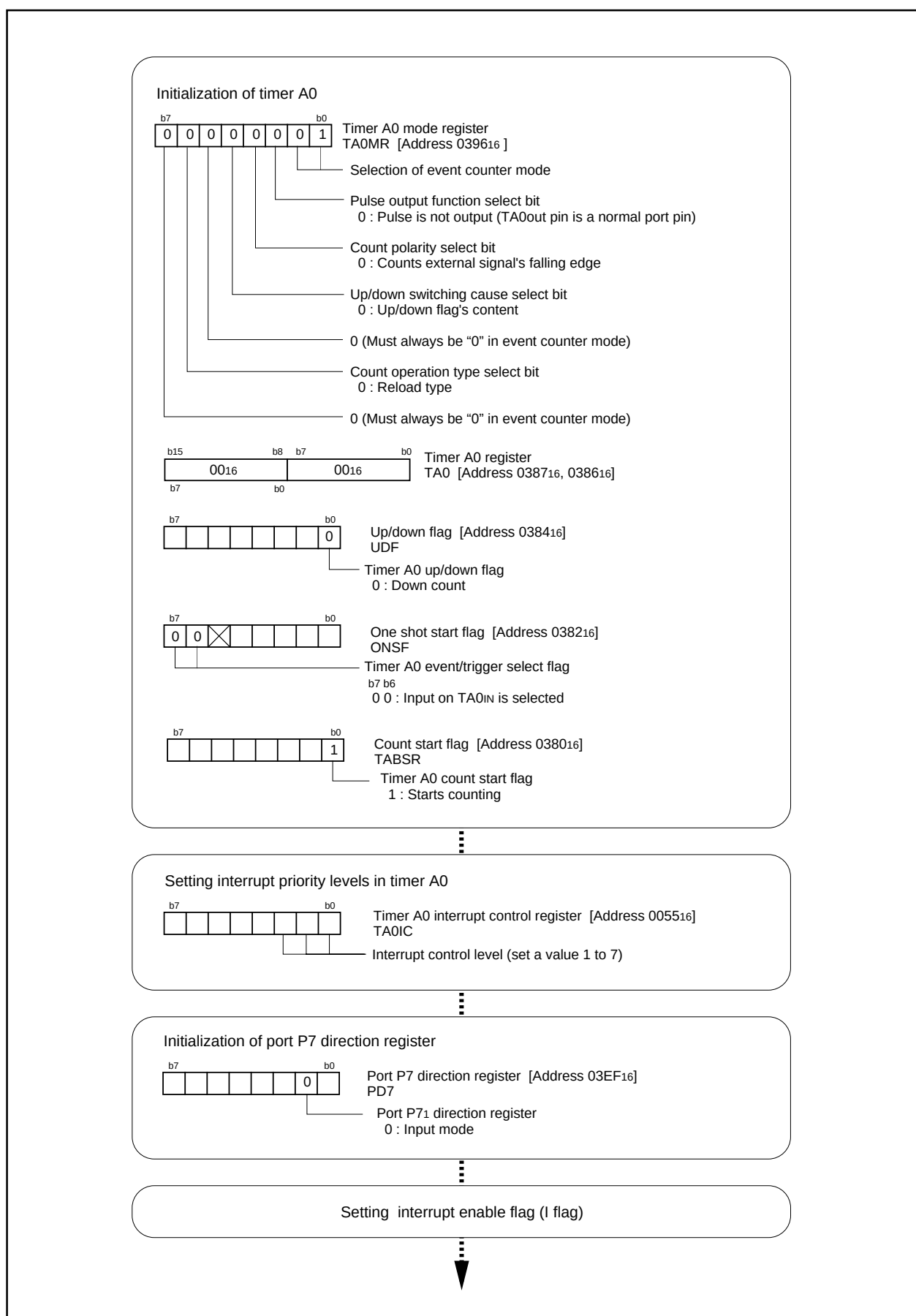


Figure 3.5.1. Set-up procedure of solution for a shortage of external interrupt pins

3.6 Memory to Memory DMA Transfer

Overview The following are steps for changing both source address and destination address to transfer data from memory to another. The DMA transfer utilizes the workings that assign a higher priority to the DMA0 transfer if transfer requests simultaneously occur in two DMA channels. Figure 3.6.1 shows the operation timing, Figure 3.6.2 shows the block diagram, and Figures 3.6.3 and 3.6.4 show the set-up procedure.

Use the following peripheral functions:

- Timer mode of timer A
- Two DMAC channels
- One-byte temporary RAM (address 0800₁₆)

Specifications

- (1) Transfer the content of memory extending over 128 bytes from address A0000₁₆ to a 128-byte area starting from address C0000₁₆. Transfer the content every time a timer A0 interrupt request occurs.
- (2) Use DMA0 for a transfer from the source to built-in memory, and DMA1 for a transfer from built-in memory to the destination.

- Operation**
- (1) A timer A interrupt request occurs. Though both a DMA0 transfer request and a DMA1 transfer request occur simultaneously, the former is executed first.
 - (2) DMA0 receives a transfer request and transfers data from the source to the built-in memory. At this time, the source address is incremented.
 - (3) Next, DMA1 receives a transfer request and transfers data involved from built-in memory to the destination. At this time, the destination address is incremented.

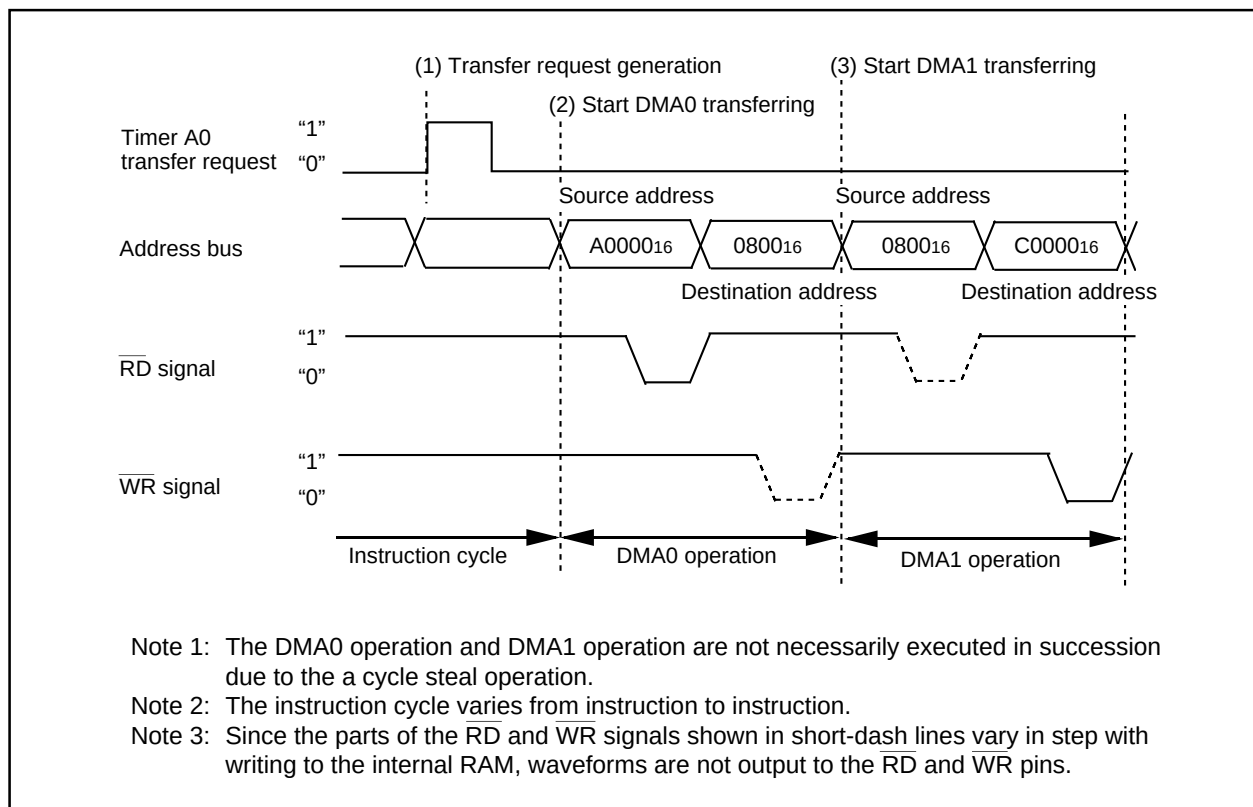


Figure 3.6.1. Operation timing of memory to memory DMA transfer

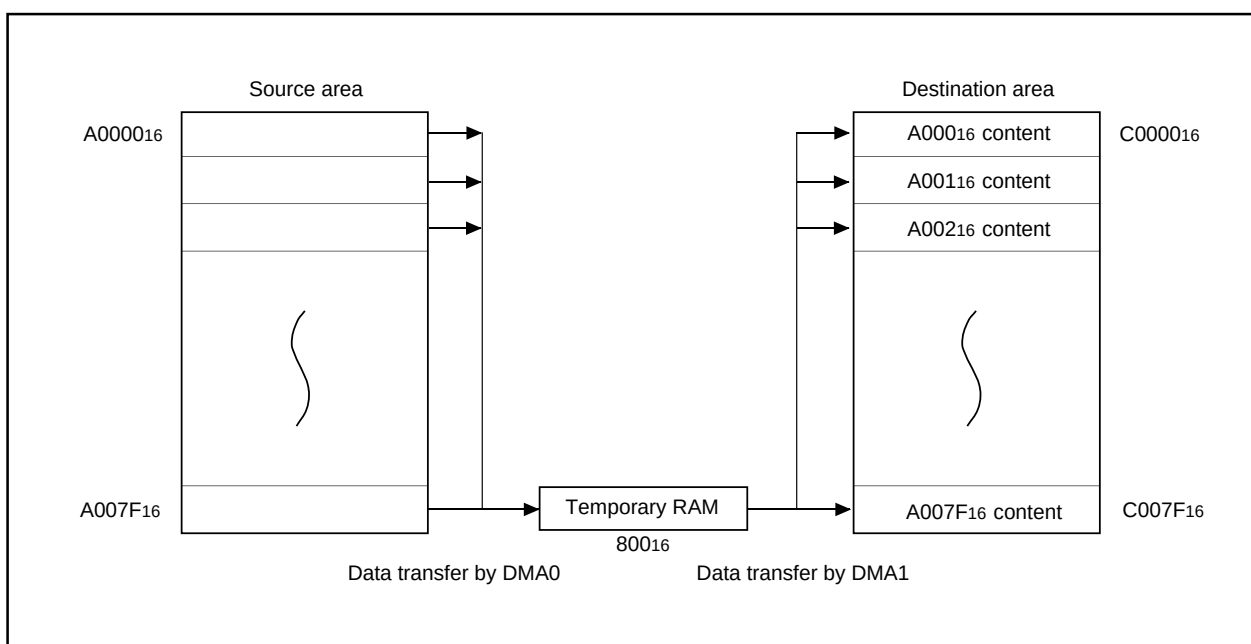


Figure 3.6.2. Block diagram of memory to memory DMA transfer

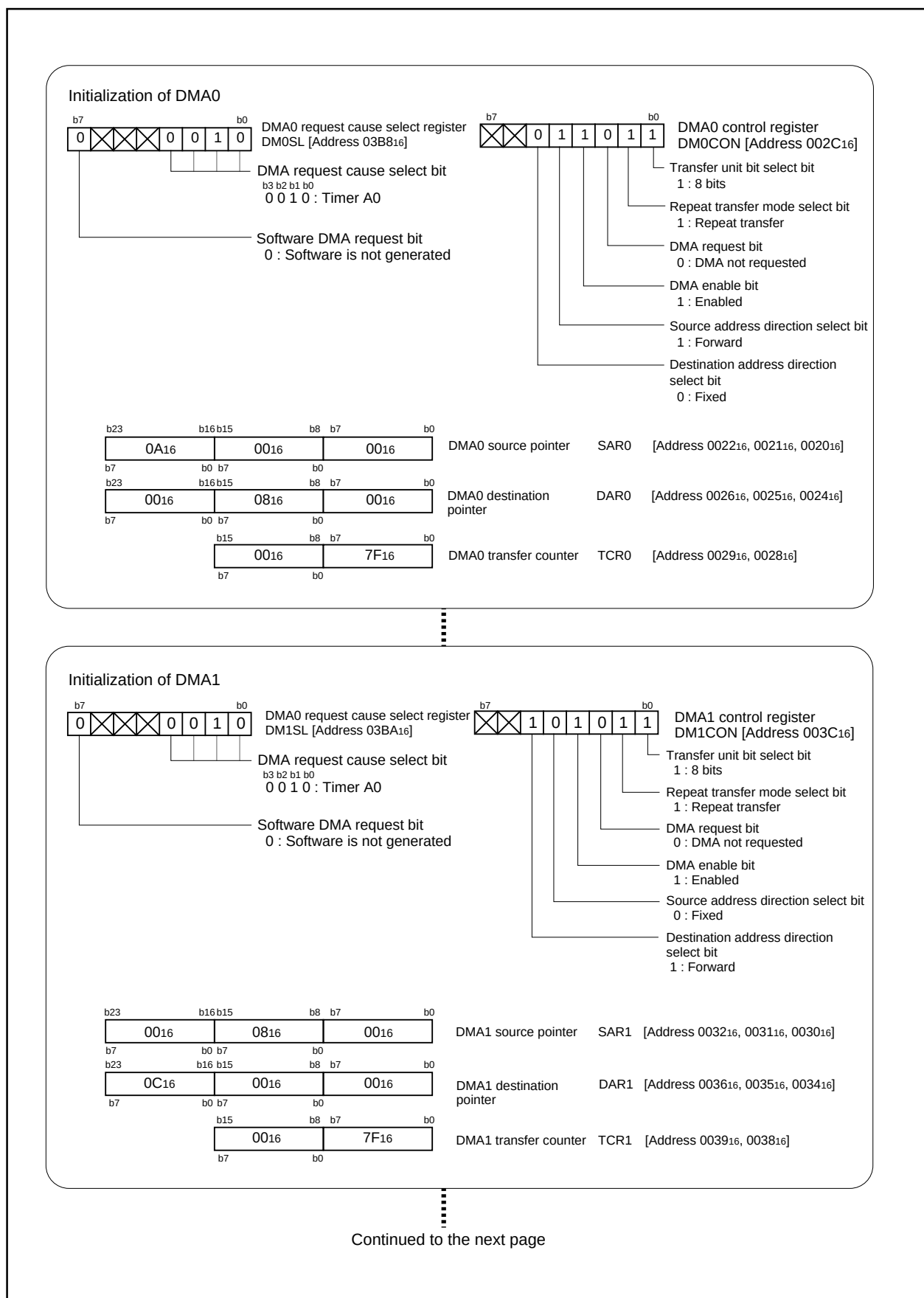


Figure 3.6.3. Set-up procedure of memory to memory DMA transfer (1)

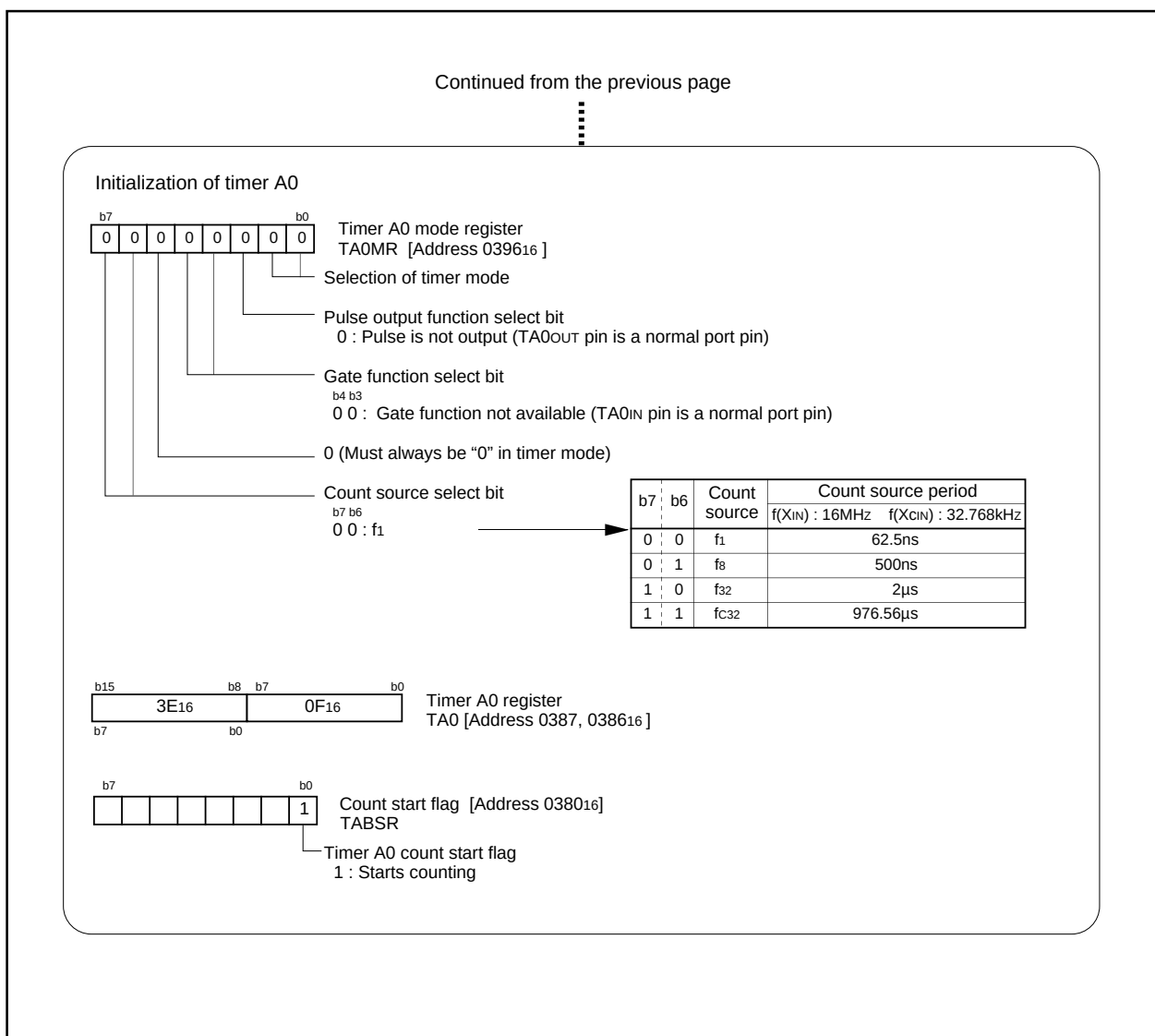


Figure 3.6.4. Set-up procedure of memory to memory DMA transfer (2)

3.7 Controlling Power Using Stop Mode

Overview The following are steps for controlling power using stop mode. Figure 3.7.1 shows the operation timing, Figure 3.7.2 shows an example of circuit, and Figures 3.7.3 and 3.7.4 show the set-up procedure.

Use the following peripheral functions:

- Key-input interrupts
- Stop mode
- Pull-up function

Specifications

- (1) Use P100 through P103 for the scan output pins of a key matrix. Use the input pins ($\overline{KI0}$ through $\overline{KI3}$) of the key-input interrupt function for the key-input reading pins. The pull-up function is also used.
- (2) If a key-input interrupt request occurs, clear the stop mode and read a key.

- Operation**
- (1) Enable a key-input interrupt and set the pull-up function to pins $\overline{KI0}$ through $\overline{KI3}$. Change the output of P100 through P103 to "L" and enter stop mode.
 - (2) If a key is pressed, "L" is input to one of pins $\overline{KI0}$ through $\overline{KI3}$ to clear stop mode. A key-input interrupt occurs to execute the key-input interrupt handling routine.
 - (3) Sequentially set P100 through P103 to "L" to determine which key was pressed.
 - (4) When the process to determine the key pressed is completed, change the output from P100 through P103 to "L" again and enter stop mode.

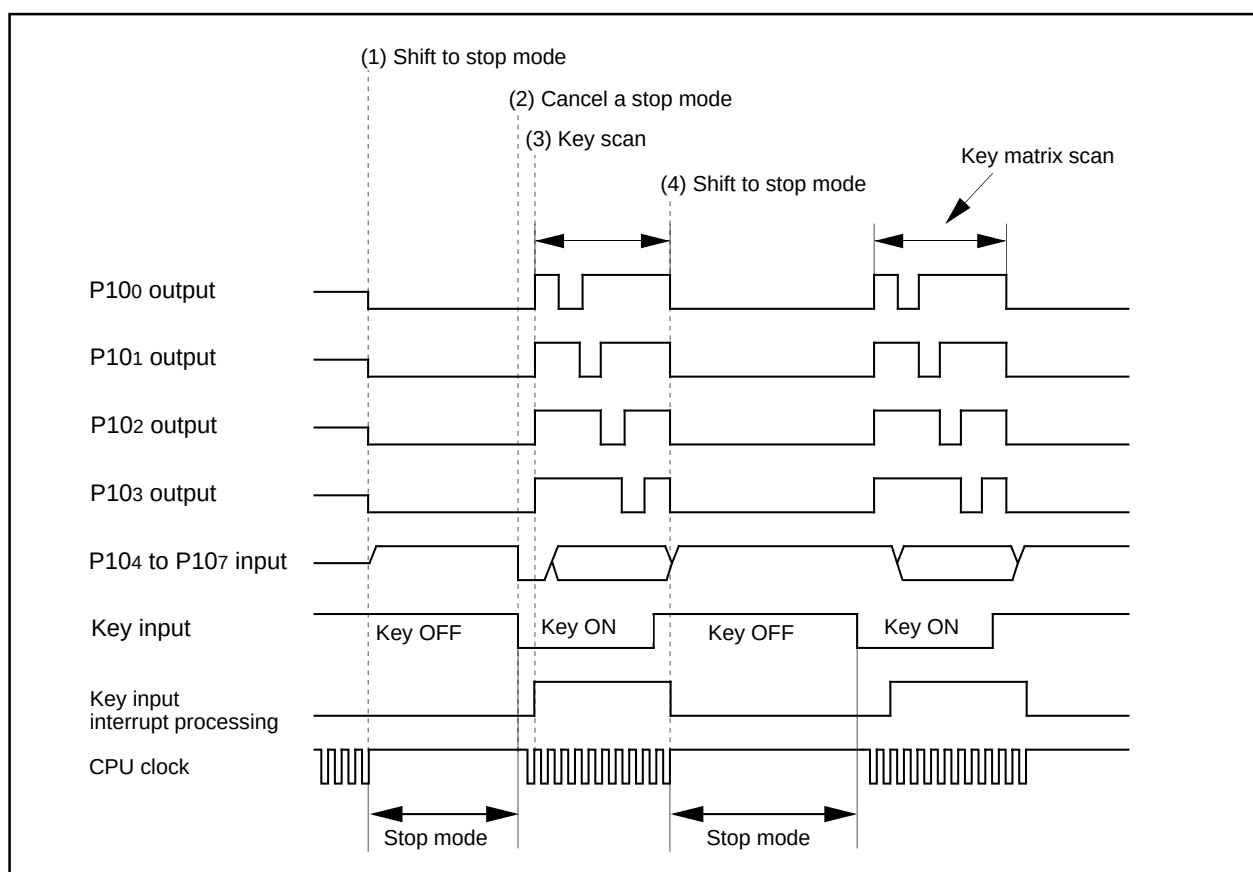


Figure 3.7.1. Operation timing of controlling power using stop mode

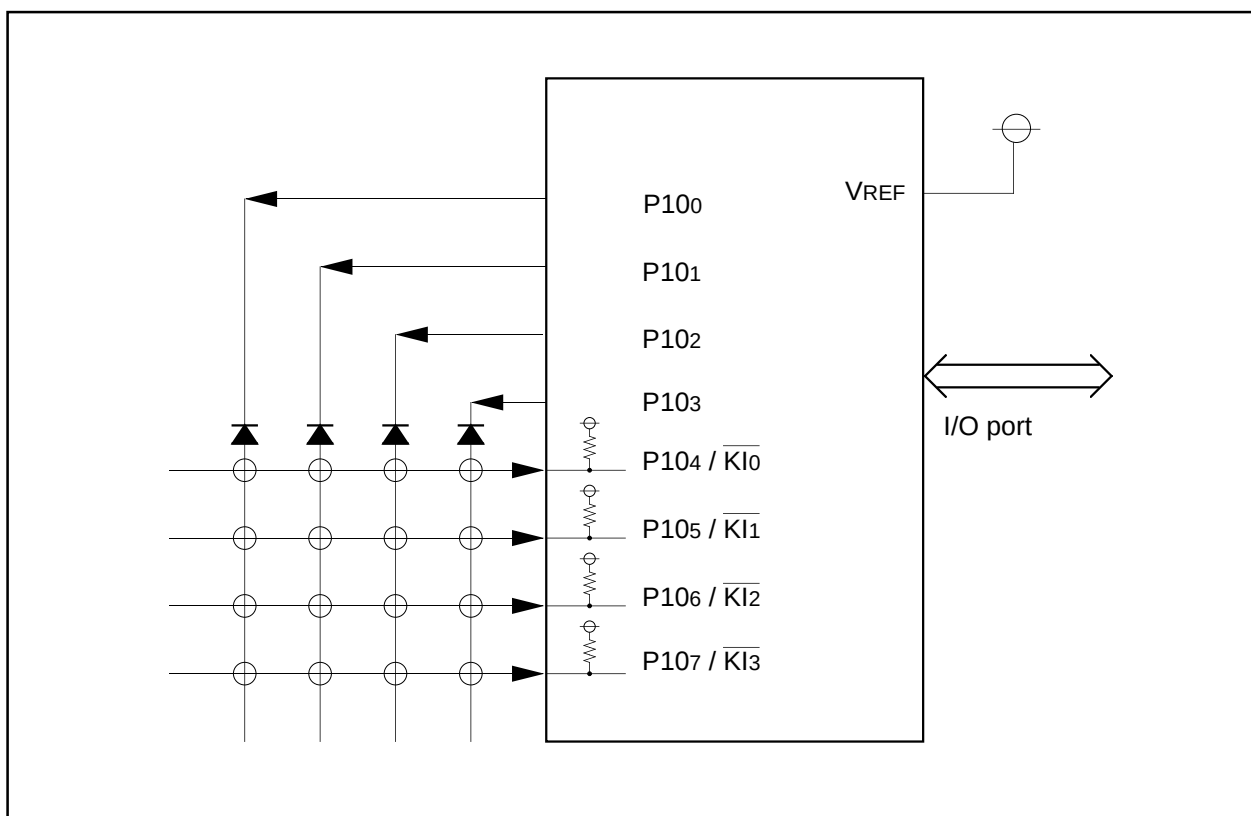


Figure 3.7.2. Example of circuit of controlling power using stop mode

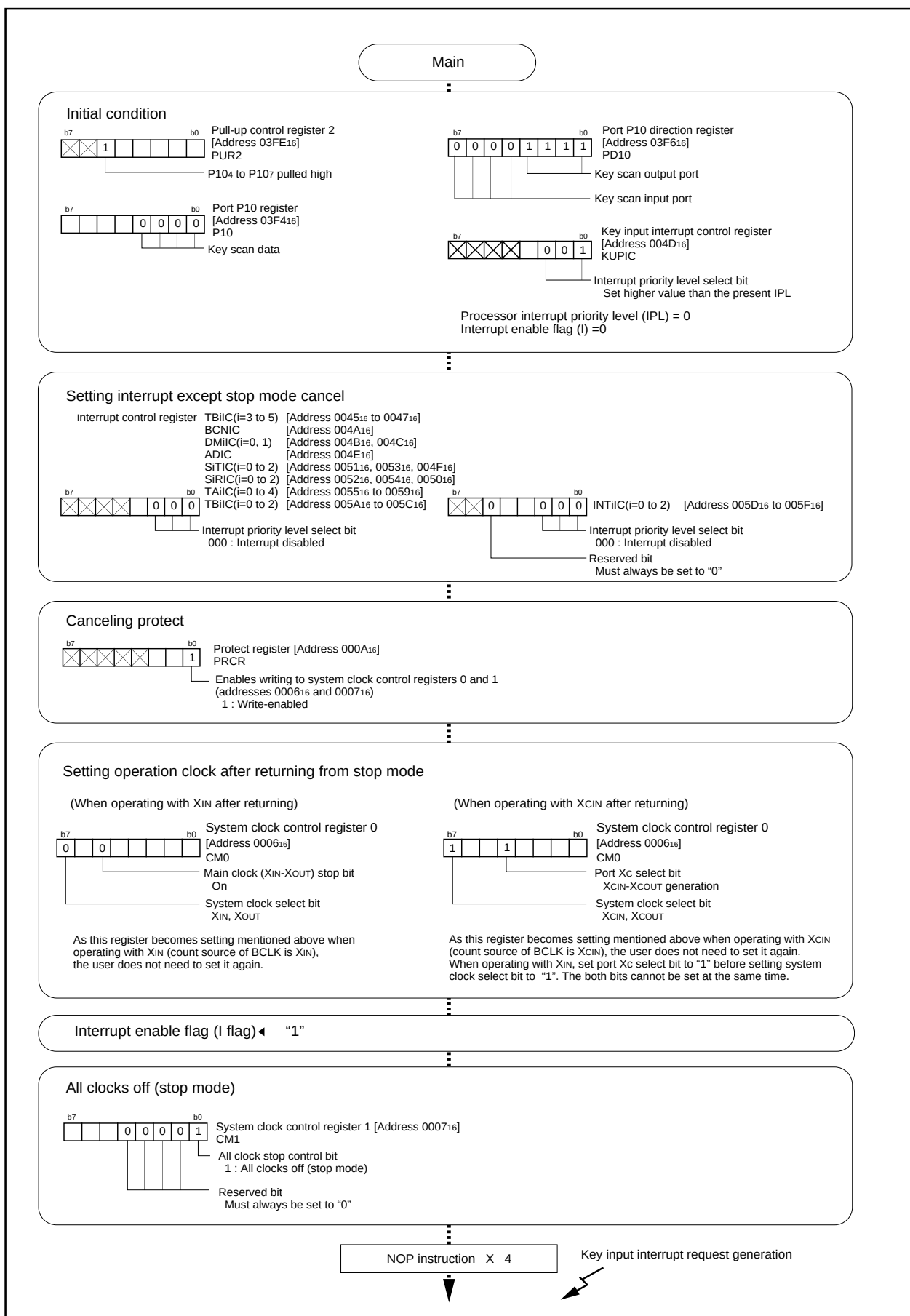


Figure 3.7.3. Set-up procedure of controlling power using stop mode (1)

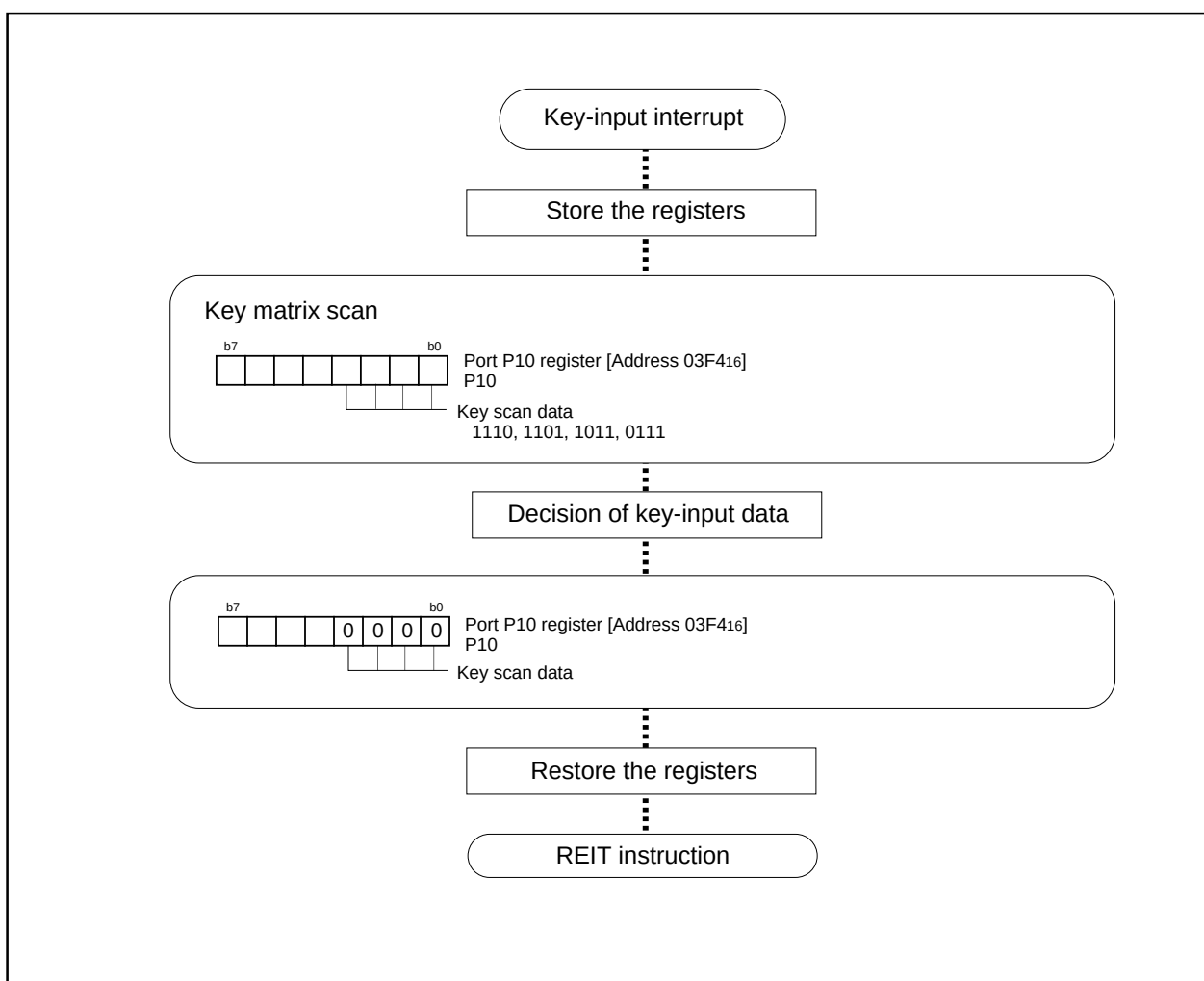


Figure 3.7.4. Set-up procedure of controlling power using stop mode (2)

3.8 Controlling Power Using Wait Mode

Overview The following are steps for controlling power using wait mode. Figure 3.8.1 shows the operation timing, and Figures 3.8.2 to 3.8.4 show the set-up procedure.

Use the following peripheral functions:

- Timer mode of timer B
- Wait mode

A flag named "F-WIT" is used in the set-up procedure. The purpose of this flag is to decide whether or not to clear wait mode. If F_WIT = "1" in the main program, the wait mode is entered; if F_WIT = "0", the wait mode is cleared.

Specifications

- (1) Connect a 32.768-kHz oscillator to XCIN to serve as the timer count source. As interrupts occur every one second, which is a count the timer reaches, the controller returns from wait mode and count the clock using a program.
- (2) Clear wait mode if a $\overline{\text{INT0}}$ interrupt request occurs.

- Operation**
- (1) Switch the system clock from XIN to XCIN to get low-speed mode.
 - (2) Stop XIN and enter wait mode. In this instance, enable the timer B2 interrupt and the $\overline{\text{INT0}}$ interrupt.
 - (3) When a timer B2 interrupt request occurs (at 1-second intervals), start supplying the BCLK from XCIN.
- At this time, count the clock within the routine that handles the timer B2 interrupts and enter wait mode again.
- (4) If a $\overline{\text{INT0}}$ interrupt occurs, start supplying the BCLK from XCIN. Start the XIN oscillation within the $\overline{\text{INT0}}$ interrupt, and switch the system clock to XIN.

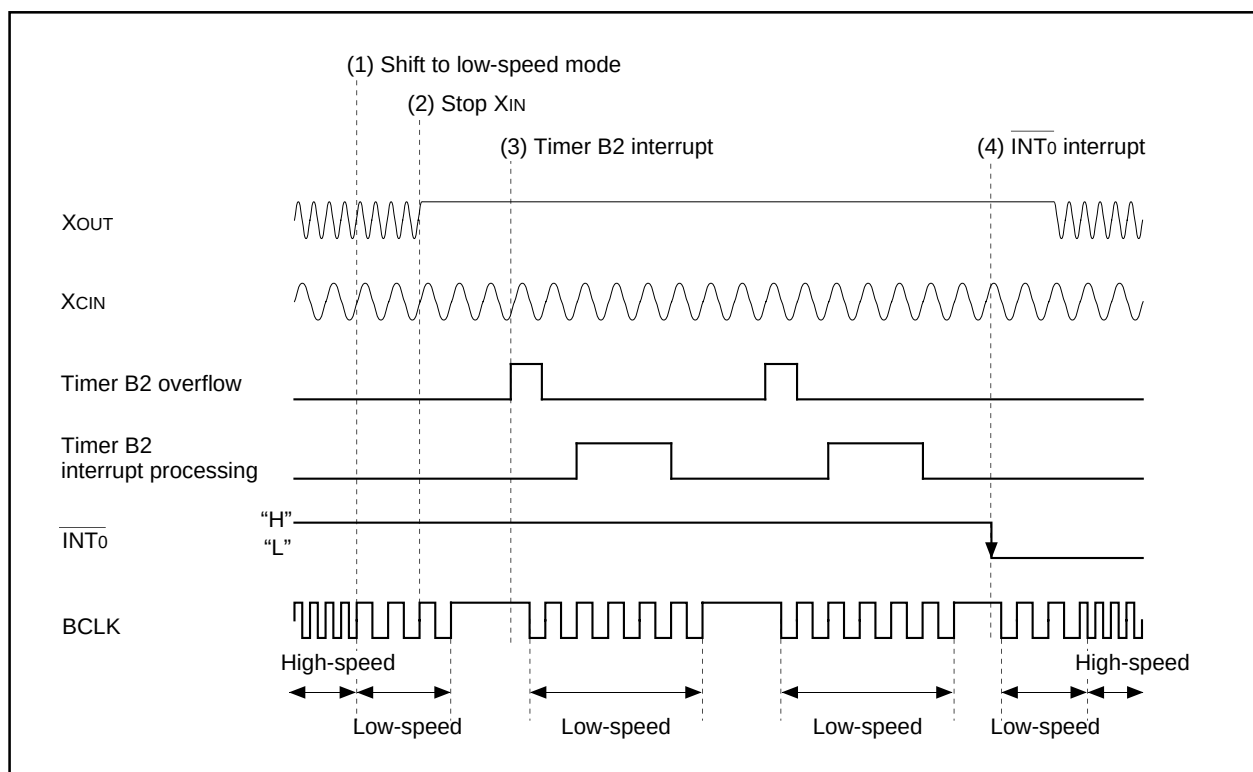


Figure 3.8.1. Operation timing of controlling power using wait mode

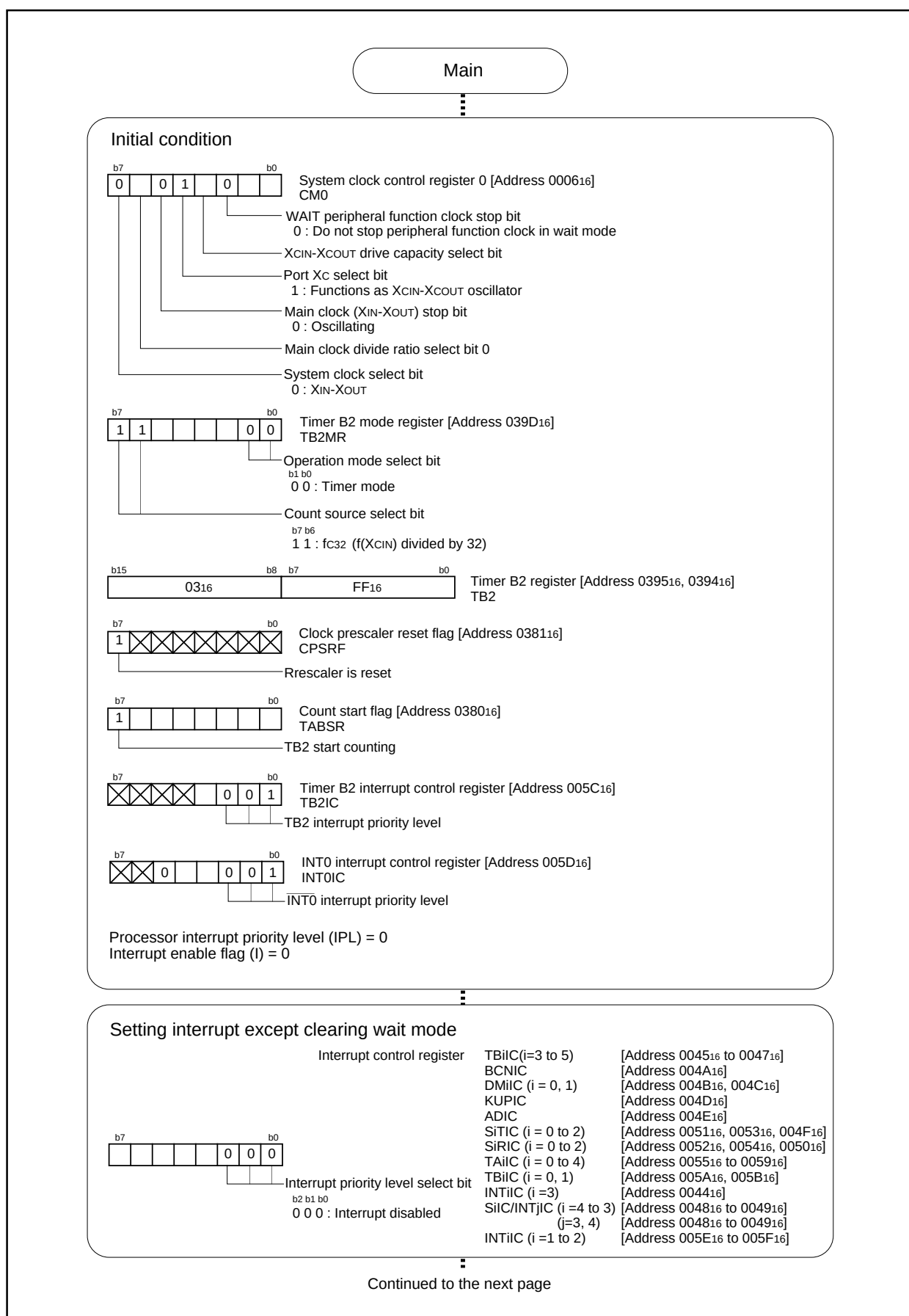


Figure 3.8.2. Set-up procedure of controlling power using wait mode (1)

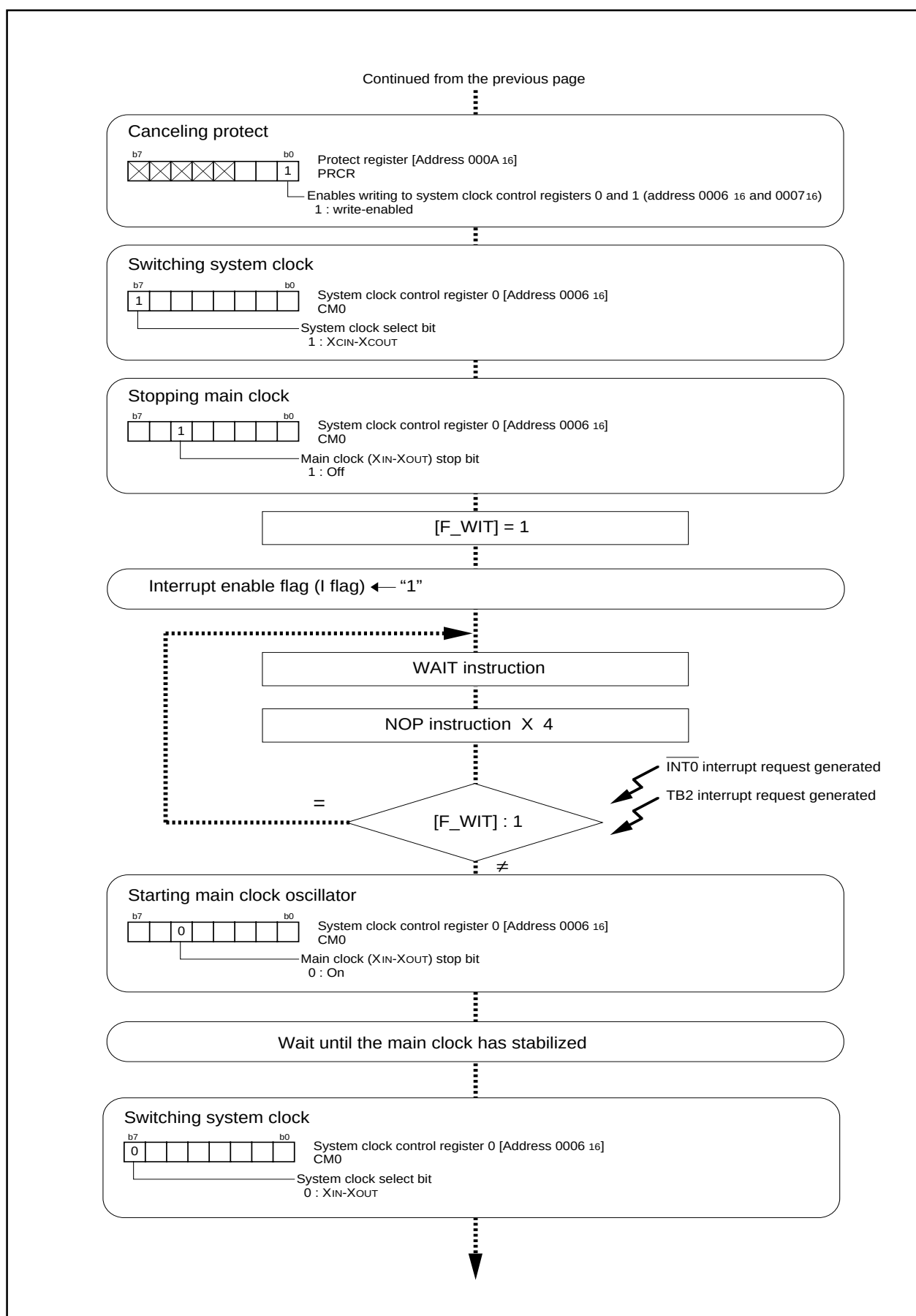


Figure 3.8.3. Set-up procedure of controlling power using wait mode (2)

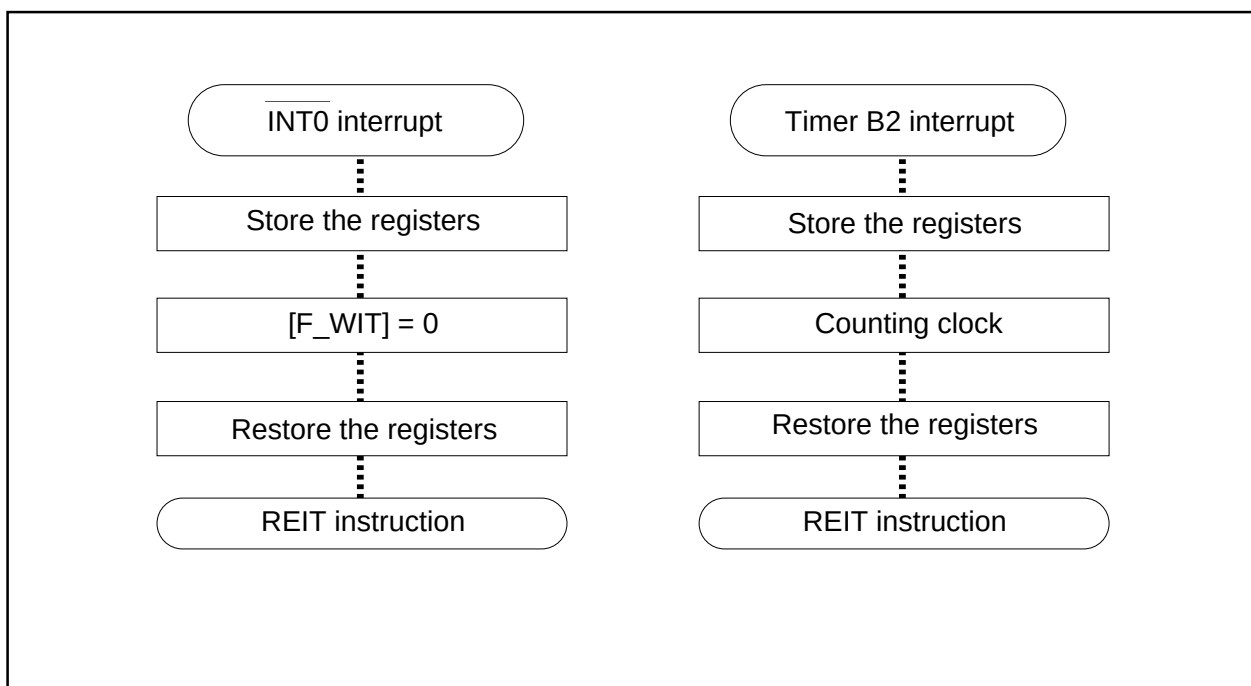


Figure 3.8.4. Set-up procedure of controlling power using wait mode (3)

[MEMO]

Chapter 4

External Buses

4.1 Overview of External Buses

Memory and I/O external expansion can be connected to microcomputer easily by using external buses. When memory expansion mode or microprocessor mode is selected for processor mode, some of the pins function as the address bus, the data bus, and as control signals and this makes the external buses be able to operate.

When accessing an external area, 8-bit data bus width or 16-bit data bus width can be selected, based on the BYTE pin level. 16-bit width is used to access an internal area, regardless of the level of the BYTE pin. Fix the BYTE pin either to "H" or "L" level. 8-bit and 16-bit data bus widths cannot be used together in an external area.

4.2 Data Access

4.2.1 Data Bus Width

If the voltage level input to the BYTE pin is “H”, the external data bus width becomes 8 bits, and P10 (/D8) through P17 (/D15) can be used as I/O ports (Figure 4.2.1).

If the voltage level input to the BYTE pin is “L”, the external data bus width becomes 16 bits, and P10 (/D8) through P17 (/D15) operate as a data bus (D8 through D15) (Figure 4.2.1).

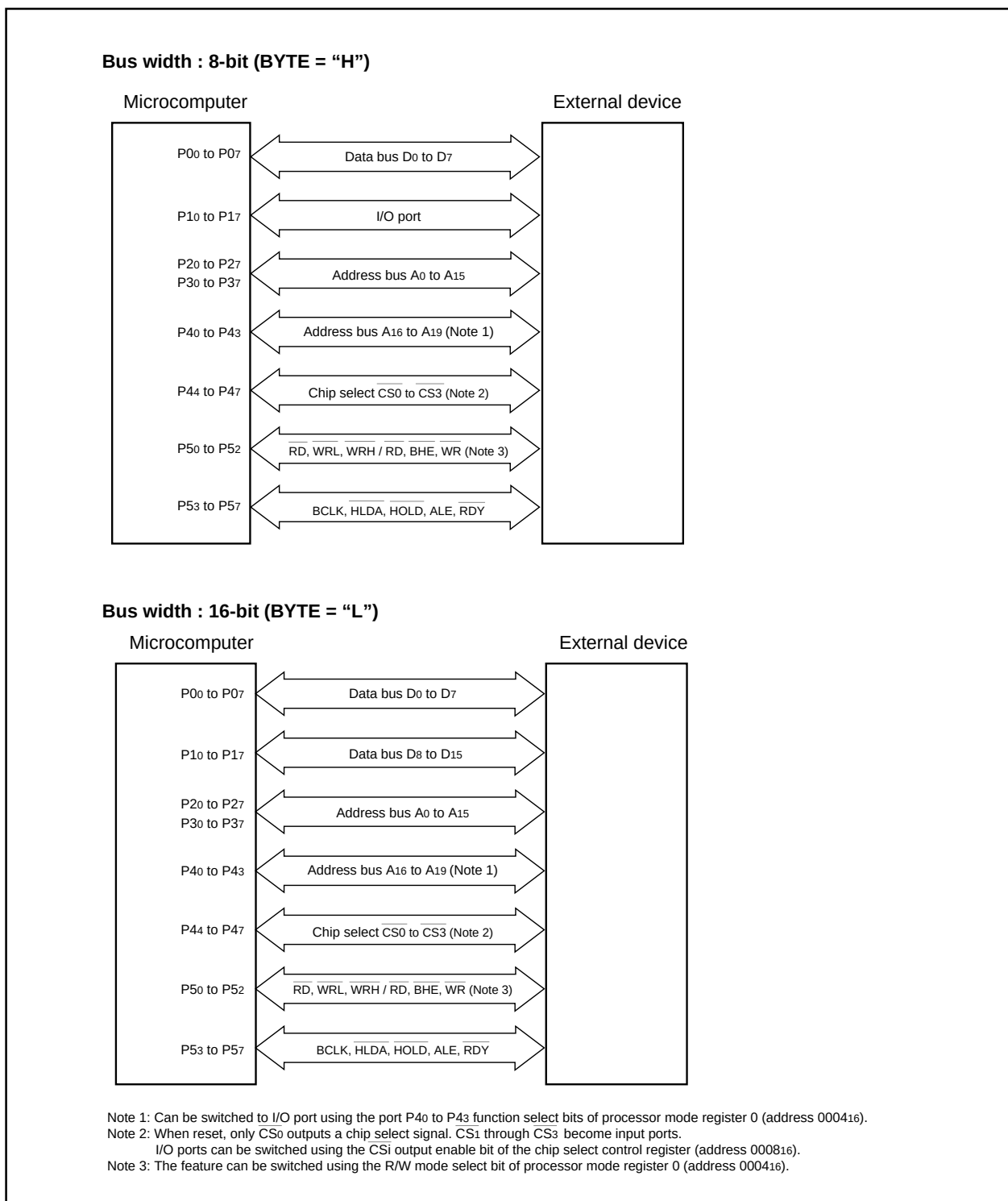


Figure 4.2.1. Level of BYTE pin and external data bus width

4.2.2 Chip Selects and Address Bus

Chip selects ($P44/\overline{CS0}$ through $P47/\overline{CS3}$) are output in areas resulting from dividing a 1-M byte memory space into four. To use the chip select, the chip select output must be enabled by setting the chip select control register. Figure 4.2.2 shows addresses in which chip selects become active ("L"). Since the extent of the internal area and the external area in memory expansion mode is different from those in microprocessor mode, there is a difference between areas for which $\overline{CS0}$ is output. When an internal ROM/RAM area is being accessed, no chip select is output, and the address bus does not change (the address of the external area that was accessed previously is held).

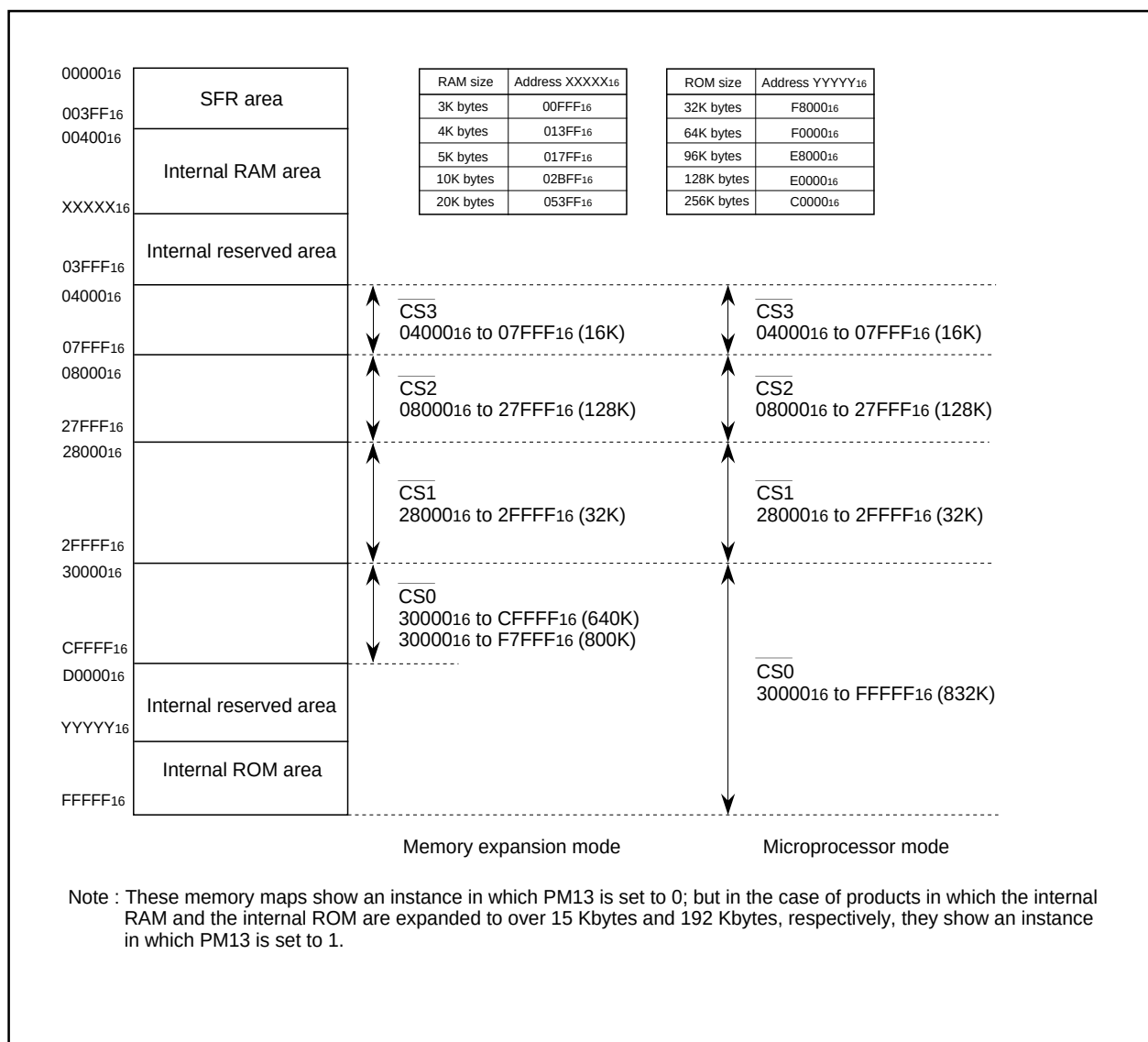


Figure 4.2.2. Addresses in which chip selects turn active ("L")

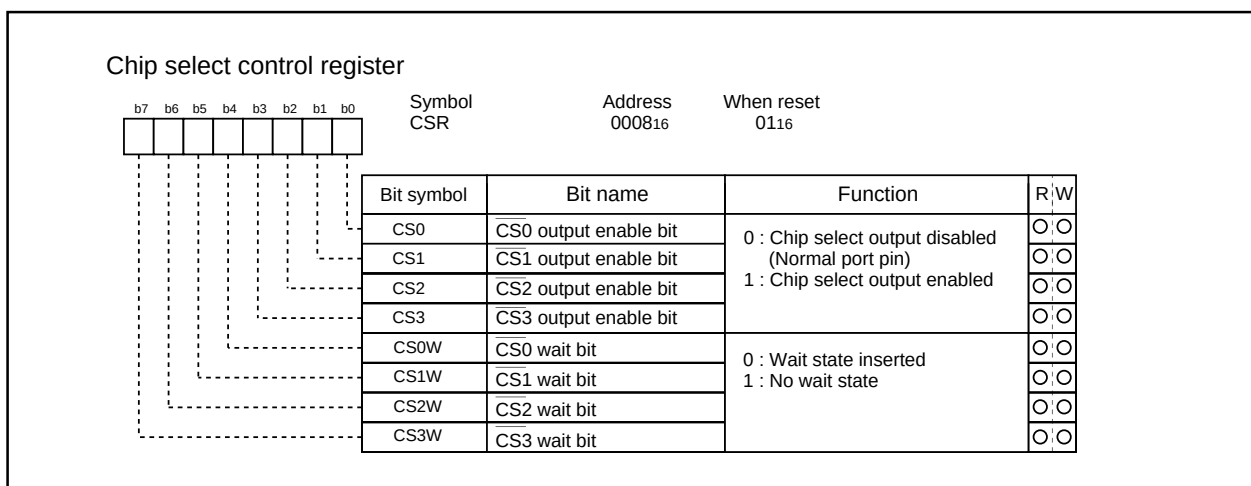


Figure 4.2.3. Chip select control register

4.2.3 Bus Types

The M16C/62A Group has two types of buses: a separate bus where separate pins are used for address output and data input/output and a multiplexed bus where pins are time- multiplexed and switched between address output and data input/output to save the number of pins used.

A separate bus is used to access devices such as ROM and RAM which have separate buses. The areas accessed via separate buses can be allocated for programs and data.

A multiplexed bus is used to access devices such as ASSPs which have multiplexed buses. The areas accessed via a multiplexed bus can only be allocated for data. Programs cannot be located in these areas.

The area accessed via a multiplex bus can be selected from three types of area $\overline{CS2}$ area, $\overline{CS1}$ area, and entire space by setting the multiplexed bus select bits (bits 4 and 5) of the processor mode register 0 (address 0004₁₆). However, the entire space cannot be selected when operating in the microprocessor mode.

Areas not accessed via multiplexed bus are accessed through separate buses.

When accessing an area set for access via a multiplexed bus the BYTE pin is "H" level, the data bus D₀ to D₇ is multiplexed with address bus A₀ to A₇.

If the BYTE pin is "L" level, the data bus D₀ to D₇ is multiplexed with address bus A₁ to A₈. In either case, the bus is switched between data and address separated only in time.

In the latter case, however, the addresses of connected devices are mapped into even addresses (every other addresses) of the M16C/62A. Therefore, be sure to access the M16C/62A's even addresses in length of bytes when accessing a connected device.

4.2.4 R/W Modes

The read/write signal that is output when accessing an external area can be selected between the $\overline{RD}/\overline{BHE}/\overline{WR}$ and the $\overline{RD}/\overline{WRH}/\overline{WRL}$ modes by setting the R/W mode select bit (bit 2) of the processor mode register 0 (address 0004₁₆). Use the $\overline{RD}/\overline{BHE}/\overline{WR}$ mode to access a 16-bit wide RAM and the $\overline{RD}/\overline{WRH}/\overline{WRL}$ mode to access an 8-bit wide RAM.

When the M16C/62A is reset, the $\overline{RD}/\overline{BHE}/\overline{WR}$ mode is selected by default. To switch over the R/W mode, change the $\overline{RD}/\overline{BHE}/\overline{WR}$ to the $\overline{RD}/\overline{WRH}/\overline{WRL}$ mode before accessing an external RAM.

Refer to the connection examples of $\overline{RD}/\overline{BHE}/\overline{WR}$ and $\overline{RD}/\overline{WRH}/\overline{WRL}$ shown in Section 4.3, "Connection Examples."

4.3 Connection Examples

4.3.1 16-bit Memory to 16-bit Width Data Bus Connection Example

Figure 4.3.1 shows an example of connecting M5M51016BTP (SRAM). In this diagram, when reset the microcomputer starts operating in single-chip mode. Change this mode to memory expansion mode in a program.

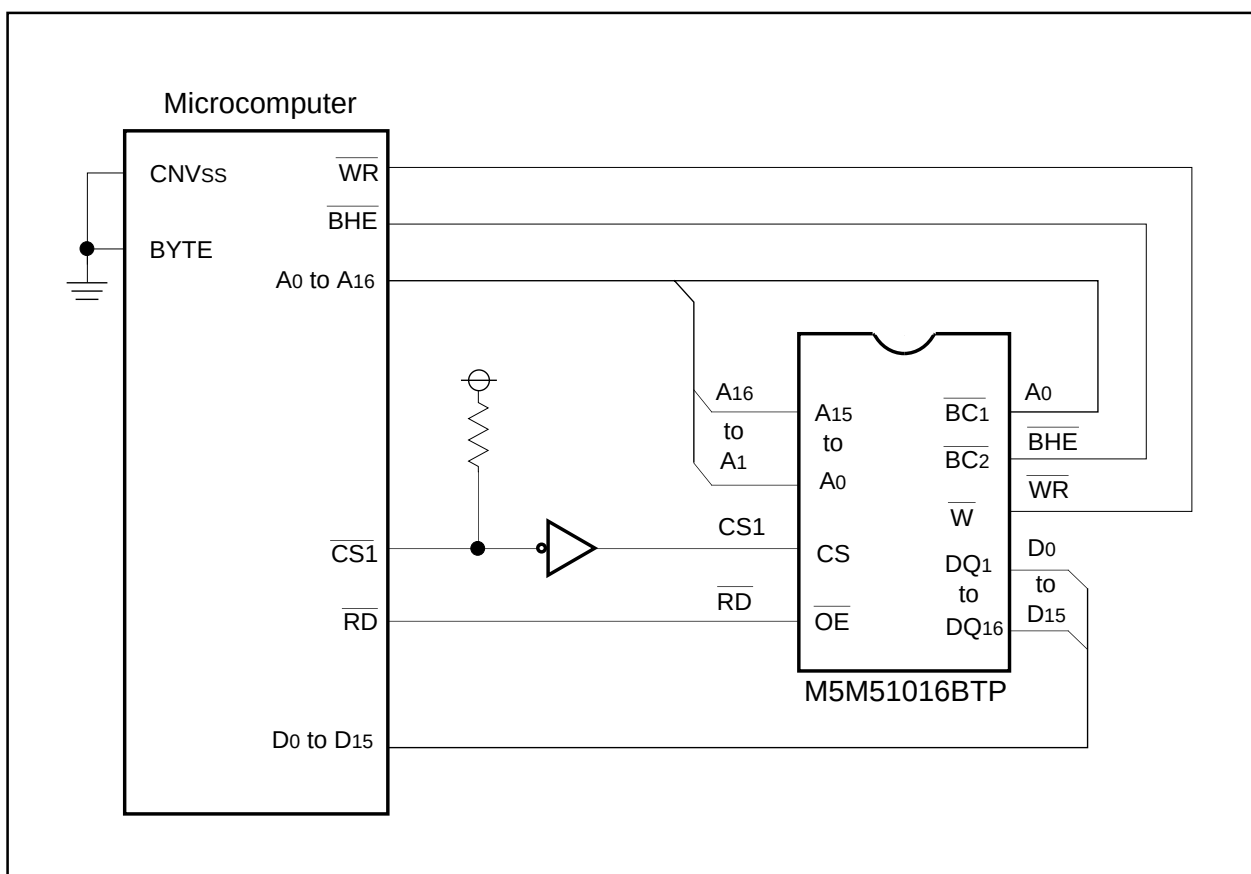


Figure 4.3.1. Example of connecting M5M51016BTP

4.3.2 8-bit Memory to 16-bit Width Data Bus Connection Example

Figure 4.3.2 shows an example of connecting two M5M5278's (SRAM) to a 16-bit data bus. In this diagram, when reset the microcomputer starts operating in single-chip mode. Change this mode to memory expansion mode in a program.

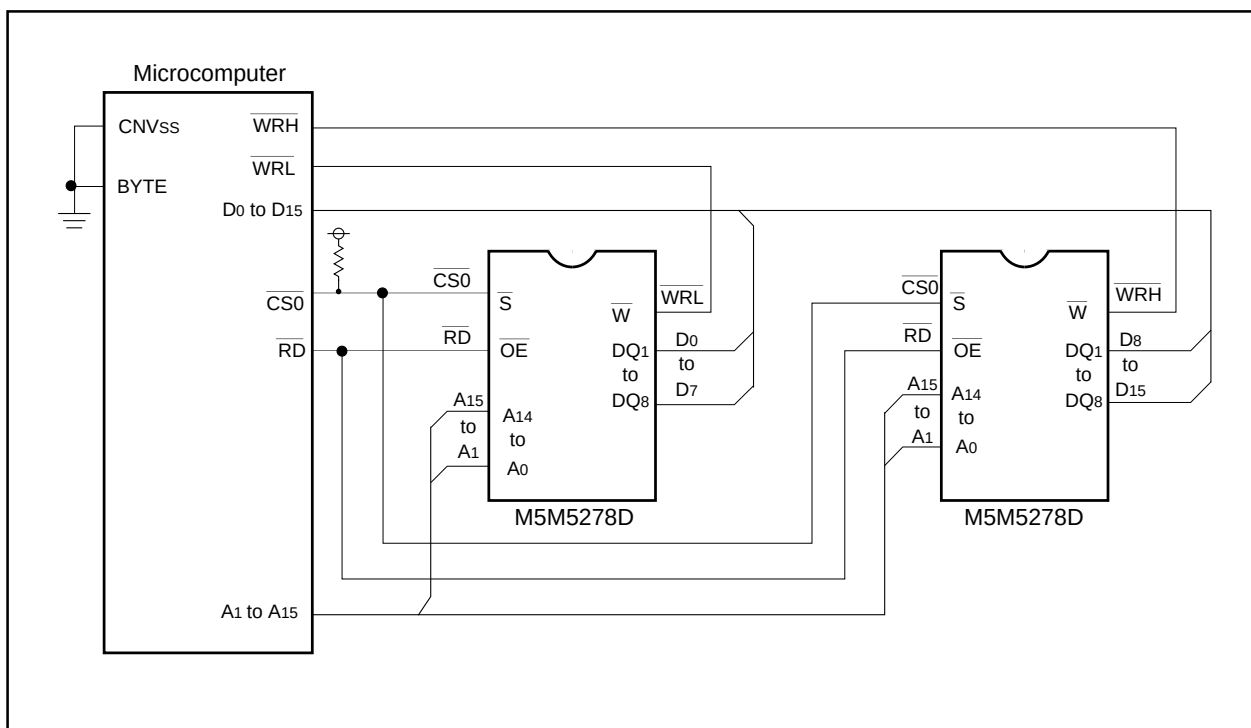


Figure 4.3.2. Example of connecting two M5M5278's to a 16-bit data bus

Figure 4.3.3 shows how to connect two Am29LV008B (flash memory). In 16-bit bus mode, the $\overline{\text{BHE}}/\overline{\text{WRH}}$ pin functions as $\overline{\text{BHE}}$. When connecting 8-bit flash memory chips to the 16-bit bus, make sure the microcomputer's $\overline{\text{WRL}}$ pin is connected to the $\overline{\text{WR}}$ pins on both flash memory chips, and that data is written to the flash memory in units of 16 bits beginning with an even address.

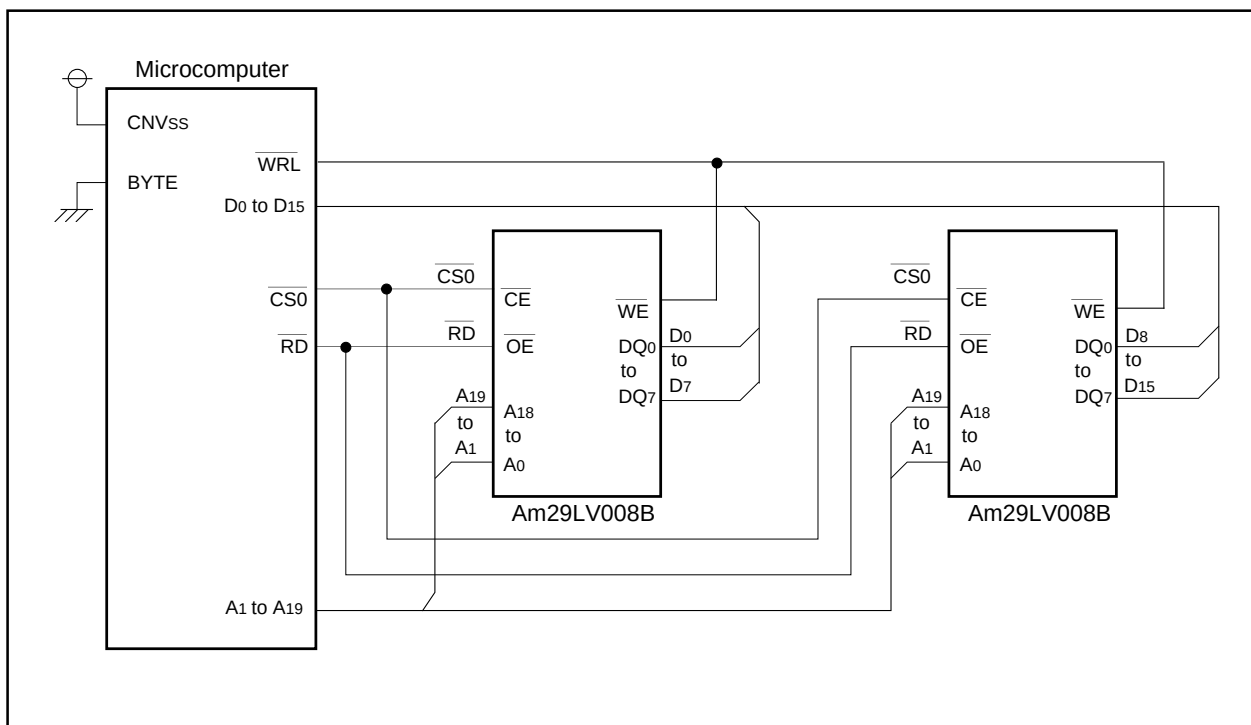


Figure 4.3.3. Example of connecting two Am29LV008B's to a 16-bit data bus

4.3.3 8-bit Memory to 8-bit Width Data Bus Connection Example

Figure 4.3.4 shows an example of connecting two M5M5278's (SRAM) to an 8-bit data bus. In this diagram, when reset the microcomputer starts operating in single-chip mode. Change this mode to memory expansion mode in a program.

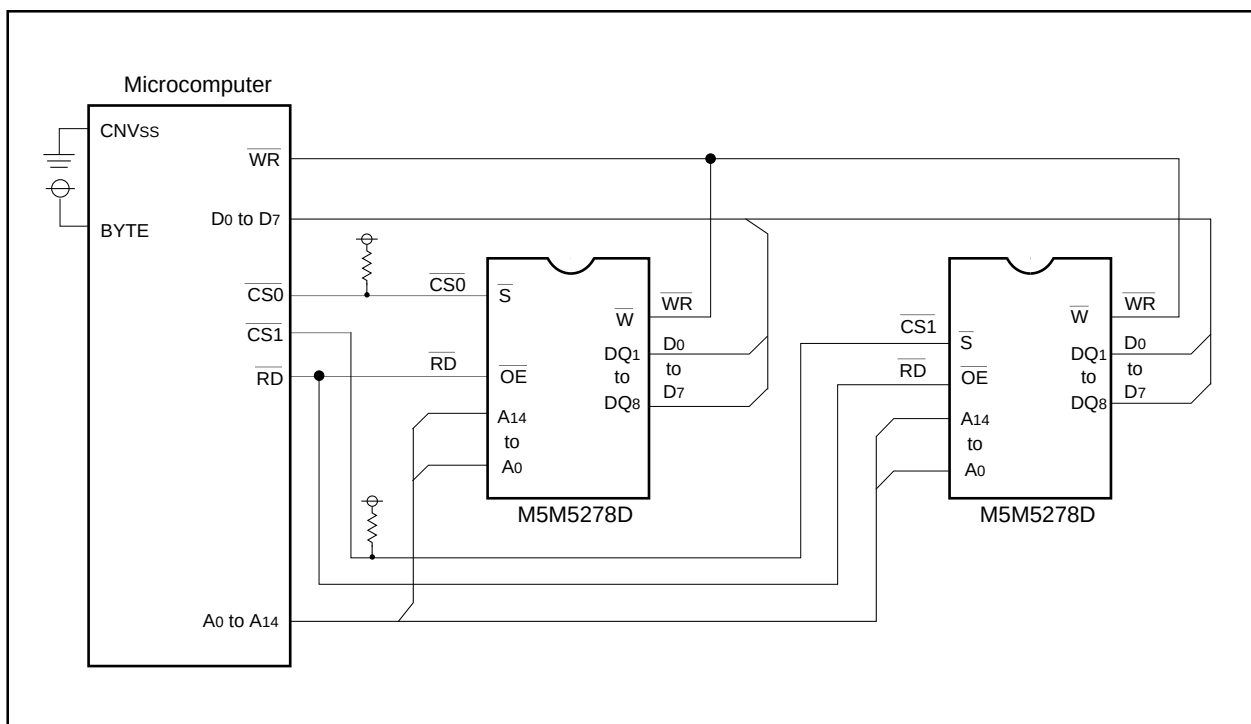


Figure 4.3.4. Example of connecting two M5M5278's to an 8-bit data bus

4.3.4 Two 8-bit and 16-Bit Memory to 16-Bit Width Data Bus Connection Example

Figure 4.3.5 shows an example of connecting M5M28F102 (16-bit flash memory) and two M5M5278's (8-bit SRAM) to a 16-bit data bus.

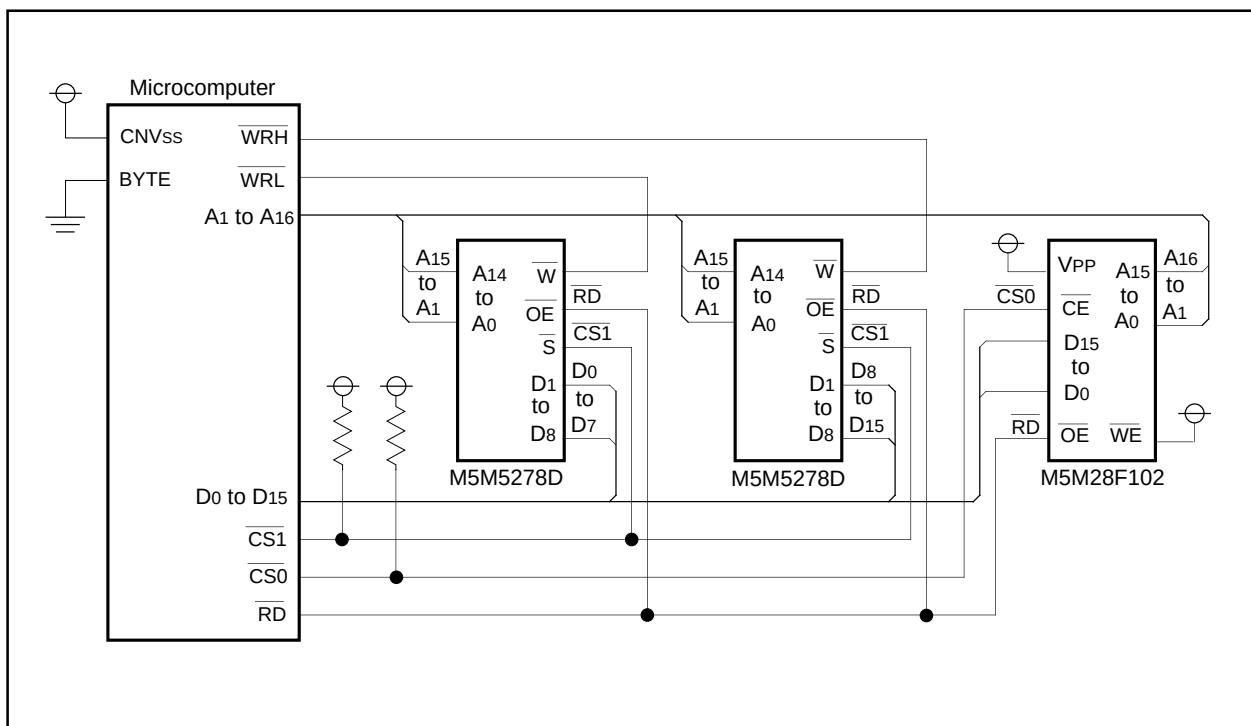


Figure 4.3.5. Example of connection of two 8-bit memories and one 16-bit memory to 16-bit width data bus

4.3.5 Chip Selects and Address Bus

When there are insufficient chip select signals, it is necessary to generate chip selects externally. Figure 4.3.6 shows an example of a connection in which the $\overline{\text{CS2}}$ (128K bytes) area is divided into four 32K byte areas.

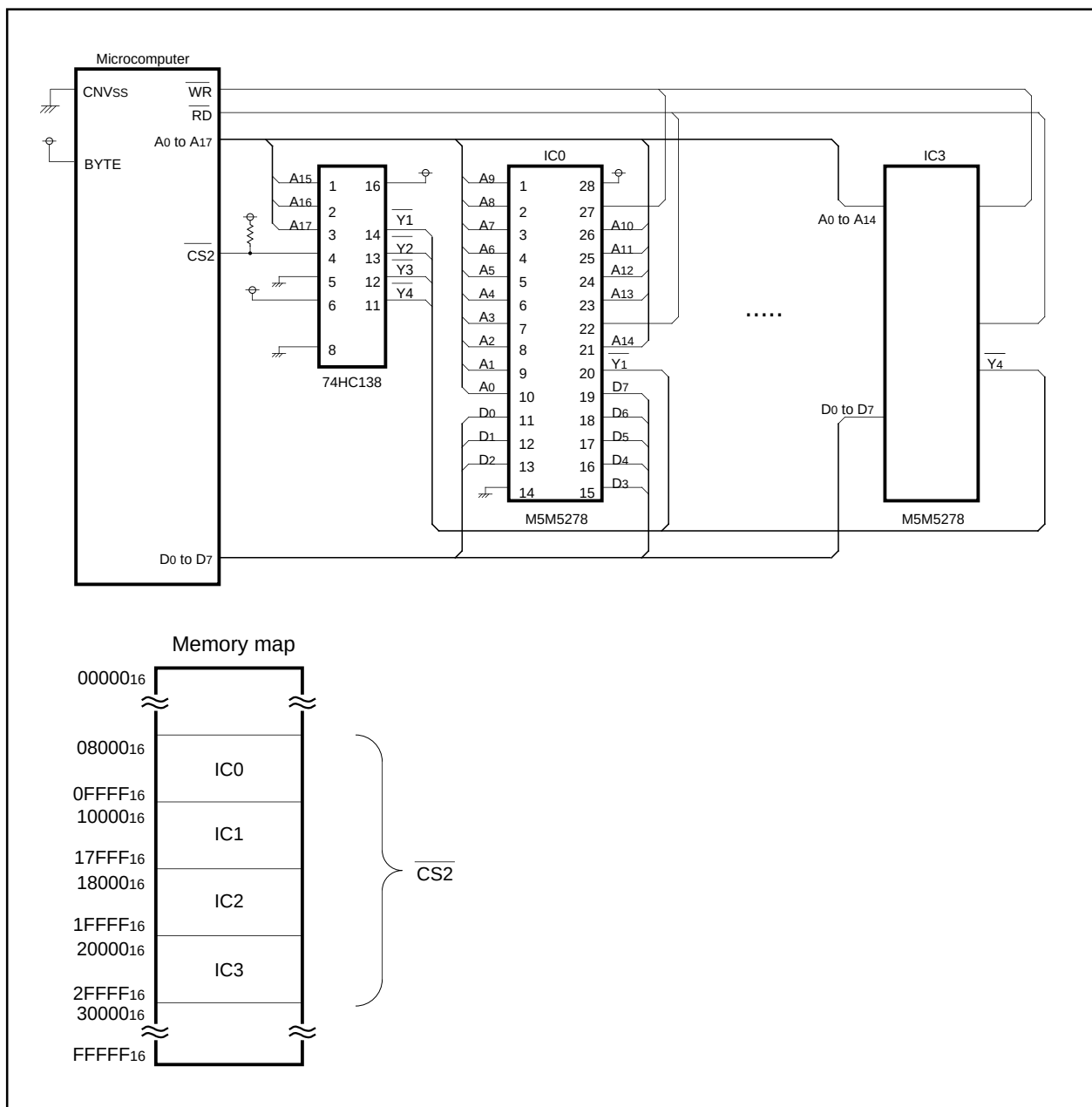


Figure 4.3.6. Chip selects and address bus

4.4 Connectable Memories

4.4.1 Operation Frequency and Access Time

Connectable memories depend upon the BCLK frequency $f(\text{BCLK})$. The frequency of $f(\text{BCLK})$ is equal to that of the BCLK, and is contingent on the oscillator's frequency and on the settings in the system clock select bits (bit 6 of address 0006₁₆, and bits 6 and 7 of address 0007₁₆).

The following are the conditional equations for the connections. Meet these conditions minimally. Figures 4.4.1 and 4.4.2 show the relation between the frequency of BCLK and memory.

(1) Read cycle time (tCR)/write cycle time (tCW)

Read cycle time (tCR) and write cycle time (tCW) must satisfy the following conditional expressions:

- **With the Wait option cleared**

$$t_{\text{CR}} < 10^9/f(\text{BCLK}) \text{ and } t_{\text{CW}} < 10^9/f(\text{BCLK})$$

- **With the Wait option selected**

$$t_{\text{CR}} < 2 \times 10^9/f(\text{BCLK}) \text{ and } t_{\text{CW}} < 2 \times 10^9/f(\text{BCLK})$$

(2) Address access time [ta(A)]

Address access time [ta(A)] must satisfy the following conditional expressions:

(a) Vcc = 5V

- **With the Wait option cleared**

$$t_{\text{a}}(\text{A}) < 10^9/f(\text{BCLK}) - 65(\text{ns})^*$$

- **With the Wait option selected**

$$t_{\text{a}}(\text{A}) < 2 \times 10^9/f(\text{BCLK}) - 65(\text{ns})^*$$

$$\begin{aligned} * 65(\text{ns}) &= t_{\text{d}}(\text{BCLK} - \text{AD}) + t_{\text{su}}(\text{DB} - \text{RD}) - t_{\text{h}}(\text{BCLK} - \text{RD}) \\ &= (\text{address output delay time}) + (\text{data input setup time}) - (\text{RD signal output hold time}) \end{aligned}$$

(b) Vcc = 3V

- **With the Wait option cleared**

$$t_{\text{a}}(\text{A}) < 10^9/f(\text{BCLK}) - 140(\text{ns})^*$$

- **With the Wait option selected**

$$t_{\text{a}}(\text{A}) < 2 \times 10^9/f(\text{BCLK}) - 140(\text{ns})^*$$

$$\begin{aligned} * 140(\text{ns}) &= t_{\text{d}}(\text{BCLK} - \text{AD}) + t_{\text{su}}(\text{DB} - \text{RD}) - t_{\text{h}}(\text{BCLK} - \text{RD}) \\ &= (\text{address output delay time}) + (\text{data input setup time}) - (\text{RD signal output hold time}) \end{aligned}$$

(3) Chip select access time [ta(S)]

Chip select access time [ta(S)] must satisfy the following conditional expressions:

(a) Vcc = 5V

- **With the Wait option cleared**

$$t_{\text{a}}(\text{S}) < 10^9/f(\text{BCLK}) - 65(\text{ns})^*$$

- **With the Wait option selected**

$$t_{\text{a}}(\text{S}) < 2 \times 10^9/f(\text{BCLK}) - 65(\text{ns})^*$$

$$\begin{aligned} * 65(\text{ns}) &= t_{\text{d}}(\text{BCLK} - \text{CS}) + t_{\text{su}}(\text{DB} - \text{RD}) - t_{\text{h}}(\text{BCLK} - \text{RD}) \\ &= (\text{chip select output delay time}) + (\text{data input setup time}) - (\text{RD signal output hold time}) \end{aligned}$$

(b) Vcc = 3V**• With the Wait option cleared**

$$t_a(S) < 10^9/f(\text{BCLK}) - 140(\text{ns})^*$$

• With the Wait option selected

$$t_a(S) < 2 \times 10^9/f(\text{BCLK}) - 140(\text{ns})^*$$

$$\begin{aligned} * 140(\text{ns}) &= t_d(\text{BCLK} - \text{CS}) + t_{su}(\text{DB} - \text{RD}) - t_h(\text{BCLK} - \text{RD}) \\ &= (\text{chip select output delay time}) + (\text{data input setup time}) - (\text{RD signal output hold time}) \end{aligned}$$

(4) Output enable time [ta(OE)]

Output enable time [ta(OE)] must satisfy the following conditional expressions:

(a) Vcc = 5V**• With the Wait option cleared**

$$t_a(\text{OE}) < 10^9/f(\text{BCLK}) \times 2 - 45(\text{ns}) = t_{ac1}(\text{RD-DB})$$

• With the Wait option selected

$$t_a(\text{OE}) < 3 \times 10^9/f(\text{BCLK}) \times 2 - 45(\text{ns}) = t_{ac2}(\text{RD-DB})$$

(b) Vcc = 3V**• With the Wait option cleared**

$$t_a(\text{OE}) < 10^9/f(\text{BCLK}) \times 2 - 90(\text{ns}) = t_{ac1}(\text{RD-DB})$$

• With the Wait option selected

$$t_a(\text{OE}) < 3 \times 10^9/f(\text{BCLK}) \times 2 - 90(\text{ns}) = t_{ac2}(\text{RD-DB})$$

(5) Data setup time [tsu(D)]

Data setup time [tsu(D)] must satisfy the following conditional expressions:

(a) Vcc = 5V**• With the Wait option cleared**

$$t_{su}(\text{D}) < 10^9/f(\text{BCLK}) \times 2 - 40(\text{ns})^*$$

• With the Wait option selected

$$t_{su}(\text{D}) < 10^9/f(\text{BCLK}) - 40(\text{ns})^*$$

$$\begin{aligned} * 40(\text{ns}) &= t_d(\text{BCLK} - \text{DB}) - t_h(\text{BCLK} - \text{WR}) \\ &= (\text{data output delay time}) - (\text{WR signal output hold time}) \end{aligned}$$

(b) Vcc = 3V**• With the Wait option cleared**

$$t_{su}(\text{D}) < 10^9/f(\text{BCLK}) \times 2 - 80(\text{ns})^*$$

• With the Wait option selected

$$t_{su}(\text{D}) < 10^9/f(\text{BCLK}) - 80(\text{ns})^*$$

$$\begin{aligned} * 80(\text{ns}) &= t_d(\text{BCLK} - \text{DB}) - t_h(\text{BCLK} - \text{WR}) \\ &= (\text{data output delay time}) - (\text{WR signal output hold time}) \end{aligned}$$

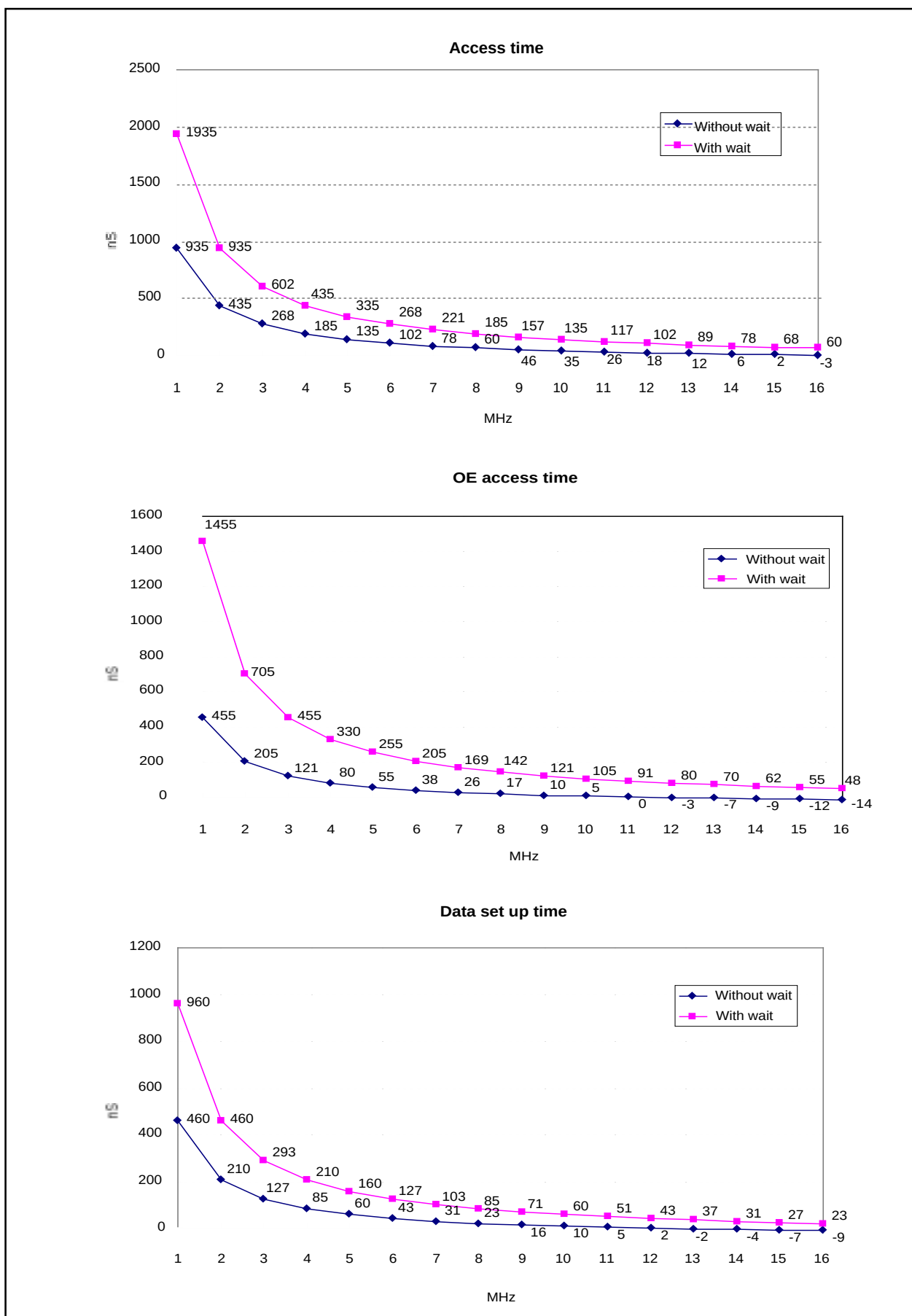


Figure 4.4.1. Relation between the frequency of BCLK and memory (Vcc = 5V)

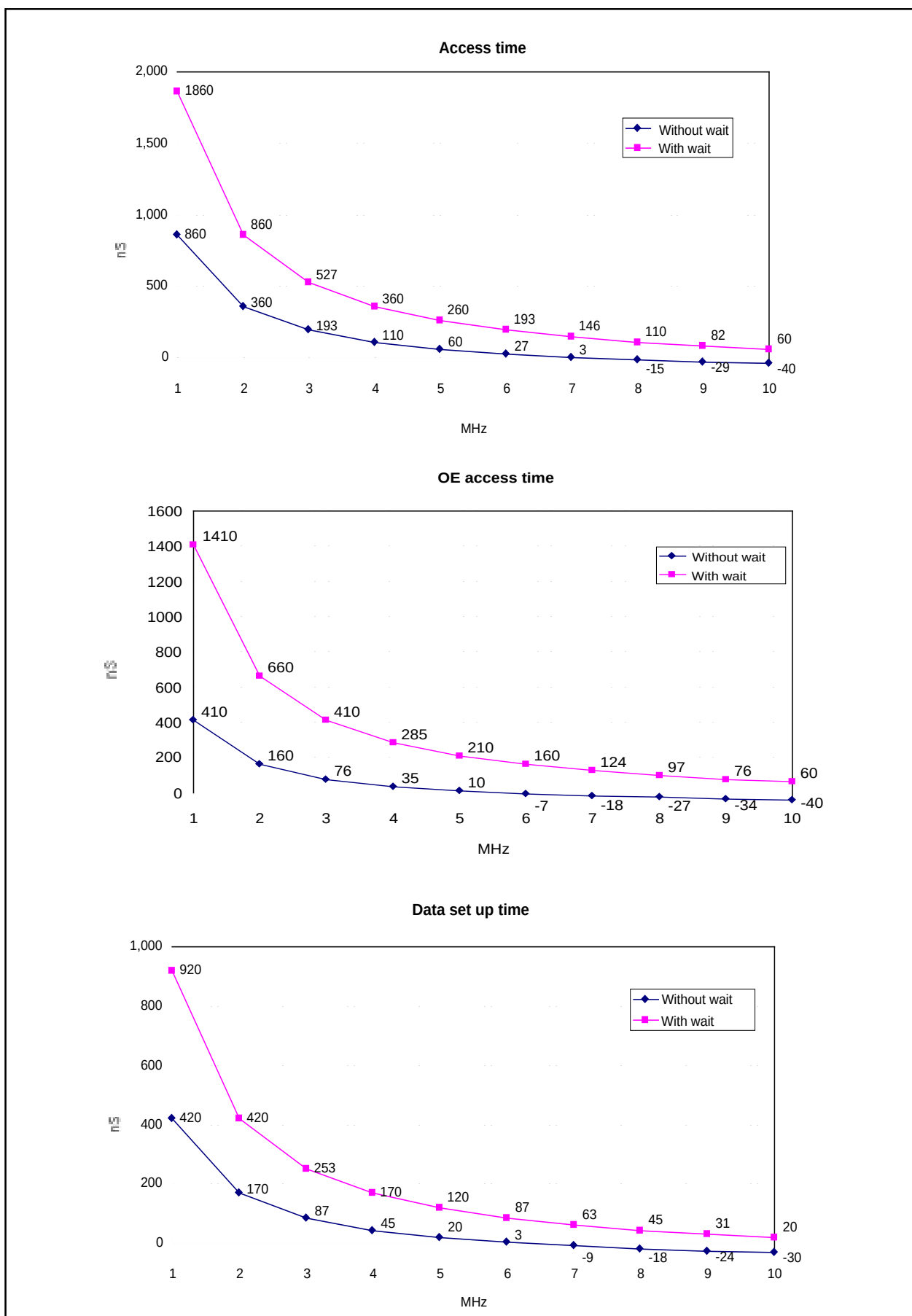


Figure 4.4.2. Relation between the frequency of BCLK and memory (Vcc = 3V)

4.4.2 Connecting Low-Speed Memory

To connect memory with long access time [$t_{a(A)}$], either decrease the frequency of BCLK or set a software wait. Using the $\overline{RDY}$ feature allows you to connect memory having the timing that precludes connection though you set software wait.

(1) Using software wait

Set software wait by using either of bit 7 (PM17) of processor mode register 1 or bits 4 through 7 (CS0W through CS3W) of the chip select control register. With software wait set, if an address space is accessed in which a separate bus is selected, the bus cycle results in two cycles of BCLK; if an address space is accessed in which a multiplex bus is selected, the bus cycle results in three cycles of BCLK.

If bit 7 (PM17) of processor mode register 1 is set to "Wait selected", the microcomputer accesses every area with this option in effect. If bit 7 (PM17) of processor mode register 1 is set to "Wait cleared", the Wait option can be either selected or cleared, chip select by chip select, by setting bits 4 through 7 (CS0W through CS3W) of the chip select control register. Figures 4.4.3 through 4.4.5 show relation of processor mode and the wait bit (PM17, CSiW).

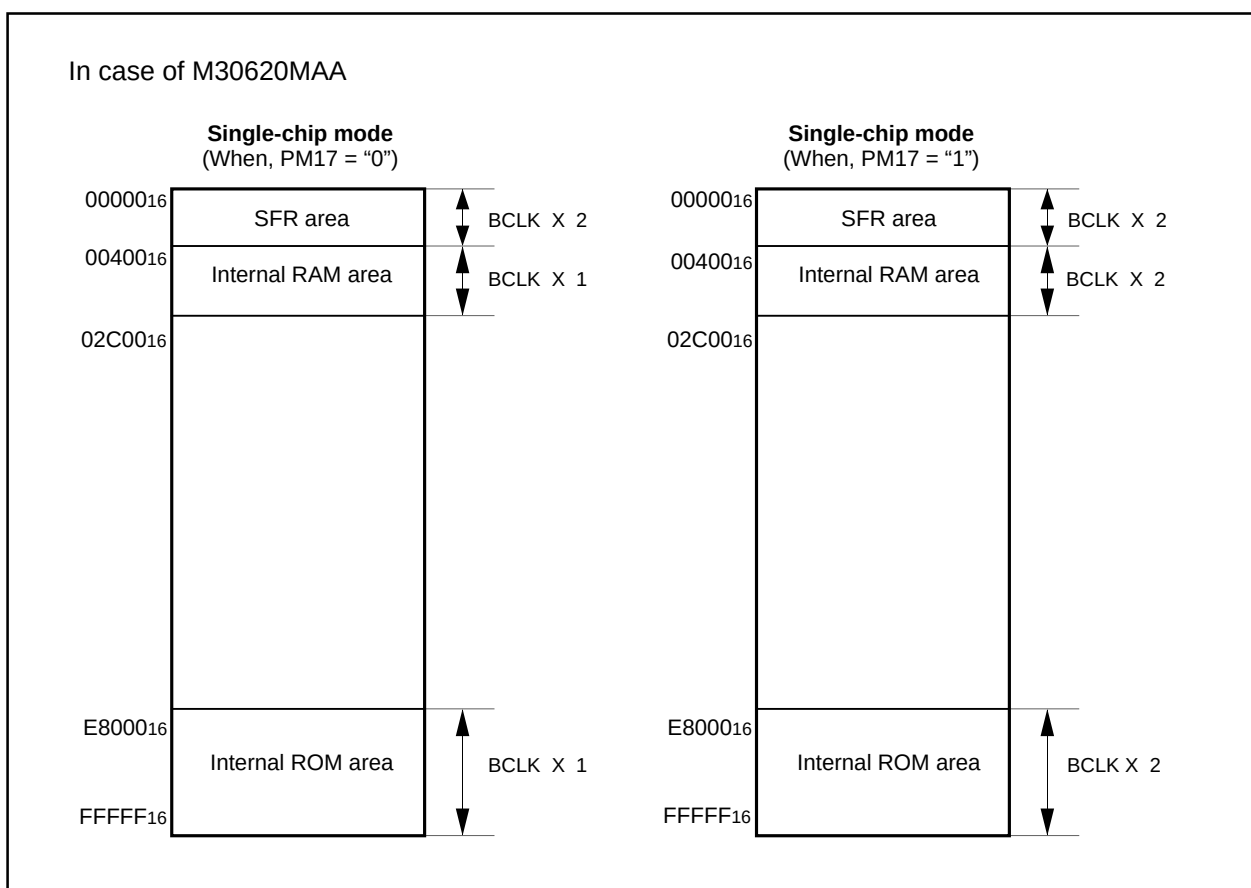


Figure 4.4.3. Relation of processor mode and the wait bit (PM17, CSiW) (1)

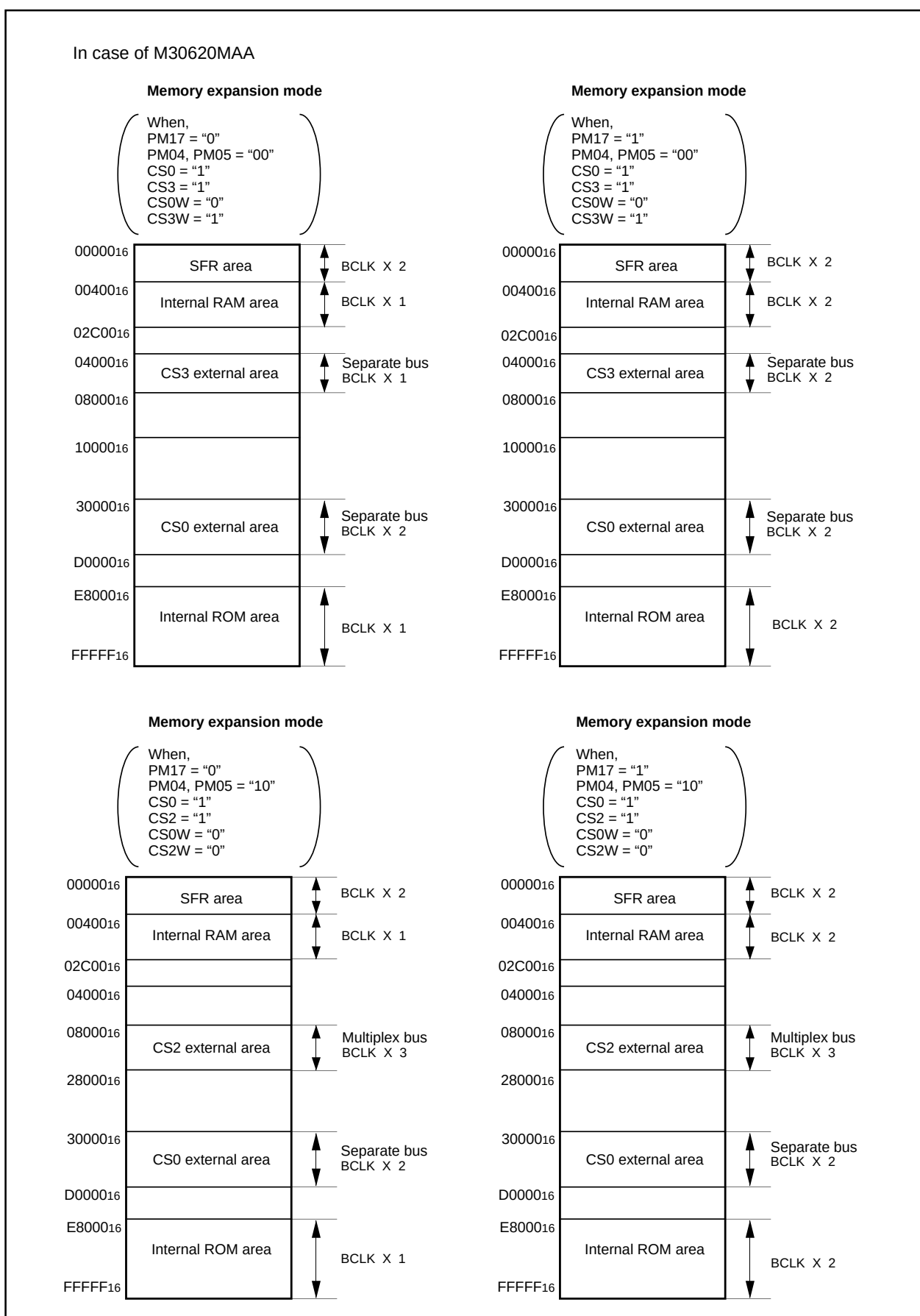


Figure 4.4.4. Relation of processor mode and the wait bit (PM17, CSiW) (2)

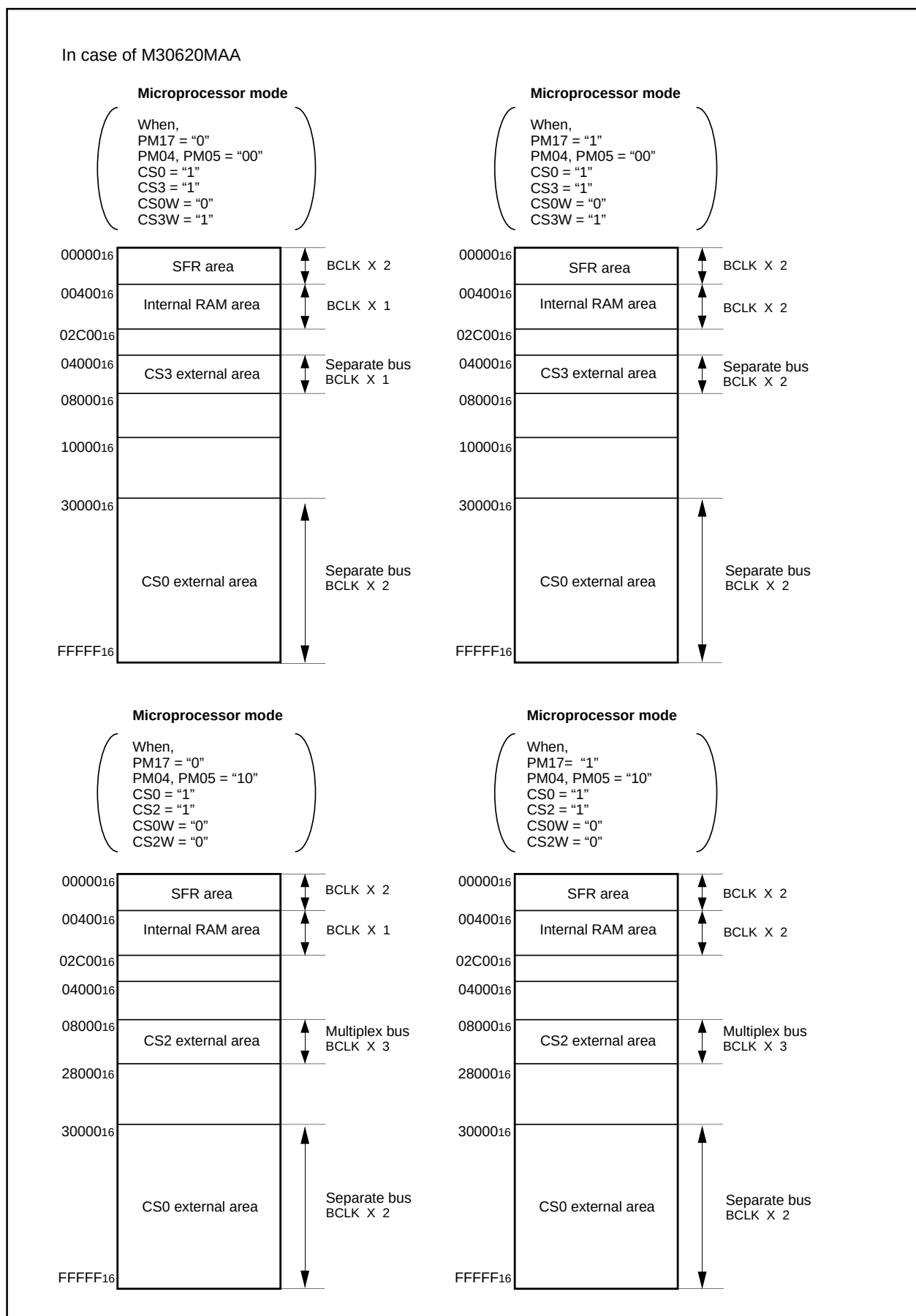


Figure 4.4.5. Relation of processor mode and the wait bit (PM17, CSiW) (3)

(2) $\overline{\text{RDY}}$ function usage

To use the $\overline{\text{RDY}}$ function, set a software wait.

The $\overline{\text{RDY}}$ function operates when the BCLK signal falls with the $\overline{\text{RDY}}$ pin at "L"; the bus does not vary for 1 BCLK, and the state at that moment is held.

The $\overline{\text{RDY}}$ function holds the state of bus for the period in which the $\overline{\text{RDY}}$ pin is at "L", and releases it when the BCLK signal falls with the $\overline{\text{RDY}}$ pin at "H". Figure 4.4.6 shows an example of $\overline{\text{RDY}}$ circuit that holds the state of bus for 1 BCLK.

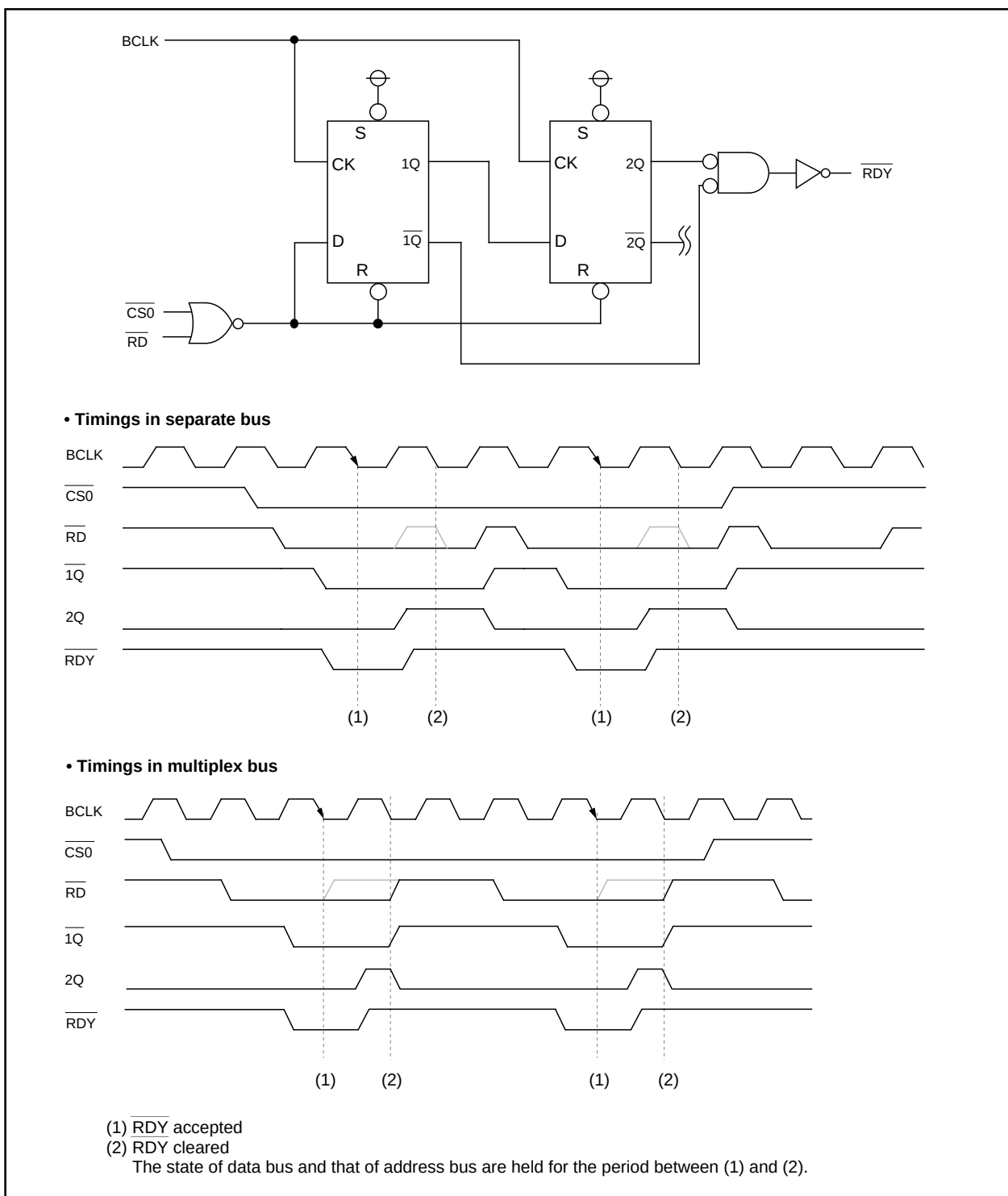


Figure 4.4.6. Example of $\overline{\text{RDY}}$ circuit holding state of bus for 1 BCLK

4.4.3 Connectable Memories

Connectable memories and their maximum frequencies are given here;

M16C/62A group maximum frequency is

16MHz (without the wait) for Vcc=5V,

10MHz (with the one wait) for Vcc=3V

(1) Flash memories (Read only mode)

(a) 3V without wait

Maximum frequency (MHz)	Model No.
3.57	M5M29GB/T160BVP-80

(b) 3V with wait

Maximum frequency (MHz)	Model No.
8.33	M5M29GB/T160BVP-80

(2) SRAM

(a) 3V without wait

Maximum frequency (MHz)	Model No.
5.12	M5M54R08AJ-12 M5M54R16AJ,ATP-12

(b) 3V with wait

Maximum frequency (MHz)	Model No.
10.0	M5M54R08AJ-12 M5M54R16AJ,ATP-12

4.5 Releasing an External Bus ($\overline{\text{HOLD}}$ input and $\overline{\text{HLDA}}$ output)

The Hold feature is to relinquish the address bus, the data bus, and the control bus on M16C/62A side in line with the Hold request from the bus master other than M16C/62A when the two or more bus masters share the address bus, the data bus, and the control bus. The Hold feature is effective only in memory expansion mode and microprocessor mode.

The sequence of using the Hold feature may be:

1. The external bus master turns the input level of the $\overline{\text{HOLD}}$ terminal to "L".
2. When M16C/62A becomes ready to relinquish buses, each bus becomes high-impedance state at the falling edge of BCLK.
3. The $\overline{\text{HLDA}}$ terminal becomes "L" at the rising edge of the next BCLK.
4. The external bus master uses a bus.
5. When the external bus master finishes using a bus, the external bus master returns the input level of the $\overline{\text{HOLD}}$ terminal to "H".
6. The output from $\overline{\text{HLDA}}$ terminal becomes "H" at the rising edge of the next BCLK.
7. Each bus returns from the high-impedance state to the former state at the falling edge of the next BCLK.

As given above, each bus invariably gets in the high-impedance state while the $\overline{\text{HLDA}}$ output is "L". Also, M16C/62A does not relinquish buses during a bus cycle. That is, if a Hold request comes in during a bus cycle, the $\overline{\text{HLDA}}$ output become "L" after that bus cycle finishes.

In the Hold state, the state of each terminal becomes as follows.

- **Address bus A0 to A19**

High-impedance state. The case in which A16 to A19 are used as ports P40 to P43 (64K byte address space) and the case in which A9 to A19 are used as ports P31 to P37 and P40 to P43 (multiplex for the whole area) in microprocessor mode and in memory expansion mode too fall under this category.

- **Data bus D0 to D15**

High-impedance state. The case in which D8 to D15 are used as ports P10 to P17 (8-bit external bus width) and the case in which D0 to D15 are used as ports P00 to P07 and P10 to P17 (multiplex for the whole area) in microprocessor mode and in memory expansion mode too fall under this category.

- **RD, WR, WRL, WRH, BHE**

High-impedance state.

- **ALE**

An internal clock signal having the same phase as BCLK is output.

- **CS0 to CS3**

High-impedance state. The case in which ports are selected by the chip selection control register too falls under this category.

Figure. 4.5.1 shows an example of relinquishing external buses.

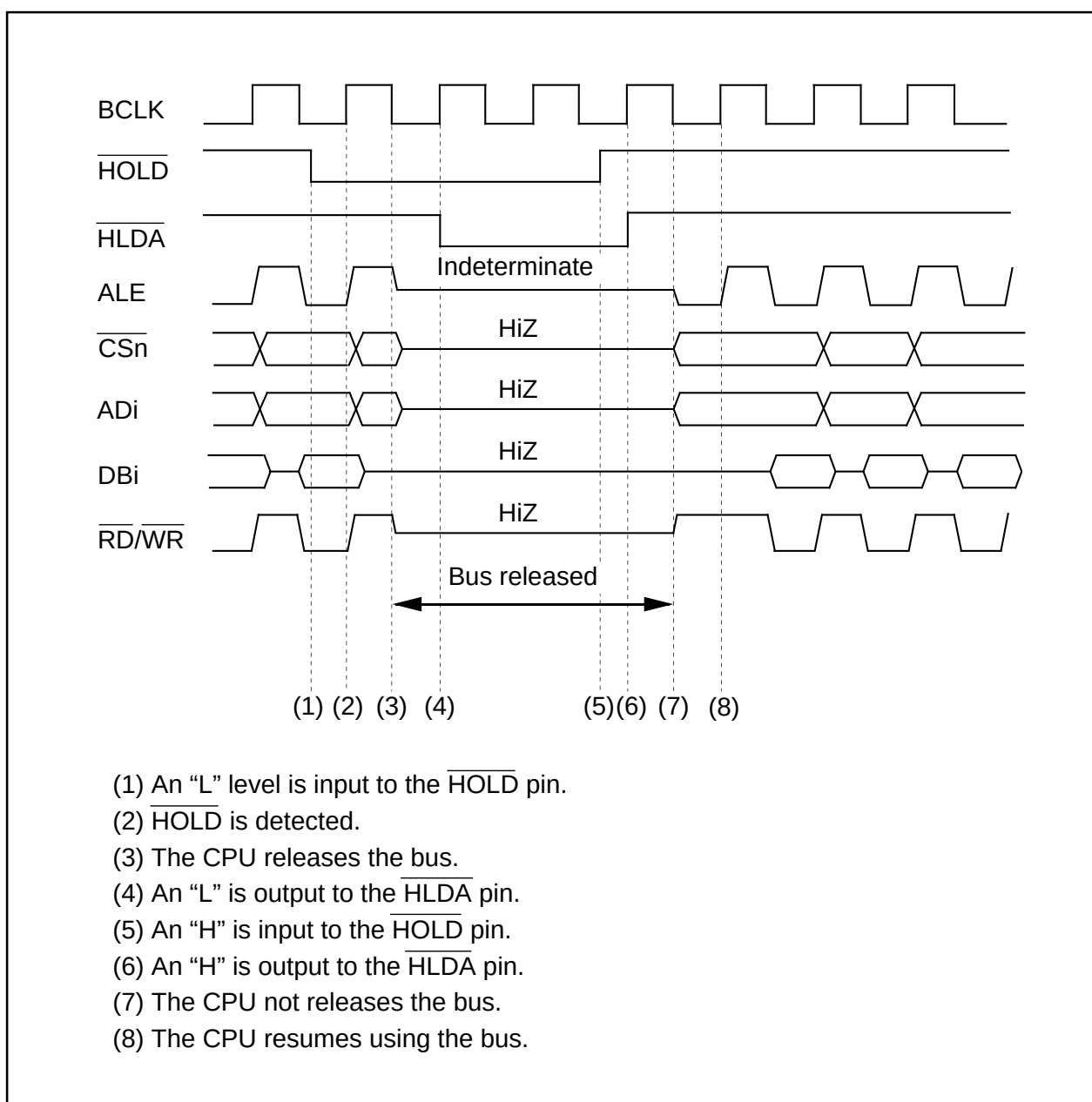


Figure 4.5.1. Example of releasing the external bus

4.6 Precautions for External Bus

- (1) The external ROM version can operate only in the microprocessor mode, so be sure to perform the following:
 - Connect the CNVSS pin to Vcc.

Chapter 5

External ROM Version

External ROM

The external ROM version can operate only in the microprocessor mode.

Functions of the external ROM version differ from those of the mask ROM version in the following. therefore, only the differences are described in this chapter:

For the other functions, refer to chapters 1 to 4.

- Memory map
- Operated in only microprocessor mode

5.1 Pin Configuration

Figures 5.1.1 and 5.1.2 show the pin configurations (top view).

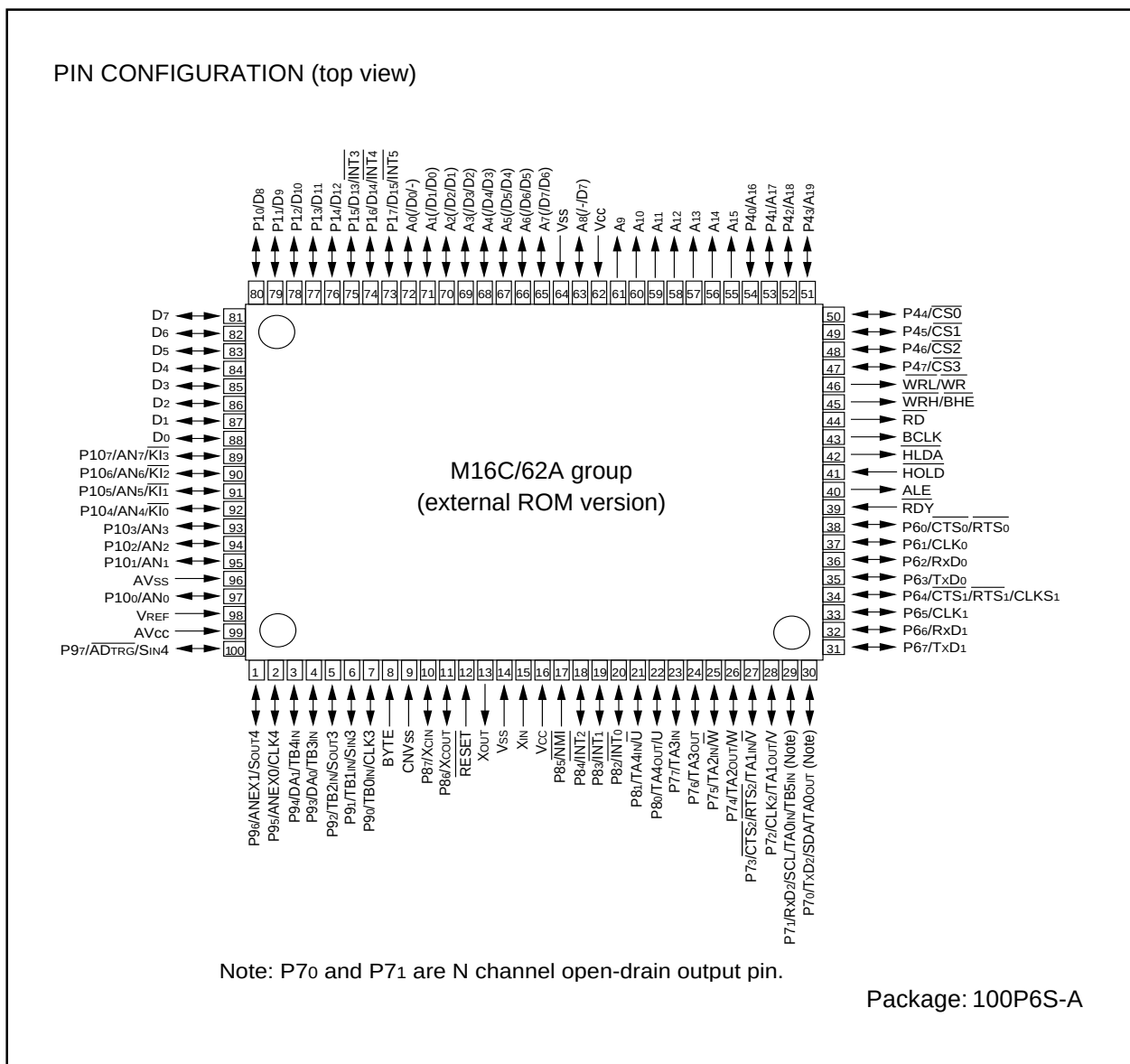


Figure 5.1.1. Pin configuration (top view)

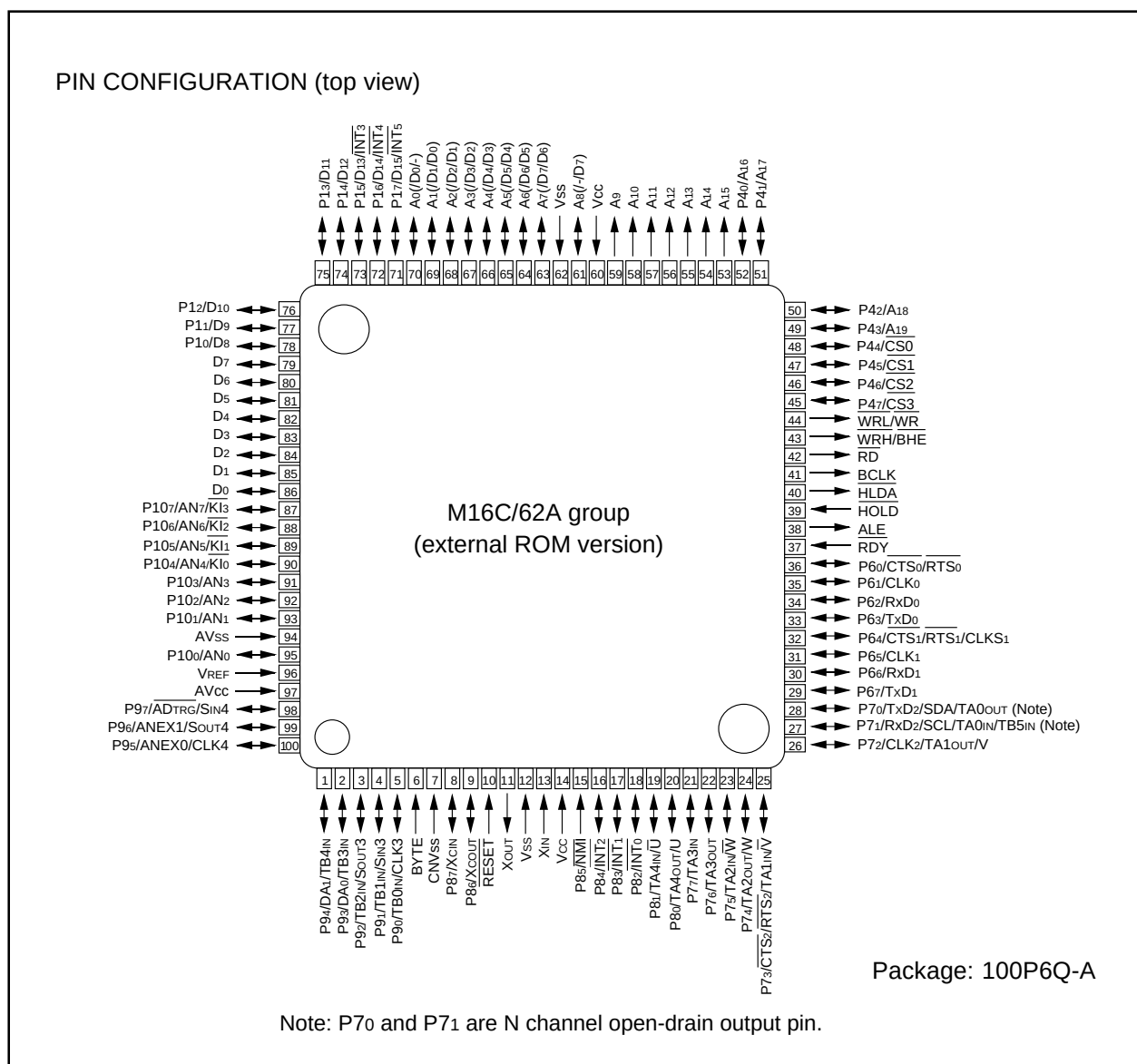


Figure 5.1.2. Pin configuration (top view)

External ROM

5.2 Pin Description

Tables 5.2.1 and 5.2.2 show the pin description.

Table 5.2.1. Pin Description (1)

Pin name	Signal name	I/O type	Function
Vcc, Vss	Power supply input		Supply 2.7 to 5.5 V to the Vcc pin. Supply 0 V to the Vss pin.
CNVss	CNVss	Input	Connect this pin to Vcc.
RESET	Reset input	Input	A "L" on this input resets the microcomputer.
XIN XOUT	Clock input Clock output	Input Output	These pins are provided for the main clock generating circuit. Connect a ceramic resonator or crystal between the XIN and the XOUT pins. To use an externally derived clock, input it to the XIN pin and leave the XOUT pin open.
BYTE	External data bus width select input	Input	This pin selects the width of an external data bus. A 16-bit width is selected when this input is "L"; an 8-bit width is selected when this input is "H". This input must be fixed to either "H" or "L".
AVcc	Analog power supply input		This pin is a power supply input for the A-D converter. Connect this pin to Vcc.
AVss	Analog power supply input		This pin is a power supply input for the A-D converter. Connect this pin to Vss.
VREF	Reference voltage input	Input	This pin is a reference voltage input for the A-D converter.
D0 to D7	Data bus	Input/output	When set as a separate bus, these pins input and output data (D0–D7).
P10 to P17	I/O port P1	Input/output	This is an 8-bit CMOS I/O port. It has an input/output port direction register that allows the user to set each pin for input or output individually.
D8 to D15	Data bus	Input/output	When set as a separate bus, these pins input and output data (D8–D15).
A0 to A7	Address bus	Output	These pins output 8 low-order address bits (A0–A7).
A0/D0 to A7/D7	Address bus/ data bus	Input/output	If the external bus is set as an 8-bit wide multiplexed bus, these pins input and output data (D0–D7) and output 8 low-order address bits (A0–A7) separated in time by multiplexing.
A0, A1/D0 to A7/D6		Output Input/output	If the external bus is set as a 16-bit wide multiplexed bus, these pins input and output data (D0–D6) and output address (A1–A7) separated in time by multiplexing. They also output address (A0).
A8 to A15	Address bus	Output	These pins output 8 middle-order address bits (A8–A15).
A8/D7, A9 to A15	Address bus/ data bus	Input/output Output	If the external bus is set as a 16-bit wide multiplexed bus, these pins input and output data (D7) and output address (A8) separated in time by multiplexing. They also output address (A9–A15).
P40 to P47	I/O port P4	Input/output	This is an 8-bit I/O port equivalent to P1.
CS0 to CS3, A16 to A19		Output Output	These pins output CS0–CS3 signals and A16–A19. CS0–CS3 are chip select signals used to specify an access space. A16–A19 are 4 high-order address bits.

Table 5.2.2. Pin Description (2)

Pin name	Signal name	I/O type	Function
$\overline{WRL}$ / $\overline{WR}$, $\overline{WRH}$ / $\overline{BHE}$, $\overline{RD}$, $\overline{BCLK}$, $\overline{HLDA}$, $\overline{HOLD}$, $\overline{ALE}$, $\overline{RDY}$	$\overline{WRL}$ / $\overline{WR}$, $\overline{WRH}$ / $\overline{BHE}$, $\overline{RD}$, $\overline{BCLK}$, $\overline{HLDA}$, $\overline{HOLD}$, $\overline{ALE}$, $\overline{RDY}$	Output Output Output Output Output Input Output Input	Output $\overline{WRL}$, $\overline{WRH}$ ($\overline{WR}$ and $\overline{BHE}$), $\overline{RD}$, $\overline{BCLK}$, $\overline{HLDA}$, and $\overline{ALE}$ signals. $\overline{WRL}$ and $\overline{WRH}$, and $\overline{BHE}$ and $\overline{WR}$ can be switched using software control. ■ $\overline{WRL}$, $\overline{WRH}$, and $\overline{RD}$ selecte With a 16-bit external data bus, data is written to even addresses when the $\overline{WRL}$ signal is "L" and to the odd addresses when the $\overline{WRH}$ signal is "L". Data is read when $\overline{RD}$ is "L". ■ $\overline{WR}$, $\overline{BHE}$, and $\overline{RD}$ selected Data is written when $\overline{WR}$ is "L". Data is read when $\overline{RD}$ is "L". Odd addresses are accessed when $\overline{BHE}$ is "L". Use this mode when using an 8-bit external data bus. While the input level at the $\overline{HOLD}$ pin is "L", the microcomputer is placed in the hold state. While in the hold state, $\overline{HLDA}$ outputs a "L" level. $\overline{ALE}$ is used to latch the address. While the input level of the $\overline{RDY}$ pin is "L", the microcomputer is in the ready state.
P60 to P67	I/O port P6	Input/output	This is an 8-bit I/O port equivalent to P1. The port can be set to have or not have a pull-up resistor in units of four bits by software. Pins in this port also function as UART0 and UART1 I/O pins as selected by software.
P70 to P77	I/O port P7	Input/output	This is an 8-bit I/O port equivalent to P6. Pins in this port also function as timer A0–A3, timer B5, or UART2 I/O pins as selected by software.
P80 to P84, P86, P87, P85	I/O port P8 I/O port P85	Input/output Input/output Input	P80 to P84, P86, and P87 are I/O ports with the same functions as P6. Using software, they can be made to function as the I/O pins for timer A4 and the input pins for external interrupts. P86 and P87 can be set using software to function as the I/O pins for a sub clock generation circuit. In this case, connect a quartz oscillator between P86 (XCOUT pin) and P87 (XCIN pin). P85 is an input-only port that also functions for NMI. The NMI interrupt is generated when the input at this pin changes from "H" to "L". The NMI function cannot be canceled using software. The pull-up cannot be set for this pin.
P90 to P97	I/O port P9	Input/output	This is an 8-bit I/O port equivalent to P6. Pins in this port also function as SI/O3,4 I/O pin, timer B0–B2 input pins, D-A converter output pins, A-D converter's extended input pins, or A-D trigger input pins as selected by software.
P100 to P107	I/O port P10	Input/output	This is an 8-bit I/O port equivalent to P6. Pins in this port also function as A-D converter input pins. Furthermore, P104–P107 also function as input pins for the key input interrupt function.

5.3 Memory Map

Figure 5.3.1 shows the memory map. Figures 5.3.2 and 5.3.3 show the SFR memory map.

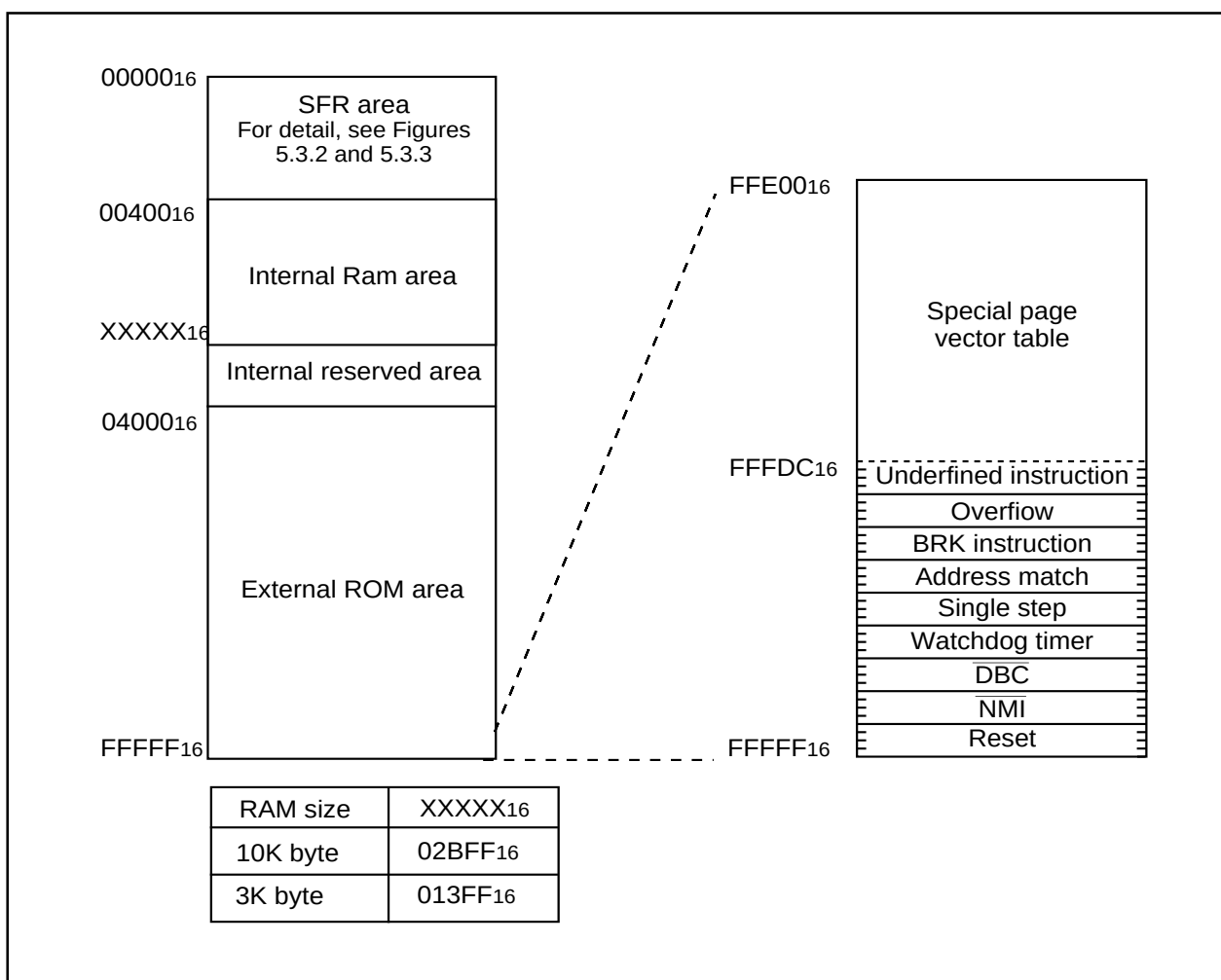


Figure 5.3.1. Memory map

0000 ₁₆		0040 ₁₆	
0001 ₁₆		0041 ₁₆	
0002 ₁₆		0042 ₁₆	
0003 ₁₆		0043 ₁₆	
0004 ₁₆	Processor mode register 0 (PM0)	0044 ₁₆	INT3 interrupt control register (INT3IC)
0005 ₁₆	Processor mode register 1 (PM1)	0045 ₁₆	Timer B5 interrupt control register (TB5IC)
0006 ₁₆	System clock control register 0 (CM0)	0046 ₁₆	Timer B4 interrupt control register (TB4IC)
0007 ₁₆	System clock control register 1 (CM1)	0047 ₁₆	Timer B3 interrupt control register (TB3IC)
0008 ₁₆	Chip select control register (CSR)	0048 ₁₆	SI/O4 interrupt control register (S4IC)
0009 ₁₆	Address match interrupt enable register (AIER)		INT5 interrupt control register (INT5IC)
000A ₁₆	Protect register (PRCR)	0049 ₁₆	SI/O3 interrupt control register (S3IC)
000B ₁₆			INT4 interrupt control register (INT4IC)
000C ₁₆		004A ₁₆	Bus collision detection interrupt control register (BCNIC)
000D ₁₆		004B ₁₆	DMA0 interrupt control register (DM0IC)
000E ₁₆	Watchdog timer start register (WDTS)	004C ₁₆	DMA1 interrupt control register (DM1IC)
000F ₁₆	Watchdog timer control register (WDC)	004D ₁₆	Key input interrupt control register (KUPIC)
0010 ₁₆		004E ₁₆	A-D conversion interrupt control register (ADIC)
0011 ₁₆	Address match interrupt register 0 (RMAD0)	004F ₁₆	UART2 transmit interrupt control register (S2TIC)
0012 ₁₆		0050 ₁₆	UART2 receive interrupt control register (S2RIC)
0013 ₁₆		0051 ₁₆	UART0 transmit interrupt control register (S0TIC)
0014 ₁₆		0052 ₁₆	UART0 receive interrupt control register (S0RIC)
0015 ₁₆	Address match interrupt register 1 (RMAD1)	0053 ₁₆	UART1 transmit interrupt control register (S1TIC)
0016 ₁₆		0054 ₁₆	UART1 receive interrupt control register (S1RIC)
0017 ₁₆		0055 ₁₆	Timer A0 interrupt control register (TA0IC)
0018 ₁₆		0056 ₁₆	Timer A1 interrupt control register (TA1IC)
0019 ₁₆		0057 ₁₆	Timer A2 interrupt control register (TA2IC)
001A ₁₆		0058 ₁₆	Timer A3 interrupt control register (TA3IC)
001B ₁₆		0059 ₁₆	Timer A4 interrupt control register (TA4IC)
001C ₁₆		005A ₁₆	Timer B0 interrupt control register (TB0IC)
001D ₁₆		005B ₁₆	Timer B1 interrupt control register (TB1IC)
001E ₁₆		005C ₁₆	Timer B2 interrupt control register (TB2IC)
001F ₁₆		005D ₁₆	INT0 interrupt control register (INT0IC)
0020 ₁₆		005E ₁₆	INT1 interrupt control register (INT1IC)
0021 ₁₆	DMA0 source pointer (SAR0)	005F ₁₆	INT2 interrupt control register (INT2IC)
0022 ₁₆		0060 ₁₆	
0023 ₁₆		0061 ₁₆	
0024 ₁₆		0062 ₁₆	
0025 ₁₆	DMA0 destination pointer (DAR0)	0063 ₁₆	
0026 ₁₆		0064 ₁₆	
0027 ₁₆		0065 ₁₆	
0028 ₁₆	DMA0 transfer counter (TCR0)		
0029 ₁₆		≈	≈
002A ₁₆		032A ₁₆	
002B ₁₆		032B ₁₆	
002C ₁₆	DMA0 control register (DM0CON)	032C ₁₆	
002D ₁₆		032D ₁₆	
002E ₁₆		032E ₁₆	
002F ₁₆		032F ₁₆	
0030 ₁₆		0330 ₁₆	
0031 ₁₆	DMA1 source pointer (SAR1)	0331 ₁₆	
0032 ₁₆		0332 ₁₆	
0033 ₁₆		0333 ₁₆	
0034 ₁₆		0334 ₁₆	
0035 ₁₆	DMA1 destination pointer (DAR1)	0335 ₁₆	
0036 ₁₆		0336 ₁₆	
0037 ₁₆		0337 ₁₆	
0038 ₁₆		0338 ₁₆	
0039 ₁₆	DMA1 transfer counter (TCR1)	0339 ₁₆	
003A ₁₆		033A ₁₆	
003B ₁₆		033B ₁₆	
003C ₁₆	DMA1 control register (DM1CON)	033C ₁₆	
003D ₁₆		033D ₁₆	
003E ₁₆		033E ₁₆	
003F ₁₆		033F ₁₆	

Note : Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

Figure 5.3.2. SFR memory map (1)

0340 ₁₆	Timer B3, 4, 5 count start flag (TBSR)	0380 ₁₆	Count start flag (TABSR)
0341 ₁₆		0381 ₁₆	Clock prescaler reset flag (CPSRF)
0342 ₁₆		0382 ₁₆	One-shot start flag (ONSF)
0343 ₁₆	Timer A1-1 register (TA11)	0383 ₁₆	Trigger select register (TRGSR)
0344 ₁₆		0384 ₁₆	Up-down flag (UDF)
0345 ₁₆	Timer A2-1 register (TA21)	0385 ₁₆	
0346 ₁₆		0386 ₁₆	Timer A0 register (TA0)
0347 ₁₆	Timer A4-1 register (TA41)	0387 ₁₆	
0348 ₁₆	Three-phase PWM control register 0(INVC0)	0388 ₁₆	Timer A1 register (TA1)
0349 ₁₆	Three-phase PWM control register 1(INVC1)	0389 ₁₆	
034A ₁₆	Three-phase output buffer register 0(IDB0)	038A ₁₆	Timer A2 register (TA2)
034B ₁₆	Three-phase output buffer register 1(IDB1)	038B ₁₆	
034C ₁₆	Dead time timer(DTT)	038C ₁₆	Timer A3 register (TA3)
034D ₁₆	Timer B2 interrupt occurrence frequency set counter(ICTB2)	038D ₁₆	
034E ₁₆		038E ₁₆	Timer A4 register (TA4)
034F ₁₆		038F ₁₆	
0350 ₁₆		0390 ₁₆	Timer B0 register (TB0)
0351 ₁₆	Timer B3 register (TB3)	0391 ₁₆	
0352 ₁₆		0392 ₁₆	Timer B1 register (TB1)
0353 ₁₆	Timer B4 register (TB4)	0393 ₁₆	
0354 ₁₆		0394 ₁₆	Timer B2 register (TB2)
0355 ₁₆	Timer B5 register (TB5)	0395 ₁₆	
0356 ₁₆		0396 ₁₆	Timer A0 mode register (TA0MR)
0357 ₁₆		0397 ₁₆	Timer A1 mode register (TA1MR)
0358 ₁₆		0398 ₁₆	Timer A2 mode register (TA2MR)
0359 ₁₆		0399 ₁₆	Timer A3 mode register (TA3MR)
035A ₁₆		039A ₁₆	Timer A4 mode register (TA4MR)
035B ₁₆	Timer B3 mode register (TB3MR)	039B ₁₆	Timer B0 mode register (TB0MR)
035C ₁₆	Timer B4 mode register (TB4MR)	039C ₁₆	Timer B1 mode register (TB1MR)
035D ₁₆	Timer B5 mode register (TB5MR)	039D ₁₆	Timer B2 mode register (TB2MR)
035E ₁₆		039E ₁₆	
035F ₁₆	Interrupt cause select register (IFSR)	039F ₁₆	
0360 ₁₆	SI/O3 transmit/receive register (S3TRR)	03A0 ₁₆	UART0 transmit/receive mode register (U0MR)
0361 ₁₆		03A1 ₁₆	UART0 bit rate generator (U0BRG)
0362 ₁₆	SI/O3 control register (S3C)	03A2 ₁₆	
0363 ₁₆	SI/O3 bit rate generator (S3BRG)	03A3 ₁₆	UART0 transmit buffer register (U0TB)
0364 ₁₆	SI/O4 transmit/receive register (S4TRR)	03A4 ₁₆	UART0 transmit/receive control register 0 (U0C0)
0365 ₁₆		03A5 ₁₆	UART0 transmit/receive control register 1 (U0C1)
0366 ₁₆	SI/O4 control register (S4C)	03A6 ₁₆	
0367 ₁₆	SI/O4 bit rate generator (S4BRG)	03A7 ₁₆	UART0 receive buffer register (U0RB)
0368 ₁₆		03A8 ₁₆	UART1 transmit/receive mode register (U1MR)
0369 ₁₆		03A9 ₁₆	UART1 bit rate generator (U1BRG)
036A ₁₆		03AA ₁₆	
036B ₁₆		03AB ₁₆	UART1 transmit buffer register (U1TB)
036C ₁₆		03AC ₁₆	UART1 transmit/receive control register 0 (U1C0)
036D ₁₆		03AD ₁₆	UART1 transmit/receive control register 1 (U1C1)
036E ₁₆		03AE ₁₆	
036F ₁₆		03AF ₁₆	UART1 receive buffer register (U1RB)
0370 ₁₆		03B0 ₁₆	UART transmit/receive control register 2 (UCON)
0371 ₁₆		03B1 ₁₆	
0372 ₁₆		03B2 ₁₆	
0373 ₁₆		03B3 ₁₆	
0374 ₁₆		03B4 ₁₆	
0375 ₁₆		03B5 ₁₆	
0376 ₁₆	UART2 special mode register 2(U2SMR2)	03B6 ₁₆	
0377 ₁₆	UART2 special mode register (U2SMR)	03B7 ₁₆	
0378 ₁₆	UART2 transmit/receive mode register (U2MR)	03B8 ₁₆	DMA0 request cause select register (DM0SL)
0379 ₁₆	UART2 bit rate generator (U2BRG)	03B9 ₁₆	
037A ₁₆		03BA ₁₆	DMA1 request cause select register (DM1SL)
037B ₁₆	UART2 transmit buffer register (U2TB)	03BB ₁₆	
037C ₁₆		03BC ₁₆	
037D ₁₆	UART2 transmit/receive control register 0 (U2C0)	03BD ₁₆	CRC data register (CRCD)
037E ₁₆	UART2 transmit/receive control register 1 (U2C1)	03BE ₁₆	CRC input register (CRCIN)
037F ₁₆	UART2 receive buffer register (U2RB)	03BF ₁₆	

Note : Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

Figure 5.3.3. SFR memory map (2)

External ROM

03C0 ₁₆	A-D register 0 (AD0)
03C1 ₁₆	
03C2 ₁₆	A-D register 1 (AD1)
03C3 ₁₆	
03C4 ₁₆	A-D register 2 (AD2)
03C5 ₁₆	
03C6 ₁₆	A-D register 3 (AD3)
03C7 ₁₆	
03C8 ₁₆	A-D register 4 (AD4)
03C9 ₁₆	
03CA ₁₆	A-D register 5 (AD5)
03CB ₁₆	
03CC ₁₆	A-D register 6 (AD6)
03CD ₁₆	
03CE ₁₆	A-D register 7 (AD7)
03CF ₁₆	
03D0 ₁₆	
03D1 ₁₆	
03D2 ₁₆	
03D3 ₁₆	
03D4 ₁₆	A-D control register 2 (ADCON2)
03D5 ₁₆	
03D6 ₁₆	A-D control register 0 (ADCON0)
03D7 ₁₆	A-D control register 1 (ADCON1)
03D8 ₁₆	D-A register 0 (DA0)
03D9 ₁₆	
03DA ₁₆	D-A register 1 (DA1)
03DB ₁₆	
03DC ₁₆	D-A control register (DACON)
03DD ₁₆	
03DE ₁₆	
03DF ₁₆	
03E0 ₁₆	
03E1 ₁₆	Port P1 register (P1)
03E2 ₁₆	
03E3 ₁₆	Port P1 direction register (PD1)
03E4 ₁₆	
03E5 ₁₆	
03E6 ₁₆	
03E7 ₁₆	
03E8 ₁₆	Port P4 register (P4)
03E9 ₁₆	
03EA ₁₆	Port P4 direction register (PD4)
03EB ₁₆	
03EC ₁₆	Port P6 register (P6)
03ED ₁₆	Port P7 register (P7)
03EE ₁₆	Port P6 direction register (PD6)
03EF ₁₆	Port P7 direction register (PD7)
03F0 ₁₆	Port P8 register (P8)
03F1 ₁₆	Port P9 register (P9)
03F2 ₁₆	Port P8 direction register (PD8)
03F3 ₁₆	Port P9 direction register (PD9)
03F4 ₁₆	Port P10 register (P10)
03F5 ₁₆	
03F6 ₁₆	Port P10 direction register (PD10)
03F7 ₁₆	
03F8 ₁₆	
03F9 ₁₆	
03FA ₁₆	
03FB ₁₆	
03FC ₁₆	Pull-up control register 0 (PUR0)
03FD ₁₆	Pull-up control register 1 (PUR1)
03FE ₁₆	Pull-up control register 2 (PUR2)
03FF ₁₆	Port control register (PCR)

Note : Locations in the SFR area where nothing is allocated are reserved areas. Do not access these areas for read or write.

Figure 5.3.4. SFR memory map (3)

5.4 Processor Mode

The external ROM version is operated only in microprocessor mode, so be sure to perform the following:

- Connect CNVss pin to Vcc.

Figure 5.4.1 shows the processor mode register 0.

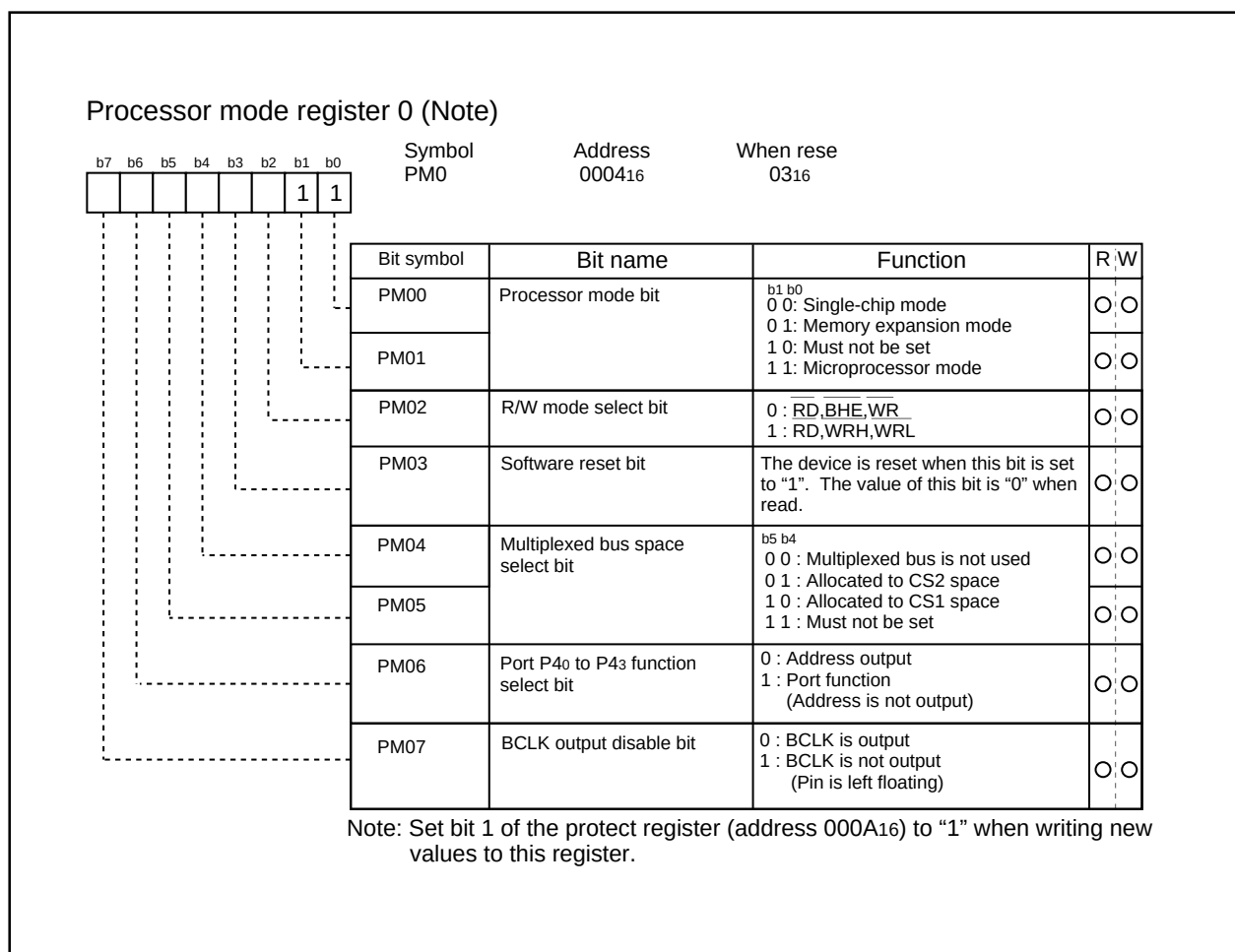


Figure 5.4.1. Processor mode register 0

Appendix 1

Appendix 1 Check Sheet

The following check sheet was created based on items which had been the source of problems in the past. We recommend you refer to the check sheet when troubleshooting.

- ☐ Are you making use of Technical News?

For the latest copy of Technical News, contact an authorized dealer.

Checks regarding register initial settings

- ☐ Has the initial setting been made in the interrupt stack pointer (ISP) at the top of the program?
- ☐ Has the initial setting been made in the user stack pointer (USP)? (Only if using the USP)
- ☐ Does the USP overlap the ISP area? (Only if using the USP)
- ☐ Is interrupt enabled after setting the ISP and USP?
- ☐ Is the top address of the variable interrupt vector table set in the interrupt table register (INTB)?
- ☐ Is interrupt enabled after setting the INTB?
- ☐ Has the initial setting been made in the frame base register (FB)? (Only if using the FB)
- ☐ Has the initial setting been made in the stack base register (SB)? (Only if using the SB)

Checks regarding the internal memory

- ☐ Does the RAM capacity used in the program exceed the RAM capacity of the microcomputer?
- ☐ Does the ROM capacity used in the program exceed the ROM capacity of the microcomputer?

Checks regarding the protect register

- ☐ Is writing enabled in the protect register (address 000A₁₆) before writing in the system clock control register (addresses 0006₁₆ and 0007₁₆)?
- ☐ Is writing enabled in the protect register before writing in the processor mode register (addresses 0004₁₆ and 0005₁₆)?
- ☐ Is writing enabled in the protect register before writing in the port P9 direction register (address 03F3₁₆)?
- ☐ Is writing effectuated in the port P9 direction register by the next instruction after writing is enabled in the protect register?
- ☐ Does not an interrupt generate between the instruction writing is enabled in the protect register and the instruction writing in the port P9 direction register?

Appendix 1

- ☐ Does not instruction DMA transfer occur between the instruction writing is enabled in the protect register and the instruction writing in the port P9 direction register starts?
- ☐ Is writing enabled in the protect register before writing in the SI/Oi (i=3,4) control register (address 036216, 036616)?
- ☐ Is writing effectuated in the SI/Oi (i=3,4) control register by the next instruction after writing is enabled in the protect register?
- ☐ Does not an interrupt generate between the instruction writing is enabled in the protect register and the instruction writing in the SI/Oi (i=3,4) control register?
- ☐ Does not instruction DMA transfer occur between the instruction writing is enabled in the protect register and the instruction writing in the SI/Oi (i=3,4) control register starts?

Checks regarding the timer

- ☐ Is the timer started after a value is set in the timer register?

Checks regarding Interrupt

- ☐ When rewrite the interrupt register, do so at a point that does not generate the interrupt request?

Checks regarding low voltage and low power consumption

- ☐ When using at low voltage, have you checked recommended operating conditions and changed the wait bit (address 000516, bit 7) to "1"?
- ☐ Does the oscillator to which the count source is going to be switched be oscillating stably, before the count source for BCLK can be changed from XIN to XCIN or vice versa?
- ☐ In the low power consumption mode, does not current flow from Vref when the Vref connection bit (bit 5 in address 03D716) is set?
- ☐ Is not voltage level of port floating in the low power consumption mode?

Checks regarding A-D converter

- ☐ Have you selected other than fAD (no dividing) for ϕ AD when using the A-D converter at Vcc = 2.7V to 4.0V?
- ☐ Have you selected no sample & hold function when using the A-D converter at Vcc = 2.7V to 4.0V?
- ☐ Have you selected 8-bit mode when using the A-D converter at Vcc = 2.7V to 4.0V?
- ☐ Does ϕ AD use it by less than 10MHz?

Appendix 2 Hexadecimal instruction CODE table

	D7 to D4	0000	0001	0010	0011	0100	0101	0110	0111
D3 to D0		0	1	2	3	4	5	6	7
0000	0	BRK	AND.B:S R0H,R0L	ADD.B:S R0H,R0L	MOV.B:S R0H,A0	BCLR:S 0,11[SB]	BNOT:S 0,11[SB]	JMP.S label	MULU.B src,dest
0001	1	MOV.B:S R0L,dsp:8[SB]	AND.B:S dsp:8[SB],R0L	ADD.B:S dsp:8[SB],R0L	MOV.B:S dsp:8[SB],A0	BCLR:S 1,11[SB]	BNOT:S 1,11[SB]	JMP.S label	MULU.W src,dest
0010	2	MOV.B:S R0L,dsp:8[FB]	AND.B:S dsp:8[FB],R0L	ADD.B:S dsp:8[FB],R0L	MOV.B:S dsp:8[FB],A0	BCLR:S 2,11[SB]	BNOT:S 2,11[SB]	JMP.S label	MOV.B:G src,dest
0011	3	MOV.B:S R0L,abs16	AND.B:S abs16,R0L	ADD.B:S abs16,R0L	MOV.B:S abs16,A0	BCLR:S 3,11[SB]	BNOT:S 3,11[SB]	JMP.S label	MOV.W:G src,dest
0100	4	NOP	AND.B:S R0L,R0H	ADD.B:S R0L,R0H	MOV.B:S R0Çk,A1	BCLR:S 4,11[SB]	BNOT:S 4,11[SB]	JMP.S label	CODE_74
0101	5	MOV.B:S R0H,dsp:8[SB]	AND.B:S dsp:8[SB],R0H	ADD.B:S dsp:8[SB],R0H	MOV.B:S dsp:8[SB],A1	BCLR:S 5,11[SB]	BNOT:S 5,11[SB]	JMP.S label	CODE_75
0110	6	MOV.B:S R0H,dsp:8[FB]	AND.B:S dsp:8[FB],R0H	ADD.B:S dsp:8[FB],R0H	MOV.B:S dsp:8[FB],A1	BCLR:S 6,11[SB]	BNOT:S 6,11[SB]	JMP.S label	CODE_76
0111	7	MOV.B:S R0H,abs16	AND.B:S abs16,R0H	ADD.B:S abs16,R0H	MOV.B:S abs16,A1	BCLR:S 7,11[SB]	BNOT:S 7,11[SB]	JMP.S label	CODE_77
1000	8	MOV.B:S R0H,R0L	OR.B:S R0H,R0L	SUB.B:S R0H,R0L	CMP.B:S R0H,R0L	BSET:S 0,11[SB]	BTST:S 0,11[SB]	JGEU/C label	MUL.B src,dest
1001	9	MOV.B:S dsp:8[SB],R0L	OR.B:S dsp:8[SB],R0L	SUB.B:S dsp:8[SB],R0L	CMP.B:S dsp:8[SB],R0L	BSET:S 1,11[SB]	BTST:S 1,11[SB]	JGTU label	MUL.W src,dest
1010	A	MOV.B:S dsp:8[FB],R0L	OR.B:S dsp:8[FB],R0L	SUB.B:S dsp:8[FB],R0L	CMP.B:S dsp:8[FB],R0L	BSET:S 2,11[SB]	BTST:S 2,11[SB]	JEQ/Z label	CODE_7A
1011	B	MOV.B:S abs16,R0L	OR.B:S abs16,R0L	SUB.B:S abs16,R0L	CMP.B:S abs16,R0L	BSET:S 3,11[SB]	BTST:S 3,11[SB]	JN label	CODE_7B
1100	C	MOV.B:S R0L,R0H	OR.B:S R0L,R0H	SUB.B:S R0L,R0H	CMP.B:S R0L,R0H	BSET:S 4,11[SB]	BTST:S 4,11[SB]	JLTU/NC label	CODE_7C
1101	D	MOV.B:S dsp:8[SB],R0H	OR.B:S dsp:8[SB],R0H	SUB.B:S dsp:8[SB],R0H	CMP.B:S dsp:8[SB],R0H	BSET:S 5,11[SB]	BTST:S 5,11[SB]	JLEU label	CODE_7D
1110	E	MOV.B:S dsp:8[FB],R0H	OR.B:S dsp:8[FB],R0H	SUB.B:S dsp:8[FB],R0H	CMP.B:S dsp:8[FB],R0H	BSET:S 6,11[SB]	BTST:S 6,11[SB]	JNE/JNZ label	CODE_7E
1111	F	MOV.B:S abs16,R0H	OR.B:S abs16,R0H	SUB.B:S abs16,R0H	CMP.B:S abs16,R0H	BSET:S 7,11[SB]	BTST:S 7,11[SB]	JPZ label	

The next instruction is arranged in each CODE.

CODE_74 : STE, MOV, PUSH, NEG, ROT, NOT, LDE, POP, SHL, SHA

CODE_75 : STE, MOV, PUSH, NEG, ROT, NOT, LDE, POP, SHL, SHA

CODE_76 : TST, XOR, AND, OR, ADD, SUB, ADC, SBB, CMP, DIVX, ROLC, RORC, DIVU, DIV, ADCF, ABS

CODE_77 : TST, XOR, AND, OR, ADD, SUB, ADC, SBB, CMP, DIVX, ROLC, RORC, DIVU, DIV, ADCF, ABS

CODE_7A : XCHG, LDC

CODE_7B : XCHG, STC

CODE_7C : MOVD_{ir}, MULU, MUL, EXTS, STC, DIVU, DIV, PUSH, DIVX, DADD, DSUB, DADC, DSBB, SMOVF, SMOVB, SSTR, ADD, LDCTX, RMPA, ENTER

CODE_7D : JMPL, JSRI, MULU, MUL, PUSHA, LDPL, ADD, JC_{nd}, BMC_{nd}, DIVU, DIV, PUSH, DIVX, DADD, DSUB, DADC, DSBB, SMOVF, SMOVB, SSTR, STCTX, RMPA, EXITD, WAIT

CODE_7E : BTSTC, BMC_{nd}, BNTST, BAND, BNAND, BOR, BNOR, BCLR, BSET, BNOT, BTST, BXOR, BNxor

CODE_EB:SHL,FSET,FCLR,MOVA,LDC,SHA,PUSHC,POPC,INT

Appendix 2 Hexadecimal instruction CODE table

	D7 to D4	1000	1001	1010	1011	1100	1101	1110	1111
D3 to D0		8	9	A	B	C	D	E	F
0000	0	TST.B src,dest	AND.B:G src,dest	ADD.B:G src,dest	ADC.B src,dest	CMP.B:G src,dest	CMP.B:Q #IMM,dest	ROT.B #IMM,dest	SHA.B #IMM,dest
0001	1	TST.W src,dest	AND.W:G src,dest	ADD.W:G src,dest	ADC.w src,dest	CMP.W:G src,dest	CMP.W:Q #IMM,dest	ROT.W #IMM,dest	SHA.W #IMM,dest
0010	2	PUSH.B:S R0L	POP.B:S R0L	MOV.W:S #IMM,A0	INC.W A0	PUSH.W:S A0	POP.W:S A0	MOV.B:S #IMM,A0	DEC.W A0
0011	3	ADD.B:S #IMM8,R0H	AND.B:S #IMM8,R0H	INC.B R0H	MOV.B:Z #0,R0H	MOV.B:S #IMM8,R0H	STNZ #IMM8,R0H	CMP.B:S #IMM8,R0H	RTS
0100	4	ADD.B:S #IMM8,R0L	AND.B:S #IMM8,R0L	INC.B R0L	MOV.B:Z #0,R0L	MOV.B:S #IMM8,R0L	STNZ #IMM8,R0L	CMP.B:S #IMM8,R0L	JMP.W label
0101	5	ADD.B:S #IMM8,dsp:8[SB]	AND.B:S #IMM8,dsp:8[SB]	INC.B dsp:8[SB]	MOV.B:Z #0,dsp:8[SB]	MOV.B:S #IMM8,dsp:8[SB]	STNZ #IMM8,dsp:8[SB]	CMP.B:S #IMM8,dsp:8[SB]	JSR.W label
0110	6	ADD.B:S #IMM8,dsp:8[FB]	AND.B:S #IMM8,dsp:8[FB]	INC.B dsp:8[FB]	MOV.B:Z #0,dsp:8[FB]	MOV.B:S #IMM8,dsp:8[FB]	STNZ #IMM8,dsp:8[FB]	CMP.B:S #IMM8,dsp:8[FB]	INTO
0111	7	ADD.B:S #IMM8,abs16	AND.B:S #IMM8,abs16	INC.B abs16	MOV.B:Z #0,abs16	MOV.B:S #IMM8,abs16	STNZ #IMM8,abs16	CMP.B:S #IMM8,abs16	
1000	8	XOR.B src,dest	OR.B:G src,dest	SUB.B:G src,dest	SBB.B src,dest	ADD.B:Q #IMM,dest	MOV.B:Q #IMM,dest	SHL.B #IMM,dest	ADJNZ.B #IMM,dest,label
1001	9	XOR.W src,dest	OR.W:G src,dest	SUB.W:G src,dest	SBB.W src,dest	ADD.W:Q #IMM,dest	MOV.W:Q #IMM,dest	SHL.W #IMM,dest	ADJNZ.W #IMM,dest,label
1010	A	PUSH.B:S R0H	POP.B:S R0H	MOV.W:S #IMM,A1	INC.W A1	PUSH.W:S A1	POP.W:S A1	MOV.B:S #IMM,A1	DEC.W A1
1011	B	SUB.B:S #IMM8,R0H	OR.B:S #IMM8,R0H	DEC.B R0H	NOT.B:S R0H	STZ #IMM8,R0H	STZX #IMM8,#IMM8,R0H	CODE_EB	REIT
1100	C	SUB.B:S #IMM8,R0L	OR.B:S #IMM8,R0L	DEC.B R0L	NOT.B:S R0L	STZ #IMM8,R0L	STZX #IMM8,#IMM8,R0L	PUSHM src	JMP.A label
1101	D	SUB.B:S #IMM8,dsp:8[SB]	OR.B:S #IMM8,dsp:8[SB]	DEC.B dsp:8[SB]	NOT.B:S dsp:8[SB]	STZ #IMM8,dsp:8[SB]	STZX #IMM8,#IMM8,dsp:8[SB]	POPM dest	JSR.A label
1110	E	SUB.B:S #IMM8,dsp:8[FB]	OR.B:S #IMM8,dsp:8[FB]	DEC.B dsp:8[FB]	NOT.B:S dsp:8[FB]	STZ #IMM8,dsp:8[FB]	STZX #IMM8,#IMM8,dsp:8[FB]	JMPS #IMM8	JMP.B label
1111	F	SUB.B:S #IMM8,abs16	OR.B:S #IMM8,abs16	DEC.B abs16	NOT.B:S abs16	STZ #IMM8,abs16	STZX #IMM8,#IMM8,abs16	JSRS #IMM8	UND

The following shows the register to select pin and the setting value.
Refer to the table as follows.

Pin function

I/O direction of pin function

Contents of pin function

See page for peripheral function

Pin name	P96/ANEX1/SOUT4	Pin No.	1 (FP)	99 (GP)	Setting register						Remarks	Page
			6,3F3h	3,3FEh	7,3D7h	6,3D7h	3,366h	2,366h				
ANEX1	I	AD extend input	0	0	1	0	0	X				1-149
SOUT4	O	Serial I/O data output	0	0	0	0	1	0				1-145
P96	I	Port input (No pulled high)	0	0	0	0	0	X				1-163
P96	I	Port input (Pulled high)	0	1	0	0	0	X				1-163
P96	O	Port output	1	X	0	0	0	X				1-163
		6,3F3h	Port P96 direction register									1-168
		3,3FEh	P94 to P97 pull-up control register									1-170
		7,3D7h	External op-amp connection mode bit of A-D control register 1									1-151
		6,3D7h	External op-amp connection mode bit of A-D control register 1									1-151
		3,366h	SI/O4 port select bit of SI/O4 control register									1-146
		2,366h	SOUT4 output disable bit of SI/O4 control register									1-146

Setting value of bit
0 : Set to "0"
1 : Set to "1"
X : Can be "0" or "1"

See page for register

A symbol to show a bit to select pin function (bit No., address)

Appendix 3 Setting register for pin function selected

Pin name			P96/ANEX1/SOUT4			Pin No.	1 (FP)		99 (GP)							
Function selection			Setting register										Remarks	Page		
			6,3F3h	3,3FEh	7,3D7h	6,3D7h	3,366h	2,366h								
ANEX1	I	AD extend input	0	0	1	0	0	X						1-149		
SOUT4	O	Serial I/O data output	0	0	0	0	1	0						1-145		
P96	I	Port input (No pulled high)	0	0	0	0	0	X						1-163		
P96	I	Port input (Pulled high)	0	1	0	0	0	X						1-163		
P96	O	Port output	1	X	0	0	0	X						1-163		
			6,3F3h	Port P96 direction register											1-168	
			3,3FEh	P94 to P97 pull-up control register											1-170	
			7,3D7h	External op-amp connection mode bit of A-D contol register 1											1-151	
			6,3D7h	External op-amp connection mode bit of A-D contol register 1											1-151	
			3,366h	SI/O4 port select bit of SI/O4 control register											1-146	
			2,366h	SOUT4 output disable bit of SI/O4 control register											1-146	

Pin name	P95/ANEX0/CLK4		Pin No.	2 (FP)		100 (GP)								
Function selection			Setting register								Remarks	Page		
			5,3F3h	3,3FEh	7,3D7h	6,3D7h	3,366h	6,366h						
ANEX0	I	AD extend input	0	0	0	1	0	X					1-149	
ANEX0	O	Output when op-amp connection mode	0	0	1	1	0	X					1-149	
SCLK4	O	Serial clock output	0	0	0	0	1	1					1-145	
SCLK4	I	Serial clock input	0	0	0	0	1	0					1-145	
P95	I	Port input (No pulled high)	0	0	0	0	0	X					1-163	
P95	I	Port input (Pulled high)	0	1	0	0	0	X					1-163	
P95	O	Port output	1	X	0	0	0	X					1-163	
			5,3F3h	Port P95 direction register										1-168
			3,3FEh	P94 to P97 pull-up control register										1-170
			7,3D7h	External op-amp connection mode bit of A-D control register 1										1-151
			6,3D7h	External op-amp connection mode bit of A-D control register 1										1-151
			3,366h	SI/O4 port select bit of SI/O4 control register										1-146
			6,366h	Synchronous clock select bit of SI/O4 control register										1-146

Pin name			P94/DA1/TB4IN		Pin No.		3 (FP)		1 (GP)								
Function selection			Setting register											Remarks	Page		
			4,3F3h		3,3FEh		1,3DCh		7,35Ch								
DA1	O	DA output	0		0		1		0							1-159	
TB4IN	I	Count source input	0		0		0		0							1-90	
P94	I	Port input (No pulled high)	0		0		0		0							1-163	
P94	I	Port input (Pulled high)	0		1		0		0							1-163	
P94	O	Port output	1		X		0		0							1-163	
			4,3F3h		Port P94 direction register												1-168
			3,3FEh		P94 to P97 pull-up control register												1-170
			1,3DCh		D-A1 output enable bit of D-A control register												1-160
			7,35Ch		Event clock select bit ot timer B4 mode register												1-90

Appendix 3 Setting register for pin function selected

Pin name	P93/DA0/TB3IN		Pin No.	4 (FP)		2 (GP)								
Function selection			Setting register									Remarks	Page	
			3,3F3h	2,3FEh	0,3DCh	7,35Bh								
DA0	O	DA output	0	0	1	0							1-159	
TB3IN	I	Count source input	0	0	0	0							1-90	
P93	I	Port input (No pulled high)	0	0	0	0							1-163	
P93	I	Port input (Pulled high)	0	1	0	0							1-163	
P93	O	Port output	1	X	0	0							1-163	
			3,3F3h	Port P93 direction register										1-168
			2,3FEh	P90 to P93 pull-up control register										1-170
			0,3DCh	D-A0 output enable bit of D-A control register										1-160
			7,35Bh	Event clock select bit of timer B3 mode register										1-90

Pin name			P92/TB2IN/SOUT3			Pin No.	5 (FP)		3 (GP)							
Function selection			Setting register										Remarks	Page		
			2,3F3h	2,3FEh	7,39Dh	3,362h	2,362h									
TB2IN	I	Count source input	0	0	0	0	X								1-90	
SOUT3	O	Serial I/O data output	0	0	0	1	0								1-145	
P92	I	Port input (No pulled high)	0	0	X	0	X								1-163	
P92	I	Port input (Pulled high)	0	1	X	0	X								1-163	
P92	O	Port output	1	X	X	0	X								1-163	
			2,3F3h	Port P92 direction register											1-168	
			2,3FEh	P90 to P93 pull-up control register											1-170	
			7,39Dh	Event clock select bit ot timer B2 mode register											1-90	
			3,362h	SI/O3 port select bit of SI/O3 control register											1-146	
			2,362h	SOUT3 output disable bit of SI/O3 control register											1-146	

Pin name			P91/TB1IN/SIN3		Pin No.		6 (FP)		4 (GP)								
Function selection					Setting register										Remarks	Page	
					1,3F3h	2,3FEh	7,39Ch	3,362h									
TB1IN	I	Count source input			0	0	0	0								1-90	
SIN3	I	Serial I/O data input			0	0	0	1								1-145	
P91	I	Port input (No pulled high)			0	0	X	0								1-163	
P91	I	Port input (Pulled high)			0	1	X	0								1-163	
P91	O	Port output			1	X	X	0								1-163	
					1,3F3h	Port P91 direction register											1-168
					2,3FEh	P90 to P93 pull-up control register											1-170
					7,39Ch	Event clock select bit of timer B1 mode register											1-90
					3,362h	SI/O3 port select bit of SI/O3 control register											1-146

Appendix 3 Setting register for pin function selected

Pin name	P90/TB0IN/CLK3		Pin No.	7 (FP)		5 (GP)							
Function selection			Setting register								Remarks	Page	
			0,3F3h	2,3FEh	7,39Bh	3,362h	6,362h						
TB0IN	I	Count source input	0	0	0	0	X						1-90
CLK3	O	Serial clock output	0	0	X	1	1						1-145
CLK3	I	Serial clock input	0	0	X	1	0						1-145
P90	I	Port input (No pulled high)	0	0	X	0	X						1-163
P90	I	Port input (Pulled high)	0	1	X	0	X						1-163
P90	O	Port output	1	X	X	0	X						1-163
			0,3F3h	Port P90 direction register									1-168
			2,3FEh	P90 to P93 pull-up control register									1-170
			7,39Bh	Event clock select bit of timer B0 mode register									1-90
			3,362h	SI/O3 port select bit of SI/O3 control register									1-146
			6,362h	Synchronous clock select bit of SI/O3 control register									1-146

Pin name	P87/XCIN		Pin No.	10 (FP)		8 (GP)								
Function selection			Setting register									Remarks	Page	
			7,3F2h	1,3FEh	4,006h									
XCIN	I	Sub clock input	0	0	1								1-36	
P87	I	Port input (No pulled high)	0	0	0								1-163	
P87	I	Port input (Pulled high)	0	1	0								1-163	
P87	O	Port output	1	X	0								1-163	
			7,3F2h	Port P87 direction register										1-168
			1,3FEh	P84 to P87 pull-up control register										1-170
			4,006h	Port Xc select bit of system clock control register 0										1-39

Pin name	P86/XCOUT		Pin No.	11 (FP)		9 (GP)						
Function selection			Setting register								Remarks	Page
			6,3F2h	1,3FEh	4,006h							
XCOUT	O	Sub clock output	0	0	1							1-36
P86	I	Port input (No pulled high)	0	0	0							1-163
P86	I	Port input (Pulled high)	0	1	0							1-163
P86	O	Port output	1	X	0							1-163
			6,3F2h	Port P86 direction register								1-168
			1,3FEh	P84 to P87 pull-up control register								1-170
			4,006h	Port Xc select bit of system clock control register 0								1-39

Appendix 3 Setting register for pin function selected

Pin name	P84/INT2		Pin No.	18 (FP)		16 (GP)								
Function selection			Setting register									Remarks	Page	
			4,3F2h	1,3FEh										
INT2	I	Interrupt input	0	X								1	1-61	
P84	I	Port input (No pulled high)	0	0									1-163	
P84	I	Port input (Pulled high)	0	1									1-163	
P84	O	Port output	1	X									1-163	
			4,3F2h	Port P84 direction register										1-168
			1,3FEh	P84 to P87 pull-up control register										1-170

Remark 1: Interrupt request bit generates by state change of a port, not by setting value of register.

Pin name	P83/INT1		Pin No.	19 (FP)		17 (GP)								
Function selection			Setting register									Remarks	Page	
			4,3F2h	1,3FEh										
INT1	I	Interrupt input	0	X								1	1-61	
P83	I	Port input (No pulled high)	0	0									1-163	
P83	I	Port input (Pulled high)	0	1									1-163	
P83	O	Port output	1	X									1-163	
			3,3F2h	Port P83 direction register										1-168
			0,3FEh	P80 to P83 pull-up control register										1-170

Remark 1: Interrupt request bit generates by state change of a port, not by setting value of register.

Pin name	P82/INT0		Pin No.	20 (FP)		18 (GP)								
Function selection			Setting register									Remarks	Page	
			2,3F2h	0,3FEh										
INT0	I	Interrupt input	0	X								1	1-61	
P82	I	Port input (No pulled high)	0	0									1-163	
P82	I	Port input (Pulled high)	0	1									1-163	
P82	O	Port output	1	X					1				1-163	
			2,3F2h	Port P82 direction register										1-168
			0,3FEh	P80 to P83 pull-up control register										1-170

Remark 1: Interrupt request bit generates by state change of a port, not by setting value of register.

Pin name	P81/TA4IN/Ū		Pin No.	21 (FP)		19 (GP)							
Function selection			Setting register									Remarks	Page
			1,3F2h	0,3FEh	7,383h	6,383h	4,39Ah	2,348h					
TA4IN	I	Gate function level input	0	X	0	0	1	0					1-78
TA4IN	I	Count source input	0	X	0	0	X	0					1-78
TA4IN	I	External trigger input	0	X	0	0	1	0					1-78
Ū	O	Ū phase output	X	X	X	X	X	1					1-96
P81	I	Port input (No pulled high)	0	0	X	X	X	0					1-163
P81	I	Port input (Pulled high)	0	1	X	X	X	0					1-163
P81	O	Port output	1	X	X	X	X	0					1-163
			1,3F2h	Port P81 direction register									1-168
			0,3FEh	P80 to P83 pull-up control register									1-170
			7,383h	Timer A4 event/trigger select bit of trigger select register									1-82
			6,383h	Timer A4 event/trigger select bit of trigger select register									1-82
			4,39Ah	Bit 4 of timer A4 mode register									1-80
			2,348h	Three phase mode select bit									1-96

Appendix 3 Setting register for pin function selected

Pin name	P80/TA4OUT/U		Pin No.	22 (FP)		20 (GP)								
Function selection			Setting register									Remarks	Page	
			0,3F2h	0,3FEh	4,39Ah	2,39Ah	7,384h	2,348h						
TA4OUT	O	Pulse output	X	X	X	1	0	0				1	1-78	
TA4OUT	I	Up/down polarity select input	0	X	1	0	0	0					1-78	
TA4OUT	I	Two-phase pulse signal input	0	X	1	0	1	0					1-78	
U	O	U phase output	X	X	X	X	X	1					1-96	
P80	I	Port input (No pulled high)	0	0	X	0	0	0					1-163	
P80	I	Port input (Pulled high)	0	1	X	0	0	0					1-163	
P80	O	Port output	1	X	X	0	0	0					1-163	
			0,3F2h	Port P80 direction register										1-168
			0,3FEh	P80 to P83 pull-up control register										1-170
			4,39Ah	Bit 4 of timer A4 mode register										1-80
			2,39Ah	Bit 2 of timer A4 mode register										1-80
			7,384h	Timer A4 two-phase pulse signal processing select bit of up/down flag										1-81
			2,348h	Three phase mode select bit										1-96

Remark 1: Can not be use when processing two-phase pulse signal.

Pin name			P77/TA3IN			Pin No.	23 (FP)		21 (GP)					
Function selection			Setting register								Remarks	Page		
			7,3EFh	7,3FDh	5,383h	4,383h	4,399h							
TA3IN	I	Gate function level input	0	X	0	0	1						1-78	
TA3IN	I	Count source input	0	X	0	0	X						1-78	
TA3IN	I	External trigger input	0	X	0	0	1						1-78	
P77	I	Port input (No pulled high)	0	0	X	X	X						1-163	
P77	I	Port input (Pulled high)	0	1	X	X	X						1-163	
P77	O	Port output	1	X	X	X	X						1-163	
			7,3EFh	Port P77 direction register										1-168
			7,3FDh	P74 to P77 pull-up control register										1-170
			5,383h	Timer A3 event/trigger select bit of trigger select register										1-82
			4,383h	Timer A3 event/trigger select bit of trigger select register										1-82
			4,399h	Bit 4 of timer A3 mode register										1-80

Pin name			P76/TA3OUT		Pin No.	24 (FP)		22 (GP)					
Function selection			Setting register								Remarks	Page	
			6,3EFh	7,3FDh	4,399h	2,399h	6,384h						
TA3OUT	O	Pulse output	X	X	X	1	0					1	1-78
TA3OUT	I	Up/down polarity select input	0	X	1	0	0						1-78
TA3OUT	I	Two-phase pulse signal input	0	X	1	0	1						1-78
P76	I	Port input (No pulled high)	0	0	X	0	0						1-163
P76	I	Port input (Pulled high)	0	1	X	0	0						1-163
P76	O	Port output	1	X	X	0	0						1-163
			6,3EFh	Port P76 direction register									1-168
			7,3FDh	P74 to P77 pull-up control register									1-170
			4,399h	Bit 4 of timer A3 mode register									1-80
			2,399h	Bit 2 of timer A3 mode register									1-80
			6,384h	Timer A3 two-phase pulse signal processing select bit of up/down flag									1-81

Remark 1: Can not be use when processing two-phase pulse signal.

Appendix 3 Setting register for pin function selected

Pin name			P75/TA2IN/ $\overline{W}$			Pin No.	25 (FP)			23 (GP)				
Function selection			Setting register									Remarks	Page	
			5,3EFh	7,3FDh	3,383h	2,383h	4,398h	2,348h						
TA2IN	I	Gate function level input	0	X	0	0	1	0					1-78	
TA2IN	I	Count source input	0	X	0	0	X	0					1-78	
TA2IN	I	External trigger input	0	X	0	0	1	0					1-78	
$\overline{W}$	O	$\overline{W}$ phase output	0	0	X	X	X	1					1-96	
P75	I	Port input (No pulled high)	0	0	X	X	X	0					1-163	
P75	I	Port input (Pulled high)	0	1	X	X	X	0					1-163	
P75	O	Port output	1	X	X	X	X	0					1-163	
			5,3EFh	Port P75 direction register										1-168
			7,3FDh	P74 to P77 pull-up control register										1-170
			3,383h	Timer A2 event/trigger select bit of trigger select register										1-82
			2,383h	Timer A2 event/trigger select bit of trigger select register										1-82
			4,398h	Bit 4 of timer A2 mode register										1-80
			2,348h	Three phase mode select bit										1-96

Pin name	P74/TA2OUT/W		Pin No.	26 (FP)		24 (GP)								
Function selection			Setting register									Remarks	Page	
			4,3EFh	7,3FDh	4,398h	2,398h	5,384h	2,348h						
TA2OUT	O	Pulse output	X	X	X	1	0	0				1	1-78	
TA2OUT	I	Up/down polarity select input	0	X	1	0	0	0					1-78	
TA2OUT	I	Two-phase pulse signal input	0	X	1	0	1	0					1-78	
W	O	W phase output	X	X	X	X	X	1					1-96	
P74	I	Port input (No pulled high)	0	0	X	0	0	0					1-163	
P74	I	Port input (Pulled high)	0	1	X	0	0	0					1-163	
P74	O	Port output	1	X	X	0	0	0					1-163	
			4,3EFh	Port P74 direction register										1-168
			7,3FDh	P74 to P77 pull-up control register										1-170
			4,398h	Bit 4 of timer A2 mode register										1-80
			2,398h	Bit 2 of timer A2 mode register										1-80
			5,384h	Timer A2 two-phase pulse signal processing select bit of up/down flag										1-81
			2,348h	Three phase mode select bit										1-96

Remark 1: Can not be use when processing two-phase pulse signal.

Appendix 3 Setting register for pin function selected

Pin name	P73/ $\overline{\text{CTS2}}$ / $\overline{\text{RTS2}}$ / $\text{TA1IN}/\overline{\text{V}}$		Pin No.	27 (FP)		25 (GP)								
Function selection			Setting register									Remarks	Page	
			3,3EFh	6,3FDh	1,383h	0,383h	4,397h	4,37Ch	2,37Ch	2,348h				
TA1IN	I	Gate function level input	0	X	0	0	1	X	X	0			1-78	
TA1IN	I	Count source input	0	X	0	0	X	X	X	0			1-78	
TA1IN	I	External trigger input	0	X	0	0	1	X	X	0			1-78	
$\overline{\text{RTS2}}$	O	$\overline{\text{RTS}}$ output	X	X	X	X	X	0	1	0		1	1-108	
$\overline{\text{CTS2}}$	I	$\overline{\text{CTS}}$ input	0	X	X	X	X	0	0	0		1	1-108	
$\overline{\text{V}}$	O	$\overline{\text{V}}$ phase output	X	X	X	X	X	X	X	1			1-96	
P73	I	Port input (No pulled high)	0	0	X	X	X	X	X	0			1-163	
P73	I	Port input (Pulled high)	0	1	X	X	X	X	X	0			1-163	
P73	O	Port output	1	X	X	X	X	X	X	0			1-163	
			3,3EFh	Port P73 direction register										1-168
			6,3FDh	P70 to P73 pull-up control register										1-170
			1,383h	Bit 1 of trigger select register										1-82
			0,383h	Bit 0 of trigger select register										1-82
			4,397h	Bit 4 of timer A1 mode register										1-80
			4,37Ch	CTS/RTS disable bit of UART2 transmit/receive control register 0										1-114
			2,37Ch	CTS/RTS select bit of UART2 transmit/receive control register 0										1-114
			2,348h	Three phase mode select bit										1-96

Remark 1 : Set serial I/O enabled by serial I/O mode select bit of UART2 transmit/receive mode register.

Pin name	P72/CLK2/TA1OUT/V		Pin No.	28 (FP)		26 (GP)								
Function selection			Setting register									Remarks	Page	
			2,3EFh	6,3FDh	4,397h	2,397h	3,378h	2,348h						
TA1OUT	O	Pulse output	X	X	X	1	X	0					1-78	
TA1OUT	I	Up/down polarity select input	0	X	1	0	X	0					1-78	
CLK2	I	Serial I/O clock input	0	0	X	X	1	0				1	1-108	
CLK2	O	Serial I/O clock output	X	0	X	X	0	0				1,2	1-108	
V	O	V phase output	X	X	X	X	X	1					1-96	
P72	I	Port input (No pulled high)	0	0	X	0	X	1					1-163	
P72	I	Port input (Pulled high)	0	1	X	0	X	0					1-163	
P72	O	Port output	1	X	X	0	X	0					1-163	
			2,3EFh	Port P72 direction register										1-168
			6,3FDh	P70 to P73 pull-up control register										1-170
			4,397h	Bit 4 of timer A1 mode register										1-80
			2,397h	Bit 2 of timer A1 mode register										1-80
			3,378h	Internal/external clock select bit of UART2 transmit/receive mode register										1-113
			2,348h	Three phase mode select bit										1-96

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART2 transmit/receive mode register.

Remark 2: It become I/O port when UART mode selected.

Appendix 3 Setting register for pin function selected

Pin name			P71/RXD2/TA0IN/TB5IN/SCL			Pin No.		29 (FP)			27 (GP)				
Function selection			Setting register									Remarks	Page		
			1,3EFh	6,3FDh	7,382h	6,382h	4,396h	7,35Dh	0,377h	3,378h					
TA0IN	I	Gate function level input	0	X	0	0	1	0	0	X			1-78		
TA0IN	I	Count source input	0	X	0	0	X	0	0	X			1-78		
TA0IN	I	External trigger input	0	X	0	0	1	0	0	X			1-78		
TB5IN	I	Count source input	0	0	X	X	X	1	X	0			1-90		
SCL	O	IIC clock output	0	0	X	X	X	0	1	0		1	1-137		
SCL	I	IIC clock input	0	0	X	X	X	0	1	1		1	1-137		
RXD2	I	Serial I/O data input	0	0	X	X	X	0	0	X		1	1-108		
P71	I	Port input	0	0	X	X	X	0	0	X			1-163		
P71	O	Port output	1	X	X	X	X	0	0	X			1-163		
			1,3EFh	Port P71 direction register										1-168	
			6,3FDh	P70 to P73 pull-up control register										1-170	
			7,382h	Bit 7 of one-shot start flag										1-82	
			6,382h	Bit 6 of one-shot start flag										1-82	
			4,396h	Bit 4 of timer A0 mode register										1-80	
			7,35Dh	Event clock select bit of timer B5 mode register										1-90	
			0,377h	IIC mode select bit										1-137	
			3,378h	Internal /external clock select bit										1-127	

Remark 1 : Set serial I/O enabled by serial I/O mode select bit of UART2 transmit/receive mode register.

Pin name	P70/TXD2/TA0OUT/SDA		Pin No.	30 (FP)		28 (GP)								
Function selection			Setting register									Remarks	Page	
			0,3EFh	6,3FDh	4,396h	2,396h	0,377h	6,376h						
TA0OUT	O	Pulse output	X	X	X	1	0	X					1-78	
TA0OUT	I	Up/down polarity select input	0	X	1	0	0	X					1-78	
TXD2	O	Serial I/O data output	X	X	X	X	0	X				1, 2	1-108	
SDA	I	IIC data input	0	0	0	0	1	1				1	1-137	
SDA	O	IIC data output	0	0	0	0	1	0				1, 2	1-137	
P70	I	Port input	0	0	0	0	0	X					1-163	
P70	O	Port output	1	X	0	0	0	X					1-163	
			0,3EFh	Port P70 direction register										1-168
			6,3FDh	P70 to P73 pull-up control register										1-170
			4,396h	Bit 4 of timer A0 mode register										1-80
			2,396h	Bit 2 of timer A0 mode register										1-80
			0,377h	IIC mode select bit										1-137
			6,376h	SDA output stop bit										1-141

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART2 transmit/receive mode register.

Remark 2: N channel open-drain output.

Appendix 3 Setting register for pin function selected

Pin name			P67/TXD1			Pin No.		31 (FP)		29 (GP)					
Function selection			Setting register								Remarks	Page			
			7,3EEh	5,3FDh											
TXD1	O	Serial I/O data output		X	X								1, 2	1-108	
P67	I	Port input (No pulled high)		0	0									1-163	
P67	I	Port input (Pulled high)		0	1									1-163	
P67	O	Port output		1	X									1-163	
				7,3EEh	Port P67 direction register									1-168	
				5,3FDh	P64 to P67 pull-up control register									1-170	

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART1 transmit/receive mode register.

Remark 2: Can be selected CMOS output or N channel open-drain output.

Pin name			P66/RXD1		Pin No.		32 (FP)		30 (GP)					
Function selection			Setting register								Remarks	Page		
			6,3EEh	5,3FDh										
RXD1	I	Serial I/O data input	0	X								1	1-108	
P66	I	Port input (No pulled high)	0	0									1-163	
P66	I	Port input (Pulled high)	0	1									1-163	
P66	O	Port output	1	X									1-163	
			6,3EEh	Port P66 direction register									1-168	
			5,3FDh	P64 to P67 pull-up control register									1-170	

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART1 transmit/receive mode register.

Pin name	P65/CLK1		Pin No.	33 (FP)		31 (GP)								
Function selection			Setting register								Remarks	Page		
			5,3EEh	5,3FDh	3,3A8h									
CLK1	I	Serial I/O clock input	0	X	1							1	1-108	
CLK1	O	Serial I/O clock output	X	X	0							1, 2	1-108	
P65	I	Port input (No pulled high)	0	0	X								1-163	
P65	I	Port input (Pulled high)	0	1	X								1-163	
P65	O	Port output	1	X	X								1-163	
			6,3EEh	Port P65 direction register										1-168
			5,3FDh	P64 to P67 pull-up control register										1-170
			3,3A8h	Internal/external clock select bit of UART1 transmit/receive mode register										1-113

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART1 transmit/receive mode register.

Remark 2: It become I/O port when UART mode selected.

Appendix 3 Setting register for pin function selected

Pin name	P64/ $\overline{\text{CTS1}}$ / $\overline{\text{RTS1}}$ /CLKS1		Pin No.	34 (FP)		32 (GP)							
Function selection			Setting register								Remarks	Page	
			4,3EEh	5,3FDh	5,3B0h	4,3B0h	4,3ACh	2,3ACh	3,3A8h				
CLKS1	O	Serial I/O clock output	X	X	1	1	1	X	0			1	1-108
$\overline{\text{RTS1}}$	O	RTS output	X	X	0	0	0	1	X			1	1-108
$\overline{\text{CTS1}}$	I	$\overline{\text{CTS}}$ input	0	X	0	0	0	0	X			1	1-108
P64	I	Port input (No pulled high)	0	0	X	X	X	X	X				1-163
P64	I	Port input (Pulled high)	0	1	X	X	X	X	X				1-163
P64	O	Port output	1	X	X	X	X	X	X				1-163
			4,3EEh	Port P64 direction register									1-168
			5,3FDh	P64 to P67 pull-up control register									1-170
			5,3B0h	CLK/CLKS select bit 1 of UART transmit/receive control register 2									1-116
			4,3B0h	CLK/CLKS select bit 0 of UART transmit/receive control register 2									1-116
			4,3ACh	CTS/RTS disable bit of UART1 transmit/receive control register 0									1-114
			2,3ACh	CTS/RTS function select bit of UART1 transmit/receive control register 0									1-114
			3,3A8h	Internal/external clock select bit of UART1 transmit/receive mode register									1-113

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART1 transmit/receive mode register.

Pin name	P63/TXD0		Pin No.	35 (FP)		33 (GP)							
Function selection			Setting register								Remarks	Page	
			3,3EEh	4,3FDh									
TXD0	O	Serial I/O data output	X	X							1, 2	1-108	
P63	I	Port input (No pulled high)	0	0								1-163	
P63	I	Port input (Pulled high)	0	1								1-163	
P63	O	Port output	1	X								1-163	
			3,3EEh	Port P63 direction register									1-168
			4,3FDh	P60 to P63 pull-up control register									1-170

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART0 transmit/receive mode register.

Remark 2: Can be selected CMOS output or N channel open-drain output.

Pin name	P62/RXD0		Pin No.	36 (FP)		34 (GP)							
Function selection			Setting register								Remarks	Page	
			2,3EEh	4,3FDh									
RXD0	I	Serial I/O data input	0	X							1	1-108	
P62	I	Port input (No pulled high)	0	0								1-163	
P62	I	Port input (Pulled high)	0	1								1-163	
P62	O	Port output	1	X								1-163	
			2,3EEh	Port P62 direction register									1-168
			4,3FDh	P60 to P63 pull-up control register									1-170

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART0 transmit/receive mode register.

Appendix 3 Setting register for pin function selected

Pin name	P61/CLK0		Pin No.	37 (FP)		35 (GP)							
Function selection			Setting register								Remarks	Page	
			1,3EEh	4,3FDh	3,3A0h								
CLK0	I	Serial I/O clock input	0	X	1						1	1-108	
CLK0	O	Serial I/O clock output	X	X	0						1, 2	1-108	
P61	I	Port input (No pulled high)	0	0	X							1-163	
P61	I	Port input (Pulled high)	0	1	X							1-163	
P61	O	Port output	1	X	X							1-163	
			1,3EEh	Port P61 direction register									1-168
			4,3FDh	P60 to P63 pull-up control register									1-170
			3,3A0h	Internal/external clock select bit of UART0 transmit/receive mode register									1-113

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART0 transmit/receive mode register.

Remark 2: It become I/O port when UART mode selected.

Pin name	P60/CTS0/RTS0		Pin No.	38 (FP)		36 (GP)								
Function selection			Setting register								Remarks	Page		
			0,3EEh	4,3FDh	4,3A4h	2,3A4h								
RTS0	O	RTS output	X	X	0	1						1	1-108	
CTS0	I	CTS input	0	X	0	0						1	1-108	
P60	I	Port input (No pulled high)	0	0	X	X							1-163	
P60	I	Port input (Pulled high)	0	1	X	X							1-163	
P60	O	Port output	1	X	X	X							1-163	
			0,3EEh	Port P60 direction register										1-168
			4,3FDh	P60 to P63 pull-up control register										1-170
			4,3A4h	CTS/RTS disable bit of UART0 transmit/receive control register 0										1-114
			2,3A4h	CTS/RTS function select bit of UART0 transmit/receive control register 0										1-114

Remark 1: Set serial I/O enabled by serial I/O mode select bit of UART0 transmit/receive mode register.

Pin name	P57/ <u>RDY</u> /CLKOUT		Pin No.	39 (FP)		37 (GP)								
Function selection			Setting register									Remarks	Page	
			7,3EBh	3,3FDh	1,004h	0,004h	1,006h	0,006h						
CLKOUT	O	CLKOUT output	X	X	0	0	Except 00						1-40	
<u>RDY</u>	I	<u>RDY</u> input	X	X	X	1	X	X				1	1-32	
P57	I	Port input (No pulled high)	0	0	0	0	0	0					1-163	
P57	I	Port input (Pulled high)	0	1	0	0	0	0					1-163	
P57	O	Port output	1	X	0	0	0	0					1-163	
			7,3EBh	Port P57 direction register										1-168
			3,3FDh	P54 to P57 pull-up control register										1-170
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			1,006h	Clock output function select bit of system clock control register 0										1-39
			0,006h	Clock output function select bit of system clock control register 0										1-39

Remark 1: When the user is using the RDY, the wait bit of relevant chip selects must be set to "0".

Appendix 3 Setting register for pin function selected

Pin name			P56/ALE		Pin No.	40(FP)		38 (GP)							
Function selection			Setting register										Remarks	Page	
			6,3EBh	3,3FDh	1,004h	0,004h									
ALE	O	ALE output	X	X	X	1								1-31	
P56	I	Port input (No pulled high)	0	0	0	0								1-163	
P56	I	Port input (Pulled high)	0	1	0	0								1-163	
P56	O	Port output	1	X	0	0								1-163	
			6,3EBh	Port P56 direction register											1-168
			3,3FDh	P54 to P57 pull-up control register											1-170
			1,004h	Processor mode bit of processor mode register 0											1-23
			0,004h	Processor mode bit of processor mode register 0											1-23

Pin name	P55/HOLD		Pin No.	41 (FP)		39 (GP)						Remarks	Page
Function selection			Setting register										
			5,3EBh	3,3FDh	1,004h	0,004h							
HOLD	I	HOLD input	X	X	X	1							1-33
P55	I	Port input (No pulled high)	0	0	0	0							1-163
P55	I	Port input (Pulled high)	0	1	0	0							1-163
P55	O	Port output	1	X	0	0							1-163
			5,3EBh	Port P55 direction register									1-168
			3,3FDh	P54 to P57 pull-up control register									1-170
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23

Pin name	P54/HLDA		Pin No.	42 (FP)		40 (GP)						Remarks	Page
Function selection			Setting register										
			4,3EBh	3,3FDh	1,004h	0,004h							
HLDA	O	HLDA output	X	X	X	1							1-28
P54	I	Port input (No pulled high)	0	0	0	0							1-163
P54	I	Port input (Pulled high)	0	1	0	0							1-163
P54	O	Port output	1	X	0	0							1-163
			4,3EBh	Port P54 direction register									1-168
			3,3FDh	P54 to P57 pull-up control register									1-170
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23

Appendix 3 Setting register for pin function selected

Pin name			P53/BCLK		Pin No.		43 (FP)		41 (GP)								
Function selection					Setting register										Remarks	Page	
					3,3EBh	2,3FDh	7,004h	1,004h	0,004h								
BCLK	O	BCLK output			X	X	0	X	1							1-28	
P53	I	Port input (No pulled high)			0	0	X	0	0							1-163	
P53	I	Port input (Pulled high)			0	1	X	0	0							1-163	
P53	O	Port output			1	X	X	0	0							1-163	
					3,3EBh	Port P53 direction register											1-168
					2,3FDh	P50 to P53 pull-up control register											1-170
					7,004h	BCLK output disable bit of processor mode register 0											1-23
					1,004h	Processor mode bit of processor mode register 0											1-23
					0,004h	Processor mode bit of processor mode register 0											1-23

Pin name	P52/ $\overline{\text{RD}}$		Pin No.	44 (FP)		42 (GP)									
Function selection			Setting register										Remarks	Page	
			2,3EBh	2,3FDh	1,004h	0,004h									
$\overline{\text{RD}}$	O	$\overline{\text{RD}}$ output	X	X	X	1								1-28	
P52	I	Port input (No pulled high)	0	0	0	0								1-163	
P52	I	Port input (Pulled high)	0	1	0	0								1-163	
P52	O	Port output	1	X	0	0								1-163	
			2,3EBh	Port P52 direction register											1-168
			2,3FDh	P50 to P53 pull-up control register											1-170
			1,004h	Processor mode bit of processor mode register 0											1-23
			0,004h	Processor mode bit of processor mode register 0											1-23

Pin name	P51/WRH/BHE		Pin No.	45 (FP)		43 (GP)							
Function selection			Setting register								Remarks	Page	
			1,3EBh	2,3FDh	2,004h	1,004h	0,004h						
BHE	O	BHE output	X	X	0	X	1						1-28
WRH	O	WRH output	X	X	1	X	1						1-28
P51	I	Port input (No pulled high)	0	0	X	0	0						1-163
P51	I	Port input (Pulled high)	0	1	X	0	0						1-163
P51	O	Port output	1	X	X	0	0						1-163
			1,3EBh	Port P51 direction register									1-168
			2,3FDh	P50 to P53 pull-up control register									1-170
			2,004h	R/W mode select bit of processor mode register 0									1-23
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23

Pin name			P50/WRL/WR		Pin No.	46 (FP)		44 (GP)							
Function selection					Setting register								Remarks	Page	
					0,3EBh	2,3FDh	2,004h	1,004h	0,004h						
WR	O	WR output		X	X	0	X	1						1-28	
WRL	O	WRL output		X	X	1	X	1						1-28	
P50	I	Port input (No pulled high)		0	0	X	0	0						1-163	
P50	I	Port input (Pulled high)		0	1	X	0	0						1-163	
P50	O	Port output		1	X	X	0	0						1-163	
					0,3EBh	Port P50 direction register									1-168
					2,3FDh	P50 to P53 pull-up control register									1-170
					2,004h	R/W select bit of processor mode register 0									1-23
					1,004h	Processor mode bit of processor mode register 0									1-23
					0,004h	Processor mode bit of processor mode register 0									1-23

Appendix 3 Setting register for pin function selected

Pin name			P47/CS3	Pin No.	47 (FP)		45 (GP)							
Function selection				Setting register								Remarks	Page	
				7,3EAh	1,3FDh	3,008h	1,004h	0,004h						
CS3	O	Chip select output		X	X	1	X	1						1-28
P47	I	Port input (No pulled high)		0 0	0 0	X 0	0 X	0 1						1-163
P47	I	Port input (Pulled high)		0 0	1 1	X 0	0 X	0 1						1-163
P47	O	Port output		1 1	X X	X 0	0 X	0 1						1-163
				7,3EAh	Port P47 direction register									1-168
				1,3FDh	P44 to P47 pull-up control register									1-170
				3,008h	CS3 output enable bit of chip select control register									1-29
				1,004h	Processor mode bit of processor mode register 0									1-23
				0,004h	Processor mode bit of processor mode register 0									1-23

Pin name			P46/CS2		Pin No.	48 (FP)		46 (GP)							
Function selection			Setting register										Remarks	Page	
			6,3EAh	1,3FDh	2,008h	1,004h	0,004h								
CS2	O	Chip select output	X	X	1	X	1							1-28	
P46	I	Port input (No pulled high)	0 0	0 0	X 0	0 X	0 1							1-163	
P46	I	Port input (Pulled high)	0 0	1 1	X 0	0 X	0 1							1-163	
P46	O	Port output	1 1	X X	X 0	0 X	0 1							1-163	
			6,3EAh	Port P46 direction register											1-168
			1,3FDh	P44 to P47 pull-up control register											1-170
			2,008h	CS2 output enable bit of chip select control register											1-29
			1,004h	Processor mode bit of processor mode register 0											1-23
			0,004h	Processor mode bit of processor mode register 0											1-23

Pin name			P45/ <u>CS1</u>		Pin No.	49 (FP)		47 (GP)							
Function selection			Setting register										Remarks	Page	
			5,3EAh	1,3FDh	1,008h	1,004h	0,004h								
<u>CS1</u>	O	Chip select output	X	X	1	X	1							1-28	
P45	I	Port input (No pulled high)	0 0	0 0	X 0	0 X	0 1							1-163	
P45	I	Port input (Pulled high)	0 0	1 0	X 0	0 X	0 1							1-163	
P45	O	Port output	1 1	X X	X 0	0 X	0 1							1-163	
			5,3EAh	Port P45 direction register											1-168
			1,3FDh	P44 to P47 pull-up control register											1-170
			1,008h	CS1 output enable bit of chip select control register											1-29
			1,004h	Processor mode bit of processor mode register 0											1-23
			0,004h	Processor mode bit of processor mode register 0											1-23

Appendix 3 Setting register for pin function selected

Pin name	P44/ $\overline{CS0}$		Pin No.	50 (FP)		48 (GP)								
Function selection			Setting register									Remarks	Page	
			4,3EAh	1,3FDh	0,008h	1,004h	0,004h							
$\overline{CS0}$	O	Chip select output	X	X	1	X	1						1-28	
P44	I	Port input (No pulled high)	0 0	0 0	X 0	0 X	0 1						1-163	
P44	I	Port input (Pulled high)	0 0	1 0	X 0	0 X	0 1						1-163	
P44	O	Port output	1 1	X X	X 0	0 X	0 1						1-163	
			4,3EAh	Port P44 direction register										1-168
			1,3FDh	P44 to P47 pull-up control register										1-170
			0,008h	CS0 output enable bit of chip select control register										1-29
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23

Pin name	P43/A19		Pin No.	51 (FP)		49 (GP)							
Function selection			Setting register									Remarks	Page
			3,3EAh	0,3FDh	6,004h	5,004h	4,004h	1,004h	0,004h				
A19	O	Address output	X	X	0	Except 11		X	1				1-28
P43	I	Port input (No pulled high)	0	0	X	X	X	0	0				1-163
			0	0	0	1	1	0	1				
			0	0	1	Except 11		X	1				
P43	I	Port input (Pulled high)	0	1	X	X	X	0	0				1-163
			0	1	0	1	1	0	1				
			0	1	1	Except 11		X	1				
P43	O	Port output	1	X	X	X	X	0	0				1-163
			1	X	0	1	1	0	1				
			1	X	1	Except 11		X	1				
			3,3EAh	Port P43 direction register									1-168
			0,3FDh	P40 to P43 pull-up control register									1-170
			6,004h	Port P40 to P43 function select bit of processor mode register 0									1-23
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23

Pin name	P42/A18		Pin No.	52 (FP)		50 (GP)							
Function selection			Setting register									Remarks	Page
			2,3EAh	0,3FDh	6,004h	5,004h	4,004h	1,004h	0,004h				
A18	O	Address output	X	X	0	Except 11		X	1				1-28
P42	I	Port input (No pulled high)	0	0	X	X	X	0	0				1-163
			0	0	0	1	1	0	1				
			0	0	1	Except 11		X	1				
P42	I	Port input (Pulled high)	0	1	X	X	X	0	0				1-163
			0	1	0	1	1	0	1				
			0	1	1	Except 11		X	1				
P42	O	Port output	1	X	X	X	X	0	0				1-163
			1	X	0	1	1	0	1				
			1	X	1	Except 11		X	1				
			2,3EAh	Port P42 direction register									1-168
			0,3FDh	P40 to P43 pull-up control register									1-170
			6,004h	Port P40 to P43 function select bit of processor mode register 0									1-23
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23

Appendix 3 Setting register for pin function selected

Pin name			P41/A17		Pin No.	53 (FP)		51 (GP)							
Function selection			Setting register									Remarks	Page		
			1,3EAh	0,3FDh	6,004h	5,004h	4,004h	1,004h	0,004h						
A17	O	Address output	X	X	0	Except 11		X	1				1-28		
P41	I	Port input (No pulled high)	0	0	X	X	X	0	0				1-163		
			0	0	0	1	1	0	1						
			0	0	1	Except 11		X	1						
P41	I	Port input (Pulled high)	0	1	X	X	X	0	0				1-163		
			0	1	0	1	1	0	1						
			0	1	1	Except 11		X	1						
P41	O	Port output	1	X	X	X	X	0	0				1-163		
			1	X	0	1	1	0	1						
			1	X	1	Except 11		X	1						
			1,3EAh	Port P41 direction register										1-168	
			0,3FDh	P40 to P43 pull-up control register										1-170	
			6,004h	Port P40 to P43 function select bit of processor mode register 0										1-23	
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23	
			1,004h	Processor mode bit of processor mode register 0										1-23	
			0,004h	Processor mode bit of processor mode register 0										1-23	

Pin name			P40/A16		Pin No.	54 (FP)		52 (GP)					
Function selection			Setting register								Remarks	Page	
			0,3EAh	0,3FDh	6,004h	5,004h	4,004h	1,004h	0,004h				
A16	O	Address output	X	X	0	Except 11		X	1				1-28
P40	I	Port input (No pulled high)	0	0	X	X	X	0	0				1-163
			0	0	0	1	1	0	1				
			0	0	1	Except 11		X	1				
P40	I	Port input (Pulled high)	0	1	X	X	X	0	0				1-163
			0	1	0	1	1	0	1				
			0	1	1	Except 11		X	1				
P40	O	Port output	1	X	X	X	X	0	0				1-163
			1	X	0	1	1	0	1				
			1	X	1	Except 11		X	1				
			0,3EAh	Port P40 direction register									1-168
			0,3FDh	P40 to P43 pull-up control register									1-170
			6,004h	Port P40 to P43 function select bit of processor mode register 0									1-23
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23

Pin name			P37/A15			Pin No.	55 (FP)		53 (GP)					
Function selection			Setting register								Remarks	Page		
			7,3E7h	7,3FCh	5,004h	4,004h	1,004h	0,004h						
A15	O	Address output	X	X	Except 11		X	1					1-28	
P37	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1					1-163	
P37	I	Port input (Pulled high)	0 0	1 1	0 1	0 1	0 0	0 1					1-163	
P37	O	Port output	1 1	X X	0 0	0 0	0 0	0 1					1-163	
			7,3E7h	Port P37 direction register									1-168	
			7,3FCh	P34 to P37 pull-up control register									1-170	
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			1,004h	Processor mode bit of processor mode register 0									1-23	
			0,004h	Processor mode bit of processor mode register 0									1-23	

Appendix 3 Setting register for pin function selected

Pin name	P36/A14		Pin No.	56 (FP)		54 (GP)								
Function selection			Setting register									Remarks	Page	
			6,3E7h	7,3FCh	5,004h	4,004h	1,004h	0,004h						
A14	O	Address output	X	X	Except 11		X	1					1-28	
P36	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1					1-163	
P36	I	Port input (Pulled high)	0 0	1 1	0 1	0 1	0 0	0 1					1-163	
P36	O	Port output	1 1	X X	0 0	0 0	0 0	0 1					1-163	
			6,3E7h	Port P36 direction register										1-168
			7,3FCh	P34 to P37 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23

Pin name	P35/A13		Pin No.	57 (FP)		55 (GP)								
Function selection			Setting register									Remarks	Page	
			5,3E7h	7,3FCh	5,004h	4,004h	1,004h	0,004h						
A13	O	Address output	X	X	Except 11		X	1					1-28	
P35	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1					1-163	
P35	I	Port input (Pulled high)	0 0	1 1	0 1	0 1	0 0	0 1					1-163	
P35	O	Port output	1 1	X X	0 0	0 0	0 0	0 1					1-163	
			5,3E7h	Port P35 direction register										1-168
			7,3FCh	P34 to P37 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23

Pin name	P34/A12		Pin No.	58 (FP)		56 (GP)								
Function selection			Setting register									Remarks	Page	
			4,3E7h	7,3FCh	5,004h	4,004h	1,004h	0,004h						
A12	O	Address output	X	X	Except 11		X	1					1-28	
P34	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1					1-163	
P34	I	Port input (Pulled high)	0 0	1 1	0 1	0 1	0 0	0 1					1-163	
P34	O	Port output	1 1	X X	0 0	0 0	0 0	0 1					1-163	
			4,3E7h	Port P34 direction register									1-168	
			7,3FCh	P34 to P37 pull-up control register									1-170	
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			1,004h	Processor mode bit of processor mode register 0									1-23	
			0,004h	Processor mode bit of processor mode register 0									1-23	

Appendix 3 Setting register for pin function selected

Pin name			P33/A11		Pin No.	59 (FP)		57 (GP)							
Function selection			Setting register									Remarks	Page		
			3,3E7h	6,3FCh	5,004h	4,004h	1,004h	0,004h							
A11	O	Address output	X	X	Except 11		X	1						1-28	
P33	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1						1-163	
P33	I	Port input (Pulled high)	0 0	1 1	0 1	0 1	0 0	0 1						1-163	
P33	O	Port output	1 1	X X	0 0	0 0	0 0	0 1						1-163	
			3,3E7h	Port P33 direction register										1-168	
			6,3FCh	P30 to P33 pull-up control register										1-170	
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23	
			1,004h	Processor mode bit of processor mode register 0										1-23	
			0,004h	Processor mode bit of processor mode register 0										1-23	

Pin name			P32/A10		Pin No.	60 (FP)		58 (GP)						
Function selection			Setting register									Remarks	Page	
			2,3E7h	6,3FCh	5,004h	4,004h	1,004h	0,004h						
A10	O	Address output	X	X	Except 11		X	1					1-28	
P32	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1					1-163	
P32	I	Port input (Pulled high)	0 0	1 1	0 1	0 1	0 0	0 1					1-163	
P32	O	Port output	1 1	X X	0 0	0 0	0 0	0 1					1-163	
			2,3E7h	Port P32 direction register										1-168
			6,3FCh	P30 to P33 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23

Pin name			P31/A9			Pin No.	61 (FP)		59 (GP)						
Function selection			Setting register										Remarks	Page	
			1,3E7h	6,3FCh	5,004h	4,004h	1,004h	0,004h							
A9	O	Address output	X	X	Except 11		X	1						1-28	
P31	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1						1-163	
P31	I	Port input (Pulled high)	0 0	1 1	X 1	X 1	0 0	0 1						1-163	
P31	O	Port output	1 1	X X	X 1	X 1	0 0	0 1						1-163	
			1,3E7h	Port P31 direction register											1-168
			6,3FCh	P30 to P33 pull-up control register											1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0											1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0											1-23
			1,004h	Processor mode bit of processor mode register 0											1-23
			0,004h	Processor mode bit of processor mode register 0											1-23

Appendix 3 Setting register for pin function selected

Pin name			P30/A8(/-/D7)			Pin No.	63 (FP)			61 (GP)				
Function selection			Setting register									Remarks	Page	
			0,3E7h	6,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
A8/D7	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L				1-28	
A8/-	O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H				1-28	
A8	O	Address output	X	X	0	0	X	1	X				1-28	
P30	I	Port input (No pulled high)	0	0	X	X	0	0	X				1-163	
P30	I	Port input (Pulled high)	0	1	X	X	0	0	X				1-163	
P30	O	Port output	1	X	X	X	0	0	X				1-163	
			0,3E7h	Port P30 direction register									1-168	
			6,3FCh	P30 to P33 pull-up control register									1-170	
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			1,004h	Processor mode bit of processor mode register 0									1-23	
			0,004h	Processor mode bit of processor mode register 0									1-23	
			BYTE	BYTE pin									1-26	

Pin name	P27/A7/(D7/D6)		Pin No.	65 (FP)		63 (GP)								
Function selection			Setting register									Remarks	Page	
			7,3E6h	5,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
A7/D6	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L				1-28	
A7/D7	I/O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H				1-28	
A7	O	Address output	X	X	0	0	X	1	X				1-28	
P27	I	Port input (No pulled high)	0	0	X	X	0	0	X				1-163	
P27	I	Port input (Pulled high)	0	1	X	X	0	0	X				1-163	
P27	O	Port output	1	X	X	X	0	0	X				1-163	
			7,3E6h	Port P27 direction register										1-168
			5,3FCh	P24 to P27 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Pin name	P26/A6/(D6/D5)		Pin No.	66 (FP)		64 (GP)								
Function selection			Setting register									Remarks	Page	
			6,3E6h	5,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
A6/D5	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L					1-28
A6/D6	I/O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H					1-28
A6	O	Address output	X	X	0	0	X	1	X					1-28
P26	I	Port input (No pulled high)	0	0	X	X	0	0	X					1-163
P26	I	Port input (Pulled high)	0	1	X	X	0	0	X					1-163
P26	O	Port output	1	X	X	X	0	0	X					1-163
			6,3E6h	Port P26 direction register										1-168
			5,3FCh	P24 to P27 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Appendix 3 Setting register for pin function selected

Pin name	P25/A5(/D5/D4)		Pin No.	67 (FP)		65 (GP)							
Function selection			Setting register									Remarks	Page
			5,3E6h	5,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE				
A5/D4	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L				1-28
A5/D5	I/O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H				1-28
A5	O	Address output	X	X	0	0	X	1	X				1-28
P25	I	Port input (No pulled high)	0	0	X	X	0	0	X				1-163
P25	I	Port input (Pulled high)	0	1	X	X	0	0	X				1-163
P25	O	Port output	1	X	X	X	0	0	X				1-163
			5,3E6h	Port P25 direction register									1-168
			5,3FCh	P24 to P27 pull-up control register									1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23
			BYTE	BYTE pin									1-26

Pin name	P24/A4(/D4/D3)		Pin No.	68 (FP)		66 (GP)							
Function selection			Setting register									Remarks	Page
			4,3E6h	5,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE				
A4/D3	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L				1-28
A4/D4	I/O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H				1-28
A4	O	Address output	X	X	0	0	X	1	X				1-28
P24	I	Port input (No pulled high)	0	0	X	X	0	0	X				1-163
P24	I	Port input (Pulled high)	0	1	X	X	0	0	X				1-163
P24	O	Port output	1	X	X	X	0	0	X				1-163
			4,3E6h	Port P24 direction register									1-168
			5,3FCh	P24 to P27 pull-up control register									1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23
			BYTE	BYTE pin									1-26

Pin name	P23/A3(/D3/D2)		Pin No.	69 (FP)		67 (GP)								
Function selection			Setting register									Remarks	Page	
			3,3E6h	4,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
A3/D2	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L				1-28	
A3/D3	I/O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H				1-28	
A3	O	Address output	X	X	0	0	X	1	X				1-28	
P23	I	Port input (No pulled high)	0	0	X	X	0	0	X				1-163	
P23	I	Port input (Pulled high)	0	1	X	X	0	0	X				1-163	
P23	O	Port output	1	X	X	X	0	0	X				1-163	
			3,3E6h	Port P23 direction register										1-168
			4,3FCh	P20 to P23 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Appendix 3 Setting register for pin function selected

Pin name			P22/A2(/D2/D1)			Pin No.	70 (FP)		68 (GP)					
Function selection			Setting register									Remarks	Page	
			2,3E6h	4,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
A2/D1	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L				1-28	
A2/D2	I/O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H				1-28	
A2	O	Address output	X	X	0	0	X	1	X				1-28	
P22	I	Port input (No pulled high)	0	0	X	X	0	0	X				1-163	
P22	I	Port input (Pulled high)	0	1	X	X	0	0	X				1-163	
P22	O	Port output	1	X	X	X	0	0	X				1-163	
			2,3E6h	Port P22 direction register										1-168
			4,3FCh	P20 to P23 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Pin name	P21/A1(/D1/D0)		Pin No.	71 (FP)		69 (GP)								
Function selection			Setting register									Remarks	Page	
			1,3E6h	4,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
A1/D0	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L				1-28	
A1/D1	I/O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H				1-28	
A1	O	Address output	X	X	0	0	X	1	X				1-28	
P21	I	Port input (No pulled high)	0	0	X	X	0	0	X				1-163	
P21	I	Port input (Pulled high)	0	1	X	X	0	0	X				1-163	
P21	O	Port output	1	X	X	X	0	0	X				1-163	
			1,3E6h	Port P21 direction register										1-168
			4,3FCh	P20 to P23 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Pin name	P20/A0(/D0/-)		Pin No.	72 (FP)		70 (GP)								
Function selection			Setting register									Remarks	Page	
			0,3E6h	4,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
A0/-	I/O	Multiplexed bus	X X	X X	0 1	1 0	X X	1 1	L L				1-28	
A0/D0	I/O	Multiplexed bus	X X	X X	X 1	1 X	X X	1 1	H H				1-28	
A0	O	Address output	X	X	0	0	X	1	X				1-28	
P20	I	Port input (No pulled high)	0	0	X	X	0	0	X				1-163	
P20	I	Port input (Pulled high)	0	1	X	X	0	0	X				1-163	
P20	O	Port output	1	X	X	X	0	0	X				1-163	
			0,3E6h	Port P20 direction register										1-168
			4,3FCh	P20 to P23 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Appendix 3 Setting register for pin function selected

Pin name			P17/D15/INT5		Pin No.	73 (FP)		71 (GP)							
Function selection			Setting register										Remarks	Page	
			7,3E3h	3,3FCh	5,004h		4,004h	1,004h	0,004h	BYTE					
D15	I/O	Data bus	X	X	Except 11		X	1	L					1-28	
INT5	I	Interrupt input	0 0	X X	X X	X X	0 X	0 1	X H					1-61	
P17	I	Port input (No pulled high)	0 0	0 0	X X	X X	0 X	0 1	X H					1-163	
P17	I	Port input (Pulled high)	0 0	1 1	X X	X X	0 X	0 1	X H					1-163	
P17	O	Port output	1 1	X X	X X	X X	0 X	0 1	X H					1-163	
			7,3E3h	Port P17 direction register											1-168
			3,3FCh	P14 to P17 pull-up control register											1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0											1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0											1-23
			1,004h	Processor mode bit of processor mode register 0											1-23
			0,004h	Processor mode bit of processor mode register 0											1-23
			BYTE	BYTE pin											1-26

Pin name	P16/D14/INT4		Pin No.	74 (FP)		72 (GP)								
Function selection			Setting register									Remarks	Page	
			6,3E3h	3,3FCh	5,004h		4,004h	1,004h	0,004h	BYTE				
D14	I/O	Data bus	X	X	Except 11		X	1	L				1-28	
INT4	I	Interrupt input	0 0	X X	X X	X X	0 X	0 1	X H				1-61	
P16	I	Port input (No pulled high)	0 0	0 0	X X	X X	0 X	0 1	X H				1-163	
P16	I	Port input (Pulled high)	0 0	1 1	X X	X X	0 X	0 1	X H				1-163	
P16	O	Port output	1 1	X X	X X	X X	0 X	0 1	X H				1-163	
			6,3E3h	Port P16 direction register										1-168
			3,3FCh	P14 to P17 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Pin name	P15/D13/INT3		Pin No.	75 (FP)		73 (GP)									
Function selection			Setting register										Remarks	Page	
			5,3E3h	3,3FCh	5,004h		4,004h	1,004h	0,004h	BYTE					
D13	I/O	Data bus	X	X	Except 11		X	1	L				1-28		
INT3	I	Interrupt input	0 0	X X	X X	X X	0 X	0 1	X H				1-61		
P15	I	Port input (No pulled high)	0 0	0 0	X X	X X	0 X	0 1	X H				1-163		
P15	I	Port input (Pulled high)	0 0	1 1	X X	X X	0 X	0 1	X H				1-163		
P15	O	Port output	1 1	X X	X X	X X	0 X	0 1	X H				1-163		
			5,3E3h	Port P15 direction register											1-168
			3,3FCh	P14 to P17 pull-up control register											1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0											1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0											1-23
			1,004h	Processor mode bit of processor mode register 0											1-23
			0,004h	Processor mode bit of processor mode register 0											1-23
			BYTE	BYTE pin											1-26

Appendix 3 Setting register for pin function selected

Pin name			P14/D12		Pin No.	76 (FP)		74 (GP)							
Function selection			Setting register									Remarks	Page		
			4,3E3h	3,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE						
D12	I/O	Data bus	X	X	Except 11		X	1	L					1-28	
P14	I	Port input (No pulled high)	0 0	0 0	X X	X X	0 X	0 1	X H					1-163	
P14	I	Port input (Pulled high)	0 0	1 1	X X	X X	0 X	0 1	X H					1-163	
P14	O	Port output	1 1	X X	X X	X X	0 X	0 1	X H					1-163	
			4,3E3h	Port P14 direction register										1-168	
			3,3FCh	P14 to P17 pull-up control register										1-170	
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23	
			1,004h	Processor mode bit of processor mode register 0										1-23	
			0,004h	Processor mode bit of processor mode register 0										1-23	
			BYTE	BYTE pin										1-26	

Pin name			P13/D11		Pin No.		77 (FP)		75 (GP)											
Function selection					Setting register								Remarks	Page						
					3,3E3h		2,3FCh		5,004h		4,004h				1,004h		0,004h		BYTE	
D11	I/O	Data bus			X		X		Except 11		X		1		L				1-28	
P13	I	Port input (No pulled high)			0 0		0 0		X X		X X		0 1		X H				1-163	
P13	I	Port input (Pulled high)			0 0		1 1		X X		X X		0 1		0 H				1-163	
P13	O	Port output			1 1		X X		X X		X X		0 1		0 H				1-163	
					3,3E3h		Port P13 direction register												1-168	
					2,3FCh		P10 to P13 pull-up control register												1-170	
					5,004h		Multiplexed bus space select bit of processor mode register 0												1-23	
					4,004h		Multiplexed bus space select bit of processor mode register 0												1-23	
					1,004h		Processor mode bit of processor mode register 0												1-23	
					0,004h		Processor mode bit of processor mode register 0												1-23	
					BYTE		BYTE pin												1-26	

Pin name			Pin No.		78 (FP)		76 (GP)							
Function selection			Setting register										Remarks	Page
			2,3E3h	2,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
D10	I/O	Data bus	X	X	Except 11		X	1	L				1-28	
P12	I	Port input (No pulled high)	0 0	0 0	X X	X X	0 X	0 1	X H				1-163	
P12	I	Port input (Pulled high)	0 0	1 1	X X	X X	0 X	0 1	X H				1-163	
P12	O	Port output	1 1	X X	X X	X X	0 X	0 1	X H				1-163	
			2,3E3h	Port P12 direction register										1-168
			2,3FCh	P10 to P13 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Appendix 3 Setting register for pin function selected

Pin name			P11/D9		Pin No.		79 (FP)		77 (GP)					
Function selection			Setting register									Remarks	Page	
			1,3E3h	2,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
D9	I/O	Data bus	X	X	Except 11		X	1	L				1-28	
P11	I	Port input (No pulled high)	0 0	0 0	X X	X X	0 X	0 1	X H				1-163	
P11	I	Port input (Pulled high)	0 0	1 1	X X	X X	0 X	0 1	X H				1-163	
P11	O	Port output	1 1	X X	X X	X X	0 X	0 1	X H				1-163	
			1,3E3h	Port P11 direction register									1-168	
			2,3FCh	P10 to P13 pull-up control register									1-170	
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			1,004h	Processor mode bit of processor mode register 0									1-23	
			0,004h	Processor mode bit of processor mode register 0									1-23	
			BYTE	BYTE pin									1-26	

Pin name	P10/D8		Pin No.	80 (FP)		78 (GP)								
Function selection			Setting register									Remarks	Page	
			0,3E3h	2,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
D8	I/O	Data bus	X	X	Except 11		X	1	L				1-28	
P10	I	Port input (No pulled high)	0 0	0 0	X X	X X	0 X	0 1	X H				1-163	
P10	I	Port input (Pulled high)	0 0	1 1	X X	X X	0 X	0 1	X H				1-163	
P10	O	Port output	1 1	X X	X X	X X	0 X	0 1	X H				1-163	
			0,3E3h	Port P10 direction register										1-168
			2,3FCh	P10 to P13 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Pin name			P07/D7		Pin No.	81 (FP)		79 (GP)					
Function selection			Setting register								Remarks	Page	
			7,3E2h	1,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE				
D7	I/O	Data bus	X	X	Except 11		X	1	X				1-28
P07	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	X 0	0 1	X H				1-163
P07	I	Port input (Pulled high)	0 0	1 1	X 1	X 1	0 0	0 1	X H				1-163
P07	O	Port output	1 1	X X	X 1	X 1	0 0	0 1	X H				1-163
			7,3E2h	Port P07 direction register									1-168
			1,3FCh	P04 to P07 pull-up control register									1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23
			1,004h	Processor mode bit of processor mode register 0									1-23
			0,004h	Processor mode bit of processor mode register 0									1-23
			BYTE	BYTE pin									1-26

Appendix 3 Setting register for pin function selected

Pin name	P06/D6		Pin No.	82 (FP)		80 (GP)								
Function selection			Setting register									Remarks	Page	
			6,3E2h	1,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
D6	I/O	Data bus	X	X	Except 11		X	1	X				1-28	
P06	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1	X H				1-163	
P06	I	Port input (Pulled high)	0 0	1 1	X 1	X 1	0 0	0 1	X H				1-163	
P06	O	Port output	1 1	X X	X 1	X 1	0 0	0 1	X H				1-163	
			6,3E2h	Port P06 direction register										1-168
			1,3FCh	P04 to P07 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Pin name	P05/D5		Pin No.	83 (FP)		81 (GP)								
Function selection			Setting register									Remarks	Page	
			5,3E2h	1,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
D5	I/O	Data bus	X	X	Except 11		X	1	X				1-28	
P05	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1	X H				1-163	
P05	I	Port input (Pulled high)	0 0	1 1	X 1	X 1	0 0	0 1	X H				1-163	
P05	O	Port output	1 1	X X	X 1	X 1	0 0	0 1	X H				1-163	
			5,3E2h	Port P05 direction register										1-168
			1,3FCh	P04 to P07 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Pin name	P04/D4		Pin No.	84 (FP)		82 (GP)								
Function selection			Setting register									Remarks	Page	
			4,3E2h	1,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
D4	I/O	Data bus	X	X	Except 11		X	1	X				1-28	
P04	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1	X H				1-163	
P04	I	Port input (Pulled high)	0 0	1 1	X 1	X 1	0 0	0 1	X H				1-163	
P04	O	Port output	1 1	X X	X 1	X 1	0 0	0 1	X H				1-163	
			4,3E2h	Port P04 direction register										1-168
			1,3FCh	P04 to P07 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Appendix 3 Setting register for pin function selected

Pin name			P03/D3		Pin No.	85 (FP)		83 (GP)						
Function selection			Setting register									Remarks	Page	
			3,3E2h	0,3FCh	5,004h		4,004h	1,004h	0,004h	BYTE				
D3	I/O	Data bus	X	X	Except 11		X	1	X				1-28	
P03	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1	X H				1-163	
P03	I	Port input (Pulled high)	0 0	1 1	X 1	X 1	0 0	0 1	X H				1-163	
P03	O	Port output	1 1	X X	X 1	X 1	0 0	0 1	X H				1-167	
			3,3E2h	Port P03 direction register										1-168
			0,3FCh	P00 to P03 pull-up control register										1-170
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23
			1,004h	Processor mode bit of processor mode register 0										1-23
			0,004h	Processor mode bit of processor mode register 0										1-23
			BYTE	BYTE pin										1-26

Pin name			P02/D2		Pin No.		86 (FP)		84 (GP)						
Function selection					Setting register							Remarks	Page		
					2,3E2h		0,3FCh	5,004h		4,004h	1,004h			0,004h	BYTE
D2	I/O	Data bus			X	X	Except 11		X	1	X			1-28	
P02	I	Port input (No pulled high)			0 0	0 0	X 1	X 1	0 0	0 1	X H			1-163	
P02	I	Port input (Pulled high)			0 0	1 1	X 1	X 1	0 0	0 1	X H			1-163	
P02	O	Port output			1 1	X X	X 1	X 1	0 0	0 1	X H			1-163	
					2,3E2h		Port P02 direction register							1-168	
					0,3FCh		P00 to P03 pull-up control register							1-170	
					5,004h		Multiplexed bus space select bit of processor mode register 0							1-23	
					4,004h		Multiplexed bus space select bit of processor mode register 0							1-23	
					1,004h		Processor mode bit of processor mode register 0							1-23	
					0,004h		Processor mode bit of processor mode register 0							1-23	
					BYTE		BYTE pin							1-26	

Pin name	P01/D1		Pin No.	87 (FP)		85 (GP)								
Function selection			Setting register										Remarks	Page
			1,3E2h	0,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE					
D1	I/O	Data bus	X	X	Except 11		X	1	X				1-28	
P01	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1	X H				1-163	
P01	I	Port input (Pulled high)	0 0	1 1	X 1	X 1	0 0	0 1	X H				1-163	
P01	O	Port output	1 1	X X	X 1	X 1	0 0	0 1	X H				1-163	
			1,3E2h	Port P01 direction register									1-168	
			0,3FCh	P00 to P03 pull-up control register									1-170	
			5,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0									1-23	
			1,004h	Processor mode bit of processor mode register 0									1-23	
			0,004h	Processor mode bit of processor mode register 0									1-23	
			BYTE	BYTE pin									1-26	

Appendix 3 Setting register for pin function selected

Pin name			P00/D0		Pin No.	88 (FP)		86 (GP)							
Function selection			Setting register									Remarks	Page		
			0,3E2h	0,3FCh	5,004h	4,004h	1,004h	0,004h	BYTE						
D0	I/O	Data bus	X	X	Except 11		X	1	X				1-28		
P00	I	Port input (No pulled high)	0 0	0 0	X 1	X 1	0 0	0 1	X H				1-163		
P00	I	Port input (Pulled high)	0 0	1 1	X 1	X 1	0 0	0 1	X H				1-163		
P00	O	Port output	1 1	X X	X 1	X 1	0 0	0 1	X H				1-163		
			0,3E2h	Port P00 direction register										1-168	
			0,3FCh	P00 to P03 pull-up control register										1-170	
			5,004h	Multiplexed bus space select bit of processor mode register 0										1-23	
			4,004h	Multiplexed bus space select bit of processor mode register 0										1-23	
			1,004h	Processor mode bit of processor mode register 0										1-23	
			0,004h	Processor mode bit of processor mode register 0										1-23	
			BYTE	BYTE pin										1-26	

Pin name	P107/AN7/KI3		Pin No.	89 (FP)		87 (GP)							
Function selection			Setting register								Remarks	Page	
			7,3F6h	5,3FEh									
KI3	I	Key input	0	X								1-62	
AN7	I	A-D input	0	0								1-149	
P107	I	Port input (No pulled high)	0	0								1-163	
P107	I	Port input (Pulled high)	0	1								1-163	
P107	O	Port output	1	X								1-163	
			7,3F6h	Port P107 direction register									1-168
			5,3FEh	P104 to P107 pull-up control register									1-170

Pin name			P106/AN6/KI2		Pin No.		90 (FP)		88 (GP)						
Function selection					Setting register								Remarks	Page	
					6,3F6h	5,3FEh									
KI2	I	Key input			0	X								1-62	
AN6	I	A-D input			0	0								1-149	
P106	I	Port input (No pulled high)			0	0								1-163	
P106	I	Port input (Pulled high)			0	1								1-163	
P106	O	Port output			1	X								1-163	
					6,3F6h	Port P106 direction register									1-168
					5,3FEh	P104 to P107 pull-up control register									1-170

Pin name			P105/AN5/K11		Pin No.		91 (FP)		89 (GP)						
Function selection					Setting register								Remarks	Page	
					5,3F6h	5,3FEh									
K11	I	Key input			0	X								1-62	
AN5	I	A-D input			0	0								1-149	
P105	I	Port input (No pulled high)			0	0								1-163	
P105	I	Port input (Pulled high)			0	1								1-163	
P105	O	Port output			1	X								1-163	
					5,3F6h	Port P105 direction register									1-168
					5,3FEh	P104 to P107 pull-up control register									1-170

Appendix 3 Setting register for pin function selected

Pin name			P104/AN4/KI0		Pin No.	92 (FP)		90 (GP)						
Function selection					Setting register								Remarks	Page
					4,3F6h	5,3FEh								
KI0	I	Key input			0	X								
AN4	I	A-D input			0	0								
P104	I	Port input (No pulled high)			0	0								
P104	I	Port input (Pulled high)			0	1								
P104	O	Port output			1	X								
					4,3F6h	Port P104 direction register								
					5,3FEh	P104 to P107 pull-up control register								

Pin name			P103/AN3			Pin No.	93 (FP)		91 (GP)						
Function selection					Setting register								Remarks	Page	
					3,3F6h	4,3FEh									
AN3	I	A-D input			0	0								1-149	
P103	I	Port input (No pulled high)			0	0								1-163	
P103	I	Port input (Pulled high)			0	1								1-163	
P103	O	Port output			1	X								1-163	
					3,3F6h	Port P103 direction register									1-168
					4,3FEh	P100 to P103 pull-up control register									1-170

Pin name			P102/AN2			Pin No.		94 (FP)		92 (GP)									
Function selection						Setting register								Remarks	Page				
						2,3F6h		4,3FEh											
AN2		I	A-D input			0		0										1-149	
P102		I	Port input (No pulled high)			0		0										1-163	
P102		I	Port input (Pulled high)			0		1										1-163	
P102		O	Port output			1		X										1-163	
						2,3F6h		Port P102 direction register										1-168	
						4,3FEh		P100 to P103 pull-up control register										1-170	

Pin name			P101/AN1			Pin No.	95 (FP)		93 (GP)					
Function selection			Setting register								Remarks	Page		
			1,3F6h	4,3FEh										
AN1	I	A-D input	0	0								1-149		
P101	I	Port input (No pulled high)	0	0								1-163		
P101	I	Port input (Pulled high)	0	1								1-163		
P101	O	Port output	1	X								1-163		
			1,3F6h	Port P101 direction register									1-168	
			4,3FEh	P100 to P103 pull-up control register									1-170	

Appendix 3 Setting register for pin function selected

Pin name	P100/AN0		Pin No.	97 (FP)		95 (GP)							
Function selection			Setting register								Remarks	Page	
			0,3F6h	4,3FEh									
AN0	I	A-D input	0	0								1-149	
P100	I	Port input (No pulled high)	0	0								1-163	
P100	I	Port input (Pulled high)	0	1								1-163	
P100	O	Port output	1	X								1-163	
			0,3F6h	Port P100 direction register									1-168
			4,3FEh	P100 to P103 pull-up control register									1-170

Pin name	P97/ $\overline{\text{ADTRG}}$ /SIN4		Pin No.	100 (FP)		98 (GP)							
Function selection			Setting register								Remarks	Page	
			7,3F3h	3,3FEh	5,3D6h	3,366h							
$\overline{\text{ADTRG}}$	I	A-D trigger input	0	0	1	0							1-149
SIN4	I	Serial I/O data input	0	0	X	1							1-145
P97	I	Port input (No pulled high)	0	0	X	0							1-163
P97	I	Port input (Pulled high)	0	1	X	0							1-163
P97	O	Port output	1	X	X	0							1-163
			7,3F3h	Port P97 direction register									1-168
			3,3FEh	P94 to P97 pull-up control register									1-170
			5,3D6h	Trigger select bit of A-D control register 0									1-151
			3,366h	SI/O4 port select bit of SI/O4 control register									1-146

Appendix 4 A practical example of connecting to the reset IC

M62015 and M62016 are reset ICs compatible with the M16C's backup mode. Here follow these ICs' overview and characteristics together with an example of connecting to the M16C when $V_{CC} = 3\text{ V}$.

• Overview of the reset ICs

Either M62015 or M62016 detects the rising edge of the power, the falling edge, and abnormal voltage of the power of the 3-V family of microcomputer systems. It is an optimal semiconductor integrated circuit to reset or release the microcomputer system.

Either M62015 or M62016 carries out 2-step power voltage detection, and is provided with two output terminals (the forced reset signal output RESET and the interrupt handling signal output INT). Either M62015 or M62016 embeds the BiCMOS process and the low power consumption circuit, and outputs optimal signals from respective output terminals with low power consumption especially in dealing with a system that requires its RAM backup.

• Characteristics of the reset ICs

* BiCMOS process low-consumption circuit configuration

Circuit current	$I_{CC} = 3\text{ }\mu\text{A}$ (standard value normal mode $V_{CC} = 3.0\text{ V}$)
	$I_{CC} = 3\text{ }\mu\text{A}$ (standard value backup mode $V_{CC} = 2.5\text{ V}$)

* Two-step power voltage detection

Normal power detection	$V_S = 2.7\text{ V}$ (standard value)
Power detection for backup	$V_{BATT} = 2.0\text{ V}$ (standard value)

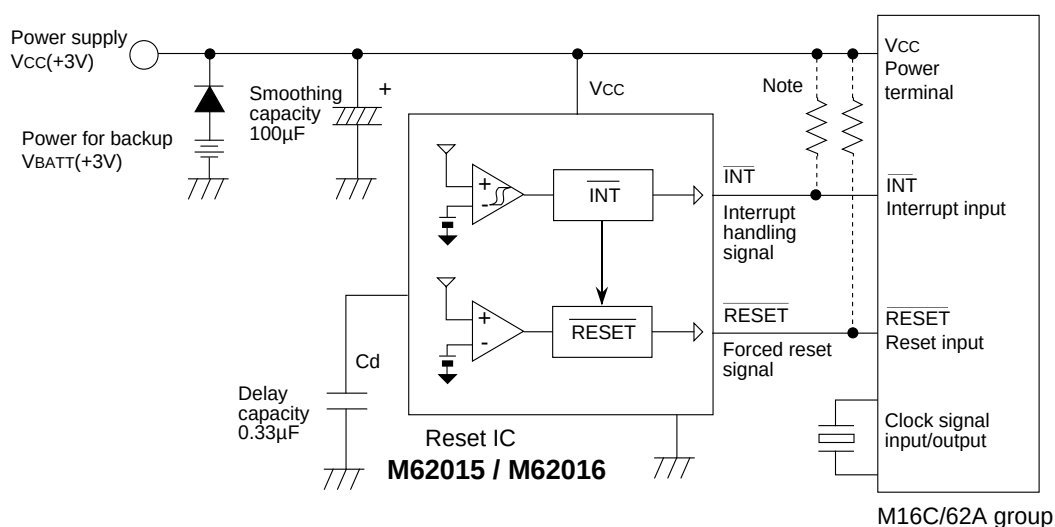
* Two outputs

Forced reset signal output	$\overline{\text{RESET}}$
Interrupt handling signal output	$\overline{\text{INT}}$

* Output form

CMOS output	: M62015
Open drain output	: M62016

• A practical example of connection



Appendix 5 Countermeasures against noise

Countermeasures against noise are described below. The following countermeasures are generally effective as countermeasures against noise, however, it is necessary not only to take measures as follows but to evaluate before actual use.

1.1 Shortest wiring length

The wiring on a printed circuit board can function as an antenna which feeds noise into the microcomputer. The shorter the total wiring length (by mm unit), the less the possibility of noise insertion into a microcomputer.

1.1.1 Package

Select the smallest possible package to make the total wiring length short.

● Reason

The wiring length depends on a microcomputer package. Use of a small package, for example QFP and not DIP, makes the total wiring length short to reduce influence of noise.

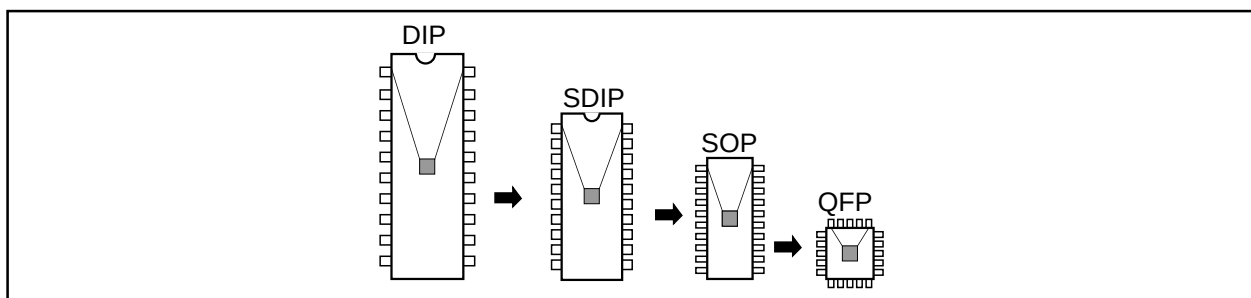


Figure 1.1.1. Selection of packages

1.1.2 Wiring for $\overline{\text{RESET}}$ pin

Make the length of wiring which is connected to the $\overline{\text{RESET}}$ pin as short as possible. Especially, connect a capacitor across the $\overline{\text{RESET}}$ pin and the Vss pin or reset IC with the shortest possible wiring (within 20mm).

● Reason

The width of a pulse input into the $\overline{\text{RESET}}$ pin is determined by the timing necessary conditions. If noise having a shorter pulse width than the standard is input to the $\overline{\text{RESET}}$ pin, the reset is released before the internal state of the microcomputer is completely initialized. This may cause a program runaway.



Figure 1.1.2. Wiring for RESET pin

1.1.3 Wiring for clock input/output pins

- Make the length of wiring which is connected to clock I/O pins as short as possible.
- Make the length of wiring (within 20 mm) across the grounding lead of a capacitor which is connected to an oscillator and the Vss pin of a microcomputer as short as possible.
- Separate the Vss pattern only for oscillation from other Vss patterns. (See Figure 1.4.3.)

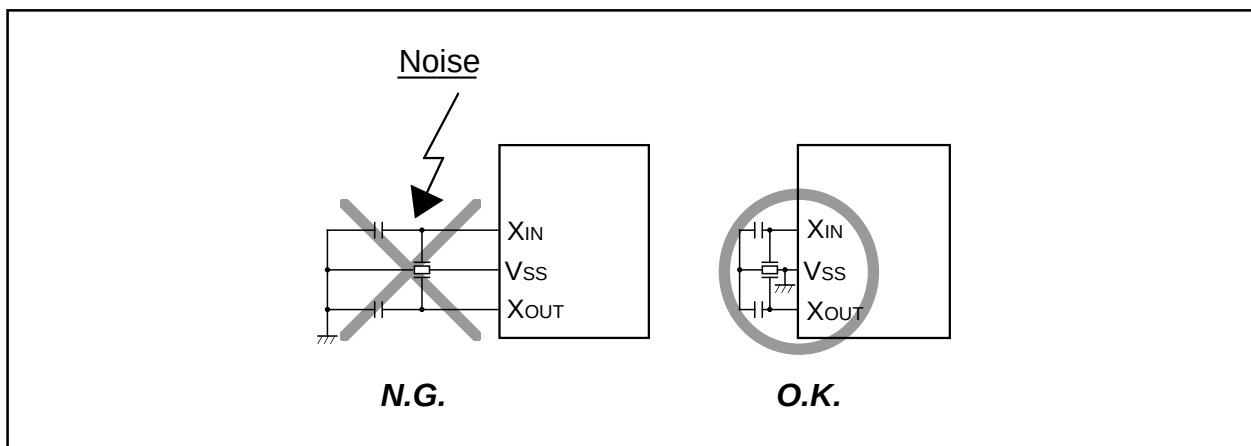


Figure 1.1.3. Wiring for clock I/O pins

● Reason

If noise enters clock I/O pins, clock waveforms may be deformed. This may cause a program failure or program runaway. Also, if a potential difference is caused by the noise between the Vss level of a microcomputer and the Vss level of an oscillator, the correct clock will not be input in the microcomputer.

1.1.4 Wiring to CNVss pin

Connect the CNVss pin to the Vss pin with the shortest possible wiring.

● Reason

The processor mode of a microcomputer is influenced by a potential at the CNVss pin. If a potential difference is caused by the noise between pins CNVss and Vss, the processor mode may become unstable. This may cause a microcomputer malfunction or a program runaway.

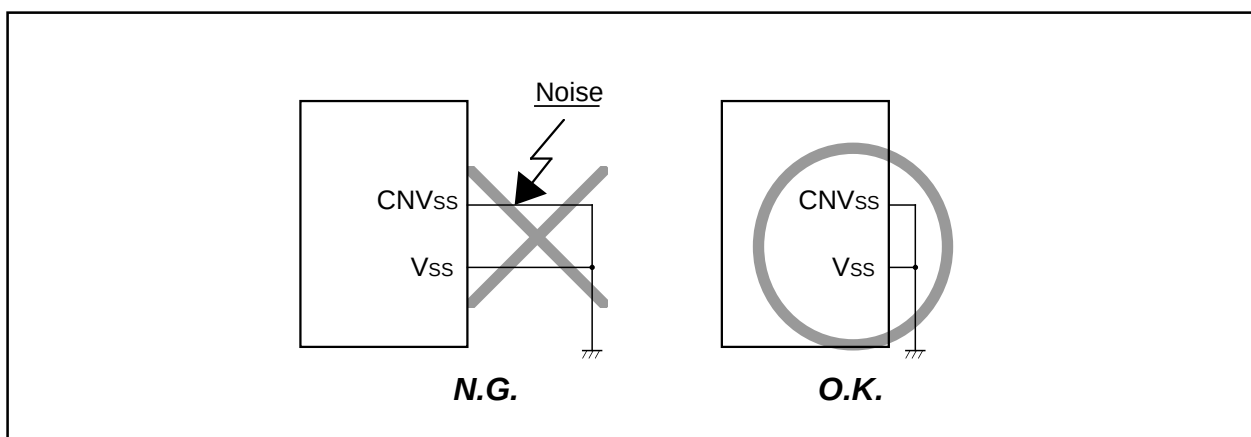


Figure 1.1.4. Wiring for CNVss pin

1.2 Connection of bypass capacitor across Vss line and Vcc line

Connect an approximately 0.1 μF bypass capacitor across the Vss line and the Vcc line as follows:

- Connect a bypass capacitor across the Vss pin and the Vcc pin at equal length.
- Connect a bypass capacitor across the Vss pin and the Vcc pin with the shortest possible wiring.
- Use lines with a larger diameter than other signal lines for Vss line and Vcc line.
- Connect the power source wiring via a bypass capacitor to the Vss pin and the Vcc pin.

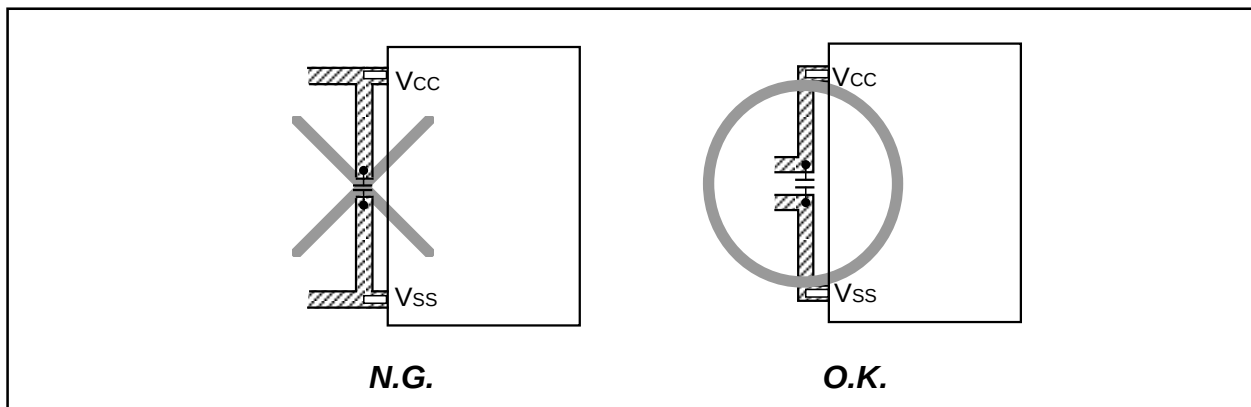


Figure 1.2.1. Bypass capacitor across the Vss line and the Vcc line

1.3 Wiring to analog input pins

- Connect an approximately 100 Ω to 1 k Ω resistor to an analog signal line which is connected to an analog input pin in series. Besides, connect the resistor to the microcomputer as close as possible.
- Connect an approximately 1000 pF capacitor across the Vss pin and the analog input pin. Besides, connect the capacitor to the Vss pin as close as possible. Also, connect the capacitor across the analog input pin and the Vss pin at equal length.

Reason

Signals which is input in an analog input pin (such as an A-D converter/comparator input pin) are usually output signals from sensor. The sensor which detects a change of event is installed far from the printed circuit board with a microcomputer, the wiring to an analog input pin is longer necessarily. This long wiring functions as an antenna which feeds noise into the microcomputer, which causes noise to an analog input pin.

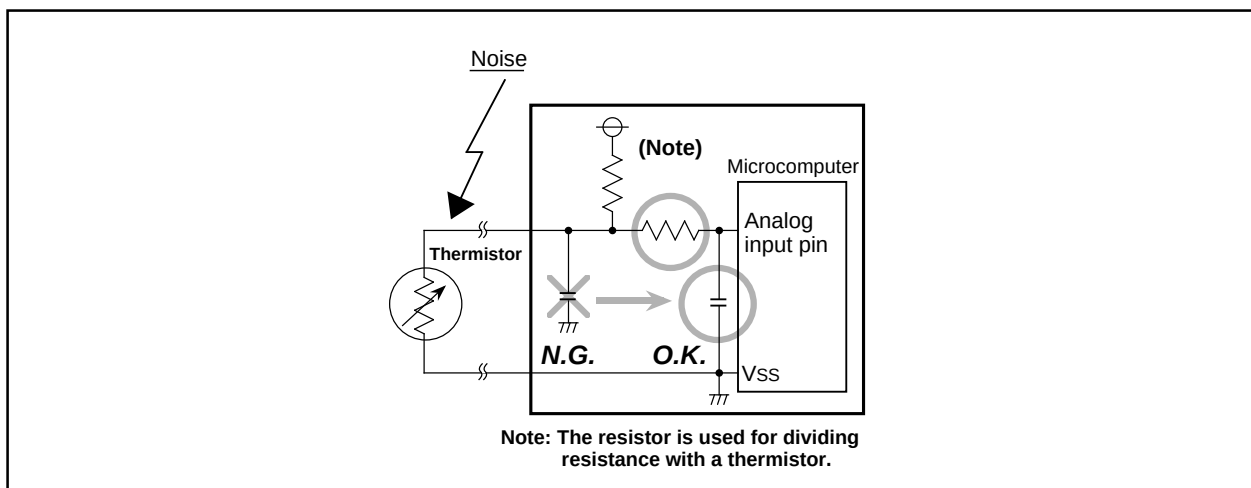


Figure 1.3.1. Analog signal line and a resistor and a capacitor

1.4 Oscillator concerns

Take care to prevent an oscillator that generates clocks for a microcomputer operation from being affected by other signals.

1.4.1 Keeping oscillator away from large current signal lines

Install a microcomputer (and especially an oscillator) as far as possible from signal lines where a current larger than the tolerance of current value flows.

● Reason

In the system using a microcomputer, there are signal lines for controlling motors, LEDs, and thermal heads or others. When a large current flows through those signal lines, strong noise occurs because of mutual inductance.

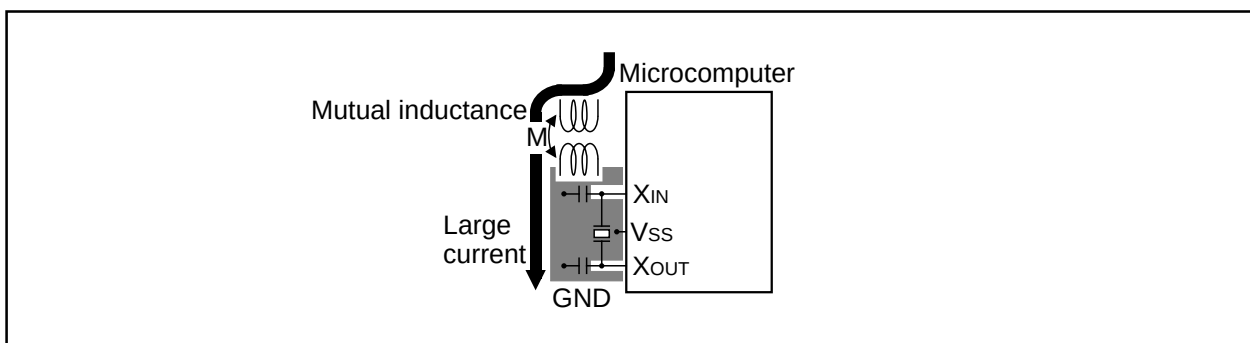


Figure 1.4.1. Wiring for a large current signal line

1.4.2 Installing oscillator away from signal lines where potential levels change frequently

Install an oscillator and a connecting pattern of an oscillator away from signal lines where potential levels change frequently. Also, do not cross such signal lines over the clock lines or the signal lines which are sensitive to noise. Or do not stretch long such signal lines parallelly to these said lines.

● Reason

Signal lines where potential levels change frequently (such as the TAOUT pin signal line) may affect other lines at signal rising edge or falling edge. If such lines cross over a clock line, clock waveforms may be deformed, which causes a microcomputer failure or a program runaway.

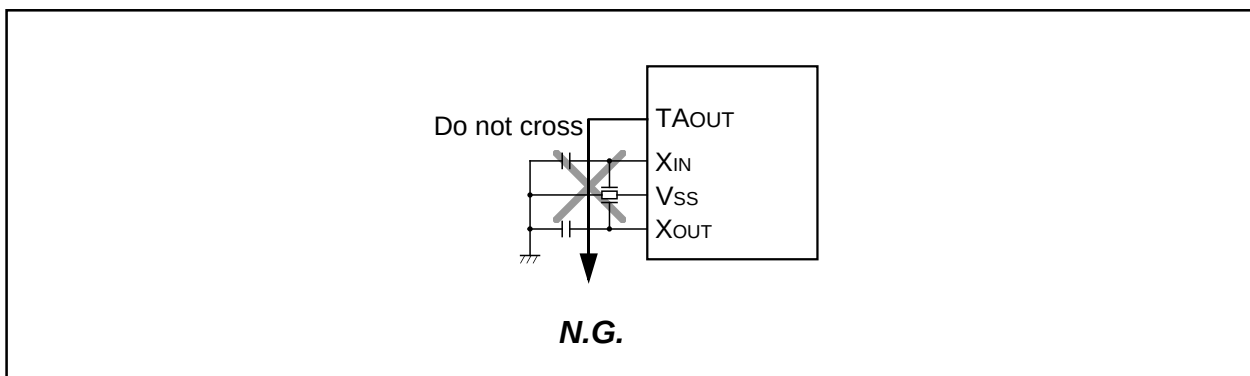


Figure 1.4.2. Wiring of signal lines where potential levels change frequently

1.4.3 Oscillator protection using Vss pattern

As for a two-sided printed circuit board, print a Vss pattern on the underside (soldering side) of the position (on the component side) where an oscillator is mounted.

Connect the Vss pattern to the microcomputer Vss pin with the shortest possible wiring. Besides, separate this Vss pattern from other Vss patterns.

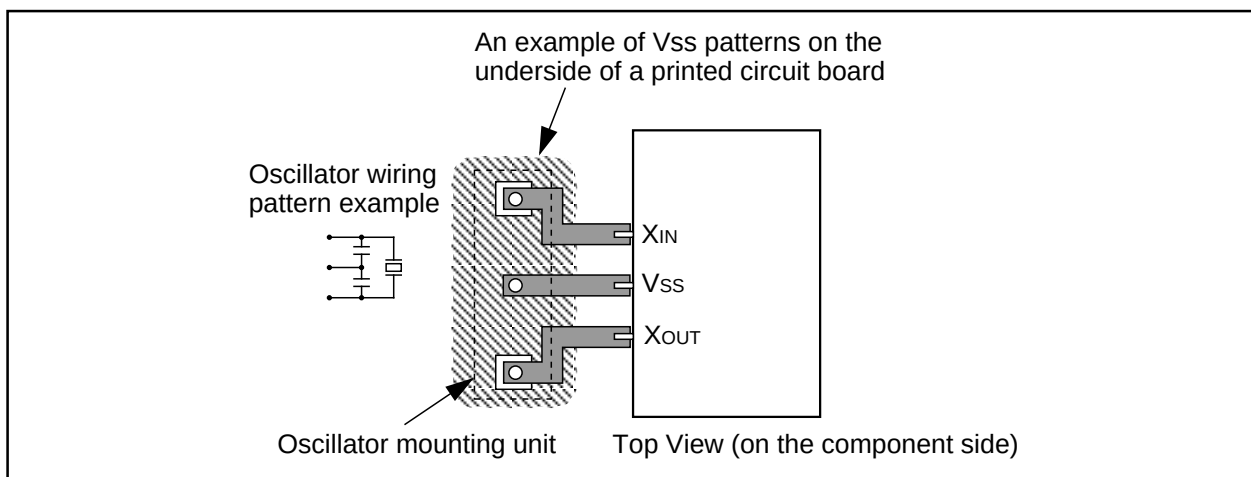


Figure 1.4.3. VSS pattern on the underside of an oscillator

1.5 Setup for I/O ports

Setup I/O ports using hardware and software as follows:

<Hardware>

- Connect a resistor of 100 Ω or more to a signal line which is connected to an I/O port in series. Besides, connect the resistor to the microcomputer as close as possible.

<Software>

- As for an input port, read data several times by a program for checking whether input levels are equal or not.
- As for an output port, since the output data may reverse because of noise, rewrite data to its port latch at fixed periods.
- Rewrite data to direction registers and pull-up control registers at fixed periods.

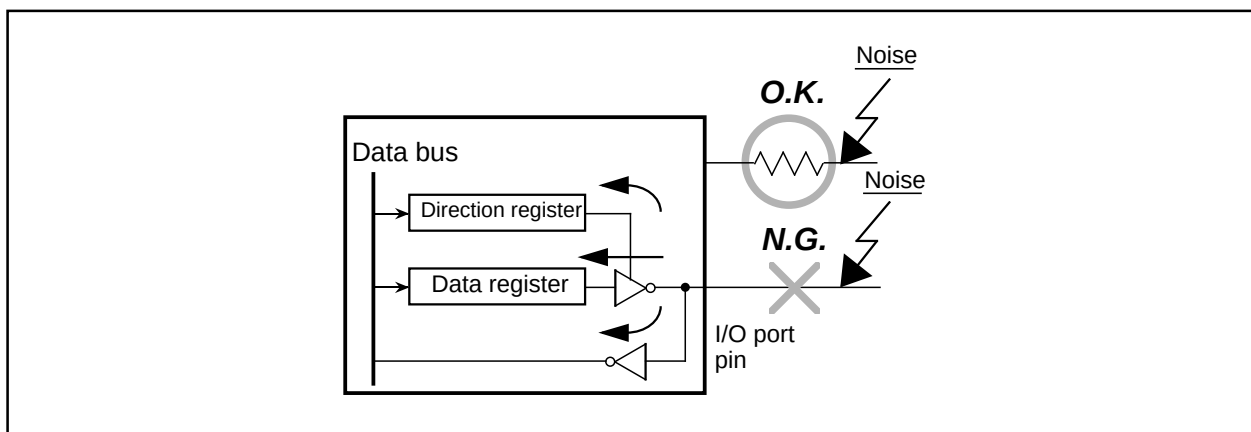


Figure 1.5.1. Setup for I/O ports

1.6 Providing of watchdog timer function by software

If a microcomputer runs away because of noise or others, it can be detected by a software watchdog timer and the microcomputer can be reset to normal operation. This is equal to or more effective than program runaway detection by a hardware watchdog timer. The following shows an example of a watchdog timer provided by software.

In the following example, to reset a microcomputer to normal operation, the main routine detects errors of the interrupt processing routine and the interrupt processing routine detects errors of the main routine.

This example assumes that interrupt processing is repeated multiple times in a single main routine processing.

<The main routine>

- Assigns a single byte of RAM to a software watchdog timer (SWDT) and writes the initial value N in the SWDT once at each execution of the main routine. The initial value N should satisfy the following condition:

$N+1 \geq (\text{Counts of interrupt processing executed in each main routine})$

As the main routine execution cycle may change because of an interrupt processing or others, the initial value N should have a margin.

- Watches the operation of the interrupt processing routine by comparing the SWDT contents with counts of interrupt processing after the initial value N has been set.
- Detects that the interrupt processing routine has failed and determines to branch to the program initialization routine for recovery processing in the following case:

If the SWDT contents do not change after interrupt processing.

<The interrupt processing routine>

- Decrements the SWDT contents by 1 at each interrupt processing.
- Determines that the main routine operates normally when the SWDT contents are reset to the initial value N at almost fixed cycles (at the fixed interrupt processing count).
- Detects that the main routine has failed and determines to branch to the program initialization routine for recovery processing in the following case:

If the SWDT contents are not initialized to the initial value N but continued to decrement and if they reach 0 or less.

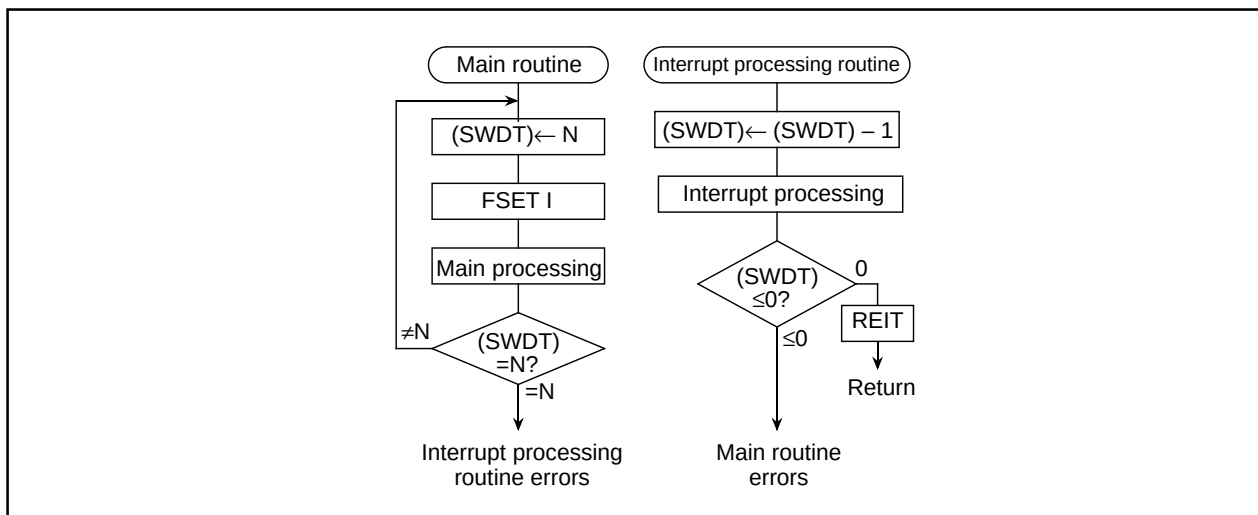


Figure 1.6.1. Watchdog timer by software

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