Description

The M16C/61 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/61 group includes a wide range of products with different internal memory types and sizes and various package types.

Features

- Memory capacity ..... ROM (See Figure 4. ROM Expansion)
  RAM 4K to 10K bytes
- Shortest instruction execution time ..... 100ns (f(X_{IN})=10MHz)
- Supply voltage ..... 4.0 to 5.5V (f(X_{IN})=10MHz)
  2.7 to 5.5V (f(X_{IN})=7MHz with software one-wait)
- Low power consumption ..... 18mW (f(X_{IN})=7MHz, with software one-wait, V_{CC} = 3V)
- Interrupts ..... 20 internal and 5 external interrupt sources, 4 software interrupt sources; 7 levels (including key input interrupt)
- Multifunction 16-bit timer ..... 5 output timers + 3 input timers
- Serial I/O (UART or clock synchronous) ..... 3 channels
- DMAC ..... 2 channels (trigger: 16 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 (P8$_5$ shared with $\overline{NMI}$ 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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Pin Configuration

Figures 1 and 2 show the pin configurations (top view).

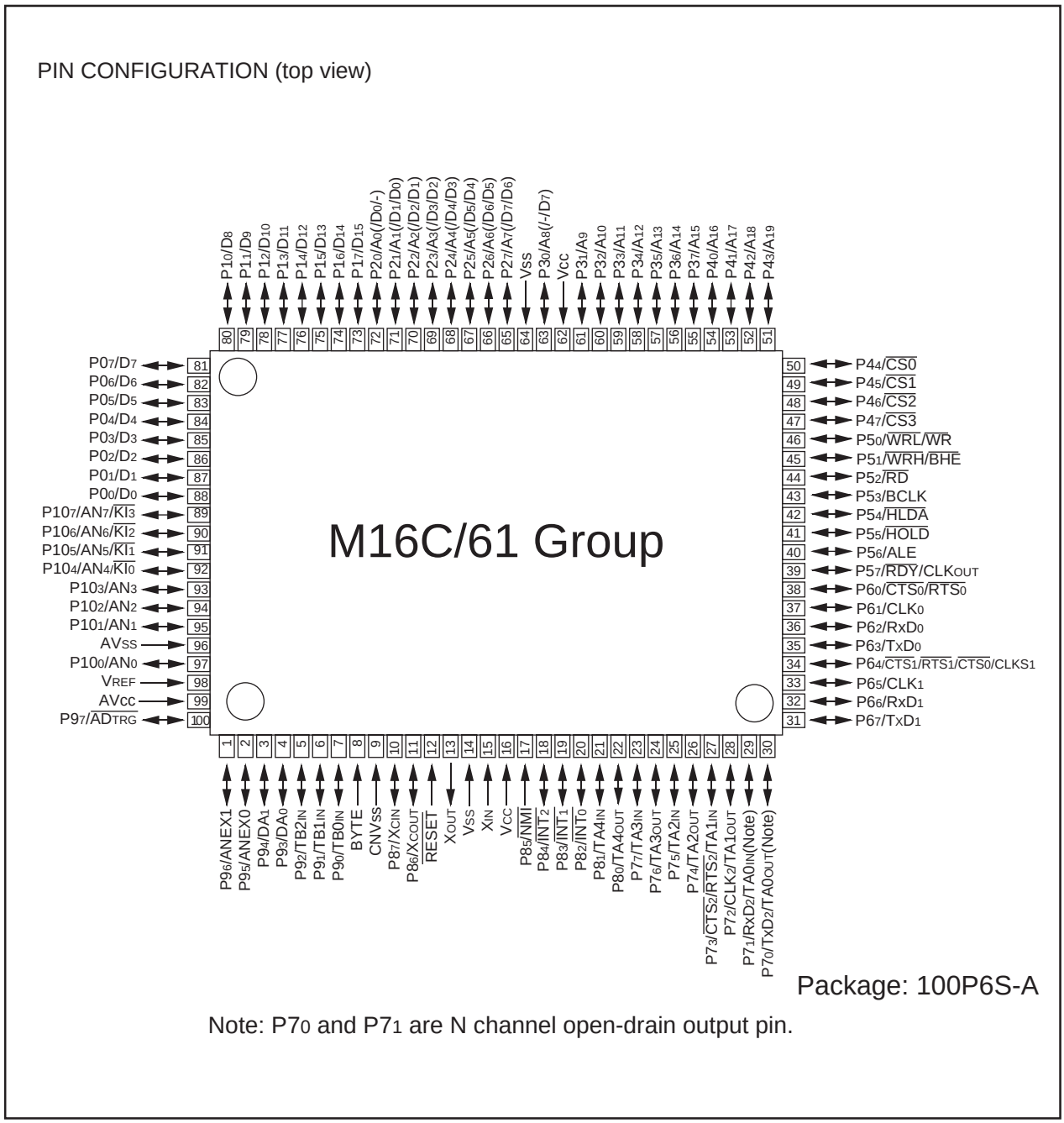
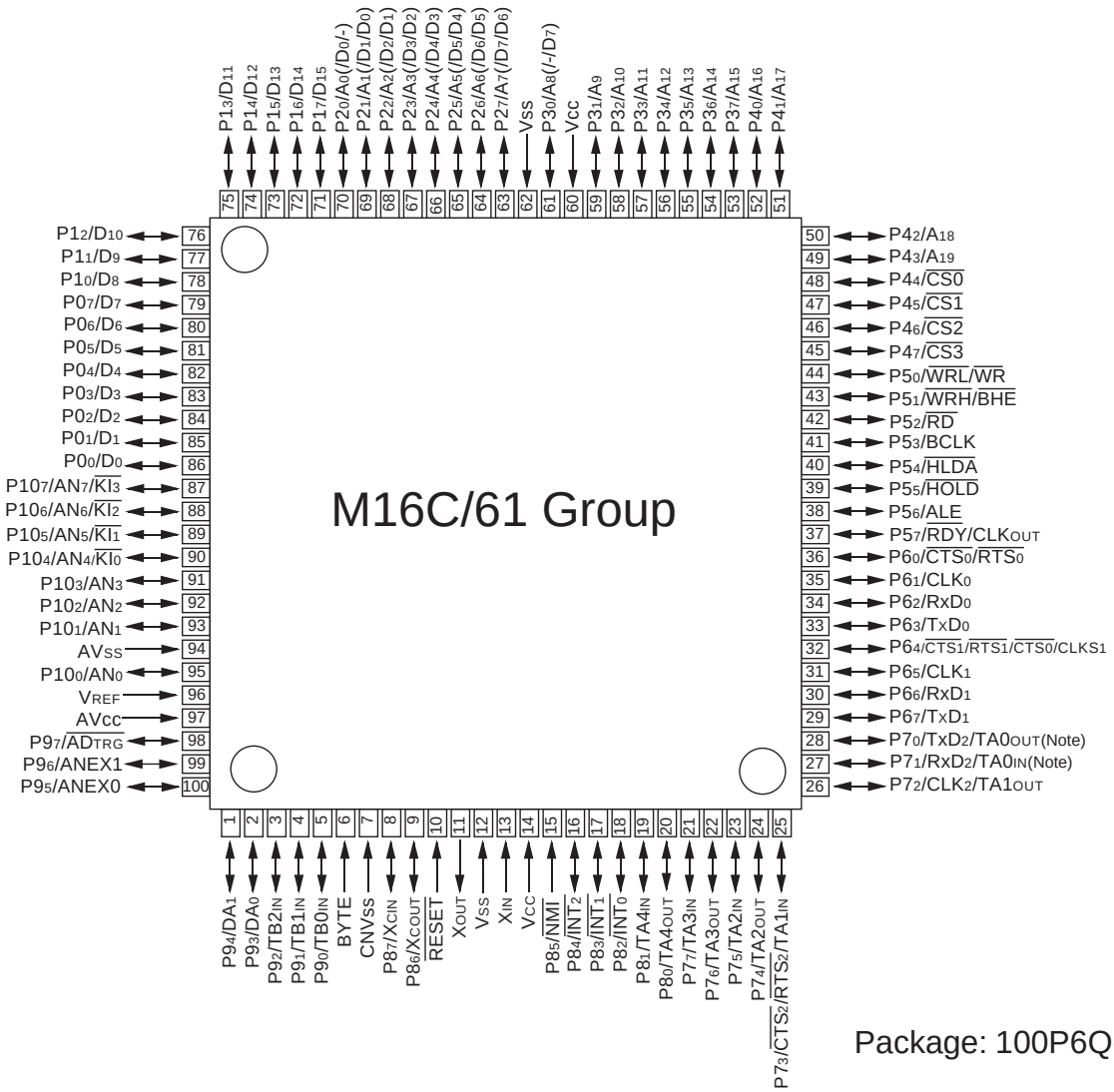


Figure 1. Pin configuration (top view)

PIN CONFIGURATION (top view)



Note: P70 and P71 are N channel open-drain output pin.

Figure 2. Pin configuration (top view)

Block Diagram

Figure 3 is a block diagram of the M16C/61 group.

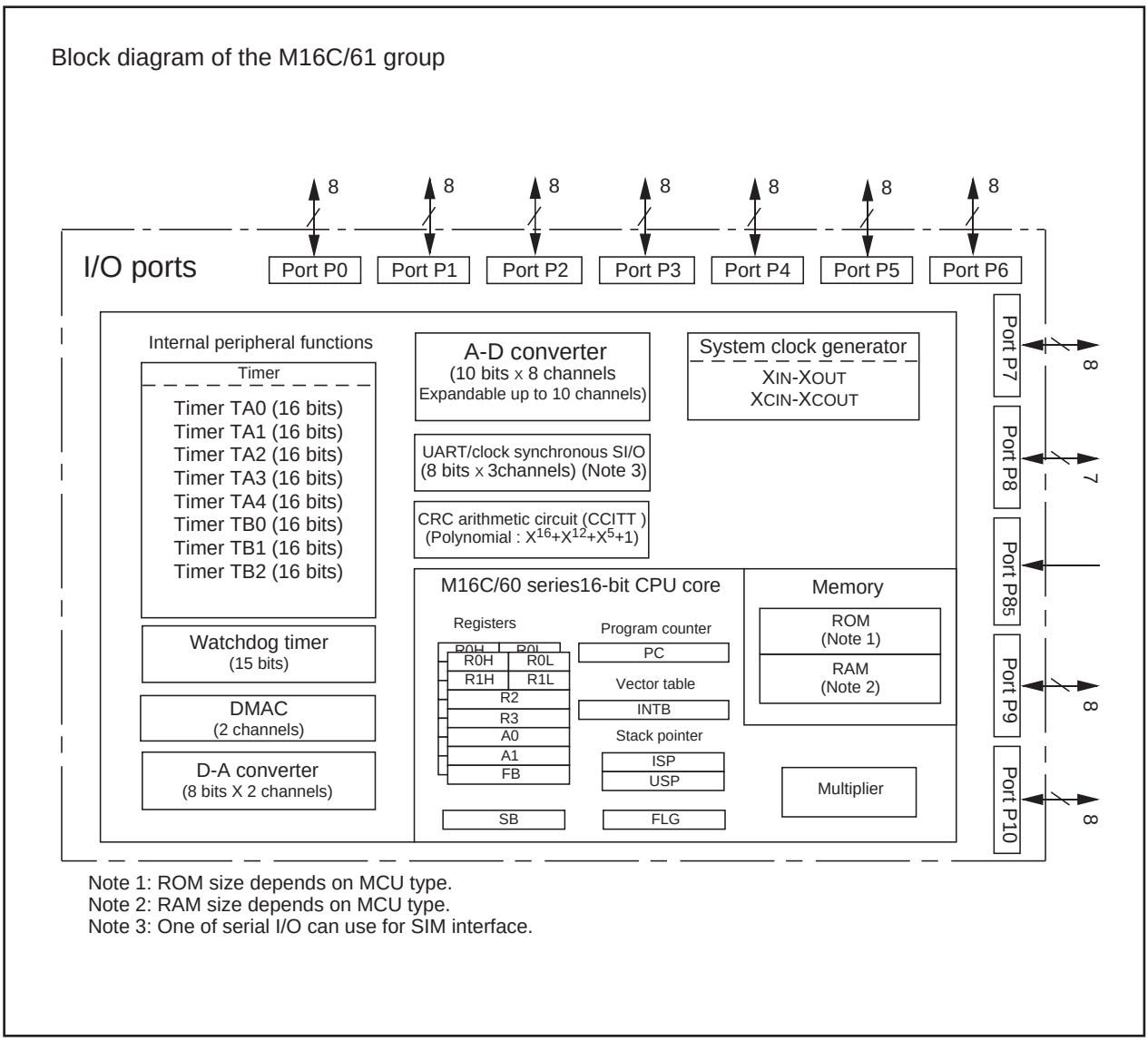


Figure 3. Block diagram of M16C/61 group

Performance Outline

Table 1 is a performance outline of M16C/61 group.

Table 1. Performance outline of M16C/61 group

Item		Performance
Number of basic instructions		91 instructions
Shortest instruction execution time		100ns(f(XIN)=10MHz)
Memory capacity	ROM	(See the Figure 4. ROM Expansion)
	RAM	4K to 10K 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	16 bits x 3
Serial I/O	UART0, UART1, UART2	(UART or clock synchronous) x 3
A-D converter		10 bits x (8 + 2) channels
D-A converter		8 bits x 2
DMAC		2 channels (trigger: 16 sources)
CRC calculation circuit		CRC - CCITT
Watchdog timer		15 bits x 1 (with prescaler)
Interrupt		20 internal and 5 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		4.0 to 5.5V (f(XIN) = 10MHz) 2.7 to 5.5V(f(XIN)=7MHz with software one-wait)
Power consumption		18mW (f(XIN) = 7MHz with software one-wait,VCC = 3V)
I/O characteristics	I/O withstand voltage	5V
	Output current	5mA
Memory expansion		Available (to a maximum of 1M bytes)
Device configuration		CMOS silicon gate
Package		100-pin plastic mold QFP

Mitsubishi plans to release the following products in the M16C/61 group:

(1) Support for mask ROM version, external ROM version, one-time PROM version, and EPROM version

(2) ROM capacity

(3) Package

100P6S-A : Plastic molded QFP (mask ROM version and one-time PROM version)

100P6Q-A : Plastic molded QFP (mask ROM version and one-time PROM version)

100D0 : Ceramic LCC (EPROM version)

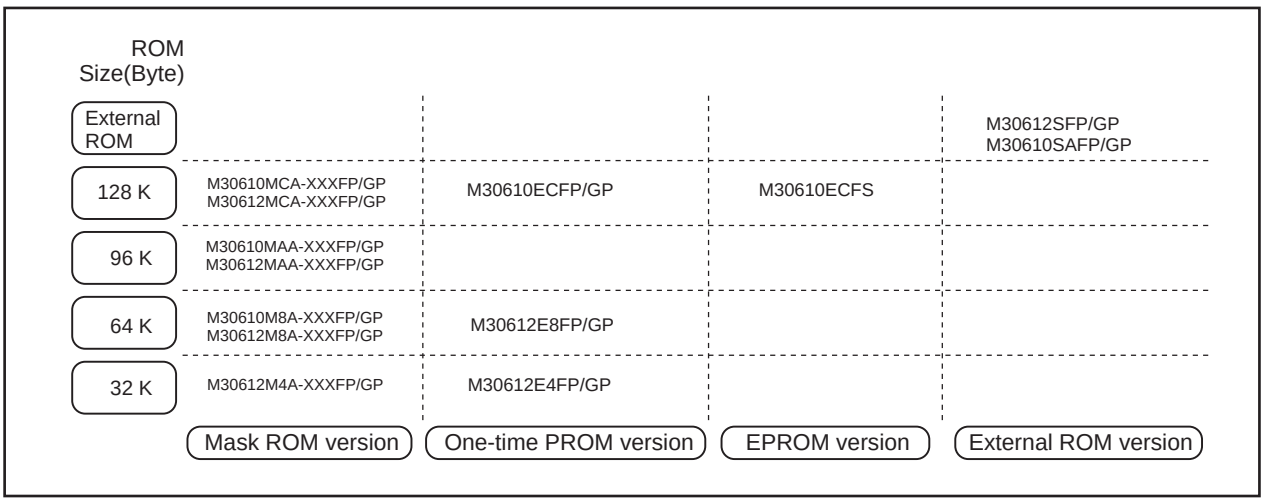


Figure 4. ROM expansion

The M16C/61 group products currently supported are listed in Table 2.

Table 2. M16C/61 group

June. 1998

Type No	ROM capacity	RAM capacity	Package type	Remarks
M30612M4A-XXXFP	32K byte	4K byte	100P6S-A	Mask ROM version
M30612M4A-XXXGP			100P6Q-A	
M30610M8A-XXXFP	64K byte	10K byte	100P6S-A	
M30610M8A-XXXGP			100P6Q-A	
M30612M8A-XXXFP		4K byte	100P6S-A	
M30612M8A-XXXGP			100P6Q-A	
M30610MAA-XXXFP	96K byte	10K byte	100P6S-A	
M30610MAA-XXXGP			100P6Q-A	
M30612MAA-XXXFP		4K byte	100P6S-A	
M30612MAA-XXXGP			100P6Q-A	
M30610MCA-XXXFP	128K byte	10K byte	100P6S-A	
M30610MCA-XXXGP			100P6Q-A	
M30612MCA-XXXFP		5K byte	100P6S-A	
M30612MCA-XXXGP			100P6Q-A	
M30612E4FP	32K byte	4K byte	100P6S-A	One-time PROM version
M30612E4GP			100P6Q-A	
M30612E8FP	64K byte	4K byte	100P6S-A	
M30612E8GP			100P6Q-A	
M30610ECFP	128K byte	10K byte	100P6S-A	
M30610ECGP			100P6Q-A	
M30610ECFS	128K byte	10K byte	100D0	EPROM version (Note)
M30610SAFP	———	10K byte	100P6S-A	External ROM version
M30610SAGP			100P6Q-A	
M30612SAFP	———	4K byte	100P6S-A	
M30612SAGP			100P6Q-A	

Note: Do not use the EPROM version for mass production, because it is a tool for program development (for evaluation).

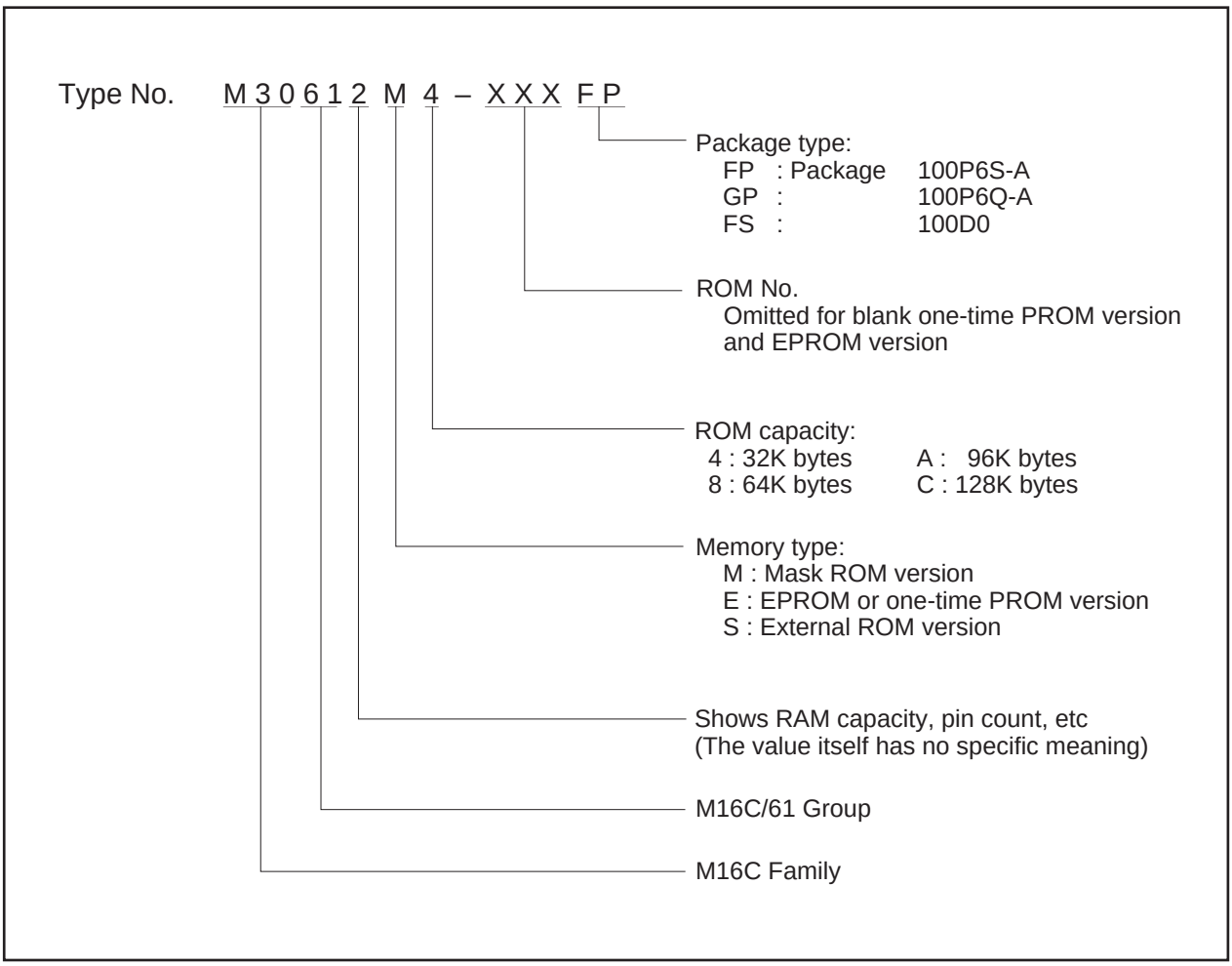


Figure 5. Type No., memory size, and package

Pin Description

Pin name	Signal name	I/O type	Function
V_{CC}, V_{SS}	Power supply input		Supply 2.7 to 5.5 V to the V_{CC} pin. Supply 0 V to the V_{SS} pin.
CNV$_{SS}$	CNV$_{SS}$	Input	This pin switches between processor modes. Connect it to the V_{SS} pin when operating in single-chip or memory expansion mode. Connect it to the V_{CC} pin when in microprocessor mode.
$\overline{\text{RESET}}$	Reset input	Input	A “L” on this input resets the microcomputer.
X_{IN} X_{OUT}	Clock input Clock output	Input Output	These pins are provided for the main clock generating circuit.Connect a ceramic resonator or crystal between the X_{IN} and the X_{OUT} pins. To use an externally derived clock, input it to the X_{IN} pin and leave the X_{OUT} 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”. When operating in single-chip mode,connect this pin to V_{SS}.
AV$_{CC}$	Analog power supply input		This pin is a power supply input for the A-D converter. Connect this pin to V_{CC}.
AV$_{SS}$	Analog power supply input		This pin is a power supply input for the A-D converter. Connect this pin to V_{SS}.
V_{REF}	Reference voltage input	Input	This pin is a reference voltage input for the A-D converter.
$P0_0$ to $P0_7$	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 set for input, the user can specify in units of four bits via software whether or not they are tied to a pull-up resistor.
D_0 to D_7		Input/output	When set as a separate bus, these pins input and output data (D_0–D_7).
$P1_0$ to $P1_7$	I/O port P1	Input/output	This is an 8-bit I/O port equivalent to P0.
D_8 to D_{15}		Input/output	When set as a separate bus, these pins input and output data (D_8–D_{15}).
$P2_0$ to $P2_7$	I/O port P2	Input/output	This is an 8-bit I/O port equivalent to P0.
A_0 to A_7		Output	These pins output 8 low-order address bits (A_0–A_7).
A_0/D_0 to A_7/D_7		Input/output	If the external bus is set as an 8-bit wide multiplexed bus, these pins input and output data (D_0–D_7) and output 8 low-order address bits (A_0–A_7) separated in time by multiplexing.
A_0, A_1/D_0 to A_7/D_6		Output Input/output	If the external bus is set as a 16-bit wide multiplexed bus, these pins input and output data (D_0–D_6) and output address (A_1–A_7) separated in time by multiplexing. They also output address (A_0).
$P3_0$ to $P3_7$	I/O port P3	Input/output	This is an 8-bit I/O port equivalent to P0.
A_8 to A_{15}		Output	These pins output 8 middle-order address bits (A_8–A_{15}).
A_8/D_7, A_9 to A_{15}		Input/output Output	If the external bus is set as a 16-bit wide multiplexed bus, these pins input and output data (D_7) and output address (A_8) separated in time by multiplexing. They also output address (A_9–A_{15}).
$P4_0$ to $P4_7$	I/O port P4	Input/output	This is an 8-bit I/O port equivalent to P0.
$\overline{CS_0}$ to $\overline{CS_3}$, A_{16} to A_{19}		Output Output	These pins output $\overline{CS_0}$–$\overline{CS_3}$ signals and A_{16}–A_{19}. $\overline{CS_0}$–$\overline{CS_3}$ are chip select signals used to specify an access space. A_{16}–A_{19} are 4 high-order address bits.

Pin Description

Pin name	Signal name	I/O type	Function
P5$_0$ to P5$_7$	I/O port P5	Input/output	This is an 8-bit I/O port equivalent to P0. In single-chip mode, P5$_7$ 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.
$\overline{WRL}$ / $\overline{WR}$, $\overline{WRH}$ / $\overline{BHE}$, $\overline{RD}$, BCLK, $\overline{HLDA}$, $\overline{HOLD}$, ALE, $\overline{RDY}$		Output Output Output Output Output Input Output Input	Output $\overline{WRL}$, $\overline{WRH}$ ($\overline{WR}$ and $\overline{BHE}$), $\overline{RD}$, BCLK, $\overline{HLDA}$, and 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. 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.
P6$_0$ to P6$_7$	I/O port P6	Input/output	This is an 8-bit I/O port equivalent to P0. Pins in this port also function as UART0 and UART1 I/O pins as selected by software.
P7$_0$ to P7$_7$	I/O port P7	Input/output	This is an 8-bit I/O port equivalent to P0 (P7$_0$ and P7$_1$ are N channel open-drain output). Pins in this port also function as timer A_0–A_3 or UART2 I/O pins as selected by software.
P8$_0$ to P8$_4$, P8$_6$, P8$_7$, P8$_5$	I/O port P8 I/O port P8$_5$	Input/output Input/output Input/output Input	P8$_0$ to P8$_4$, P8$_6$, and P8$_7$ are I/O ports with the same functions as P0. Using software, they can be made to function as the I/O pins for timer A4 and the input pins for external interrupts. P8$_6$ and P8$_7$ 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 P8$_6$ (X_{COUT} pin) and P8$_7$ (X_{CIN} pin). P8$_5$ is an input-only port that also functions for $\overline{NMI}$. The $\overline{NMI}$ interrupt is generated when the input at this pin changes from "H" to "L". The $\overline{NMI}$ function cannot be cancelled using software. The pull-up cannot be set for this pin.
P9$_0$ to P9$_7$	I/O port P9	Input/output	This is an 8-bit I/O port equivalent to P0. Pins in this port also function as Timer B0–B2 input pins, D-A converter output pins, A-D converter extended input pins, or A-D trigger input pins as selected by software.
P10$_0$ to P10$_7$	I/O port P10	Input/output	This is an 8-bit I/O port equivalent to P0. Pins in this port also function as A-D converter input pins. Furthermore, P10$_4$–P10$_7$ also function as input pins for the key input interrupt function.

Operation of Functional Blocks

The M16C/61 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 6 is a memory map of the M16C/61 group. The address space extends the 1M bytes from address 00000_{16} to $FFFFF_{16}$. From $FFFFF_{16}$ down is ROM. For example, in the M30612M4A-XXXFP, there is 32K bytes of internal ROM from $F8000_{16}$ to $FFFFF_{16}$. The vector table for fixed interrupts such as the reset and $\overline{NMI}$ are mapped to $FFFDC_{16}$ to $FFFFF_{16}$. 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 00400_{16} up is RAM. For example, in the M30612M4A-XXXFP, 4K bytes of internal RAM is mapped to the space from 00400_{16} to $013FF_{16}$. In addition to storing data, the RAM also stores the stack used when calling subroutines and when interrupts are generated.

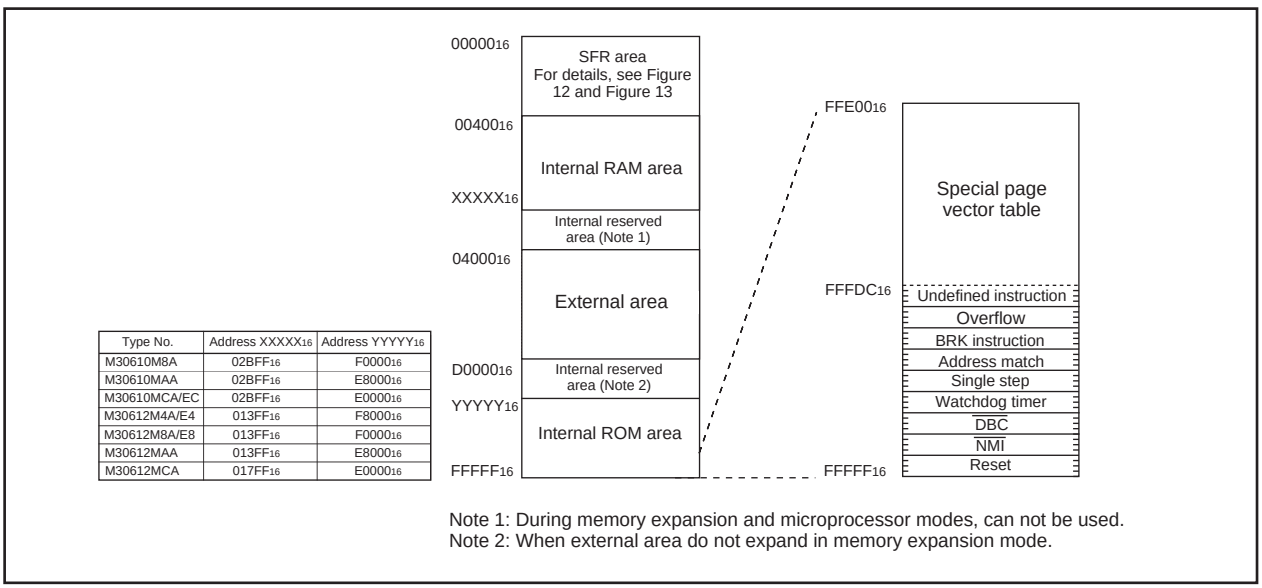
The SFR area is mapped to 00000_{16} to $003FF_{16}$. This area accommodates the control registers for peripheral devices such as I/O ports, A-D converter, serial I/O, and timers, etc. Any part of the SFR area that is not occupied is reserved and cannot be used for other purposes.

The special page vector table is mapped to $FFE00_{16}$ to $FFFDB_{16}$. 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 M30612M4A-XXXFP, the following spaces cannot be used.

- The space between 01400_{16} and $03FFF_{16}$
- The space between $D0000_{16}$ and $F7FFF_{16}$ (When external area do not expand in memory expansion mode)

Do not expand the external area in single chip mode. A part of internal memory cannot be used depending on MCU.



Type No.	Address XXXXX$_{16}$	Address YYYYY$_{16}$
M30610M8A	02BFF$_{16}$	F0000$_{16}$
M30610MAA	02BFF$_{16}$	E8000$_{16}$
M30610MCA/EC	02BFF$_{16}$	E0000$_{16}$
M30612M4A/E4	013FF$_{16}$	F8000$_{16}$
M30612M8A/E8	013FF$_{16}$	F0000$_{16}$
M30612MAA	013FF$_{16}$	E8000$_{16}$
M30612MCA	017FF$_{16}$	E0000$_{16}$

Note 1: During memory expansion and microprocessor modes, can not be used.
Note 2: When external area do not expand in memory expansion mode.

Figure 6. Memory map

Central Processing Unit (CPU)

The CPU has a total of 13 registers shown in Figure 7. Seven of these registers (R0, R1, R2, R3, A0, A1, and FB) come in two sets; therefore, these have two register banks.

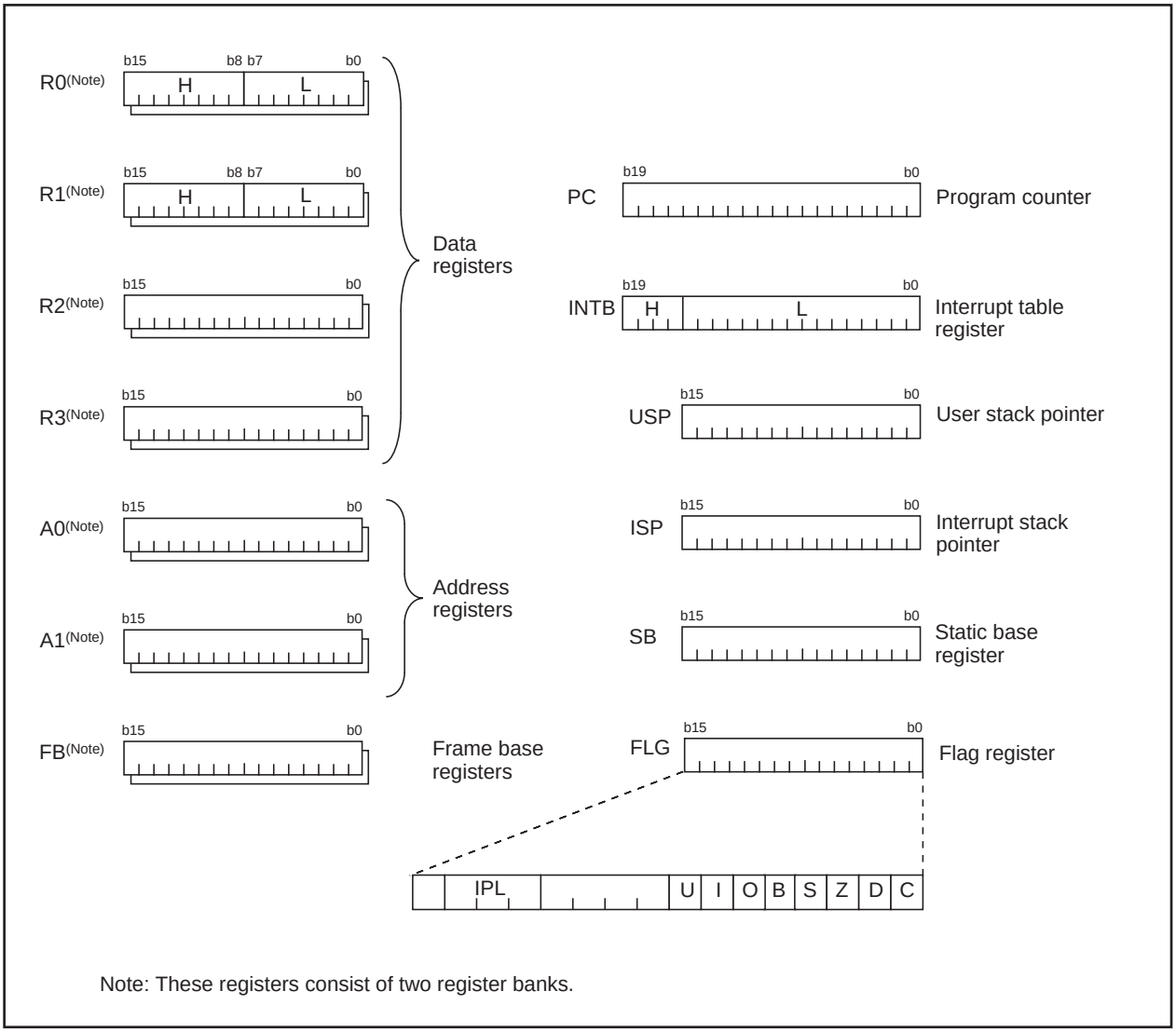


Figure 7. Central processing unit register

(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 8 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.

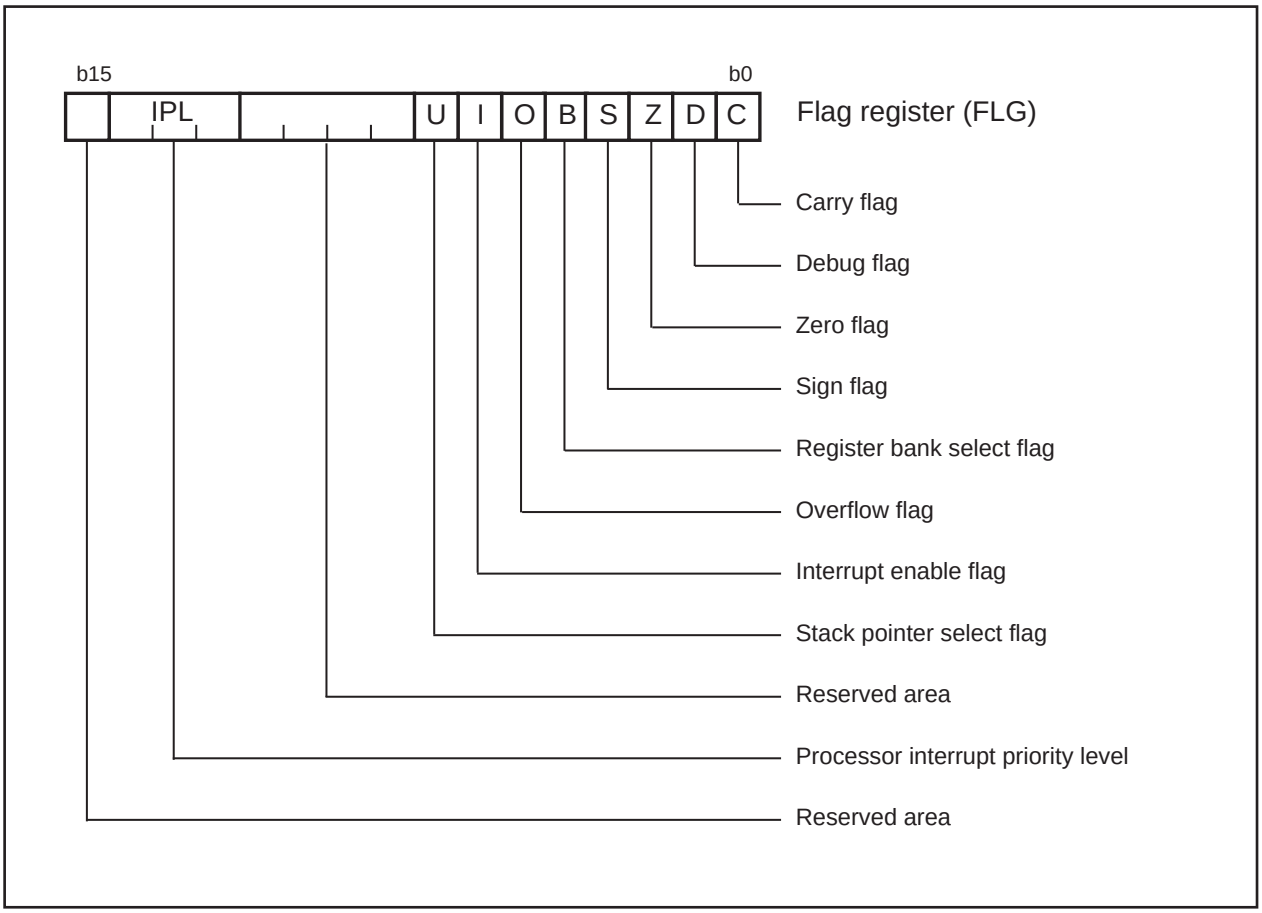


Figure 8. Flag register (FLG)

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” (0.2VCC 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 9 shows the example reset circuit. Figure 10 shows the reset sequence.

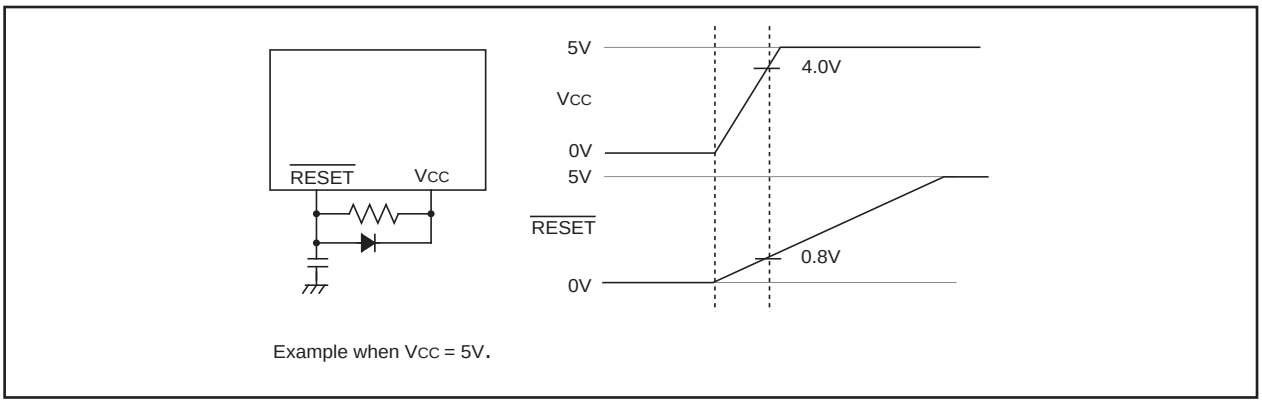


Figure 9. Example reset circuit

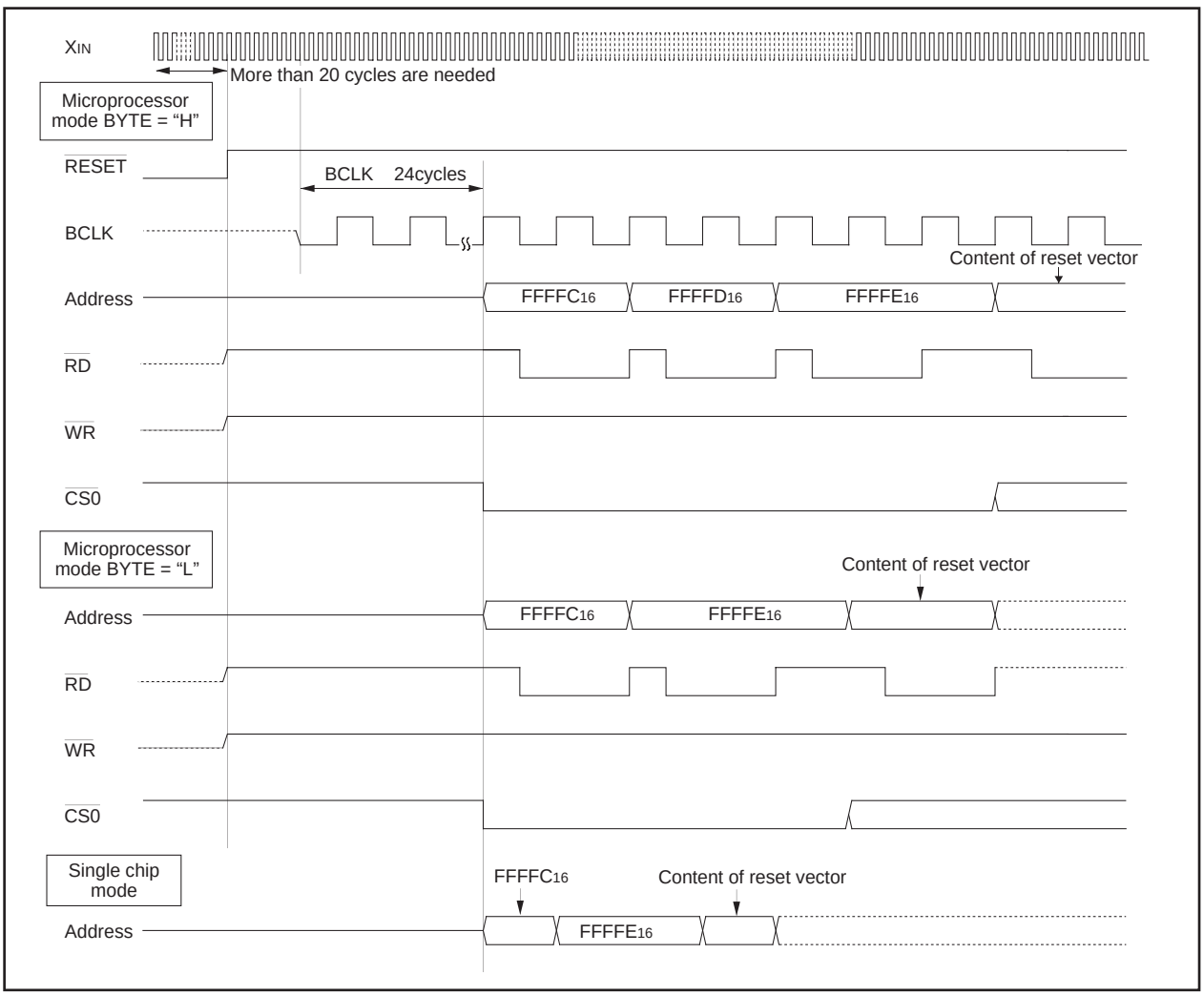


Figure 10. Reset sequence

Table 3 shows the statuses of the other pins while the $\overline{\text{RESET}}$ pin level is “L”. Figure 11 shows the internal status of the microcomputer immediately after the reset is cancelled.

Table 3. Pin status when $\overline{\text{RESET}}$ pin level is “L”

Pin name	Status		
	CNV$_{SS}$ = V$_{SS}$	CNV$_{SS}$ = V$_{CC}$	
		BYTE = V$_{SS}$	BYTE = V$_{CC}$
P0	Input port (floating)	Data input (floating)	Data input (floating)
P1	Input port (floating)	Data input (floating)	Input port (floating)
P2, P3, P4$_0$ to P4$_3$	Input port (floating)	Address output (undefined)	Address output (undefined)
P4$_4$	Input port (floating)	$\overline{\text{CS0}}$ output (“H” level is output)	$\overline{\text{CS0}}$ output (“H” level is output)
P4$_5$ to P4$_7$	Input port (floating)	Input port (floating)	Input port (floating)
P5$_0$	Input port (floating)	$\overline{\text{WR}}$ output (“H” level is output)	$\overline{\text{WR}}$ output (“H” level is output)
P5$_1$	Input port (floating)	$\overline{\text{BHE}}$ output (undefined)	$\overline{\text{BHE}}$ output (undefined)
P5$_2$	Input port (floating)	$\overline{\text{RD}}$ output (“H” level is output)	$\overline{\text{RD}}$ output (“H” level is output)
P5$_3$	Input port (floating)	BCLK output	BCLK output
P5$_4$	Input port (floating)	$\overline{\text{HLDA}}$ output (The output value depends on the input to the $\overline{\text{HOLD}}$ pin)	$\overline{\text{HLDA}}$ output (The output value depends on the input to the $\overline{\text{HOLD}}$ pin)
P5$_5$	Input port (floating)	$\overline{\text{HOLD}}$ input (floating)	$\overline{\text{HOLD}}$ input (floating)
P5$_6$	Input port (floating)	ALE output (“L” level is output)	ALE output (“L” level is output)
P5$_7$	Input port (floating)	$\overline{\text{RDY}}$ input (floating)	$\overline{\text{RDY}}$ input (floating)
P6, P7, P8$_0$ to P8$_4$, P8$_6$, P8$_7$, P9, P10	Input port (floating)	Input port (floating)	Input port (floating)

(1) Processor mode register 0 (Note)	(0004_{16})···	00_{16}
(2) Processor mode register 1	(0005_{16})···	00xxxxx0
(3) System clock control register 0	(0006_{16})···	01001000
(4) System clock control register 1	(0007_{16})···	00100000
(5) Chip select control register	(0008_{16})···	00000001
(6) Address match interrupt enable register	(0009_{16})···	xxxxxx00
(7) Protect register	($000A_{16}$)···	xxxxx000
(8) Watchdog timer control register	($000F_{16}$)···	000????
(9) Address match interrupt register 0	(0010_{16})···	00_{16}
	(0011_{16})···	00_{16}
	(0012_{16})···	xxxx0000
(10) Address match interrupt register 1	(0014_{16})···	00_{16}
	(0015_{16})···	00_{16}
	(0016_{16})···	xxxx0000
(11) DMA0 control register	($002C_{16}$)···	00000?00
(12) DMA1 control register	($003C_{16}$)···	00000?00
(13) Bus collision detection interrupt control register	($004A_{16}$)···	xxxx?000
(14) DMA0 interrupt control register	($004B_{16}$)···	xxxx?000
(15) DMA1 interrupt control register	($004C_{16}$)···	xxxx?000
(16) Key input interrupt control register	($004D_{16}$)···	xxxx?000
(17) A-D conversion interrupt control register	($004E_{16}$)···	xxxx?000
(18) UART2 transmit interrupt control register	($004F_{16}$)···	xxxx?000
(19) UART2 receive interrupt control register	(0050_{16})···	xxxx?000
(20) UART0 transmit interrupt control register	(0051_{16})···	xxxx?000
(21) UART0 receive interrupt control register	(0052_{16})···	xxxx?000
(22) UART1 transmit interrupt control register	(0053_{16})···	xxxx?000
(23) UART1 receive interrupt control register	(0054_{16})···	xxxx?000
(24) Timer A0 interrupt control register	(0055_{16})···	xxxx?000
(25) Timer A1 interrupt control register	(0056_{16})···	xxxx?000
(26) Timer A2 interrupt control register	(0057_{16})···	xxxx?000
(27) Timer A3 interrupt control register	(0058_{16})···	xxxx?000
(28) Timer A4 interrupt control register	(0059_{16})···	xxxx?000
(29) Timer B0 interrupt control register	($005A_{16}$)···	xxxx?000
(30) Timer B1 interrupt control register	($005B_{16}$)···	xxxx?000
(31) Timer B2 interrupt control register	($005C_{16}$)···	xxxx?000
(32) INT0 interrupt control register	($005D_{16}$)···	xx00?000
(33) INT1 interrupt control register	($005E_{16}$)···	xx00?000
(34) INT2 interrupt control register	($005F_{16}$)···	xx00?000
(35) UART2 transmit/receive mode register	(0378_{16})···	00_{16}
(36) UART2 transmit/receive control register 0	($037C_{16}$)···	00001000
(37) UART2 transmit/receive control register 1	($037D_{16}$)···	00000010
(38) Count start flag	(0380_{16})···	00_{16}
(39) Clock prescaler reset flag	(0381_{16})···	0xxxxxxx
(40) One-shot start flag	(0382_{16})···	00x00000
(41) Trigger select flag	(0383_{16})···	00_{16}
(42) Up-down flag	(0384_{16})···	00_{16}
(43) Timer A0 mode register	(0396_{16})···	00_{16}
(44) Timer A1 mode register	(0397_{16})···	00_{16}
(45) Timer A2 mode register	(0398_{16})···	00_{16}
(46) Timer A3 mode register	(0399_{16})···	00_{16}
(47) Timer A4 mode register	($039A_{16}$)···	00_{16}
(48) Timer B0 mode register	($039B_{16}$)···	00?x0000
(49) Timer B1 mode register	($039C_{16}$)···	00?x0000
(50) Timer B2 mode register	($039D_{16}$)···	00?x0000
(51) UART0 transmit/receive mode register	($03A0_{16}$)···	00_{16}
(52) UART0 transmit/receive control register 0	($03A4_{16}$)···	00001000
(53) UART0 transmit/receive control register 1	($03A5_{16}$)···	00000010
(54) UART1 transmit/receive mode register	($03A8_{16}$)···	00_{16}
(55) UART1 transmit/receive control register 0	($03AC_{16}$)···	00001000
(56) UART1 transmit/receive control register 1	($03AD_{16}$)···	00000010
(57) UART transmit/receive control register 2	($03B0_{16}$)···	x0000000
(58) DMA0 cause select register	($03B8_{16}$)···	00_{16}
(59) DMA1 cause select register	($03BA_{16}$)···	00_{16}
(60) A-D control register 2	($03D4_{16}$)···	0000xxx0
(61) A-D control register 0	($03D6_{16}$)···	00000???
(62) A-D control register 1	($03D7_{16}$)···	00_{16}
(63) D-A control register	($03DC_{16}$)···	00_{16}
(64) Port P0 direction register	($03E2_{16}$)···	00_{16}
(65) Port P1 direction register	($03E3_{16}$)···	00_{16}
(66) Port P2 direction register	($03E6_{16}$)···	00_{16}
(67) Port P3 direction register	($03E7_{16}$)···	00_{16}
(68) Port P4 direction register	($03EA_{16}$)···	00_{16}
(69) Port P5 direction register	($03EB_{16}$)···	00_{16}
(70) Port P6 direction register	($03EE_{16}$)···	00_{16}
(71) Port P7 direction register	($03EF_{16}$)···	00_{16}
(72) Port P8 direction register	($03F2_{16}$)···	00x00000
(73) Port P9 direction register	($03F3_{16}$)···	00_{16}
(74) Port P10 direction register	($03F6_{16}$)···	00_{16}
(75) Pull-up control register 0	($03FC_{16}$)···	00_{16}
(76) Pull-up control register 1	($03FD_{16}$)···	00_{16}
(77) Pull-up control register 2	($03FE_{16}$)···	00_{16}
(78) Data registers (R0/R1/R2/R3)		0000_{16}
(79) Address registers (A0/A1)		0000_{16}
(80) Frame base register (FB)		0000_{16}
(81) Interrupt table register (INTB)		00000_{16}
(82) User stack pointer (USP)		0000_{16}
(83) Interrupt stack pointer (ISP)		0000_{16}
(84) Static base register (SB)		0000_{16}
(85) Flag register (FLG)		0000_{16}

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: When the V_{CC} level is applied to the CNV_{SS} pin, it is 03_{16} at a reset.

Figure 11. Device's internal status after a reset is cleared

0000₁₆	
0001₁₆	
0002₁₆	
0003₁₆	
0004₁₆	Processor mode register 0 (PM0)
0005₁₆	Processor mode register 1(PM1)
0006₁₆	System clock control register 0 (CM0)
0007₁₆	System clock control register 1 (CM1)
0008₁₆	Chip select control register (CSR)
0009₁₆	Address match interrupt enable register (AIER)
000A₁₆	Protect register (PRCR)
000B₁₆	
000C₁₆	
000D₁₆	
000E₁₆	Watchdog timer start register (WDTS)
000F₁₆	Watchdog timer control register (WDC)
0010₁₆	Address match interrupt register 0 (RMAD0)
0011₁₆	
0012₁₆	
0013₁₆	
0014₁₆	Address match interrupt register 1 (RMAD1)
0015₁₆	
0016₁₆	
0017₁₆	
0018₁₆	
0019₁₆	
001A₁₆	
001B₁₆	
001C₁₆	
001D₁₆	
001E₁₆	
001F₁₆	
0020₁₆	DMA0 source pointer (SAR0)
0021₁₆	
0022₁₆	
0023₁₆	
0024₁₆	DMA0 destination pointer (DAR0)
0025₁₆	
0026₁₆	
0027₁₆	
0028₁₆	DMA0 transfer counter (TCR0)
0029₁₆	
002A₁₆	
002B₁₆	
002C₁₆	DMA0 control register (DM0CON)
002D₁₆	
002E₁₆	
002F₁₆	
0030₁₆	DMA1 source pointer (SAR1)
0031₁₆	
0032₁₆	
0033₁₆	
0034₁₆	DMA1 destination pointer (DAR1)
0035₁₆	
0036₁₆	
0037₁₆	
0038₁₆	DMA1 transfer counter (TCR1)
0039₁₆	
003A₁₆	
003B₁₆	
003C₁₆	DMA1 control register (DM1CON)
003D₁₆	
003E₁₆	
003F₁₆	

0040₁₆	
0041₁₆	
0042₁₆	
0043₁₆	
0044₁₆	
0045₁₆	
0046₁₆	
0047₁₆	
0048₁₆	
0049₁₆	
004A₁₆	Bus collision detection interrupt control register (BCNIC)
004B₁₆	DMA0 interrupt control register (DM0IC)
004C₁₆	DMA1 interrupt control register (DM1IC)
004D₁₆	Key input interrupt control register (KUPIC)
004E₁₆	A-D conversion interrupt control register (ADIC)
004F₁₆	UART2 transmit interrupt control register (S2TIC)
0050₁₆	UART2 receive interrupt control register (S2RIC)
0051₁₆	UART0 transmit interrupt control register (S0TIC)
0052₁₆	UART0 receive interrupt control register (S0RIC)
0053₁₆	UART1 transmit interrupt control register (S1TIC)
0054₁₆	UART1 receive interrupt control register (S1RIC)
0055₁₆	Timer A0 interrupt control register (TA0IC)
0056₁₆	Timer A1 interrupt control register (TA1IC)
0057₁₆	Timer A2 interrupt control register (TA2IC)
0058₁₆	Timer A3 interrupt control register (TA3IC)
0059₁₆	Timer A4 interrupt control register (TA4IC)
005A₁₆	Timer B0 interrupt control register (TB0IC)
005B₁₆	Timer B1 interrupt control register (TB1IC)
005C₁₆	Timer B2 interrupt control register (TB2IC)
005D₁₆	INT0 interrupt control register (INT0IC)
005E₁₆	INT1 interrupt control register (INT1IC)
005F₁₆	INT2 interrupt control register (INT2IC)
≈	≈
0363₁₆	
0364₁₆	
0365₁₆	
0366₁₆	
0367₁₆	
0368₁₆	
0369₁₆	
036A₁₆	
036B₁₆	
036C₁₆	
036D₁₆	
036E₁₆	
036F₁₆	
0370₁₆	
0371₁₆	
0372₁₆	
0373₁₆	
0374₁₆	
0375₁₆	
0376₁₆	
0377₁₆	
0378₁₆	UART2 transmit/receive mode register (U2MR)
0379₁₆	UART2 bit rate generator (U2BRG)
037A₁₆	UART2 transmit buffer register (U2TB)
037B₁₆	
037C₁₆	UART2 transmit/receive control register 0 (U2C0)
037D₁₆	UART2 transmit/receive control register 1 (U2C1)
037E₁₆	UART2 receive buffer register (U2RB)
037F₁₆	

Figure 12. Location of peripheral unit control registers

038016	Count start flag (TABSR)
038116	Clock prescaler reset flag (CPSRF)
038216	One-shot start flag (ONSF)
038316	Trigger select register (TRGSR)
038416	Up-down flag (UDF)
038516	
038616	Timer A0 (TA0)
038716	
038816	Timer A1 (TA1)
038916	
038A16	Timer A2 (TA2)
038B16	
038C16	Timer A3 (TA3)
038D16	
038E16	Timer A4 (TA4)
038F16	
039016	Timer B0 (TB0)
039116	
039216	Timer B1 (TB1)
039316	
039416	Timer B2 (TB2)
039516	
039616	Timer A0 mode register (TA0MR)
039716	Timer A1 mode register (TA1MR)
039816	Timer A2 mode register (TA2MR)
039916	Timer A3 mode register (TA3MR)
039A16	Timer A4 mode register (TA4MR)
039B16	Timer B0 mode register (TB0MR)
039C16	Timer B1 mode register (TB1MR)
039D16	Timer B2 mode register (TB2MR)
039E16	
039F16	
03A016	UART0 transmit/receive mode register (U0MR)
03A116	UART0 bit rate generator (U0BRG)
03A216	UART0 transmit buffer register (U0TB)
03A316	
03A416	UART0 transmit/receive control register 0 (U0C0)
03A516	UART0 transmit/receive control register 1 (U0C1)
03A616	UART0 receive buffer register (U0RB)
03A716	
03A816	UART1 transmit/receive mode register (U1MR)
03A916	UART1 bit rate generator (U1BRG)
03AA16	UART1 transmit buffer register (U1TB)
03AB16	
03AC16	UART1 transmit/receive control register 0 (U1C0)
03AD16	UART1 transmit/receive control register 1 (U1C1)
03AE16	UART1 receive buffer register (U1RB)
03AF16	
03B016	UART transmit/receive control register 2 (UCON)
03B116	
03B216	
03B316	
03B416	
03B516	
03B616	
03B716	
03B816	DMA0 cause select register (DM0SL)
03B916	
03BA16	DMA1 cause select register (DM1SL)
03BB16	
03BC16	CRC data register (CRCD)
03BD16	
03BE16	CRC input register (CRCIN)
03BF16	

03C016	A-D register 0 (AD0)
03C116	
03C216	A-D register 1 (AD1)
03C316	
03C416	A-D register 2 (AD2)
03C516	
03C616	A-D register 3 (AD3)
03C716	
03C816	A-D register 4 (AD4)
03C916	
03CA16	A-D register 5 (AD5)
03CB16	
03CC16	A-D register 6 (AD6)
03CD16	
03CE16	A-D register 7 (AD7)
03CF16	
03D016	
03D116	
03D216	
03D316	
03D416	A-D control register 2 (ADCON2)
03D516	
03D616	A-D control register 0 (ADCON0)
03D716	A-D control register 1 (ADCON1)
03D816	D-A register 0 (DA0)
03D916	
03DA16	D-A register 1 (DA1)
03DB16	
03DC16	D-A control register (DACON)
03DD16	
03DE16	
03DF16	
03E016	Port P0 (P0)
03E116	Port P1 (P1)
03E216	Port P0 direction register (PD0)
03E316	Port P1 direction register (PD1)
03E416	Port P2 (P2)
03E516	Port P3 (P3)
03E616	Port P2 direction register (PD2)
03E716	Port P3 direction register (PD3)
03E816	Port P4 (P4)
03E916	Port P5 (P5)
03EA16	Port P4 direction register (PD4)
03EB16	Port P5 direction register (PD5)
03EC16	Port P6 (P6)
03ED16	Port P7 (P7)
03EE16	Port P6 direction register (PD6)
03EF16	Port P7 direction register (PD7)
03F016	Port P8 (P8)
03F116	Port P9 (P9)
03F216	Port P8 direction register (PD8)
03F316	Port P9 direction register (PD9)
03F416	Port P10 (P10)
03F516	
03F616	Port P10 direction register (PD10)
03F716	
03F816	
03F916	
03FA16	
03FB16	
03FC16	Pull-up control register 0 (PUR0)
03FD16	Pull-up control register 1 (PUR1)
03FE16	Pull-up control register 2 (PUR2)
03FF16	

Figure 13. Location of peripheral unit control registers

Software Reset

Writing "1" to bit 3 of the processor mode register 0 (address 0004_{16}) applies a (software) reset to the microcomputer. A software reset has almost 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. 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).

  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 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 0004_{16}). Do not set the processor mode bits to "10_2".

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. 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**

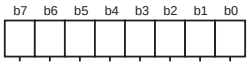
  The microcomputer begins operation in single-chip mode after being reset. Memory expansion mode is selected by writing "01_2" to the processor mode is selected bits.

- **Applying Vcc to CNVss pin**

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

Figure 14 shows the processor mode register 0 and 1. Figure 15 shows the memory maps applicable for each of the modes.

Processor mode register 0 (Note 1)

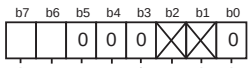


Symbol: PM0 | Address: 0004_{16} | When reset: 00_{16} (Note 2)

Bit symbol	Bit name	Function	R	W
PM00	Processor mode bit	b1 b0 0 0: Single-chip mode 0 1: Memory expansion mode 1 0: Inhibited 1 1: Microprocessor mode	○	○
PM01			○	○
PM02	R/W mode select bit	0 : $\overline{RD}$,$\overline{BHE}$,$\overline{WR}$ 1 : RD,WRH,WRL	○	○
PM03	Software reset bit	The device is reset when this bit is set to “1”. The value of this bit is “0” when read.	○	○
PM04	Multiplexed bus space select bit	b5 b4 0 0 : Multiplexed bus is not used 0 1 : Allocated to CS2 space 1 0 : Allocated to CS1 space 1 1 : Allocated to entire space (Note4)	○	○
PM05			○	○
PM06	Port $P4_0$ to $P4_3$ function select bit (Note 3)	0 : Address output 1 : Port function (Address is not output)	○	○
PM07	BCLK output disable bit	0 : BCLK is output 1 : BCLK is not output (Pin is left floating)	○	○

Note 1: Set bit 1 of the protect register (address $000A_{16}$) to “1” when writing new values to this register.
Note 2: If the V_{CC} voltage is applied to the CNV_{SS}, the value of this register when reset is 03_{16}. (PM00 and PM01 both are set to “1”.)
Note 3: Valid in microprocessor and memory expansion modes.
Note 4: 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.
The higher-order address becomes a port if the entire space multiplexed bus is chosen, so only 256 bytes can be used in each chip select.

Processor mode register 1 (Note 1)

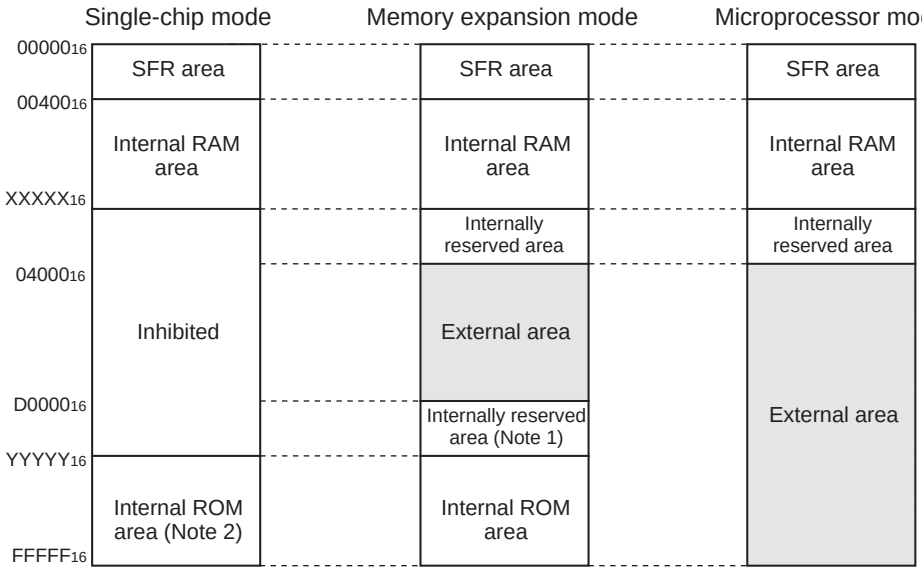


Symbol: PM1 | Address: 0005_{16} | When reset: $00XXXXX0_2$

Bit symbol	Bit name	Function	R	W
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.			—	—
Reserved bit		Must always be set to “0”	○	○
PM16	External memory area expansion bit (Note 2)	0 : Do not expand 1 : Expand	○	○
PM17	Wait bit	0 : No wait state 1 : Wait state inserted	○	○

Note 1: Set bit 1 of the protect register (address $000A_{16}$) to “1” when writing new values to this register.
Note 2: When this bit is set to “1” in memory expansion mode, M30612M4A/E4 provides the means of using part of internal reserved area as an external area. Set this bit to “0” except M30612M4A/E4. Set this bit to “0” in single chip mode.

Figure 14. Processor mode register 0 and 1



Type No.	Address XXXXX₁₆	Address YYYYY₁₆
M30610M8A	02BFF₁₆	F0000₁₆
M30610MAA	02BFF₁₆	E8000₁₆
M30610MCA/EC	02BFF₁₆	E0000₁₆
M30612M4A/E4	013FF₁₆	F8000₁₆
M30612M8A/E8	013FF₁₆	F0000₁₆
M30612MAA	013FF₁₆	E8000₁₆
M30612MCA	017FF₁₆	E0000₁₆

External area : Accessing this area allows the user to access a device connected externally to the microcomputer.

Note 1: This area becomes external area when PM16 (external memory area expansion bit) = “1” in M30612M4A/E4. Set “0” except M30612M4A/E4.
Note 2: Set “0” to PM16 (external memory area expansion bit) in single chip mode.

Figure 15. Memory maps in each processor mode

Bus Settings

The BYTE pin and bits 4 to 6 of the processor mode register 0 (address 0004_{16}) are used to change the bus settings.

Table 4 shows the factors used to change the bus settings.

Table 4. 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. $P4_0$ to $P4_3$ 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 $P4_0$ to $P4_3$ 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 an 8-bit data bus selected (BYTE pin = “H”), the 8 bits from D_0 to D_7 are multiplexed with A_0 to A_7.

  With a 16-bit data bus selected (BYTE pin = “L”), the 8 bits from D_0 to D_7 are multiplexed with A_1 to A_8. D_8 to D_{15} 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 $P5_6$.

  Before accessing the multiplex bus, always set the CSi wait bit of the chip select control register to “0”.

  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.

  The higher-order address becomes a port if the entire space multiplexed bus is chosen, so only 256 bytes can be used in each chip select.

Table 5. 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"
$P0_0$ to $P0_7$	I/O port	Data bus	Data bus	Data bus	Data bus	I/O port
$P1_0$ to $P1_7$	I/O port	I/O port	Data bus	I/O port	Data bus	I/O port
$P2_0$	I/O port	Address bus /data bus(Note 2)	Address bus	Address bus	Address bus	Address bus /data bus
$P2_1$ to $P2_7$	I/O port	Address bus /data bus(Note 2)	Address bus /data bus(Note 2)	Address bus	Address bus	Address bus /data bus
$P3_0$	I/O port	Address bus	Address bus /data bus(Note 2)	Address bus	Address bus	Address bus
$P3_1$ to $P3_7$	I/O port	Address bus	Address bus	Address bus	Address bus	I/O port
$P4_0$ to $P4_3$ Port $P4_0$ to $P4_3$ function select bit = 1	I/O port	I/O port	I/O port	/O port	I/O port	I/O port
$P4_0$ to $P4_3$ Port $P4_0$ to $P4_3$ function select bit = 0	I/O port	Address bus	Address bus	Address bus	Address bus	I/O port
$P4_4$ to $P4_7$	I/O port	$\overline{CS}$ (chip select) or programmable I/O port (For details, refer to "Bus control")				
$P5_0$ to $P5_3$	I/O port	Outputs $\overline{RD}$, $\overline{WRL}$, $\overline{WRH}$, and BCLK or $\overline{RD}$, $\overline{BHE}$, $\overline{WR}$, and BCLK (For details, refer to "Bus control")				
$P5_4$	I/O port	$\overline{HLDA}$	$\overline{HLDA}$	$\overline{HLDA}$	$\overline{HLDA}$	$\overline{HLDA}$
$P5_5$	I/O port	$\overline{HOLD}$	$\overline{HOLD}$	$\overline{HOLD}$	$\overline{HOLD}$	$\overline{HOLD}$
$P5_6$	I/O port	ALE	ALE	ALE	ALE	ALE
$P5_7$	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.
The higher-order address becomes 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

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 A_0 to A_{19} 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 D_0 to D_7 function as the data bus. When BYTE is "L", the 16 ports D_0 to D_{15} function as the data bus.

Both the address and data bus retain their previous states when internal ROM or RAM is accessed. Also, 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 $P4_4$ to $P4_7$. Bits 0 to 3 of the chip select control register (address 0008_{16}) 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, $P4_4$ to $P4_7$ 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. Therefore, when using $\overline{CS1}$ to $\overline{CS3}$, external pull-up resistors are required. Figure 16 shows the chip select control register.

The chip select signal can be used to split the external area into as many as four blocks. Table 6 shows the external memory areas specified using the chip select signal.

Table 6. External areas specified by the chip select signals

Chip select	Specified address range	
	Memory expansion mode	Microprocessor mode
$\overline{CS0}$	30000_{16} to $CFFFF_{16}$ (640K)	30000_{16} to $FFFFF_{16}$ (832K)
	30000_{16} to $F7FFF_{16}$ (800K) (Note)	
$\overline{CS1}$	28000_{16} to $2FFFF_{16}$ (32K)	28000_{16} to $2FFFF_{16}$ (32K)
$\overline{CS2}$	08000_{16} to $27FFF_{16}$ (128K)	08000_{16} to $27FFF_{16}$ (128K)
$\overline{CS3}$	04000_{16} to $07FFF_{16}$ (16K)	04000_{16} to $07FFF_{16}$ (16K)

Note: When PM16 (External memory area expansion bit) = "1". (Only M30612M4A/E4 is valid.)

Chip select control register

Symbol: CSR | Address: 0008_{16} | When reset: 01_{16}

Bit symbol	Bit name	Function	R	W
CS0	$\overline{CS0}$ output enable bit	0 : Chip select output disabled (Normal port pin) 1 : Chip select output enabled	○	○
CS1	$\overline{CS1}$ output enable bit		○	○
CS2	$\overline{CS2}$ output enable bit		○	○
CS3	$\overline{CS3}$ output enable bit		○	○
CS0W	$\overline{CS0}$ wait bit	0 : Wait state inserted 1 : No wait state	○	○
CS1W	$\overline{CS1}$ wait bit		○	○
CS2W	$\overline{CS2}$ wait bit		○	○
CS3W	$\overline{CS3}$ wait bit		○	○

Figure 16. Chip select control register

(3) Read/write signals

With a 16-bit data bus (BYTE pin ="L"), bit 2 of the processor mode register 0 (address 0004_{16}) 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 0004_{16}) to "0".) Tables 7 and 8 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 0004_{16}) 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 $000A_{16}$) to "1".

Table 7. 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 8. 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.

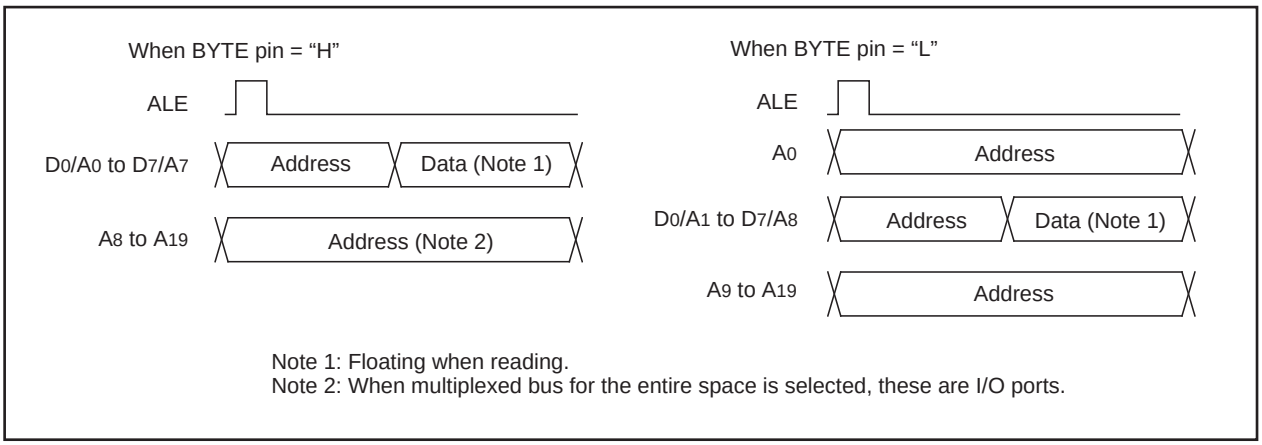


Figure 17. ALE signal and address/data bus

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

$\overline{RDY}$ is a signal that facilitates access to an external device that requires long access time. As shown in Figure 18, if an “L” is being input to the $\overline{RDY}$ at the BCLK falling edge, the bus turns to the wait state. If an “H” is being input to the $\overline{RDY}$ pin at the BCLK falling edge, the bus cancels the wait state. Table 9 shows the state of the microcomputer with the bus in the wait state, and Figure 18 shows an example in which the $\overline{RD}$ signal is prolonged by the $\overline{RDY}$ signal.

The $\overline{RDY}$ signal is useful in accessing an external area in a bus cycle with software wait operating. The $\overline{RDY}$ signal turns null if software wait is not operating, but the non-used pins should be properly treated in this instance too.

Table 9. Microcomputer status in ready state (Note)

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

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

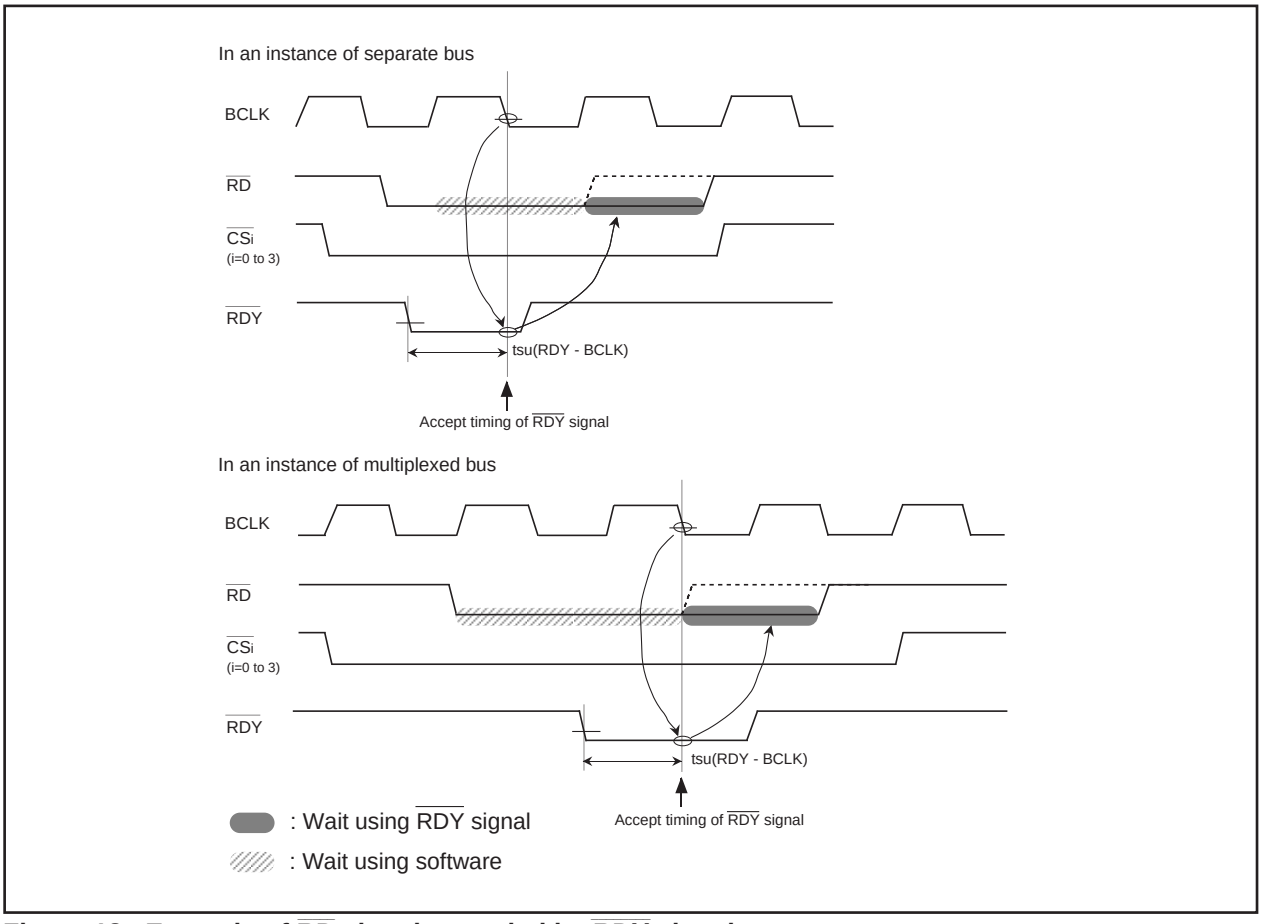


Figure 18. Example of $\overline{RD}$ signal extended by $\overline{RDY}$ signal

(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 10 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.

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

Figure 19. Bus-using priorities

Table 10. 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 11 shows the external bus status when the internal area is accessed.

Table 11. 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 (0004_{16}) (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 $000A_{16}$) 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 0005_{16}) (Note) and bits 4 to 7 of the chip select control register (address 0008_{16}).

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”, bits 4 to 7 of the chip select control register are invalid and a wait is applied to all external memory areas (two or three BCLK cycles). When V_{CC} is in the range 2.7V to 4.0V, set the wait bit to “1”. However, this is not necessary if the oscillation frequency is less than 3MHz.

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 $\overline{CS0}$ to $\overline{CS3}$. 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, the corresponding bits of the chip select control register must be set to “0” if using the multiplex bus to access the external memory area.

Table 12 shows the software wait and bus cycles. Figure 20 shows example 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 $000A_{16}$) to “1”.

Table 12. 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 (Note)	3 BCLK cycles
	Multiplex bus	1	0 (Note)	3 BCLK cycles

Note: Always set to “0”.

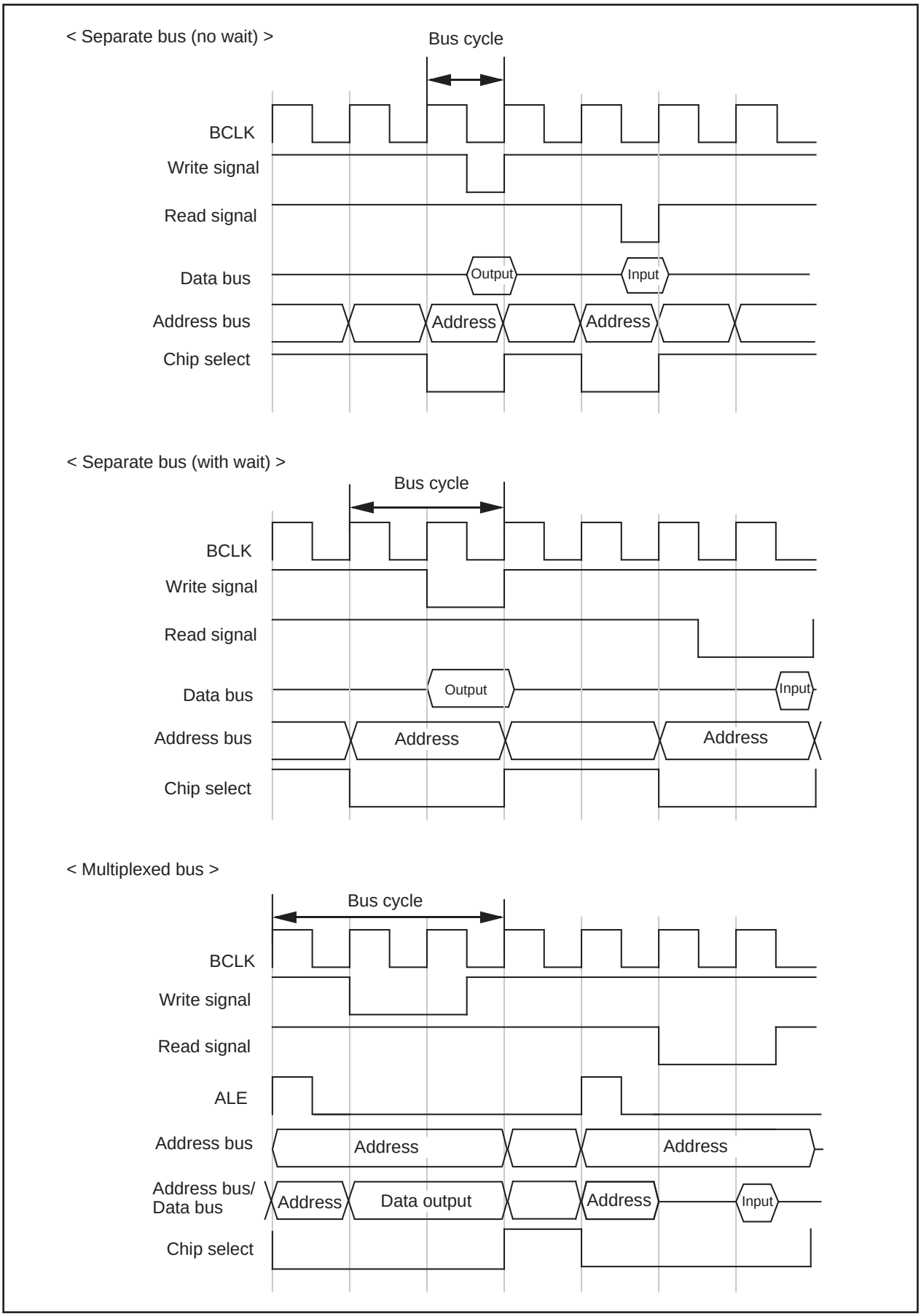


Figure 20. Typical bus timings using software wait

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 13. 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 21 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 22 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 21 and 22 vary with each oscillator used. Use the values recommended by the manufacturer of your oscillator.

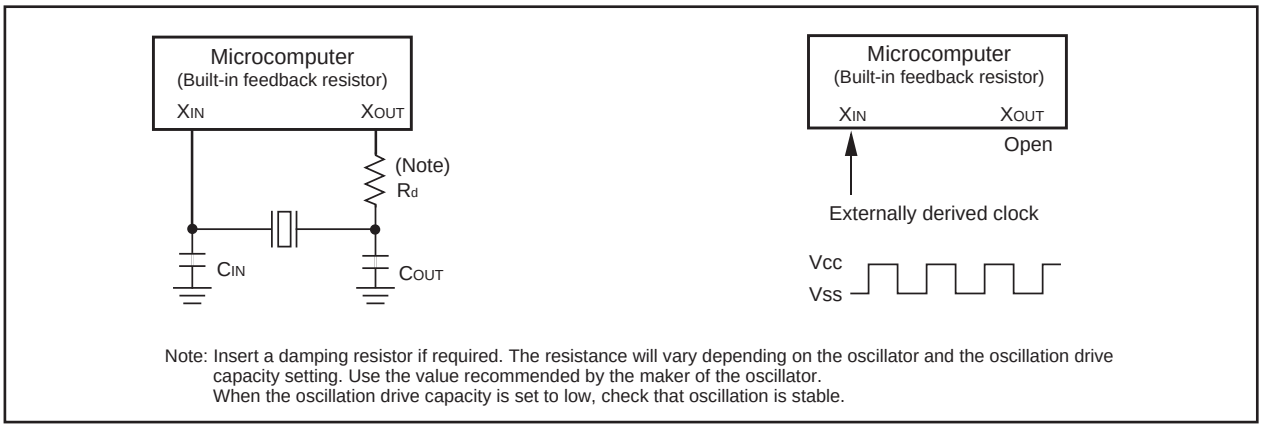


Figure 21. Examples of main clock

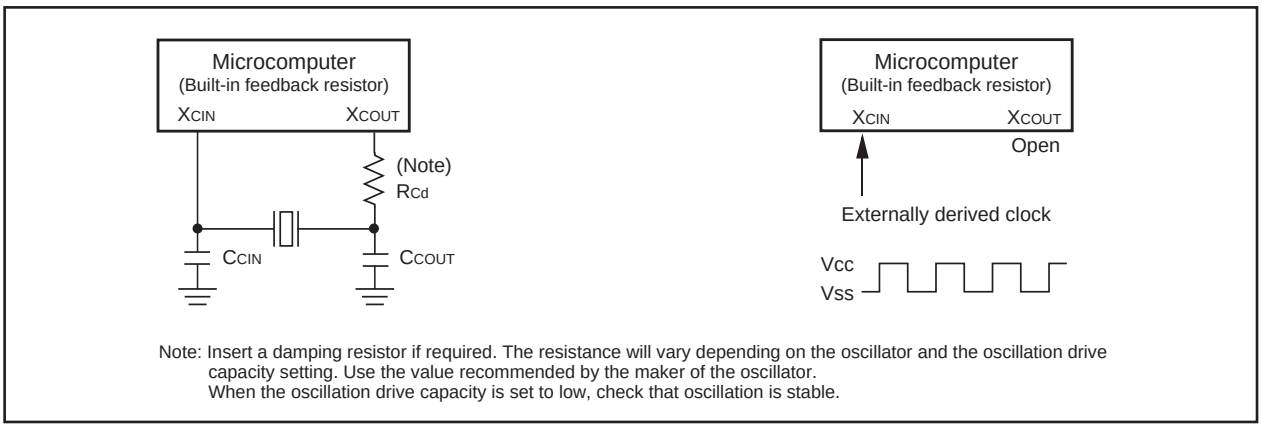


Figure 22. Examples of sub clock

Clock Control

Figure 23 shows the block diagram of the clock generating circuit.

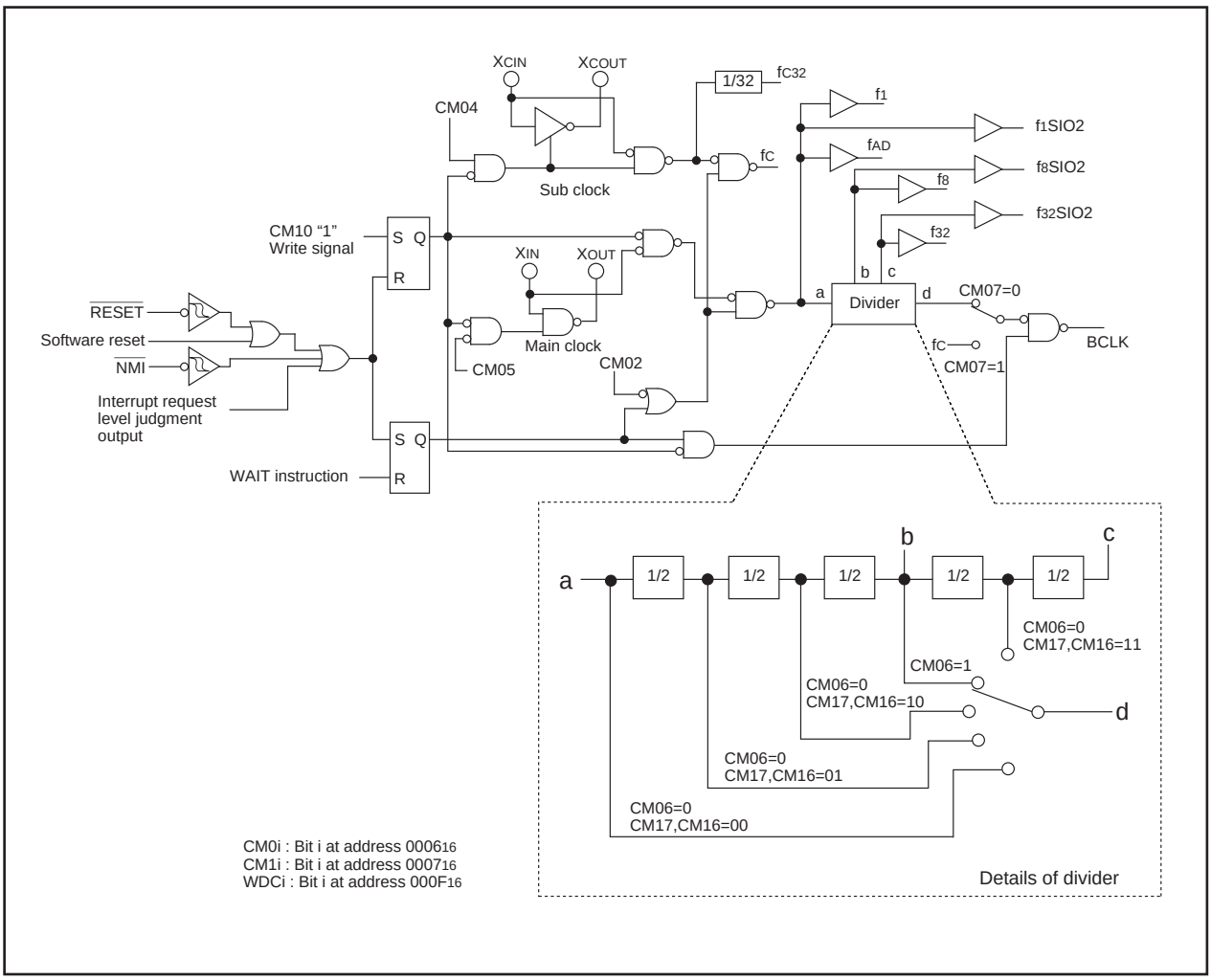


Figure 23. Clock generating circuit

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 0006_{16}). Stopping the clock reduces the power dissipation.

After the oscillation of the main clock oscillation circuit has stabilized, the drive capacity of the XOUT pin can be reduced using the XIN-XOUT drive capacity select bit (bit 5 at address 0007_{16}). Reducing the drive capacity of the XOUT pin reduces the power dissipation. This bit defaults to "1" when shifting to stop mode and after a reset.

(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 0006_{16}), the sub clock can be selected as the BCLK by using the system clock select bit (bit 7 at address 0006_{16}). 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 XCOUT pin can be reduced using the XCIN-XCOUT drive capacity select bit (bit 3 at address 0006_{16}). Reducing the drive capacity of the XCOUT pin reduces the power dissipation. This bit changes to "1" when shifting to stop mode and at a reset.

(3) BCLK

The BCLK is the clock that drives the CPU, and is either the main clock or fc or is derived by dividing the main clock by 2, 4, 8, or 16. The BCLK is derived by dividing the main clock by 8 after a reset.

When shifting to stop mode, the main clock division select bit (bit 6 at 0006_{16}) is set to "1".

(4) Peripheral function clock

- **f_1, f_8, f_{32}, f_{1SIO2}, f_{8SIO2}, f_{32SIO2}**

The clock for the peripheral devices is derived from the main clock or by dividing it by 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 0006_{16}) to "1" and then executing a WAIT instruction.

- **f_{AD}**

This clock has the same frequency as the main clock and is used for A-D conversion.

(5) f_{C32}

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

(6) f_C

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

Figure 24 shows the system clock control registers 0 and 1.

System clock control register 0 (Note 1)

b7	b6	b5	b4	b3	b2	b1	b0

Symbol	Address	When reset
CM0	0006_{16}	48_{16}

Bit symbol	Bit name	Function	R	W
CM00	Clock output function select bit	b1 b0 0 0 : I/O port $P5_7$ 0 1 : f_C output 1 0 : f_8 output 1 1 : f_{32} output	O	O
CM01			O	O
CM02	WAIT peripheral function clock stop bit	0 : Do not stop f_1, f_8, f_{32} in wait mode 1 : Stop f_1, f_8, f_{32} in wait mode	O	O
CM03	XCIN-XCOUT drive capacity select bit (Note 2)	0 : LOW 1 : HIGH	O	O
CM04	Port XC select bit	0 : I/O port 1 : XCIN-XCOUT generation	O	O
CM05	Main clock (XIN-XOUT) stop bit (Note 4) (Note 5)	0 : On 1 : Off	O	O
CM06	Main clock division select bit 0 (Note 2)	0 : CM16 and CM17 valid 1 : Division by 8 mode	O	O
CM07	System clock select bit (Note 6)	0 : XIN, XOUT 1 : XCIN, XCOUT	O	O

Note 1: Set bit 0 of the protect register (address $000A_{16}$) to "1" before writing to this register.
Note 2: Changes to "1" when shiffing to stop mode.
Note 3: When entering power saving mode, main clock stops using this bit. When returning from stop mode and operating with XIN, set this bit to "0". When main clock oscillation is operating by itself, 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 ON, so XIN turns pulled up to XOUT ("H") via the feedback resistor.
Note 6: Set port Xc select bit (CM04) to "1" before writing to this bit. The both bits can not be written at the same time.

System clock control register 1 (Note 1)

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

Symbol	Address	When reset
CM1	0007_{16}	20_{16}

Bit symbol	Bit name	Function	R	W
CM10	All clock stop control bit (Note4)	0 : Clock on 1 : All clocks off (stop mode)	O	O
Reserved bit		Always set to "0"	O	O
Reserved bit		Always set to "0"	O	O
Reserved bit		Always set to "0"	O	O
Reserved bit		Always set to "0"	O	O
CM15	XIN-XOUT drive capacity select bit (Note 2)	0 : LOW 1 : HIGH	O	O
CM16	Main clock division select bit 1 (Note 3)	b7 b6 0 0 : No division mode 0 1 : Division by 2 mode 1 0 : Division by 4 mode 1 1 : Division by 16 mode	O	O
CM17				

Note 1: Set bit 0 of the protect register (address $000A_{16}$) to "1" before writing to this register.
Note 2: Changes to "1" when shiffing to stop mode.
Note 3: Can be selected when bit 6 of the system clock control register 0 (address 0006_{16}) 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 turns null.

Figure 24. Clock control registers 0 and 1

Clock Output

In single-chip mode, the clock output function select bits (bits 0 and 1 at address 0006_{16}) enable f_8, f_{32}, or f_C to be output from the $P5_7/CLK_{OUT}$ pin. When the WAIT peripheral function clock stop bit (bit 2 at address 0006_{16}) is set to "1", the output of f_8 and f_{32} stops when a WAIT instruction is executed.

Stop Mode

Writing "1" to the all-clock stop control bit (bit 0 at address 0007_{16}) 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, f_1 to f_{32}, f_{1SIO2} to f_{32SIO2}, f_C, f_{C32}, and f_{AD} 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) functions provided an external clock is selected. Table 14 shows the status of the ports in stop mode.

Stop mode is cancelled by a hardware reset or interrupt. If an interrupt is to be used to cancel stop mode, that interrupt must first have been enabled.

When shifting to stop mode, the main clock division select bit 0 (bit 6 at 0006_{16}) is set to "1".

Table 14. Port status during stop mode

Pin		Memory expansion mode Microprocessor mode	Single-chip mode
Address bus, data bus, $\overline{CS0}$ to $\overline{CS3}$		Retains status before stop mode	
$\overline{RD}$, $\overline{WR}$, $\overline{BHE}$, $\overline{WRL}$, $\overline{WRH}$		"H"	
$\overline{HLDA}$, BCLK		"H"	
ALE		"H"	
Port		Retains status before stop mode	Retains status before stop mode
CLK_{OUT}	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, BCLK stops and the microcomputer enters the wait mode. In this mode, oscillation continues but 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. Table 15 shows the status of the ports in wait mode. Wait mode is cancelled by a hardware reset or interrupt. If an interrupt is used to cancel wait mode, the microcomputer restarts using as BCLK, the clock that had been selected when the WAIT instruction was executed.

Table 15. Port status during wait mode

Pin		Memory expansion mode Microprocessor mode	Single-chip mode
Address bus, data bus, $\overline{CS0}$ to $\overline{CS3}$		Retains status before wait mode	
$\overline{RD}$, $\overline{WR}$, $\overline{BHE}$, $\overline{WRL}$, $\overline{WRH}$		“H”	
$\overline{HLDA}$,BCLK		“H”	
ALE		“H”	
Port		Retains status before wait mode	Retains status before wait mode
CLK_{OUT}	When f_C selected	Valid only in single-chip mode	Does not stop
	When f_8, f_{32} 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

Power dissipation can be reduced and low-voltage operation achieved by changing the count source for BCLK. Table 16 shows the operating modes corresponding to the settings of system clock control registers 0 and 1.

After a reset, operation defaults to division by 8 mode. When shifting to stop mode, the main clock division select bit 0 (bit 6 at address 0006_{16}) is set to "1". 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. Note that oscillation of the main clock must have stabilized before transferring from this mode to another mode.

(4) Division by 16 mode

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

(5) No-division mode

The main clock is used as the BCLK.

(6) Low-speed mode

f_C 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

f_C is the BCLK and the main clock is stopped.

Table 16. 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 internal clock 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 internal clock 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 25 is the state transition diagram of the above modes.

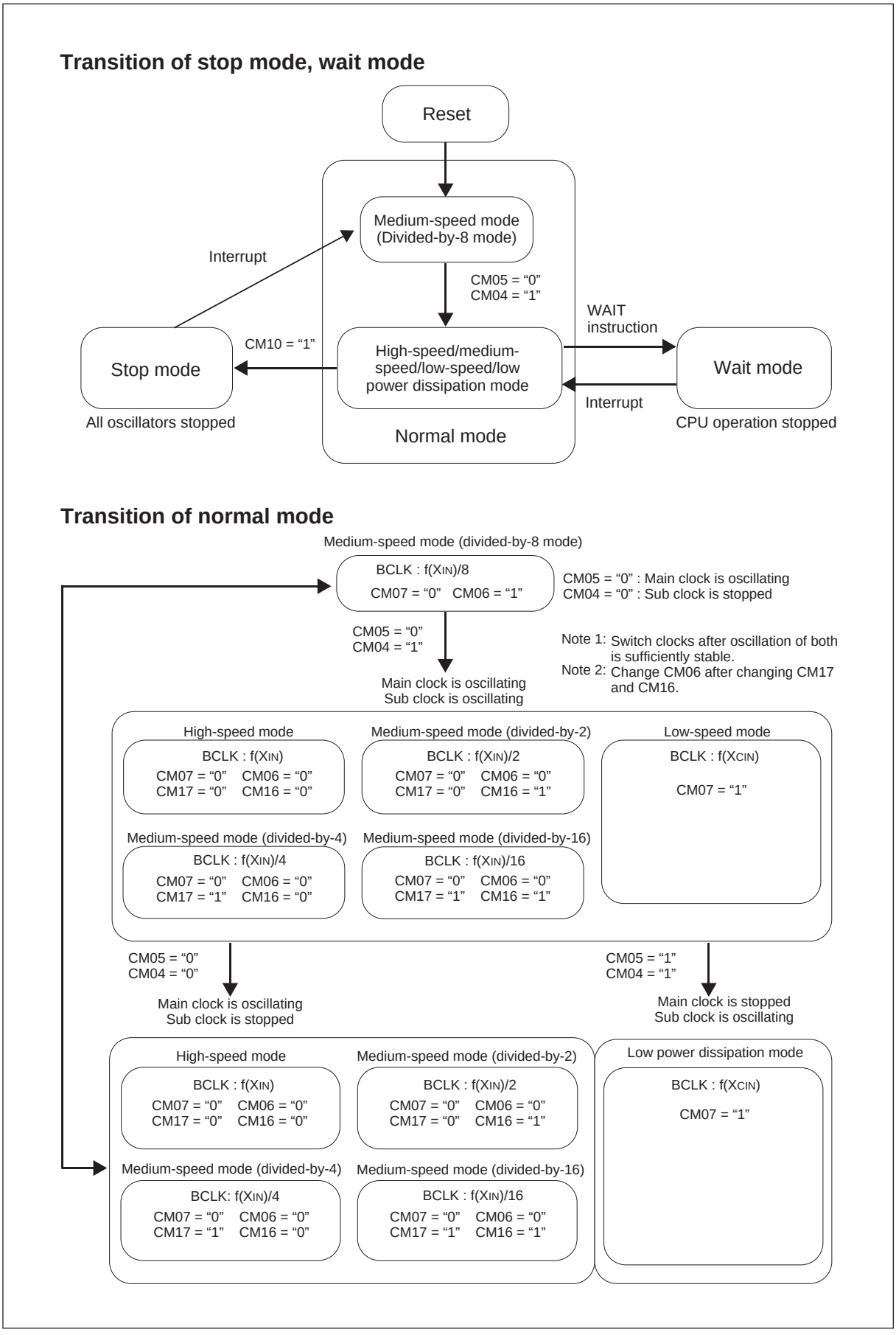


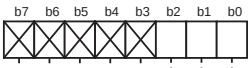
Figure 25. State transition diagram of Power control mode

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 26 shows the protect register. The values in the processor mode register 0 (address 0004_{16}), processor mode register 1 (address 0005_{16}), system clock control register 0 (address 0006_{16}), system clock control register 1 (address 0007_{16}) and port P9 direction register (address $03F3_{16}$) 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 write-enable bit (bit 2 at address $000A_{16}$), 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 $000A_{16}$) and processor mode register 0 and 1 write-enable bit (bit 1 at $000A_{16}$) 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”.

Protect register



Symbol: PRCR
Address: $000A_{16}$
When reset: $XXXXX000_2$

Bit symbol	Bit name	Function	R	W
PRC0	Enables writing to system clock control registers 0 and 1 (addresses 0006_{16} and 0007_{16})	0 : Write-inhibited 1 : Write-enabled	○	○
PRC1	Enables writing to processor mode registers 0 and 1 (addresses 0004_{16} and 0005_{16})	0 : Write-inhibited 1 : Write-enabled	○	○
PRC2	Enables writing to port P9 direction register (address $03F3_{16}$) (Note)	0 : Write-inhibited 1 : Write-enabled	○	○
Nothing is assigned. In an attempt to write to these bits, write “0”. The value, if read, turns out to be indeterminate.			–	–

Note: Writing a value to an address after “1” is written to this bit returns the bit to “0” . Other bits do not automatically return to “0” and they must therefore be reset by the program.

Figure 26. Protect register

Overview of Interrupt

Type of Interrupts

Figure 27 lists the types of interrupts.

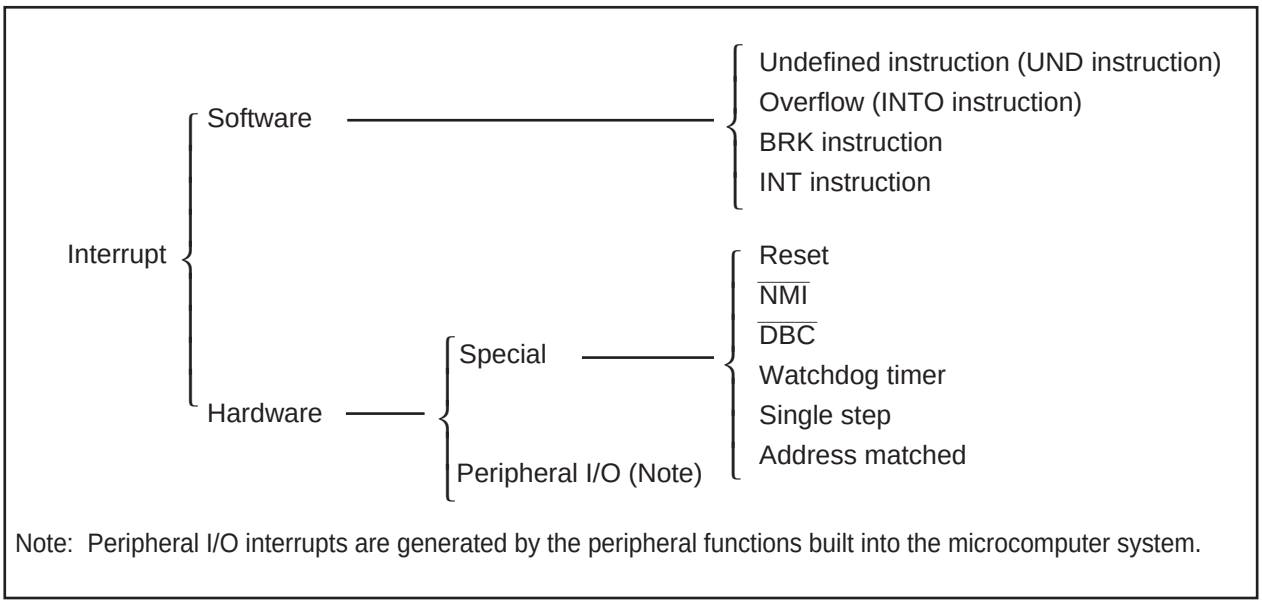


Figure 27. Classification of interrupts

- 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 assiging 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. For address match interrupt, see 2.11 Address match Interrupt.

(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 and UART2 transmission interrupt**

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

- **UART0, UART1 and UART2 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 B2 interrupt**

  These are interrupts that timer B generates.

- **$\overline{\text{INT0}}$ interrupt through $\overline{\text{INT2}}$ interrupt**

  An $\overline{\text{INT}}$ interrupt occurs if either a rising edge or a falling 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 28 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.

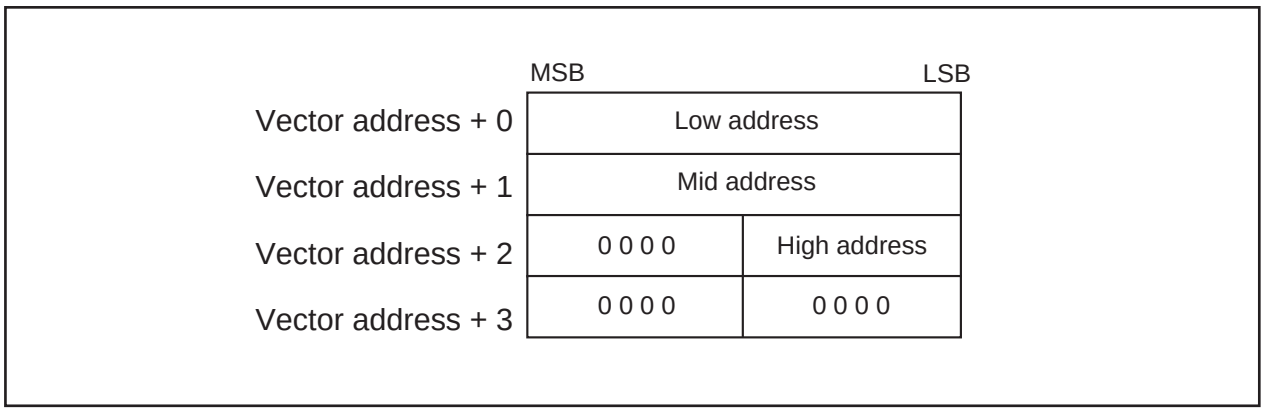


Figure 28. Format for specifying interrupt vector addresses

• 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. Table17 shows the interrupts assigned to the fixed vector tables and addresses of vector tables.

Table 17. 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	FFFDC16 to FFFDF16	Interrupt on UND instruction
Overflow	FFFE016 to FFFE316	Interrupt on INTO instruction
BRK instruction	FFFE416 to FFFE716	If the vector contains FF16, program execution starts from the address shown by the vector in the variable vector table
Address match	FFFE816 to FFFEB16	There is an address-matching interrupt enable bit
Single step (Note)	FFFEC16 to FFFEF16	Do not use
Watchdog timer	FFFF016 to FFFF316	
$\overline{\text{DBC}}$ (Note)	FFFF416 to FFFF716	Do not use
NMI	FFFF816 to FFFFB16	External interrupt by input to $\overline{\text{NMI}}$ pin
Reset	FFFFC16 to FFFFF16	

Note: Interrupts used for debugging purposes only.

• **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 18 shows the interrupts assigned to the variable vector tables and addresses of vector tables.

Table 18. 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)	BRK instruction	Cannot be masked I flag
Software interrupt number 10	+40 to +43 (Note)	Bus collision detection	
Software interrupt number 11	+44 to +47 (Note)	DMA0	
Software interrupt number 12	+48 to +51 (Note)	DMA1	
Software interrupt number 13	+52 to +55 (Note)	Key input interrupt	
Software interrupt number 14	+56 to +59 (Note)	A-D	
Software interrupt number 15	+60 to +63 (Note)	UART2 transmit	
Software interrupt number 16	+64 to +67 (Note)	UART2 receive	
Software interrupt number 17	+68 to +71 (Note)	UART0 transmit	
Software interrupt number 18	+72 to +75 (Note)	UART0 receive	
Software interrupt number 19	+76 to +79 (Note)	UART1 transmit	
Software interrupt number 20	+80 to +83 (Note)	UART1 receive	
Software interrupt number 21	+84 to +87 (Note)	Timer A0	
Software interrupt number 22	+88 to +91 (Note)	Timer A1	
Software interrupt number 23	+92 to +95 (Note)	Timer A2	
Software interrupt number 24	+96 to +99 (Note)	Timer A3	
Software interrupt number 25	+100 to +103 (Note)	Timer A4	
Software interrupt number 26	+104 to +107 (Note)	Timer B0	
Software interrupt number 27	+108 to +111 (Note)	Timer B1	
Software interrupt number 28	+112 to +115 (Note)	Timer B2	
Software interrupt number 29	+116 to +119 (Note)	$\overline{\text{INT0}}$	
Software interrupt number 30	+120 to +123 (Note)	$\overline{\text{INT1}}$	
Software interrupt number 31	+124 to +127 (Note)	$\overline{\text{INT2}}$	
Software interrupt number 32 to Software interrupt number 63	+128 to +131 (Note) to +252 to +255 (Note)	Software interrupt	Cannot be masked I flag

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

Interrupt Control

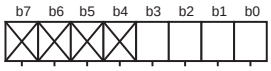
Descriptions are given here regarding how to enable or disable maskable interrupts and how to set the priority to be accepted. What is described here does not apply to non-maskable interrupts.

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 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 29 shows the memory map of the interrupt control registers.

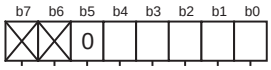
Interrupt control register

Symbol	Address	When reset
BCNIC	004A16	XXXXX0002
DMiIC(i=0, 1)	004B16, 004C16	XXXXX0002
KUPIC	004D16	XXXXX0002
ADIC	004E16	XXXXX0002
SiTIC(i=0 to 2)	005116, 005316, 004F16	XXXXX0002
SiRIC(i=0 to 2)	005216, 005416, 005016	XXXXX0002
TAiIC(i=0 to 4)	005516 to 005916	XXXXX0002
TBiIC(i=0 to 2)	005A16 to 005C16	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 dose not generate the interrupt request for that register. For details, see the precautions for interrupts.



Symbol	Address	When reset
INTiIC(i=0 to 2)	005D16 to 005F16	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		Always 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 dose not generate the interrupt request for that register. For details, see the precautions for interrupts.

Figure 29. 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.
Table19 shows the settings of interrupt priority levels and Table 20 shows the interrupt levels enabled, according to the consist 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 19. Settings of interrupt priority levels

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

Table 20. Interrupt levels enabled according to the contents of the IPL

IPL (IPL_2 IPL_1 IPL_0)	Enabled interrupt priority levels
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 00000_{16}.
(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 1) 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 30 shows the interrupt response time.

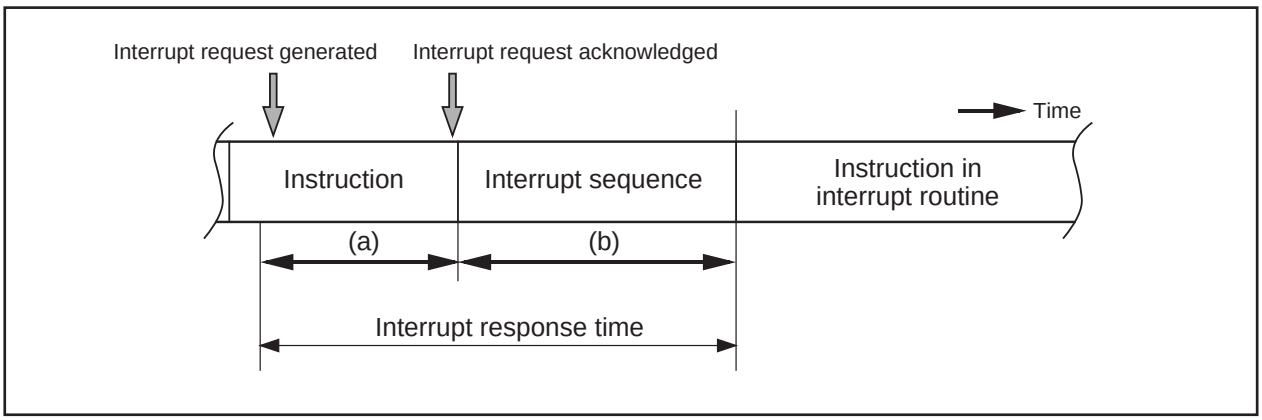


Figure 30. Interrupt response time

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 21.

Table 21. 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 coincidence interrupt or of a single-step interrupt.

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

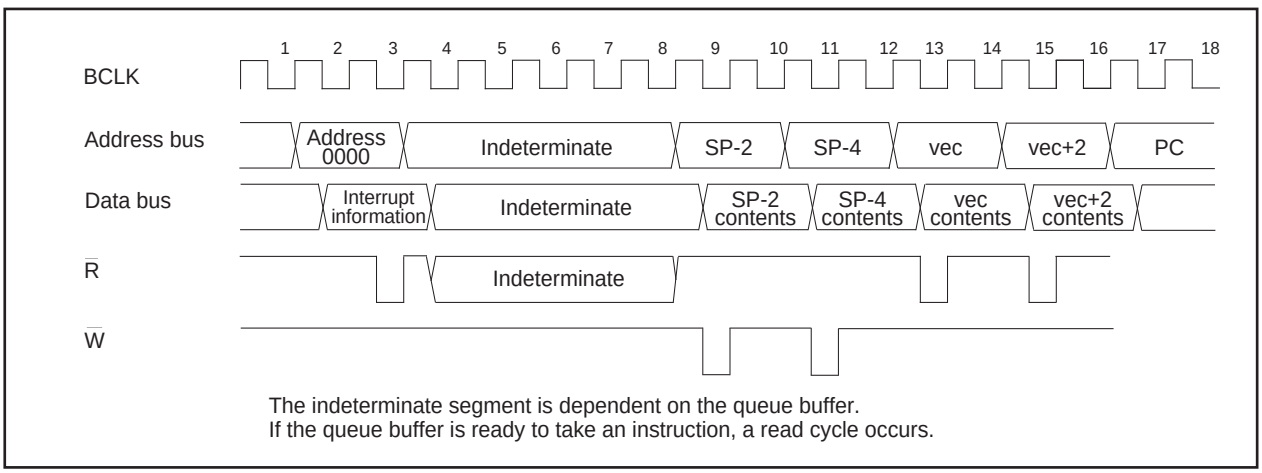


Figure 31. Time required for executing the interrupt sequence

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 22 is set in the IPL.

Table 22. Relationship between interrupts without interrupt priority levels and IPL

Interrupt sources without priority levels	Value set in the IPL
Watchdog timer, $\overline{\text{NMI}}$	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 32 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).

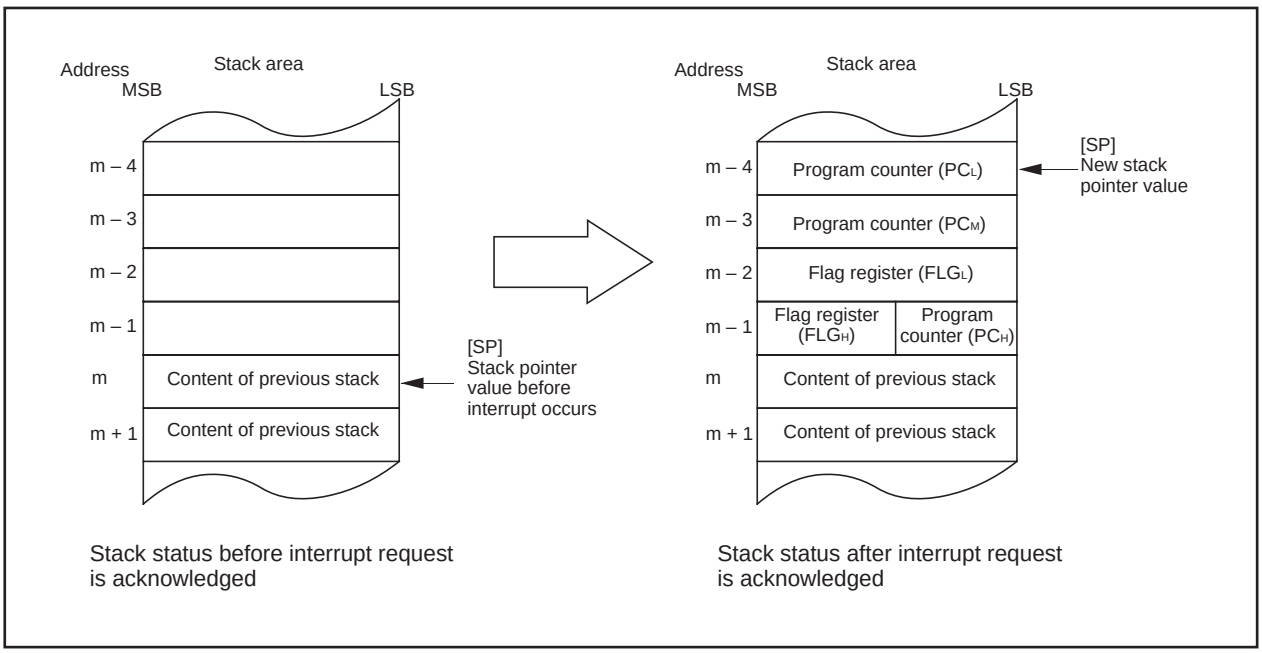
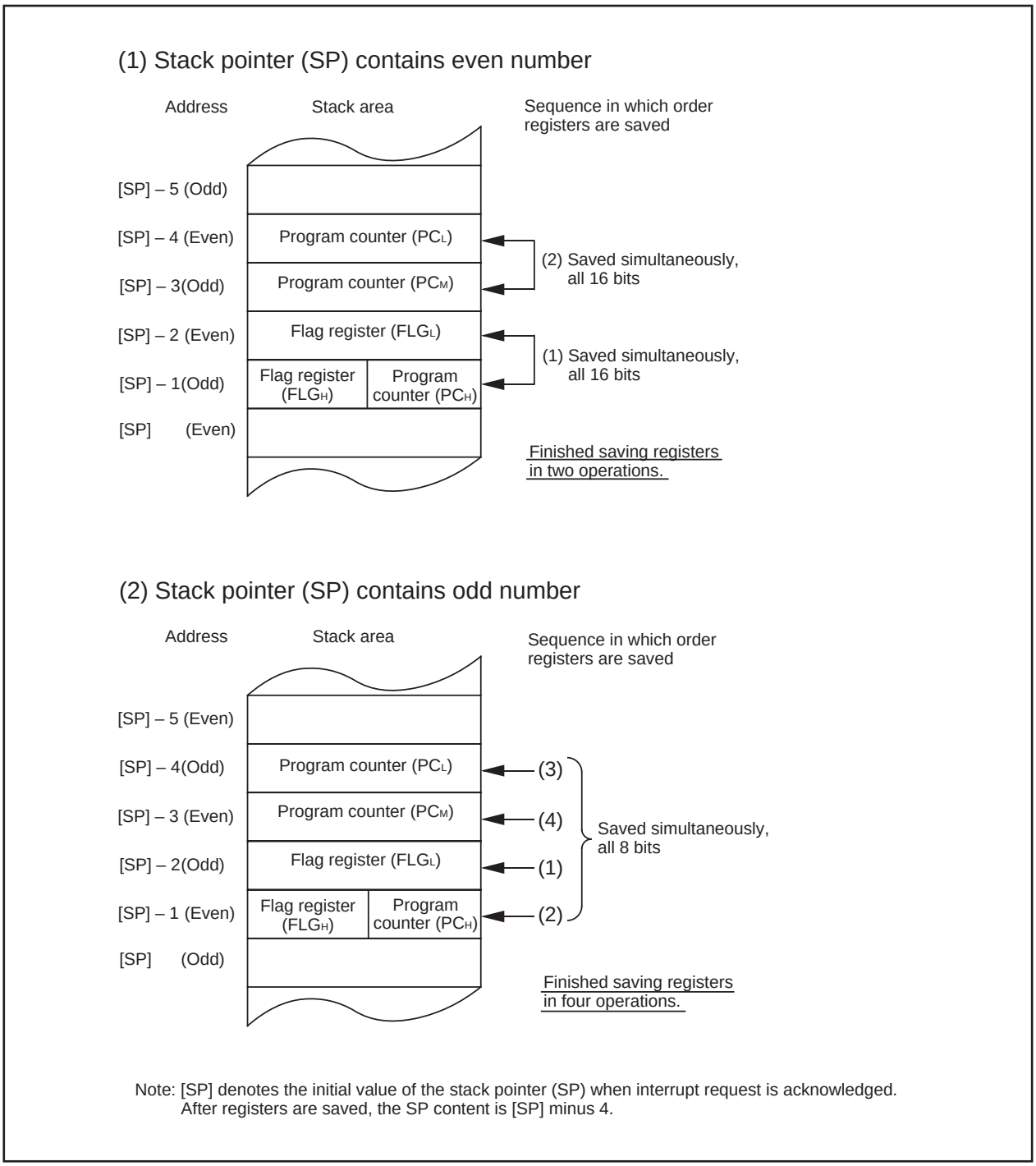


Figure 32. State of stack before and after acceptance of interrupt request

The operation of saving registers carried out in the interrupt sequence is dependent on whether the content of the stack pointer, 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 33 shows the operation of the saving registers.

Note: Stack pointer indicated by U flag.



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 33. 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 34 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 34. 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 35 shows the circuit that judges the interrupt priority level.

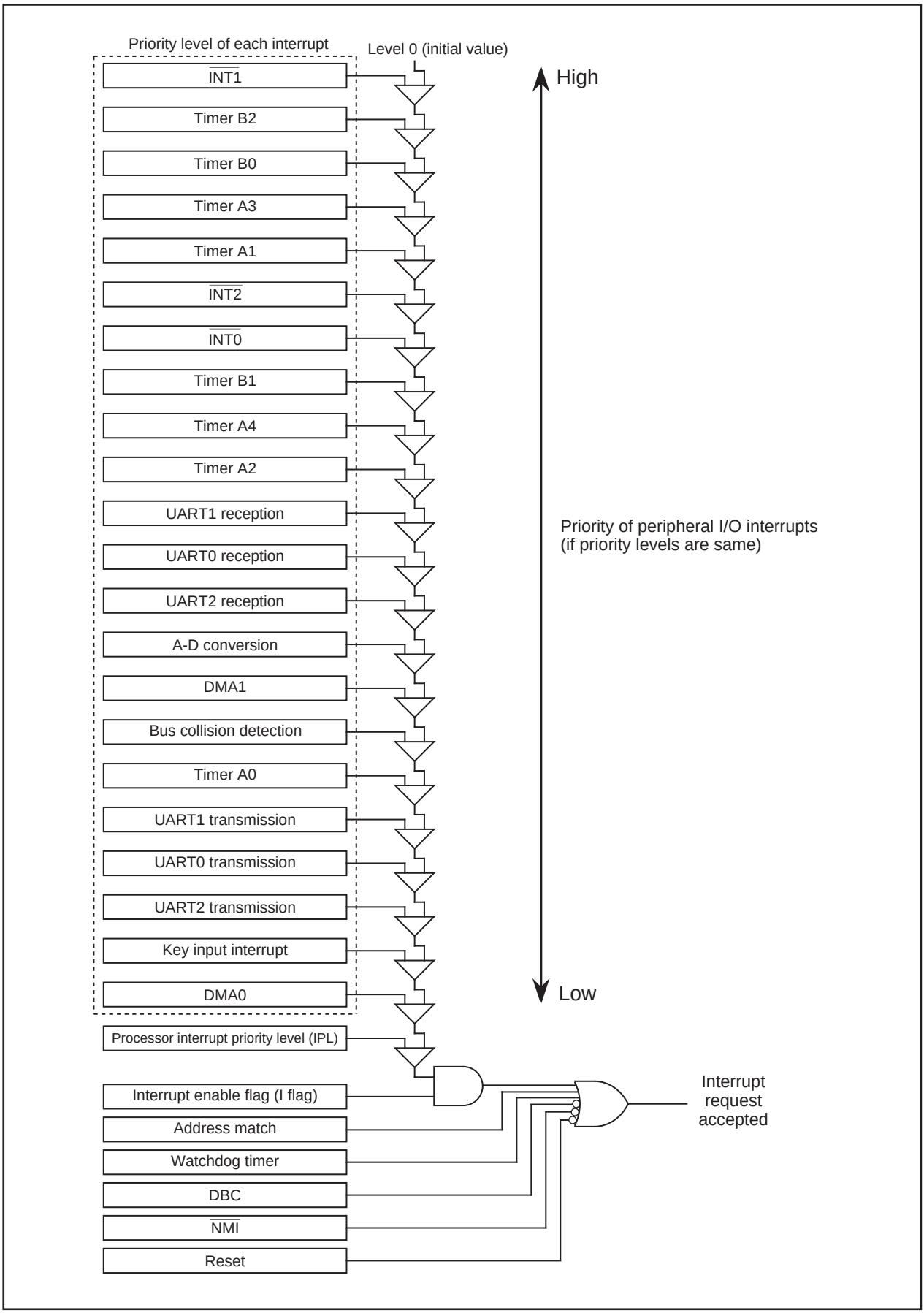


Figure 35. Maskable interrupts priorities (peripheral I/O interrupts)

INT Interrupt

INT0 to INT2 are triggered by the edges of external inputs. The edge polarity is selected using the polarity select bit.

NMI Interrupt

An NMI interrupt is generated when the input to the P85/NMI pin changes from “H” to “L”. The 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 36 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.

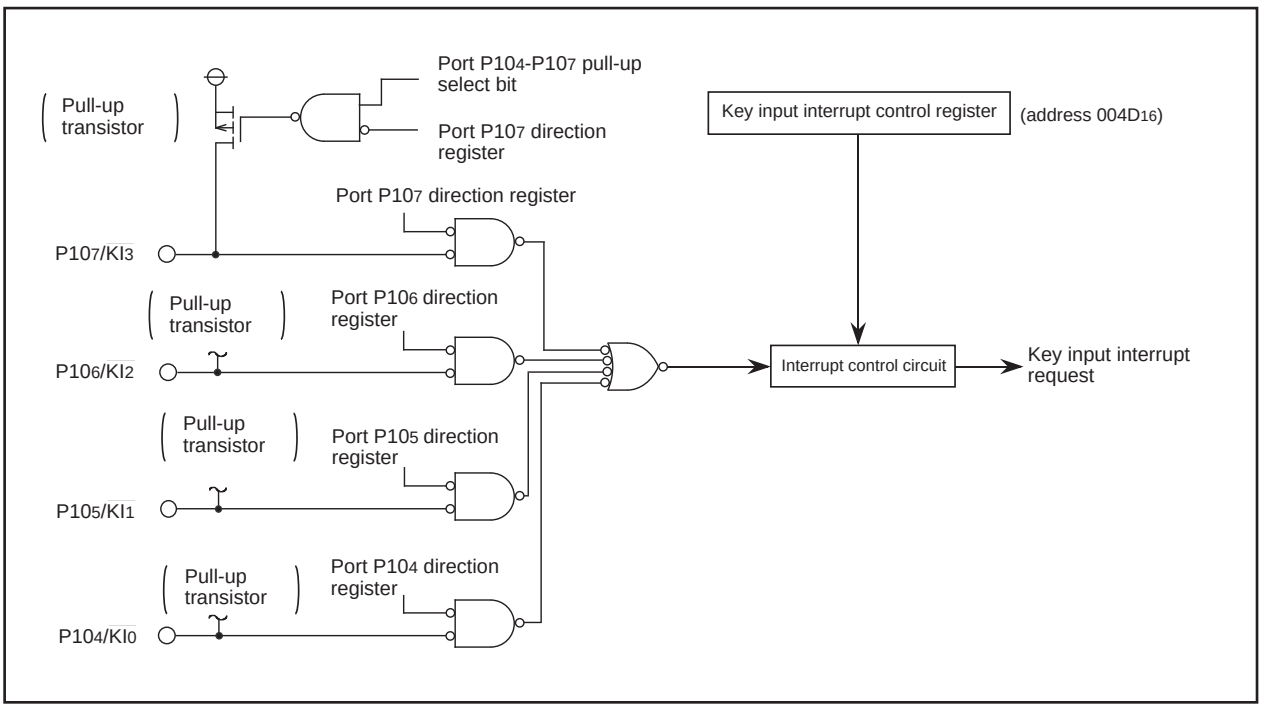


Figure 36. Block diagram of key input interrupt

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). The value of the program counter (PC) for an address match interrupt varies depending on the instruction being executed.

Figure 37 shows the address match interrupt-related registers.

Address match interrupt enable register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	When reset
AIER	0009_{16}	$XXXXXX00_2$

Bit symbol	Bit name	Function	R	W
AIER0	Address match interrupt 0 enable bit	0 : Interrupt disabled 1 : Interrupt enabled	○	○
AIER1	Address match interrupt 1 enable bit	0 : Interrupt disabled 1 : Interrupt enabled	○	○
Nothing is assigned. In an attempt to write to these bits, write “0”. The value, if read, turns out to be indeterminated.			—	—

Address match interrupt register i (i = 0, 1)

(b23) b7 (b19) b3 (b16)(b15) b0 b7 (b8) b0 b7 b0

Symbol	Address	When reset
RMAD0	0012_{16} to 0010_{16}	$X00000_{16}$
RMAD1	0016_{16} to 0014_{16}	$X00000_{16}$

Function	Values that can be set	R	W
Address setting register for address match interrupt	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 indeterminated.		—	—

Figure 37. Address match interrupt-related registers

Precautions for Interrupts

(1) Reading address 00000$_{16}$

- When maskable interrupt is occurred, CPU read 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 00000$_{16}$ will then be set to “0”.
  Reading address 00000$_{16}$ by software sets enabled highest priority interrupt source request bit to “0”.
  Though the interrupt is generated, the interrupt routine may not be executed.
  Do not read address 00000$_{16}$ by software.

(2) Setting the stack pointer

- The value of the stack pointer immediately after reset is initialized to 0000$_{16}$. 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 point 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

- As for the $\overline{\text{NMI}}$ interrupt pin, an interrupt cannot be disabled. Connect it to the V_{CC} pin via a resistor (pull-up) if unused. Be sure to work on it.
- The $\overline{\text{NMI}}$ pin also serves as P8$_5$, 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 $\overline{\text{INT}_0}$ through $\overline{\text{INT}_2}$ regardless of the CPU operation clock.
- When the polarity of the $\overline{\text{INT}_0}$ to $\overline{\text{INT}_2}$ pins is changed, the interrupt request bit is sometimes set to "1". After changing the polarity, set the interrupt request bit to "0". Figure 38 shows the procedure for changing the $\overline{\text{INT}}$ interrupt generate factor.

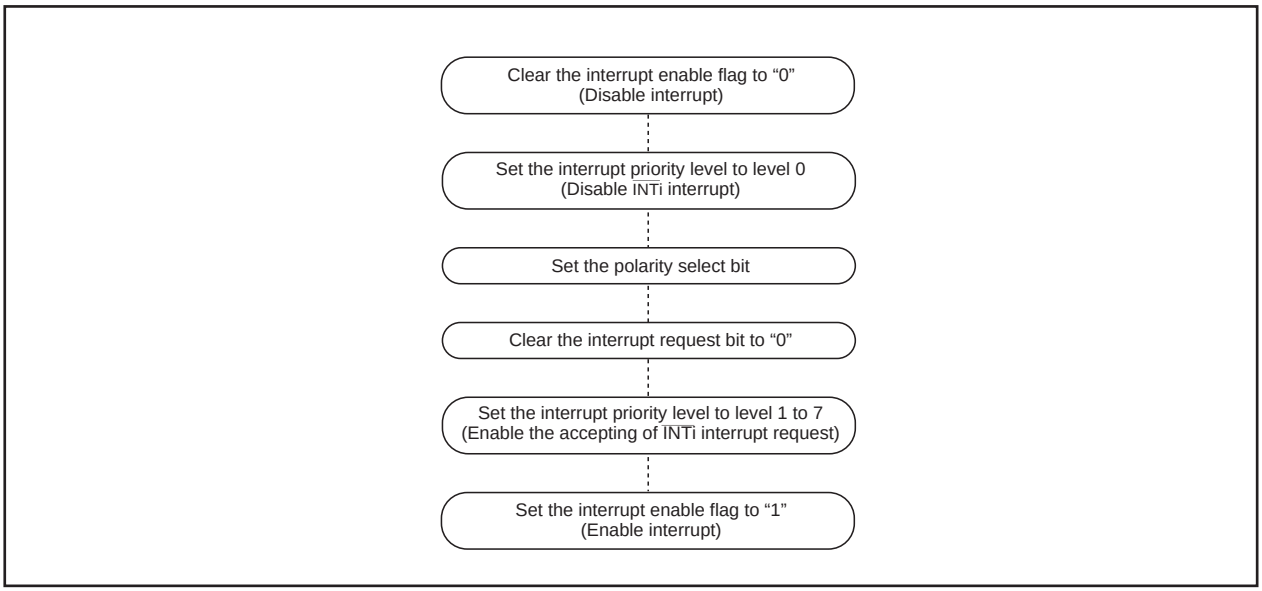


Figure 38. Switching condition of INT interrupt request

(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                    ; 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

Watchdog Timer

The watchdog timer has the function of detecting when the program is out of control. 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 XIN 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 XCIN 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 pre-scaler.

With XIN chosen for BCLK

$$\text{Watchdog timer period} = \frac{\text{pre-scaler dividing ratio (16 or 128) X watchdog timer count (32768)}}{\text{BCLK}}$$

With XCIN chosen for BCLK

$$\text{Watchdog timer period} = \frac{\text{pre-scaler dividing ratio (2) X watchdog timer count (32768)}}{\text{BCLK}}$$

For example, suppose that BCLK runs at 10 MHz and that 16 has been chosen for the dividing ratio of the pre-scaler, then the watchdog timer's period becomes approximately 52.4 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).
Figure 39 shows the block diagram of the watchdog timer. Figure 40 shows the watchdog timer-related registers.

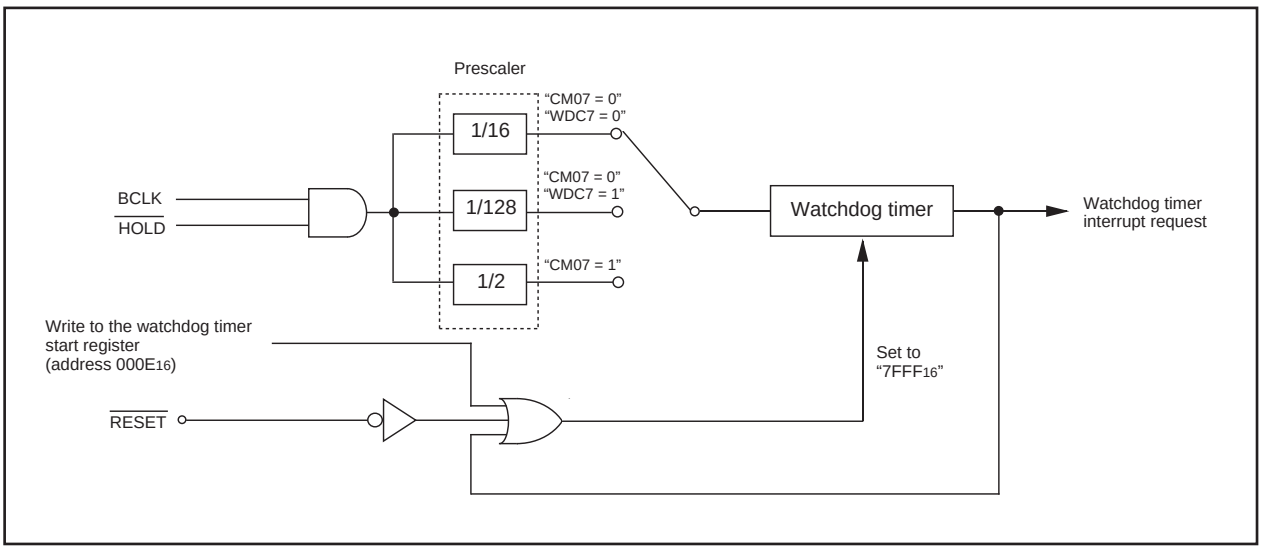


Figure 39. Block diagram of watchdog timer

Watchdog timer control register

b7	b6	b5	b4	b3	b2	b1	b0
	0	0					

Symbol: WDC
Address: 000F16
When reset: 000XXXXX2

Bit symbol	Bit name	Function	R	W
High-order bit of watchdog timer			○	×
Reserved bit		Must always be set to “0”	○	○
Reserved bit		Must always be set to “0”	○	○
WDC7	Prescaler select bit	0 : Divided by 16 1 : Divided by 128	○	○

Watchdog timer start register

b7	b0

Symbol: WDTS
Address: 000E16
When reset: Indeterminate

Function	R	W
The watchdog timer is initialized and starts counting after a write instruction to this register. The watchdog timer value is always initialized to “7FFF16” regardless of whatever value is written.	×	○

Figure 40. Watchdog timer control and start registers

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 41 shows the block diagram of the DMAC. Table 23 shows the DMAC specifications. Figure 42 to Figure 43 show the registers used by the DMAC.

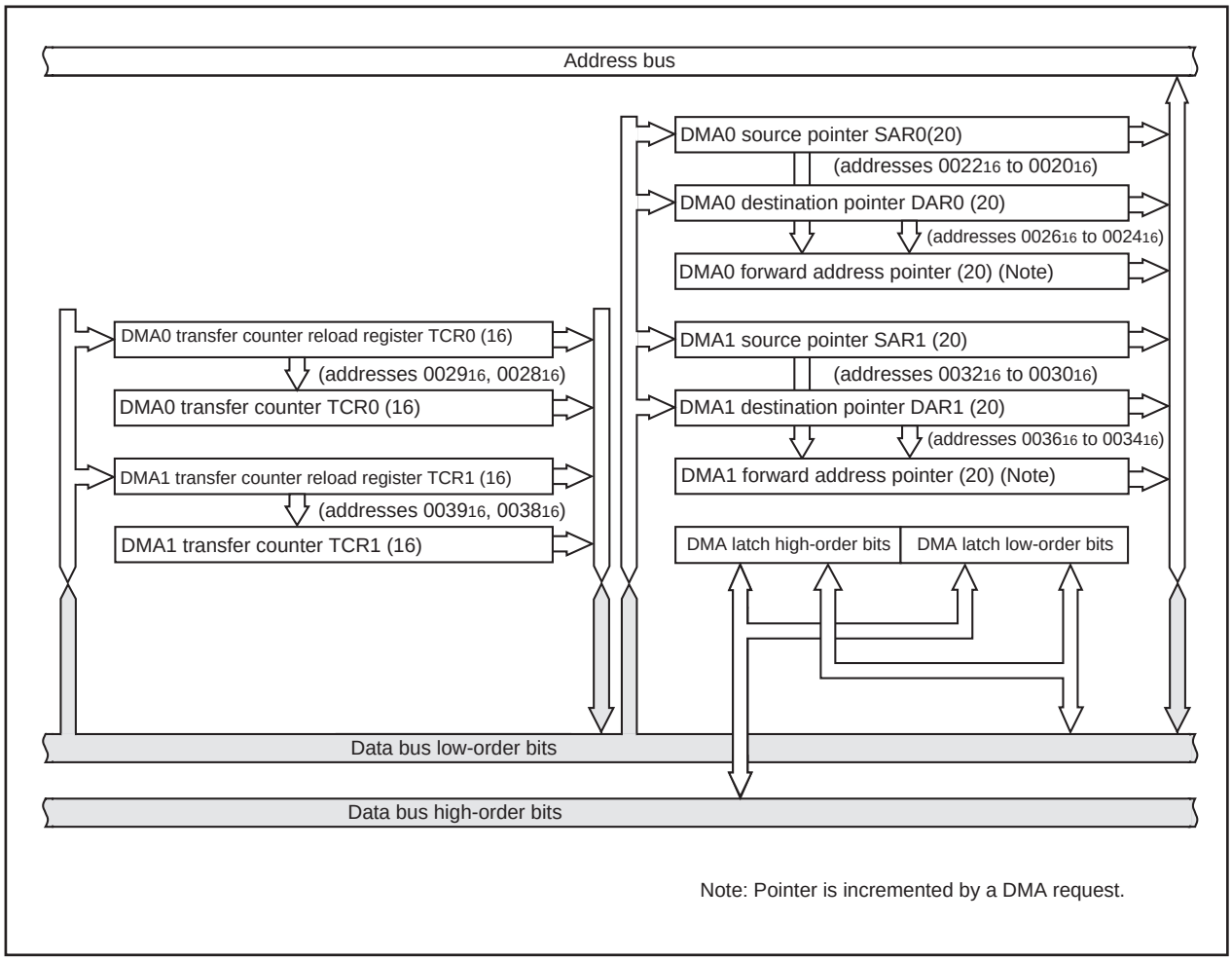


Figure 41. Block diagram of DMAC

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.

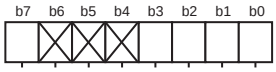
If the DMAC is active (the DMA enable bit is set to 1), data transfer starts every time a DMA transfer request signal occurs. If the cycle of the occurrences of DMA transfer request signals is higher than the DMA transfer cycle, there can be instances in which the number of transfer requests doesn't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

Table 23. 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 $\overline{INT0}$ or $\overline{INT1}$ ($\overline{INT0}$ can be selected by DMA0, $\overline{INT1}$ by DMA1) Timer A0 to timer A4 interrupt requests Timer B0 to timer B2 interrupt requests UART0 transmission and reception interrupt requests UART1 transmission and reception interrupt requests (UART1 transmission can be selected by DMA0, UART1 reception by DMA1) UART2 transmission and reception 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
Forward address pointer and load timing for transfer counter	At the time of starting data transfer immediately after turning the DMAC active, re 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.

DMAi request cause select register

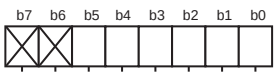


Symbol: DMiSL(i=0,1) | Address: $03B8_{16}$,$03BA_{16}$ | When reset: 00_{16}

Bit symbol	Bit name	Function	R	W
DSEL0	DMA request cause select bit	b3 b2 b1 b0 0 0 0 0 : Falling edge of $\overline{INT0}$ / $\overline{INT1}$ pin (Note 1) 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 0 1 1 0 : Timer A4 0 1 1 1 : Timer B0 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 transmit / UART1 receive (Note 2)	○	○
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”.			–	–
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”)	○	○

Note 1: Address $03B8_{16}$ is for $\overline{INT0}$; address $03BA_{16}$ is for $\overline{INT1}$.
Note 2: Address $03B8_{16}$ is for UART1 transmit ; address $03BA_{16}$ is for UART1 receive.

DMAi control register



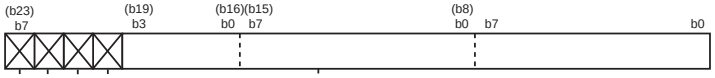
Symbol: DMiCON(i=0,1) | Address: $002C_{16}$, $003C_{16}$ | When reset: $00000X00_2$

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 42. DMAC register (1)

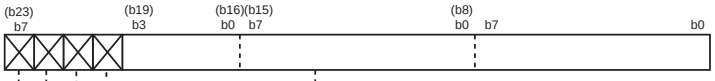
DMAi source pointer (i = 0, 1)



Symbol	Address	When reset
SAR0	0022_{16} to 0020_{16}	Indeterminate
SAR1	0032_{16} to 0030_{16}	Indeterminate

Function	Transfer count 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”.		–	–

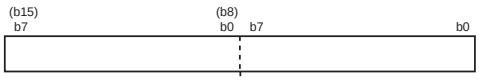
DMAi destination pointer (i = 0, 1)



Symbol	Address	When reset
DAR0	0026_{16} to 0024_{16}	Indeterminate
DAR1	0036_{16} to 0034_{16}	Indeterminate

Function	Transfer count 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	Address	When reset
TCR0	0029_{16}, 0028_{16}	Indeterminate
TCR1	0039_{16}, 0038_{16}	Indeterminate

Function	Transfer count specification	R	W
• Transfer counter Set a value one less than the transfer count	0000_{16} to $FFFF_{16}$	○	○

Figure 43. DMAC register (2)

(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

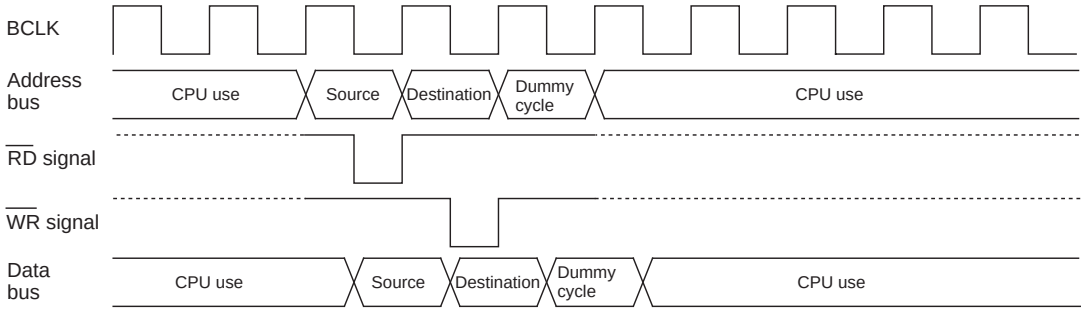
When transferring 16-bit data over an 8-bit data bus (BYTE pin = “H”) in memory expansion mode and microprocessor mode, the 16 bits of data are sent in two 8-bit blocks. Therefore, two bus cycles are required for reading the data and two are required for writing the data. Also, in contrast to when the 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

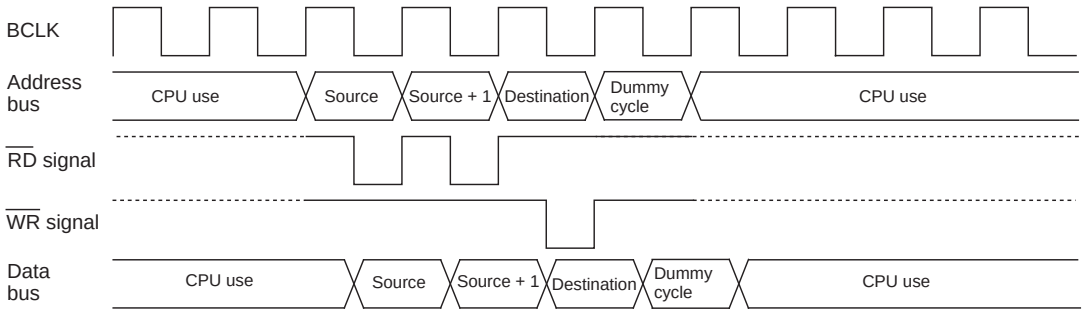
When the SFR area or a memory area with a software wait is accessed, the number of cycles is increased for the wait by 1 bus cycle. The length of the cycle is determined by BCLK.

Figure 44 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 36, 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.

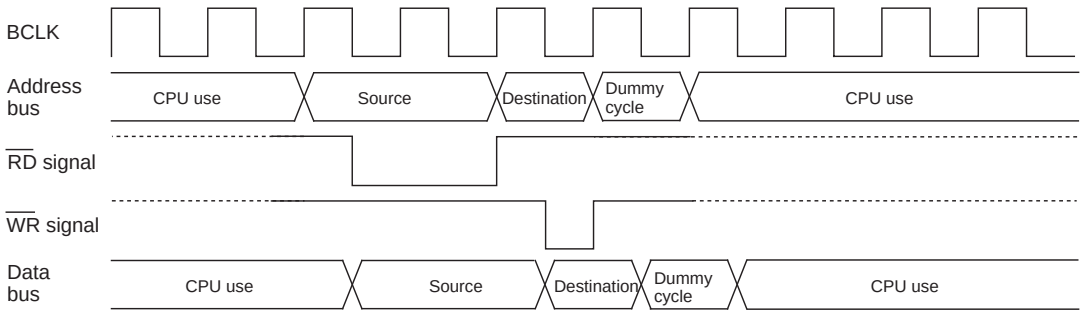
(1) 8-bit transfers
16-bit transfers from even address and the source address is even.



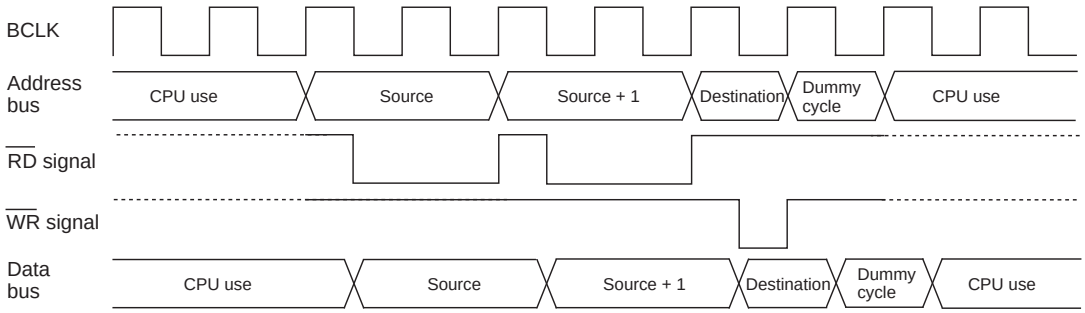
(2) 16-bit transfers and the source address is odd
Transferring 16-bit data on an 8-bit data bus (In this case, there are also two destination write cycles).



(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 write cycles).



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

Figure 44. Example of the transfer cycles for a source read

(2) DMAC transfer cycles

Any combination of even or odd transfer read and write addresses is possible. Table 24 shows the number of DMAC transfer cycles.

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

No. of transfer cycles per transfer unit = No. of read cycles x j + No. of write cycles x k

Table 24. 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 1 or to 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 1 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 INTi pin (i depends on which DMAC channel is used).

Selecting the INTi 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 INTi 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 45 An example of DMA transfer effected by external factors.

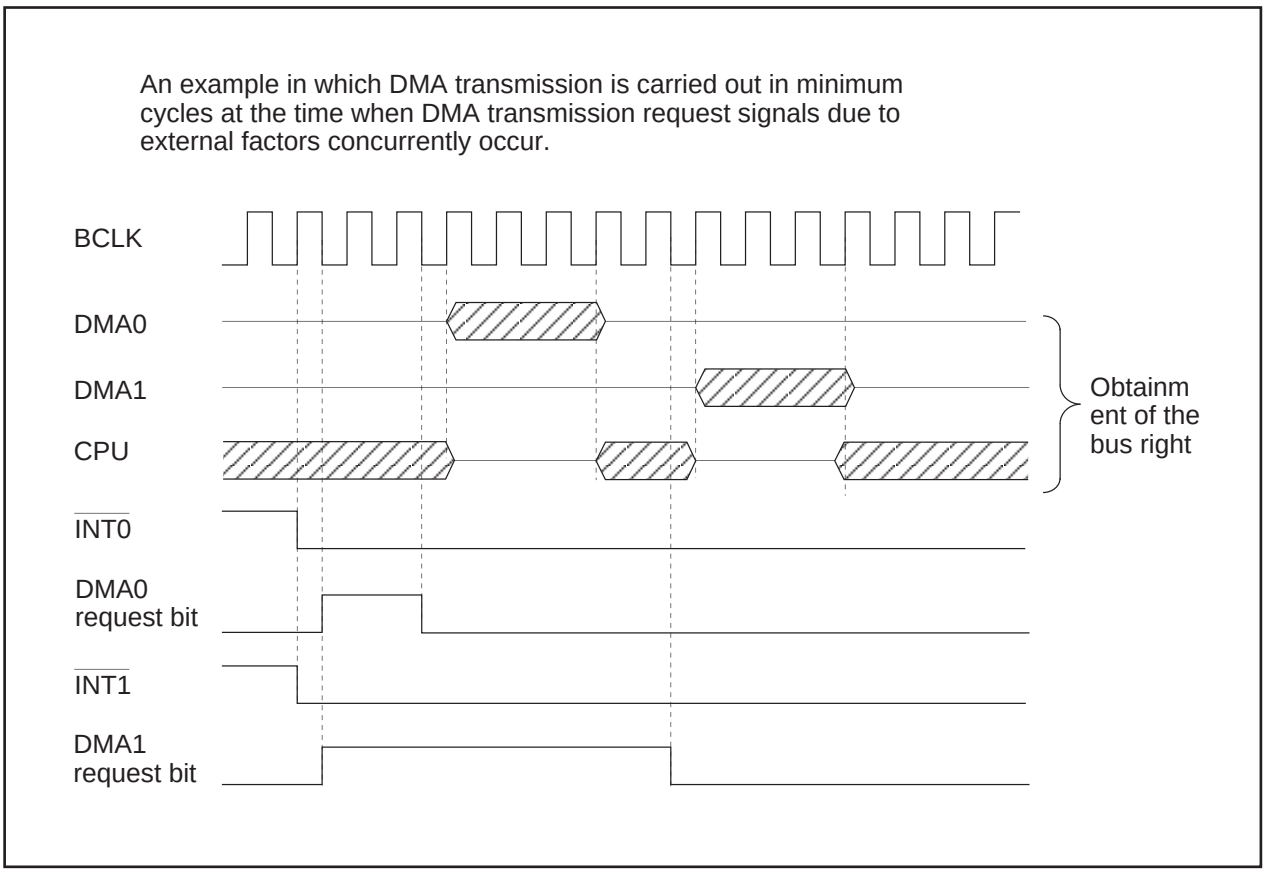


Figure 45. An example of DMA transfer effected by external factors

Timer

There are eight 16-bit timers. These timers can be classified by function into timers A (five) and timers B (three). All these timers function independently. Figure 46 shows the block diagram of timers.

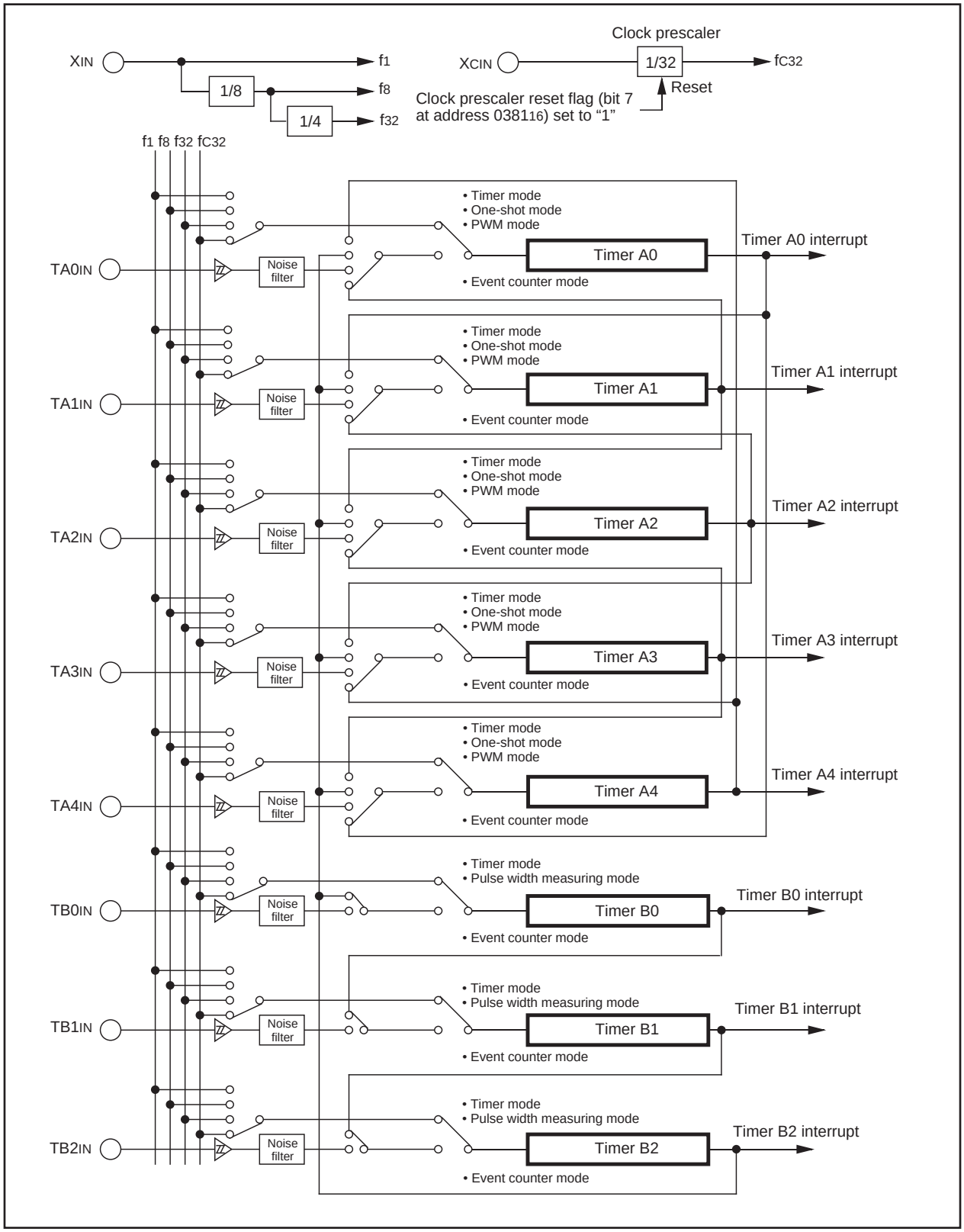


Figure 46. Block diagram of timer

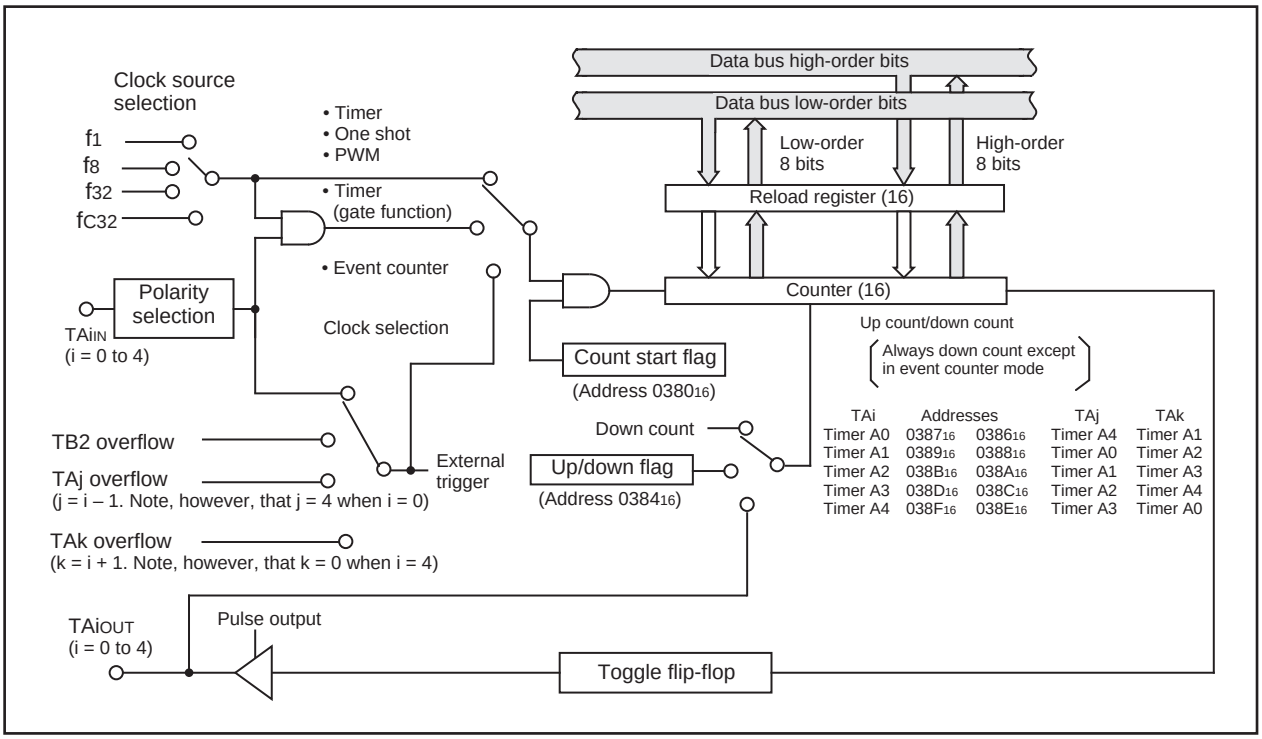
Timer A

Figure 47 shows the block diagram of timer A. Figures 48 to 50 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 "0000$_{16}$".
- Pulse width modulation (PWM) mode: The timer outputs pulses of a given width.



TAi	Addresses		TAj	TAk
Timer A0	0387$_{16}$	0386$_{16}$	Timer A4	Timer A1
Timer A1	0389$_{16}$	0388$_{16}$	Timer A0	Timer A2
Timer A2	038B$_{16}$	038A$_{16}$	Timer A1	Timer A3
Timer A3	038D$_{16}$	038C$_{16}$	Timer A2	Timer A4
Timer A4	038F$_{16}$	038E$_{16}$	Timer A3	Timer A0

Figure 47. Block diagram of timer A

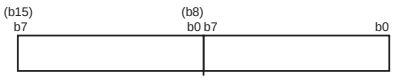
Timer Ai mode register

Symbol	Address	When reset
TAiMR(i=0 to 4)	0396$_{16}$ to 039A$_{16}$	00$_{16}$

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 0 0 : Timer mode 0 1 : Event counter mode 1 0 : One-shot timer mode 1 1 : Pulse width modulation (PWM) mode	○	○
TMOD1			○	○
MR0	Function varies with each operation mode		○	○
MR1			○	○
MR2			○	○
MR3			○	○
TCK0	Count source select bit (Function varies with each operation mode)		○	○
TCK1			○	○

Figure 48. Timer A-related registers (1)

Timer Ai register (Note)

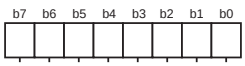


Symbol	Address	When reset
TA0	0387$_{16}$,0386$_{16}$	Indeterminate
TA1	0389$_{16}$,0388$_{16}$	Indeterminate
TA2	038B$_{16}$,038A$_{16}$	Indeterminate
TA3	038D$_{16}$,038C$_{16}$	Indeterminate
TA4	038F$_{16}$,038E$_{16}$	Indeterminate

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$_{16}$	×	○
• Pulse width modulation mode (16-bit PWM) Functions as a 16-bit pulse width modulator	0000$_{16}$ to FFFE$_{16}$	×	○
• 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$_{16}$ (Both high-order and low-order addresses)	×	○

Note: Read and write data in 16-bit units.

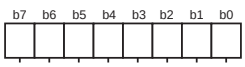
Count start flag



Symbol	Address	When reset
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		○	○

Up/down flag

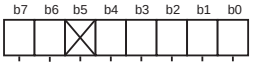


Symbol	Address	When reset
UDF	0384$_{16}$	00$_{16}$

Bit symbol	Bit name	Function	R	W
TA0UD	Timer A0 up/down flag	0 : Down count 1 : Up count This specification becomes valid when the up/down flag content is selected for up/down switching cause	○	○
TA1UD	Timer A1 up/down flag		○	○
TA2UD	Timer A2 up/down flag		○	○
TA3UD	Timer A3 up/down flag		○	○
TA4UD	Timer A4 up/down flag		○	○
TA2P	Timer A2 two-phase pulse signal processing select bit	0 : two-phase pulse signal processing disabled 1 : two-phase pulse signal processing enabled When not using the two-phase pulse signal processing function, set the select bit to “0”	×	○
TA3P	Timer A3 two-phase pulse signal processing select bit		×	○
TA4P	Timer A4 two-phase pulse signal processing select bit		×	○

Figure 49. Timer A-related registers (2)

One-shot start flag

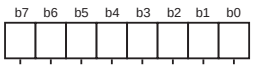


Symbol	Address	When reset
ONSF	0382_{16}	$00X00000_2$

Bit symbol	Bit name	Function	R	W
TA0OS	Timer A0 one-shot start flag	1 : Timer start When read, the value is “0”	○	○
TA1OS	Timer A1 one-shot start flag		○	○
TA2OS	Timer A2 one-shot start flag		○	○
TA3OS	Timer A3 one-shot start flag		○	○
TA4OS	Timer A4 one-shot start flag		○	○
Nothing is assigned. In an attempt to write to this bit, write “0”. The value, if read, turns out to be indeterminate.			—	—
TA0TGL	Timer A0 event/trigger select bit	b7 b6 0 0 : Input on $TA0_{IN}$ is selected (Note) 0 1 : TB2 overflow is selected 1 0 : TA4 overflow is selected 1 1 : TA1 overflow is selected	○	○
TA0TGH			○	○

Note: Set the corresponding port direction register to “0”.

Trigger select register

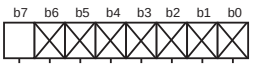


Symbol	Address	When reset
TRGSR	0383_{16}	00_{16}

Bit symbol	Bit name	Function	R	W
TA1TGL	Timer A1 event/trigger select bit	b1 b0 0 0 : Input on $TA1_{IN}$ is selected (Note) 0 1 : TB2 overflow is selected 1 0 : TA0 overflow is selected 1 1 : TA2 overflow is selected	○	○
TA1TGH			○	○
TA2TGL	Timer A2 event/trigger select bit	b3 b2 0 0 : Input on $TA2_{IN}$ is selected (Note) 0 1 : TB2 overflow is selected 1 0 : TA1 overflow is selected 1 1 : TA3 overflow is selected	○	○
TA2TGH			○	○
TA3TGL	Timer A3 event/trigger select bit	b5 b4 0 0 : Input on $TA3_{IN}$ is selected (Note) 0 1 : TB2 overflow is selected 1 0 : TA2 overflow is selected 1 1 : TA4 overflow is selected	○	○
TA3TGH			○	○
TA4TGL	Timer A4 event/trigger select bit	b7 b6 0 0 : Input on $TA4_{IN}$ is selected (Note) 0 1 : TB2 overflow is selected 1 0 : TA3 overflow is selected 1 1 : TA0 overflow is selected	○	○
TA4TGH			○	○

Note: Set the corresponding port direction register to “0”.

Clock prescaler reset flag



Symbol	Address	When reset
CPSRF	0381_{16}	$0XXXXXXX_2$

Bit symbol	Bit name	Function	R	W
Nothing is assigned. In an attempt to write to these bits, write “0”. The value, if read, turns out to be indeterminate.			—	—
CPSR	Clock prescaler reset flag	0 : No effect 1 : Prescaler is reset (When read, the value is “0”)	○	○

Figure 50. Timer A-related registers (3)

(1) Timer mode

In this mode, the timer counts an internally generated count source. (See Table 25.) Figure 51 shows the timer Ai mode register in timer mode.

Table 25. 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

Timer Ai mode register

b7	b6	b5	b4	b3	b2	b1	b0
		0				0	0

Symbol: TAiMR(i=0 to 4) Address: 039_{16} to $039A_{16}$ When reset: 00_{16}

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 0 0 : Timer mode	○	○
TMOD1			○	○
MR0	Pulse output function select bit	0 : Pulse is not output (TAiOUT pin is a normal port pin) 1 : Pulse is output (Note 1) (TAiOUT pin is a pulse output pin)	○	○
MR1	Gate function select bit	b4 b3 0 X (Note 2): Gate function not available (TAiIN pin is a normal port pin) 1 0 : Timer counts only when TAiIN pin is held "L" (Note 3) 1 1 : Timer counts only when TAiIN pin is held "H" (Note 3)	○	○
MR2			○	○
MR3	0 (Must always be fixed to "0" in timer mode)		○	○
TCK0	Count source select bit	b7 b6 0 0 : f_1 0 1 : f_8 1 0 : f_{32} 1 1 : f_{C32}	○	○
TCK1			○	○

Note 1: The settings of the corresponding port register and port direction register are invalid.
Note 2: The bit can be "0" or "1".
Note 3: Set the corresponding port direction register to "0".

Figure 51. Timer Ai mode register in timer mode

(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 26 lists timer specifications when counting a single-phase external signal. Figure 52 shows the timer Ai mode register in event counter mode.

Table 27 lists timer specifications when counting a two-phase external signal. Figure 53 shows the timer Ai mode register in event counter mode.

Table 26. Timer specifications in event counter mode (when not processing two-phase pulse signal)

Item	Specification
Count source	• External signals input to TAiIN 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
TAiIN 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.

Timer Ai mode register

b7	b6	b5	b4	b3	b2	b1	b0
		0				0	1

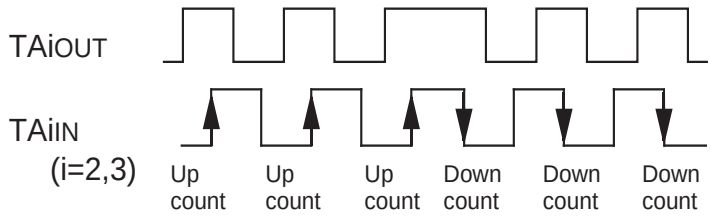
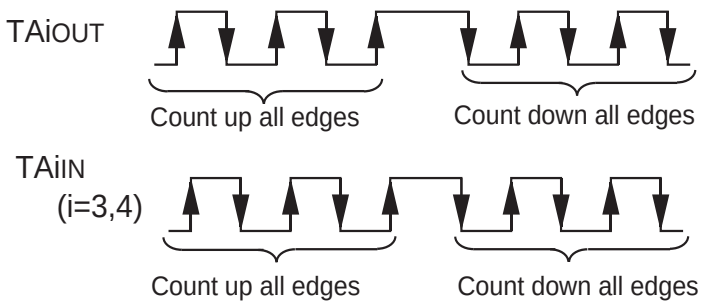
Symbol: TAiMR(i = 0, 1) Address: 039_{16}, 039_{16} When reset: 00_{16}

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 0 1 : Event counter mode (Note 1)	○	○
TMOD1			○	○
MR0	Pulse output function select bit	0 : Pulse is not output (TAiOUT pin is a normal port pin) 1 : Pulse is output (Note 2) (TAiOUT pin is a pulse output pin)	○	○
MR1	Count polarity select bit (Note 3)	0 : Counts external signal's falling edge 1 : Counts external signal's rising edge	○	○
MR2	Up/down switching cause select bit	0 : Up/down flag's content 1 : TAiOUT pin's input signal (Note 4)	○	○
MR3	0 (Must always be fixed to "0" in event counter mode)		○	○
TCK0	Count operation type select bit	0 : Reload type 1 : Free-run type	○	○
TCK1	Invalid in event counter mode Can be "0" or "1"		○	○

Note 1: In event counter mode, the count source is selected by the event / trigger select bit (addresses 0382_{16} and 0383_{16}).
Note 2: The settings of the corresponding port register and port direction register are invalid.
Note 3: Valid only when counting an external signal.
Note 4: When an "L" signal is input to the TAiOUT pin, the downcount is activated. When "H", the upcount is activated. Set the corresponding port direction register to "0".

Figure 52. Timer Ai mode register in event counter mode

Table 27. 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)
Divide ratio	1/ (FFFF16 - 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
TAiOUT pin function	Two-phase pulse input
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	• Normal processing operation 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 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: This does not apply when the free-run function is selected.

Timer Ai mode register
(When not using two-phase pulse signal processing)

b7	b6	b5	b4	b3	b2	b1	b0
		0				0	1

Symbol: TAiMR(i = 2 to 4) — Address: 039816 to 039A16 — When reset: 0016

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 0 1 : Event counter mode	○	○
TMOD1			○	○
MR0	Pulse output function select bit	0 : Pulse is not output (TAiOUT pin is a normal port pin) 1 : Pulse is output (Note 1) (TAiOUT pin is a pulse output pin)	○	○
MR1	Count polarity select bit (Note 2)	0 : Counts external signal's falling edges 1 : Counts external signal's rising edges	○	○
MR2	Up/down switching cause select bit	0 : Up/down flag's content 1 : TAiOUT pin's input signal (Note 3)	○	○
MR3	0 : (Must always be “0” in event counter mode)		○	○
TCK0	Count operation type select bit	0 : Reload type 1 : Free-run type	○	○
TCK1	Two-phase pulse signal processing operation select bit (Note 4)(Note 5)	0 : Normal processing operation 1 : Multiply-by-4 processing operation	○	○

Note 1: The settings of the corresponding port register and port direction register are invalid.
Note 2: This bit is valid when only counting an external signal.
Note 3: Set the corresponding port direction register to “0”.
Note 4: This bit is valid for the timer A3 mode register.
For timer A2 and A4 mode registers, this bit can be “0 ”or “1”.
Note 5: When performing two-phase pulse signal processing, make sure the two-phase pulse signal processing operation select bit (address 038416) is set to “1”. Also, always be sure to set the event/trigger select bit (addresses 038216 and 038316) to “00”.

Timer Ai mode register
(When using two-phase pulse signal processing)

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

Symbol: TAiMR(i = 2 to 4) — Address: 039816 to 039A16 — When reset: 0016

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 0 1 : Event counter mode	○	○
TMOD1			○	○
MR0	0 (Must always be “0” when using two-phase pulse signal processing)		○	○
MR1	0 (Must always be “0” when using two-phase pulse signal processing)		○	○
MR2	1 (Must always be “1” when using two-phase pulse signal processing)		○	○
MR3	0 (Must always be “0” when using two-phase pulse signal processing)		○	○
TCK0	Count operation type select bit	0 : Reload type 1 : Free-run type	○	○
TCK1	Two-phase pulse processing operation select bit (Note 1)(Note 2)	0 : Normal processing operation 1 : Multiply-by-4 processing operation	○	○

Note 1: This bit is valid for timer A3 mode register.
For timer A2 and A4 mode registers, this bit can be “0” or “1”.
Note 2: When performing two-phase pulse signal processing, make sure the two-phase pulse signal processing operation select bit (address 038416) is set to “1”. Also, always be sure to set the event/trigger select bit (addresses 038216 and 038316) to “00”.

Figure 53. Timer Ai mode register in event counter mode

(3) One-shot timer mode

In this mode, the timer operates only once. (See Table 28.) When a trigger occurs, the timer starts up and continues operating for a given period. Figure 54 shows the timer Ai mode register in one-shot timer mode.

Table 28. 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 0000_{16}, 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 0000_{16} • The count start flag is reset (= 0)
Interrupt request generation timing	The count reaches 0000_{16}
TAi_{IN} pin function	Programmable I/O port or trigger input
TAi_{OUT} 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)

Timer Ai mode register

b7	b6	b5	b4	b3	b2	b1	b0
		0				1	0

Symbol: TAiMR(i = 0 to 4) Address: 0396_{16} to $039A_{16}$ When reset: 00_{16}

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 1 0 : One-shot timer mode	○	○
TMOD1			○	○
MR0	Pulse output function select bit	0 : Pulse is not output (TAi_{OUT} pin is a normal port pin) 1 : Pulse is output (Note 1) (TAi_{OUT} pin is a pulse output pin)	○	○
MR1	External trigger select bit (Note 2)	0 : Falling edge of TAi_{IN} pin's input signal (Note 3) 1 : Rising edge of TAi_{IN} pin's input signal (Note 3)	○	○
MR2	Trigger select bit	0 : One-shot start flag is valid 1 : Selected by event/trigger select register	○	○
MR3	0 (Must always be "0" in one-shot timer mode)		○	○
TCK0	Count source select bit	b7 b6 0 0 : f_1 0 1 : f_8 1 0 : f_{32} 1 1 : f_{C32}	○	○
TCK1			○	○

Note 1: The settings of the corresponding port register and port direction register are invalid.
Note 2: Valid only when the TAi_{IN} pin is selected by the event/trigger select bit (addresses 0382_{16} and 0383_{16}). If timer overflow is selected, this bit can be "1" or "0".
Note 3: Set the corresponding port direction register to "0".

Figure 54. Timer Ai mode register in one-shot timer mode

(4) Pulse width modulation (PWM) mode

In this mode, the timer outputs pulses of a given width in succession. (See Table 29.) In this mode, the counter functions as either a 16-bit pulse width modulator or an 8-bit pulse width modulator. Figure 55 shows the configuration of the timer Ai mode register in pulse width modulation mode. Figure 56 shows an example of how a 16-bit pulse width modulator operates. Figure 57 shows an example of how an 8-bit pulse width modulator operates.

Table 29. 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 / fi n : Set value • Cycle time $(2^{16} - 1)$ / fi fixed
8-bit PWM	• High level width n X (m+1) / fi n : values set to timer Ai register's high-order address • Cycle time $(2^8 - 1)$ X (m +1) / fi 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)

Timer Ai mode register

b7	b6	b5	b4	b3	b2	b1	b0
					1	1	1

Symbol	Address	When reset
TAiMR(i=0 to 4)	0396_{16} to $039A_{16}$	00_{16}

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 1 1 : PWM mode	○	○
TMOD1			○	○
MR0	1 (Must always be fixed to "1" in PWM mode)		○	○
MR1	External trigger select bit (Note 1)	0: Falling edge of TAiIN pin's input signal (Note 2) 1: Rising edge of TAiIN pin's input signal (Note 2)	○	○
MR2	Trigger select bit	0: Count start flag is valid 1: Selected by event/trigger select register	○	○
MR3	16/8-bit PWM mode select bit	0: Functions as a 16-bit pulse width modulator 1: Functions as an 8-bit pulse width modulator	○	○
TCK0	Count source select bit	b7 b6 0 0 : f_1 0 1 : f_8 1 0 : f_{32} 1 1 : f_{C32}	○	○
TCK1			○	○

Note 1: Valid only when the TAiIN pin is selected by the event/trigger select bit (addresses 0382_{16} and 0383_{16}). If timer overflow is selected, this bit can be "1" or "0
Note 2: Set the corresponding port direction register to "0".

Figure 55. Configuration of timer Ai mode register in pulse width modulation mode

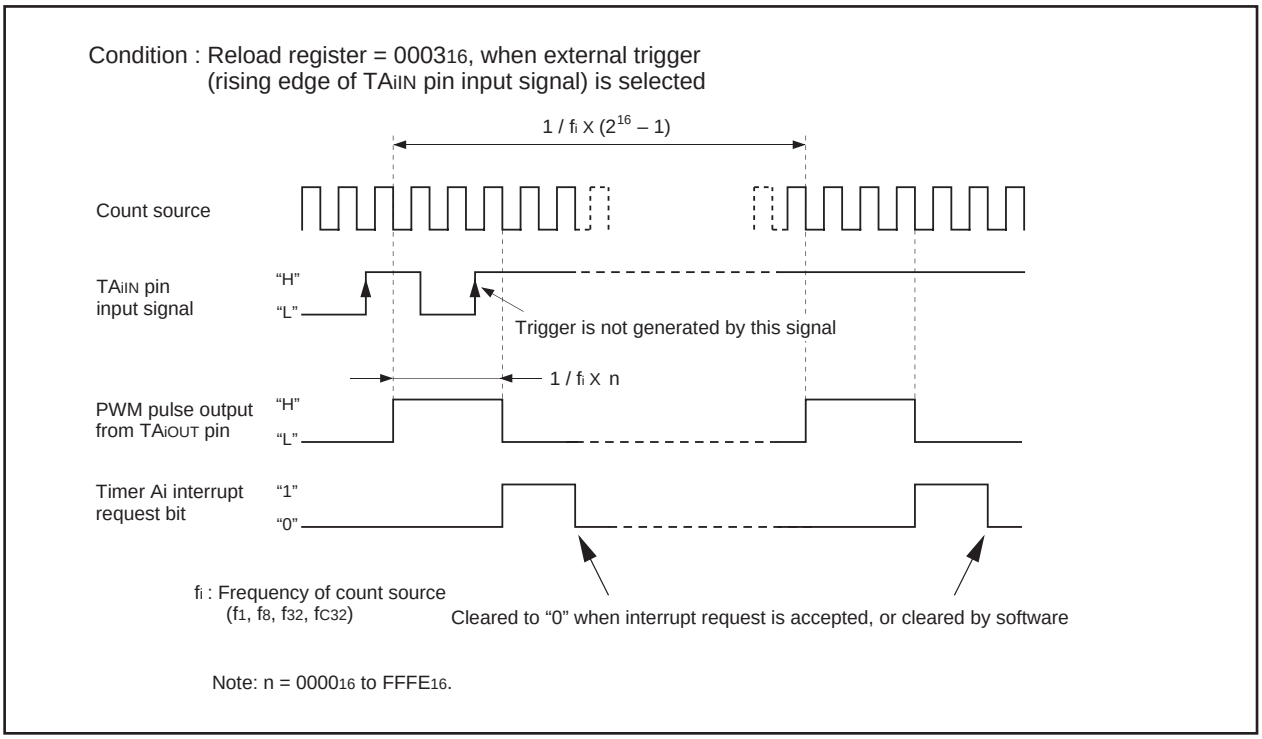


Figure 56. Example of how a 16-bit pulse width modulator operates

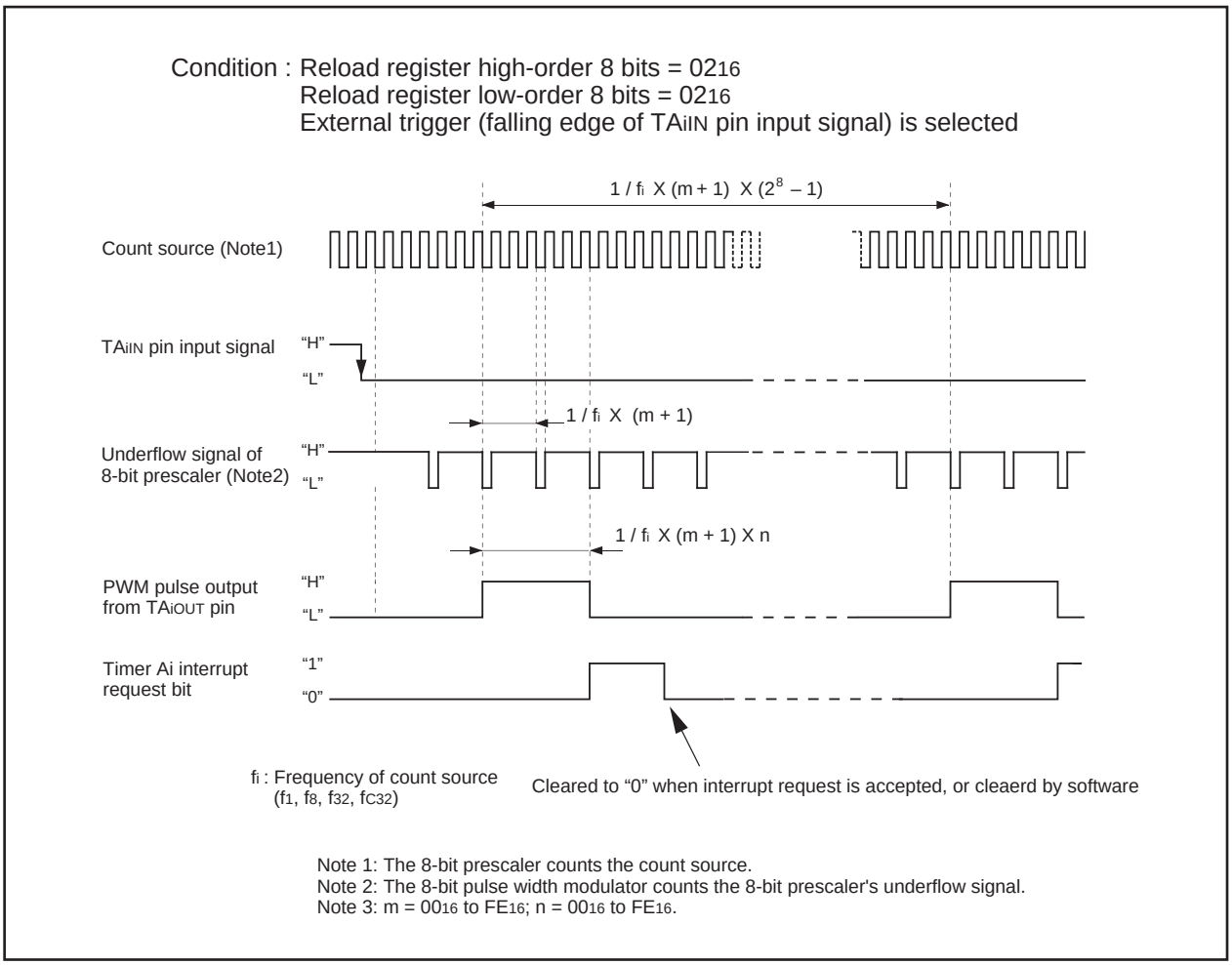


Figure 57. Example of how an 8-bit pulse width modulator operates

Timer B

Figure 58 shows the block diagram of timer B. Figures 59 and 60 show the timer B-related registers.
Use the timer Bi mode register (i = 0 to 2) 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.

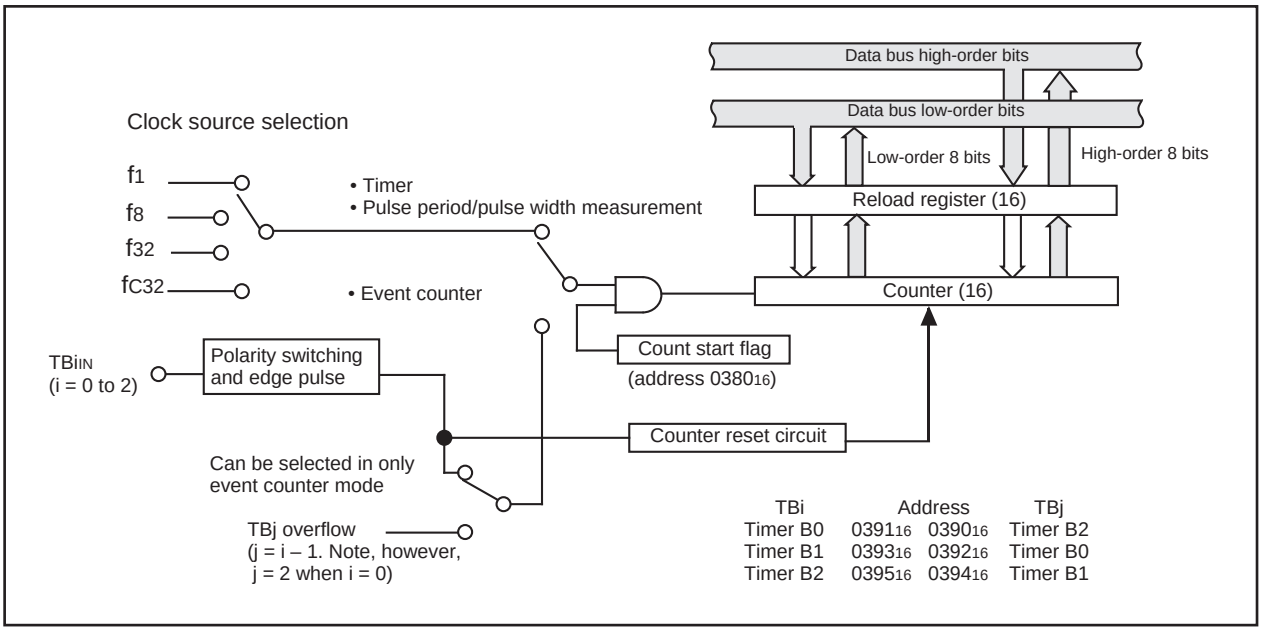


Figure 58. Block diagram of timer B

Timer Bi mode register

b7	b6	b5	b4	b3	b2	b1	b0

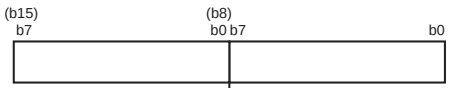
Symbol: TBiMR(i = 0 to 2) | Address: 039B16 to 039D16 | When reset: 00XX00002

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 0 0 : Timer mode 0 1 : Event counter mode 1 0 : Pulse period/pulse width measurement mode 1 1 : Inhibited	○	○
TMOD1			○	○
MR0	Function varies with each operation mode		○	○
MR1			○	○
MR2			○ (Note 1) × (Note 2)	○ ×
MR3			○	×
TCK0	Count source select bit (Function varies with each operation mode)		○	○
TCK1			○	○

Note 1: Timer B0.
Note 2: Timer B1, timer B2.

Figure 59. Timer B-related registers (1)

Timer Bi register (Note)

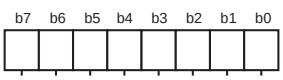


Symbol	Address	When reset
TB0	0391_{16}, 0390_{16}	Indeterminate
TB1	0393_{16}, 0392_{16}	Indeterminate
TB2	0395_{16}, 0394_{16}	Indeterminate

Function	Values that can be set	R	W
• Timer mode Counts the timer's period	0000_{16} to $FFFF_{16}$	○	○
• Event counter mode Counts external pulses input or a timer overflow	0000_{16} to $FFFF_{16}$	○	○
• Pulse period / pulse width measurement mode Measures a pulse period or width	——	○	×

Note: Read and write data in 16-bit units.

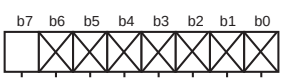
Count start flag



Symbol	Address	When reset
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		○	○

Clock prescaler reset flag



Symbol	Address	When reset
CPSRF	0381_{16}	$0XXXXXXX_2$

Bit symbol	Bit name	Function	R	W
Nothing is assigned. In an attempt to write to these bits, write “0”. The value, if read, turns out to be indeterminate.			—	—
CPSR	Clock prescaler reset flag	0 : No effect 1 : Prescaler is reset (When read, the value is “0”)	○	○

Figure 60. Timer B-related registers (2)

(1) Timer mode

In this mode, the timer counts an internally generated count source. (See Table 30.) Figure 61 shows the timer Bi mode register in timer mode.

Table 30. Timer specifications in timer mode

Item	Specification
Count source	f_1, f_8, f_{32}, f_{C32}
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
TBi_{IN} 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)

Timer Bi mode register

b7	b6	b5	b4	b3	b2	b1	b0
						0	0

Symbol: TBiMR(i=0 to 2) Address: $039B_{16}$ to $039D_{16}$ When reset: $00XX0000_2$

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 0 0 : Timer mode	○	○
TMOD1			○	○
MR0	Invalid in timer mode Can be “0” or “1”		○	○
MR1			○	○
MR2	0 (Fixed to “0” in timer mode ; i = 0)		○ (Note 1)	○
	Nothing is assiigned (i = 1,2). In an attempt to write to this bit, write “0” . The value, if read, turns out to be indeterminate.		× (Note 2)	×
MR3	Invalid in timer mode. In an attempt to write to this bit, write “0” . The value, if read in timer mode, turns out to be indeterminate.		○	×
TCK0	Count source select bit	b7 b6 0 0 : f_1 0 1 : f_8 1 0 : f_{32} 1 1 : f_{C32}	○	○
TCK1			○	○

Note 1: Timer B0.
Note 2: Timer B1, timer B2.

Figure 61. Timer Bi mode register in timer mode

(2) Event counter mode

In this mode, the timer counts an external signal or an internal timer's overflow. (See Table 31.) Figure 62 shows the timer Bi mode register in event counter mode.

Table 31. 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)

Timer Bi mode register

b7	b6	b5	b4	b3	b2	b1	b0
						0	1

Symbol	Address	When reset
TBiMR(i=0 to 2)	039B16 to 039D16	00XX00002

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 0 1 : Event counter mode	○	○
TMOD1			○	○
MR0	Count polarity select bit (Note 1)	b3 b2 0 0 : Counts external signal's falling edges 0 1 : Counts external signal's rising edges 1 0 : Counts external signal's falling and rising edges 1 1 : Inhibited	○	○
MR1			○	○
MR2	0 (Fixed to "0" in event counter mode; i = 0)		○ (Note 2)	○
	Nothing is assigned (i = 1, 2). In an attempt to write to this bit, write "0" . The value, if read, turns out to be indeterminate.		× (Note 3)	×
MR3	Invalid in event counter mode. In an attempt to write to this bit, write "0" . The value, if read in event counter mode, turns out to be indeterminate.		○	×
TCK0	Invalid in event counter mode. Can be "0" or "1".		○	○
TCK1	Event clock select	0 : Input from TBiIN pin (Note 4) 1 : TBj overflow (j = i – 1; however, j = 2 when i = 0)	○	○

Note 1: Valid only when input from the TBiIN pin is selected as the event clock.
If timer's overflow is selected, this bit can be "0" or "1".
Note 2: Timer B0.
Note 3: Timer B1, timer B2.
Note 4: Set the corresponding port direction register to "0".

Figure 62. Timer Bi mode register in event counter mode

(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 32.) Figure 63 shows the timer Bi mode register in pulse period/pulse width measurement mode. Figure 64 shows the operation timing when measuring a pulse period. Figure 65 shows the operation timing when measuring a pulse width.

Table 32. Timer specifications in pulse period/pulse width measurement mode

Item	Specification
Count source	f_1, f_8, f_{32}, f_{C32}
Count operation	• Up count • Counter value "0000_{16}" 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.)
TBi_{IN} 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.

Timer Bi mode register

b7	b6	b5	b4	b3	b2	b1	b0
						1	0

Symbol: TBiMR(i=0 to 2) Address: $039B_{16}$ to $039D_{16}$ When reset: $00XX0000_2$

Bit symbol	Bit name	Function	R	W
TMOD0	Operation mode select bit	b1 b0 1 0 : Pulse period / pulse width measurement mode	○	○
TMOD1			○	○
MR0	Measurement mode select bit	b3 b2 0 0 : Pulse period measurement (Interval between measurement pulse's falling edge to falling edge) 0 1 : Pulse period measurement (Interval between measurement pulse's rising edge to rising edge) 1 0 : Pulse width measurement (Interval between measurement pulse's falling edge to rising edge, and between rising edge to falling edge) 1 1 : Inhibited	○	○
MR1			○	○
MR2	0 (Fixed to "0" in pulse period/pulse width measurement mode; i = 0)		○ (Note 2)	○
	Nothing is assigned (i = 1, 2). In an attempt to write to this bit, write "0" . The value, if read, turns out to be indeterminate.		× (Note 3)	×
MR3	Timer Bi overflow flag (Note 1)	0 : Timer did not overflow 1 : Timer has overflowed	○	×
TCK0	Count source select bit	b7 b6 0 0 : f_1 0 1 : f_8 1 0 : f_{32} 1 1 : f_{C32}	○	○
TCK1			○	○

Note 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. This flag cannot be set to "1" by software.
Note 2: Timer B0.
Note 3: Timer B1, timer B2.

Figure 63. Timer Bi mode register in pulse period/pulse width measurement mode

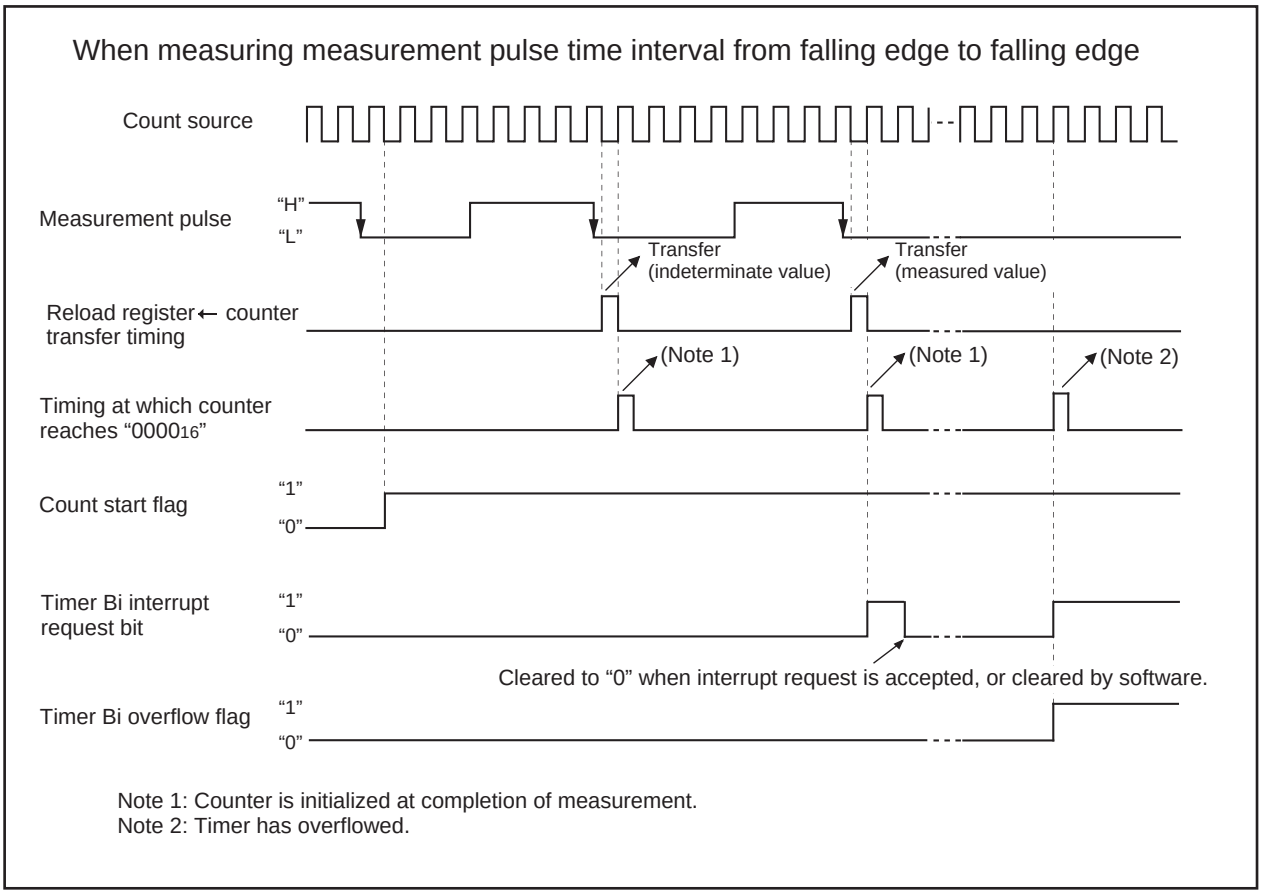


Figure 64. Operation timing when measuring a pulse period

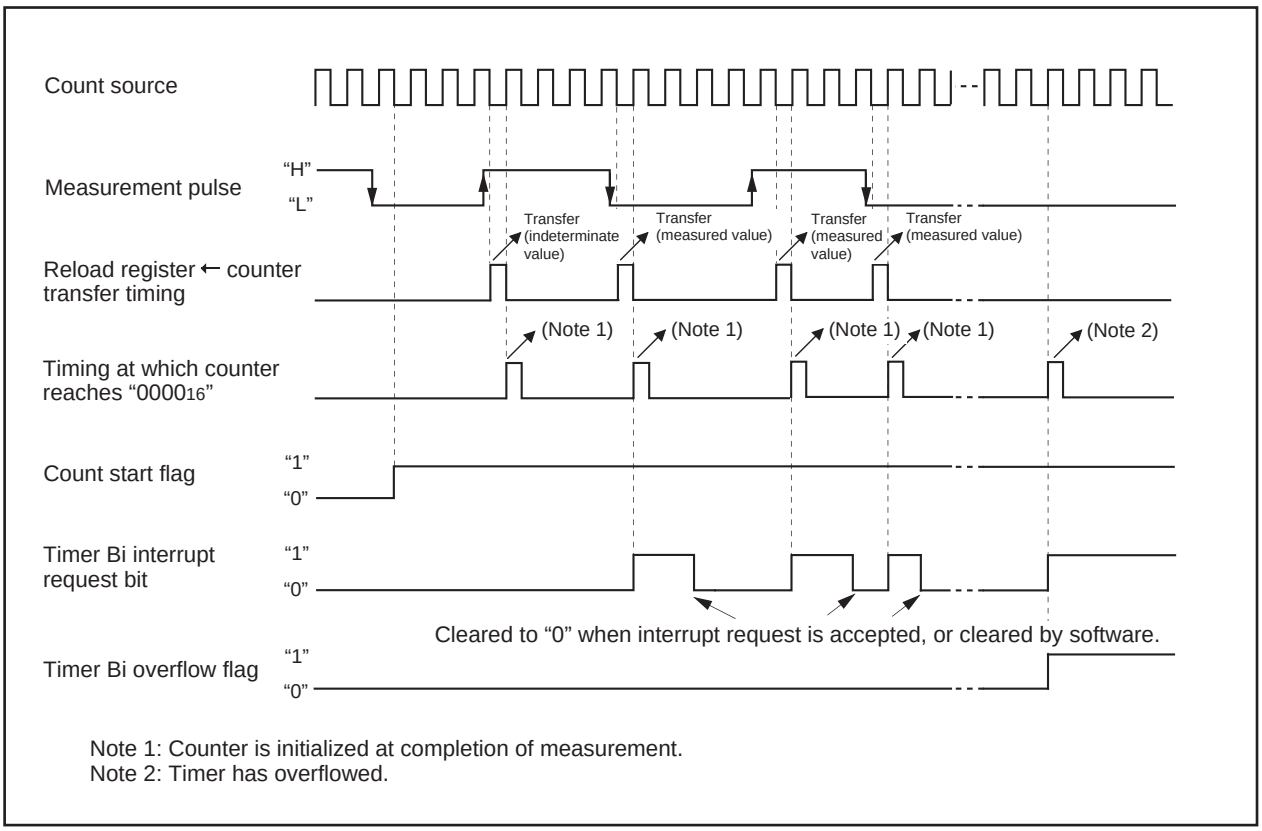


Figure 65. Operation timing when measuring a pulse width

Serial I/O

Serial I/O is configured as three channels: UART0, UART1 and UART2. UART0, UART1 and UART2 each have an exclusive timer to generate a transfer clock, so they operate independently of each other.
Figure 66 shows the block diagram of UART0, UART1 and UART2. Figure 67 and figure 68 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 03A0$_{16}$, 03A8$_{16}$ and 037$8_{16}$) 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.
UART0 through UART2 are almost equal in their functions with minor exceptions. UART2, in particular, is compliant with 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.

Note: SIM : Subscriber Identity Module

Table 33 shows the comparison of functions of UART0 through UART2, and Figures 69 through 73 show the registers related to UARTi.

Table 33. 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
Separate $\overline{CTS}$/$\overline{RTS}$ pins	Possible	Impossible	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.

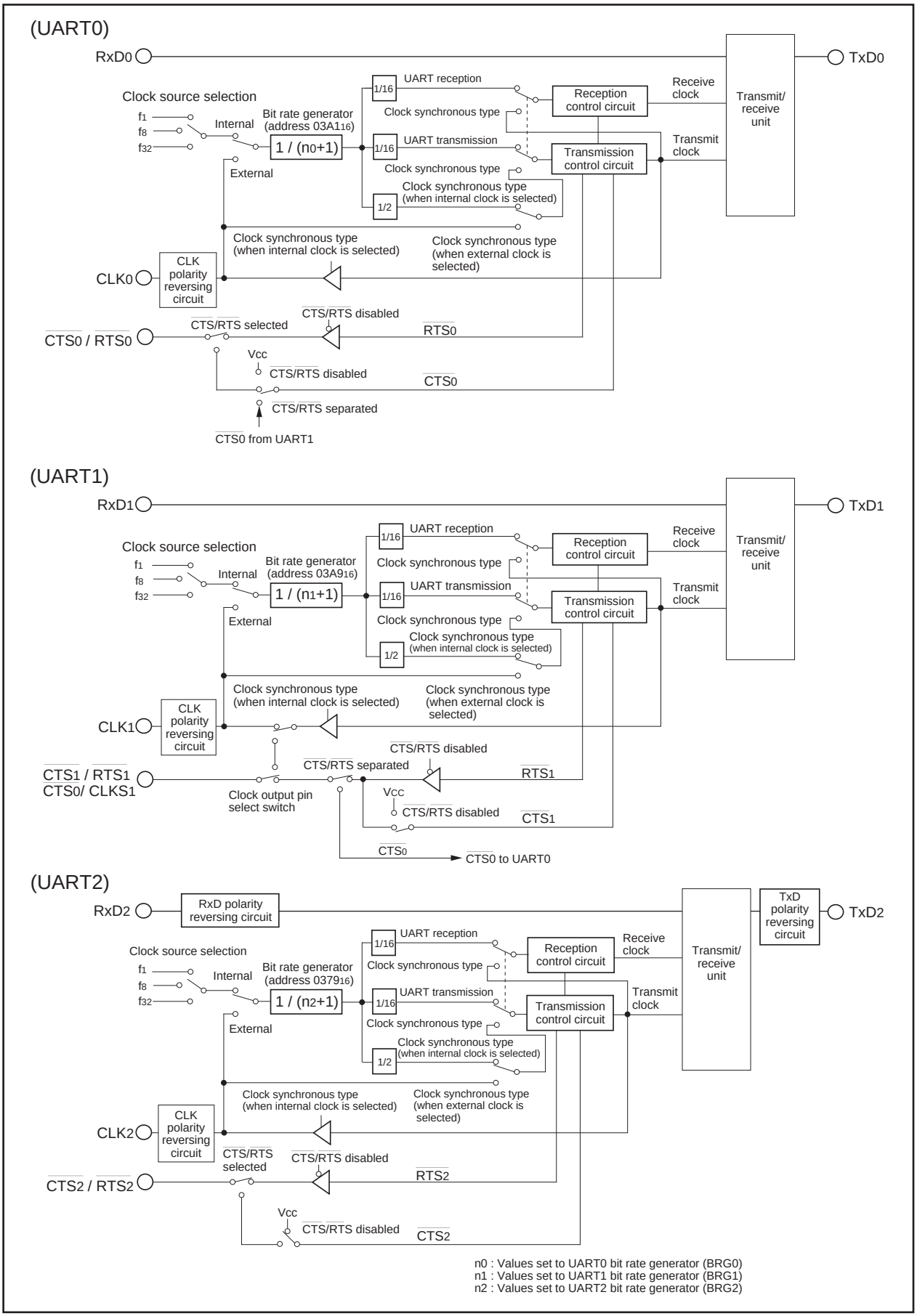


Figure 66. Block diagram of UARTi (i = 0 to 2)

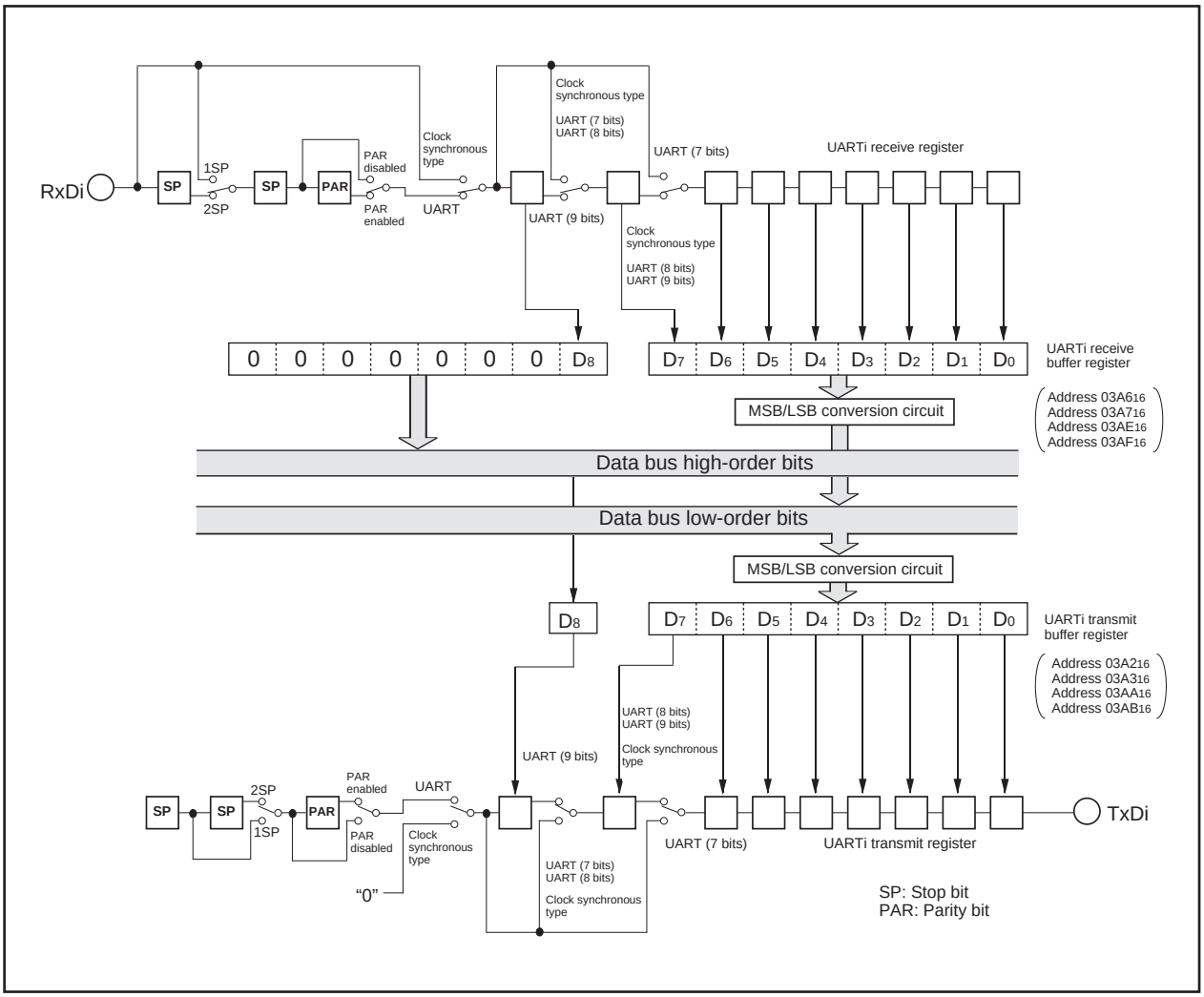


Figure 67. Block diagram of UARTi (i = 0, 1) transmit/receive unit

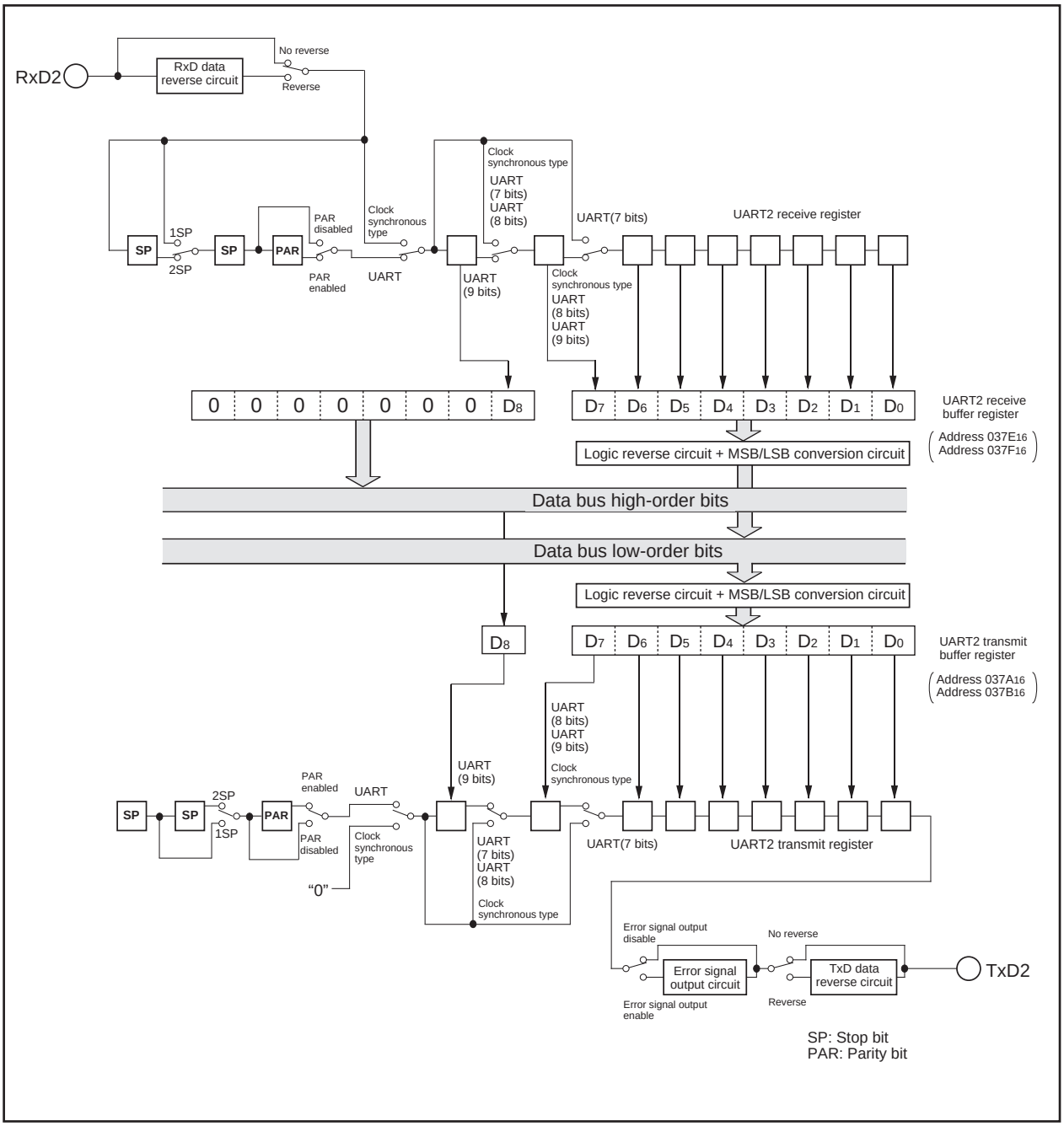


Figure 68. Block diagram of UART2 transmit/receive unit

UARTi transmit buffer register

(b15) b7 (b8) b0 b7 b0

Symbol	Address	When reset
U0TB	$03A3_{16}$, $03A2_{16}$	Indeterminate
U1TB	$03AB_{16}$, $03AA_{16}$	Indeterminate
U2TB	$037B_{16}$, $037A_{16}$	Indeterminate

Function	R	W
Transmit data	×	○
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be indeterminate.	—	—

UARTi receive buffer register

(b15) b7 (b8) b0 b7 b0

Symbol	Address	When reset
U0RB	$03A7_{16}$, $03A6_{16}$	Indeterminate
U1RB	$03AF_{16}$, $03AE_{16}$	Indeterminate
U2RB	$037F_{16}$, $037E_{16}$	Indeterminate

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
—	——	Receive data	Receive data	○	×
Nothing is assigned. In an attempt to write to these bits, write "0". The value, if read, turns out to be indeterminate.				—	—
OER	Overrun error flag (Note)	0 : No overrun error 1 : Overrun error found	0 : No overrun error 1 : Overrun error found	○	×
FER	Framing error flag (Note)	Invalid	0 : No framing error 1 : Framing error found	○	×
PER	Parity error flag (Note)	Invalid	0 : No parity error 1 : Parity error found	○	×
SUM	Error sum flag (Note)	Invalid	0 : No error 1 : Error found	○	×

Note: Bits 15 through 12 are set to "0" when the serial I/O mode select bit (bits 2 to 0 at addresses $03A0_{16}$, $03A8_{16}$ and 0378_{16}) are set to "000_2" or the receive enable bit is set to "0".
(Bit 15 is set to "0" when bits 14 to 12 all are set to "0".) Bits 14 and 13 are also set to "0" when the lower byte of the UARTi receive buffer register (addresses $03A6_{16}$, $03AE_{16}$ and $037E_{16}$) is read out.

UARTi bit rate generator

b7 b0

Symbol	Address	When reset
U0BRG	$03A1_{16}$	Indeterminate
U1BRG	$03A9_{16}$	Indeterminate
U2BRG	0379_{16}	Indeterminate

Function	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}	×	○

Figure 69. Serial I/O-related registers (1)

UARTi transmit/receive mode register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol: UiMR(i=0,1) | Address: 03A0$_{16}$, 03A8$_{16}$ | When reset: 00$_{16}$

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
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 : Inhibited 0 1 1 : Inhibited 1 1 1 : Inhibited	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 : Inhibited 0 1 1 : Inhibited 1 1 1 : Inhibited	○	○
SMD1				○	○
SMD2				○	○
CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock	0 : Internal clock 1 : External clock	○	○
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	○	○

UART2 transmit/receive mode register

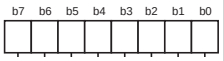
b7 b6 b5 b4 b3 b2 b1 b0

Symbol: U2MR | Address: 037816 | When reset: 00$_{16}$

Bit symbol	Bit name	Function (During clock synchronous serial I/O mode)	Function (During UART mode)	R	W
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 : Inhibited 0 1 1 : Inhibited 1 1 1 : Inhibited	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 : Inhibited 0 1 1 : Inhibited 1 1 1 : Inhibited	○	○
SMD1				○	○
SMD2				○	○
CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock	0 : Internal clock 1 : External clock	○	○
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”	○	○

Figure 70. Serial I/O-related registers (2)

UARTi transmit/receive control register 0

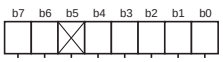


Symbol: UiC0(i=0,1) — Address: 03A4$_{16}$, 03AC$_{16}$ — When reset: 08$_{16}$

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 : f_1 is selected 0 1 : f_8 is selected 1 0 : f_{32} is selected 1 1 : Inhibited	b1 b0 0 0 : f_1 is selected 0 1 : f_8 is selected 1 0 : f_{32} is selected 1 1 : Inhibited	○	○
CLK1				○	○
CRS	$\overline{CTS}$/$\overline{RTS}$ function select bit	Valid when bit 4 = "0" 0 : $\overline{CTS}$ function is selected (Note 1) 1 : RTS function is selected (Note 2)	Valid when bit 4 = "0" 0 : $\overline{CTS}$ 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	$\overline{CTS}$/$\overline{RTS}$ disable bit	0 : $\overline{CTS}$/$\overline{RTS}$ function enabled 1 : CTS/RTS function disabled (P6$_0$ and P6$_4$ function as programmable I/O port)	0 : $\overline{CTS}$/$\overline{RTS}$ function enabled 1 : $\overline{CTS}$/$\overline{RTS}$ function disabled (P6$_0$ and P6$_4$ 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



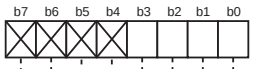
Symbol: U2C0 — Address: 037C$_{16}$ — When reset: 08$_{16}$

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 : f_1 is selected 0 1 : f_8 is selected 1 0 : f_{32} is selected 1 1 : Inhibited	b1 b0 0 0 : f_1 is selected 0 1 : f_8 is selected 1 0 : f_{32} is selected 1 1 : Inhibited	○	○
CLK1				○	○
CRS	$\overline{CTS}$/$\overline{RTS}$ function select bit	Valid when bit 4 = "0" 0 : $\overline{CTS}$ function is selected (Note 1) 1 : RTS function is selected (Note 2)	Valid when bit 4 = "0" 0 : $\overline{CTS}$ function is selected (Note 1) 1 : $\overline{RTS}$ 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	$\overline{CTS}$/$\overline{RTS}$ disable bit	0 : $\overline{CTS}$/$\overline{RTS}$ function enabled 1 : CTS/RTS function disabled (P7$_3$ functions programmable I/O port)	0 : $\overline{CTS}$/$\overline{RTS}$ function enabled 1 : CTS/RTS function disabled (P7$_3$ 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 71. Serial I/O-related registers (3)

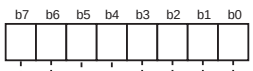
UARTi transmit/receive control register 1



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

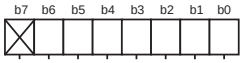


Symbol: U2C1 | Address: 037D$_{16}$ | When reset: 02$_{16}$

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	○	×
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	Invalid	○	○
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 72. Serial I/O-related registers (4)

UART transmit/receive control register 2



Symbol: UCON | Address: $03B0_{16}$ | When reset: $X0000000_2$

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	Invalid	○	○
U1RRM	UART1 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enabled	Invalid	○	○
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”	○	○
RCSP	Separate $\overline{CTS}/\overline{RTS}$ bit	0 : $\overline{CTS}/\overline{RTS}$ shared pin 1 : $\overline{CTS}/\overline{RTS}$ separated	0 : $\overline{CTS}/\overline{RTS}$ shared pin 1 : $\overline{CTS}/\overline{RTS}$ separated	○	○
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 $03A8_{16}$) = “0”.

Figure 73. Serial I/O-related registers (5)

(1) Clock synchronous serial I/O mode

The clock synchronous serial I/O mode uses a transfer clock to transmit and receive data. Table 34 and table 35 list the specifications of the clock synchronous serial I/O mode. Figure 74 shows the UARTi transmit/receive mode register.

Table 34. 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 03A0$_{16}$, 03A8$_{16}$, 0378$_{16}$ = "0") : fi/ 2(n+1) (Note 1) fi = f1, f8, f32 • When external clock is selected (bit 3 at addresses 03A0$_{16}$, 03A8$_{16}$, 0378$_{16}$ = "1") : Input from CLKi pin
Transmission/reception control	• $\overline{\text{CTS}}$ function/$\overline{\text{RTS}}$ function/$\overline{\text{CTS}}$, $\overline{\text{RTS}}$ function chosen to be invalid
Transmission start condition	• To start transmission, the following requirements must be met: – Transmit enable bit (bit 0 at addresses 03A5$_{16}$, 03AD$_{16}$, 037D$_{16}$) = "1" – Transmit buffer empty flag (bit 1 at addresses 03A5$_{16}$, 03AD$_{16}$, 037D$_{16}$) = "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 03A4$_{16}$, 03AC$_{16}$, 037C$_{16}$) = "0": CLKi input level = "H" – CLKi polarity select bit (bit 6 at addresses 03A4$_{16}$, 03AC$_{16}$, 037C$_{16}$) = "1": CLKi input level = "L"
Reception start condition	• To start reception, the following requirements must be met: – Receive enable bit (bit 2 at addresses 03A5$_{16}$, 03AD$_{16}$, 037D$_{16}$) = "1" – Transmit enable bit (bit 0 at addresses 03A5$_{16}$, 03AD$_{16}$, 037D$_{16}$) = "1" – Transmit buffer empty flag (bit 1 at addresses 03A5$_{16}$, 03AD$_{16}$, 037D$_{16}$) = "0" • Furthermore, if external clock is selected, the following requirements must also be met: – CLKi polarity select bit (bit 6 at addresses 03A4$_{16}$, 03AC$_{16}$, 037C$_{16}$) = "0": CLKi input level = "H" – CLKi polarity select bit (bit 6 at addresses 03A4$_{16}$, 03AC$_{16}$, 037C$_{16}$) = "1": CLKi input level = "L"
Interrupt request generation timing	• When transmitting – Transmit interrupt cause select bit (bits 0, 1 at address 03B0$_{16}$, bit 4 at address 037D$_{16}$) = "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 03B0$_{16}$, bit 4 at address 037D$_{16}$) = "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 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 00$_{16}$ to FF$_{16}$ 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 is not set to "1".

Table 35. Specifications of clock synchronous serial I/O mode (2)

Item	Specification
Select function	• CLK polarity selection Whether transmit data is output/input 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) (Note) UART1 transfer clock can be chosen by software to be output from one of the two pins set • Separate $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ pins (UART0) (Note) UART0 $\overline{\text{CTS}}$ and $\overline{\text{RTS}}$ pins each can be assigned to separate pins • 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. • TxD, RxD I/O polarity reverse (UART2) This function is reversing TxD port output and RxD port input. All I/O data level is reversed.

Note: The transfer clock output from multiple pins and the separate $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ pins functions cannot be selected simultaneously.

UARTi transmit/receive mode registers

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

Symbol: UiMR(i=0,1) — Address: $03A0_{16}$, $03A8_{16}$ — When reset: 00_{16}

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	○	○
STPS	Invalid in clock synchronous serial I/O mode		○	○
PRY			○	○
PRYE			○	○
SLEP	0 (Must always be “0” in clock synchronous serial I/O mode)		○	○

UART2 transmit/receive mode register

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

Symbol: U2MR — Address: 0378_{16} — When reset: 00_{16}

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	○	○
STPS	Invalid in clock synchronous serial I/O mode		○	○
PRY			○	○
PRYE			○	○
IOPOL	TxD, RxD I/O polarity reverse bit (Note)	0 : No reverse 1 : Reverse	○	○

Note: Usually set to “0”.

Figure 74. UARTi transmit/receive mode register in clock synchronous serial I/O mode

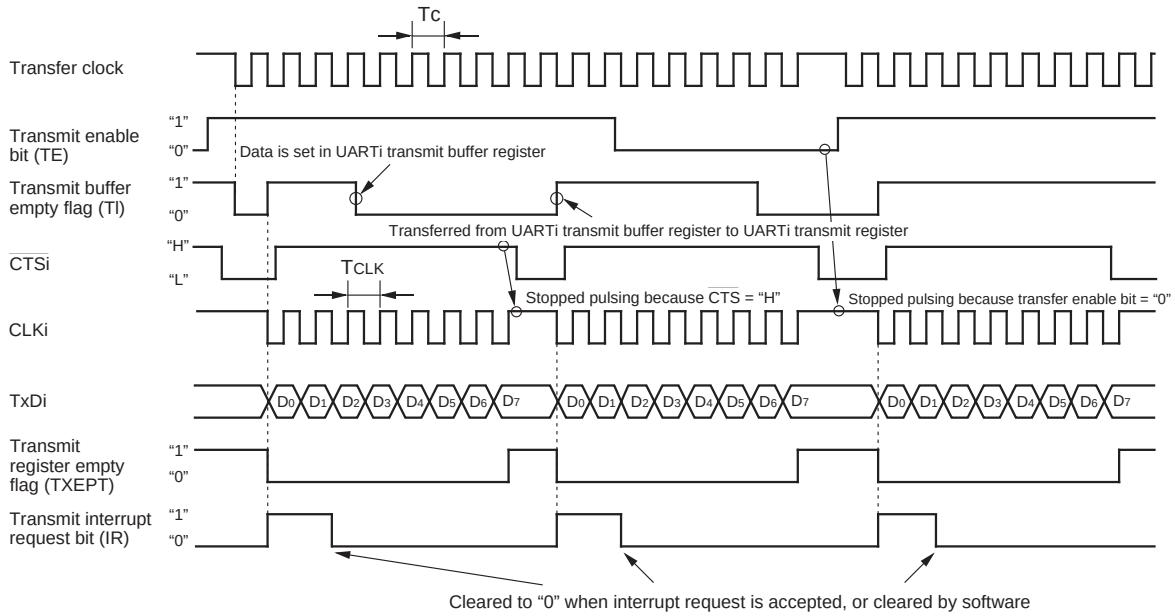
Table 36 lists the functions of the input/output pins during clock synchronous serial I/O mode. This table shows the pin functions when the transfer clock output from multiple pins and the separate $\overline{CTS}/\overline{RTS}$ pins functions are not selected. Note that for a period from when the UARTi operation mode is selected to when transfer starts, the TxDi pin outputs a "H". (If the N-channel open-drain is selected, this pin is in floating state.)

Table 36. Input/output pin functions in clock synchronous serial I/O mode

Pin name	Function	Method of selection
TxDi ($P6_3$, $P6_7$, $P7_0$)	Serial data output	(Outputs dummy data when performing reception only)
RxDi ($P6_2$, $P6_6$, $P7_1$)	Serial data input	Port $P6_2$, $P6_6$ and $P7_1$ direction register (bits 2 and 6 at address $03EE_{16}$, bit 1 at address $03EF_{16}$)= "0" (Can be used as an input port when performing transmission only)
CLKi ($P6_1$, $P6_5$, $P7_2$)	Transfer clock output	Internal/external clock select bit (bit 3 at address $03A0_{16}$, $03A8_{16}$, 0378_{16}) = "0"
	Transfer clock input	Internal/external clock select bit (bit 3 at address $03A0_{16}$, $03A8_{16}$, 0378_{16}) = "1" Port $P6_1$, $P6_5$ and $P7_2$ direction register (bits 1 and 5 at address $03EE_{16}$, bit 2 at address $03EF_{16}$) = "0"
$\overline{CTS}i/\overline{RTS}i$ ($P6_0$, $P6_4$, $P7_3$)	$\overline{CTS}$ input	$\overline{CTS}/\overline{RTS}$ disable bit (bit 4 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) ="0" $\overline{CTS}/\overline{RTS}$ function select bit (bit 2 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) = "0" Port $P6_0$, $P6_4$ and $P7_3$ direction register (bits 0 and 4 at address $03EE_{16}$, bit 3 at address $03EF_{16}$) = "0"
	$\overline{RTS}$ output	$\overline{CTS}/\overline{RTS}$ disable bit (bit 4 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) = "0" $\overline{CTS}/\overline{RTS}$ function select bit (bit 2 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) = "1"
	Programmable I/O port	$\overline{CTS}/\overline{RTS}$ disable bit (bit 4 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) = "1"

(when transfer clock output from multiple pins and separate $\overline{CTS}/\overline{RTS}$ pins functions are not selected)

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

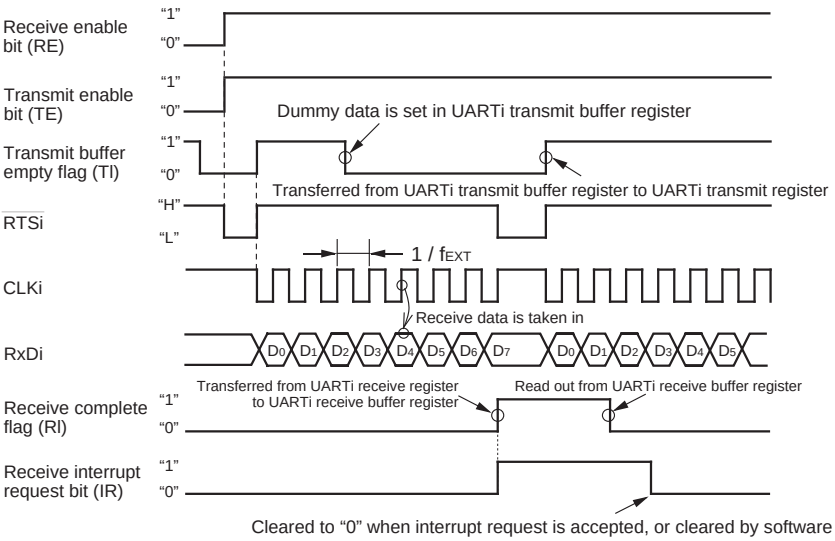


Shown in ( ) are bit symbols.

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".

Tc = TCLK = 2(n + 1) / fi
fi: frequency of BRGi count source (f1, f8, f32)
n: value set to BRGi

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



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".

fEXT: frequency of external clock

Meet the following conditions are met when the CLK input before data reception = "H"
- Transmit enable bit → "1"
- Receive enable bit → "1"
- Dummy data write to UARTi transmit buffer register

Figure 75. Typical transmit/receive timings in clock synchronous serial I/O mode

(a) Polarity select function

As shown in Figure 76, the CLK polarity select bit (bit 6 at addresses 03A4$_{16}$, 03AC$_{16}$, 037C$_{16}$) allows selection of the polarity of the transfer clock.

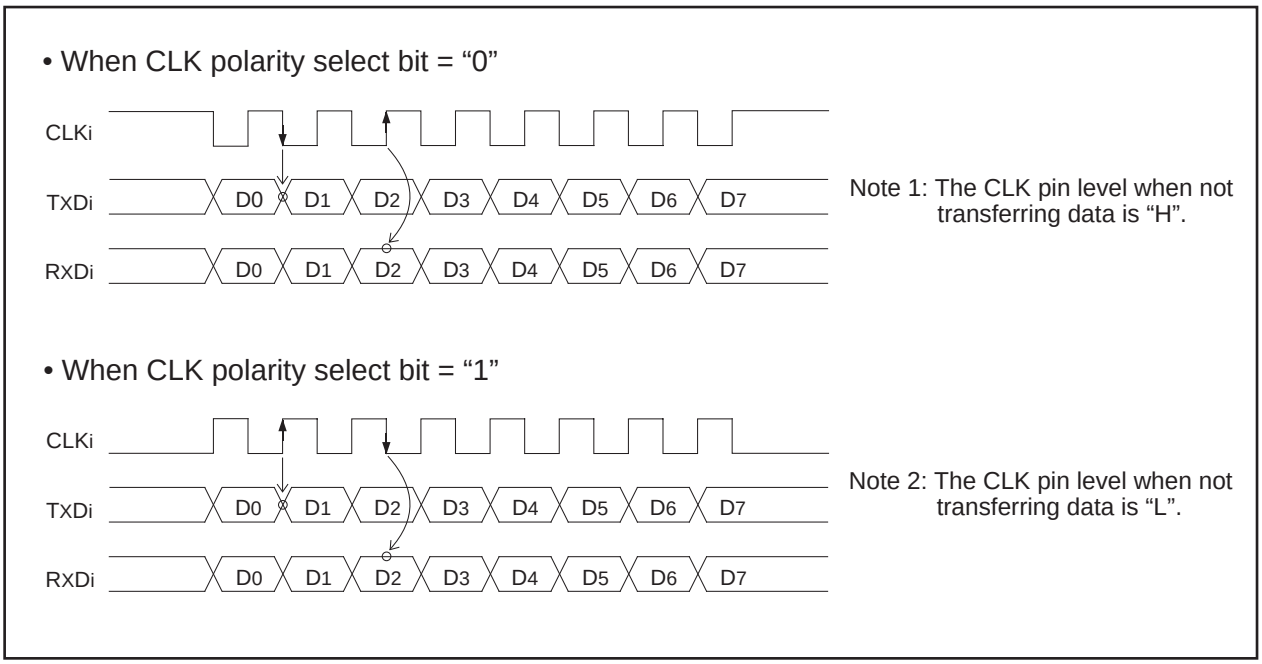


Figure 76. Polarity of transfer clock

(b) LSB first/MSB first select function

As shown in Figure 77, when the transfer format select bit (bit 7 at addresses 03A4$_{16}$, 03AC$_{16}$, 037C$_{16}$) = “0”, the transfer format is “LSB first”; when the bit = “1”, the transfer format is “MSB first”.

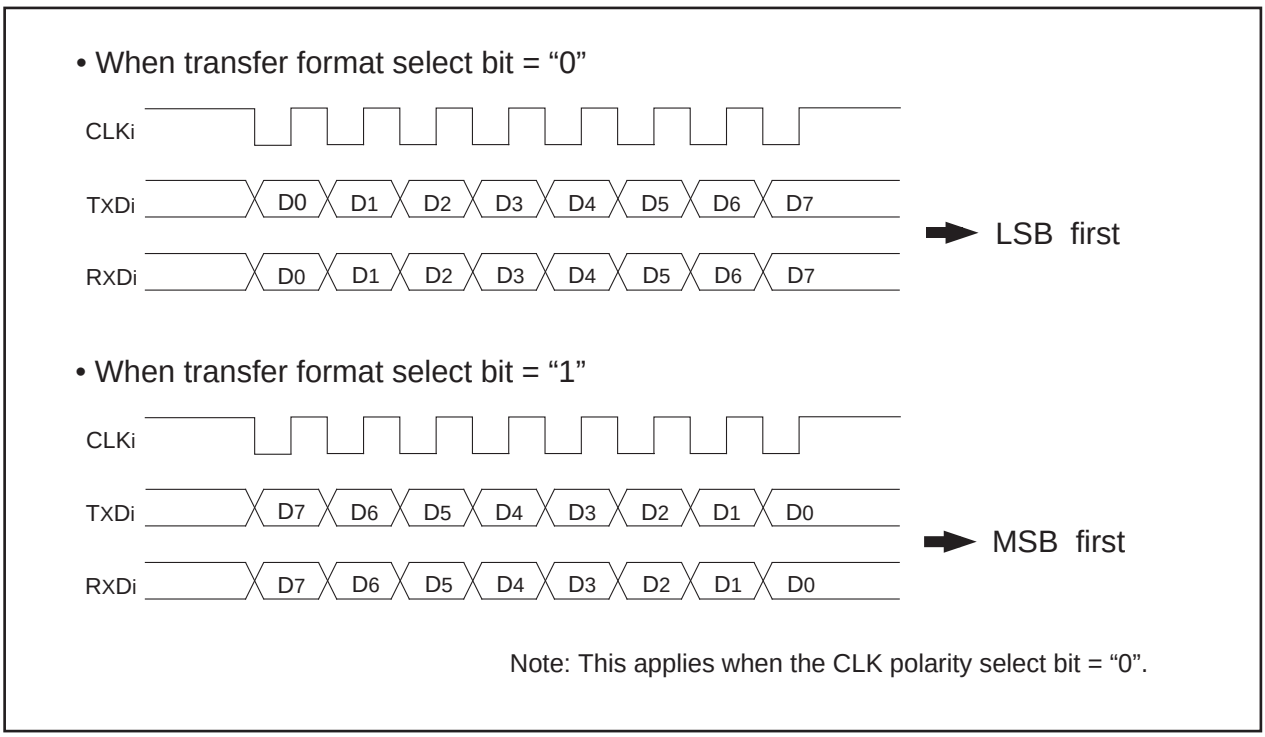


Figure 77. Transfer format

(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 03B0$_{16}$). (See Figure 78.) The multiple pins function is valid only when the internal clock is selected for UART1. Note that when this function is selected, UART1 $\overline{CTS}/\overline{RTS}$ function cannot be used.

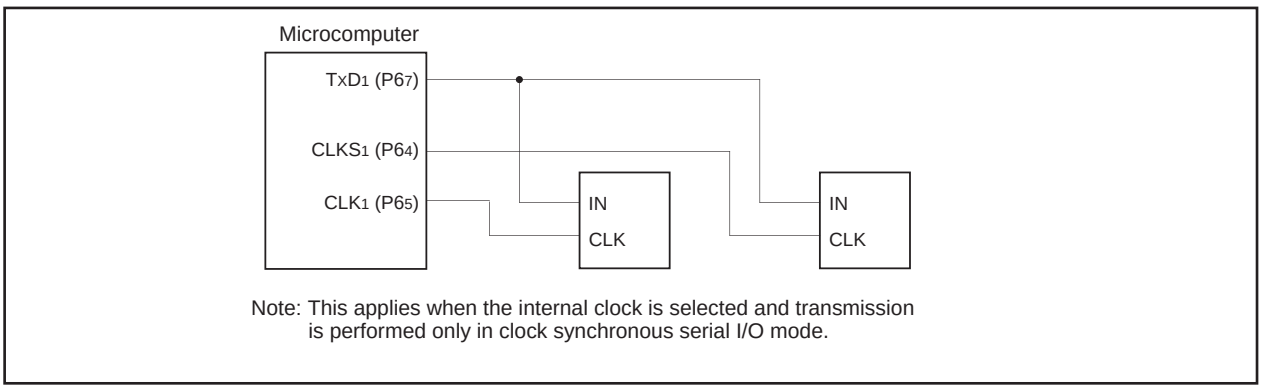


Figure 78. The transfer clock output from the multiple pins function usage

(d) Continuous receive mode

If the continuous receive mode enable bit (bits 2 and 3 at address 03B0$_{16}$, bit 5 at address 037D$_{16}$) 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) Separate $\overline{CTS}/\overline{RTS}$ pins function (UART0)

This function works the same way as in the clock asynchronous serial I/O (UART) mode. The method of setting and the input/output pin functions are both the same, so refer to select function in the next section, "(2) Clock asynchronous serial I/O (UART) mode." Note that this function is invalid if the transfer clock output from the multiple pins function is selected.

(f) Serial data logic switch function (UART2)

When the data logic select bit (bit6 at address 037D$_{16}$) = "1", and writing to transmit buffer register or reading from receive buffer register, data is reversed. Figure 79 shows the example of serial data logic switch timing.

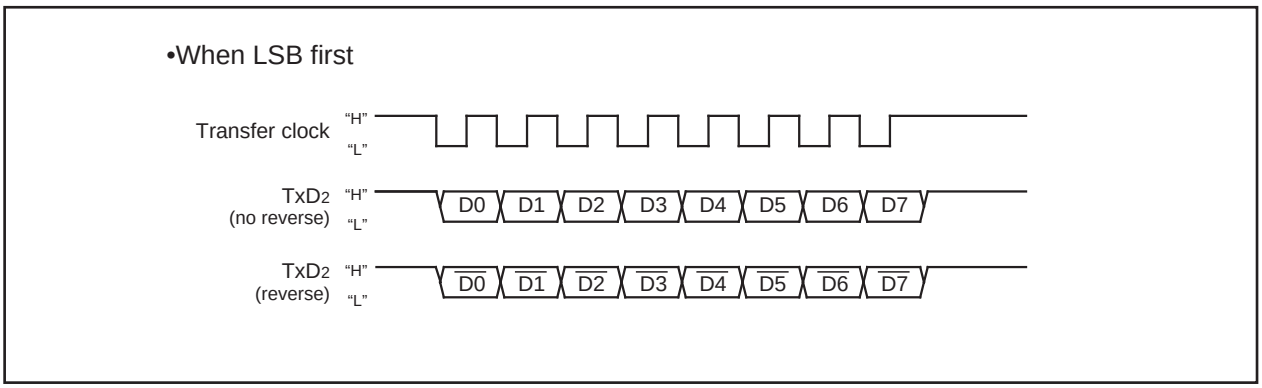


Figure 79. Serial data logic switch timing

(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. Table 37 and table 38 list the specifications of the UART mode. Figure 80 shows the UARTi transmit/receive mode register.

Table 37. 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 $03A0_{16}$, $03A8_{16}$, 0378_{16} = “0”) : fi/16(n+1) (Note 1) fi = f_1, f_8, f_{32} • When external clock is selected (bit 3 at addresses $03A0_{16}$, $03A8_{16}$, 0378_{16} =“1”) : f_{EXT}/16(n+1)(Note 1) (Note 2)
Transmission/reception control	• $\overline{CTS}$ function/$\overline{RTS}$ function/$\overline{CTS}$, $\overline{RTS}$ function chosen to be invalid
Transmission start condition	• To start transmission, the following requirements must be met: - Transmit enable bit (bit 0 at addresses $03A5_{16}$, $03AD_{16}$, $037D_{16}$) = “1” - Transmit buffer empty flag (bit 1 at addresses $03A5_{16}$, $03AD_{16}$, $037D_{16}$) = “0” - When $\overline{CTS}$ function selected, $\overline{CTS}$ input level = “L”
Reception start condition	• To start reception, the following requirements must be met: - Receive enable bit (bit 2 at addresses $03A5_{16}$, $03AD_{16}$, $037D_{16}$) = “1” - Start bit detection
Interrupt request generation timing	• When transmitting - Transmit interrupt cause select bits (bits 0,1 at address $03B0_{16}$, bit4 at address $037D_{16}$) = “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 $03B0_{16}$, bit4 at address $037D_{16}$) = “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 00_{16} to FF_{16} 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 is not set to “1”.

Table 38. Specifications of UART Mode (2)

Item	Specification
Select function	• Separate $\overline{CTS}$/$\overline{RTS}$ pins (UART0) UART0 $\overline{CTS}$ and $\overline{RTS}$ pins each can be assigned to separate pins • Sleep mode selection (UART0, UART1) This mode is used to transfer data to and from one of multiple slave microcomputers • Serial data logic switch (UART2) This function is reversing logic value of transferring data. Start bit, parity bit and stop bit are not reversed. • TxD, RxD I/O polarity switch This function is reversing TxD port output and RxD port input. All I/O data level is reversed.

UARTi transmit / receive mode registers

b7	b6	b5	b4	b3	b2	b1	b0

Symbol: UiMR(i=0,1) — Address: $03A0_{16}$, $03A8_{16}$ — When reset: 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	○	○
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	○	○

UART2 transmit / receive mode register

b7	b6	b5	b4	b3	b2	b1	b0

Symbol: U2MR — Address: 0378_{16} — When reset: 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	○	○
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 80. UARTi transmit/receive mode register in UART mode

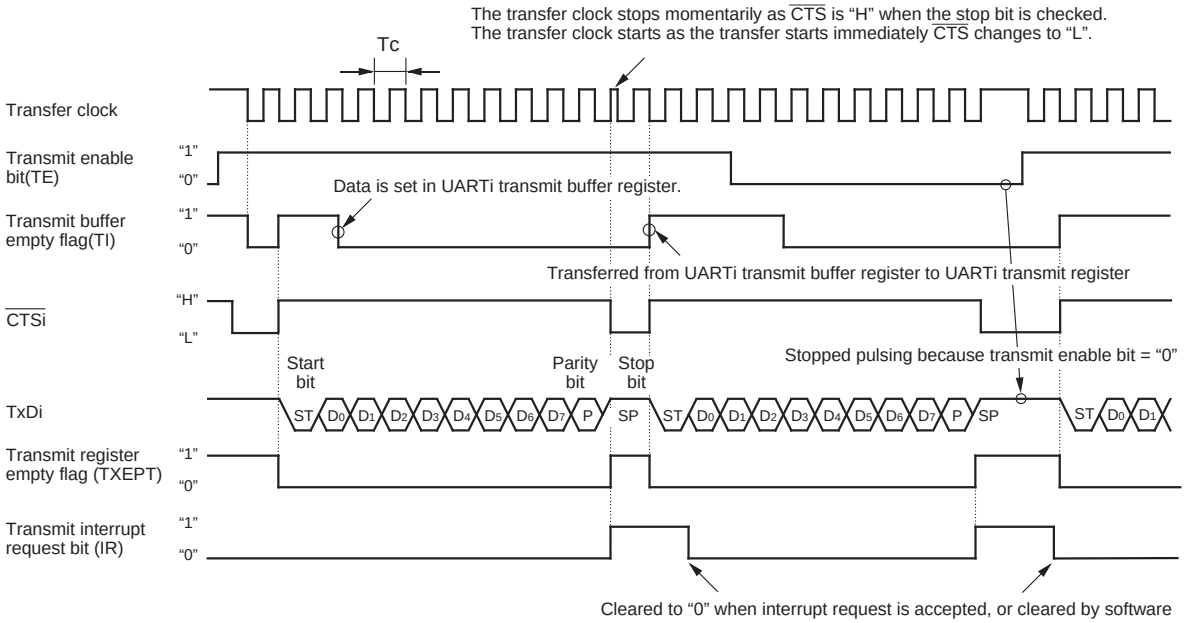
Table 39 lists the functions of the input/output pins during UART mode. This table shows the pin functions when the separate $\overline{CTS}/\overline{RTS}$ pins function is not selected. Note that for a period from when the UARTi operation mode is selected to when transfer starts, the TxDi pin outputs a "H". (If the N-channel open-drain is selected, this pin is in floating state.)

Table 39. Input/output pin functions in UART mode

Pin name	Function	Method of selection
TxDi ($P6_3$, $P6_7$, $P7_0$)	Serial data output	
RxDi ($P6_2$, $P6_6$, $P7_1$)	Serial data input	Port $P6_2$, $P6_6$ and $P7_1$ direction register (bits 2 and 6 at address $03EE_{16}$, bit 1 at address $03EF_{16}$)= "0" (Can be used as an input port when performing transmission only)
CLKi ($P6_1$, $P6_5$, $P7_2$)	Programmable I/O port	Internal/external clock select bit (bit 3 at address $03A0_{16}$, $03A8_{16}$, 0378_{16}) = "0"
	Transfer clock input	Internal/external clock select bit (bit 3 at address $03A0_{16}$, $03A8_{16}$, 0378_{16}) = "1" Port $P6_1$, $P6_5$ and $P7_2$ direction register (bits 1 and 5 at address $03EE_{16}$, bit 2 at address $03EF_{16}$) = "0"
$\overline{CTS}i/\overline{RTS}i$ ($P6_0$, $P6_4$, $P7_3$)	$\overline{CTS}$ input	$\overline{CTS}/\overline{RTS}$ disable bit (bit 4 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) ="0" $\overline{CTS}/\overline{RTS}$ function select bit (bit 2 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) = "0" Port $P6_0$, $P6_4$ and $P7_3$ direction register (bits 0 and 4 at address $03EE_{16}$, bit 3 at address $03EF_{16}$) = "0"
	$\overline{RTS}$ output	$\overline{CTS}/\overline{RTS}$ disable bit (bit 4 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) = "0" $\overline{CTS}/\overline{RTS}$ function select bit (bit 2 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) = "1"
	Programmable I/O port	$\overline{CTS}/\overline{RTS}$ disable bit (bit 4 at address $03A4_{16}$, $03AC_{16}$, $037C_{16}$) = "1"

(when separate $\overline{CTS}/\overline{RTS}$ pins function is not selected)

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

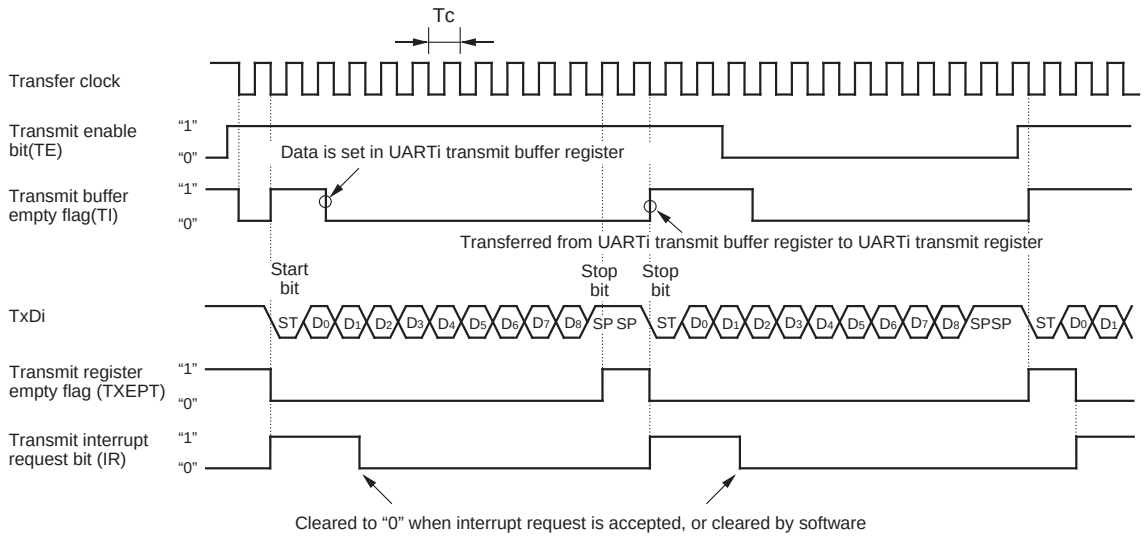


Shown in ( ) are bit symbols.

The above timing applies to the following settings :
- Parity is enabled.
- One stop bit.
- CTS function is selected.
- Transmit interrupt cause select bit = "1".

Tc = 16 (n + 1) / fi or 16 (n + 1) / fEXT
fi : frequency of BRGi count source (f1, f8, f32)
fEXT : 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".

Tc = 16 (n + 1) / fi or 16 (n + 1) / fEXT
fi : frequency of BRGi count source (f1, f8, f32)
fEXT : frequency of BRGi count source (external clock)
n : value set to BRGi

Figure 81. Typical transmit timings in UART mode

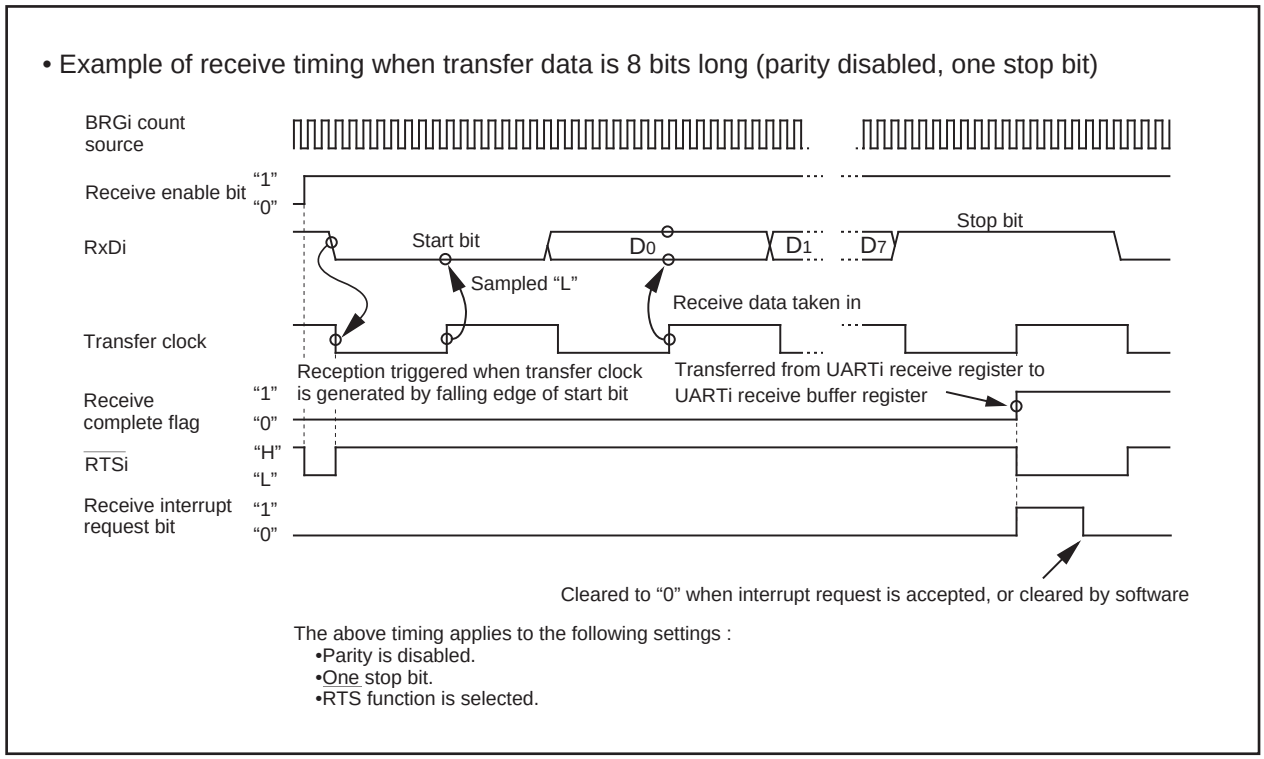
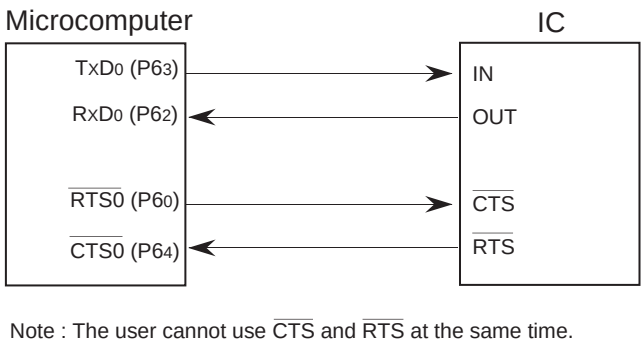


Figure 82. Typical receive timing in UART mode

(a) Separate $\overline{\text{CTS}}/\overline{\text{RTS}}$ pins function (UART0)

Setting the $\overline{\text{CTS}}/\overline{\text{RTS}}$ separate bit (bit 6 of address $03B0_{16}$) to "1" inputs/outputs the $\overline{\text{CTS}}$ signal and $\overline{\text{RTS}}$ signal from different pins. Choose which to use, $\overline{\text{CTS}}$ or $\overline{\text{RTS}}$, by use of the $\overline{\text{CTS}}/\overline{\text{RTS}}$ function select bit (bit 2 of address $03A4_{16}$). This function is effective in UART0 only. With this function chosen, the user cannot use the $\overline{\text{CTS}}/\overline{\text{RTS}}$ function. Set "0" both to the $\overline{\text{CTS}}/\overline{\text{RTS}}$ function select bit (bit 2 of address $03AC_{16}$) and to the $\overline{\text{CTS}}/\overline{\text{RTS}}$ disable bit (bit 4 of address $03AC_{16}$).



Note : The user cannot use $\overline{\text{CTS}}$ and $\overline{\text{RTS}}$ at the same time.

Figure 83. The separate $\overline{\text{CTS}}/\overline{\text{RTS}}$ pins function usage

(b) 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 $03A0_{16}$, $03A8_{16}$) 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".

(c) 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 84 shows the example of timing for switching serial data logic.

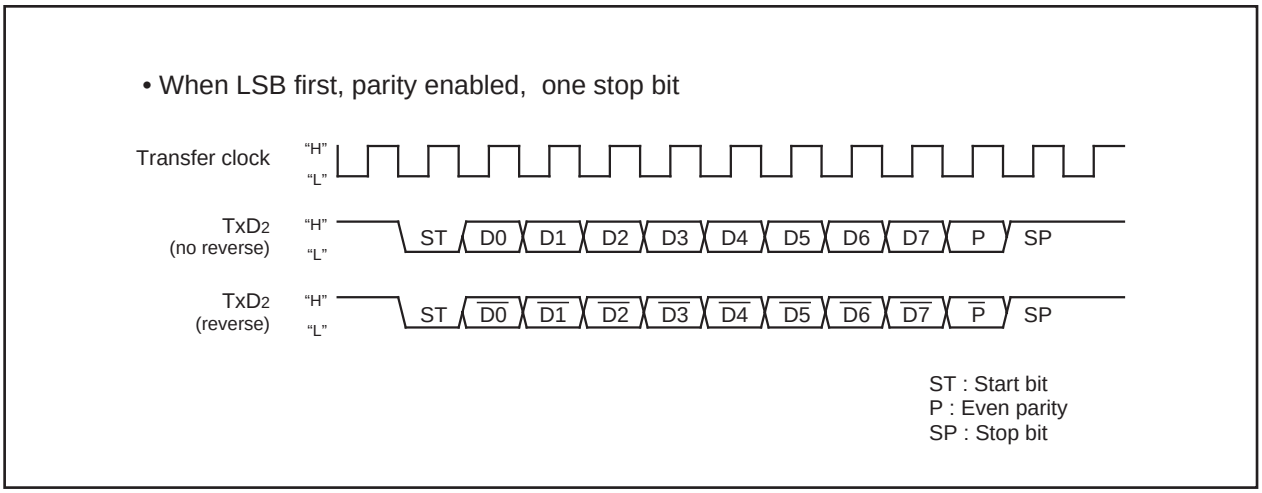


Figure 84. Timing for switching serial data logic

(d) 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.

(e) 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 85 shows the example of detection timing of a buss collision (in UART mode).

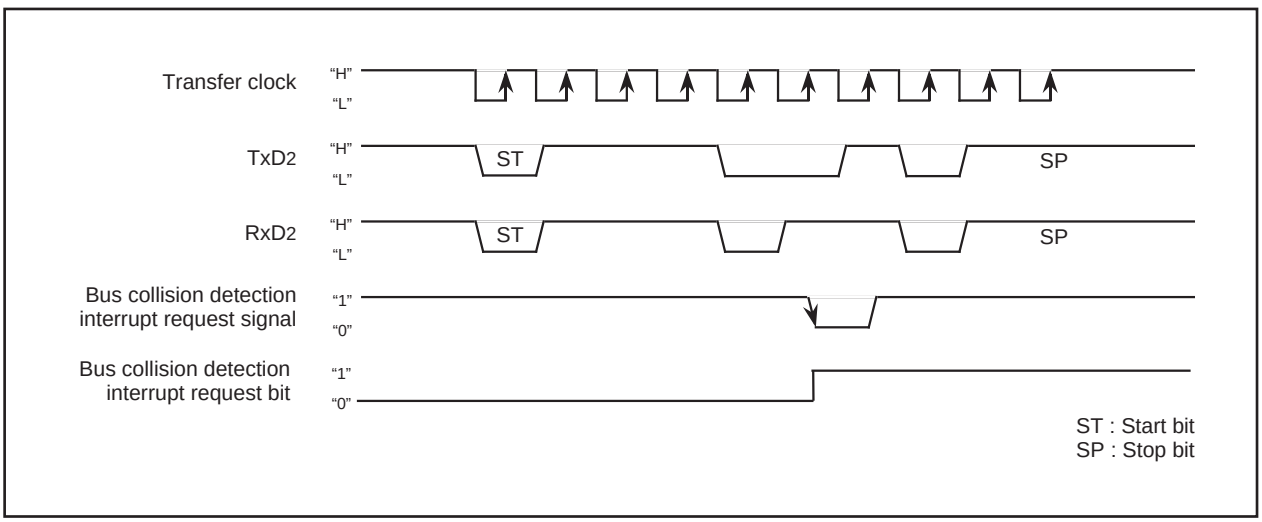


Figure 85. Detection timing of a bus collision (in UART mode)

(3) Clock-asynchronous serial I/O mode (compliant with 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 40 shows the specifications of clock-asynchronous serial I/O mode (compliant with the SIM interface).

Table 40. Specifications of clock-asynchronous serial I/O mode (compliant with the SIM interface)

Item	Specification
Transfer data format	• Transfer data 8-bit UART mode (bit 2 through bit 0 of address 0378_{16} = “101_2”) • One stop bit (bit 4 of address 0378_{16} = “0”) • With the direct format chosen Set parity to “even” (bit 5 and bit 6 of address 0378_{16} = “1” and “1” respectively) Set data logic to “direct” (bit 6 of address $037D_{16}$ = “0”). Set transfer format to LSB (bit 7 of address $037C_{16}$ = “0”). • With the inverse format chosen Set parity to “odd” (bit 5 and bit 6 of address 0378_{16} = “0” and “1” respectively) Set data logic to “inverse” (bit 6 of address $037D_{16}$ = “1”) Set transfer format to MSB (bit 7 of address $037C_{16}$ = “1”)
Transfer clock	• With the internal clock chosen (bit 3 of address 0378_{16} = “0”) : fi / 16 (n + 1) (Note 1) : fi=f_1, f_8, f_{32} • With an external clock chosen (bit 3 of address 0378_{16} = “1”) : f_{EXT} / 16 (n+1) (Note 1) (Note 2)
Transmission / reception control	• Disable the $\overline{CTS}$ and $\overline{RTS}$ function (bit 4 of address $037C_{16}$ = “1”)
Other settings	• The sleep mode select function is not available for UART2 • Set transmission interrupt factor to “transmission completed” (bit 4 of address $037D_{16}$ = “1”)
Transmission start condition	• To start transmission, the following requirements must be met: - Transmit enable bit (bit 0 of address $037D_{16}$) = “1” - Transmit buffer empty flag (bit 1 of address $037D_{16}$) = “0”
Reception start condition	• To start reception, the following requirements must be met: - Reception enable bit (bit 2 of address $037D_{16}$) = “1” - Detection of a start bit
Interrupt request generation timing	• When transmitting When data transmission from the UART2 transfer register is completed (bit 4 of address $037D_{16}$ = “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 3) • 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 TxD_2 pin by use of the parity error signal output function (bit 7 of address $037D_{16}$ = “1”) when a parity error is detected - On the transmission side, a parity error is detected by the level of input to the RxD_2 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 00_{16} to FF_{16} that is set to the UARTi bit rate generator.

Note 2: f_{EXT} is input from the CLK_2 pin.

Note 3: If an overrun error occurs, the UART2 receive buffer will have the next data written in. Note also that the UARTi receive interrupt request bit is not set to “1”.

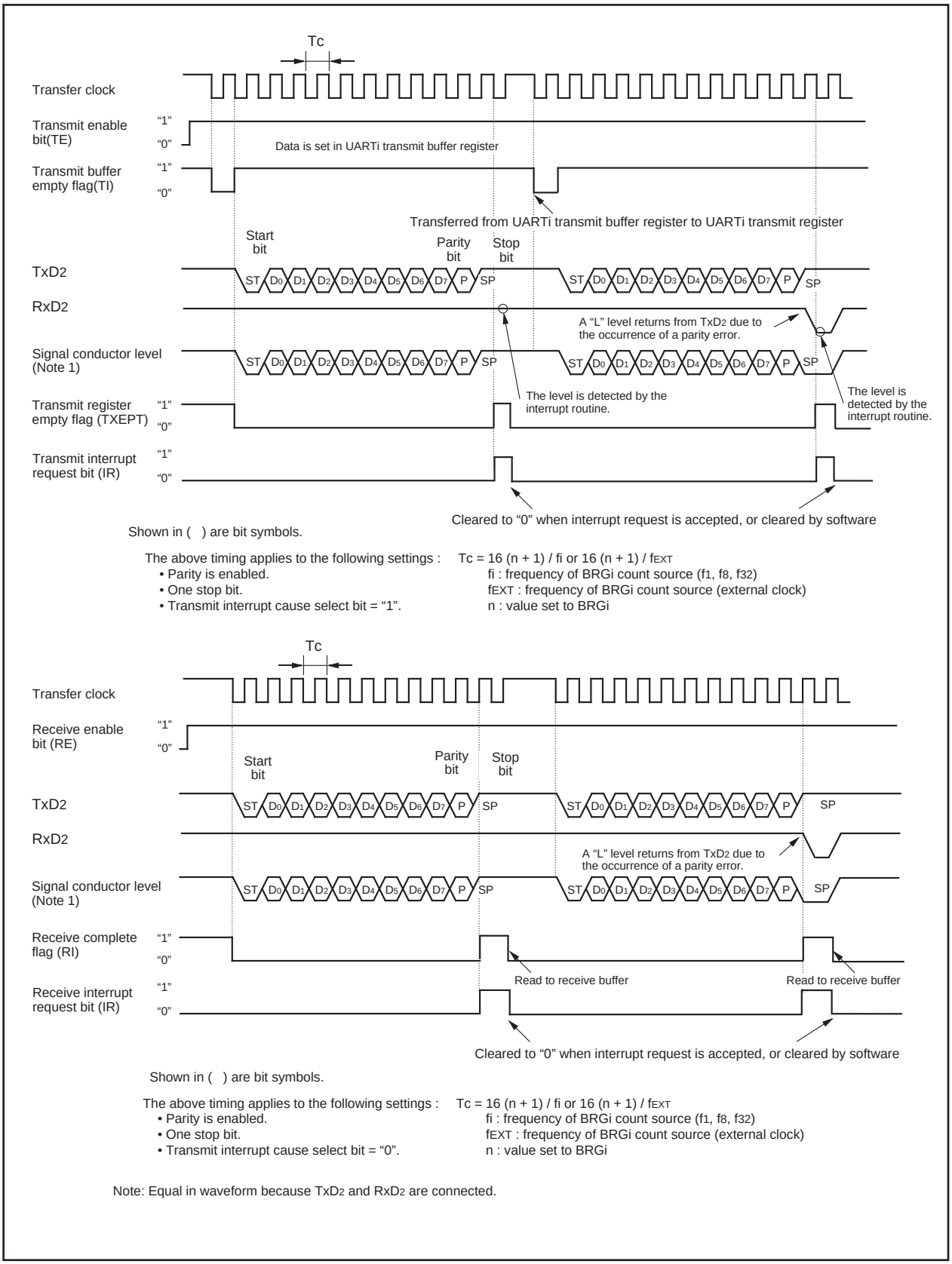


Figure 86. Typical transmit/receive timing in UART mode (compliant with the SIM interface)

(a) Function for outputting a parity error signal

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. In step with this function, the generation timing of a transmission completion interrupt changes to the detection timing of a parity error signal. Figure 87 shows the output timing of the parity error signal.

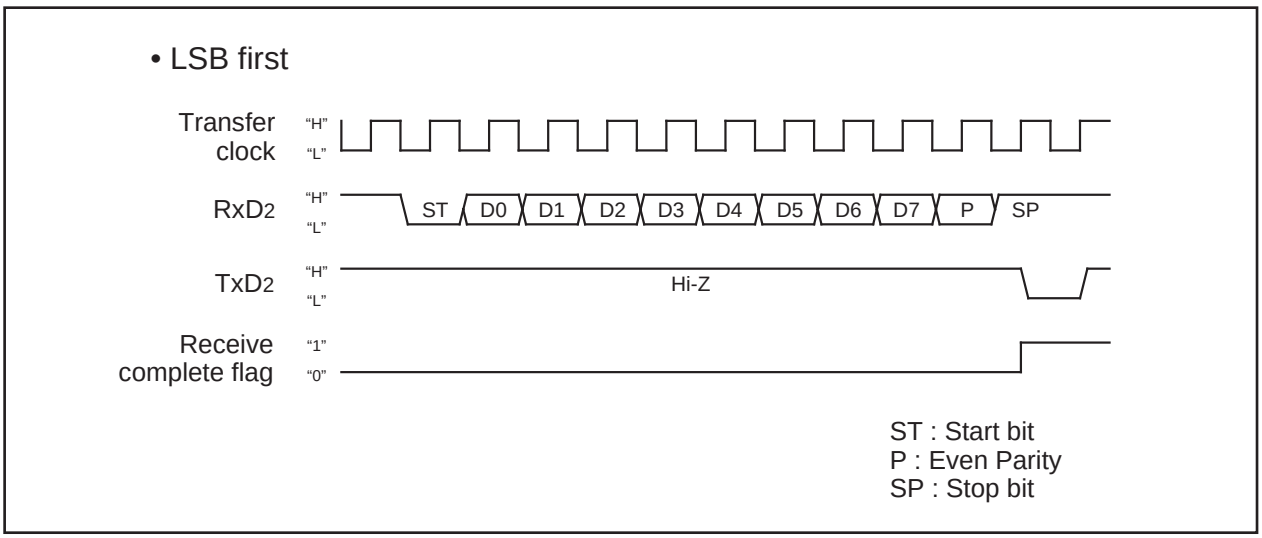


Figure 87. Output timing of the parity error signal

(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 88 shows the SIM interface format.

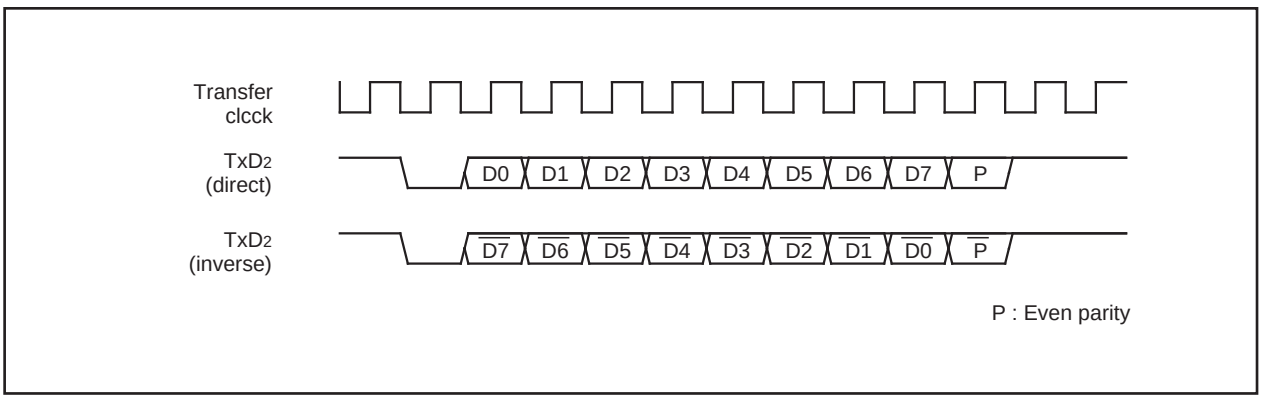


Figure 88. SIM interface format

Figure 89 shows the example of connecting the SIM interface. Connect TxD_2 and RxD_2 and apply pull-up.

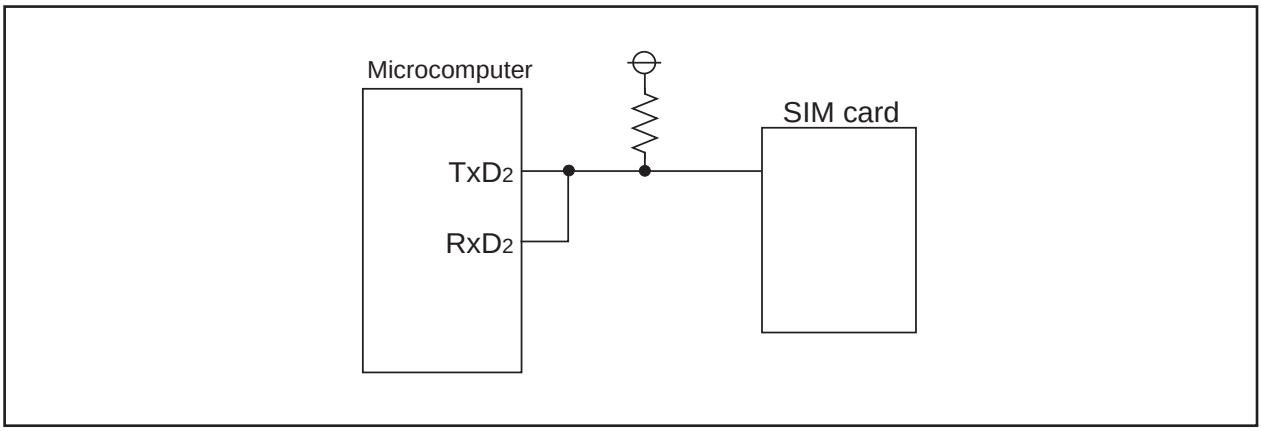


Figure 89. Connecting the SIM interface

A-D Converter

The A-D converter consists of one 10-bit successive approximation A-D converter circuit with a capacitive coupling amplifier. Pins $P10_0$ to $P10_7$, $P9_5$, and $P9_6$ 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 $03D7_{16}$) can be used to isolate the resistance ladder of the A-D converter from the reference voltage input pin (V_{REF}) when the A-D converter is not used. Doing so stops any current flowing into the resistance ladder from V_{REF}, reducing the power dissipation. When using the A-D converter, start A-D conversion only after setting bit 5 of $03D7_{16}$ to connect V_{REF}. 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 41 shows the performance of the A-D converter. Figure 90 shows the block diagram of the A-D converter, and Figures 91 and 92 show the A-D converter-related registers.

Table 41. Performance of A-D converter

Item	Performance
Method of A-D conversion	Successive approximation (capacitive coupling amplifier)
Analog input voltage (Note 1)	0V to AV_{CC} (V_{CC})
Operating clock ϕAD (Note 2)	V_{CC} = 5V f_{AD}/divide-by-2 of f_{AD}/divide-by-4 of f_{AD}, $f_{AD}=f(X_{IN})$ V_{CC} = 3V divide-by-2 of f_{AD}/divide-by-4 of f_{AD}, $f_{AD}=f(X_{IN})$
Resolution	8-bit or 10-bit (selectable)
Absolute precision	V_{CC} = 5V • Without sample and hold function ±3LSB • With sample and hold function (8-bit resolution) ±2LSB • With sample and hold function (10-bit resolution) AN_0 to AN_7 input : ±3LSB ANEX0 and ANEX1 input (including mode in which external operation amp is connected) : ±7LSB V_{CC} = 3V • Without sample and hold function (8-bit resolution) ±2LSB
Operating modes	One-shot mode, repeat mode, single sweep mode, repeat sweep mode 0, and repeat sweep mode 1
Analog input pins	8pins (AN_0 to AN_7) + 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 retriggered) A-D conversion starts when the A-D conversion start flag is “1” and the $\overline{ADTRG}$/$P9_7$ 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: 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.

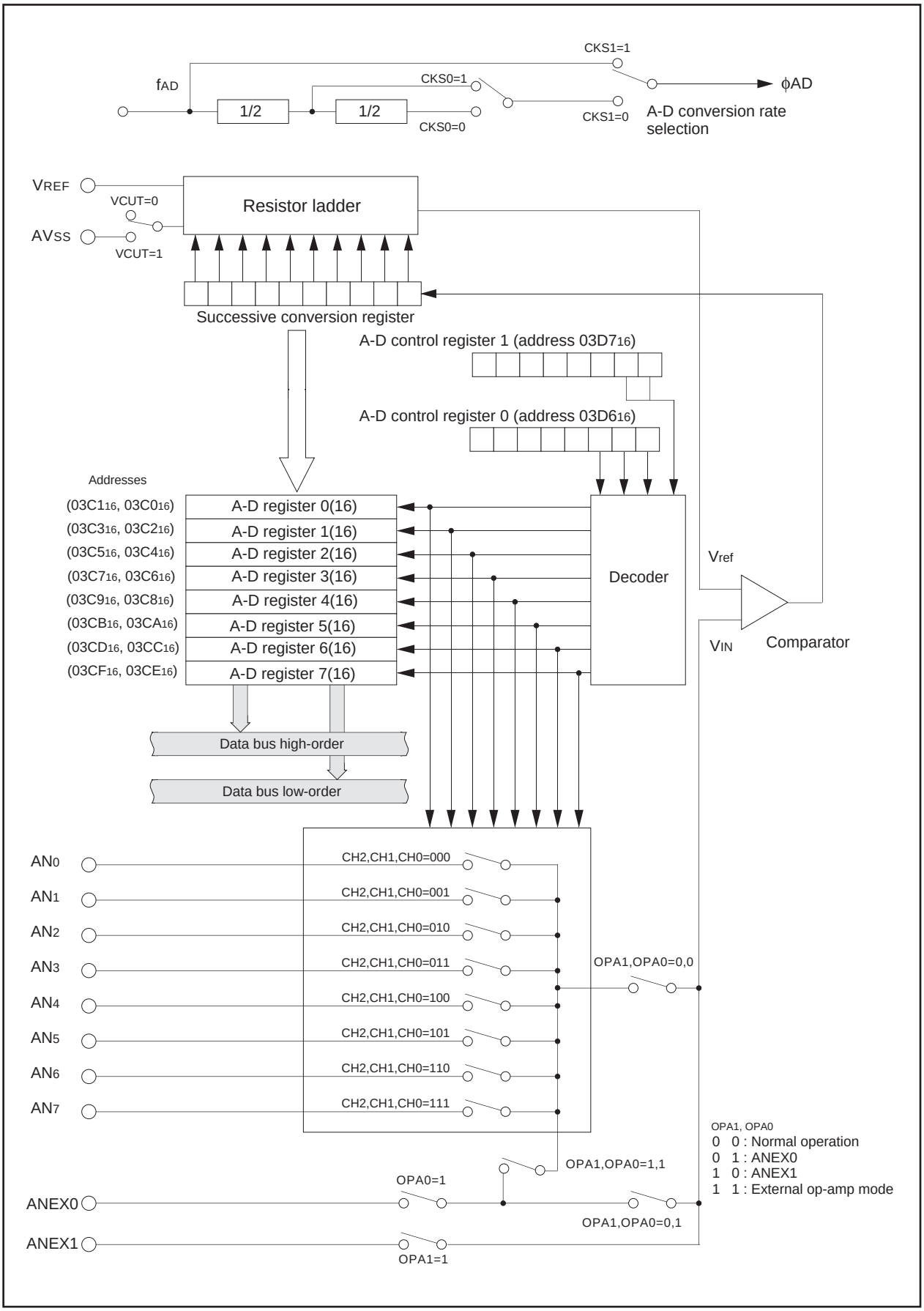


Figure 90. Block diagram of A-D converter

A-D control register 0 (Note)

b7	b6	b5	b4	b3	b2	b1	b0

Symbol	Address	When reset
ADCON0	$03D6_{16}$	$00000XXX_2$

Bit symbol	Bit name	Function	R	W
CH0	Analog input pin select bit	b2 b1 b0 0 0 0 : AN_0 is selected 0 0 1 : AN_1 is selected 0 1 0 : AN_2 is selected 0 1 1 : AN_3 is selected 1 0 0 : AN_4 is selected 1 0 1 : AN_5 is selected 1 1 0 : AN_6 is selected 1 1 1 : AN_7 is selected	○	○
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	○	○
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 : $f_{AD}/4$ is selected 1 : $f_{AD}/2$ is selected	○	○

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

A-D control register 1 (Note)

b7	b6	b5	b4	b3	b2	b1	b0

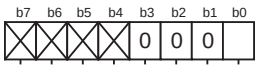
Symbol	Address	When reset
ADCON1	$03D7_{16}$	00_{16}

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 : AN_0, AN_1 (2 pins) 0 1 : AN_0 to AN_3 (4 pins) 1 0 : AN_0 to AN_5 (6 pins) 1 1 : AN_0 to AN_7 (8 pins)	○	○
SCAN1		When repeat sweep mode 1 is selected b1 b0 0 0 : AN_0 (1 pin) 0 1 : AN_0, AN_1 (2 pins) 1 0 : AN_0 to AN_2 (3 pins) 1 1 : AN_0 to AN_3 (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 : $f_{AD}/2$ or $f_{AD}/4$ is selected 1 : f_{AD} 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 91. A-D converter-related registers (1)

A-D control register 2 (Note)



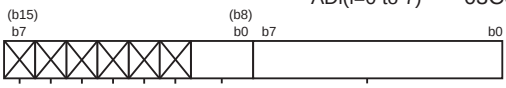
Symbol: ADCON2 | Address: $03D4_{16}$ | When reset: $0000XXX0_2$

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		Always 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: $03C0_{16}$ to $03CF_{16}$ | When 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 92. 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 42 shows the specifications of one-shot mode. Figure 93 shows the A-D control register in one-shot mode.

Table 42. 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

A-D control register 0 (Note 1)

b7	b6	b5	b4	b3	b2	b1	b0
			0	0			

Symbol ADCON0 — Address $03D6_{16}$ — When reset $00000XXX_2$

Bit symbol	Bit name	Function	R	W
CH0	Analog input pin select bit	b2 b1 b0 0 0 0 : AN_0 is selected 0 0 1 : AN_1 is selected 0 1 0 : AN_2 is selected 0 1 1 : AN_3 is selected 1 0 0 : AN_4 is selected 1 0 1 : AN_5 is selected 1 1 0 : AN_6 is selected 1 1 1 : AN_7 is selected (Note 2)	○	○
CH1			○	○
CH2			○	○
MD0	A-D operation mode select bit 0	b4 b3 0 0 : One-shot mode (Note 2)	○	○
MD1			○	○
TRG	Trigger select bit	0 : Software trigger 1 : AD_{TRG} trigger	○	○
ADST	A-D conversion start flag	0 : A-D conversion disabled 1 : A-D conversion started	○	○
CKS0	Frequency select bit 0	0: $f_{AD}/4$ is selected 1: $f_{AD}/2$ 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)

b7	b6	b5	b4	b3	b2	b1	b0
		1			0		

Symbol ADCON1 — Address $03D7_{16}$ — When reset 00_{16}

Bit symbol	Bit name	Function	R	W
SCAN0	A-D sweep pin select bit	Invalid in one-shot mode	○	○
SCAN1			○	○
MD2	A-D operation mode select bit 1	0 : Any mode other than repeat sweep mode 1	○	○
BITS	8/10-bit mode select bit	0 : 8-bit mode 1 : 10-bit mode	○	○
CKS1	Frequency select bit1	0 : $f_{AD}/2$ or $f_{AD}/4$ is selected 1 : f_{AD} is selected	○	○
VCUT	Vref connect bit	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 93. A-D conversion register in one-shot mode

(2) Repeat mode

In repeat mode, the pin selected using the analog input pin select bit is used for repeated A-D conversion. Table 43 shows the specifications of repeat mode. Figure 94 shows the A-D control register in repeat mode.

Table 43. 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 AN_0 to AN_7, as selected
Reading of result of A-D converter	Read A-D register corresponding to selected pin

A-D control register 0 (Note 1)

b7	b6	b5	b4	b3	b2	b1	b0
			0	1			

Symbol ADCON0 — Address $03D6_{16}$ — When reset $00000XXX_2$

Bit symbol	Bit name	Function	R	W
CH0	Analog input pin select bit	b2 b1 b0 0 0 0 : AN_0 is selected 0 0 1 : AN_1 is selected 0 1 0 : AN_2 is selected 0 1 1 : AN_3 is selected 1 0 0 : AN_4 is selected 1 0 1 : AN_5 is selected 1 1 0 : AN_6 is selected 1 1 1 : AN_7 is selected (Note 2)	○	○
CH1			○	○
CH2			○	○
MD0	A-D operation mode select bit 0	b4 b3 0 1 : Repeat mode (Note 2)	○	○
MD1			○	○
TRG	Trigger select bit	0 : Software trigger 1 : AD_{TRG} trigger	○	○
ADST	A-D conversion start flag	0 : A-D conversion disabled 1 : A-D conversion started	○	○
CKS0	Frequency select bit 0	0 : $f_{AD}/4$ is selected 1 : $f_{AD}/2$ 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)

b7	b6	b5	b4	b3	b2	b1	b0
		1			0		

Symbol ADCON1 — Address $03D7_{16}$ — When reset 00_{16}

Bit symbol	Bit name	Function	R	W
SCAN0	A-D sweep pin select bit	Invalid in repeat mode	○	○
SCAN1			○	○
MD2	A-D operation mode select bit 1	0 : Any mode other than 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 : $f_{AD}/2$ or $f_{AD}/4$ is selected 1 : f_{AD} is selected	○	○
VCUT	Vref connect bit	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 94. 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 44 shows the specifications of single sweep mode. Figure 95 shows the A-D control register in single sweep mode.

Table 44. 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	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

A-D control register 0 (Note)

b7	b6	b5	b4	b3	b2	b1	b0
			1	0			

Symbol ADCON0 — Address $03D6_{16}$ — When reset $00000XXX_2$

Bit symbol	Bit name	Function	R	W
CH0	Analog input pin select bit	Invalid in single sweep mode	O	O
CH1			O	O
CH2			O	O
MD0	A-D operation mode select bit 0	b4 b3 1 0 : Single sweep mode	O	O
MD1			O	O
TRG	Trigger select bit	0 : Software trigger 1 : AD_{TRG} trigger	O	O
ADST	A-D conversion start flag	0 : A-D conversion disabled 1 : A-D conversion started	O	O
CKS0	Frequency select bit 0	0 : $f_{AD}/4$ is selected 1 : $f_{AD}/2$ is selected	O	O

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

A-D control register 1 (Note 1)

b7	b6	b5	b4	b3	b2	b1	b0
		1			0		

Symbol ADCON1 — Address $03D7_{16}$ — When reset 00_{16}

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 : AN_0, AN_1 (2 pins) 0 1 : AN_0 to AN_3 (4 pins) 1 0 : AN_0 to AN_5 (6 pins) 1 1 : AN_0 to AN_7 (8 pins)	O	O
SCAN1			O	O
MD2	A-D operation mode select bit 1	0 : Any mode other than repeat sweep mode 1	O	O
BITS	8/10-bit mode select bit	0 : 8-bit mode 1 : 10-bit mode	O	O
CKS1	Frequency select bit 1	0 : $f_{AD}/2$ or $f_{AD}/4$ is selected 1 : f_{AD} is selected	O	O
VCUT	Vref connect bit	1 : Vref connected	O	O
OPA0	External op-amp connection mode bit (Note 2)	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	O	O
OPA1			O	O

Note 1: If the A-D control register is rewritten during A-D conversion, the conversion result is indeterminate.
Note 2: Neither '01' nor '10' can be selected with the external op-amp connection mode bit.

Figure 95. A-D conversion register in single sweep mode

(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 45 shows the specifications of repeat sweep mode 0. Figure 96 shows the A-D control register in repeat sweep mode 0.

Table 45. Repeat sweep mode 0 specifications

Item	Specification
Function	The pins selected by the A-D sweep pin select bit are used for repeat sweep 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)

A-D control register 0 (Note)

b7	b6	b5	b4	b3	b2	b1	b0
			1	1			

Symbol: ADCON0 — Address: $03D6_{16}$ — When reset: $00000XXX_2$

Bit symbol	Bit name	Function	R	W
CH0	Analog input pin select bit	Invalid in repeat sweep mode 0	O	O
CH1			O	O
CH2			O	O
MD0	A-D operation mode select bit 0	b4 b3 1 1 : Repeat sweep mode 0	O	O
MD1			O	O
TRG	Trigger select bit	0 : Software trigger 1 : AD_{TRG} trigger	O	O
ADST	A-D conversion start flag	0 : A-D conversion disabled 1 : A-D conversion started	O	O
CKS0	Frequency select bit 0	0 : $f_{AD}/4$ is selected 1 : $f_{AD}/2$ is selected	O	O

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

A-D control register 1 (Note 1)

b7	b6	b5	b4	b3	b2	b1	b0
		1			0		

Symbol: ADCON1 — Address: $03D7_{16}$ — When reset: 00_{16}

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 : AN_0, AN_1 (2 pins) 0 1 : AN_0 to AN_3 (4 pins) 1 0 : AN_0 to AN_5 (6 pins) 1 1 : AN_0 to AN_7 (8 pins)	O	O
SCAN1			O	O
MD2	A-D operation mode select bit 1	0 : Any mode other than repeat sweep mode 1	O	O
BITS	8/10-bit mode select bit	0 : 8-bit mode 1 : 10-bit mode	O	O
CKS1	Frequency select bit 1	0 : $f_{AD}/2$ or $f_{AD}/4$ is selected 1 : f_{AD} is selected	O	O
VCUT	Vref connect bit	1 : Vref connected	O	O
OPA0	External op-amp connection mode bit (Note 2)	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	O	O
OPA1			O	O

Note 1: If the A-D control register is rewritten during A-D conversion, the conversion result is indeterminate.
Note 2: Neither "01" nor "10" can be selected with the external op-amp connection mode bit.

Figure 96. 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 46 shows the specifications of repeat sweep mode 1. Figure 97 shows the A-D control register in repeat sweep mode 1.

Table 46. Repeat sweep mode 1 specifications

Item	Specification
Function	All pins perform repeat sweep A-D conversion, with emphasis on the pin or pins selected by the A-D sweep pin select bit Example : AN_0 selected $AN_0 \rightarrow AN_1 \rightarrow AN_0 \rightarrow AN_2 \rightarrow AN_0 \rightarrow AN_3$, 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	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)

A-D control register 0 (Note)

b7	b6	b5	b4	b3	b2	b1	b0
			1	1			

Symbol ADCON0 — Address 03D6₁₆ — When reset 00000XXX₂

Bit symbol	Bit name	Function	R	W
CH0	Analog input pin select bit	Invalid in repeat sweep mode 1	O	O
CH1			O	O
CH2			O	O
MD0	A-D operation mode select bit 0	b4 b3 1 1 : Repeat sweep mode 1	O	O
MD1			O	O
TRG	Trigger select bit	0 : Software trigger 1 : AD_{TRG} trigger	O	O
ADST	A-D conversion start flag	0 : A-D conversion disabled 1 : A-D conversion started	O	O
CKS0	Frequency select bit 0	0 : $f_{AD}/4$ is selected 1 : $f_{AD}/2$ is selected	O	O

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

A-D control register 1 (Note 1)

b7	b6	b5	b4	b3	b2	b1	b0
		1			1		

Symbol ADCON1 — Address 03D7₁₆ — When reset 00₁₆

Bit symbol	Bit name	Function	R	W
SCAN0	A-D sweep pin select bit	When repeat sweep mode 1 is selected b1 b0 0 0 : AN_0 (1 pin) 0 1 : AN_0, AN_1 (2 pins) 1 0 : AN_0 to AN_2 (3 pins) 1 1 : AN_0 to AN_3 (4 pins)	O	O
SCAN1			O	O
MD2	A-D operation mode select bit 1	1 : Repeat sweep mode 1	O	O
BITS	8/10-bit mode select bit	0 : 8-bit mode 1 : 10-bit mode	O	O
CKS1	Frequency select bit 1	0 : $f_{AD}/2$ or $f_{AD}/4$ is selected 1 : f_{AD} is selected	O	O
VCUT	Vref connect bit	1 : Vref connected	O	O
OPA0	External op-amp connection mode bit (Note 2)	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	O	O
OPA1			O	O

Note 1: If the A-D control register is rewritten during A-D conversion, the conversion result is indeterminate.
Note 2: Neither ‘01’ nor ‘10’ can be selected with the external op-amp connection mode bit.

Figure 97. 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 03D4$_{16}$) to “1”. When sample and hold is selected, the rate of conversion of each pin increases. As a result, a 28 f AD cycle is achieved with 8-bit resolution and 33 f 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 03D7$_{16}$) 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 03D7$_{16}$) 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 03D7$_{16}$) is “1” and bit 7 is “1”, input via AN$_0$ to AN$_7$ 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 98 is an example of how to connect the pins in external operation amp mode.

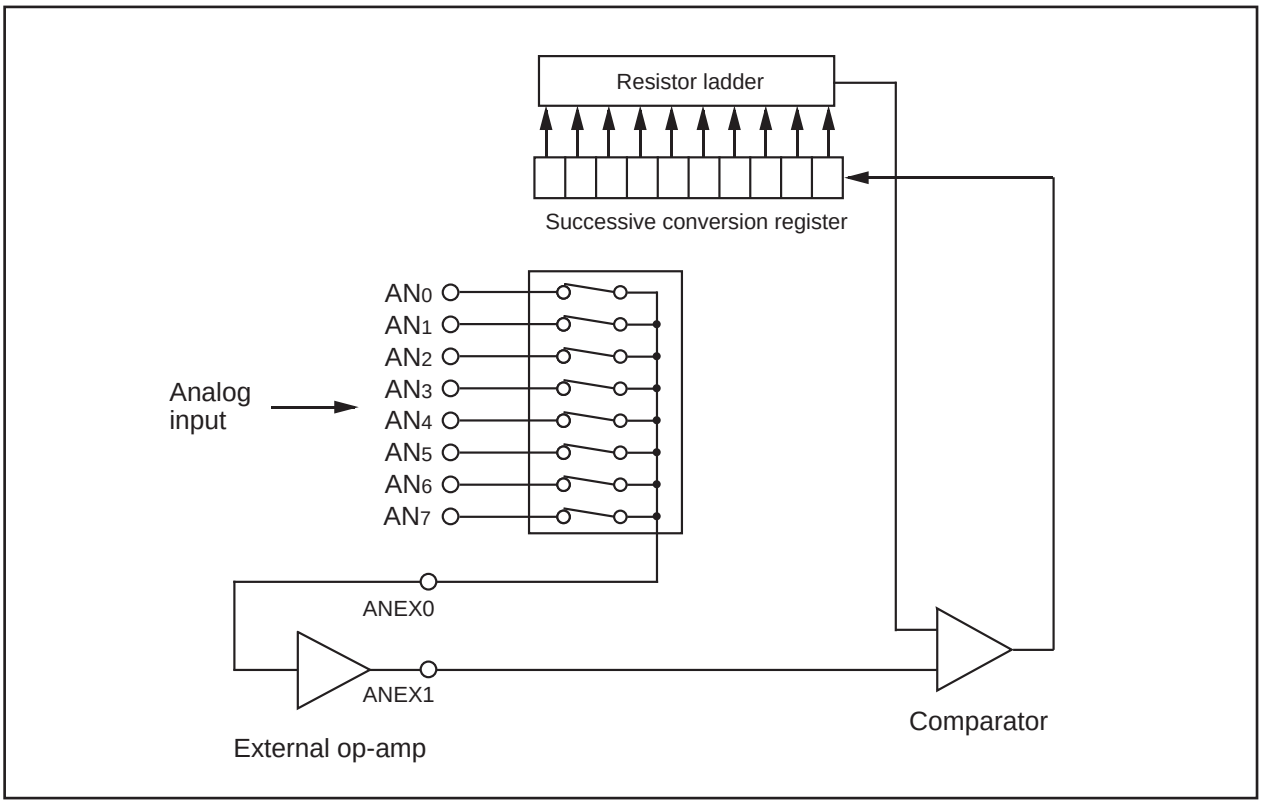


Figure 98. Example of external op-amp connection mode

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.

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 47 lists the performance of the D-A converter. Figure 99 shows the block diagram of the D-A converter. Figure 100 shows the D-A control register. Figure 101 shows the D-A converter equivalent circuit.

Table 47. Performance of D-A converter

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

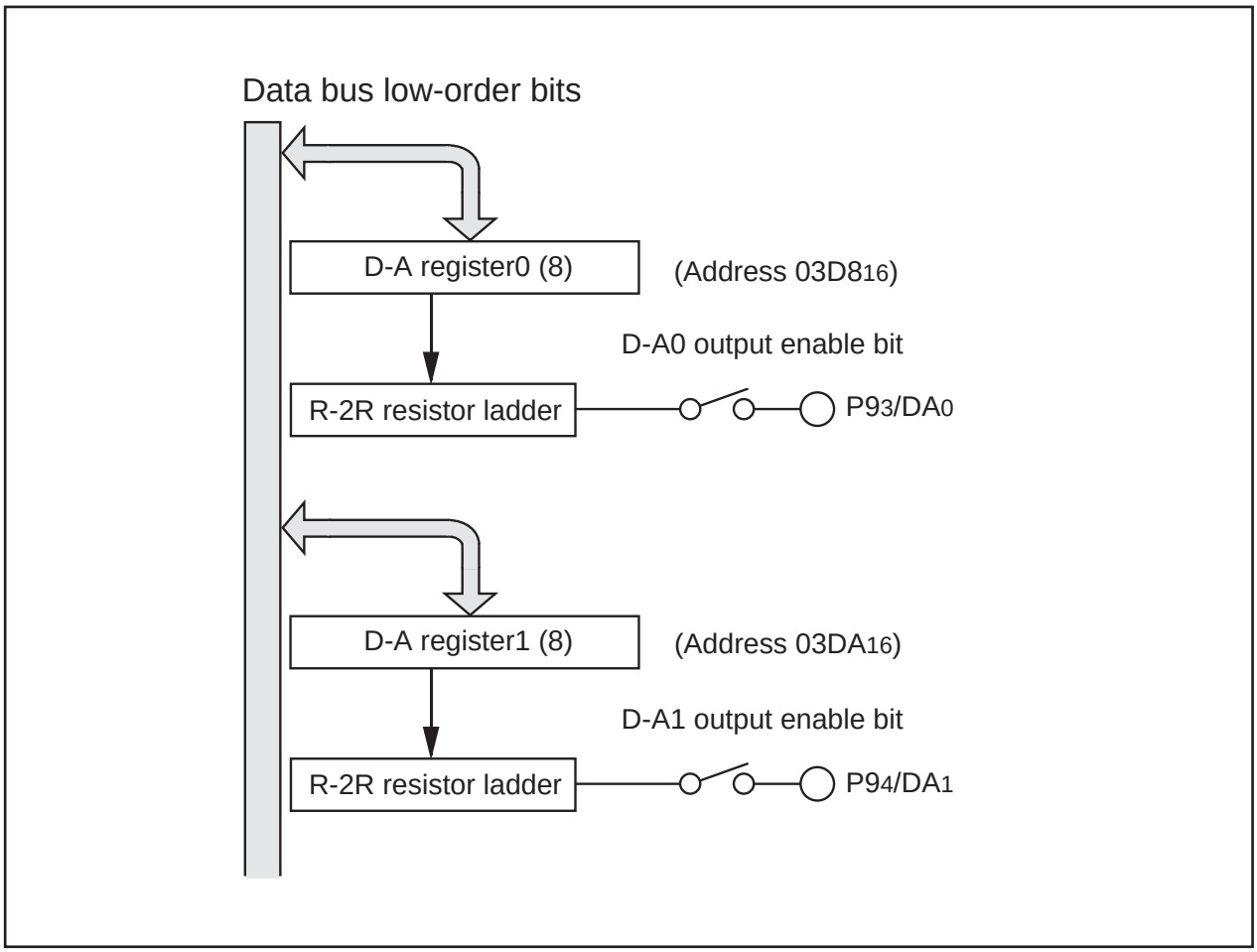
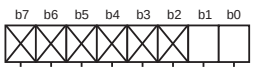


Figure 99. Block diagram of D-A converter

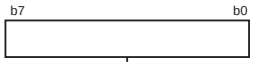
D-A control register



Symbol: DACON | Address: $03DC_{16}$ | When reset: 00_{16}

Bit symbol	Bit name	Function	R	W
DA0E	D-A0 output enable bit	0 : Output disabled 1 : Output enabled	○	○
DA1E	D-A1 output enable bit	0 : Output disabled 1 : Output enabled	○	○
Nothing is assigned. In an attempt to write to these bits, write “0”. The value, if read, turns out to be “0”.			–	–

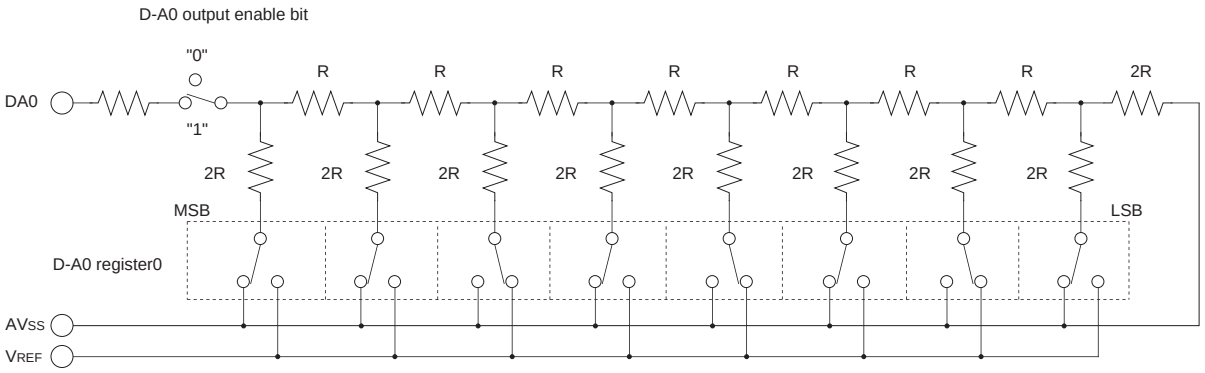
D-A register



Symbol: DAi (i = 0,1) | Address: $03D8_{16}$, $03DA_{16}$ | When reset: Indeterminate

Function	R	W
Output value of D-A conversion	○	○

Figure 100. D-A control register



Note 1: The above diagram shows an instance in which the D-A register is assigned $2A_{16}$.
Note 2: The same circuit as this is also used for D-A1.
Note 3: To reduce the current consumption when the D-A converter is not used, set the D-A output enable bit to 0 and set the D-A control register to 00_{16} so that no current flows in the resistors Rs and 2Rs.

Figure 101. 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 102 shows the block diagram of the CRC circuit. Figure 103 shows the CRC-related registers. Figure 104 shows the calculation example using the CRC calculation circuit

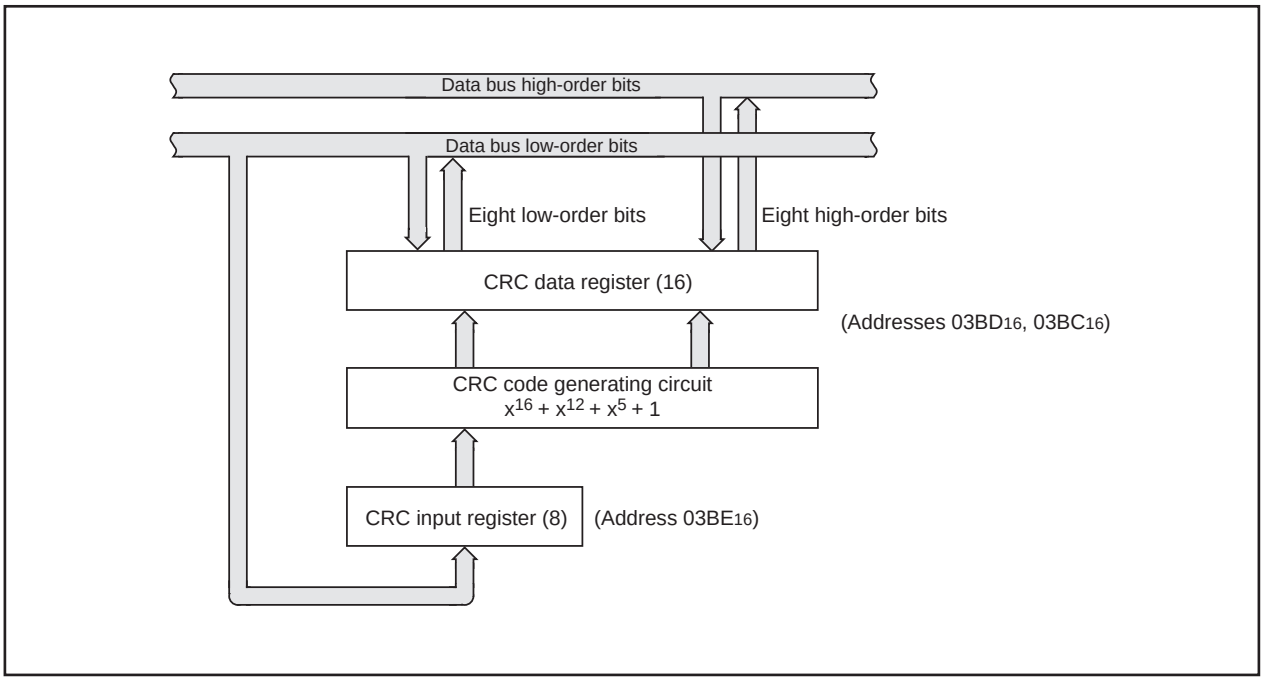


Figure 102. Block diagram of CRC circuit

CRC data register

(b15) (b8) b7 b0 b7 b0

Symbol	Address	When reset
CRCD	03BD16, 03BC16	Indeterminate

Function	Values that can be set	R	W
CRC calculation result output register	000016 to FFFF16	O	O

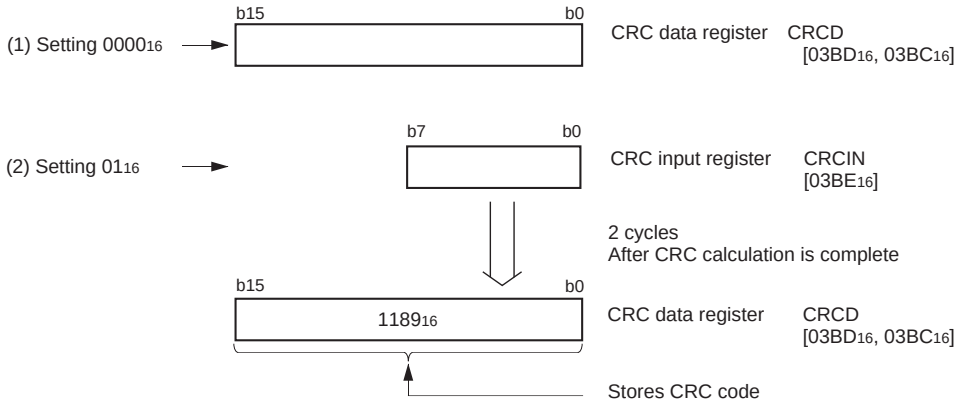
CRC input register

b7 b0

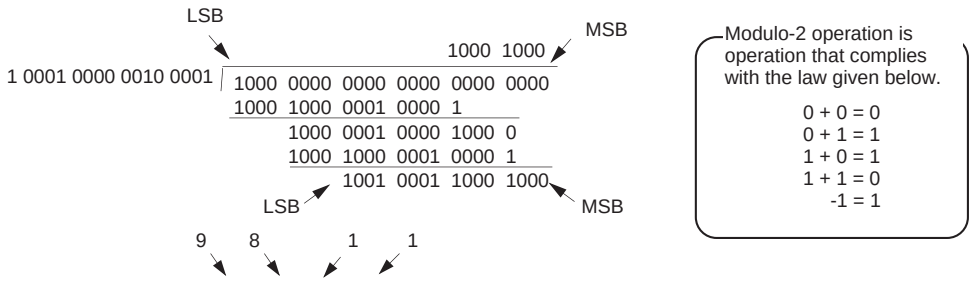
Symbo	Address	When reset
CRCIN	03BE16	Indeterminate

Function	Values that can be set	R	W
Data input register	0016 to FF16	O	O

Figure 103. CRC-related registers



The code resulting from sending 01_{16} in LSB first mode is (1000 0000). Thus the CRC code in the generating polynomial, $(X^{16} + X^{12} + X^5 + 1)$, becomes the remainder resulting from dividing (1000 0000) X^{16} by (1 0001 0000 0010 0001) in conformity with the modulo-2 operation.



Thus the CRC code becomes (1001 0001 1000 1000). Since the operation is in LSB first mode, the (1001 0001 1000 1000) corresponds to 1189_{16} in hexadecimal notation. If the CRC operation in MSB first mode is necessary in the CRC operation circuit built in the M16C, switch between the LSB side and the MSB side of the input-holding bits, and carry out the CRC operation. Also switch between the MSB and LSB of the result as stored in CRC data.

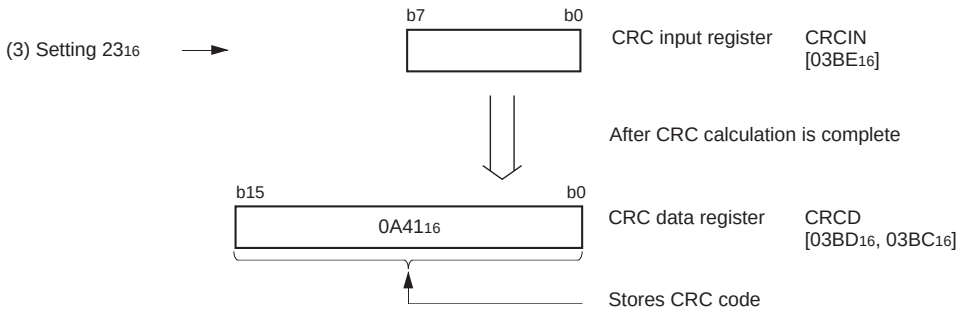


Figure 104. Calculation example using the CRC calculation circuit

Programmable I/O Ports

There are 87 programmable I/O ports: P0 to P10 (excluding P8$_5$). 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. P8$_5$ is an input-only port and has no built-in pull-up resistance.

Figures 105 to 108 show the programmable I/O ports. Figure 109 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 110 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.

Note: There is no direction register bit for P8$_5$.

(2) Port registers

Figure 111 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.

(3) Pull-up control registers

Figure 112 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, P0 to P5 operate as the bus and the pull-up control register setting is invalid.

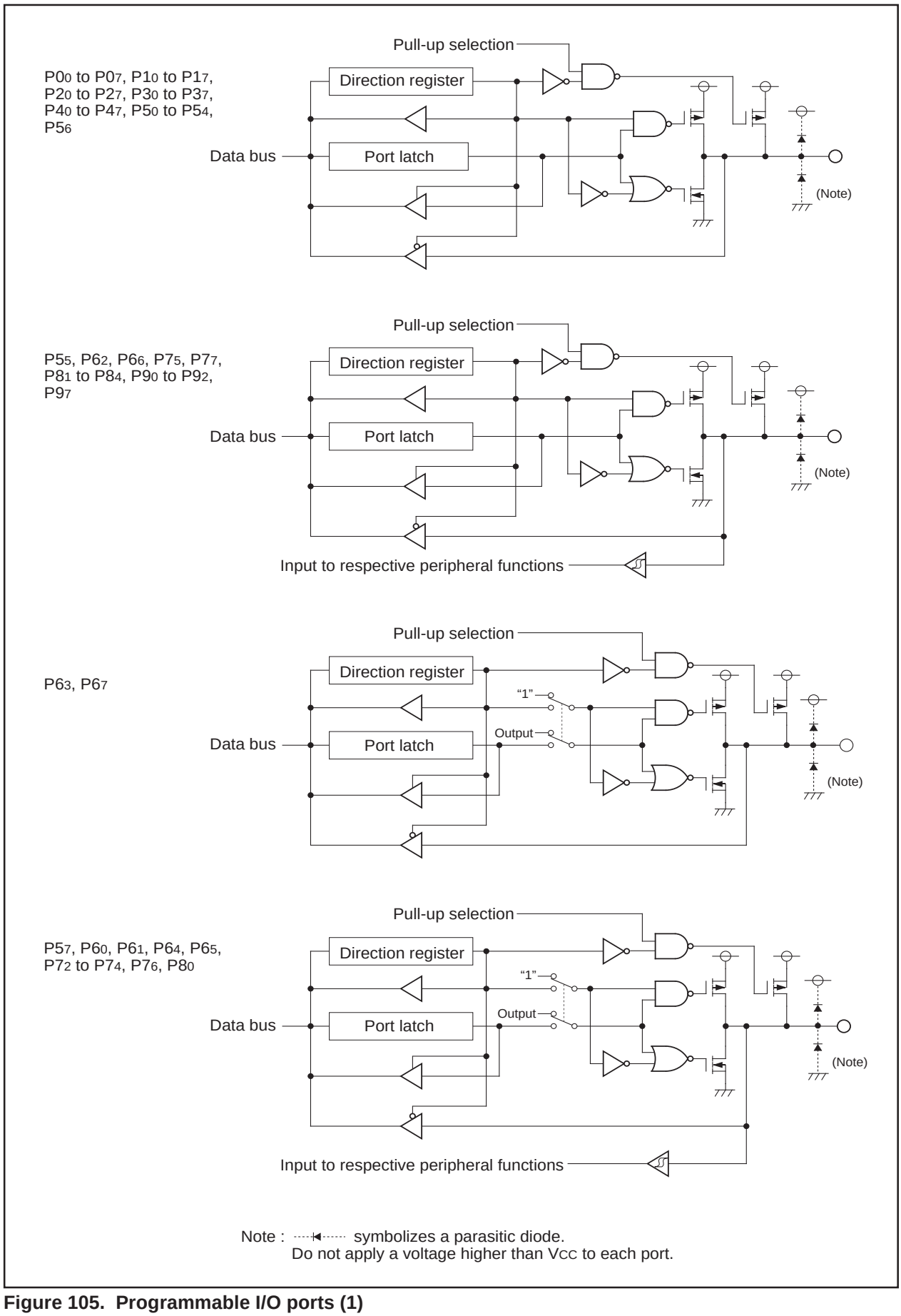


Figure 105. Programmable I/O ports (1)

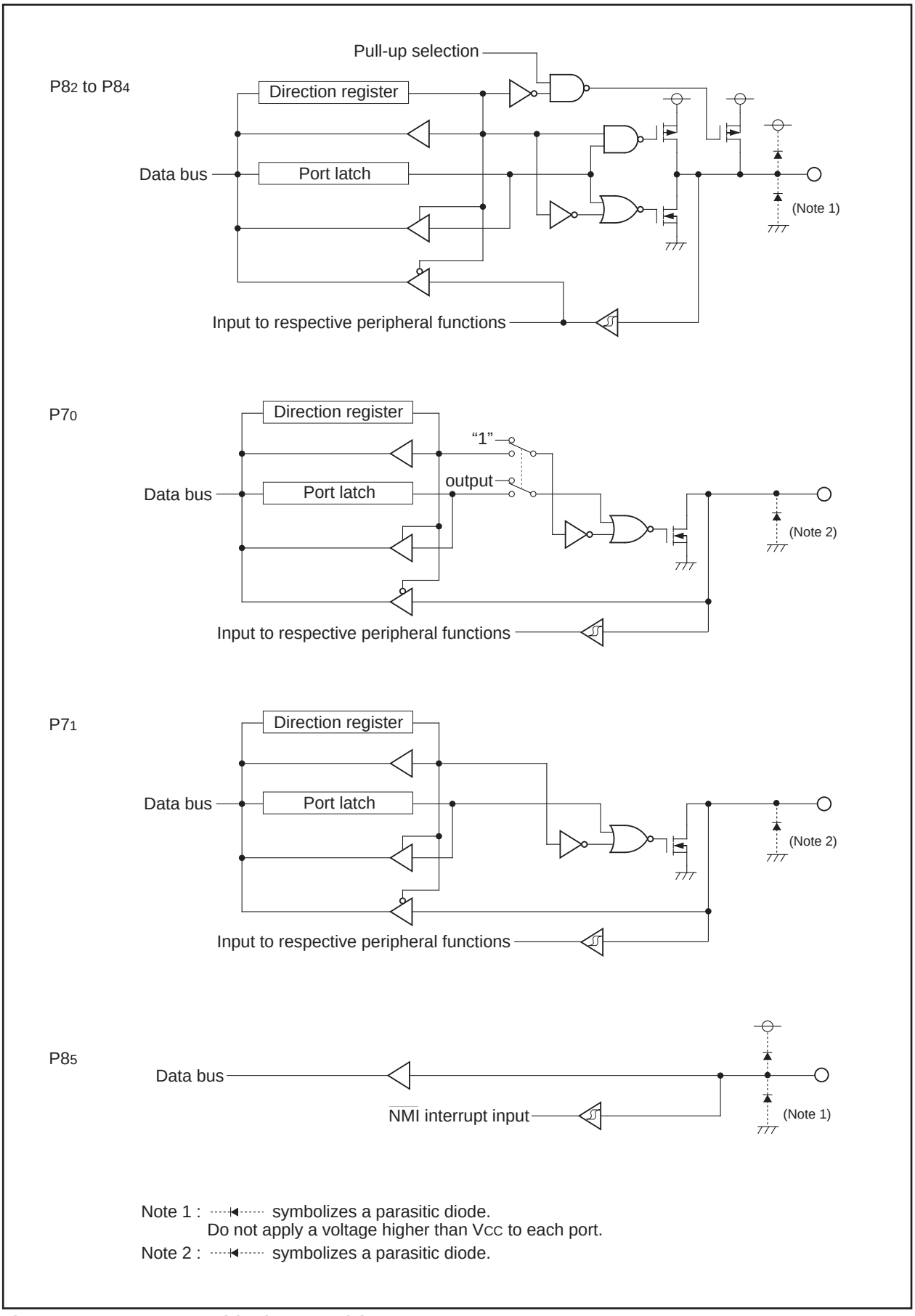


Figure 106. Programmable I/O ports (2)

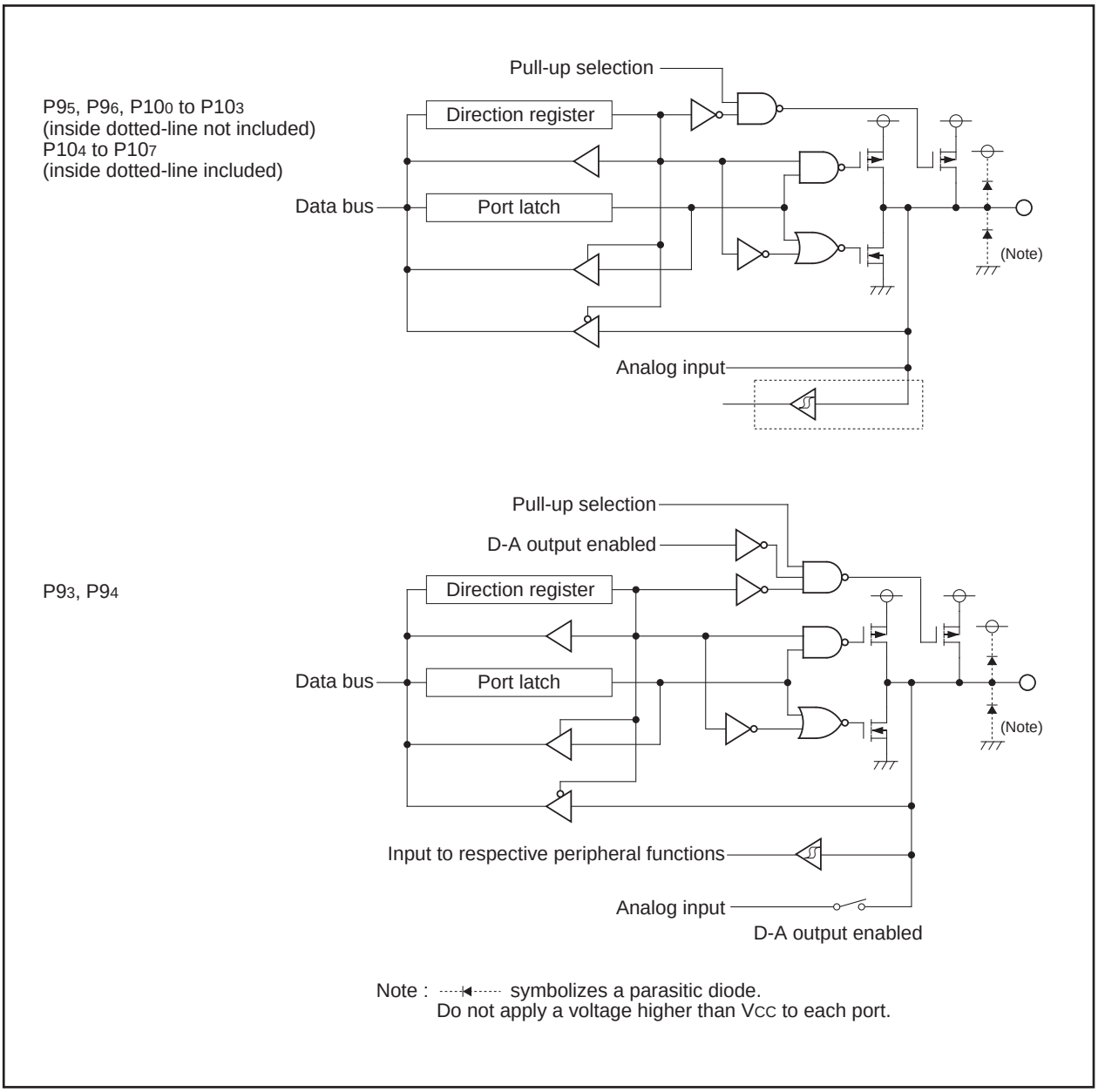


Figure 107. Programmable I/O ports (3)

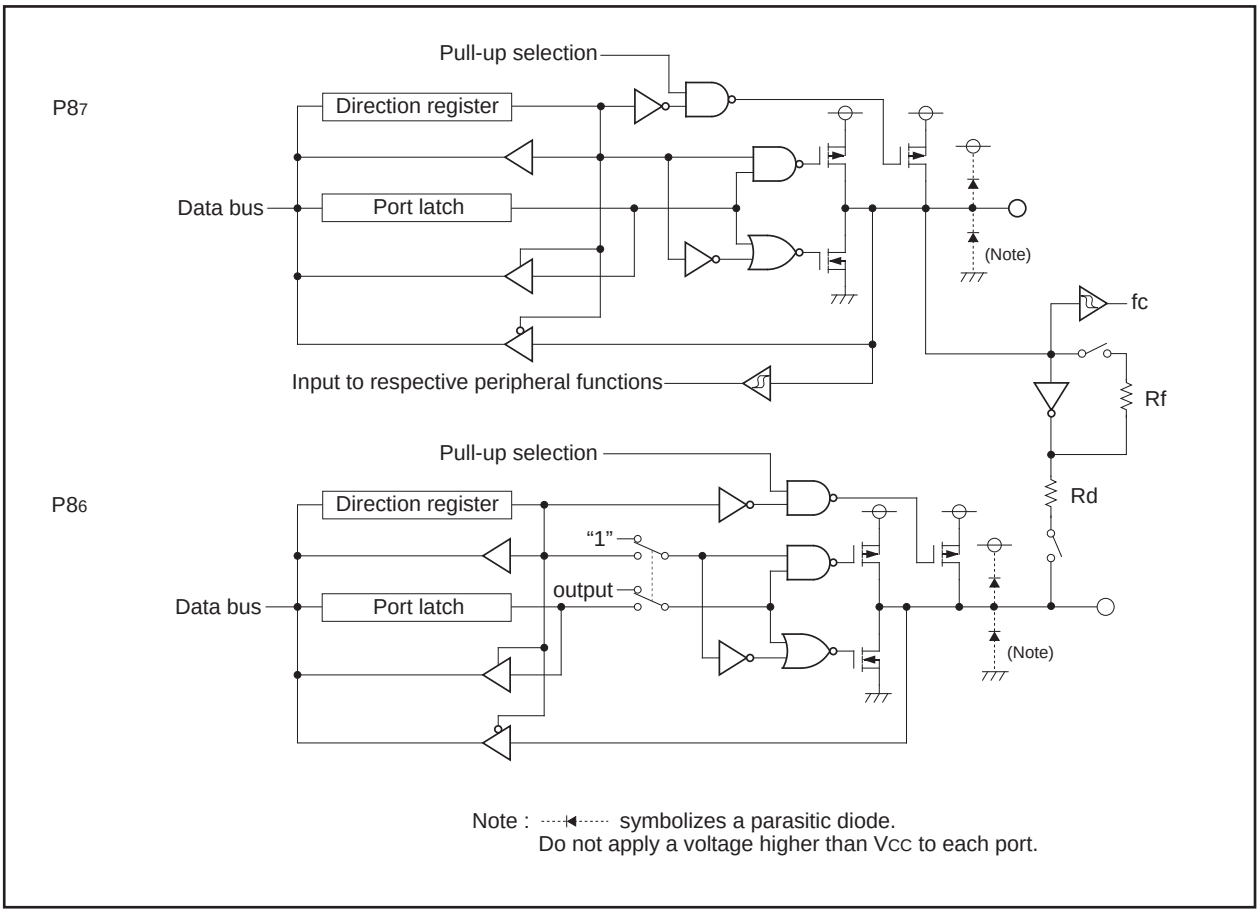


Figure 108. Programmable I/O ports (4)

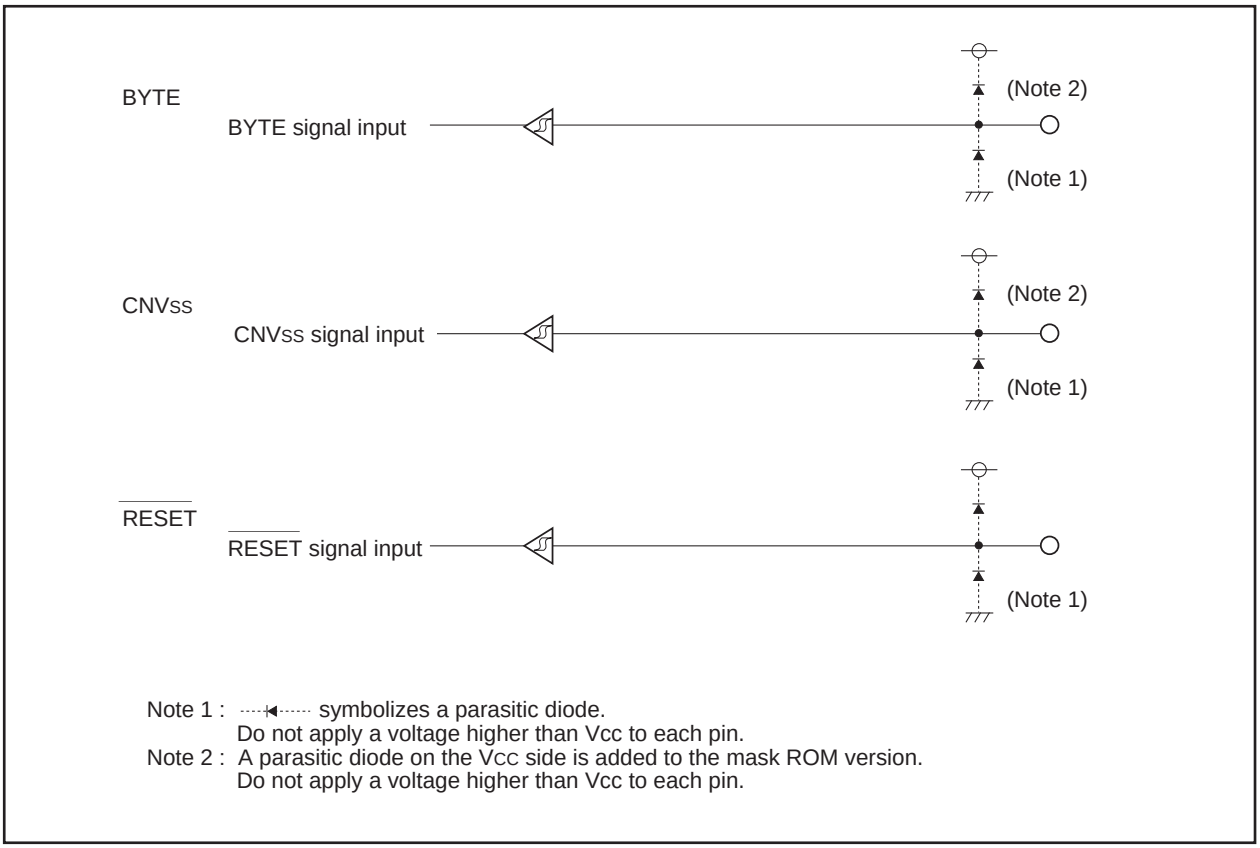


Figure 109. I/O pins

Port Pi direction register (Note)

b7	b6	b5	b4	b3	b2	b1	b0

Symbol: PDi (i = 0 to 10, except 8)
Address: 03E2$_{16}$, 03E3$_{16}$, 03E6$_{16}$, 03E7$_{16}$, 03EA$_{16}$, 03EB$_{16}$, 03EE$_{16}$, 03EF$_{16}$, 03F3$_{16}$, 03F6$_{16}$
When reset: 00$_{16}$

Bit symbol	Bit name	Function	R	W
PDi_0	Port Pi$_0$ direction register	0 : Input mode (Functions as an input port) 1 : Output mode (Functions as an output port) (i = 0 to 10 except 8)	○	○
PDi_1	Port Pi$_1$ direction register		○	○
PDi_2	Port Pi$_2$ direction register		○	○
PDi_3	Port Pi$_3$ direction register		○	○
PDi_4	Port Pi$_4$ direction register		○	○
PDi_5	Port Pi$_5$ direction register		○	○
PDi_6	Port Pi$_6$ direction register		○	○
PDi_7	Port Pi$_7$ direction register		○	○

Note: Set bit 2 of protect register (address 000A$_{16}$) to “1” before rewriting to the port P9 direction register.

Port P8 direction register

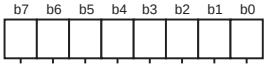
b7	b6	b5	b4	b3	b2	b1	b0
		☒					

Symbol: PD8
Address: 03F2$_{16}$
When reset: 00X00000$_2$

Bit symbol	Bit name	Function	R	W
PD8_0	Port P8$_0$ direction register	0 : Input mode (Functions as an input port) 1 : Output mode (Functions as an output port)	○	○
PD8_1	Port P8$_1$ direction register		○	○
PD8_2	Port P8$_2$ direction register		○	○
PD8_3	Port P8$_3$ direction register		○	○
PD8_4	Port P8$_4$ direction register		○	○
Nothing is assigned. In an attempt to write to this bit, write “0”. The value, if read, turns out to be indeterminate.			—	—
PD8_6	Port P8$_6$ direction register	0 : Input mode (Functions as an input port) 1 : Output mode (Functions as an output port)	○	○
PD8_7	Port P8$_7$ direction register		○	○

Figure 110. Direction register

Port Pi register

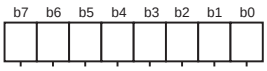


Symbol	Address	When reset
Pi (i = 0 to 10, except 8)	03E0$_{16}$, 03E1$_{16}$, 03E4$_{16}$, 03E5$_{16}$, 03E8$_{16}$	Indeterminate
	03E9$_{16}$, 03EC$_{16}$, 03ED$_{16}$, 03F1$_{16}$, 03F4$_{16}$	Indeterminate

Bit symbol	Bit name	Function	R	W
PDi_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) (i = 0 to 10 except 8)	○	○
PDi_1	Port Pi$_1$ register		○	○
PDi_2	Port Pi$_2$ register		○	○
PDi_3	Port Pi$_3$ register		○	○
PDi_4	Port Pi$_4$ register		○	○
PDi_5	Port Pi$_5$ register		○	○
PDi_6	Port Pi$_6$ register		○	○
PDi_7	Port Pi$_7$ register		○	○

Note : Since P7$_0$ and P7$_1$ are N-channel open drain ports, the data is high-impedance.

Port P8 register

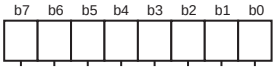


Symbol	Address	When reset
P8	03F0$_{16}$	Indeterminate

Bit symbol	Bit name	Function	R	W
PD8_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	○	○
PD8_1	Port P8$_1$ register		○	○
PD8_2	Port P8$_2$ register		○	○
PD8_3	Port P8$_3$ register		○	○
PD8_4	Port P8$_4$ register		○	○
PD8_5	Port P8$_5$ register		○	×
PD8_6	Port P8$_6$ register		○	○
PD8_7	Port P8$_7$ register		○	○

Figure 111. Port register

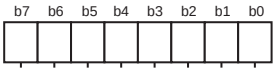
Pull-up control register 0



Symbol: PUR0 | Address: 03FC16 | When reset: 0016

Bit symbol	Bit name	Function	R	W
PU00	P00 to P03 pull-up	The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high	O	O
PU01	P04 to P07 pull-up		O	O
PU02	P10 to P13 pull-up		O	O
PU03	P14 to P17 pull-up		O	O
PU04	P20 to P23 pull-up		O	O
PU05	P24 to P27 pull-up		O	O
PU06	P30 to P33 pull-up		O	O
PU07	P34 to P37 pull-up		O	O

Pull-up control register 1

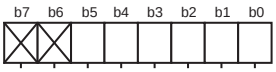


Symbol: PUR1 | Address: 03FD16 | When reset: 0016

Bit symbol	Bit name	Function	R	W
PU10	P40 to P43 pull-up	The corresponding port is pulled high with a pull-up resistor 0 : Not pulled high 1 : Pulled high	O	O
PU11	P44 to P47 pull-up		O	O
PU12	P50 to P53 pull-up		O	O
PU13	P54 to P57 pull-up		O	O
PU14	P60 to P63 pull-up		O	O
PU15	P64 to P67 pull-up		O	O
PU16	P70 to P73 pull-up (Note)		O	O
PU17	P74 to P77 pull-up		O	O

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

Pull-up control register 2



Symbol: PUR2 | Address: 03FE16 | When reset: 0016

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	O	O
PU21	P84 to P87 pull-up (Except P85)		O	O
PU22	P90 to P93 pull-up		O	O
PU23	P94 to P97 pull-up		O	O
PU24	P100 to P103 pull-up		O	O
PU25	P104 to P107 pull-up		O	O
Nothing is assigned. In an attempt to write to these bits, write “0”. The value, if read, turns out to be “0”.			—	—

Figure 112. Pull-up control register

Table 48. Example connection of unused pins in single-chip mode

Pin name	Connection
Ports P0 to P10 (excluding P8$_5$)	After setting for input mode, connect every pin to V_{SS} or V_{CC} via a resistor; or after setting for output mode, leave these pins open.
X_{OUT} (Note)	Open
$\overline{NMI}$	Connect via resistor to V_{CC} (pull-up)
AV_{CC}	Connect to V_{CC}
AV_{SS}, V_{REF}, BYTE	Connect to V_{SS}

Note: With external clock input to X_{IN} pin.

Table 49. Example connection of unused pins in memory expansion mode and microprocessor mode

Pin name	Connection
Ports P6 to P10 (excluding P8$_5$)	After setting for input mode, connect every pin to V_{SS} or V_{CC} via a resistor; or after setting for output mode, leave these pins open.
$\overline{BHE}$, ALE, $\overline{HLDA}$, X_{OUT}(Note), BCLK	Open
$\overline{HOLD}$, $\overline{RDY}$, $\overline{NMI}$	Connect via resistor to V_{CC} (pull-up)
AV_{CC}	Connect to V_{CC}
AV_{SS}, V_{REF}	Connect to V_{SS}

Note: With external clock input to X_{IN} pin.

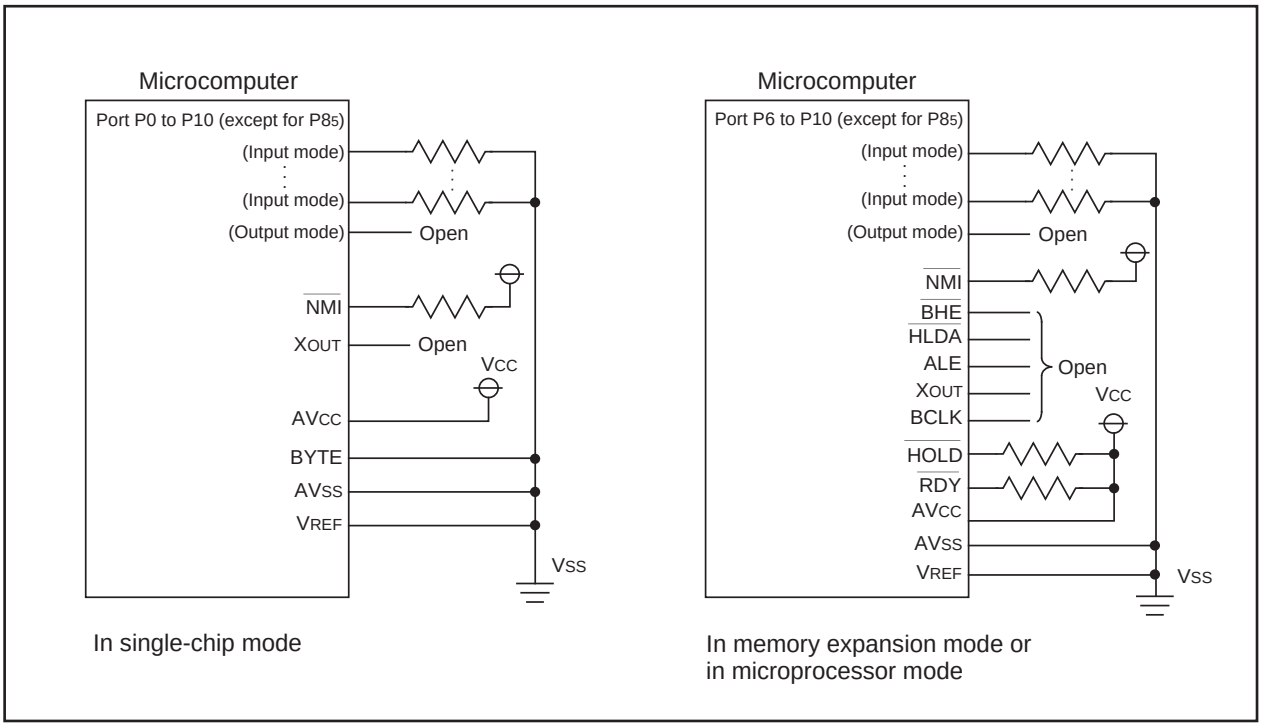


Figure 113. Example connection of unused pins

Usage Precaution

Timer A (timer mode)

(1) 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 gets "$FFFF_{16}$". 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.

Timer A (event counter mode)

(1) 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 gets "$FFFF_{16}$" by underflow or "0000_{16}" 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.

(2) When stop counting in free run type, set timer again.

Timer A (one-shot timer mode)

(1) 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 TAi_{OUT} pin outputs "L" level.
- The interrupt request generated and the timer Ai interrupt request bit goes to "1".

(2) 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.

Timer A (pulse width modulation mode)

(1) 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.

(2) Setting the count start flag to "0" while PWM pulses are being output causes the counter to stop counting. If the TAi_{OUT} 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 TAi_{OUT} pin is outputting an "L" level in this instance, the level does not change, and the timer Ai interrupt request bit does not becomes "1".

Timer B (timer mode, event counter mode)

(1) 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 gets "$FFFF_{16}$". 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.

Timer B (pulse period/pulse width measurement mode)

(1) If changing the measurement mode select bit is set after a count is started, the timer Bi interrupt request bit goes to "1".

(2) 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.

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 μs or longer.

(2) When changing A-D operation mode, select analog input pin again.

(3) Using one-shot mode or single sweep mode
Read the correspondence A-D register after confirming A-D conversion is finished. (It is known by A-D conversion interrupt request bit.)

(4) Using repeat mode, repeat sweep mode 0 or repeat sweep mode 1
Use the undivided main clock as the internal CPU clock.

Stop Mode and Wait Mode

(1) When returning from stop mode by hardware reset, $\overline{\text{RESET}}$ pin must be set to "L" level until main clock oscillation is stabilized.

(2) 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 every-clock stop 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 every-clock stop bit to 1.

Interrupts

(1) Reading address 00000_{16}

- When maskable interrupt is occurred, CPU read 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 00000_{16} will then be set to "0".
Reading address 00000_{16} by software sets enabled highest priority interrupt source request bit to "0".
Though the interrupt is generated, the interrupt routine may not be executed.
Do not read address 00000_{16} by software.

(2) Setting the stack pointer

- The value of the stack pointer immediately after reset is initialized to 0000_{16}. 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 point 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 $\overline{NMI}$ interrupt

- As for the $\overline{NMI}$ interrupt pin, an interrupt cannot be disabled. Connect it to the V_{CC} pin via a resistor (pull-up) if unused. Be sure to work on it.
- Do not get either into stop mode or into wait mode with the $\overline{NMI}$ pin set to “L”.

(4) External interrupt

- When the polarity of the $\overline{INT_0}$ to $\overline{INT_2}$ pins is changed, the interrupt request bit is sometimes set to "1". After changing the polarity, set the interrupt request bit to "0".

(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                     ; 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

External ROM version

The external ROM version is operated only in microprocessor mode, so be sure to perform the following:

- Connect CNVss pin to Vcc.
- Fix the processor mode bit to "11$_2$"

Built-in PROM version

(1) All built-in PROM versions

High voltage is required to program to the built-in PROM. Be careful not to apply excessive voltage. Be especially careful during power-on.

(2) One Time PROM version

One Time PROM versions shipped in blank (M30612E4FP, M30612E4GP, M30612E8FP, M30612E8GP, M30610ECFP, M30610ECGP), of which built-in PROMs are programmed by users, are also provided. For these microcomputers, a programming test and screening are not performed in the assembly process and the following processes. To improve their reliability after programming, we recommend to program and test as flow shown in Figure 114 before use.

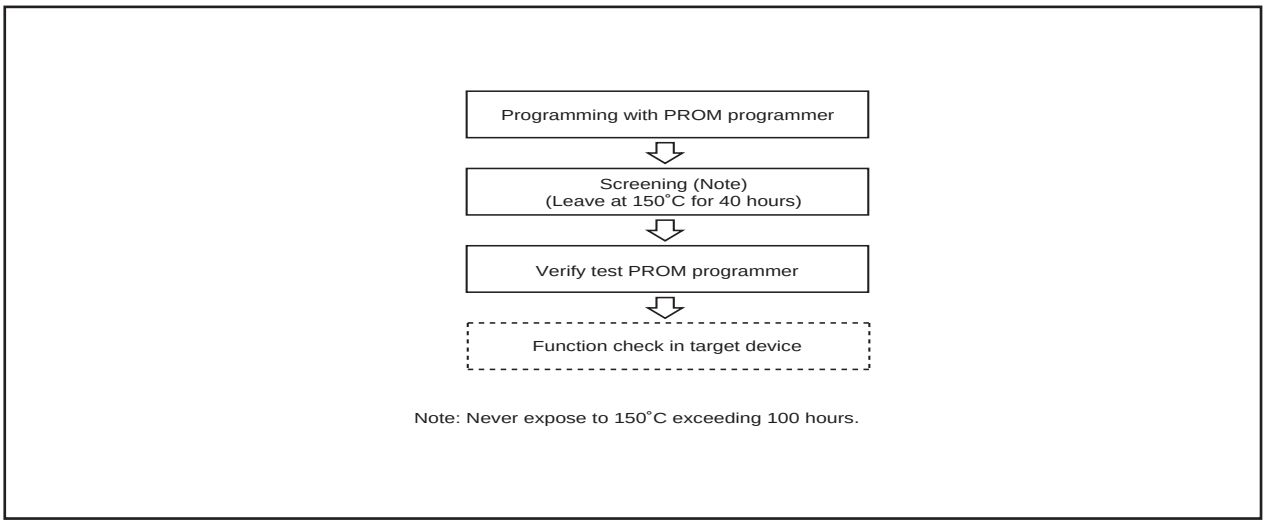


Figure 114. Programming and test flow for One Time PROM version

(3) EPROM version

- Cover the transparent glass window with a shield or others during the read mode because exposing to sun light or fluorescent lamp can cause erasing the information.
  A shield to cover the transparent window is available from Mitsubishi Electric Corp. Be careful that the shield does not touch the EPROM lead pins.
- Clean the transparent glass before erasing. Fingers' flat and paste disturb the passage of ultraviolet rays and may affect badly the erasure capability.
- The EPROM version is a tool only for program development (for evaluation), and do not use it for the mass product run.

Items to be submitted when ordering masked ROM version

Please submit the following when ordering masked ROM products:

(1) Mask ROM confirmation form

(2) Mark specification sheet

(3) ROM data : EPROMs or floppy disks

*: In the case of EPROMs, there sets of EPROMs are required per pattern.

*: In the case of floppy disks, 3.5-inch double-sided high-density disk (IBM format) is required per pattern.

Items to be submitted when ordering data to be written to ROM

Please submit the following when ordering data to be written to one-time PROM products at the factory:

(1) ROM writing order form

(2) Mark specification sheet

(3) ROM data : EPROMs or floppy disks

*: In the case of EPROMs, there sets of EPROMs are required per pattern.

*: In the case of floppy disks, 3.5-inch double-sided high-density disk (IBM format) is required per pattern.

Table 50. Absolute maximum ratings

Symbol	Parameter	Condition	Rated value	Unit
V_{CC}	Supply voltage	V_{CC} = AV$_{CC}$	–0.3 to 6.5 (Note 3)	V
AVcc	Analog supply voltage	V_{CC} = AV$_{CC}$	–0.3 to 6.5 (Note 3)	V
V_I	Input 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$_7$, P9$_0$ to P9$_7$, P10$_0$ to P10$_7$, $\overline{\text{RESET}}$, V_{REF}, X_{IN}		–0.3 to Vcc+0.3	V
V_I	Input voltage P7$_0$, P7$_1$, CNVss, BYTE		–0.3 to 6.5 (Note 1, Note 3)	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 Vcc+0.3	V
V_O	Output voltage P7$_0$, P7$_1$		–0.3 to 6.5 (Note 3)	V
P_d	Power dissipation	Ta=25 ˚C	300	mW
T_{opr}	Operating ambient temperature		–20 to 85 / –40 to 85 (Note 2)	˚C
T_{stg}	Storage temperature		–65 to 150	˚C

Note 1: When writing to EPROM ,only CNVss is –0.3 to 13 (V) .

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

Note 3: –0.3V to 6.5V for M30610M8A, M30610MAA, M30610MCA, M30612M4A, M30612M8A, M30612MAA, M30612MCA, M30610SA and M30612SA.
Otherwise, –0.3V to 7.0V is used.

Table 51. Recommended operating conditions (referenced to Vcc = 2.7V to 5.5V at Ta = –20 to 85ºC / –40 to 85ºC (Note 3) unless otherwise specified)

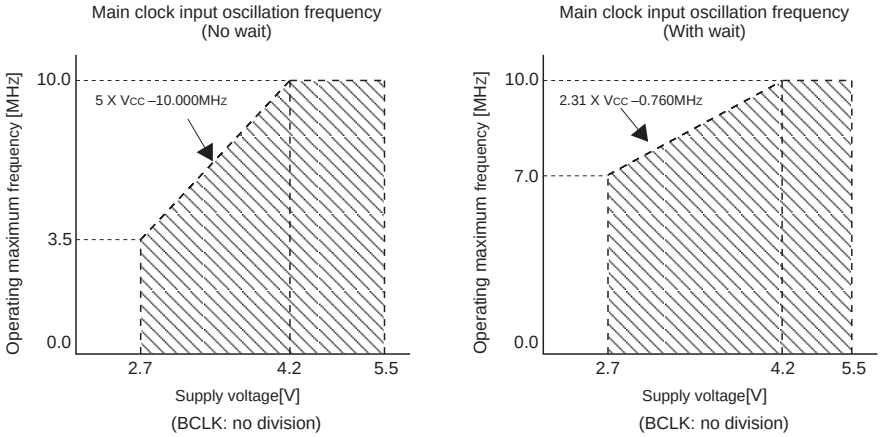
Symbol	Parameter			Standard			Unit
				Min	Typ.	Max.	
Vcc	Supply voltage			2.7	5.0	5.5	V
AVcc	Analog supply voltage				Vcc		V
Vss	Supply voltage				0		V
AVss	Analog supply voltage				0		V
V_{IH}	HIGH input voltage	$P3_1$ to $P3_7$, $P4_0$ to $P4_7$, $P5_0$ to $P5_7$, $P6_0$ to $P6_7$, $P7_2$ to $P7_7$, $P8_0$ to $P8_7$, $P9_0$ to $P9_7$, $P10_0$ to $P10_7$, X_{IN}, $\overline{RESET}$, CNVss, BYTE		0.8Vcc		Vcc	V
		$P7_0$, $P7_1$		0.8Vcc		6.5	V
		$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P2_0$ to $P2_7$, $P3_0$ (during single-chip mode)		0.8Vcc		Vcc	V
		$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P2_0$ to $P2_7$, $P3_0$ (data input function during memory expansion and microprocessor modes)		0.5Vcc		Vcc	V
V_{IL}	LOW input voltage	$P3_1$ 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}, $\overline{RESET}$, CNVss, BYTE		0		0.2Vcc	V
		$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P2_0$ to $P2_7$, $P3_0$ (during single-chip mode)		0		0.2Vcc	V
		$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P2_0$ to $P2_7$, $P3_0$ (data input function during memory expansion and microprocessor modes)		0		0.16Vcc	V
$I_{OH (peak)}$	HIGH peak output current	$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P2_0$ to $P2_7$, $P3_0$ to $P3_7$, $P4_0$ to $P4_7$, $P5_0$ to $P5_7$, $P6_0$ to $P6_7$, $P7_2$ to $P7_7$, $P8_0$ to $P8_4$, $P8_6$, $P8_7$, $P9_0$ to $P9_7$, $P10_0$ to $P10_7$				-10.0	mA
$I_{OH (avg)}$	HIGH average output current	$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P2_0$ to $P2_7$, $P3_0$ to $P3_7$, $P4_0$ to $P4_7$, $P5_0$ to $P5_7$, $P6_0$ to $P6_7$, $P7_2$ to $P7_7$, $P8_0$ to $P8_4$, $P8_6$, $P8_7$, $P9_0$ to $P9_7$, $P10_0$ to $P10_7$				-5.0	mA
$I_{OL (peak)}$	LOW peak output current	$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P2_0$ to $P2_7$, $P3_0$ to $P3_7$, $P4_0$ to $P4_7$, $P5_0$ to $P5_7$, $P6_0$ to $P6_7$, $P7_0$ to $P7_7$, $P8_0$ to $P8_4$, $P8_6$, $P8_7$, $P9_0$ to $P9_7$, $P10_0$ to $P10_7$				10.0	mA
$I_{OL (avg)}$	LOW average output current	$P0_0$ to $P0_7$, $P1_0$ to $P1_7$, $P2_0$ to $P2_7$, $P3_0$ to $P3_7$, $P4_0$ to $P4_7$, $P5_0$ to $P5_7$, $P6_0$ to $P6_7$, $P7_0$ to $P7_7$, $P8_0$ to $P8_4$, $P8_6$, $P8_7$, $P9_0$ to $P9_7$, $P10_0$ to $P10_7$				5.0	mA
f (X_{IN})	Main clock input oscillation frequency		No wait	Vcc =4.0V to 5.5V	0		10	MHz
				Vcc =2.7V to 4.0V	0		5 X Vcc –10.000	MHz
			With wait	Vcc =4.0V to 5.5V	0		10	MHz
				Vcc =2.7V to 4.0V	0		2.31 X Vcc +0.760	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, $P8_6$, $P8_7$, P9, and P10 must be 80mA max. The total I_{OH} (peak) for ports P0, P1, P2, $P8_6$, $P8_7$, P9, and P10 must be 80mA max. The total I_{OL} (peak) for ports P3, P4, P5, P6, P7, and $P8_0$ to $P8_4$ must be 80mA max. The total I_{OH} (peak) for ports P3, P4, P5, P6, $P7_2$ to $P7_7$, and $P8_0$ to $P8_4$ must be 80mA max.

Note 3: Specify a product of –40 to 85°C to use it.

Note 4: The relationship between main clock input frequency and power supply voltage is as below.



Vcc = 5V

Table 52. Electrical characteristics (referenced to Vcc = 5V, Vss = 0V at Ta = 25°C, f(XIN) = 10MHz unless otherwise specified)

Symbol	Parameter		Measuring condition		Standard Min	Standard Typ.	Standard Max.	Unit
VOH	HIGH output voltage	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	IOH=-5mA		3.0			V
VOH	HIGH output voltage	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	IOH=-200µA		4.7			V
VOH	HIGH output voltage	XOUT	HIGHPOWER	IOH=-1mA	3.0			V
			LOWPOWER	IOH=-0.5mA	3.0			
	HIGH output voltage	XCOUT	HIGHPOWER	With no load applied		3.0		V
			LOWPOWER	With no load applied		1.6		
VOL	LOW output voltage	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	IOL=5mA				2.0	V
VOL	LOW output voltage	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	IOL=200µA				0.45	V
VOL	LOW output voltage	XOUT	HIGHPOWER	IOL=1mA			2.0	V
			LOWPOWER	IOL=0.5mA			2.0	
	LOW output voltage	XCOUT	HIGHPOWER	With no load applied		0		V
			LOWPOWER	With no load applied		0		
VT+-VT-	Hysteresis	HOLD, RDY, TA0IN to TA4IN, TB0IN to TB2IN, INT0 to INT2, ADTRG, CTS0, CTS1, CLK0, CLK1, TA2OUT to TA4OUT, NMI, KI0 to KI3			0.2		0.8	V
VT+-VT-	Hysteresis	RESET			0.2		1.8	V
IIH	HIGH input 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 P87, P90 to P97, P100 to P107, XIN, RESET, CNVss, BYTE	VI=5V				5.0	µA
IIL	LOW input 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 P87, P90 to P97, P100 to P107, XIN, RESET, CNVss, BYTE	VI=0V				-5.0	µA
RPULLUP	Pull-up resistance	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	VI=0V		30.0	50.0	167.0	kΩ
RfXIN	Feedback resistance XIN					1.0		MΩ
RfCXIN	Feedback resistance XCIN					6.0		MΩ
V RAM	RAM retention voltage		When clock is stopped		2.0			V
Icc	Power supply current		In single-chip mode, the output pins are open and other pins are Vss	f(XIN)=10MHz Square wave, no division		19.0	38.0	mA
				f(XCIN)=32kHz Square wave		90.0		µA
				f(XCIN)=32kHz When a WAIT instruction is executed		4.0		µA
				Ta=25°C when clock is stopped			1.0	µA
				Ta=85°C when clock is stopped			20.0	

Vcc = 5V

Table 53. A-D conversion characteristics (referenced to Vcc = AVcc = VREF = 5V, Vss = AVss = 0V at Ta = 25°C, f(XIN) = 10MHz unless otherwise specified)

Symbol	Parameter		Measuring condition		Standard			Unit
					Min.	Typ.	Max.	
–	Resolution		VREF = Vcc				10	Bits
–	Absolute accuracy	Sample & hold function not available	VREF = Vcc = 5V				±3	LSB
		Sample & hold function available(10bit)	VREF =Vcc = 5V	AN0 to AN7 input			±3	LSB
				ANEX0, ANEX1 input, External op-amp connection mode			±7	LSB
		Sample & hold function available(8bit)	VREF = Vcc = 5V				±2	LSB
RLADDER	Ladder resistance		VREF = Vcc		10		40	kΩ
tCONV	Conversion time(10bit)				3.3			µs
tCONV	Conversion time(8bit)				2.8			µs
tSAMP	Sampling time				0.3			µs
VREF	Reference voltage				2		Vcc	V
VIA	Analog input voltage				0		VREF	V

Table 54. D-A conversion characteristics (referenced to Vcc = 5V, Vss = AVss = 0V, VREF = 5V at Ta = 25°C, f(XIN) = 10MHz unless otherwise specified)

Symbol	Parameter	Measuring condition	Standard			Unit
			Min.	Typ.	Max.	
–	Resolution				8	Bits
–	Absolute accuracy				1.0	%
tsu	Setup time				3	µs
RO	Output resistance		4	10	20	kΩ
IVREF	Reference power supply input current	(Note)			1.5	mA

Note: This applies when using one D-A converter, with the D-A register for the unused D-A converter set to "00$_{16}$".
The A-D converter's ladder resistance is not included.
Also, when the Vref is unconnected at the A-D control register, IVREF is sent.

Vcc = 5V

Timing requirements (referenced to Vcc = 5V, Vss = 0V at Ta = 25°C unless otherwise specified)

Table 55. 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		15	ns
t_f	External clock fall time		15	ns

Table 56. 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
$t_{su(RDY-BCLK)}$	$\overline{RDY}$ input setup time	30		ns
$t_{su(HOLD-BCLK)}$	$\overline{HOLD}$ input setup time	40		ns
$t_{h(RD-DB)}$	Data input hold time	0		ns
$t_{h(BCLK-RDY)}$	$\overline{RDY}$ input hold time	0		ns
$t_{h(BCLK-HOLD)}$	$\overline{HOLD}$ input hold time	0		ns
$t_{d(BCLK-HLDA)}$	$\overline{HLDA}$ output delay time		40	ns

Note: Calculated according to the BCLK frequency as follows:

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

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

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

VCC = 5V

Timing requirements (referenced to VCC = 5V, VSS = 0V at Ta = 25°C unless otherwise specified)

Table 57. Timer A input (counter input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	100		ns
$t_{w(TAH)}$	TAiIN input HIGH pulse width	40		ns
$t_{w(TAL)}$	TAiIN input LOW pulse width	40		ns

Table 58. Timer A input (gating input in timer mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	400		ns
$t_{w(TAH)}$	TAiIN input HIGH pulse width	200		ns
$t_{w(TAL)}$	TAiIN input LOW pulse width	200		ns

Table 59. Timer A input (external trigger input in one-shot timer mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	200		ns
$t_{w(TAH)}$	TAiIN input HIGH pulse width	100		ns
$t_{w(TAL)}$	TAiIN input LOW pulse width	100		ns

Table 60. 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	100		ns
$t_{w(TAL)}$	TAiIN input LOW pulse width	100		ns

Table 61. 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

Vcc = 5V

Timing requirements (referenced to Vcc = 5V, Vss = 0V at Ta = 25°C unless otherwise specified)

Table 62. Timer B input (counter input in event counter mode)

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

Table 63. Timer B input (pulse period measurement mode)

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

Table 64. Timer B input (pulse width measurement mode)

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

Table 65. A-D trigger input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(AD)}$	$\overline{ADTRG}$ input cycle time (trigger able minimum)	1000		ns
$t_{w(ADL)}$	$\overline{ADTRG}$ input LOW pulse width	125		ns

Table 66. 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 67. External interrupt $\overline{INTi}$ inputs

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(INH)}$	$\overline{INTi}$ input HIGH pulse width	250		ns
$t_{w(INL)}$	$\overline{INTi}$ input LOW pulse width	250		ns

VCC = 5V

Switching characteristics (referenced to VCC = 5V, VSS = 0V at Ta = 25°C, CM15 = "1" unless otherwise specified)

Table 68. 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 115		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:

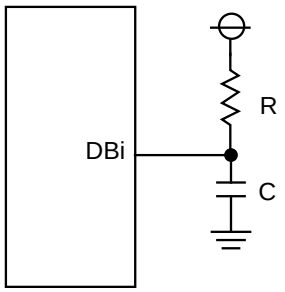
$$td(DB - WR) = \frac{10^9}{f(BCLK) \times 2} - 40 \quad [ns]$$

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 = 1kΩ, hold time of output "L" level is

$$t = -30pF \times 1k\Omega \times \ln (1 - 0.2V_{CC} / V_{CC})$$
$$= 6.7ns.$$



VCC = 5V

Switching characteristics (referenced to VCC = 5V, VSS = 0V at Ta = 25°C, CM15 = "1" unless otherwise specified)

Table 69. 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 115		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:

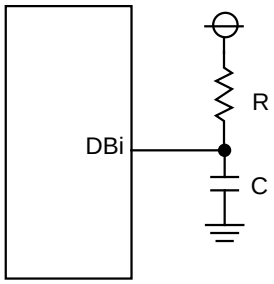
$$td(DB - WR) = \frac{10^9}{f(BCLK)} - 40 \quad [ns]$$

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 = 1kΩ, hold time of output "L" level is

$t = -30pF \times 1k\Omega \times \ln(1 - 0.2V_{CC} / V_{CC})$
$= 6.7ns.$



VCC = 5V

Switching characteristics (referenced to VCC = 5V, VSS = 0V at Ta = 25°C, CM15 = "1" unless otherwise specified)

Table 70. 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 115		25	ns
$t_{h(BCLK-AD)}$	Address output hold time (BCLK standard)		4		ns
$t_{h(RD-AD)}$	Address output hold time (RD standard)		(Note)		ns
$t_{h(WR-AD)}$	Address output hold time (WR standard)		(Note)		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)		(Note)		ns
$t_{h(WR-CS)}$	Chip select output hold time (WR standard)		(Note)		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)		(Note)		ns
$t_{h(WR-DB)}$	Data output hold time (WR standard)		(Note)		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)		(Note)		ns
$t_{h(ALE-AD)}$	ALE signal output hold time (Adderss 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:

$$th(RD - AD) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$th(WR - AD) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$th(RD - CS) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$th(WR - CS) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$td(DB - WR) = \frac{10^9 \times 3}{f(BCLK) \times 2} - 40 \quad [ns]$$

$$th(WR - DB) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$td(AD - ALE) = \frac{10^9}{f(BCLK) \times 2} - 25 \quad [ns]$$

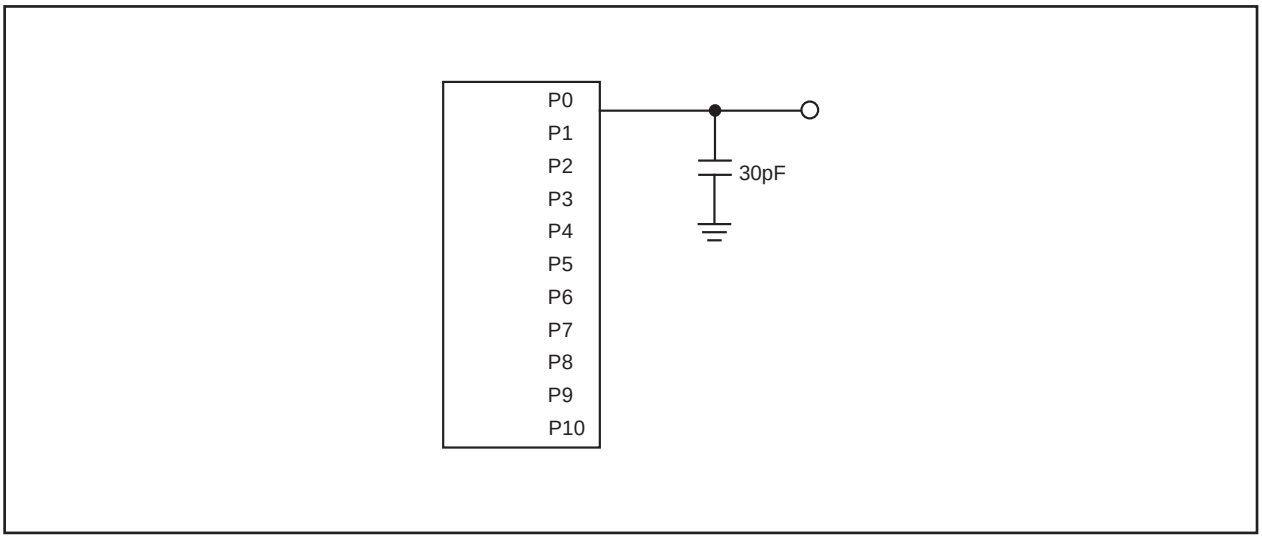
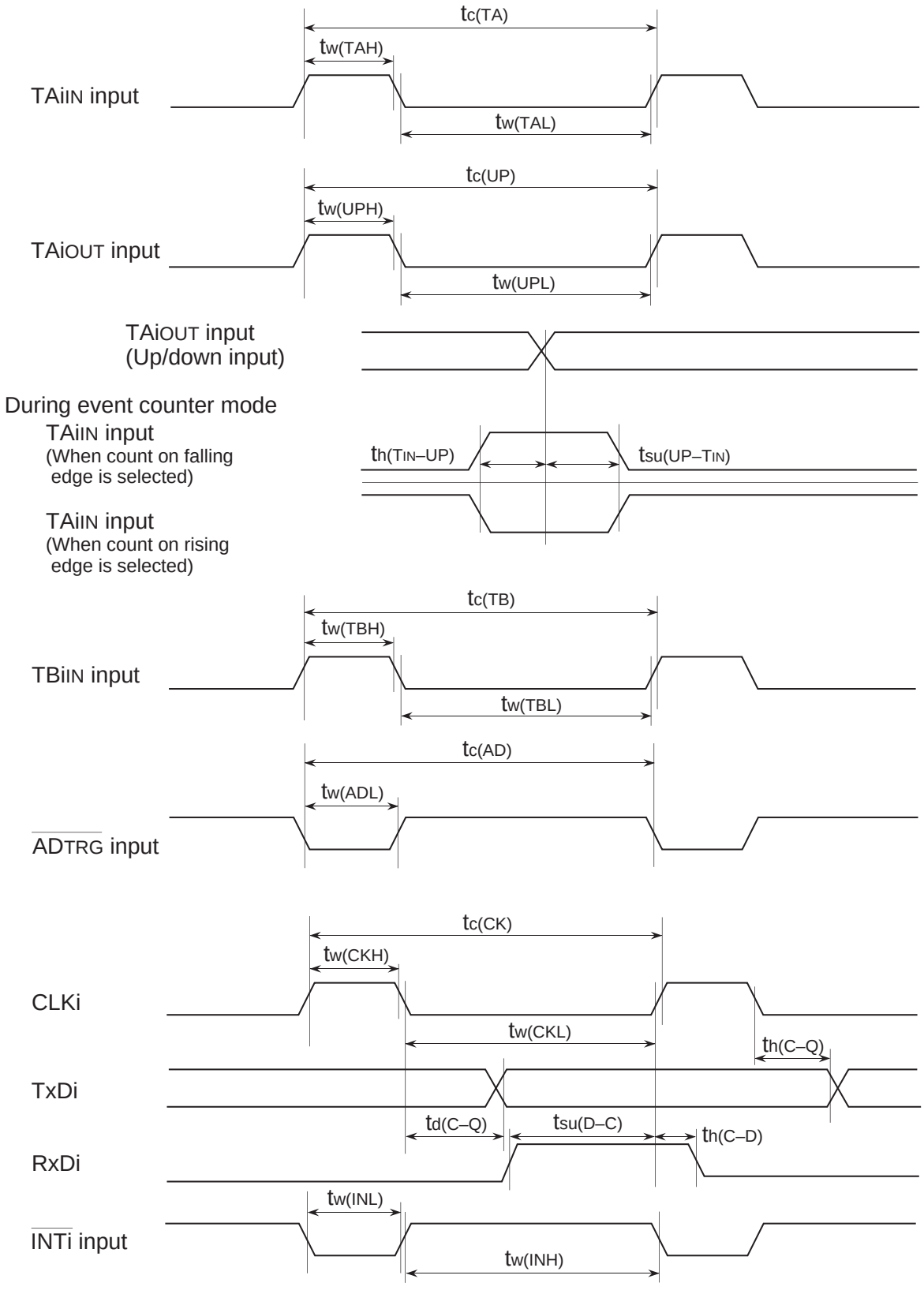


Figure 115. Port P0 to P10 measurement circuit

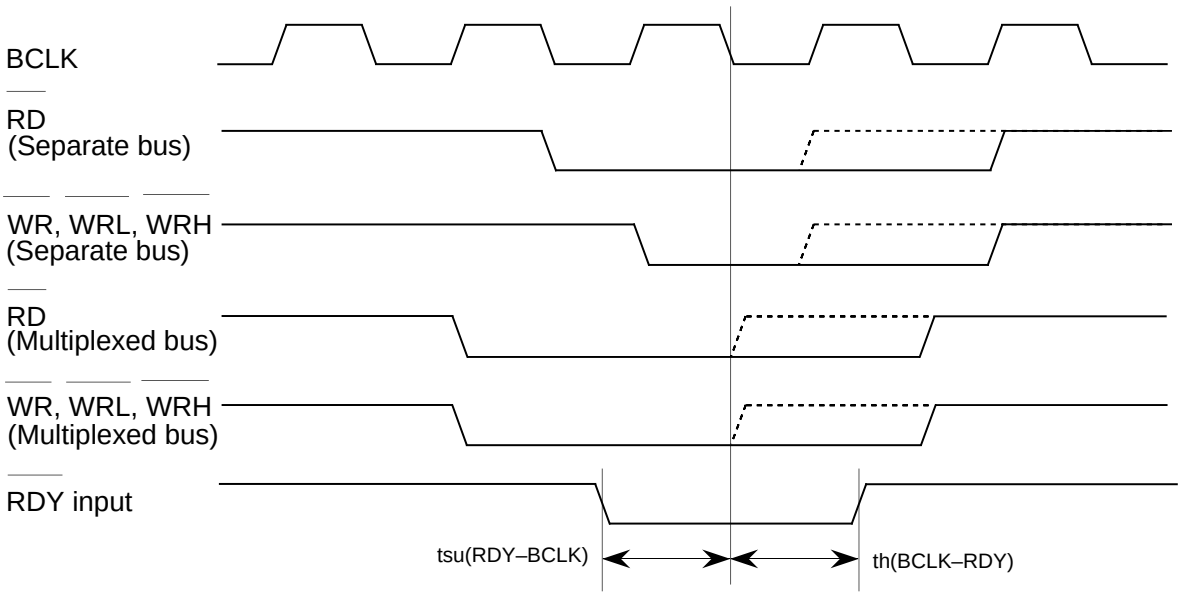
Vcc = 5V


tc(TA)
tw(TAH)
TAiIN input
tw(TAL)
tc(UP)
tw(UPH)
TAiOUT input
tw(UPL)
TAiOUT input
(Up/down input)
During event counter mode
TAiIN input
(When count on falling edge is selected)
th(TIN–UP)
tsu(UP–TIN)
TAiIN input
(When count on rising edge is selected)
tc(TB)
tw(TBH)
TBiIN input
tw(TBL)
tc(AD)
tw(ADL)
ADTRG input
tc(CK)
tw(CKH)
CLKi
tw(CKL)
th(C–Q)
TxDi
td(C–Q)
tsu(D–C)
th(C–D)
RxDi
tw(INL)
INTi input
tw(INH)

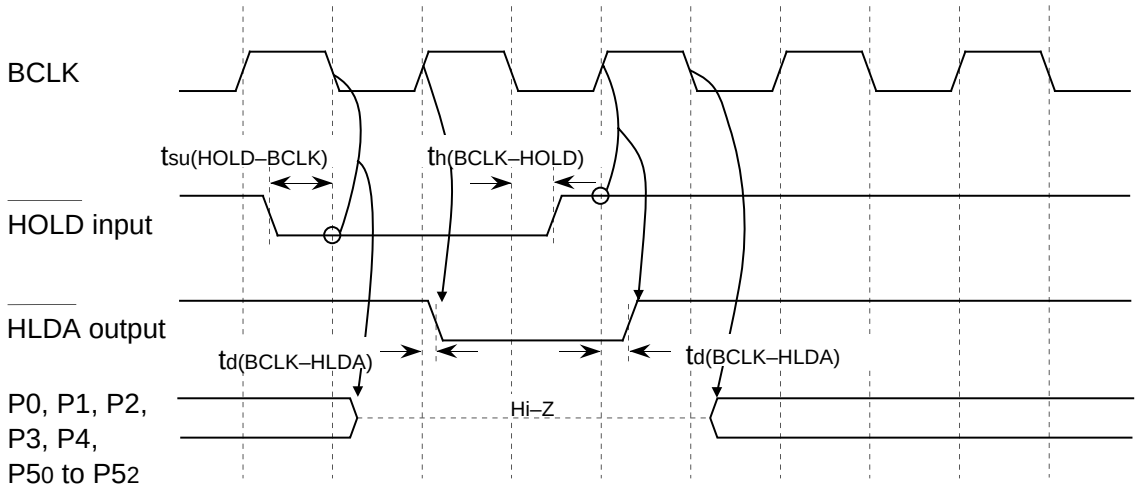
Vcc = 5V

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.

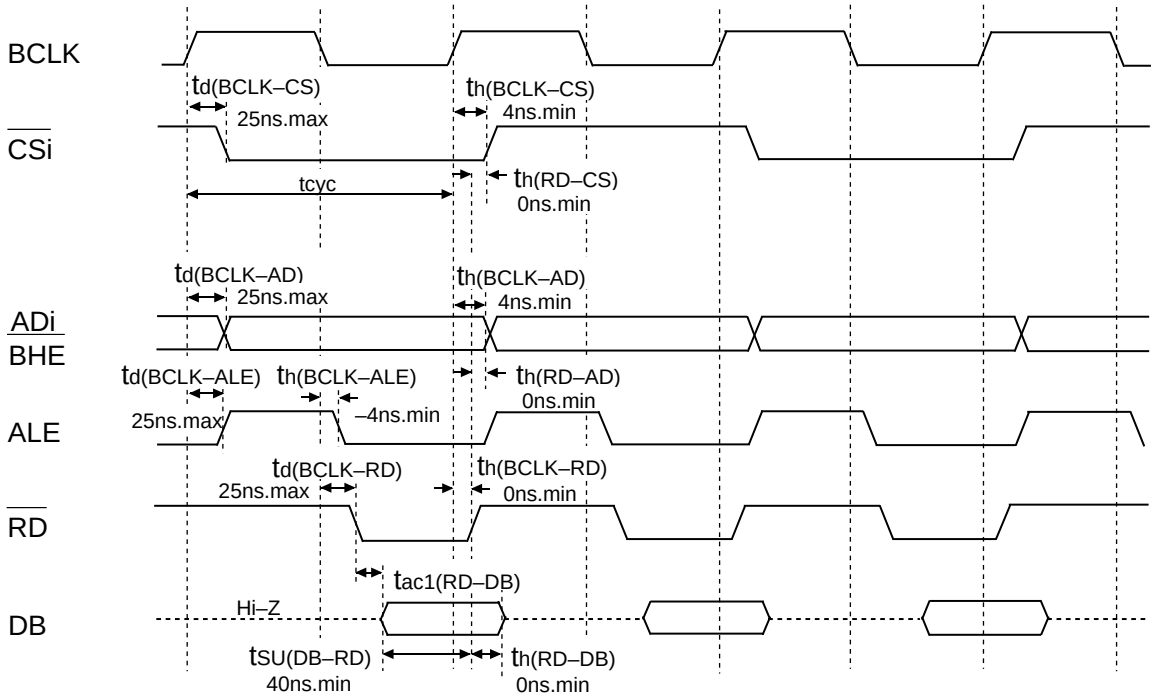
Measuring conditions :

- VCC=5V
- Input timing voltage : Determined with VIL=1.0V, VIH=4.0V
- Output timing voltage : Determined with VOL=2.5V, VOH=2.5V

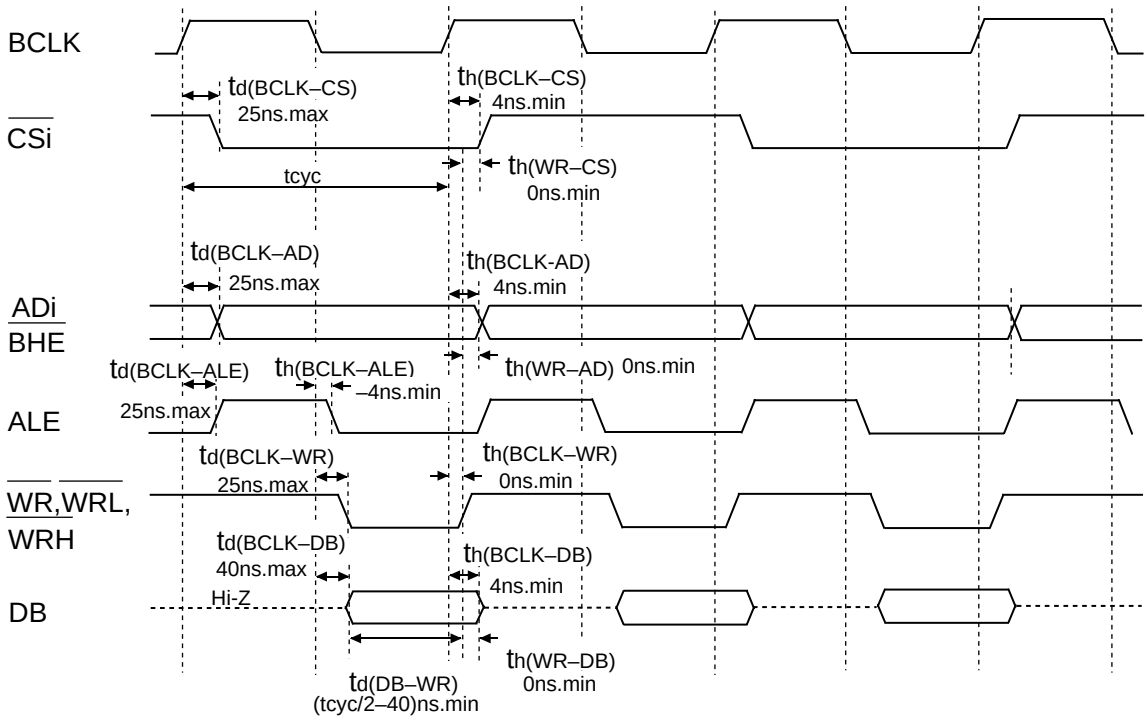
Memory Expansion Mode and Microprocessor Mode
(With no wait)

Vcc = 5V

Read timing



Write timing

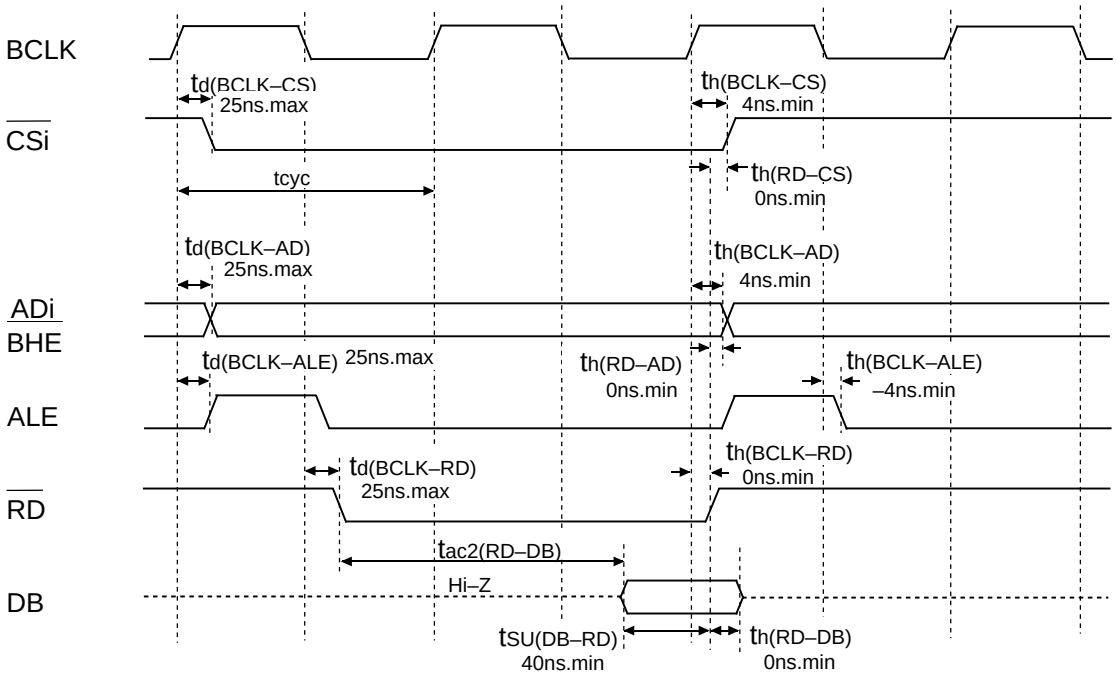


Memory Expansion Mode and Microprocessor Mode

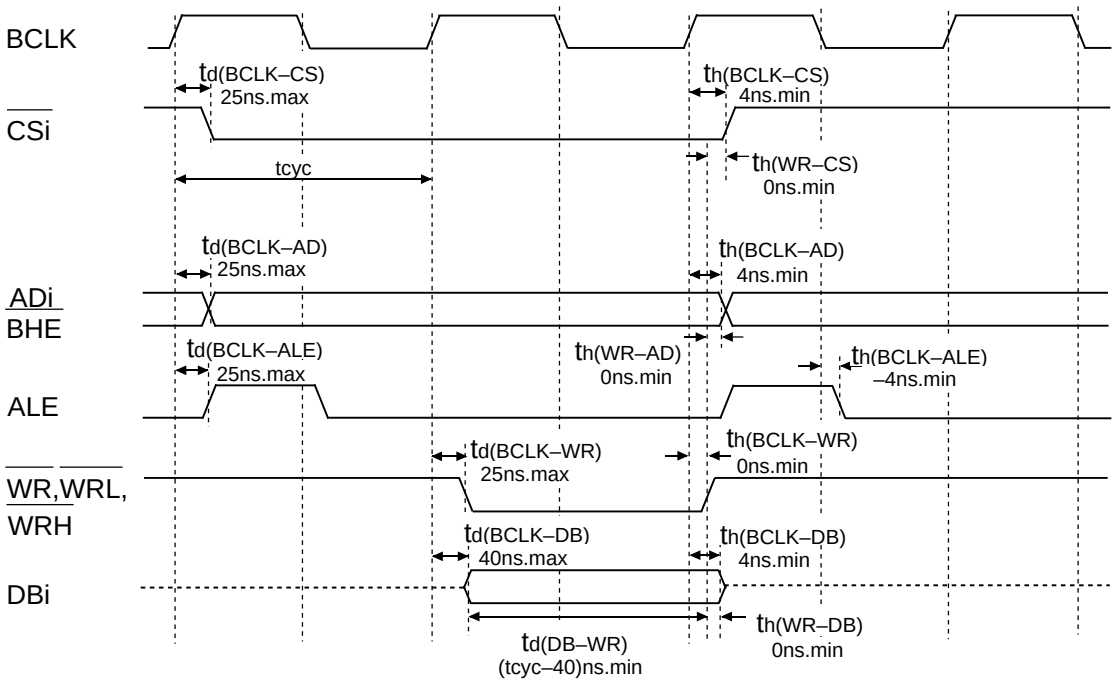
Vcc = 5V

(When accessing external memory area with wait)

Read timing



Write timing



Measuring conditions :

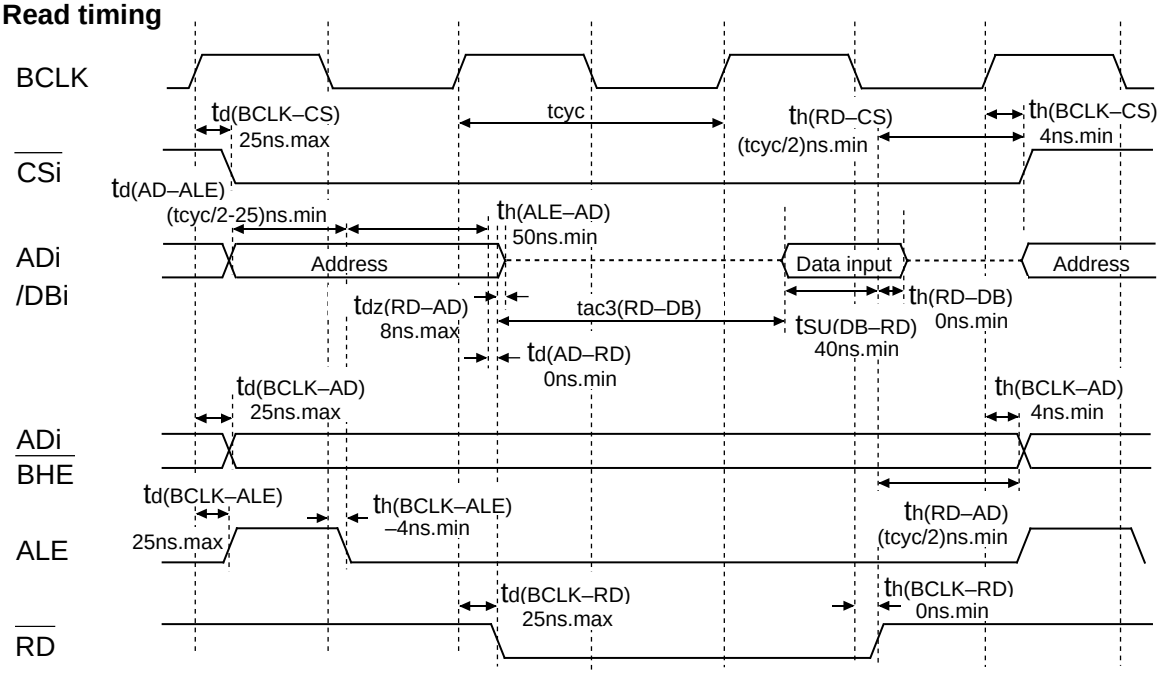
- Vcc=5V
- Input timing voltage : Determined with: VIL=0.8V, VIH=2.5V
- Output timing voltage : Determined with: VOL=0.8V, VOH=2.0V

Memory Expansion Mode and Microprocessor Mode

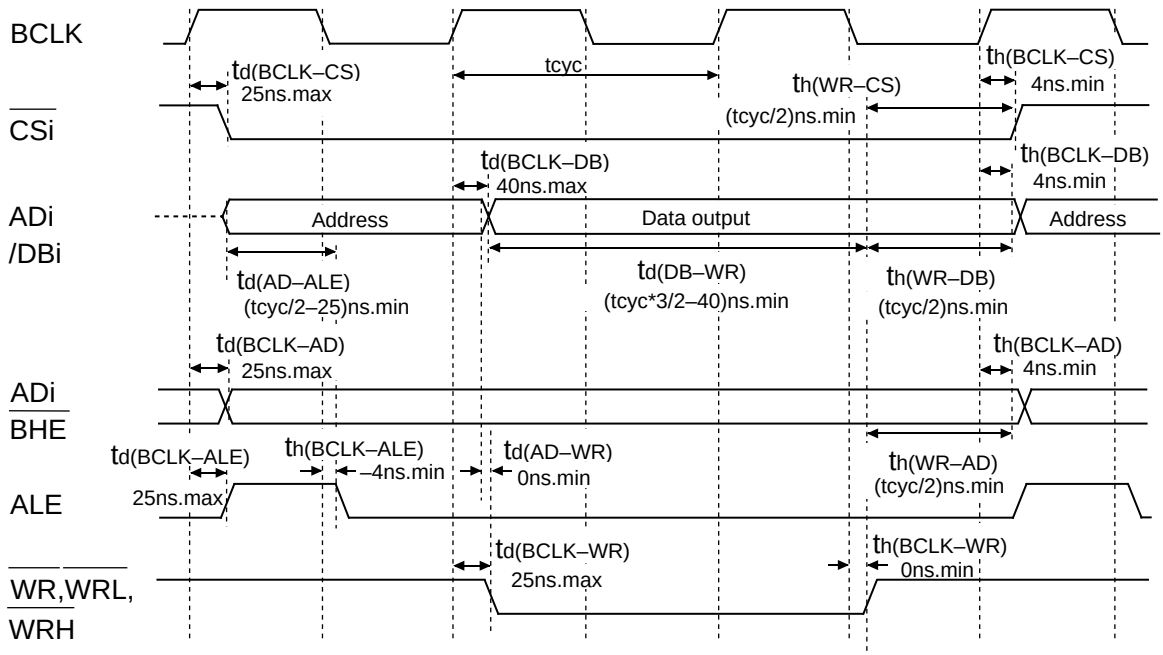
VCC = 5V

(When accessing external memory area with wait, and select multiplexed bus)

Read timing



Write timing



Measuring conditions :

- VCC=5V
- Input timing voltage : Determined with VIL=0.8V, VIH=2.5V
- Output timing voltage : Determined with VOL=0.8V, VOH=2.0V

Vcc = 3V

Table 71. Electrical characteristics (referenced to Vcc = 3V, Vss = 0V at Ta = 25°C, f(XIN) = 7MHz with wait)

Symbol	Parameter		Measuring condition		Standard Min	Standard Typ.	Standard Max.	Unit
VOH	HIGH output voltage 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		IOH=-1mA		2.5			V
VOH	HIGH output voltage XOUT	HIGHPOWER	IOH=-0.1mA		2.5			V
		LOWPOWER	IOH=-50µA		2.5			
	HIGH output voltage XCOUT	HIGHPOWER	With no load applied			3.0		V
		LOWPOWER	With no load applied			1.6		
VOL	LOW output voltage 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		IOL=1mA				0.5	V
VOL	LOW output voltage XOUT	HIGHPOWER	IOL=0.1mA				0.5	V
		LOWPOWER	IOL=50µA				0.5	
	LOW output voltage XCOUT	HIGHPOWER	With no load applied			0		V
		LOWPOWER	With no load applied			0		
VT+-VT-	Hysteresis HOLD, RDY, TA0IN to TA4IN, TB0IN to TB2IN, INT0 to INT2, ADTRG, CTS0, CTS1, CLK0, CLK1, TA2OUT to TA4OUT, NMI, KI0 to KI3				0.2		0.8	V
VT+-VT-	Hysteresis RESET				0.2		1.8	V
IIH	HIGH input 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 P87, P90 to P97,P100 to P107, XIN, RESET, CNVss, BYTE		VI=3V				4.0	µA
IIL	LOW input 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 P87, P90 to P97,P100 to P107, XIN, RESET, CNVss, BYTE		VI=0V				-4.0	µA
RPULLUP	Pull-up resistance 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		VI=0V		66.0	120.0	500.0	kΩ
RfXIN	Feedback resistance XIN					3.0		MΩ
RfCXIN	Feedback resistance XCIN					10.0		MΩ
VRAM	RAM retention voltage		When clock is stopped		2.0			V
Icc	Power supply current		In single-chip mode, the output pins are open and other pins are Vss	f(XIN)=7MHz Square wave, no division		6.0	15.0	mA
				f(XCIN)=32kHz Square wave		40.0		µA
				f(XCIN)=32kHz When a WAITinstruction is executed. Oscillation capacity High (Note)		2.8		µA
				f(XCIN)=32kHz When a WAIT instruction is executed. Oscillation capacity Low (Note)		0.9		µA
				Ta=25°C when clock is stopped			1.0	µA
				Ta=85°C when clock is stopped			20.0	

Note: With one timer operated using fc32.

Vcc = 3V

Table 72. A-D conversion characteristics (referenced to Vcc = AVcc = VREF = 3V, Vss = AVss = 0V at Ta = 25°C, f(XIN) = 7MHz unless otherwise specified)

Symbol	Parameter		Measuring condition	Standard			Unit
				Min.	Typ.	Max	
–	Resolution		VREF = VCC			10	Bits
–	Absolute accuracy	Sample & hold function not available (8 bit)	VREF = VCC = 3V, ϕ_{AD} = f(XIN)/2			±2	LSB
RLADDER	Ladder resistance		VREF = VCC	10		40	kΩ
tCONV	Conversion time(8bit)			14.0			µs
VREF	Reference voltage			2.7		VCC	V
VIA	Analog input voltage			0		VREF	V

Table 73. D-A conversion characteristics (referenced to VCC = 3V, VSS = AVSS = 0V, VREF = 3V at Ta = 25°C, f(XIN) = 7MHz unless otherwise specified)

Symbol	Parameter	Measuring condition	Standard			Unit
			Min.	Typ.	Max	
–	Resolution				8	Bits
–	Absolute accuracy				1.0	%
tsu	Setup time				3	µs
RO	Output resistance		4	10	20	kΩ
IVREF	Reference power supply input current	(Note)			1.0	mA

Note: This applies when using one D-A converter, with the D-A register for the unused D-A converter set to "00$_{16}$".

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

Also, when the Vref is unconnected at the A-D control register, IVREF is sent.

Vcc = 3V

Timing requirements (referenced to Vcc = 3V, Vss = 0V at Ta = 25°C unless otherwise specified)

Table 74. External clock input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t_c	External clock input cycle time	143		ns
$t_{w(H)}$	External clock input HIGH pulse width	60		ns
$t_{w(L)}$	External clock input LOW pulse width	60		ns
t_r	External clock rise time		18	ns
t_f	External clock fall time		18	ns

Table 75. 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
$t_{su(RDY-BCLK)}$	$\overline{RDY}$ input setup time	60		ns
$t_{su(HOLD-BCLK)}$	$\overline{HOLD}$ input setup time	80		ns
$t_{h(RD-DB)}$	Data input hold time	0		ns
$t_{h(BCLK-RDY)}$	$\overline{RDY}$ input hold time	0		ns
$t_{h(BCLK-HOLD)}$	$\overline{HOLD}$ input hold time	0		ns
$t_{d(BCLK-HLDA)}$	$\overline{HLDA}$ output delay time		100	ns

Note: Calculated according to the BCLK frequency as follows:

$$t_{ac1(RD-DB)} = \frac{10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

$$t_{ac2(RD-DB)} = \frac{3 \times 10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

$$t_{ac3(RD-DB)} = \frac{3 \times 10^9}{f(BCLK) \times 2} - 90 \quad [ns]$$

VCC = 3V

Timing requirements (referenced to VCC = 3V, VSS = 0V at Ta = 25°C unless otherwise specified)

Table 76. 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 77. 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 78. 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 79. 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 80. 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

VCC = 3V

Timing requirements (referenced to VCC = 3V, VSS = 0V at Ta = 25°C unless otherwise specified)

Table 81. 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 82. 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 83. 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 84. 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 85. 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 86. 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

VCC = 3V

Switching characteristics (referenced to VCC = 3V, VSS = 0V at Ta = 25°C, CM15 = "1" unless otherwise specified)

Table 87. 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 115		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:

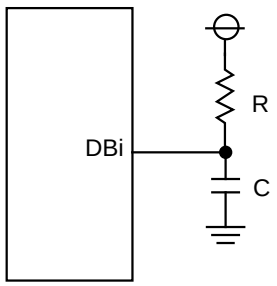
$$td(DB - WR) = \frac{10^9}{f(BCLK) \times 2} - 80 \quad [ns]$$

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 = 1kΩ, hold time of output "L" level is

$$t = -30pF \times 1k\Omega \times \ln(1 - 0.2V_{CC} / V_{CC})$$
$$= 6.7ns.$$



VCC = 3V

Switching characteristics (referenced to VCC = 3V, VSS = 0V at Ta = 25°C, CM15 = "1" unless otherwise specified)

Table 88. 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 115		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:

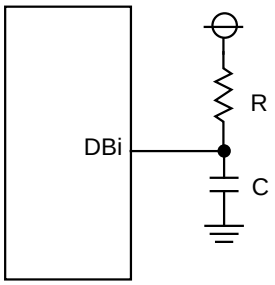
$$td(DB - WR) = \frac{10^9}{f(BCLK)} - 80 \quad [ns]$$

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 = 1kΩ, hold time of output "L" level is

$t = -30pF \times 1k\Omega \times \ln(1 - 0.2V_{CC} / V_{CC})$
$= 6.7ns.$



VCC = 3V

Switching characteristics (referenced to VCC = 3V, VSS = 0V at Ta = 25°C, CM15 = "1" unless otherwise specified)

Table 89. 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 115		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)		ns
$t_{h(WR-AD)}$	Address output hold time (WR standard)		(Note)		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)		ns
$t_{h(WR-CS)}$	Chip select output hold time (WR standard)		(Note)		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)		ns
$t_{h(WR-DB)}$	Data output hold time (WR standard)		(Note)		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)		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:

$$th(RD - AD) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$th(WR - AD) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$th(RD - CS) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$th(WR - CS) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

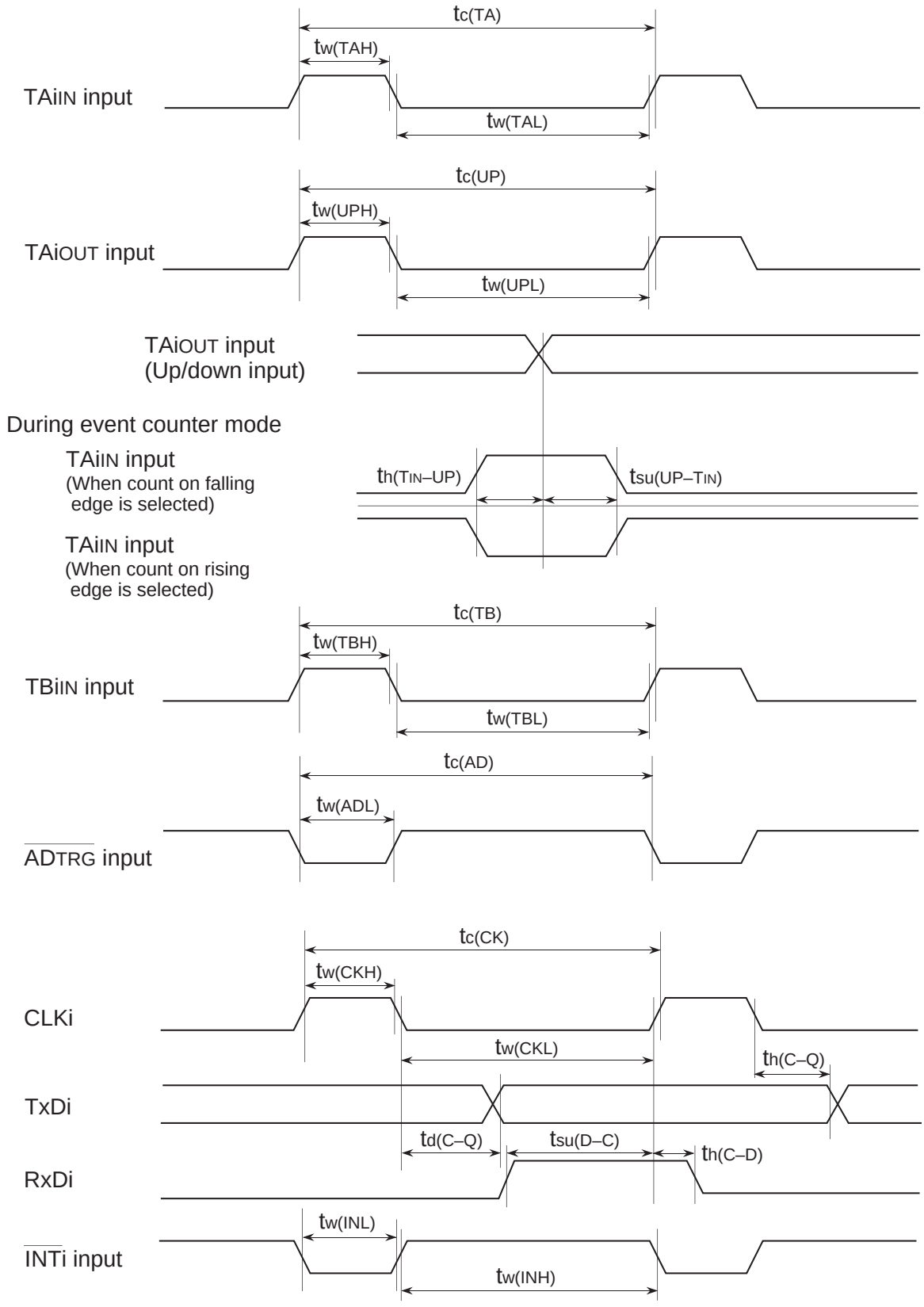
$$td(DB - WR) = \frac{10^9 \times 3}{f(BCLK) \times 2} - 80 \quad [ns]$$

$$th(WR - DB) = \frac{10^9}{f(BCLK) \times 2} \quad [ns]$$

$$td(AD - ALE) = \frac{10^9}{f(BCLK) \times 2} - 60 \quad [ns]$$

Timing (Vcc = 3V)

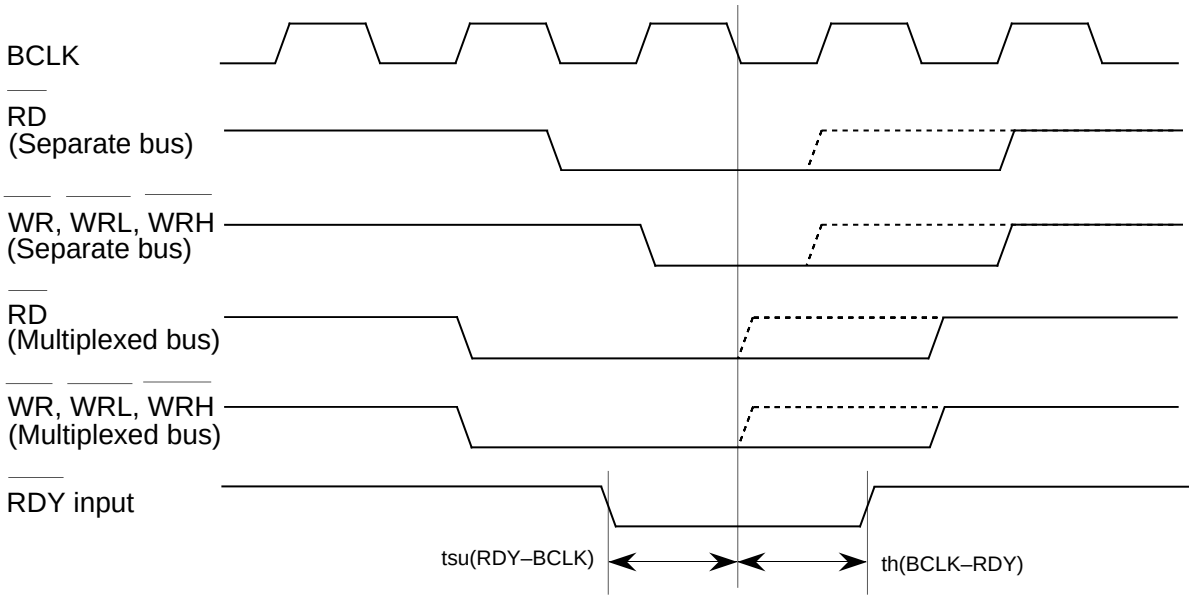
Vcc = 3V



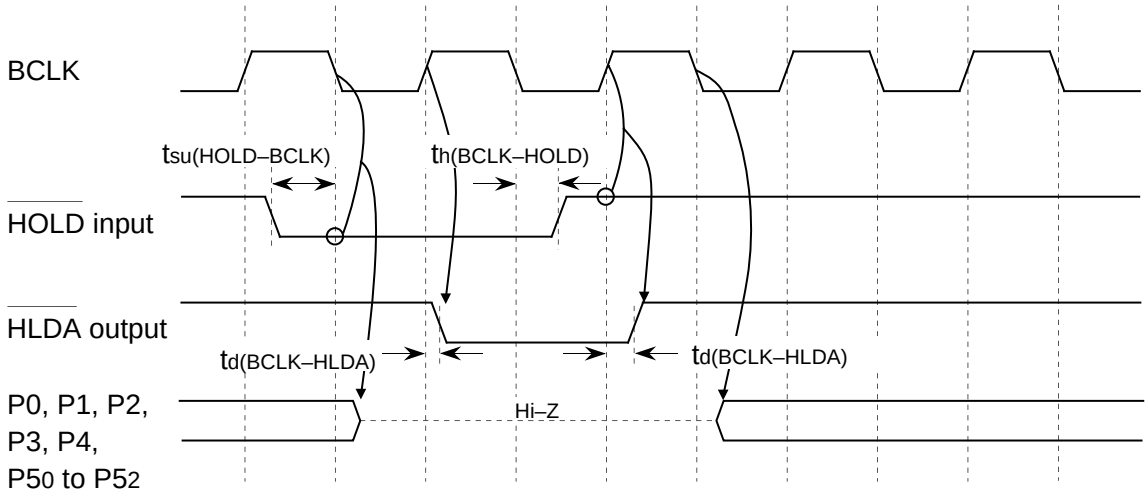
Vcc = 3V

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.

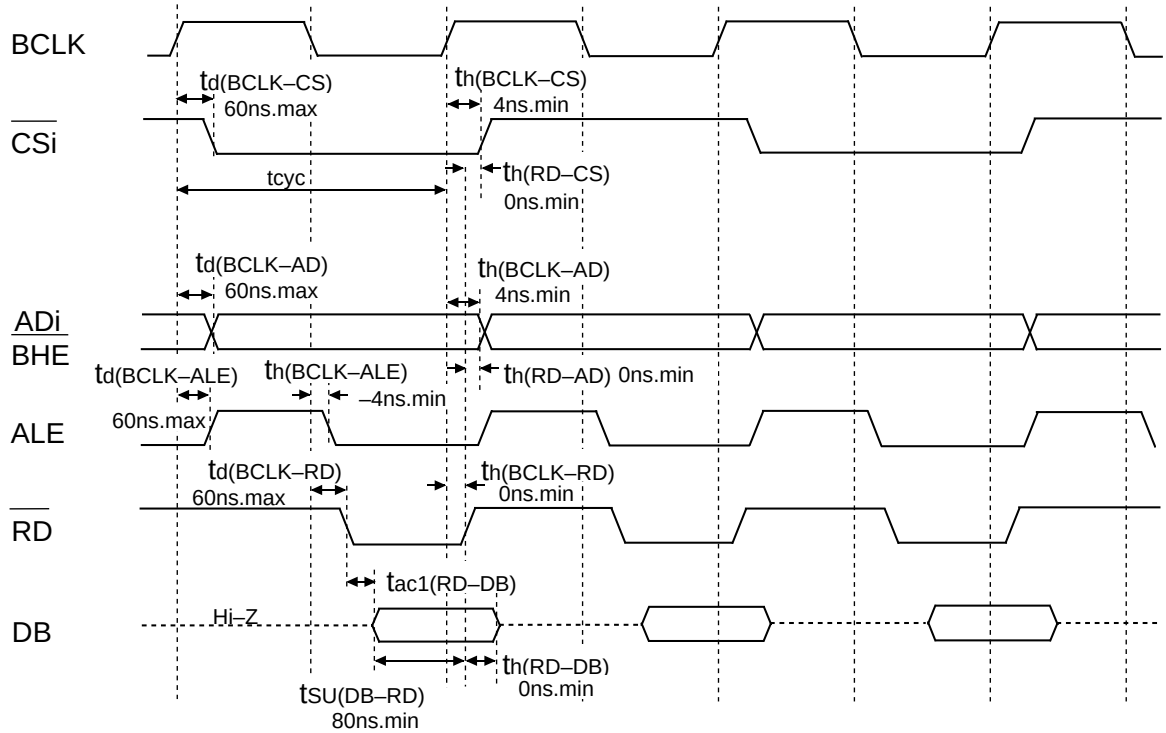
Measuring conditions :

- VCC=3V
- Input timing voltage : Determined with VIL=0.6V, VIH=2.4V
- Output timing voltage : Determined with VOL=1.5V, VOH=1.5V

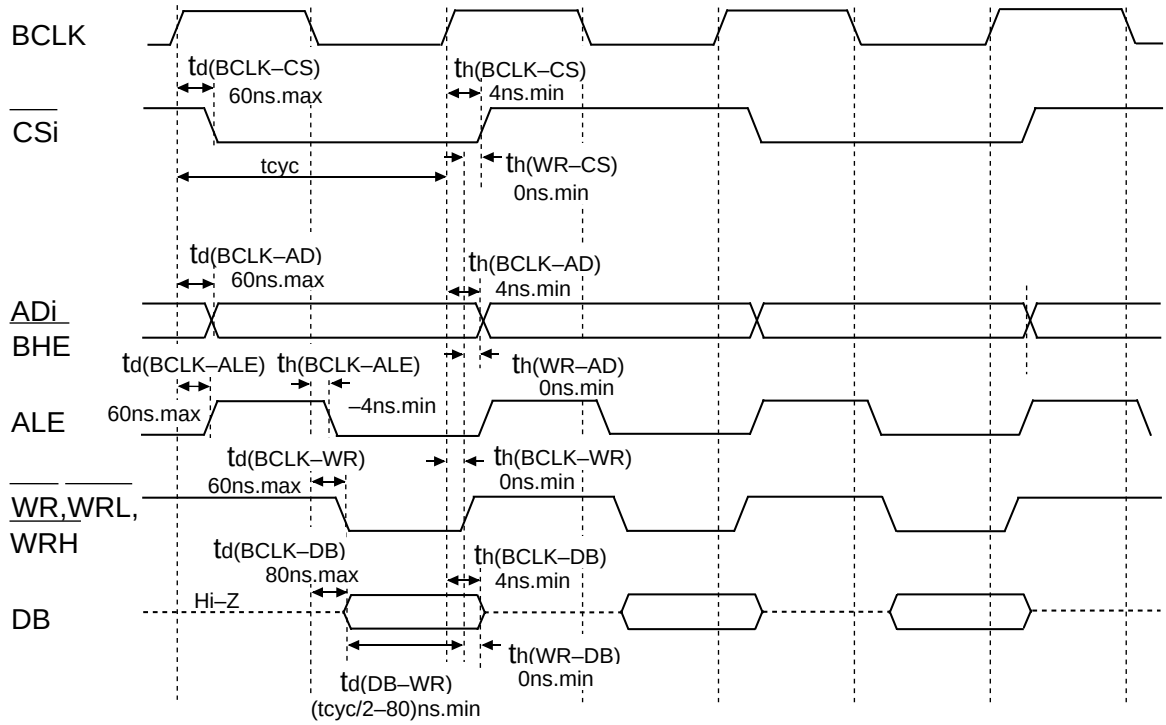
Memory Expansion Mode and Microprocessor Mode
(With no wait)

Vcc = 3V

Read timing



Write timing

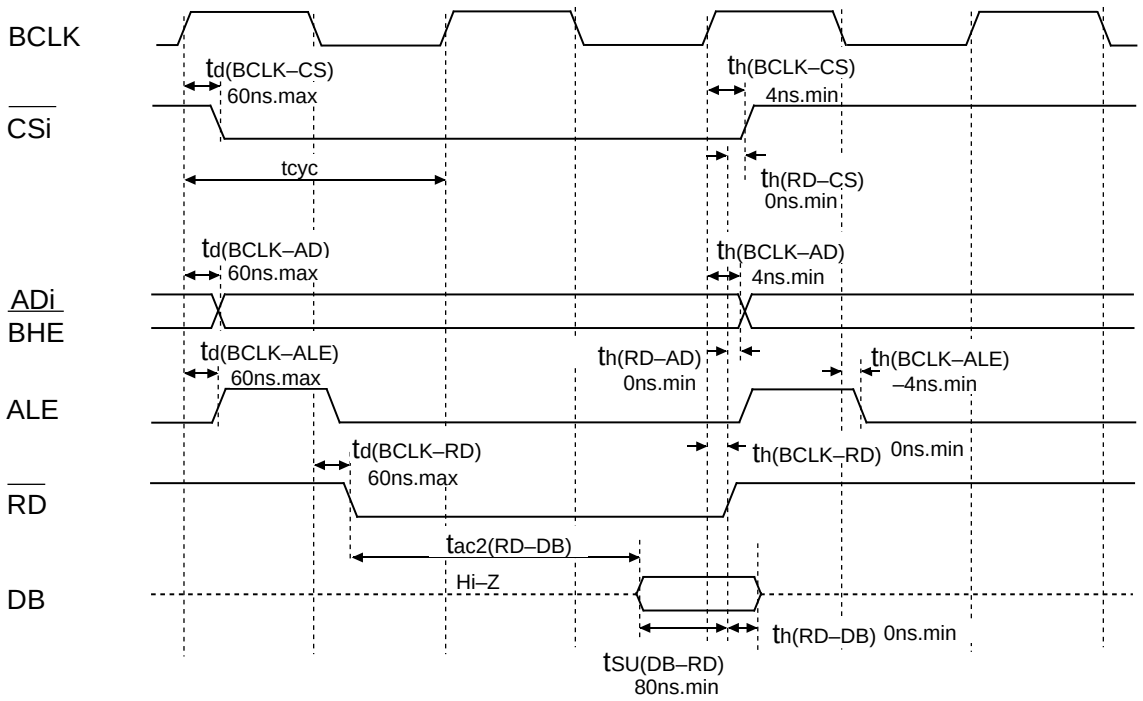


Memory Expansion Mode and Microprocessor Mode

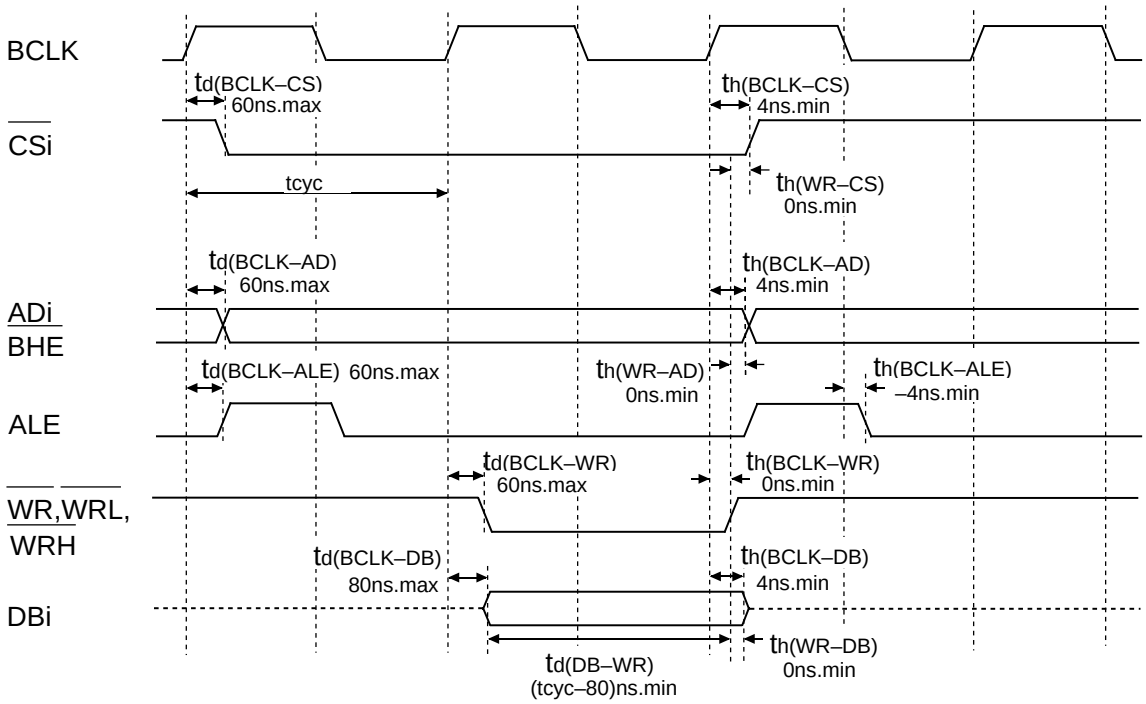
Vcc = 3V

(When accessing external memory area with wait)

Read timing



Write timing



Measuring conditions :

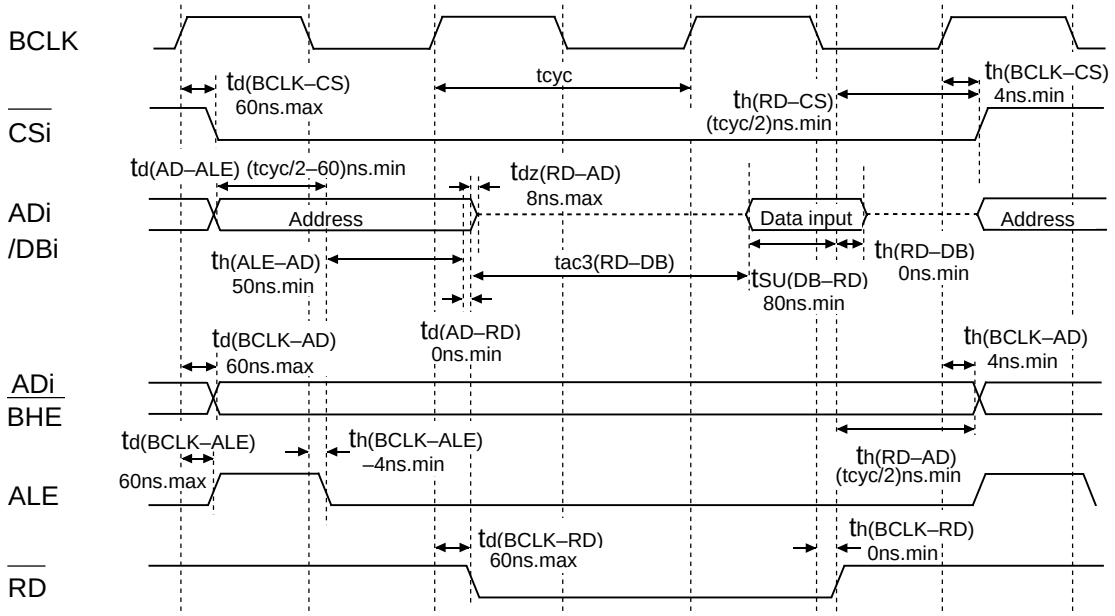
- Vcc=3V
- Input timing voltage : Determined with VIL=0.48V, VIH=1.5V
- Output timing voltage : Determined with VOL=1.5V, VOH=1.5V

Vcc = 3V

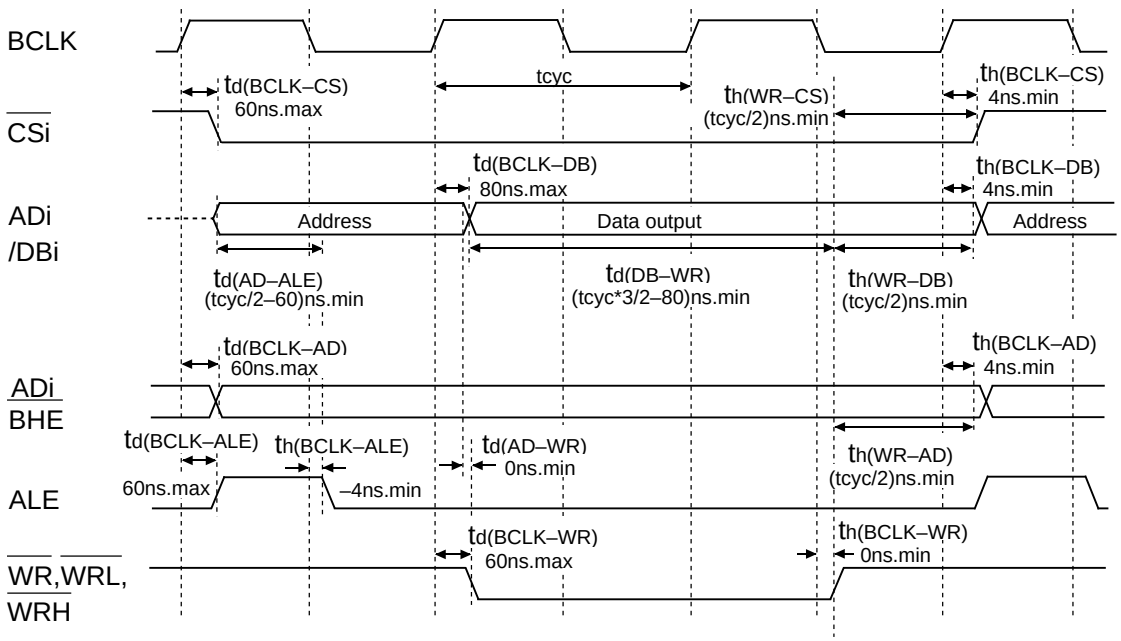
Memory Expansion Mode and Microprocessor Mode

(When accessing external memory area with wait, and select multiplexed bus)

Read timing



Write timing



Measuring conditions :

- Vcc=3V
- Input timing voltage : Determined with VIL=0.48V,VIH=1.5V
- Output timing voltage : Determined with VOL=1.5V,VOH=1.5V

GZZ—SH11—53B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30610M8A-XXXFP/GP MASK ROM CONFIRMATION FORM

Receipt	Date :	
	Section head signature	Supervisor sighature

Note : Please complete all items marked ※.

※	Customer	Company name	TEL ( )	Issuance signature	Submitted by	Supervisor
		Date issued	Date :			

※1. Check sheet

Name the product you order, and choose which to give in, EPROMs or floppy disks.
If you order by means of EPROMs, three sets of EPROMs are required per pattern. If you order by means of floppy disks, one floppy disk is required per pattern.

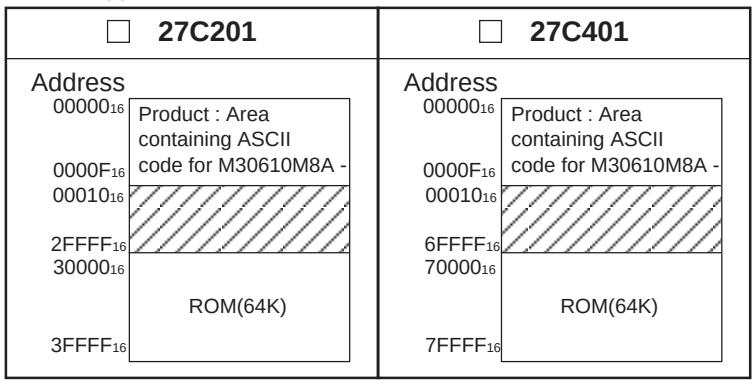
☐ In the case of EPROMs

Mitsubishi will create the mask using the data on the EPROMs supplied, providing the data is the same on at least two of those sets. Mitsubishi will, therefore, only accept liability if there is any discrepancy between the data on the EPROM sets and the ROM data written to the product. Please carefully check the data on the EPROMs being submitted to Mitsubishi.

Microcomputer type No. : ☐ M30610M8A-XXXFP ☐ M30610M8A-XXXGP

Checksum code for total EPROM area : | | | | | (hex)

EPROM type :



(1) Write "FF16" to the lined area.
(2) The area from 00000₁₆ to 0000F₁₆ is for storing data on the product type name.
The ASCII code for 'M30610M8A-' is shown at right.
The data in this table must be written to address 00000₁₆ to 0000F₁₆.
Both address and data are shown in hex.

Address		
00000₁₆	'M'	= 4D₁₆
00001₁₆	'3'	= 33₁₆
00002₁₆	'0'	= 30₁₆
00003₁₆	'6'	= 36₁₆
00004₁₆	'1'	= 31₁₆
00005₁₆	'0'	= 30₁₆
00006₁₆	'M'	= 4D₁₆
00007₁₆	'8'	= 38₁₆

Address		
00008₁₆	'A'	= 41₁₆
00009₁₆	'—'	= 2D₁₆
0000A₁₆		FF₁₆
0000B₁₆		FF₁₆
0000C₁₆		FF₁₆
0000D₁₆		FF₁₆
0000E₁₆		FF₁₆
0000F₁₆		FF₁₆

GZZ— SH11— 53B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30610M8A-XXXFP/GP
MASK ROM CONFIRMATION FORM

The ASCII code for the type No. can be written to EPROM addresses 00000_{16} to $0000F_{16}$ by specifying the pseudo-instructions for the respective EPROM type shown in the following table at the beginning of the assembler source program.

EPROM type	27C201	27C401
Code entered in source program	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 0C0000H △ .BYTE △ ' M30610M8A- '	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 080000H △ .BYTE △ ' M30610M8A- '

Note: The ROM cannot be processed if the type No. written to the EPROM does not match the type No. in the check sheet.

☐ In the case of floppy disks

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.

※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 M30610M8A-XXXFP, submit the 100P6S mark specification sheet. For the M30610M8A-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 you use?
f(XIN) = ☐ MHz

(2) Which kind of XCIN-XCOUT oscillation circuit is used?
☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ( )
What frequency do you use?
f(XCIN) = ☐ kHz

(3) Which operation mode do you use?
☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

(4) Which operating ambient temperature do you use?
☐ –10 °C to 75 °C ☐ –20 °C to 75 °C ☐ –40 °C to 75 °C
☐ –10 °C to 85 °C ☐ –20 °C to 85 °C ☐ –40 °C to 85 °C

(5) Which operating supply voltage do you use?
☐ 2.7V to 3.2V ☐ 3.2V to 3.7V ☐ 3.7V to 4.2V
☐ 4.2V to 4.7V ☐ 4.7V to 5.2V ☐ 5.2V to 5.5V

Thank you cooperation.

※ 4. Special item (Indicate none if there is no specified item)

GZZ—SH11—52B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30610MAA-XXXFP/GP MASK ROM CONFIRMATION FORM

Receipt	Date :	
	Section head signature	Supervisor sighature

Note : Please complete all items marked ※.

※	Customer	Company name	TEL ( )	Issuance signature	Submitted by	Supervisor
		Date issued	Date :			

※1. Check sheet

Name the product you order, and choose which to give in, EPROMs or floppy disks.
If you order by means of EPROMs, three sets of EPROMs are required per pattern. If you order by means of floppy disks, one floppy disk is required per pattern.

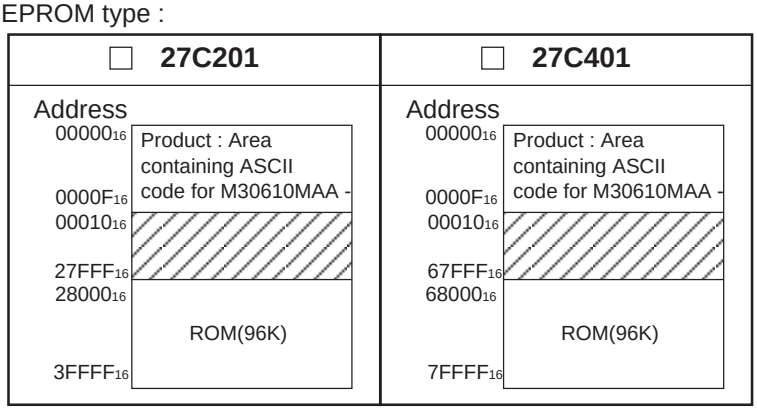
☐ In the case of EPROMs

Mitsubishi will create the mask using the data on the EPROMs supplied, providing the data is the same on at least two of those sets. Mitsubishi will, therefore, only accept liability if there is any discrepancy between the data on the EPROM sets and the ROM data written to the product. Please carefully check the data on the EPROMs being submitted to Mitsubishi.

Microcomputer type No. : ☐ M30610MAA-XXXFP ☐ M30610MAA-XXXGP

Checksum code for total EPROM area : | | | | | (hex)

EPROM type :



(1) Write "FF16" to the lined area.
(2) The area from 00000₁₆ to 0000F₁₆ is for storing data on the product type name.
The ASCII code for 'M30610MAA-' is shown at right.
The data in this table must be written to address 00000₁₆ to 0000F₁₆.
Both address and data are shown in hex.

Address			Address	
00000₁₆	'M'	= 4D₁₆	00008₁₆	'A' = 41₁₆
00001₁₆	'3'	= 33₁₆	00009₁₆	'—' = 2D₁₆
00002₁₆	'0'	= 30₁₆	0000A₁₆	FF₁₆
00003₁₆	'6'	= 36₁₆	0000B₁₆	FF₁₆
00004₁₆	'1'	= 31₁₆	0000C₁₆	FF₁₆
00005₁₆	'0'	= 30₁₆	0000D₁₆	FF₁₆
00006₁₆	'M'	= 4D₁₆	0000E₁₆	FF₁₆
00007₁₆	'A'	= 41₁₆	0000F₁₆	FF₁₆

GZZ—SH11—52B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30610MAA-XXXFP/GP MASK ROM CONFIRMATION FORM

The ASCII code for the type No. can be written to EPROM addresses 00000_{16} to $0000F_{16}$ by specifying the pseudo-instructions for the respective EPROM type shown in the following table at the beginning of the assembler source program.

EPROM type	27C201	27C401
Code entered in source program	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 0C0000H △ .BYTE △ ' M30610MAA- '	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 080000H △ .BYTE △ ' M30610MAA- '

Note: The ROM cannot be processed if the type No. written to the EPROM does not match the type No. in the check sheet.

☐ In the case of floppy disks

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.

※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 M30610MAA-XXXFP, submit the 100P6S mark specification sheet. For the M30610MAA-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 you use?
f(XIN) = ☐ MHz

(2) Which kind of XCIN-XCOUT oscillation circuit is used?
☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ( )
What frequency do you use?
f(XCIN) = ☐ kHz

(3) Which operation mode do you use?
☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

(4) Which operating ambient temperature do you use?
☐ –10 °C to 75 °C ☐ –20 °C to 75 °C ☐ –40 °C to 75 °C
☐ –10 °C to 85 °C ☐ –20 °C to 85 °C ☐ –40 °C to 85 °C

(5) Which operating supply voltage do you use?
☐ 2.7V to 3.2V ☐ 3.2V to 3.7V ☐ 3.7V to 4.2V
☐ 4.2V to 4.7V ☐ 4.7V to 5.2V ☐ 5.2V to 5.5V

Thank you cooperation.

※ 4. Special item (Indicate none if there is no specified item)

GZZ—SH11—51B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30610MCA-XXXFP/GP MASK ROM CONFIRMATION FORM

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

Name the product you order, and choose which to give in, EPROMs or floppy disks.
If you order by means of EPROMs, three sets of EPROMs are required per pattern. If you order by means of floppy disks, one floppy disk is required per pattern.

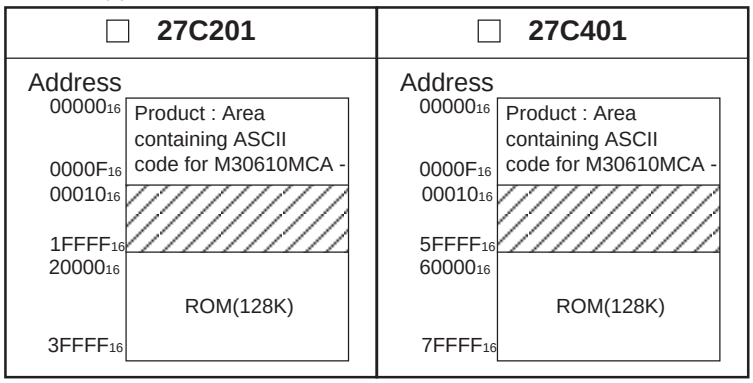
☐ In the case of EPROMs

Mitsubishi will create the mask using the data on the EPROMs supplied, providing the data is the same on at least two of those sets. Mitsubishi will, therefore, only accept liability if there is any discrepancy between the data on the EPROM sets and the ROM data written to the product. Please carefully check the data on the EPROMs being submitted to Mitsubishi.

Microcomputer type No. : ☐ M30610MCA-XXXFP ☐ M30610MCA-XXXGP

Checksum code for total EPROM area : | | | | | (hex)

EPROM type :



(1) Write "FF16" to the lined area.
(2) The area from 00000₁₆ to 0000F₁₆ is for storing data on the product type name.
The ASCII code for 'M30610MCA-' is shown at right.
The data in this table must be written to address 00000₁₆ to 0000F₁₆.
Both address and data are shown in hex.

Address			Address	
00000₁₆	'M'	= 4D₁₆	00008₁₆	'A' = 41₁₆
00001₁₆	'3'	= 33₁₆	00009₁₆	'—' = 2D₁₆
00002₁₆	'0'	= 30₁₆	0000A₁₆	FF₁₆
00003₁₆	'6'	= 36₁₆	0000B₁₆	FF₁₆
00004₁₆	'1'	= 31₁₆	0000C₁₆	FF₁₆
00005₁₆	'0'	= 30₁₆	0000D₁₆	FF₁₆
00006₁₆	'M'	= 4D₁₆	0000E₁₆	FF₁₆
00007₁₆	'C'	= 43₁₆	0000F₁₆	FF₁₆

GZZ— SH11— 51B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30610MCA-XXXFP/GP
MASK ROM CONFIRMATION FORM

The ASCII code for the type No. can be written to EPROM addresses 00000_{16} to $0000F_{16}$ by specifying the pseudo-instructions for the respective EPROM type shown in the following table at the beginning of the assembler source program.

EPROM type	27C201	27C401
Code entered in source program	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 0C0000H △ .BYTE △ ' M30610MCA- '	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 080000H △ .BYTE △ ' M30610MCA- '

Note: The ROM cannot be processed if the type No. written to the EPROM does not match the type No. in the check sheet.

☐ In the case of floppy disks

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.

※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 M30610MCA-XXXFP, submit the 100P6S mark specification sheet. For the M30610MCA-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 you use?
$f(X_{IN})$ = ☐ MHz

(2) Which kind of X_{CIN}-X_{COUT} oscillation circuit is used?
☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ( )
What frequency do you use?
$f(X_{CIN})$ = ☐ kHz

(3) Which operation mode do you use?
☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

(4) Which operating ambient temperature do you use?
☐ –10 °C to 75 °C ☐ –20 °C to 75 °C ☐ –40 °C to 75 °C
☐ –10 °C to 85 °C ☐ –20 °C to 85 °C ☐ –40 °C to 85 °C

(5) Which operating supply voltage do you use?
☐ 2.7V to 3.2V ☐ 3.2V to 3.7V ☐ 3.7V to 4.2V
☐ 4.2V to 4.7V ☐ 4.7V to 5.2V ☐ 5.2V to 5.5V

Thank you cooperation.

※ 4. Special item (Indicate none if there is no specified item)

GZZ— SH12— 35B <79A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30612M4A-XXXFP/GP MASK ROM CONFIRMATION FORM

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

Name the product you order, and choose which to give in, EPROMs or floppy disks.
If you order by means of EPROMs, three sets of EPROMs are required per pattern. If you order by means of floppy disks, one floppy disk is required per pattern.

☐ In the case of EPROMs

Mitsubishi will create the mask using the data on the EPROMs supplied, providing the data is the same on at least two of those sets. Mitsubishi will, therefore, only accept liability if there is any discrepancy between the data on the EPROM sets and the ROM data written to the product. Please carefully check the data on the EPROMs being submitted to Mitsubishi.

Microcomputer type No. : ☐ M30612M4A-XXXFP ☐ M30612M4A-XXXGP

Checksum code for total EPROM area : | | | | | (hex)

EPROM type :

☐ 27C201	☐ 27C401
Address 00000_{16} Product : Area containing ASCII code for M30612M4A - $0000F_{16}$ 00010_{16} $37FFF_{16}$ 38000_{16} ROM(32K) $3FFFF_{16}$	Address 00000_{16} Product : Area containing ASCII code for M30612M4A - $0000F_{16}$ 00010_{16} $77FFF_{16}$ 78000_{16} ROM(32K) $7FFFF_{16}$

(1) Write "FF_{16}" to the lined area.
(2) The area from 00000_{16} to $0000F_{16}$ is for storing data on the product type name.
The ASCII code for 'M30612M4A-' is shown at right.
The data in this table must be written to address 00000_{16} to $0000F_{16}$.
Both address and data are shown in hex.

Address		
00000_{16}	'M '	$= 4D_{16}$
00001_{16}	'3 '	$= 33_{16}$
00002_{16}	'0 '	$= 30_{16}$
00003_{16}	'6 '	$= 36_{16}$
00004_{16}	'1 '	$= 31_{16}$
00005_{16}	'2 '	$= 32_{16}$
00006_{16}	'M '	$= 4D_{16}$
00007_{16}	'4 '	$= 34_{16}$

Address		
00008_{16}	' A '	$= 41_{16}$
00009_{16}	' — '	$= 2D_{16}$
$0000A_{16}$		FF_{16}
$0000B_{16}$		FF_{16}
$0000C_{16}$		FF_{16}
$0000D_{16}$		FF_{16}
$0000E_{16}$		FF_{16}
$0000F_{16}$		FF_{16}

GZZ— SH12— 35B <79A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30612M4A-XXXFP/GP
MASK ROM CONFIRMATION FORM

The ASCII code for the type No. can be written to EPROM addresses 0000_{16} to $0000F_{16}$ by specifying the pseudo-instructions for the respective EPROM type shown in the following table at the beginning of the assembler source program.

EPROM type	27C201	27C401
Code entered in source program	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 0C0000H △ .BYTE △ ' M30612M4A- '	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 080000H △ .BYTE △ ' M30612M4A- '

Note: The ROM cannot be processed if the type No. written to the EPROM does not match the type No. in the check sheet.

☐ In the case of floppy disks

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.

※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 M30612M4A-XXXFP, submit the 100P6S mark specification sheet. For the M30612M4A-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 you use?
f(X_{IN}) = ☐ MHz

(2) Which kind of X_{CIN}-X_{COUT} oscillation circuit is used?
☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ( )
What frequency do you use?
f(X_{CIN}) = ☐ kHz

(3) Which operation mode do you use?
☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

(4) Which operating ambient temperature do you use?
☐ –10 °C to 75 °C ☐ –20 °C to 75 °C ☐ –40 °C to 75 °C
☐ –10 °C to 85 °C ☐ –20 °C to 85 °C ☐ –40 °C to 85 °C

(5) Which operating supply voltage do you use?
☐ 2.7V to 3.2V ☐ 3.2V to 3.7V ☐ 3.7V to 4.2V
☐ 4.2V to 4.7V ☐ 4.7V to 5.2V ☐ 5.2V to 5.5V

Thank you cooperation.

※ 4. Special item (Indicate none if there is no specified item)

GZZ— SH12— 34B <79A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30612M8A-XXXFP/GP MASK ROM CONFIRMATION FORM

Receipt	Date :	
	Section head signature	Supervisor sighature

Note : Please complete all items marked ※.

※	Customer	Company name	TEL ( )	Issuance signature	Submitted by	Supervisor
		Date issued	Date :			

※1. Check sheet

Name the product you order, and choose which to give in, EPROMs or floppy disks.
If you order by means of EPROMs, three sets of EPROMs are required per pattern. If you order by means of floppy disks, one floppy disk is required per pattern.

☐ In the case of EPROMs

Mitsubishi will create the mask using the data on the EPROMs supplied, providing the data is the same on at least two of those sets. Mitsubishi will, therefore, only accept liability if there is any discrepancy between the data on the EPROM sets and the ROM data written to the product. Please carefully check the data on the EPROMs being submitted to Mitsubishi.

Microcomputer type No. : ☐ M30612M8A-XXXFP ☐ M30612M8A-XXXGP

Checksum code for total EPROM area : | | | | | (hex)

EPROM type :

☐ **27C201**	☐ **27C401**
Address 00000_{16} Product : Area containing ASCII code for M30612M8A - $0000F_{16}$ 00010_{16} $2FFFF_{16}$ 30000_{16} ROM(64K) $3FFFF_{16}$	Address 00000_{16} Product : Area containing ASCII code for M30612M8A - $0000F_{16}$ 00010_{16} $6FFFF_{16}$ 70000_{16} ROM(64K) $7FFFF_{16}$

(1) Write "FF_{16}" to the lined area.
(2) The area from 00000_{16} to $0000F_{16}$ is for storing data on the product type name.
The ASCII code for 'M30612M8A-' is shown at right.
The data in this table must be written to address 00000_{16} to $0000F_{16}$.
Both address and data are shown in hex.

Address		Address	
00000_{16}	'M' = $4D_{16}$	00008_{16}	'A' = 41_{16}
00001_{16}	'3' = 33_{16}	00009_{16}	'—' = $2D_{16}$
00002_{16}	'0' = 30_{16}	$0000A_{16}$	FF_{16}
00003_{16}	'6' = 36_{16}	$0000B_{16}$	FF_{16}
00004_{16}	'1' = 31_{16}	$0000C_{16}$	FF_{16}
00005_{16}	'2' = 32_{16}	$0000D_{16}$	FF_{16}
00006_{16}	'M' = $4D_{16}$	$0000E_{16}$	FF_{16}
00007_{16}	'8' = 38_{16}	$0000F_{16}$	FF_{16}

GZZ— SH12— 34B <79A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30612M8A-XXXFP/GP MASK ROM CONFIRMATION FORM

The ASCII code for the type No. can be written to EPROM addresses 0000_{16} to $0000F_{16}$ by specifying the pseudo-instructions for the respective EPROM type shown in the following table at the beginning of the assembler source program.

EPROM type	27C201	27C401
Code entered in source program	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 0C0000H △ .BYTE △ ' M30612M8A- '	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 080000H △ .BYTE △ ' M30612M8A- '

Note: The ROM cannot be processed if the type No. written to the EPROM does not match the type No. in the check sheet.

☐ In the case of floppy disks

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.

※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 M30612M8A-XXXFP, submit the 100P6S mark specification sheet. For the M30612M8A-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 you use?
f(XIN) = ☐ MHz

(2) Which kind of XCIN-XCOUT oscillation circuit is used?
☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ( )
What frequency do you use?
f(XCIN) = ☐ kHz

(3) Which operation mode do you use?
☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

(4) Which operating ambient temperature do you use?
☐ –10 °C to 75 °C ☐ –20 °C to 75 °C ☐ –40 °C to 75 °C
☐ –10 °C to 85 °C ☐ –20 °C to 85 °C ☐ –40 °C to 85 °C

(5) Which operating supply voltage do you use?
☐ 2.7V to 3.2V ☐ 3.2V to 3.7V ☐ 3.7V to 4.2V
☐ 4.2V to 4.7V ☐ 4.7V to 5.2V ☐ 5.2V to 5.5V

Thank you cooperation.

※ 4. Special item (Indicate none if there is no specified item)

GZZ—SH12—55B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30612MAA-XXXFP/GP MASK ROM CONFIRMATION FORM

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

Name the product you order, and choose which to give in, EPROMs or floppy disks.
If you order by means of EPROMs, three sets of EPROMs are required per pattern. If you order by means of floppy disks, one floppy disk is required per pattern.

☐ In the case of EPROMs

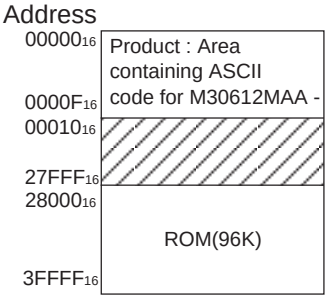
Mitsubishi will create the mask using the data on the EPROMs supplied, providing the data is the same on at least two of those sets. Mitsubishi will, therefore, only accept liability if there is any discrepancy between the data on the EPROM sets and the ROM data written to the product. Please carefully check the data on the EPROMs being submitted to Mitsubishi.

Microcomputer type No. : ☐ M30612MAA-XXXFP ☐ M30612MAA-XXXGP

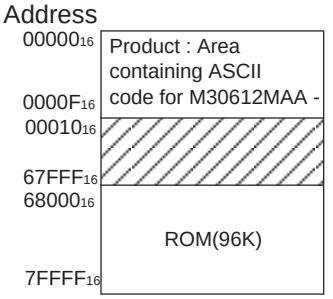
Checksum code for total EPROM area : | | | | | (hex)

EPROM type :

☐ **27C201**



☐ **27C401**



(1) Write "FF16" to the lined area.
(2) The area from 0000016 to 0000F16 is for storing data on the product type name.
The ASCII code for 'M30612MAA-' is shown at right.
The data in this table must be written to address 0000016 to 0000F16.
Both address and data are shown in hex.

Address			Address	
00000₁₆	'M'	= 4D₁₆	00008₁₆	'A' = 41₁₆
00001₁₆	'3'	= 33₁₆	00009₁₆	'—' = 2D₁₆
00002₁₆	'0'	= 30₁₆	0000A₁₆	FF₁₆
00003₁₆	'6'	= 36₁₆	0000B₁₆	FF₁₆
00004₁₆	'1'	= 31₁₆	0000C₁₆	FF₁₆
00005₁₆	'2'	= 32₁₆	0000D₁₆	FF₁₆
00006₁₆	'M'	= 4D₁₆	0000E₁₆	FF₁₆
00007₁₆	'A'	= 41₁₆	0000F₁₆	FF₁₆

GZZ— SH11— 55B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30612MAA-XXXFP/GP MASK ROM CONFIRMATION FORM

The ASCII code for the type No. can be written to EPROM addresses 00000_{16} to $0000F_{16}$ by specifying the pseudo-instructions for the respective EPROM type shown in the following table at the beginning of the assembler source program.

EPROM type	27C201	27C401
Code entered in source program	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 0C0000H △ .BYTE △ ' M30612MAA- '	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 080000H △ .BYTE △ ' M30612MAA- '

Note: The ROM cannot be processed if the type No. written to the EPROM does not match the type No. in the check sheet.

☐ In the case of floppy disks

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.

※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 M30612MAA-XXXFP, submit the 100P6S mark specification sheet. For the M30612MAA-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 you use?
f(XIN) = ☐ MHz

(2) Which kind of XCIN-XCOUT oscillation circuit is used?
☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ( )
What frequency do you use?
f(XCIN) = ☐ kHz

(3) Which operation mode do you use?
☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

(4) Which operating ambient temperature do you use?
☐ –10 °C to 75 °C ☐ –20 °C to 75 °C ☐ –40 °C to 75 °C
☐ –10 °C to 85 °C ☐ –20 °C to 85 °C ☐ –40 °C to 85 °C

(5) Which operating supply voltage do you use?
☐ 2.7V to 3.2V ☐ 3.2V to 3.7V ☐ 3.7V to 4.2V
☐ 4.2V to 4.7V ☐ 4.7V to 5.2V ☐ 5.2V to 5.5V

Thank you cooperation.

※ 4. Special item (Indicate none if there is no specified item)

GZZ—SH11—54B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30612MCA-XXXFP/GP MASK ROM CONFIRMATION FORM

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

Name the product you order, and choose which to give in, EPROMs or floppy disks.
If you order by means of EPROMs, three sets of EPROMs are required per pattern. If you order by means of floppy disks, one floppy disk is required per pattern.

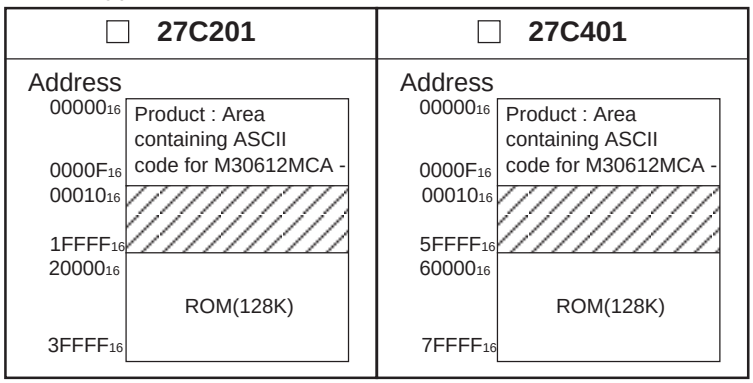
☐ In the case of EPROMs

Mitsubishi will create the mask using the data on the EPROMs supplied, providing the data is the same on at least two of those sets. Mitsubishi will, therefore, only accept liability if there is any discrepancy between the data on the EPROM sets and the ROM data written to the product. Please carefully check the data on the EPROMs being submitted to Mitsubishi.

Microcomputer type No. : ☐ M30612MCA-XXXFP ☐ M30612MCA-XXXGP

Checksum code for total EPROM area : | | | | | (hex)

EPROM type :



(1) Write "FF16" to the lined area.
(2) The area from 0000016 to 0000F16 is for storing data on the product type name.
The ASCII code for 'M30612MCA-' is shown at right.
The data in this table must be written to address 0000016 to 0000F16.
Both address and data are shown in hex.

Address			Address	
00000₁₆	'M '	= 4D₁₆	00008₁₆	' A ' = 41₁₆
00001₁₆	' 3 '	= 33₁₆	00009₁₆	' — ' = 2D₁₆
00002₁₆	' 0 '	= 30₁₆	0000A₁₆	FF₁₆
00003₁₆	' 6 '	= 36₁₆	0000B₁₆	FF₁₆
00004₁₆	' 1 '	= 31₁₆	0000C₁₆	FF₁₆
00005₁₆	' 2 '	= 32₁₆	0000D₁₆	FF₁₆
00006₁₆	'M '	= 4D₁₆	0000E₁₆	FF₁₆
00007₁₆	'C '	= 43₁₆	0000F₁₆	FF₁₆

GZZ—SH11—54B <71A0>

Mask ROM number	

MITSUBISHI ELECTRIC SINGLE-CHIP 16-BIT MICROCOMPUTER M30612MCA-XXXFP/GP
MASK ROM CONFIRMATION FORM

The ASCII code for the type No. can be written to EPROM addresses 00000_{16} to $0000F_{16}$ by specifying the pseudo-instructions for the respective EPROM type shown in the following table at the beginning of the assembler source program.

EPROM type	27C201	27C401
Code entered in source program	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 0C0000H △ .BYTE △ ' M30612MCA- '	△ .SECTION△ASCIICODE, ROM DATA △ .ORG △ 080000H △ .BYTE △ ' M30612MCA- '

Note: The ROM cannot be processed if the type No. written to the EPROM does not match the type No. in the check sheet.

☐ In the case of floppy disks

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.

※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 M30612MCA-XXXFP, submit the 100P6S mark specification sheet. For the M30612MCA-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 you use?
$f(X_{IN})$ = ☐ MHz

(2) Which kind of X_{CIN}-X_{COUT} oscillation circuit is used?
☐ Ceramic resonator ☐ Quartz-crystal oscillator
☐ External clock input ☐ Other ( )
What frequency do you use?
$f(X_{CIN})$ = ☐ kHz

(3) Which operation mode do you use?
☐ Single-chip mode ☐ Memory expansion mode
☐ Microprocessor mode

(4) Which operating ambient temperature do you use?
☐ –10 °C to 75 °C ☐ –20 °C to 75 °C ☐ –40 °C to 75 °C
☐ –10 °C to 85 °C ☐ –20 °C to 85 °C ☐ –40 °C to 85 °C

(5) Which operating supply voltage do you use?
☐ 2.7V to 3.2V ☐ 3.2V to 3.7V ☐ 3.7V to 4.2V
☐ 4.2V to 4.7V ☐ 4.7V to 5.2V ☐ 5.2V to 5.5V

Thank you cooperation.

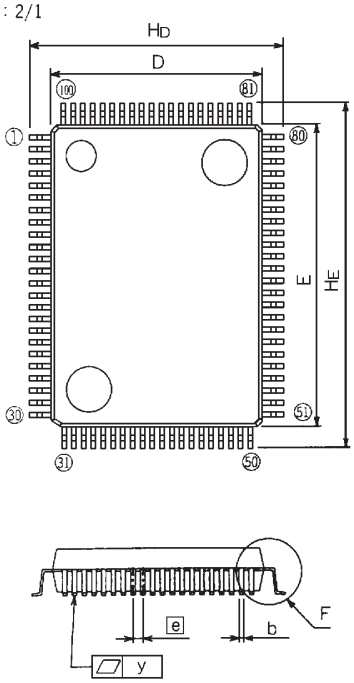
※ 4. Special item (Indicate none if there is no specified item)

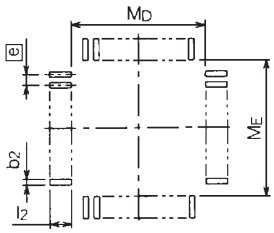
100P6S-A

Plastic 100pin 14×20mm body QFP

EIAJ Package Code	JEDEC Code	Weight(g)	Lead Material
QFP100-P-1420-0.65	—	1.58	Alloy 42

Scale : 2/1





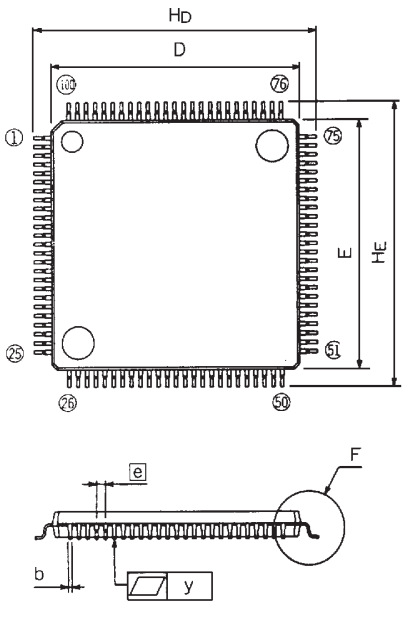
Recommended Mount Pad

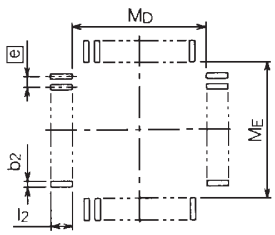
Symbol	Dimension in Millimeters		
	Min	Nom	Max
A	—	—	3.05
A_1	0	0.1	0.2
A_2	—	2.8	—
b	0.25	0.3	0.4
c	0.13	0.15	0.2
D	13.8	14.0	14.2
E	19.8	20.0	20.2
e	—	0.65	—
H_D	16.5	16.8	17.1
H_E	22.5	22.8	23.1
L	0.4	0.6	0.8
L_1	—	1.4	—
y	—	—	0.1
θ	0°	—	10°
b_2	—	0.35	—
l_2	1.3	—	—
M_D	—	14.6	—
M_E	—	20.6	—

100P6Q-A

Plastic 100pin 14×14mm body LQFP

EIAJ Package Code	JEDEC Code	Weight(g)	Lead Material
LQFP100-P-1414-0.50	—		Cu Alloy





Symbol	Dimension in Millimeters		
	Min	Nom	Max
A	—	—	1.7
A_1	0	0.1	0.2
A_2	—	1.4	—
b	0.13	0.18	0.28
c	0.105	0.125	0.175
D	13.9	14.0	14.1
E	13.9	14.0	14.1
e	—	0.5	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
L	0.3	0.5	0.7
L_1	—	1.0	—
y	—	—	0.1
θ	0°	—	10°
b_2	—	0.225	—
l_2	1.0	—	—
M_D	—	14.4	—
M_E	—	14.4	—

Differences between M16C/61 group and M30600M8

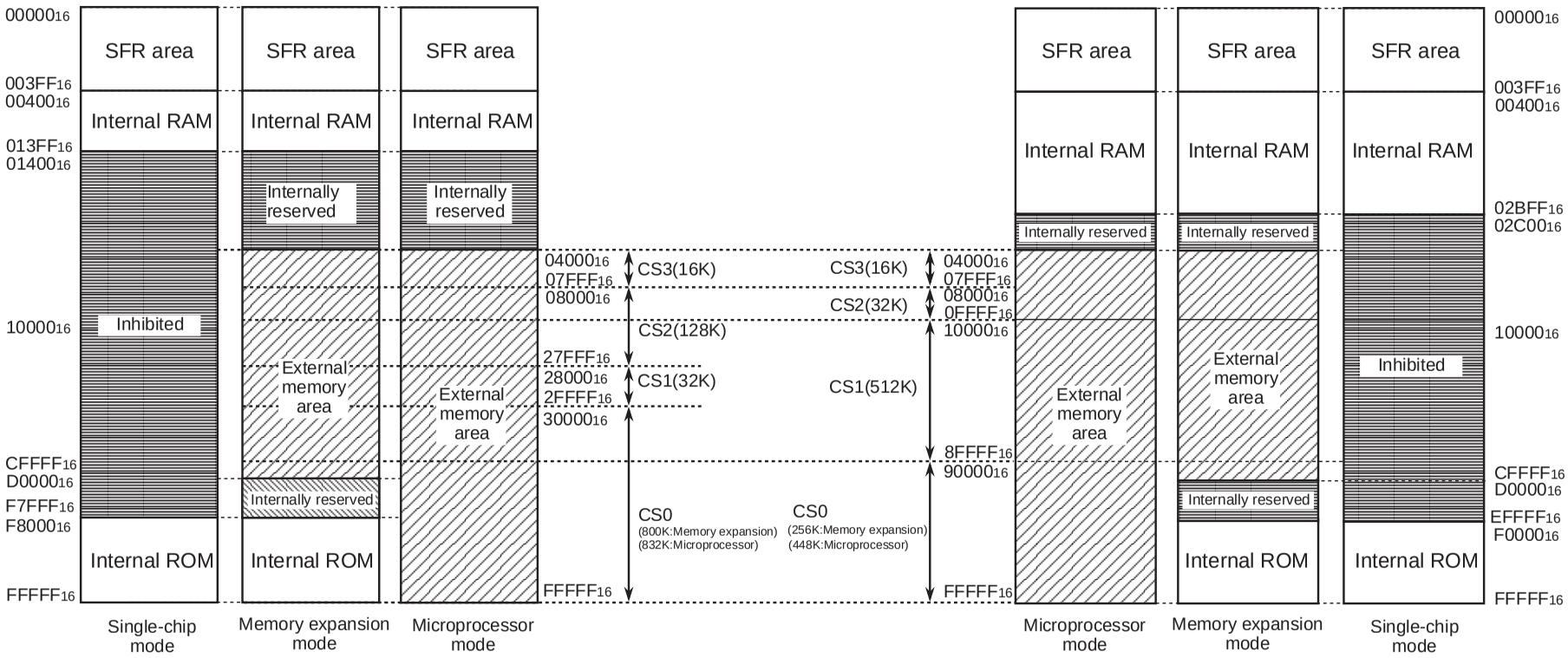
Type name		M16C/61 group	M30600M8
Internal memory size	ROM	See Figure 4. ROM Expansion	64 K bytes
	RAM	4 K to 10 K bytes	10 K bytes
Chip select		CS0 30000_{16} to FFFFF$_{16}$ (besides internal area) CS1 2800_{16} to 2FFFF$_{16}$ CS2 0800_{16} to 27FFF$_{16}$ CS3 0400_{16} to 07FFF$_{16}$	CS0 90000_{16} to FFFFF$_{16}$ (besides internal area) CS1 1000_{16} to 8FFFF$_{16}$ CS2 0800_{16} to 0FFFF$_{16}$ CS3 0400_{16} to 07FFF$_{16}$
Internal area on memory expansion mode		SFR area 0000_{16} to 003FF$_{16}$ RAM area 0040_{16} to 03FFF$_{16}$ ROM area D0000$_{16}$ to FFFFF$_{16}$ (PM16=0) ROM area F8000$_{16}$ to FFFFF$_{16}$ (PM16=1) (Note)	SFR area 0000_{16} to 003FF$_{16}$ RAM area 0040_{16} to 03FFF$_{16}$ ROM area D0000$_{16}$ to FFFFF$_{16}$ (FIX)
Serial I/O		3 channel (clocked SIO / UART) :2 channel (clocked SIO / UART / SIM)	2 channel (clocked SIO / UART)
Port P7$_0$ to P7$_3$ function		Port P7$_0$ TxD$_2$ / TA0$_{OUT}$ Port P7$_1$ RxD$_2$ / TA0$_{IN}$ Port P7$_2$ CLK$_2$ / TA1$_{OUT}$ Port P7$_3$ CTS$_2$ / RTS$_2$ / TA1$_{IN}$	Port P7$_0$ TA0$_{OUT}$ Port P7$_1$ TA0$_{IN}$ Port P7$_2$ TA1$_{OUT}$ Port P7$_3$ TA1$_{IN}$
Port output style		Port P7$_0$ and Port P7$_1$ are N-channel open drain Others are CMOS	All Ports are CMOS
Port P9$_3$ and P9$_4$ pull-up set up condition		All of the following: • Pull-up is selected. • DA output is enabled. • Input port is selected.	Both of the following: • Pull-up is selected. • Input port is selected.
Interrupt sources		Internal 20 sources External 5 sources Software 4 sources Add 3 sources -trans., recv. and arbit. for UART2	Internal 17 sources External 5 sources Software 4 sources
DMA request		DMA0 / DMA1 1100 UART2 trans. / UART2 trans. 1101 UART2 recv. / UART2 recv. 1110 A-D / A-D 1111 UART1 trans. / UART1 recv.	DMA0 / DMA1 1100 UART1 trans. / UART1 trans. 1101 UART1 recv. / UART1 recv. 1110 A-D / A-D 1111 prohibited / prohibited

Note: M30612M4A/E4 only.

Memory map Comparison

M30612M4 Memory area (ROM 32K bytes, RAM 4K bytes)

M30600M8 Memory area (ROM 64K bytes, RAM 10K bytes)



Internal area

External area(possible to use for external devices)

Inhibited

Internally reserved for ROM(possible to use for external devices under PM16=1)

MITSUBISHI SEMICONDUCTORS
M16C/61 Group DATA SHEET REV.C

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