

Description

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The M16C/62T 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 or a 80-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/62T group includes a wide range of products with different internal memory types and sizes and various package types.

Features

- Memory capacity M30623M4T-XXXGP : ROM 32K bytes, RAM 3K bytes
M30622M8T/M8V-XXXFP, M30623M8T/M8V-XXXGP : ROM 64K bytes, RAM 4K bytes
M30622MCT/MCV-XXXFP, M30623MCT/MCV-XXXGP : ROM 128K bytes, RAM 5K bytes
M30622ECT/ECV-XXXFP, M30623ECT/ECV-XXXGP : PROM 128K bytes, RAM 5K bytes
- Shortest instruction execution time 62.5ns (f(XIN)=16MHz, VCC=5V)
- Supply voltage Mask ROM version : 4.2 to 5.5V (f(XIN)=16MHz, without software wait)
One-time PROM version : 4.5 to 5.5V (f(XIN)=16MHz, without software wait)
- Low power consumption 140mW (VCC = 5V, f(XIN)=16MHz)
- Interrupts 25 internal interrupt sources, 8 external interrupt sources (M30622(100-pin package))
/ 5 sources (M30623(80-pin package)), 4 software interrupt sources,
7 levels (including key input interrupt)
- Multifunction 16-bit timer 5 I/O timers + 6 input timers(M30622(100-pin package))
3 I/O timers + 5 input timers(M30623(80-pin package))
- Inside 16-bit timer 3 timers(only M30623(80-pin package))(Note 1)
- Serial I/O • M30622(100-pin package) : 3 for UART or clock synchronous + 2 for synchronous
• M30623(80-pin package) : 3 for UART or clock synchronous(one of exclusive UART)
+ 2 for synchronous(one of exclusive transmission)
- DMAC 2 channels (trigger: 24 sources)
- A-D converter 10 bits X 8 channels (Expandable up to 26 channels)
- D-A converter 8 bits X 2 channels
- CRC calculation circuit 1 circuit
- Watchdog timer 1 line
- Programmable I/O 87 lines(M30622(100-pin package)), 70 lines(M30623(80-pin package))
- Input port 1 line (P85 shared with NMI pin)
- Memory expansion Available (to 1.2M bytes or 4M bytes)
- Chip select output 4 lines(only M30622(100-pin package))(Note 2)
- Clock generating circuit 2 built-in clock generation circuits (built-in feedback resistor, and external ceramic or quartz oscillator)

Note 1: In M30623(80-pin package), these timers have no corresponding external pin can be used as internal timers.

Note 2: M30623(80-pin package) has no external pin for chip select output.

Applications

Audio, cameras, office equipment, communications equipment, portable equipment, cars, etc

Specifications written in this manual are believed to be accurate, but are not guaranteed to be entirely free of error.
Specifications in this manual may be changed for functional or performance improvements. Please make sure your manual is the latest edition.

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Description

Pin Configuration

Figures 1.1.1 show the pin configurations (top view) of M30622(100-pin package) and 1.1.2 show the pin configurations (top view) of M30623(80-pin package).

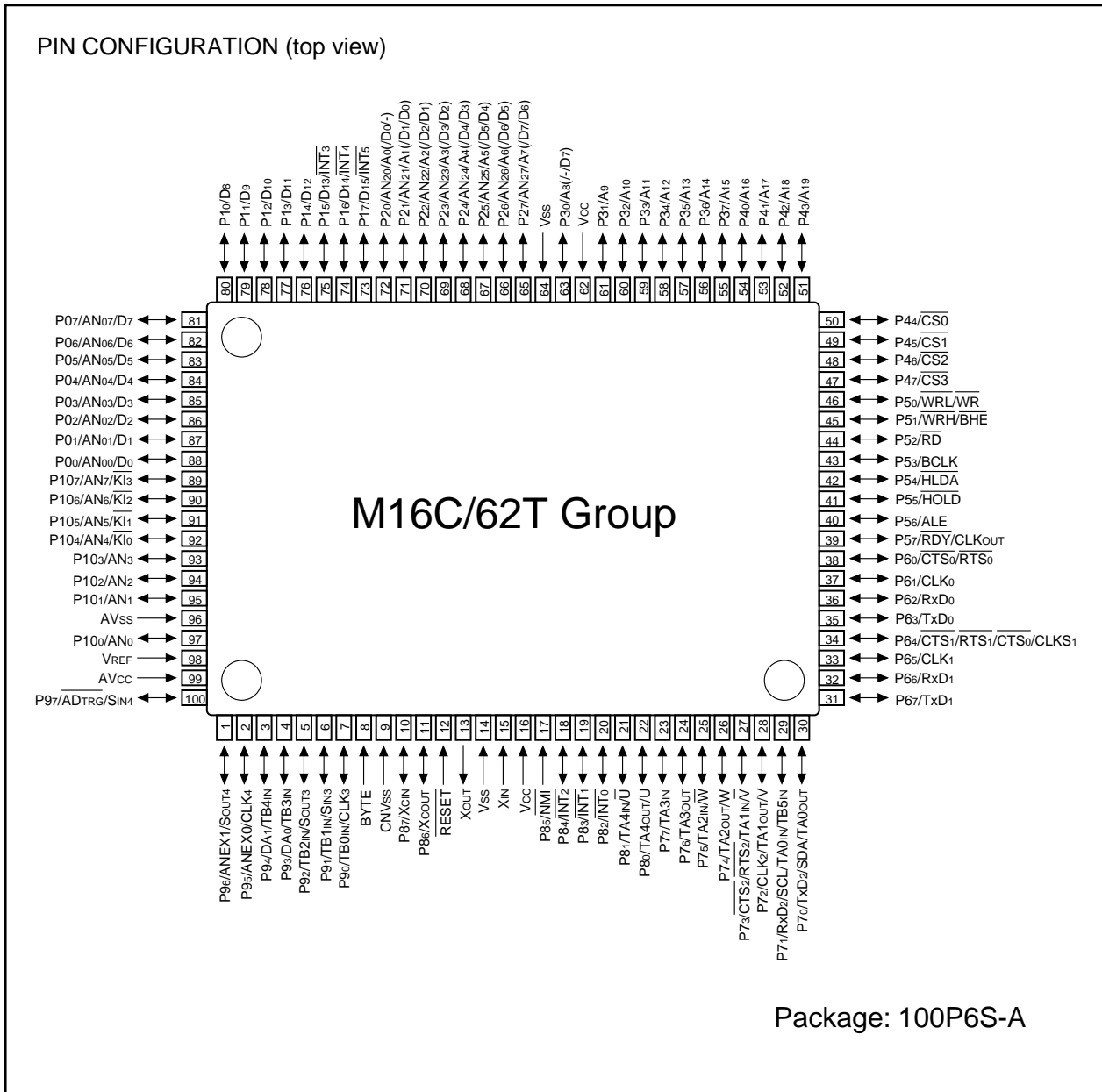


Figure 1.1.1. Pin configuration (top view) of M30622 (100-pin package)

Description

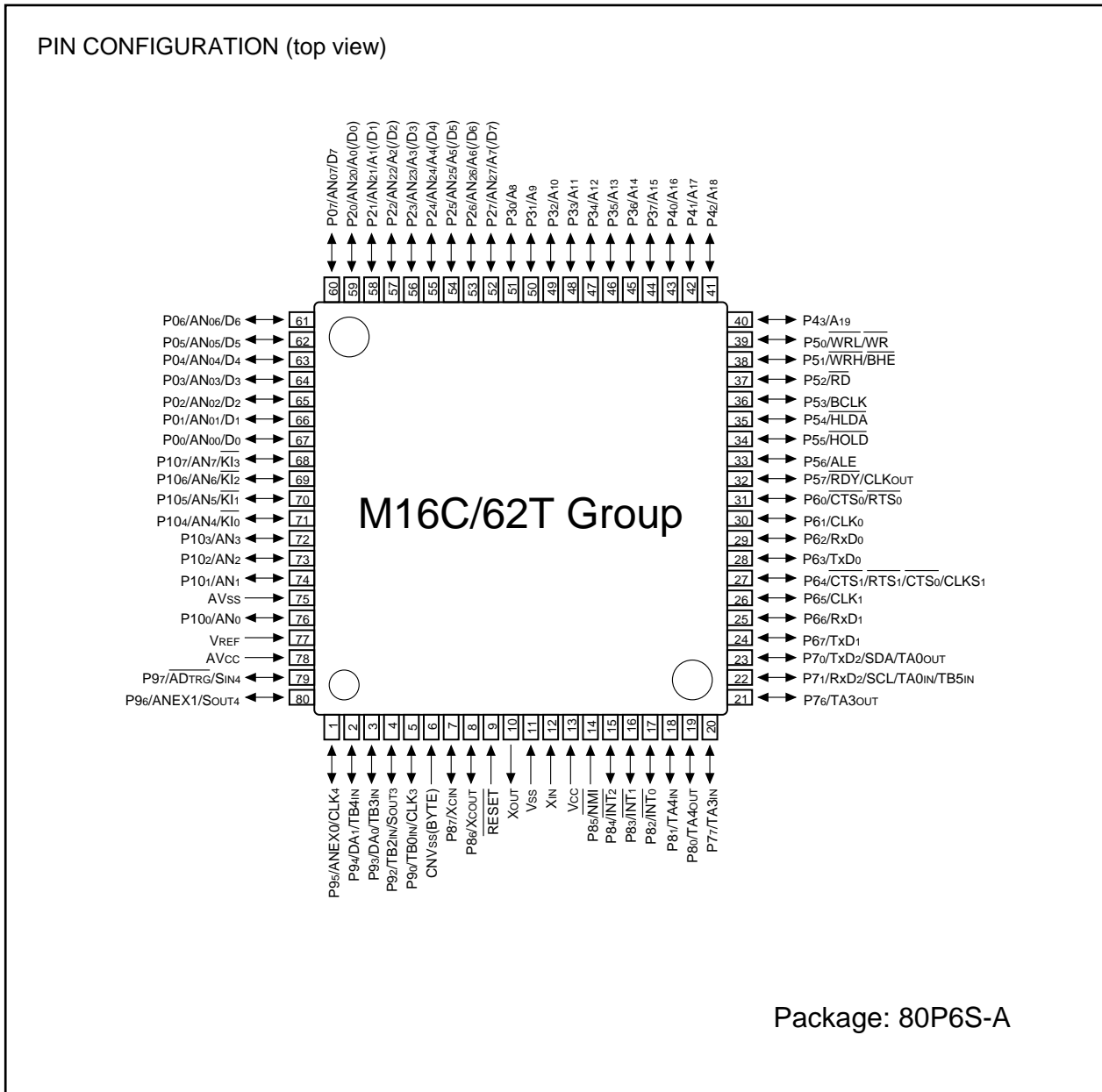


Figure 1.1.2. Pin configuration (top view) of M30623 (80-pin package)

Description

Block Diagram

Figure 1.1.3 is block diagrams of M30622(100-pin package) and 1.1.4 is block diagrams of M30623(80-pin package).

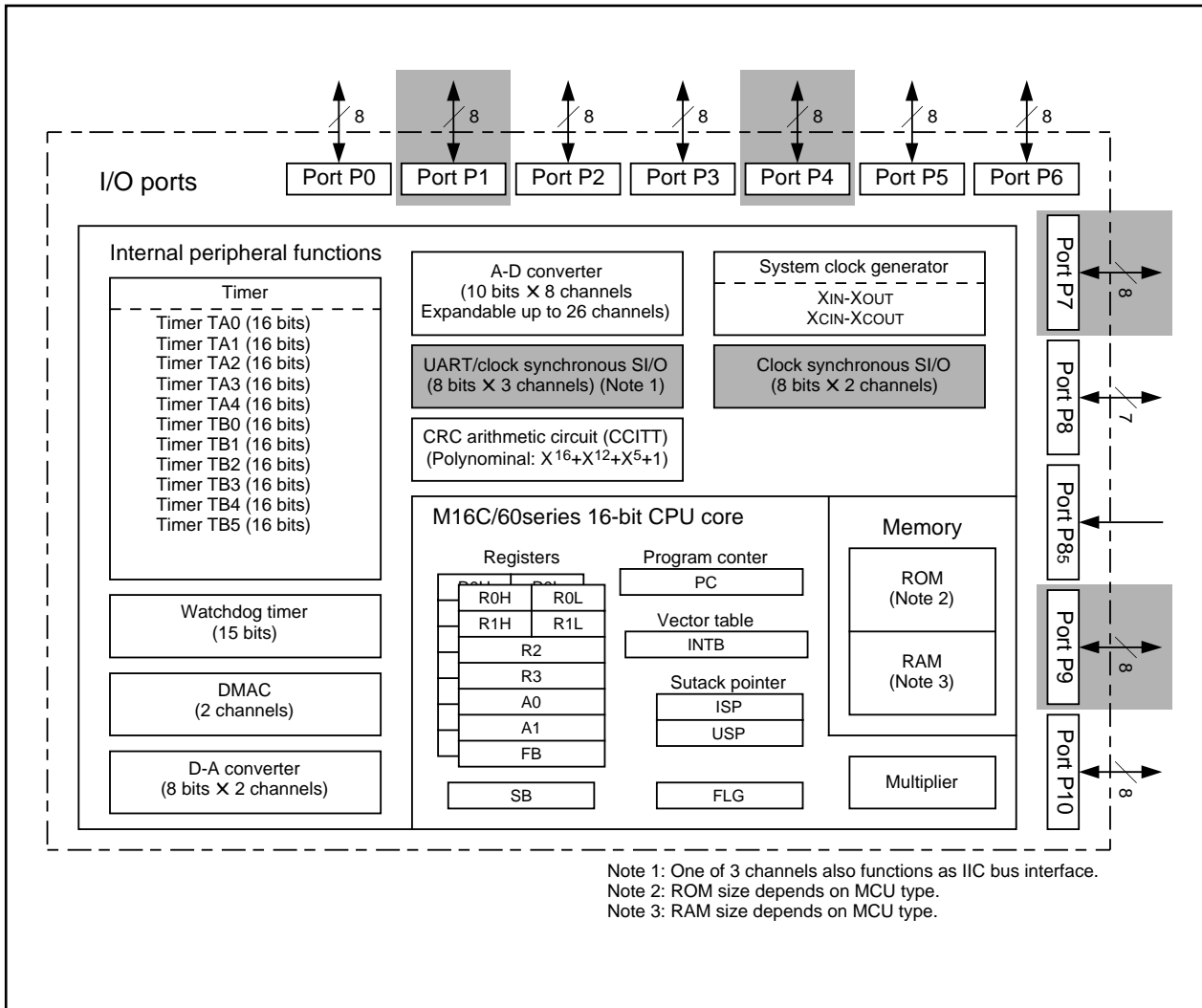


Figure 1.1.3. Block diagram of M30622 (100-pin package)

Description

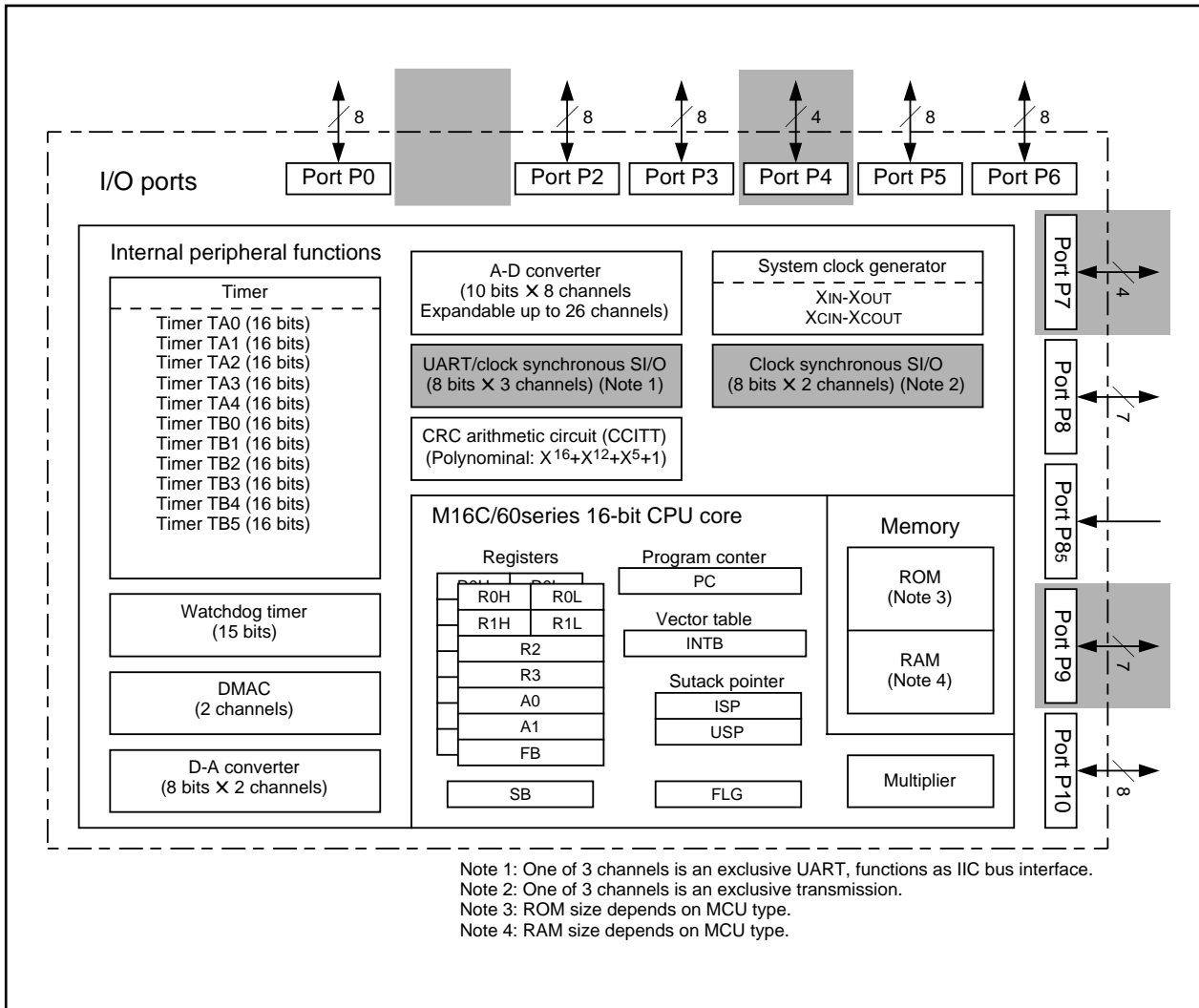


Figure 1.1.4. Block diagram of M30623 (80-pin package)

Description

Performance Outline

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

Table 1.1.1. Performance outline of M16C/62T group

Item		Performance	
		M30622(100-pin package)	M30623(80-pin package)
Number of basic instructions		91 instructions	
Shortest instruction execution time		62.5ns(f(XIN)=16MHz, Vcc=5V)	
Memory capacity	ROM	32Kbytes (M30623M4T-XXXGP) 64Kbytes (M30622M8T/M8V-XXXFP, M30623M8T/M8V-XXXGP) 128Kbytes (M30622MCT/MCV-XXXFP, M30623MCT/MCV-XXXGP, M30622ECT/ECV-XXXFP, M30623ECT/ECV-XXXGP)	
	RAM	3Kbytes (M30623M4T-XXXGP) 4Kbytes (M30622M8T/M8V-XXXFP, M30623M8T/M8V-XXXGP) 5Kbytes (M30622MCT/MCV-XXXFP, M30623MCT/MCV-XXXGP, M30622ECT/ECV-XXXFP, M30623ECT/ECV-XXXGP)	
I/O port	P0, P2, P3, P5, P6, P10	8 bits x 6	
	P1	8 bits x 1	—
	P4, P7	8 bits x 2	4 bits x 2
	P8 (except P8s)	7 bits x 1	
	P9	8 bits x 1	7 bits x 1
Input port	P8s	1 bit x 1	
Multifunction timer	TA0, A3, TA4	16 bits x 3 (cycle timer, external / internal event count, pulse output)	
	TA1, TA2	16 bits x 2 (cycle timer, external / internal event count, pulse output)	16 bits x 2 (cycle timer, internal event count)
	TB0, TB2 to TB5	16 bits x 5 (cycle timer, external / internal event count, pulse period / pulse width measurement)	
	TB1	16 bits x 1 (cycle timer, external / internal event count, pulse period / pulse width measurement)	16 bits x 1 (cycle timer, internal event count)
Serial I/O	UART0, UART1	(UART or clock synchronous) x 2	
	UART2	(UART or clock synchronous) x 1	UART x 1
	SI/O3	(Clock synchronous) x 1	(Clock synchronous) x 1 (exclusive transmission)
	SI/O4	(Clock synchronous) x 1	
A-D converter		10 bits x (8 x 3 + 2) channels	
D-A converter		8 bits x 2 channels	
DMAC		2 channels (trigger: 24 sources)	
CRC calculation circuit		CRC-CCITT	
Watchdog timer		15 bits x 1 (with prescaler)	
Interrupt		25 internal and 8 external sources, 4 software sources, 7 levels	25 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		Mask ROM version : 4.2 to 5.5V (f(XIN)=16MHz, without software wait) One-time PROM version : 4.5 to 5.5V (f(XIN)=16MHz, without software wait)	
Power consumption		140mW (Vcc=5V, f(XIN) = 16MHz)	
I/O characteristics	I/O withstand voltage	5V	
	Output current	5mA	
Memory expansion		Available (to 1.2M bytes or 4M bytes) (The M16C/62T group is not guaranteed to operate in memory expansion.)	
Operating ambient temperature		85°C guaranteed version : -40°C to 85°C, 125°C guaranteed version : -40°C to 125°C	
Device configuration		CMOS high performance silicon gate	
Package		100-pin plastic mold QFP	80-pin plastic mold QFP

Description

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

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

One-time PROM version has the equally functions mask ROM version, with the exception of built-in electric-programming-possible PROM.

(2) ROM capacity

(3) Package(number of pin)

100P6S-A : 100-pin plastic molded QFP

80P6S-A : 80-pin plastic molded QFP

(4) Support for 85°C guaranteed version, 125°C guaranteed version

125°C guaranteed version M30622MxV/ECV-XXXFP, M30623MxV/ECV-XXXGP is supported. These are different from 85°C guaranteed version M30622MxT/ECT-XXXFP, M30623MxT/ECT-XXXGP on operating ambient temperature and the terms of the use, and so please inquire.

ROM size	100-pin package		80-pin package	
128K bytes	M30622MCT-XXXFP M30622MCMV-XXXFP	M30622ECT-XXXFP M30622ECTFP* M30622ECV-XXXFP M30622ECVFP*	M30623MCT-XXXGP M30623MCMV-XXXGP	M30623ECT-XXXGP M30623ECTGP* M30623ECV-XXXGP M30623ECVGP*
64K bytes	M30622M8T-XXXFP M30622M8V-XXXFP		M30623M8T-XXXGP M30623M8V-XXXGP	
32K bytes			M30623M4T-XXXGP	
	Mask ROM version	One-time PROM version	Mask ROM version	One-time PROM version

* Shipped in blank

Note 1: It may change in the future.
 Note 2: Use shipped in blank of one-time PROM version as the trial, development of program.
 In case of vehicle-mount test or mass production, use shipped in programming.

Figure 1.1.5. ROM expansion

Now: Mar.1999.

Description

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

Table 1.1.2. M16C/62T group

Now: Mar.1999.

Type No.	ROM capacity	RAM capacity	Characteristic	Package	Remarks	
M30622M8T-XXXFP	64K bytes	4K bytes	85 °C guaranteed version	100P6S-A	Mask ROM version	
M30622M8V-XXXFP			125 °C guaranteed version (Note 3)		Mask ROM version	
M30622MCT-XXXFP	128K bytes	5K bytes	85 °C guaranteed version		One-time PROM version (programming)	
M30622ECT-XXXFP					One-time PROM version (blank)	
M30622MCT-XXXFP			125 °C guaranteed version (Note 3)		Mask ROM version	
M30622ECV-XXXFP					One-time PROM version (programming)	
M30622ECVFP					One-time PROM version (blank)	
M30623M4T-XXXGP					32K bytes	3K bytes
M30623M8T-XXXGP	64K bytes	4K bytes	85 °C guaranteed version		80P6S-A	Mask ROM version
M30623M8V-XXXGP			125 °C guaranteed version (Note 3)			Mask ROM version
M30623MCT-XXXGP	128K bytes	5K bytes	85 °C guaranteed version	Mask ROM version		
M30623ECT-XXXGP				One-time PROM version (programming)		
M30623ECTGP			One-time PROM version (blank)			
M30623MCT-XXXGP			125 °C guaranteed version (Note 3)	Mask ROM version		
M30623ECV-XXXGP				One-time PROM version (programming)		
M30623ECVGP				One-time PROM version (blank)		

Note 1: It may change in the future.

Note 2: Use shipped in blank of one-time PROM version as the trial, development of program.

In case of vehicle-mount test or mass production, use shipped in programming.

Note 3: It is different from 85°C guaranteed version on operating ambient temperature and the terms of the use, please inquire.

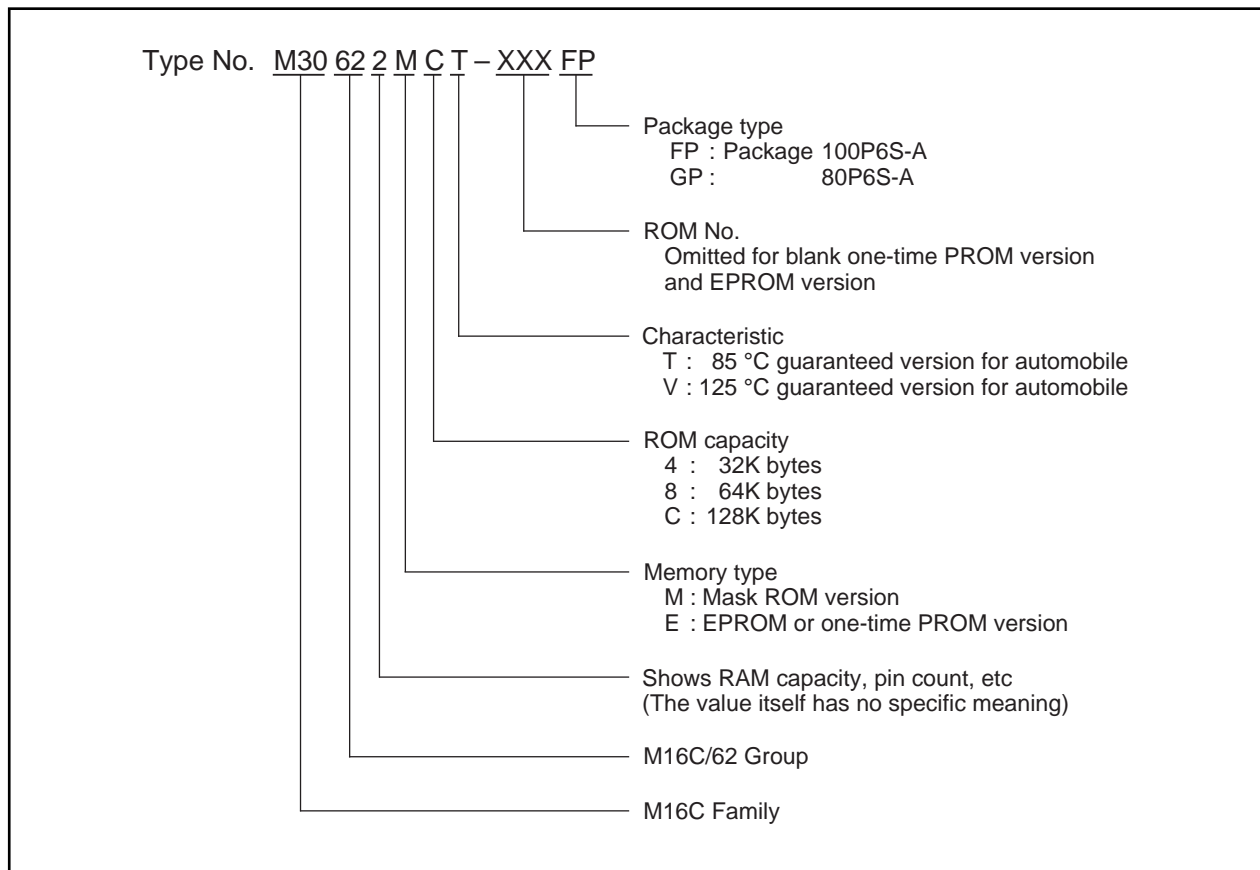


Figure 1.1.6. Type No., memory size, and package

Pin Description

Pin Description

Pin name	Signal name	I/O type	Function
Vcc, Vss	Power supply input		Supply 4.2 V to 5.5 V to the Vcc pin. Supply 0 V to the Vss pin.
CNVss	CNVss	Input	This pin switches between processor modes. Connect it to the Vss pin when operating in single-chip or memory expansion mode. Connect it to the Vcc pin when operating in microprocessor mode.
RESET	Reset input	Input	A "L" on this input resets the microcomputer.
XIN XOUT	Clock input Clock output	Input Output	These pins are provided for the main clock generating circuit. Connect a ceramic resonator or crystal between the XIN and the XOUT pins. To use an externally derived clock, input it to the XIN pin and leave the XOUT pin open.
BYTE	External data bus width select input	Input	This pin selects the width of an external data bus. A 16-bit width is selected when this input is "L"; an 8-bit width is selected when this input is "H". This input must be fixed to either "H" or "L". When operating in single-chip mode, connect this pin to Vss. In M30623 (80-pin package), the BYTE signal is internally connected to the CNVss signal.
AVcc	Analog power supply input		This pin is a power supply input for the A-D converter. Connect this pin to Vcc.
AVss	Analog power supply input		This pin is a power supply input for the A-D converter. Connect this pin to Vss.
VREF	Reference voltage input	Input	This pin is a reference voltage input for the A-D converter.
P00 to P07	I/O port P0	Input/output	This is an 8-bit CMOS I/O port. It has an input/output port direction register that allows the user to set each pin for input or output individually. When 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. Pins in this port also function as A-D converter extended input pins as selected by software when operating in single-chip mode.
D0 to D7		Input/output	When set as a separate bus, these pins input and output data (D0–D7).
P10 to P17	I/O port P1	Input/output	This is an 8-bit I/O port equivalent to P0. Pins in this port also function as external interrupt pins as selected by software.
D8 to D15		Input/output	When set as a separate bus, these pins input and output data (D8–D15).
P20 to P27	I/O port P2	Input/output	This is an 8-bit I/O port equivalent to P0. Pins in this port also function as A-D converter extended input pins as selected by software when operating in single-chip mode.
A0 to A7		Output	These pins output 8 low-order address bits (A0–A7).
A0/D0 to A7/D7		Input/output	If the external bus is set as an 8-bit wide multiplexed bus, these pins input and output data (D0–D7) and output 8 low-order address bits (A0–A7) separated in time by multiplexing.
A0, A1/D0 to A7/D6		Output Input/output	If the external bus is set as a 16-bit wide multiplexed bus, these pins input and output data (D0–D6) and output address (A1–A7) separated in time by multiplexing. They also output address (A0).
P30 to P37	I/O port P3	Input/output	This is an 8-bit I/O port equivalent to P0.
A8 to A15		Output	These pins output 8 middle-order address bits (A8–A15).
A8/D7, A9 to A15		Input/output	If the external bus is set as a 16-bit wide multiplexed bus, these pins input and output data (D7) and output address (A8) separated in time by multiplexing. They also output address (A9–A15).

Pin Description

Pin Description

Pin name	Signal name	I/O type	Function	
P40 to P47	I/O port P4	Input/output	This is an 8-bit I/O port equivalent to P0.	
CS0 to CS3, A16 to A19		Output Output	These pins output CS0–CS3 signals and A16–A19. CS0–CS3 are chip select signals used to specify an access space. A16–A19 are 4 high-order address bits.	
P50 to P57	I/O port P5	Input/output	This is an 8-bit I/O port equivalent to P0. In single-chip mode, P57 in this port outputs a divide-by-8 or divide-by-32 clock of XIN or a clock of the same frequency as XCIN as selected by software.	
WRL/WR, WRH/BHE, RD, BCLK, HLDA, HOLD, ALE, RDY		Output Output Output Output Output Input Output Input	Output WRL, WRH (WR and BHE), RD, BCLK, HLDA, and ALE signals. WRL and WRH, and BHE and WR can be switched using software control. <ul style="list-style-type: none"> ■ WRL, WRH, and RD selected With a 16-bit external data bus, data is written to even addresses when the WRL signal is "L" and to the odd addresses when the WRH signal is "L". Data is read when RD is "L". ■ WR, BHE, and RD selected Data is written when WR is "L". Data is read when RD is "L". Odd addresses are accessed when BHE is "L". Use this mode when using an 8-bit external data bus. While the input level at the HOLD pin is "L", the microcomputer is placed in the hold state. While in the hold state, HLDA outputs a "L" level. ALE is used to latch the address. While the input level of the RDY pin is "L", the microcomputer is in the ready state. 	
P60 to P67		I/O port P6	Input/output	This is an 8-bit I/O port equivalent to P0. Pins in this port also function as UART0 and UART1 I/O pins as selected by software.
P70 to P77		I/O port P7	Input/output	This is an 8-bit I/O port equivalent to P0 (P70 and P71 are N channel open-drain output). Pins in this port also function as timer A0–A3, timer B5 or UART2 I/O pins as selected by software.
P80 to P84, P86, P87, P85		I/O port P8	Input/output Input/output Input/output Input	P80 to P84, P86 and P87 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. P86 and P87 can be set using software to function as the I/O pins for a sub clock generation circuit. In this case, connect a quartz oscillator between P86 (XCOUT pin) and P87 (XCIN pin). P85 is an input-only port that also functions for NMI. The NMI interrupt is generated when the input at this pin changes from "H" to "L". The NMI function cannot be cancelled using software. The pull-up cannot be set for this pin.
		I/O port P85	Input	
P90 to P97	I/O port P9	Input/output	This is an 8-bit I/O port equivalent to P0. Pins in this port also function as SI/O 3, 4 I/O pins, timer B0–B4 input pins, D-A converter output pins, A-D converter extended input pins, or A-D trigger input pins as selected by software.	
P100 to P107	I/O port P10	Input/output	This is an 8-bit I/O port equivalent to P0. Pins in this port also function as A-D converter input pins. Furthermore, P104–P107 also function as input pins for the key input interrupt function.	

Note 1: In M30623(80-pin package), the following signals do not have the corresponding external pin.

- P10/D8 to P14/D12, P15/D13/INT3 to P17/D15/INT5
- P44/CS0 to P47/CS3
- P72/CLK2/TA1OUT/V, P73/CST2/RTS2/TA1IN/V, P74/TA2OUT/W, P75/TA2IN/W
- P91/TB1IN/SIN3

Note 2: The M16C/62T group is not guaranteed to operate in memory expansion and microprocessor modes.

Operation of Functional Blocks

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

The following explains each unit.

Memory

Figure 1.4.1 is a memory map of the M16C/62T group. The address space extends the 1M bytes from address 00000₁₆ to FFFFF₁₆.

Internal ROM is located as the following, in M30623M4T-XXXGP from address F8000₁₆ to FFFFF₁₆ (32K bytes), in M30622M8T/M8V-XXXFP and M30623M8T/M8V-XXXGP from address F0000₁₆ to FFFFF₁₆ (64K bytes), in M30622MCT/MCV-XXXFP and M30623MCT/MCV-XXXGP from address E0000₁₆ to FFFFF₁₆ (128K bytes).

The vector table for fixed interrupts such as the reset and $\overline{\text{NMI}}$ are mapped to FFFDC₁₆ to FFFFF₁₆. The starting address of the interrupt routine is stored here. The address of the vector table for timer interrupts, etc., can be set as desired using the internal register (INTB). See the section on interrupts for details.

Internal RAM is located as the following, in M30623M4T-XXXGP from address 00400₁₆ to 00FFF₁₆ (3K bytes), in M30622M8T/M8V-XXXFP and M30623M8T/M8V-XXXGP from address 00400₁₆ to 013FF₁₆ (4K bytes), in M30622MCT/MCV-XXXFP and M30623MCT/MCV-XXXGP from address 00400₁₆ to 017FF₁₆ (5K bytes). In addition to storing data, the RAM also stores the stack used when calling subroutines and when interrupts are generated.

The SFR area is mapped to 00000₁₆ to 003FF₁₆. This area accommodates the control registers for peripheral devices such as I/O ports, A-D converter, serial I/O, and timers, etc. Figures 1.7.1 to 1.7.3 are location of peripheral unit control registers. Any part of the SFR area that is not occupied is reserved and cannot be used for other purposes.

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

In memory expansion mode and microprocessor mode, a part of the spaces are reserved and cannot be used. For example, in the M30623MCT/MCV-XXXGP, the following spaces cannot be used.

- The space between 01000₁₆ and 03FFF₁₆ (Memory expansion and microprocessor modes)
- The space between D0000₁₆ and D7FFF₁₆ (Memory expansion mode)

But the M16C/62T group is not guaranteed to operate in memory expansion and microprocessor modes.

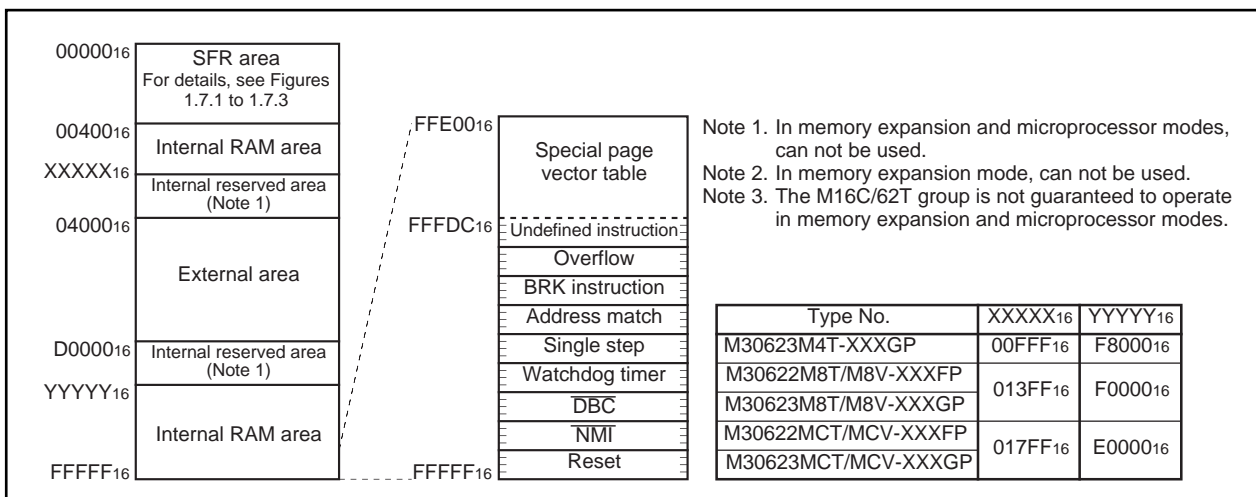


Figure 1.4.1. Memory map

Central Processing Unit (CPU)

The CPU has a total of 13 registers shown in Figure 1.5.1. Seven of these registers (R0, R1, R2, R3, A0, A1, and FB) come in two sets; therefore, these have two register banks.

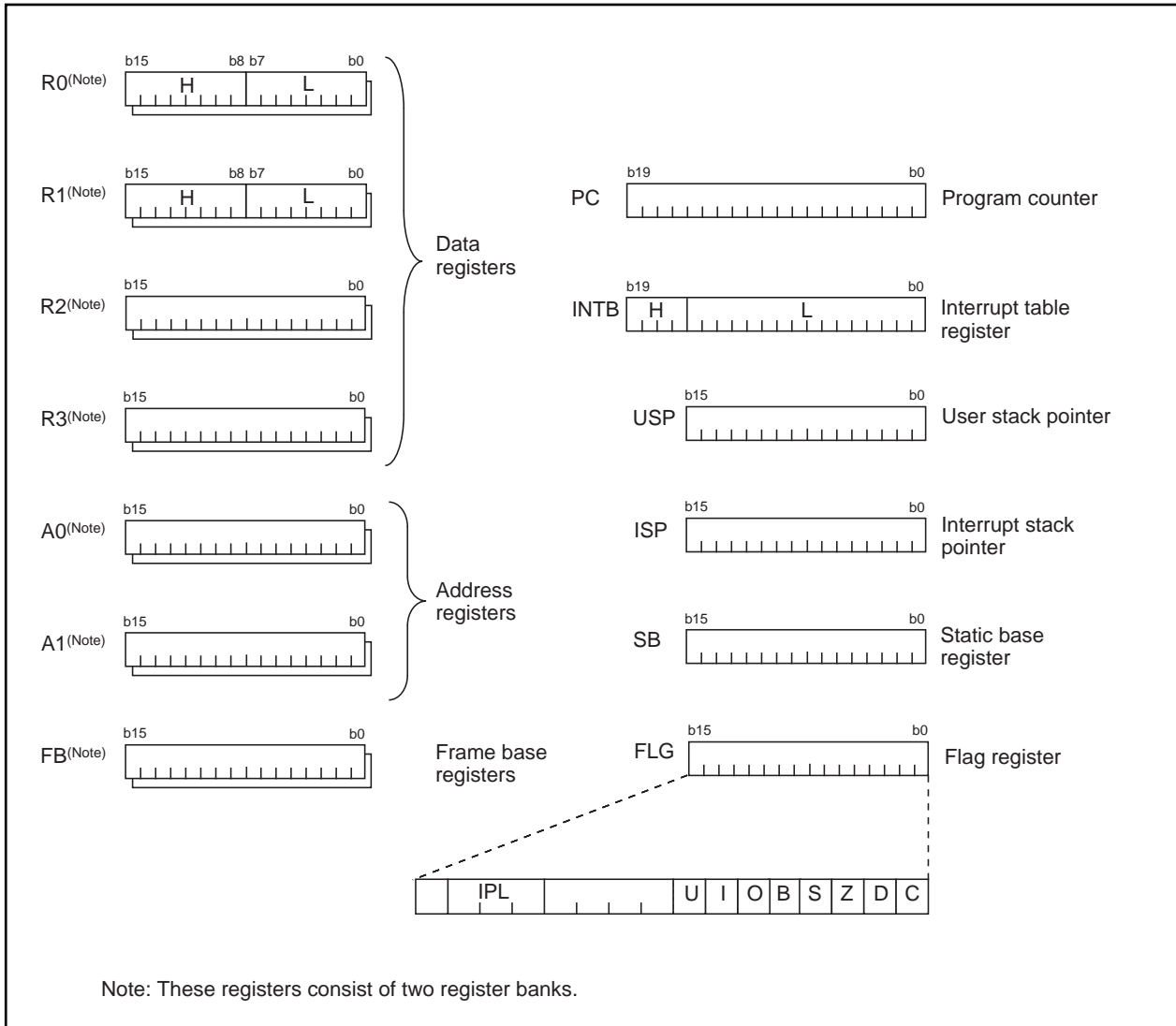


Figure 1.5.1. Central processing unit register

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

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

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

(2) Address registers (A0 and A1)

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

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

(3) Frame base register (FB)

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

(4) Program counter (PC)

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

(5) Interrupt table register (INTB)

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

(6) Stack pointer (USP/ISP)

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

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

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

(7) Static base register (SB)

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

(8) Flag register (FLG)

Flag register (FLG) is configured with 11 bits, each bit is used as a flag. Figure 1.5.2 shows the flag register (FLG). The following explains the function of each flag:

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

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

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

This flag enables a single-step interrupt.

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

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

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

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

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

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

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

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

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

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

This flag enables a maskable interrupt.

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

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

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

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

• **Bits 8 to 11: Reserved area**

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

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

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

• **Bit 15: Reserved area**

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

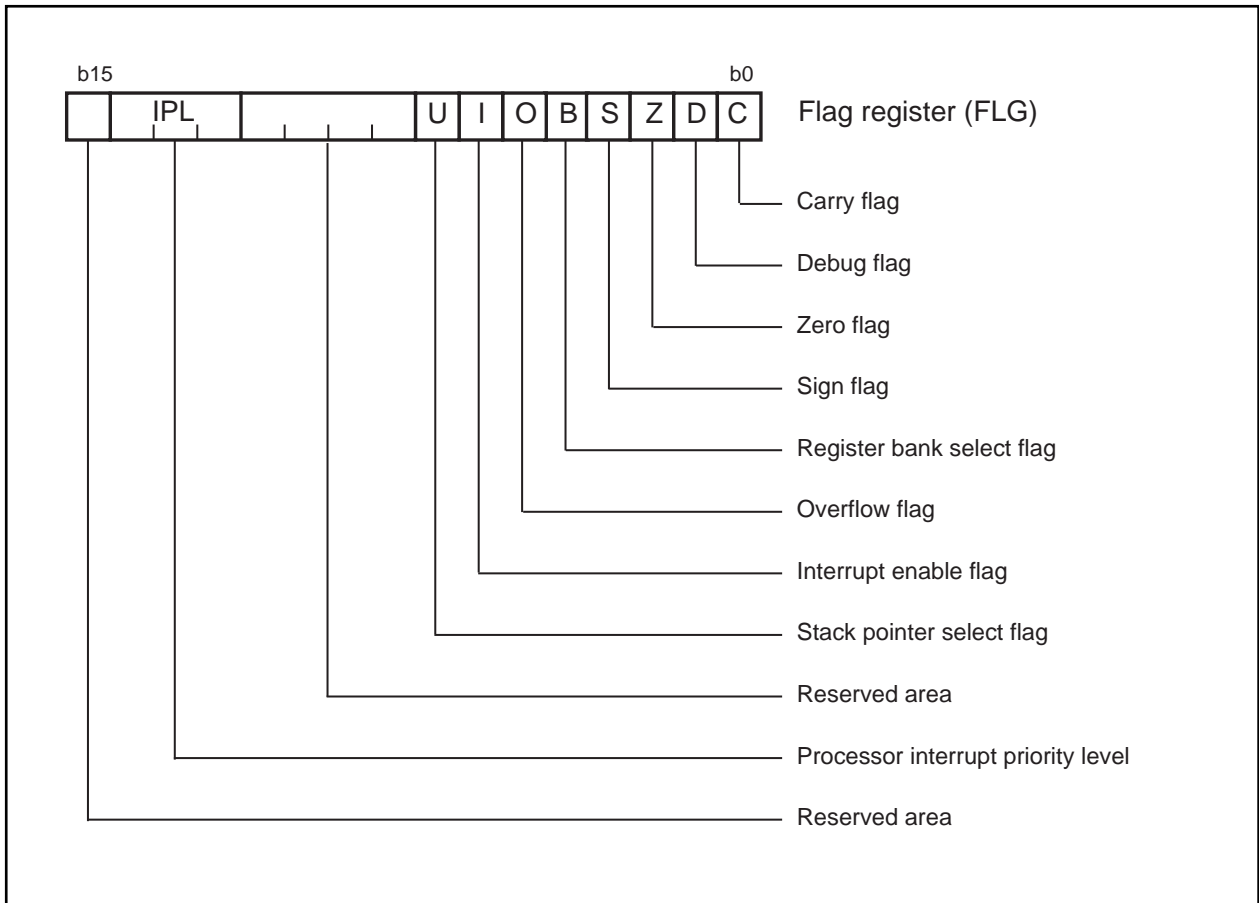


Figure 1.5.2. Flag register (FLG)

Reset

Reset

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

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

Figure 1.6.1 shows the example reset circuit. Figure 1.6.2 shows the reset sequence.

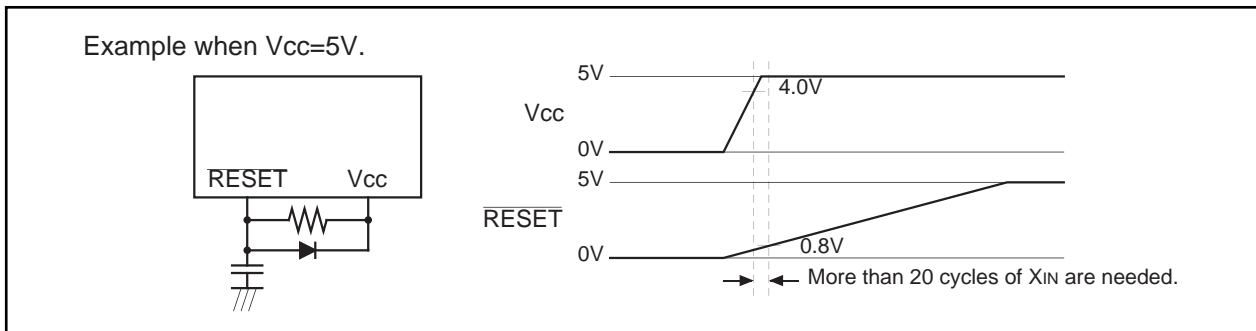


Figure 1.6.1. Example reset circuit

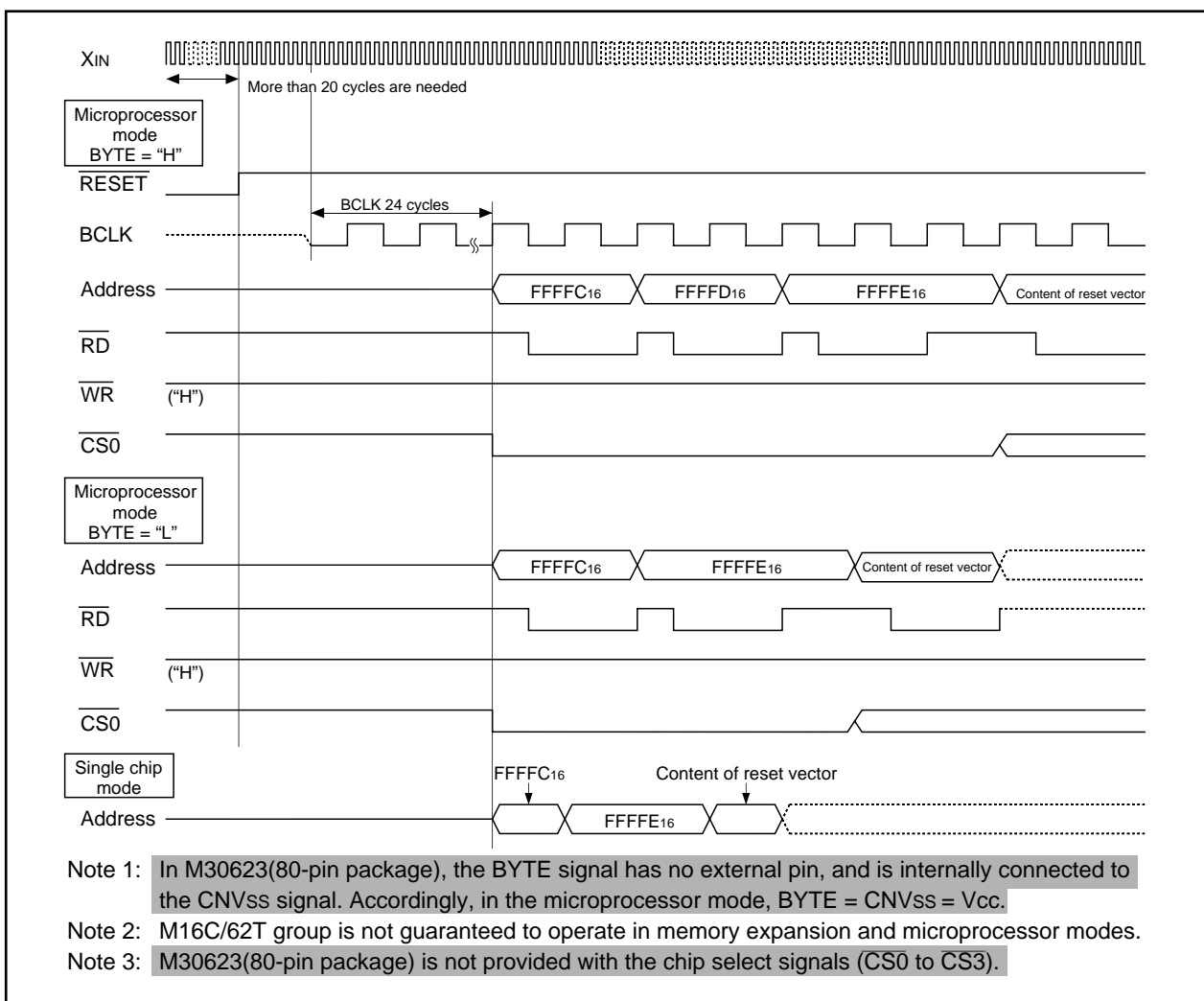


Figure 1.6.2. Reset sequence

Table 1.6.1 shows the statuses of the other pins while the $\overline{\text{RESET}}$ pin level is "L". Figures 1.6.3 and 1.6.4 show the internal status of the microcomputer immediately after the reset is cancelled.

Table 1.6.1. Pin status when $\overline{\text{RESET}}$ pin level is "L"

Pin name	Status		
	CNVss = Vss	CNVss = Vcc	
		BYTE = Vss (Note 1)	BYTE = Vcc
P0	Input port (floating)	Data input (floating)	Data input (floating)
P1	Input port (floating)	Data input (floating)	Input port (floating)
P2, P3, P40 to P43	Input port (floating)	Address output (undefined)	Address output (undefined)
P44	Input port (floating)	$\overline{\text{CS0}}$ output ("H" level is output)	$\overline{\text{CS0}}$ output ("H" level is output)
P45 to P47	Input port (floating) (pull-up resistor is on)	Input port (floating) (pull-up resistor is on)	Input port (floating) (pull-up resistor is on)
P50	Input port (floating)	$\overline{\text{WR}}$ output ("H" level is output)	$\overline{\text{WR}}$ output ("H" level is output)
P51	Input port (floating)	$\overline{\text{BHE}}$ output (undefined)	$\overline{\text{BHE}}$ output (undefined)
P52	Input port (floating)	$\overline{\text{RD}}$ output ("H" level is output)	$\overline{\text{RD}}$ output ("H" level is output)
P53	Input port (floating)	BCLK output	BCLK output
P54	Input port (floating)	$\overline{\text{HLDA}}$ output (The output value depends on the input to the HOLD pin)	$\overline{\text{HLDA}}$ output (The output value depends on the input to the HOLD pin)
P55	Input port (floating)	$\overline{\text{HOLD}}$ input (floating)	$\overline{\text{HOLD}}$ input (floating)
P56	Input port (floating)	ALE output ("L" level is output)	ALE output ("L" level is output)
P57	Input port (floating)	$\overline{\text{RDY}}$ input (floating)	$\overline{\text{RDY}}$ input (floating)
P6, P7, P80 to P84, P86, P87, P9, P10	Input port (floating)	Input port (floating)	Input port (floating)

Note 1: In M30623(80-pin package), the BYTE signal has no external pin, and is internally connected to the CNVss signal. Accordingly, in the microprocessor mode, BYTE = CNVss = Vcc.

Note 2: In M30623(80-pin package), Port P1, P44 to P47, P72 to P75 and P91 have no external pin, and are internally the above conditions. After reset, set these ports to one of the following conditions.

- Be output mode, and output "L" level.
- Pull-up resistor is on.

Reset

(1) Processor mode register 0 (Note 1)	(0004 ₁₆)***	00 ₁₆	(24) A-D conversion interrupt control register	(004E ₁₆)***	XXXX?000
(2) Processor mode register 1	(0005 ₁₆)***	00000X0	(25) UART2 transmit interrupt control register	(004F ₁₆)***	XXXX?000
(3) System clock control register 0	(0006 ₁₆)***	01001000	(26) UART2 receive interrupt control register	(0050 ₁₆)***	XXXX?000
(4) System clock control register 1	(0007 ₁₆)***	00100000	(27) UART0 transmit interrupt control register	(0051 ₁₆)***	XXXX?000
(5) Chip select control register	(0008 ₁₆)***	00000001	(28) UART0 receive interrupt control register	(0052 ₁₆)***	XXXX?000
(6) Address match interrupt enable register	(0009 ₁₆)***	XXXXXX00	(29) UART1 transmit interrupt control register	(0053 ₁₆)***	XXXX?000
(7) Protect register	(000A ₁₆)***	XXXXXX00	(30) UART1 receive interrupt control register	(0054 ₁₆)***	XXXX?000
(8) Data bank register	(000B ₁₆)***	00 ₁₆	(31) Timer A0 interrupt control register	(0055 ₁₆)***	XXXX?000
(9) Watchdog timer control register	(000F ₁₆)***	00*????	(32) Timer A1 interrupt control register	(0056 ₁₆)***	XXXX?000
(10) Address match interrupt register 0	(0010 ₁₆)***	00 ₁₆	(33) Timer A2 interrupt control register	(0057 ₁₆)***	XXXX?000
	(0011 ₁₆)***	00 ₁₆	(34) Timer A3 interrupt control register	(0058 ₁₆)***	XXXX?000
	(0012 ₁₆)***	XXXXX000	(35) Timer A4 interrupt control register	(0059 ₁₆)***	XXXX?000
(11) Address match interrupt register 1	(0014 ₁₆)***	00 ₁₆	(36) Timer B0 interrupt control register	(005A ₁₆)***	XXXX?000
	(0015 ₁₆)***	00 ₁₆	(37) Timer B1 interrupt control register	(005B ₁₆)***	XXXX?000
	(0016 ₁₆)***	XXXXX000	(38) Timer B2 interrupt control register	(005C ₁₆)***	XXXX?000
(12) DMA0 control register	(002C ₁₆)***	00000?00	(39) INT0 interrupt control register	(005D ₁₆)***	XX00?000
(13) DMA1 control register	(003C ₁₆)***	00000?00	(40) INT1 interrupt control register	(005E ₁₆)***	XX00?000
(14) INT3 interrupt control register	(0044 ₁₆)***	XX00?000	(41) INT2 interrupt control register	(005F ₁₆)***	XX00?000
(15) Timer B5 interrupt control register	(0045 ₁₆)***	XXXX?000	(42) Timer B3,4,5 count start flag	(0340 ₁₆)***	000XXXXX
(16) Timer B4 interrupt control register	(0046 ₁₆)***	XXXX?000	(43) Three-phase PWM control register 0	(0348 ₁₆)***	00 ₁₆
(17) Timer B3 interrupt control register	(0047 ₁₆)***	XXXX?000	(44) Three-phase PWM control register 1	(0349 ₁₆)***	00 ₁₆
(18) SI/O4 interrupt control register	(0048 ₁₆)***	XX00?000	(45) Three-phase output buffer register 0	(034A ₁₆)***	00 ₁₆
(19) SI/O3 interrupt control register	(0049 ₁₆)***	XX00?000	(46) Three-phase output buffer register 1	(034B ₁₆)***	00 ₁₆
(20) Bus collision detection interrupt control register	(004A ₁₆)***	XXXX?000	(47) Timer B3 mode register	(035B ₁₆)***	00?X0000
(21) DMA0 interrupt control register	(004B ₁₆)***	XXXX?000	(48) Timer B4 mode register	(035C ₁₆)***	00?X0000
(22) DMA1 interrupt control register	(004C ₁₆)***	XXXX?000	(49) Timer B5 mode register	(035D ₁₆)***	00?X0000
(23) Key input interrupt control register	(004D ₁₆)***	XXXX?000	(50) Interrupt cause select register	(035F ₁₆)***	00 ₁₆

* : This bit is the cold start / warm start flag, is set to "0" at power on reset (refer to Page 71).
X : Nothing is mapped to this bit.
? : Undefined
The content of other registers and RAM is undefined when the microcomputer is reset.
The initial values must therefore be set.
Note 1 : When the Vcc level is applied to the CNVss pin, it is 03₁₆ at a reset.

Figure 1.6.3. Device's internal status after a reset is cleared

Reset

(51) SI/O3 control register	(0362 ₁₆)	0 1 0 0 0 0 0 0	(79) A-D control register 2	(03D4 ₁₆)	0 0 0 0 X X X 0
(52) SI/O4 control register	(0366 ₁₆)	0 1 0 0 0 0 0 0	(80) A-D control register 0	(03D6 ₁₆)	0 0 0 0 0 0 ? ?
(53) UART2 special mode register	(0377 ₁₆)	00 ₁₆	(81) A-D control register 1	(03D7 ₁₆)	00 ₁₆
(54) UART2 transmit/receive mode register	(0378 ₁₆)	00 ₁₆	(82) D-A control register	(03DC ₁₆)	00 ₁₆
(55) UART2 transmit/receive control register 0	(037C ₁₆)	0 0 0 0 1 0 0 0	(83) Port P0 direction register	(03E2 ₁₆)	00 ₁₆
(56) UART2 transmit/receive control register 1	(037D ₁₆)	0 0 0 0 0 0 1 0	(84) Port P1 direction register	(03E3 ₁₆)	00 ₁₆
(57) Count start flag	(0380 ₁₆)	00 ₁₆	(85) Port P2 direction register	(03E6 ₁₆)	00 ₁₆
(58) Clock prescaler reset flag	(0381 ₁₆)	X X X X X X X X	(86) Port P3 direction register	(03E7 ₁₆)	00 ₁₆
(59) One-shot start flag	(0382 ₁₆)	0 X X 0 0 0 0 0	(87) Port P4 direction register	(03EA ₁₆)	00 ₁₆
(60) Trigger select flag	(0383 ₁₆)	00 ₁₆	(88) Port P5 direction register	(03EB ₁₆)	00 ₁₆
(61) Up-down flag	(0384 ₁₆)	00 ₁₆	(89) Port P6 direction register	(03EE ₁₆)	00 ₁₆
(62) Timer A0 mode register	(0396 ₁₆)	00 ₁₆	(90) Port P7 direction register	(03EF ₁₆)	00 ₁₆
(63) Timer A1 mode register	(0397 ₁₆)	00 ₁₆	(91) Port P8 direction register	(03F2 ₁₆)	0 0 X 0 0 0 0 0
(64) Timer A2 mode register	(0398 ₁₆)	00 ₁₆	(92) Port P9 direction register	(03F3 ₁₆)	00 ₁₆
(65) Timer A3 mode register	(0399 ₁₆)	00 ₁₆	(93) Port P10 direction register	(03F6 ₁₆)	00 ₁₆
(66) Timer A4 mode register	(039A ₁₆)	00 ₁₆	(94) Pull-up control register 0	(03FC ₁₆)	00 ₁₆
(67) Timer B0 mode register	(039B ₁₆)	0 0 ? X 0 0 0 0	(95) Pull-up control register 1 (Note 1)	(03FD ₁₆)	00 ₁₆
(68) Timer B1 mode register	(039C ₁₆)	0 0 ? X 0 0 0 0	(96) Pull-up control register 2	(03FE ₁₆)	00 ₁₆
(69) Timer B2 mode register	(039D ₁₆)	0 0 ? X 0 0 0 0	(97) Port control register	(03FF ₁₆)	00 ₁₆
(70) UART0 transmit/receive mode register	(03A0 ₁₆)	00 ₁₆	(98) Data registers (R0/R1/R2/R3)		0000 ₁₆
(71) UART0 transmit/receive control register 0	(03A4 ₁₆)	0 0 0 0 1 0 0 0	(99) Address registers(A0/A1)		0000 ₁₆
(72) UART0 transmit/receive control register 1	(03A5 ₁₆)	0 0 0 0 0 0 1 0	(100) Frame base register (FB)		0000 ₁₆
(73) UART1 transmit/receive mode register	(03A8 ₁₆)	00 ₁₆	(101) Interrupt table register (INTB)		0000 ₁₆
(74) UART1 transmit/receive control register 0	(03AC ₁₆)	0 0 0 0 1 0 0 0	(102) User stack pointer (USP)		0000 ₁₆
(75) UART1 transmit/receive control register 1	(03AD ₁₆)	0 0 0 0 0 0 1 0	(103) Interrupt stack pointer (ISP)		0000 ₁₆
(76) UART transmit/receive control register 2	(03B0 ₁₆)	X 0 0 0 0 0 0 0	(104) Static base register (SB)		0000 ₁₆
(77) DMA0 cause select register	(03B8 ₁₆)	00 ₁₆	(105) Flag register (FLG)		0000 ₁₆
(78) DMA1 cause select register	(03BA ₁₆)	00 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 1 : When the Vcc level is applied to the CNVss pin, it is 02₁₆ at a reset.

Figure 1.6.4. Device's internal status after a reset is cleared

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

Figure 1.7.2. Location of peripheral unit control registers (2)

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

Figure 1.7.3. Location of peripheral unit control registers (3)

Memory Space Expansion Features

Here follows the description of the memory space expansion function.

With the processor running in memory expansion mode or in microprocessor mode, the memory space expansion features provide the means of expanding the accessible space. The memory space expansion features run in one of the three modes given below.

- (1) Normal mode (no expansion)
- (2) Memory space expansion mode 1 (to be referred as expansion mode 1)
- (3) Memory space expansion mode 2 (to be referred as expansion mode 2)

Use bits 5 and 4 (PM15, PM14) of processor mode register 1 to select a desired mode. The external memory area the chip select signal indicates is different in each mode so that the accessible memory space varies. Table 1.8.1 shows how to set individual modes and corresponding accessible memory spaces. For external memory area the chip select signal indicates, see Table 1.12.1 on page 33.

But M30623 (80-pin package) is not provided with the output pin for the chip select signal. And, the M16C/62T group is not guaranteed to operate in memory expansion and microprocessor modes.

Table 1.8.1. The way of setting memory space expansion modes and corresponding memory spaces

Expansion mode	How to set PM15 and PM14	Accessible memory space
Normal mode (no expansion)	0, 0	Up to 1M byte
Expansion mode 1	1, 0	Up to 1.2M bytes
Expansion mode 2	1, 1	Up to 4M bytes

Here follows the description of individual modes.

(1) Normal mode (a mode with memory not expanded)

'Normal mode' means a mode in which memory is not expanded.

Figure 1.8.1 shows the memory maps and the chip select areas in normal mode.

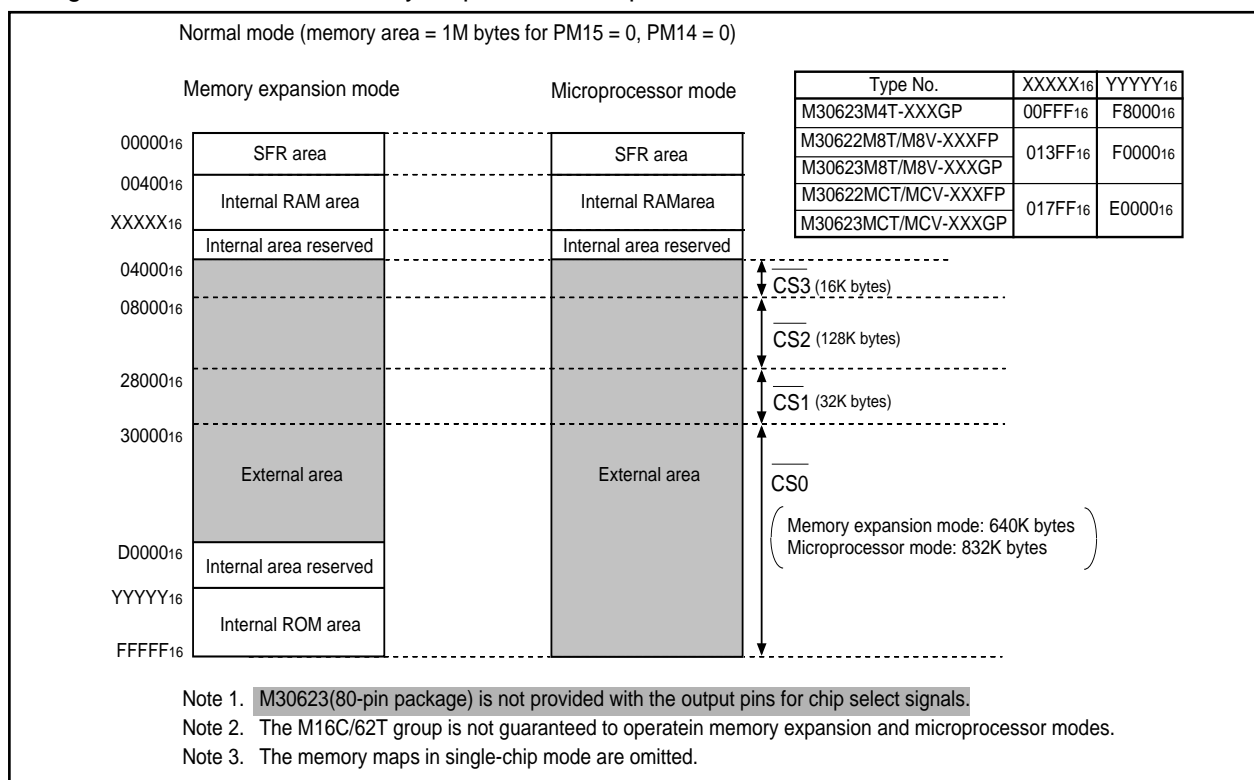


Figure 1.8.1. The memory maps and the chip select areas in normal mode

(2) Expansion mode 1

In this mode, the memory space can be expanded by 176K bytes in addition to that in normal mode.

Figure 1.8.2 shows the memory location and chip select area in expansion mode 1.

In accessing data in expansion mode 1, $\overline{CS3}$, $\overline{CS2}$, and $\overline{CS1}$ go active in the area from 04000_{16} through $2FFFF_{16}$; in fetching a program, $\overline{CS0}$ goes active. That is, the address space is expanded by using the area from 04000_{16} through $2FFFF_{16}$ (176K bytes) appropriately for accessing data ($\overline{CS3}$, $\overline{CS2}$, $\overline{CS1}$) and fetching a program ($\overline{CS0}$).

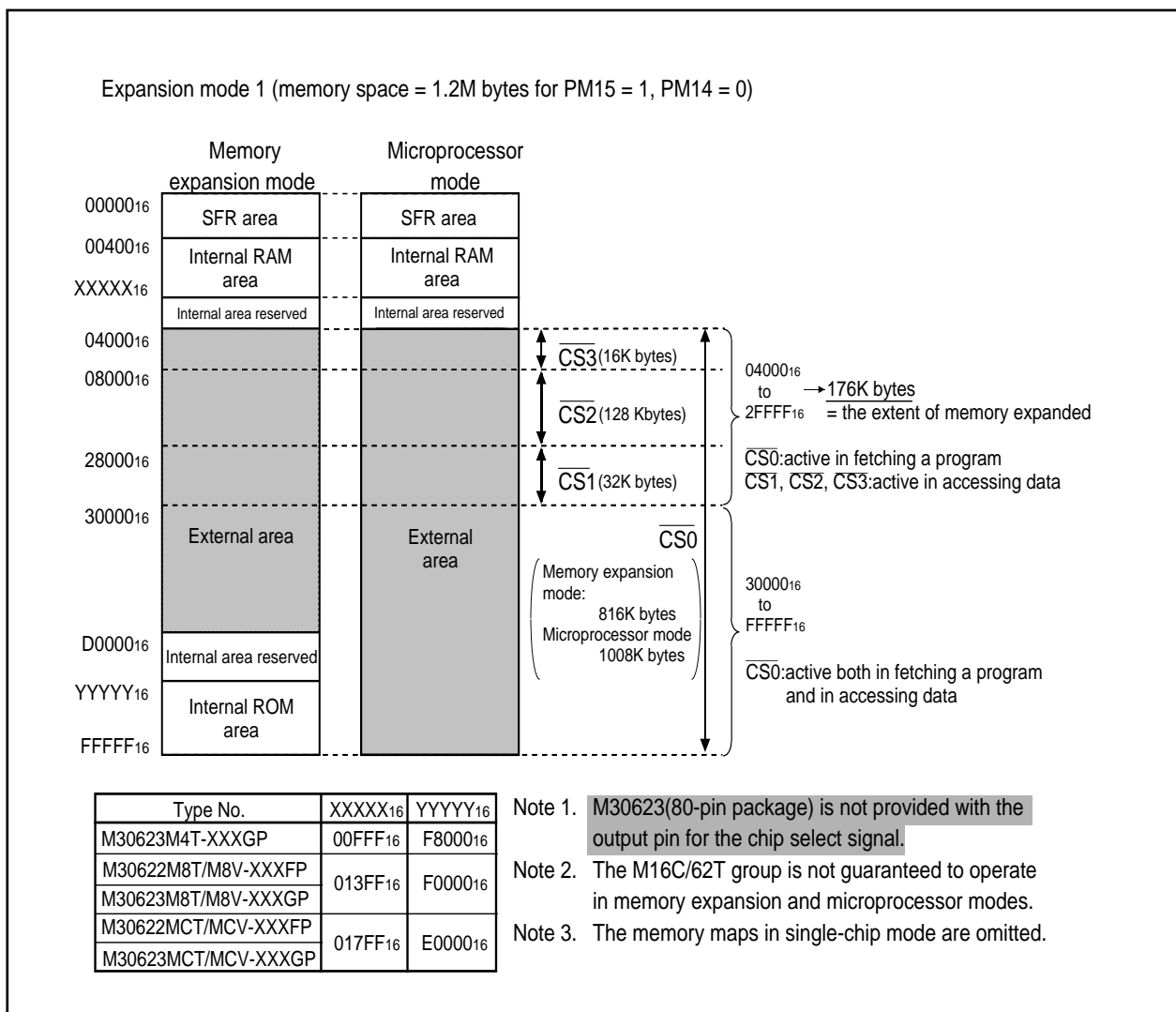


Figure 1.8.2. Memory location and chip select area in expansion mode 1

A connection example

Figure 1.8.3 shows a connection example of the MCU with the external memories in expansion mode 1. In this example, $\overline{CS0}$ is connected with a 1-M byte flash ROM and $\overline{CS2}$ is connected with a 128-K byte SRAM.

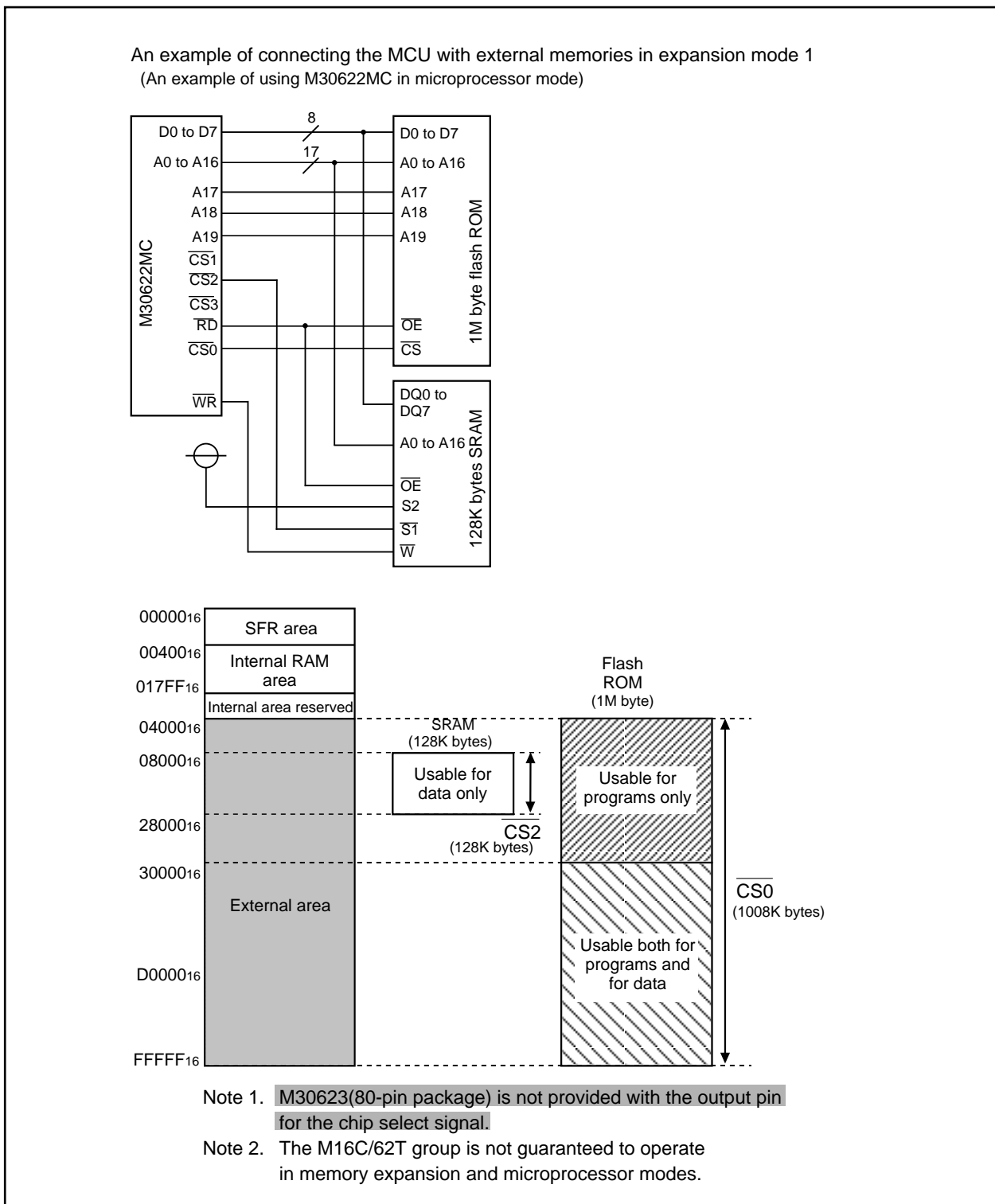


Figure 1.8.3. External memory connect example in expansion mode 1

(3) Expansion mode 2

In expansion mode 2, the data bank register (0000B₁₆) goes effective. Figure 1.8.4 shows the data bank register.

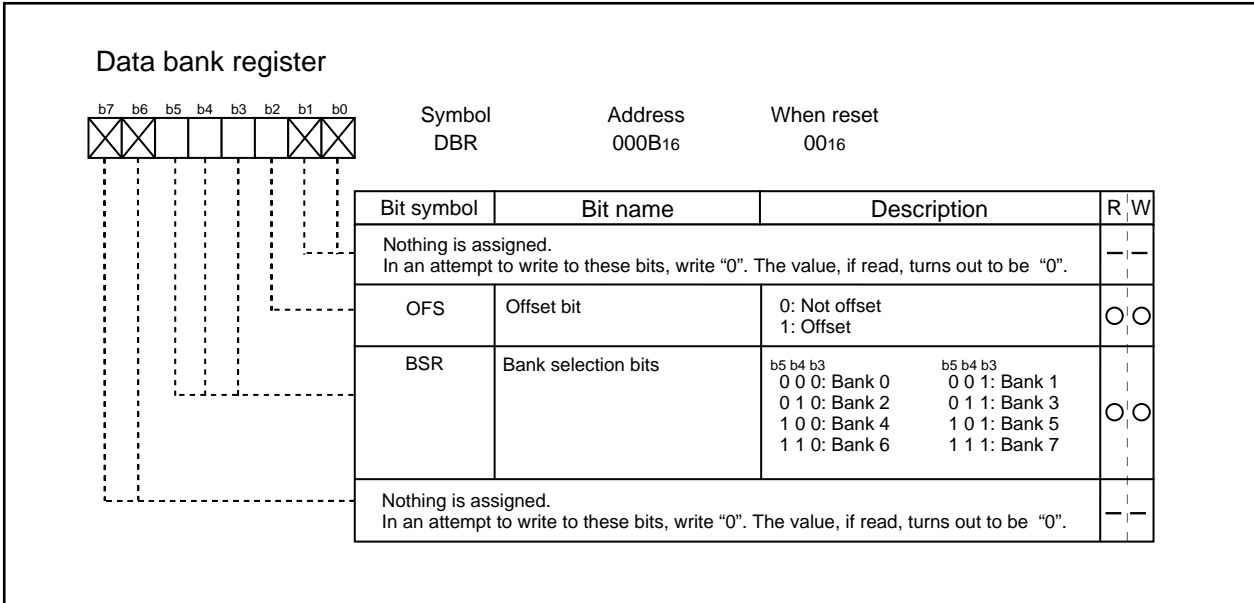


Figure 1.8.4. Data bank register

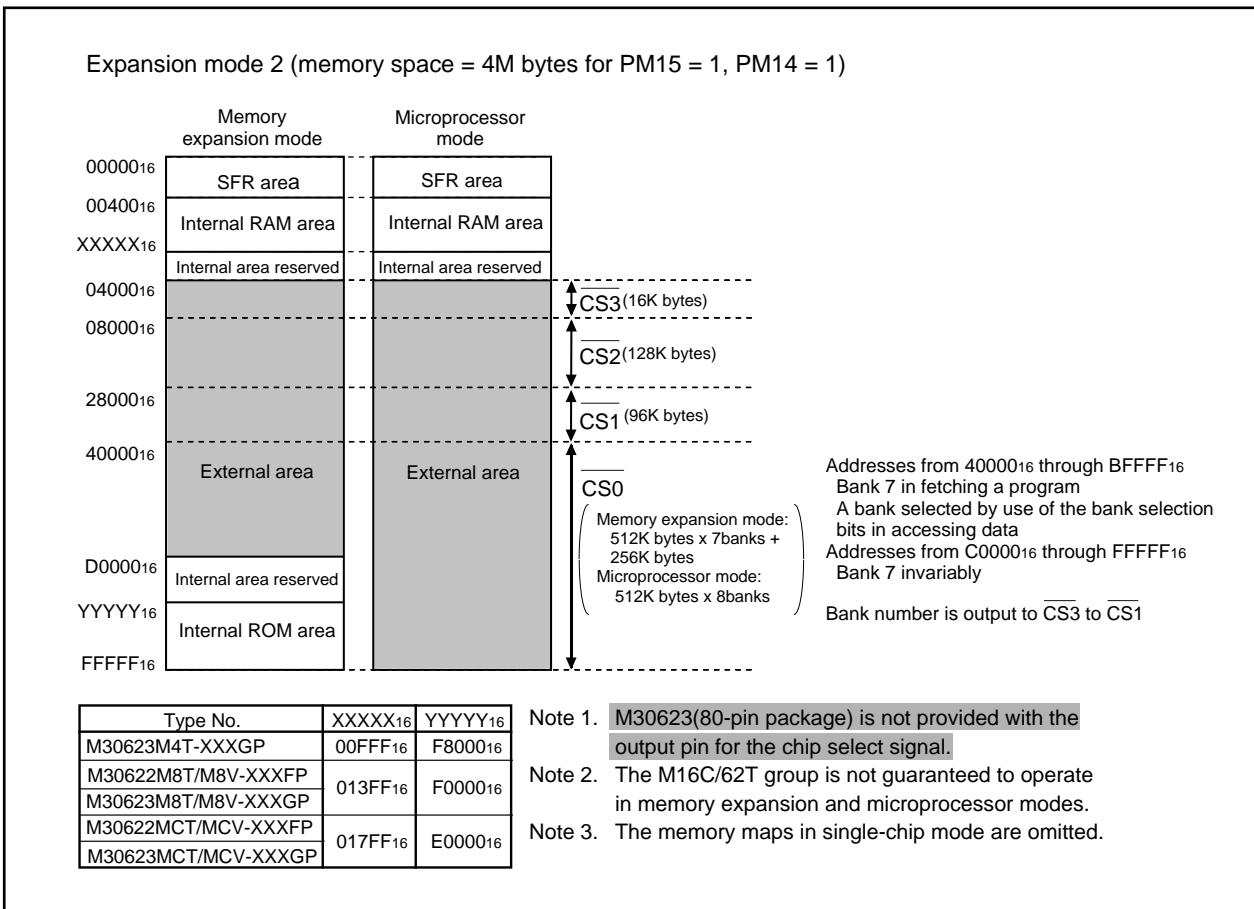


Figure 1.8.5. Memory location and chip select area in expansion mode 2

The data bank register is made up of the bank selection bits (bits 5 through 3) and the offset bit (bit 2). The bank selection bits are used to set a bank number for accessing data lying between 40000₁₆ and BFFFF₁₆. Assigning 1 to the offset bit provides the means to set offsets covering 40000₁₆.

Figure 1.8.5 shows the memory location and chip select areas in expansion mode 2.

The area relevant to $\overline{CS0}$ ranges from 40000₁₆ through FFFFF₁₆. As for the area from 40000₁₆ through BFFFF₁₆, the bank number set by use of the bank selection bits are output from the output terminals $\overline{CS3}$ - $\overline{CS1}$ only in accessing data. In fetching a program, bank 7 (1112) is output from $\overline{CS3}$ - $\overline{CS1}$. As for the area from C0000₁₆ through FFFFF₁₆, bank 7 (1112) is output from $\overline{CS3}$ - $\overline{CS1}$ without regard to accessing data or to fetching a program.

In accessing an area irrelevant to $\overline{CS0}$, a chip select signal $\overline{CS3}$ (4000₁₆ - 7FFF₁₆), $\overline{CS2}$ (8000₁₆ - 27FFF₁₆), and $\overline{CS1}$ (28000₁₆ - 3FFFF₁₆) is output depending on the address as in the past.

Figure 1.8.6 shows an example of connecting the MCU with a 4-M byte ROM and to a 128-K byte SRAM. Connect the chip select of 4-M byte ROM with $\overline{CS0}$. Connect M16C's $\overline{CS3}$, $\overline{CS2}$, and $\overline{CS1}$ with address inputs A21, A20, and A19 respectively. Connect M16C's output A19 with address input A18. Figure 1.8.7 shows the relationship between addresses of the 4-M byte ROM and those of M16C.

With no offsets effected, banks switch from one 512-K byte segment to another 512-K byte segment. Bank selection bits need to be changed in dealing with data lying across the boundary between banks every time a bank switches to another. Assigning 1 to the offset bit brings about offsets covering 40000₁₆ so that data can be accessed without changing the bank selection bits. For instance, accessing 80000₁₆ of bank 0 with offsets effected causes the output bank number to turn to 1, and AD19 is inverted to be output; this results in accessing 40000₁₆ of bank 1.

On the other hand, the SRAM's chip select assumes that $\overline{CS0}=1$ (not selected) and $\overline{CS2}=0$ (selected), so connect $\overline{CS0}$ with S2 and $\overline{CS2}$ with $\overline{S1}$. If the SRAM doesn't have a bipolar chip select input terminal, decode $\overline{CS0}$ and $\overline{CS2}$ externally.

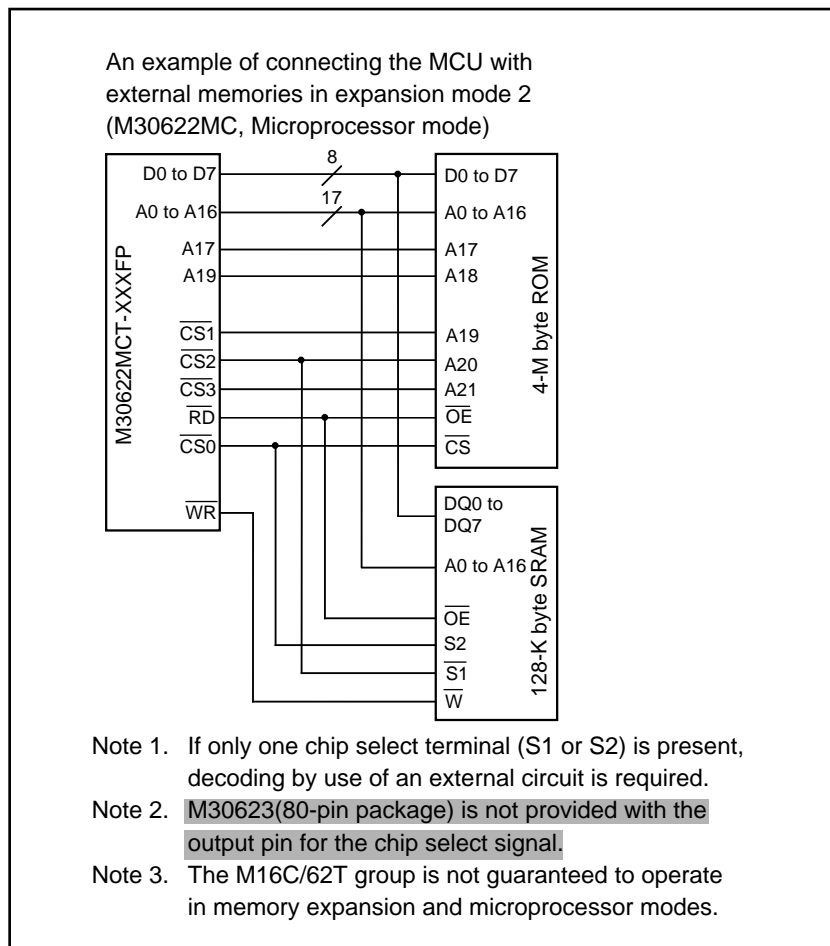


Figure 1.8.6. An example of connecting the MCU with external memories in expansion mode 2

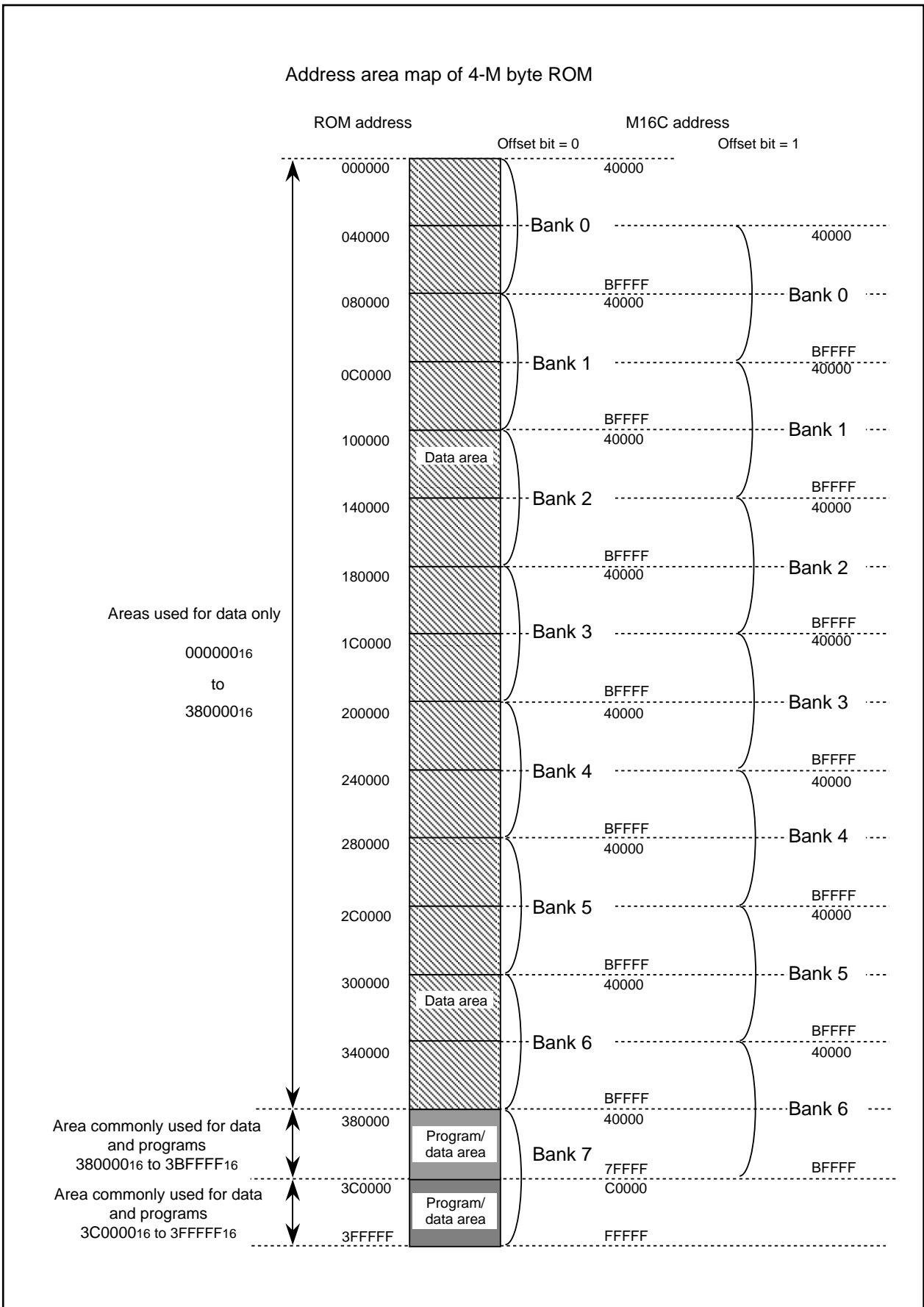


Figure 1.8.7. Relationship between addresses on 4-M byte ROM and those on M16C

Software Reset

Writing “1” to bit 3 of the processor mode register 0 (address 000416) applies a (software) reset to the microcomputer. A software reset has 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.

But M16C/62T group is not guaranteed to operate in memory expansion and microprocessor modes.

- **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 000416). Do not set the processor mode bits to “102”.

Regardless of the level of the CNVSS pin, changing the processor mode bits selects the mode. Therefore, never change the processor mode bits when changing the contents of other bits. Also do not attempt to shift to or from the microprocessor mode within the program stored in the internal ROM area.

- **Applying Vss to CNVss pin**

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

- **Applying Vcc to CNVss pin**

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

Figure 1.9.1 shows the processor mode register 0 and 1.

Figure 1.10.1 shows the memory maps applicable for each of the modes when memory area does not be expanded (normal mode).

Processor Mode

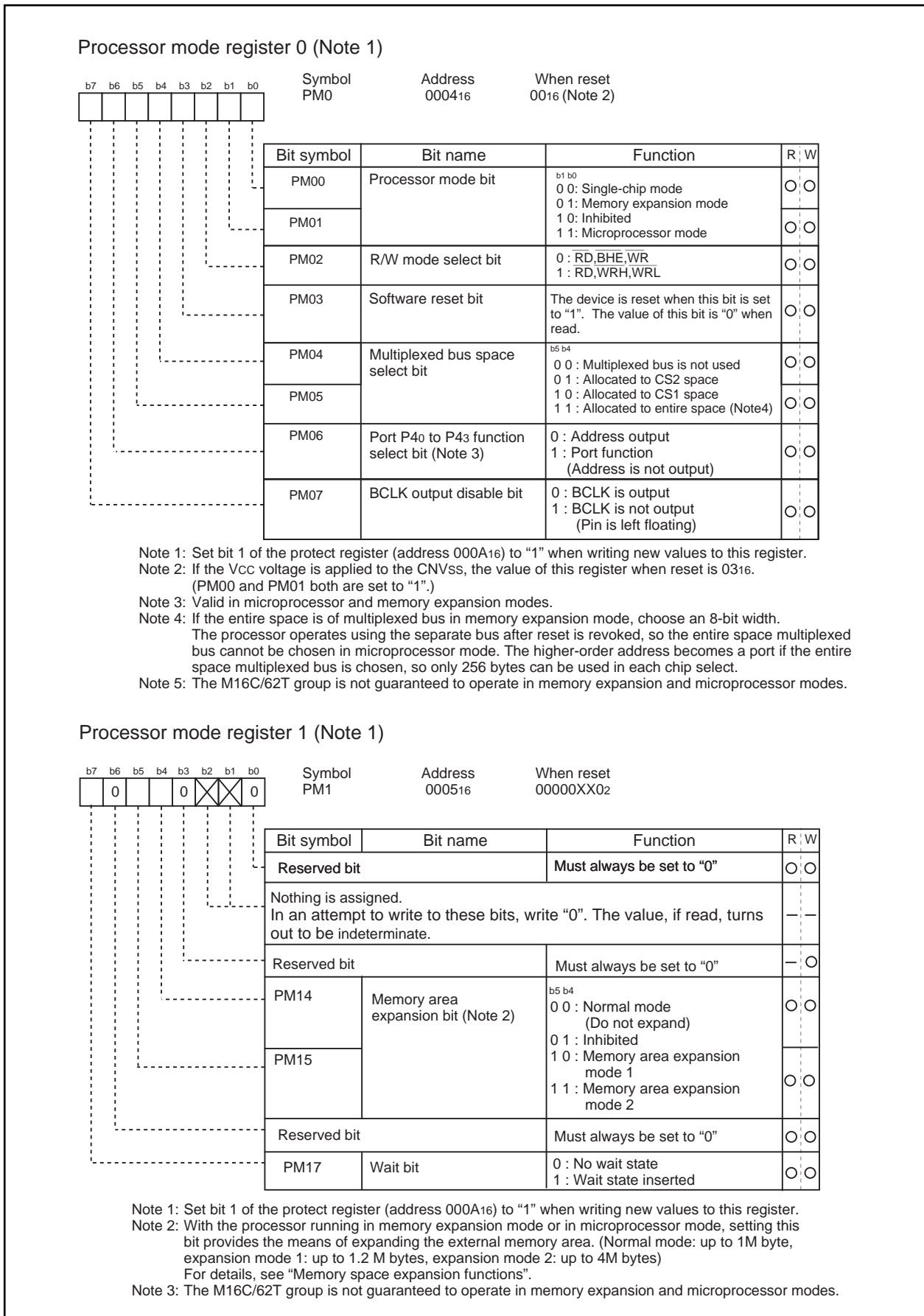


Figure 1.9.1. Processor mode register 0 and 1

Processor Mode

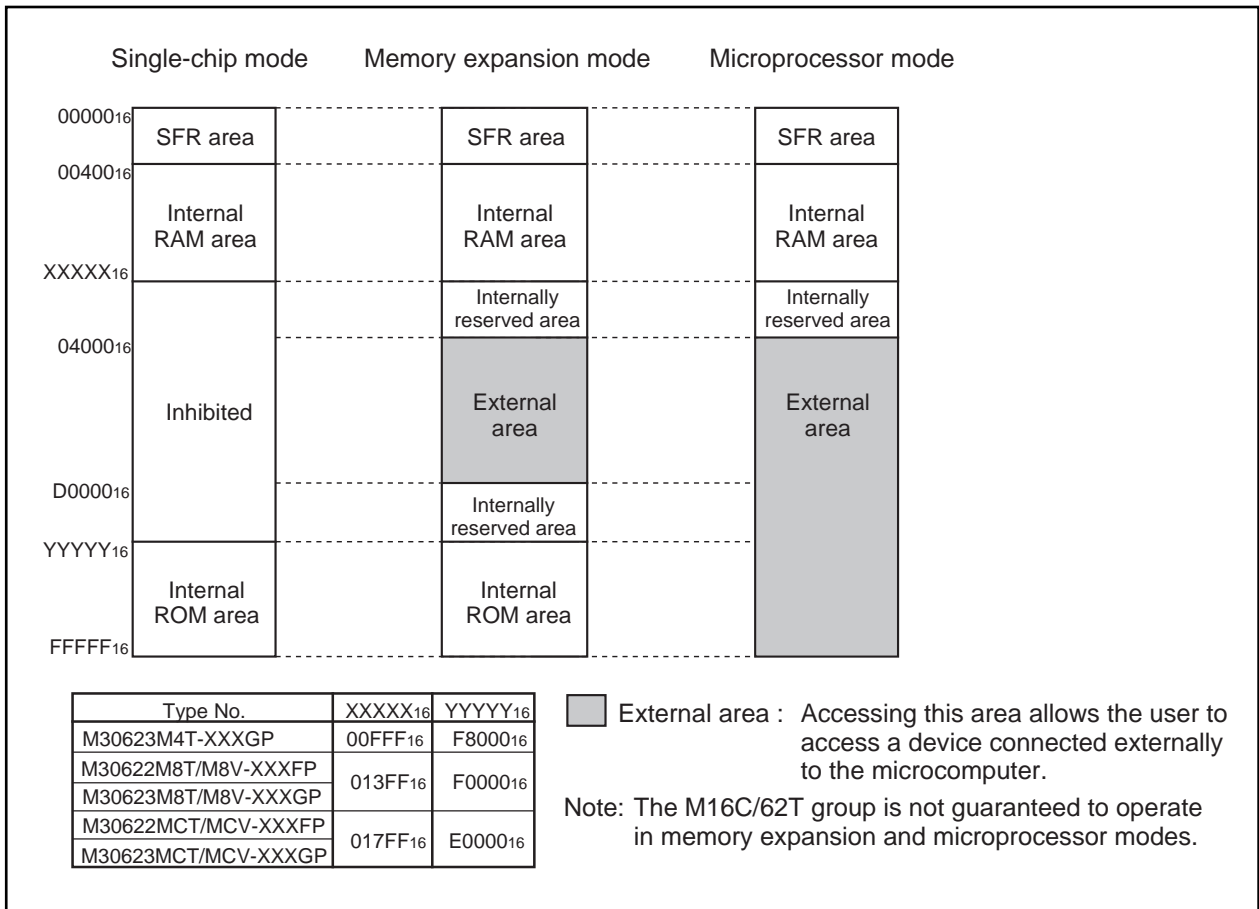


Figure 1.10.1. Memory maps in each processor mode (without memory area expansion, normal mode)

Bus Settings

The BYTE pin and bits 4 to 6 of the processor mode register 0 (address 0004₁₆) are used to change the bus settings. In M30623(80-pin package), the BYTE signal has no external pin, and is internally connected to the CNVss signal. Accordingly, the external data bus width can be used only 8 bits.

M16C/62T group is not guaranteed to operate in memory expansion and microprocessor modes.

Table 1.11.1 shows the factors used to change the bus settings.

Table 1.11.1. Factors for switching bus settings

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

Note 1: In M30623(80-pin package), the external data bus width cannot be switched (be fixed 8 bits).

(1) Selecting external address bus width

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

(2) Selecting external data bus width

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

(3) Selecting separate/multiplex bus

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

• Separate bus

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

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

• Multiplex bus

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

With a 16-bit data bus selected (BYTE pin = "L"), the 8 bits from D₀ to D₇ are multiplexed with A₁ to A₈. D₈ to D₁₅ are not multiplexed. In this case, the external devices connected to the multiplexed bus are mapped to the microcomputer's even addresses (every 2nd address). To access these external devices, access the even addresses as bytes.

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

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

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

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

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.

Bus Settings

Table 1.11.2. Pin functions for each processor mode

Processor mode	Single-chip mode	Memory expansion / microprocessor modes				Memory expansion mode (Note 1)
		"01", "10" (Either CS1 or CS2 is for multiplexed bus and others are for separate bus)		"00" (separate bus)		"11" (Note 2) (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 bits "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 3)	Address bus	Address bus	Address bus	Address bus /data bus
P2 ₁ to P2 ₇	I/O port	Address bus/ data bus (Note 3)	Address bus/ data bus (Note 3)	Address bus	Address bus	Address bus /data bus
P3 ₀	I/O port	Address bus	Address bus/ data bus (Note 3)	Address bus	Address bus	A ₈ /D ₇
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	I/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 \overline{BCLK} or \overline{RD} , \overline{BHE} , \overline{WR} , and \overline{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: In M30623(80-pin package), set the data bus width to 8 bits by any of the following operations, to transfer the microcomputer to memory expansion mode correctly.

- At reset, input "H" to the CNVss (BYTE) pin to start the program in microprocessor mode. Then, set the processor mode bit to memory expansion mode.
- At reset, input "L" to the CNVss (BYTE) pin to start the program in single-chip mode, and input "H" to this pin. Then, set the processor mode bit to memory expansion mode.

Note 2: 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 3: Address bus when in separate bus mode.

Note 4: In M30623(80-pin package), P1, P44 to P47 have no corresponding external pin.

Note 5: M16C/62T group is not guaranteed to operate in memory expansion and microprocessor modes.

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.

M30623(80-pin package), in which the BYTE pin is connected to the CNVSS pin, and the external data bus width can be used 8 bits.

M16C/62T group is not guaranteed to operate in memory expansion and microprocessor modes.

(1) Address bus/data bus

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

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

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

(2) Chip select signal (In M30623(80-pin package), the chip select signals have no corresponding external pin.)

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

In microprocessor mode, only $\overline{CS0}$ outputs the chip select signal after the reset state has been cancelled. $\overline{CS1}$ to $\overline{CS3}$ function as input ports. Figure 1.12.1 shows the chip select control register.

The chip select signal can be used to split the external area into as many as four blocks. Tables 1.12.1 and 1.12.2 show the external memory areas specified using the chip select signal.

Table 1.12.1. External areas specified by the chip select signals

Memory space expansion mode	Processor mode	Chip select signal				
		$\overline{CS0}$	$\overline{CS1}$	$\overline{CS2}$	$\overline{CS3}$	
Specified address range	Normal mode (PM15,14=0,0)	Memory expansion mode	30000 ₁₆ to CFFFF ₁₆ (640K bytes)	28000 ₁₆ to 2FFFF ₁₆ (32K bytes)	08000 ₁₆ to 27FFF ₁₆ (128K bytes)	04000 ₁₆ to 07FFF ₁₆ (16K bytes)
		Microprocessor mode	30000 ₁₆ to FFFFF ₁₆ (832K bytes)			
	Expansion mode 1 (PM15,14=1,0)	Memory expansion mode	04000 ₁₆ to CFFFF ₁₆ (816K bytes)			
		Microprocessor mode	04000 ₁₆ to FFFFF ₁₆ (1008K bytes)			
	Expansion mode 2 (PM15,14=1,1)	Memory expansion mode	40000 ₁₆ to BFFFF ₁₆ (512K bytes X 7 + 256K bytes)	28000 ₁₆ to 3FFFF ₁₆ (96K bytes)		
		Microprocessor mode	40000 ₁₆ to FFFFF ₁₆ (512K bytes X 8)			

Note 1: In M30623(80-pin package), the chip select signals have no corresponding external pin.

Note 2: The M16C/62T Group is not guaranteed to operate in memory expansion and microprocessor modes.

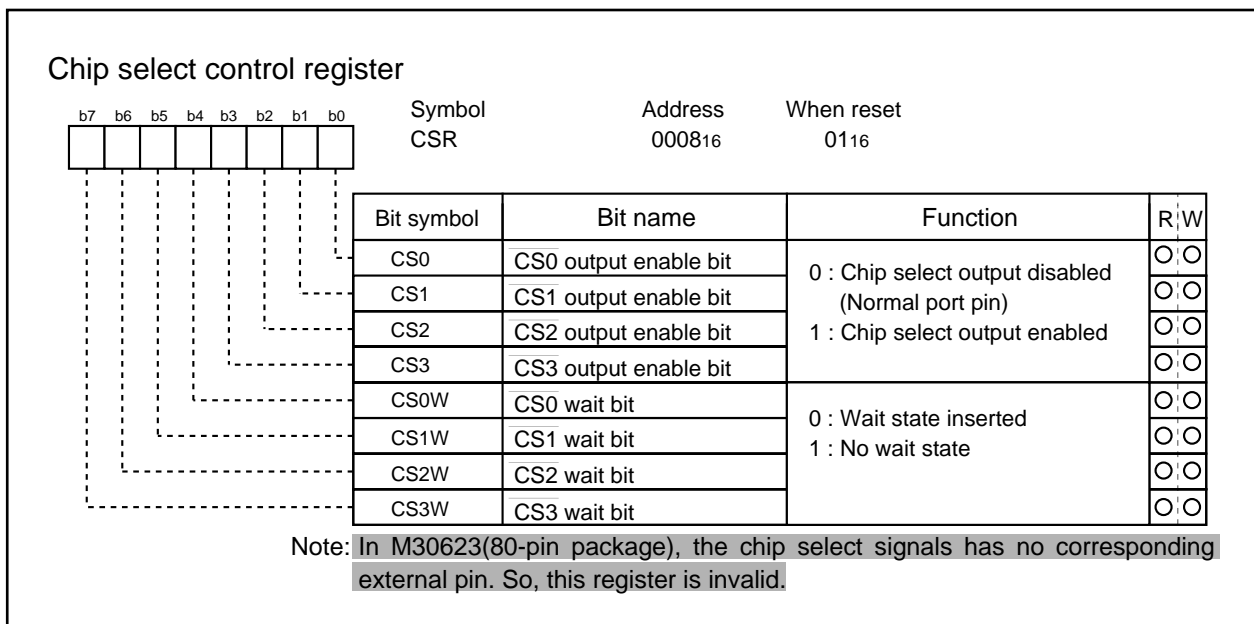


Figure 1.12.1. Chip select control register

(3) Read/write signals

With a 16-bit data bus (BYTE pin = "L"), bit 2 of the processor mode register 0 (address 0004₁₆) select the combinations of \overline{RD} , \overline{BHE} , and \overline{WR} signals or \overline{RD} , \overline{WRL} , and \overline{WRH} signals. With an 8-bit data bus (BYTE pin = "H"), use the combination of \overline{RD} , \overline{WR} , and \overline{BHE} signals. (Set bit 2 of the processor mode register 0 (address 0004₁₆) to "0".) Tables 1.12.2 and 1.12.3 show the operation of these signals.

After a reset has been cancelled, the combination of \overline{RD} , \overline{WR} , and \overline{BHE} signals is automatically selected. When switching to the \overline{RD} , \overline{WRL} , and \overline{WRH} combination, do not write to external memory until bit 2 of the processor mode register 0 (address 0004₁₆) has been set (Note 1).

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

Table 1.12.2. Operation of \overline{RD} , \overline{WRL} , and \overline{WRH} signals

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

Table 1.12.3. 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

Note 1: M30623(80-pin package) can operate only when BYTE = "H".

(4) ALE signal

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

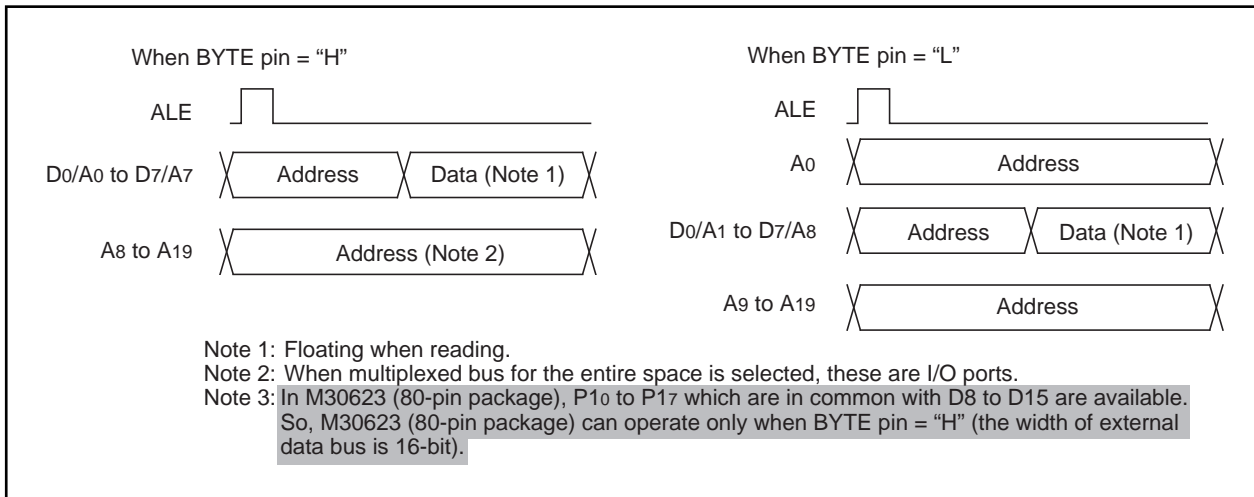


Figure 1.12.2. ALE signal and address/data bus

(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 1.12.3, 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 1.12.4 shows the state of the microcomputer with the bus in the wait state, and Figure 1.12.3 shows an example in which the \overline{RD} signal is prolonged by the \overline{RDY} signal.

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

Table 1.12.4. Microcomputer status in ready state (Note 1)

Item	Status
Oscillation	On
R/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 1: The \overline{RDY} signal cannot be received immediately prior to a software wait.

Note 2: In M30623(80-pin package), CS signals have no corresponding external pin.

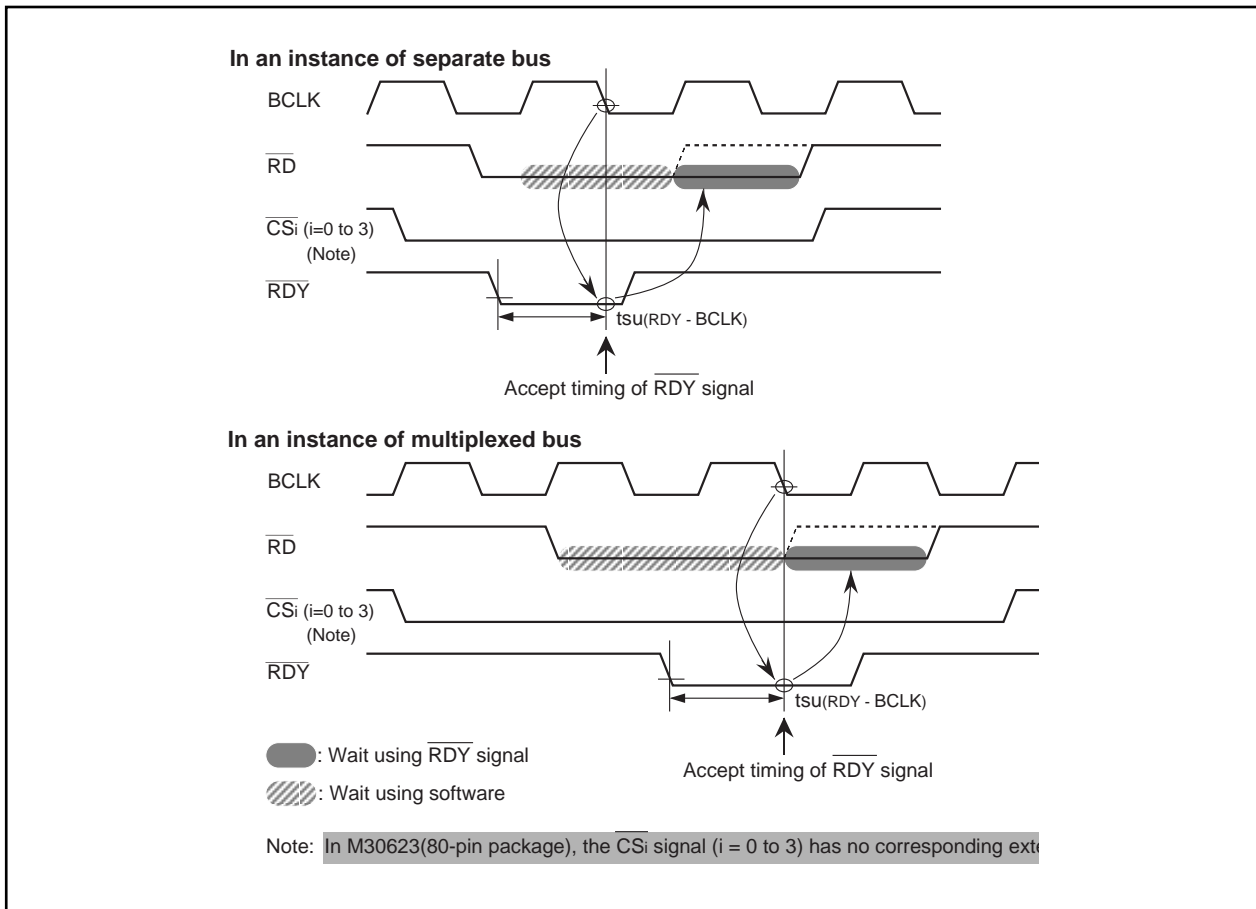


Figure 1.12.3. Example of RD signal extended by RDY signal

(6) Hold signal

The hold signal is used to transfer the bus privileges from the CPU to the external circuits. Inputting “L” to the 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 HLDA pin as long as “L” is input to the HOLD pin. Table 1.12.5 shows the microcomputer status in the hold state.

Bus-using priorities are given to HOLD, DMAC, and CPU in order of decreasing precedence.

HOLD > DMAC > CPU

Figure 1.12.4. Bus-using priorities

Table 1.12.5. Microcomputer status in hold state

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

Note 1: In M30623(80-pin package), P1, P44 to P47(CS0 to CS3) and P72 to P75, P91 have no corresponding external pin, but are internally the above conditions.

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

Table 1.12.6 shows the external bus status when the internal area is accessed.

Table 1.12.6. 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
	When write	Output data
\overline{RD} , \overline{WR} , \overline{WRL} , \overline{WRH}	\overline{RD} , \overline{WR} , \overline{WRL} , \overline{WRH} output	Output "H"
\overline{BHE}	\overline{BHE} output	Maintain status before accessed status of external area
\overline{CS}	Output "H"	Output "H"
ALE	Output "L"	Output "L"

Note 1: In M30623(80-pin package), \overline{CS} signals have no corresponding external pin.

(8) BCLK output

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

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

(9) Software wait

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

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

When the wait bit of the processor mode register 1 is "0", software waits can be set independently for each of the 4 areas selected using the chip select signal. Bits 4 to 7 of the chip select control register correspond to chip selects $\overline{CS0}$ 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, insert a software wait if using the multiplex bus to access the external memory area.

Table 1.12.7 shows the software wait and bus cycles. Figure 1.12.5 shows example bus timing when using software waits.

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

Note 2: In M30623(80-pin package), the chip select signals have no corresponding external pin.

Table 1.12.7. Software waits and bus cycles

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

Note: When using the RDY signal, always set to "0".

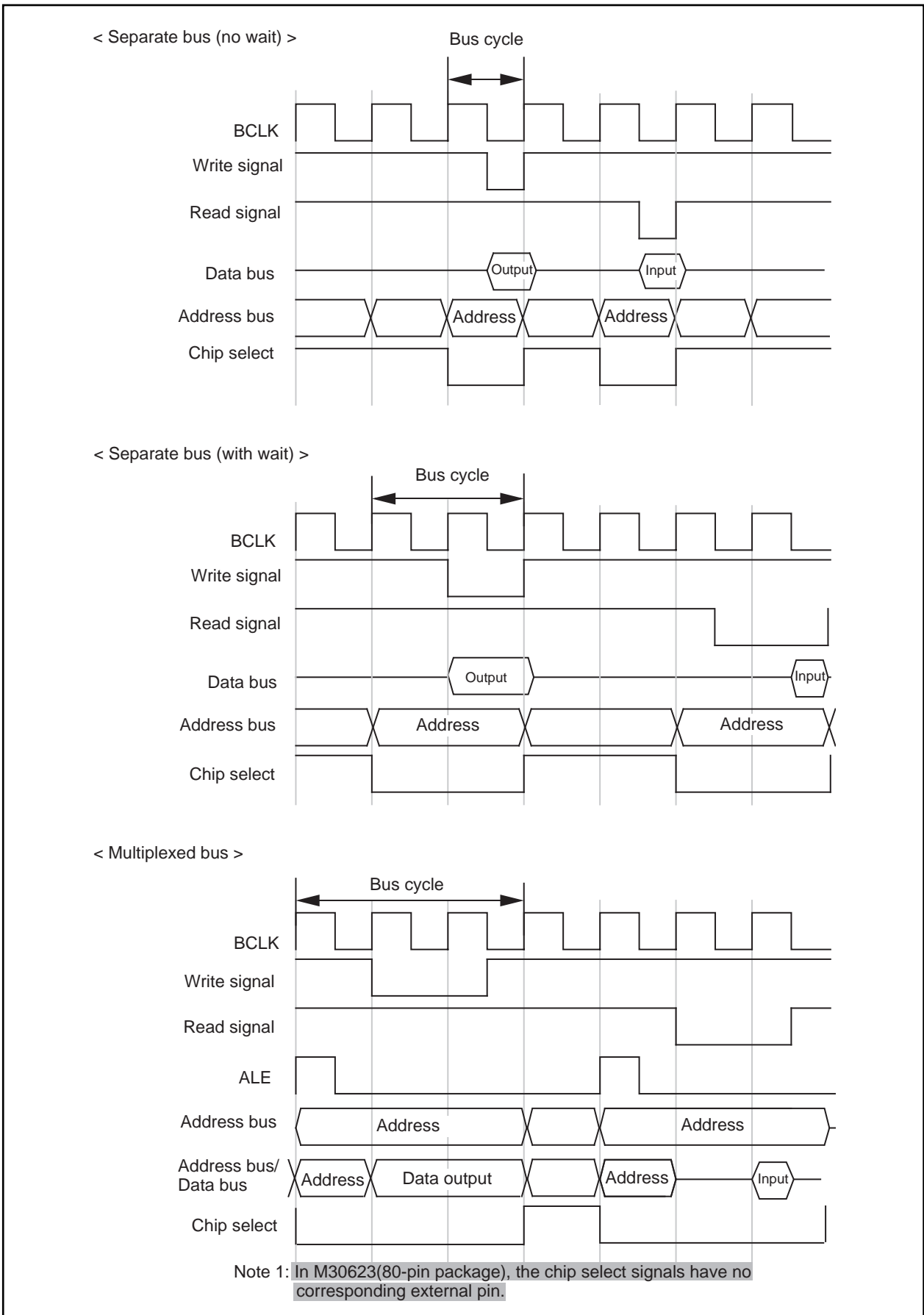


Figure 1.12.5. Typical bus timings using software wait

Clock Generating Circuit

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

Table 1.13.1. Main clock and sub clock generating circuits

	Main clock generating circuit	Sub clock generating circuit
Use of clock	<ul style="list-style-type: none"> • CPU's operating clock source • Internal peripheral units' operating clock source 	<ul style="list-style-type: none"> • CPU's operating clock source • Timer A/B's count clock source
Usable oscillator	Ceramic or crystal oscillator	Crystal oscillator
Pins to connect oscillator	XIN, XOUT	XCIN, XCOUT
Oscillation stop/restart function	Available	Available
Oscillator status immediately after reset	Oscillating	Stopped
Other	Externally derived clock can be input	

Example of oscillator circuit

Figure 1.13.1 shows some examples of the main clock circuit, one using an oscillator connected to the circuit, and the other one using an externally derived clock for input. Figure 1.13.2 shows some examples of sub clock circuits, one using an oscillator connected to the circuit, and the other one using an externally derived clock for input. Circuit constants in Figures 1.13.1 and 1.13.2 vary with each oscillator used. Use the values recommended by the manufacturer of your oscillator.

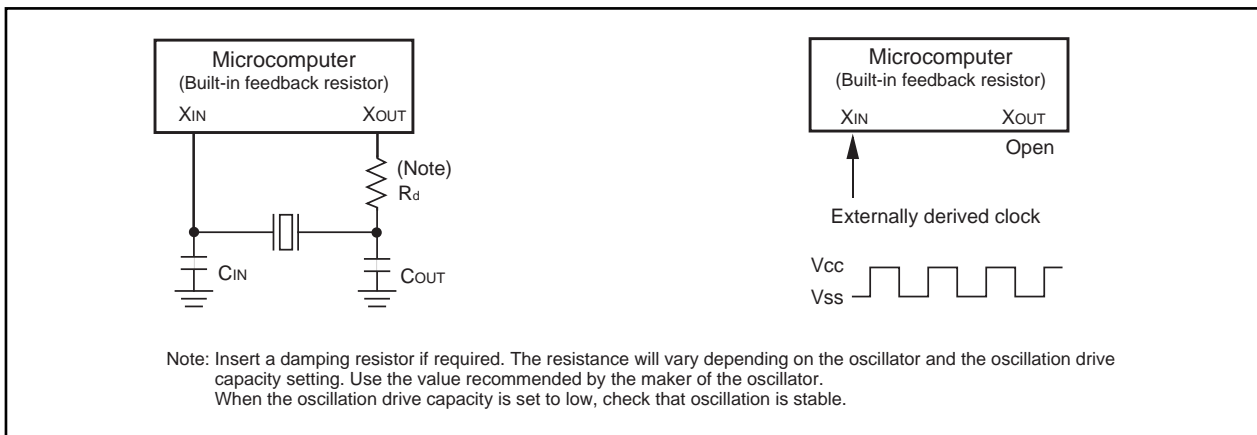


Figure 1.13.1. Examples of main clock

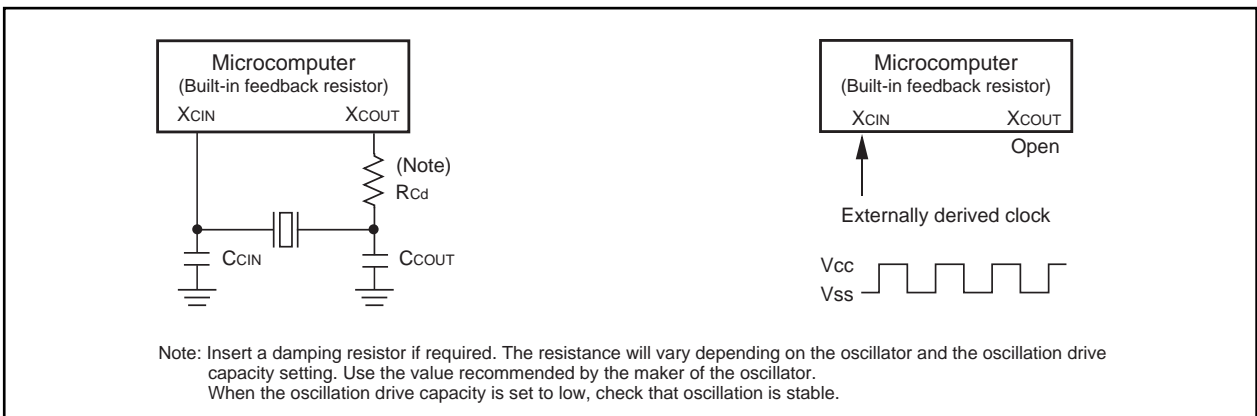


Figure 1.13.2. Examples of sub clock

Clock Control

Figure 1.13.3 shows the block diagram of the clock generating circuit.

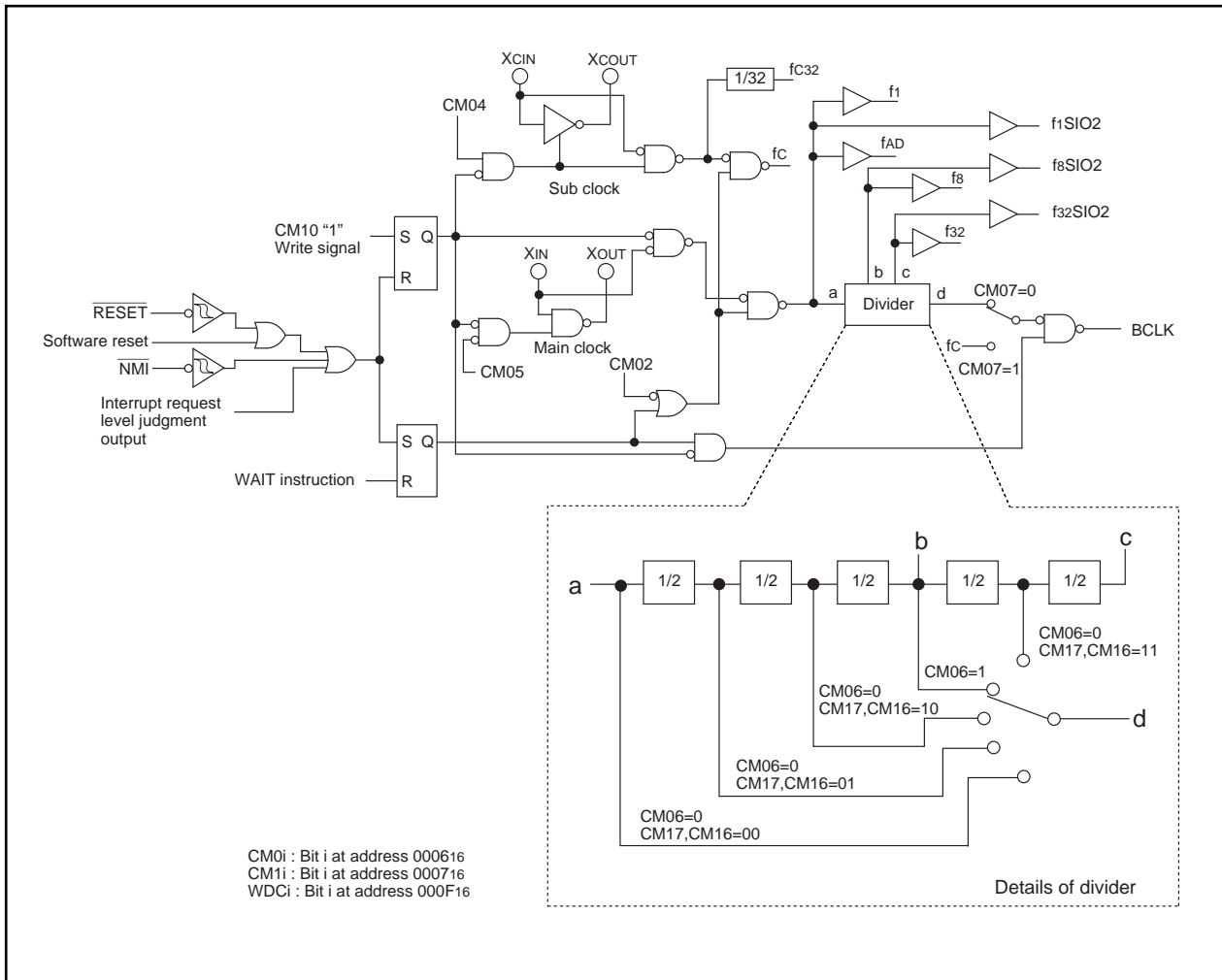


Figure 1.13.3. Clock generating circuit

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

(1) Main clock

The main clock is generated by the main clock oscillation circuit. After a reset, the clock is divided by 8 to the BCLK. The clock can be stopped using the main clock stop bit (bit 5 at address 0006₁₆). Stopping the clock 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 0007₁₆). 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 0006₁₆), the sub clock can be selected as the BCLK by using the system clock select bit (bit 7 at address 0006₁₆). However, be sure that the sub clock oscillation has fully stabilized before switching.

After the oscillation of the sub clock oscillation circuit has stabilized, the drive capacity of the XCOUT pin can be reduced using the XCIN-XCOUT drive capacity select bit (bit 3 at address 0006₁₆). 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 0006₁₆) is set to "1".

(4) Peripheral function clock

- f1, f8, f32, f1SIO2, f8SIO2, f32SIO2

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 0006₁₆) to "1" and then executing a WAIT instruction.

- fAD

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

(5) fc32

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

(6) fc

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

Figure 1.13.4 shows the system clock control registers 0 and 1.

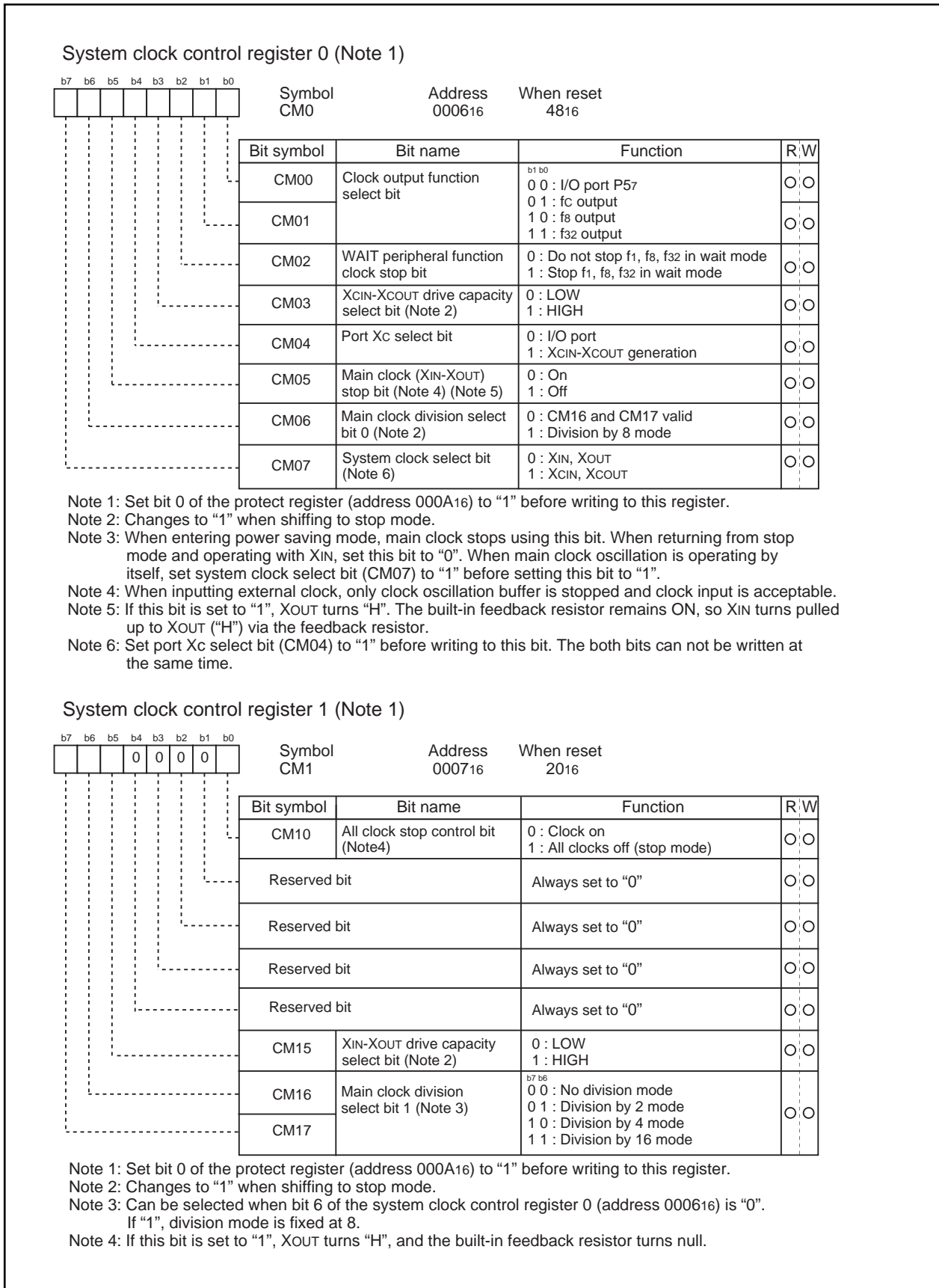


Figure 1.13.4. Clock control registers 0 and 1

Clock Output

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

Stop Mode

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

Because the oscillation, BCLK, f₁ to f₃₂, f₁SIO₂ to f₃₂SIO₂, 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 UART_i(i = 0 to 2) functions provided an external clock is selected. Table 1.13.2 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 0006₁₆) is set to "1".

Table 1.13.2. 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"	
HLDA, BCLK "H"			
ALE "H"			
Port		Retains status before stop mode	
CLKOUT	When f _c 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

Note 1: In M30623(80-pin package), $\overline{CS0}$ to $\overline{CS3}$ have no corresponding external pin, but are internally the above conditions.

Wait Mode

When a WAIT instruction is executed, the BCLK stops and the microcomputer enters the wait mode. In this mode, oscillation continues but the BCLK and watchdog timer stop. Writing "1" to the WAIT peripheral function clock stop bit and executing a WAIT instruction stops the clock being supplied to the internal peripheral functions, allowing power dissipation to be reduced. Table 1.13.3 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 1.13.3. 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"	
HLDA, BCLK		"H"	
ALE		"H"	
Port		Retains status before wait mode	Retains status before wait mode
CLKOUT	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.

Note 1: In M30623(80-pin package), CS0 to CS3 have no corresponding external pin, but are internally the above conditions.

Status Transition of BCLK

Power dissipation can be reduced and low-voltage operation achieved by changing the count source for BCLK. Table 1.13.4 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 000616) 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

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

(7) Low power dissipation mode

fc is the BCLK and the main clock is stopped.

Table 1.13.4. Operating modes dictated by settings of system clock control registers 0 and 1

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

Power control

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

Modes

Power control is available in three modes.

(a) Normal operation mode

- **High-speed mode**

Divide-by-1 frequency of the main clock becomes the BCLK. The CPU operates with the 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 1.13.5 is the state transition diagram of the above modes.

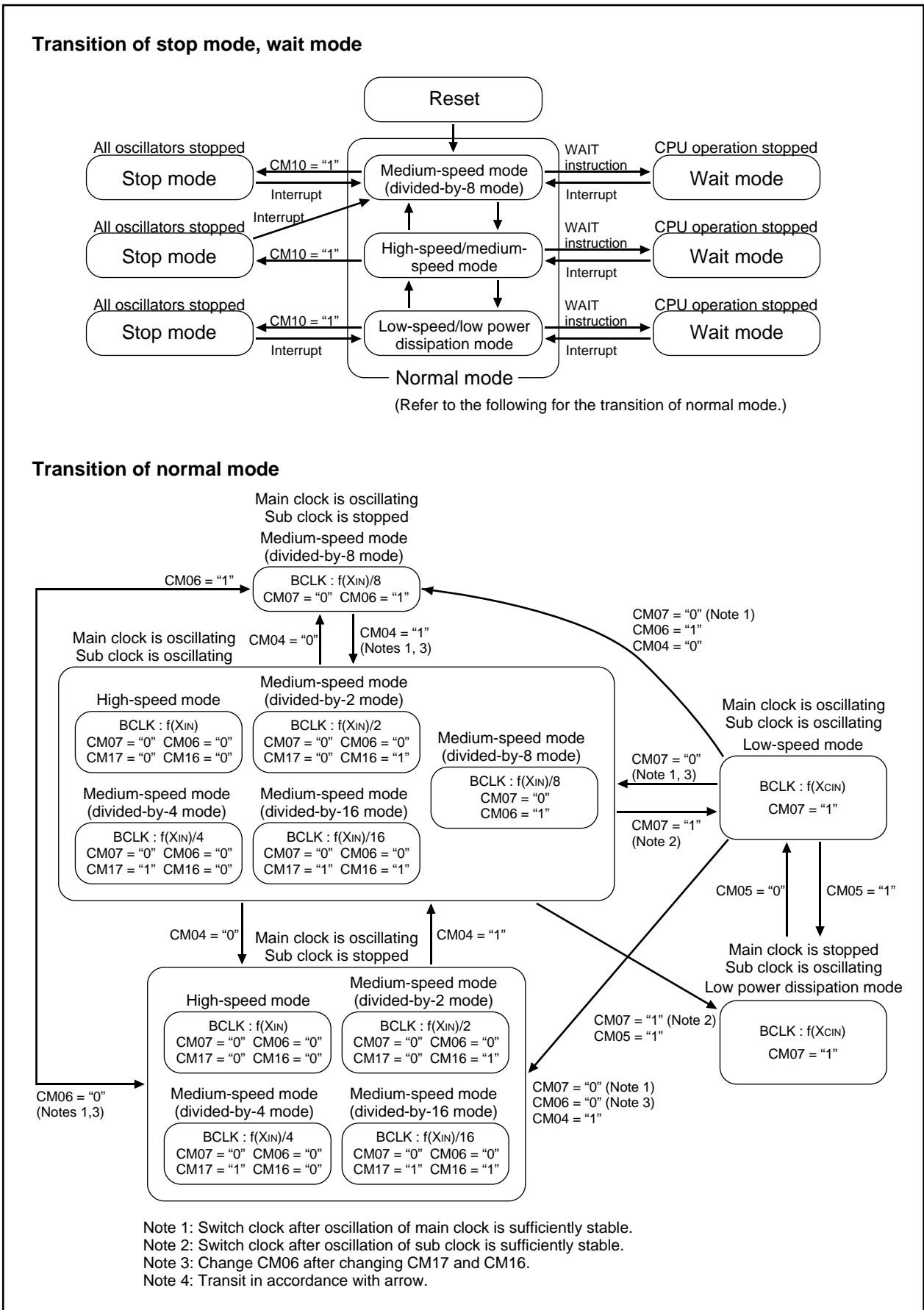


Figure 1.13.5. State transition diagram of Power control mode

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 1.13.6 shows the protect register. The values in the processor mode register 0 (address 0004₁₆), processor mode register 1 (address 0005₁₆), system clock control register 0 (address 0006₁₆), system clock control register 1 (address 0007₁₆), port P9 direction register (address 03F3₁₆), SI/O3 control register (address 0362₁₆) and SI/O4 control register (address 0366₁₆) can only be changed when the respective bit in the protect register is set to "1". Therefore, important outputs can be allocated to port P9.

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

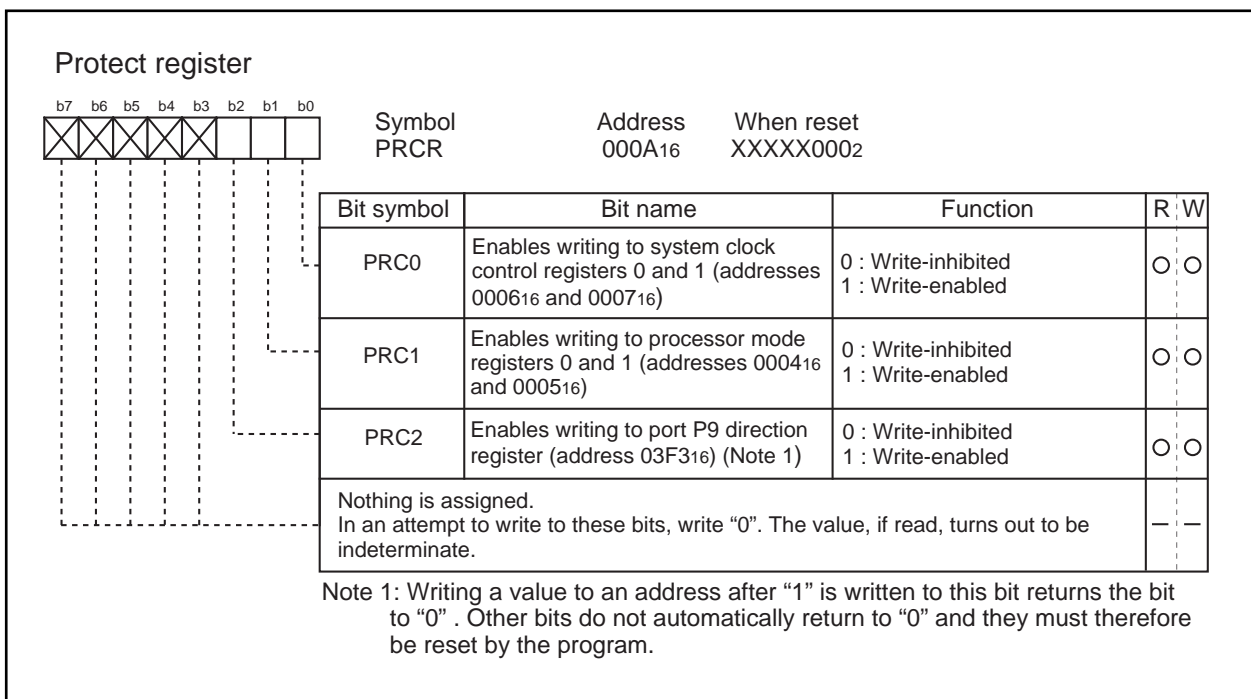


Figure 1.13.6. Protect register

Overview of Interrupt

Type of Interrupts

Figure 1.14.1 lists the types of interrupts.

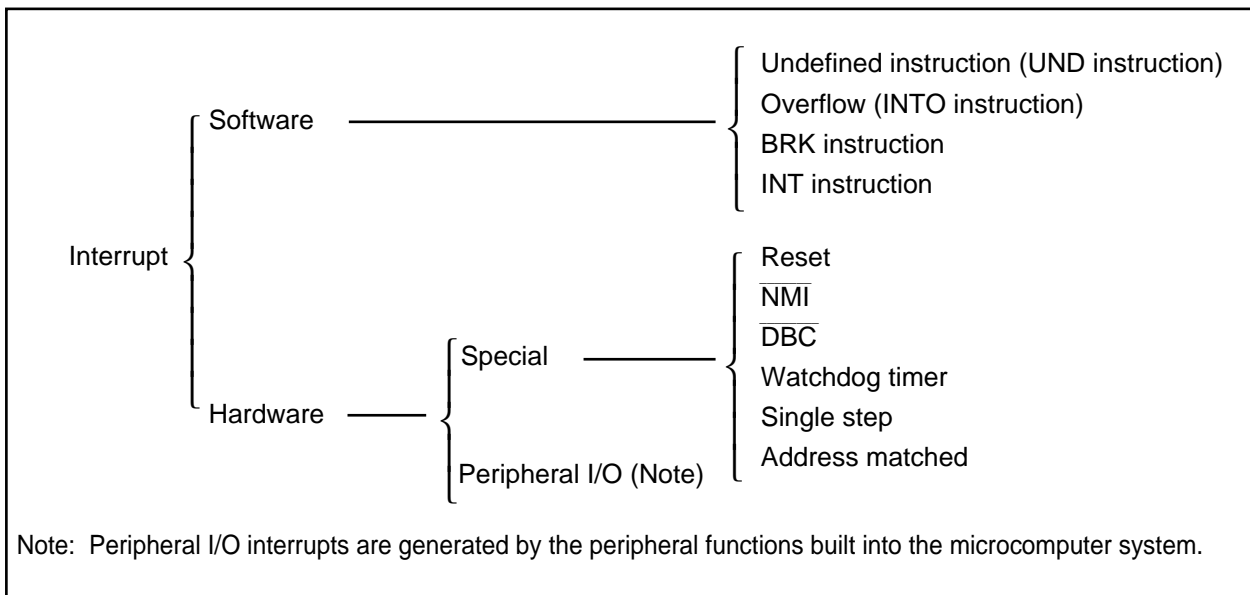


Figure 1.14.1. Classification of interrupts

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

Software Interrupts

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

- **Undefined instruction interrupt**

An undefined instruction interrupt occurs when executing the UND instruction.

- **Overflow interrupt**

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

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

- **BRK interrupt**

A BRK interrupt occurs when executing the BRK instruction.

- **INT interrupt**

An INT interrupt occurs when assigning 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.

- **NMI interrupt**

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

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

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

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

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

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

These are interrupts that timer A generates

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

These are interrupts that timer B generates.

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

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

Note 1: In M30623 (80-pin package), can not use $\overline{\text{INT3}}$ to $\overline{\text{INT5}}$ as the interrupt factors, because P15/D13/ $\overline{\text{INT3}}$ to P17/D15/ $\overline{\text{INT5}}$ have no corresponding external pin.

Interrupts and Interrupt Vector Tables

If an interrupt request is accepted, a program branches to the interrupt routine set in the interrupt vector table. Set the first address of the interrupt routine in each vector table. Figure 1.14.2 shows the format for specifying the address.

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

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

Figure 1.14.2. Format for specifying interrupt vector addresses

• Fixed vector tables

The fixed vector table is a table in which addresses are fixed. The vector tables are located in an area extending from FFFDC₁₆ to FFFFF₁₆. One vector table comprises four bytes. Set the first address of interrupt routine in each vector table. Table 1.14.1 shows the interrupts assigned to the fixed vector tables and addresses of vector tables.

Table 1.14.1. Interrupts assigned to the fixed vector tables and addresses of vector tables

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

Note: Interrupts used for debugging purposes only.

• Variable vector tables

The addresses in the variable vector table can be modified, according to the user's settings. Indicate the first address using the interrupt table register (INTB). The 256-byte area subsequent to the address the INTB indicates becomes the area for the variable vector tables. One vector table comprises four bytes. Set the first address of the interrupt routine in each vector table. Table 1.14.2 shows the interrupts assigned to the variable vector tables and addresses of vector tables.

Table 1.14.2. Interrupts assigned to the variable vector tables and addresses of vector tables

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

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

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

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

Note 4: In M30623 (80-pin package), can not use $\overline{\text{INT3}}$ to $\overline{\text{INT5}}$ as the interrupt factor, because P15/D13/ $\overline{\text{INT3}}$ to P17/D15/ $\overline{\text{INT5}}$ have no corresponding external pin.

Interrupt Control

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

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

Figure 1.14.3 shows the memory map of the interrupt control registers.

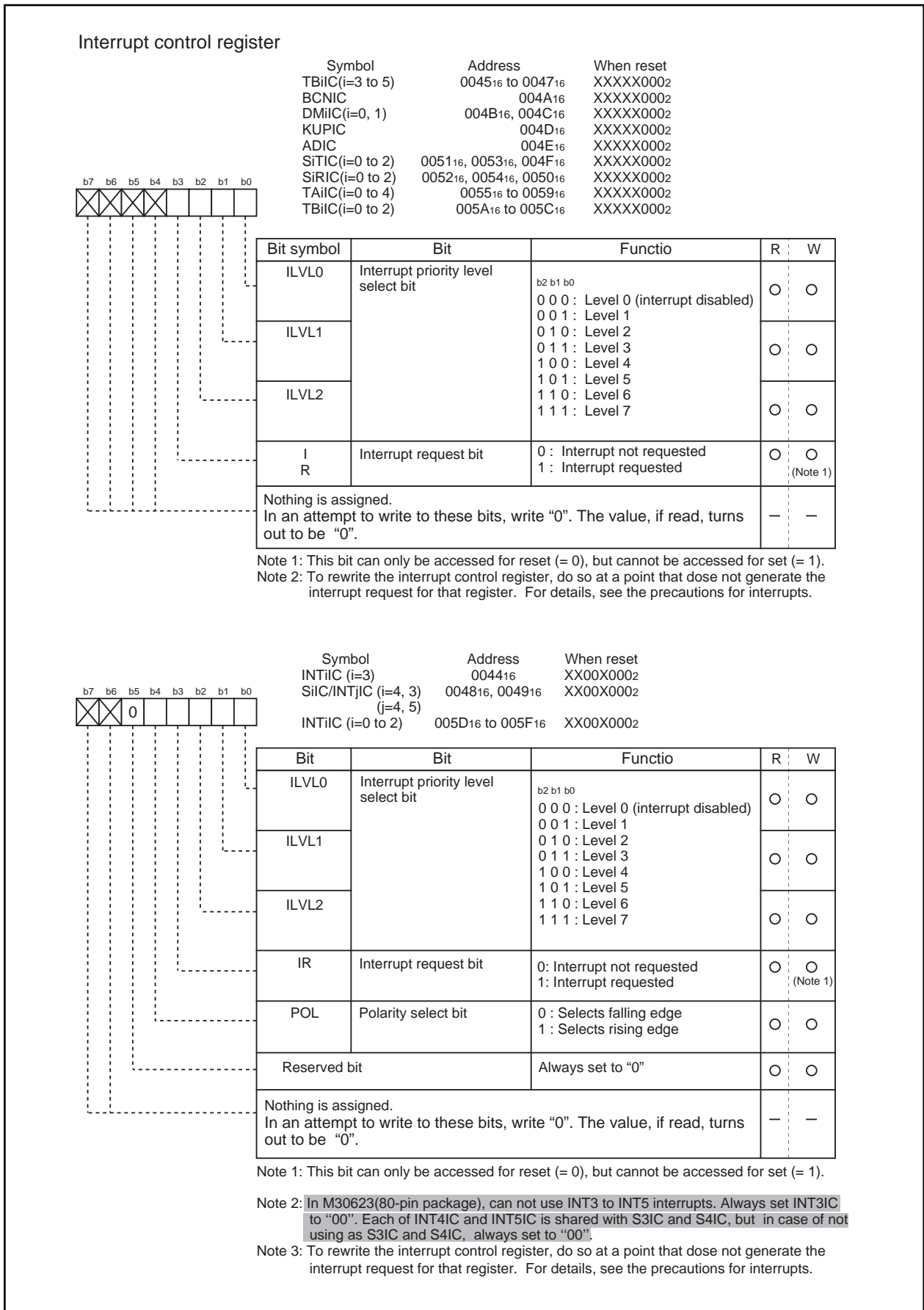


Figure 1.14.3. Interrupt control registers

Interrupt Enable Flag (I flag)

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

Interrupt Request Bit

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

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

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

Table 1.14.3 shows the settings of interrupt priority levels and Table 1.14.4 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 1.14.3. Settings of interrupt priority levels

Interrupt priority level select bit	Interrupt priority level	Priority order
b2 b1 b0 0 0 0	Level 0 (interrupt disabled)	————
0 0 1	Level 1	Low ↓ High
0 1 0	Level 2	
0 1 1	Level 3	
1 0 0	Level 4	
1 0 1	Level 5	
1 1 0	Level 6	
1 1 1	Level 7	

Table 1.14.4. Interrupt levels enabled according to the contents of the IPL

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

Rewrite the interrupt control register

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

Example 1:

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

Example 2:

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

Example 3:

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

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

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

Instructions : AND, OR, BCLR, BSET

Interrupt Sequence

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

If an interrupt occurs during execution of an instruction, the processor determines its priority when the execution of the instruction is completed, and transfers control to the interrupt sequence from the next cycle. If an interrupt occurs during execution of either the SMOVB, SMOVF, SSTR or RMPA instruction, the processor temporarily suspends the instruction being executed, and transfers control to the interrupt sequence.

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

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

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

Note: This register cannot be utilized by the user.

Interrupt Response Time

'Interrupt response time' is the period between the instant an interrupt occurs and the instant the first instruction within the interrupt routine has been executed. This time comprises the period from the occurrence of an interrupt to the completion of the instruction under execution at that moment (a) and the time required for executing the interrupt sequence (b). Figure 1.14.4 shows the interrupt response time.

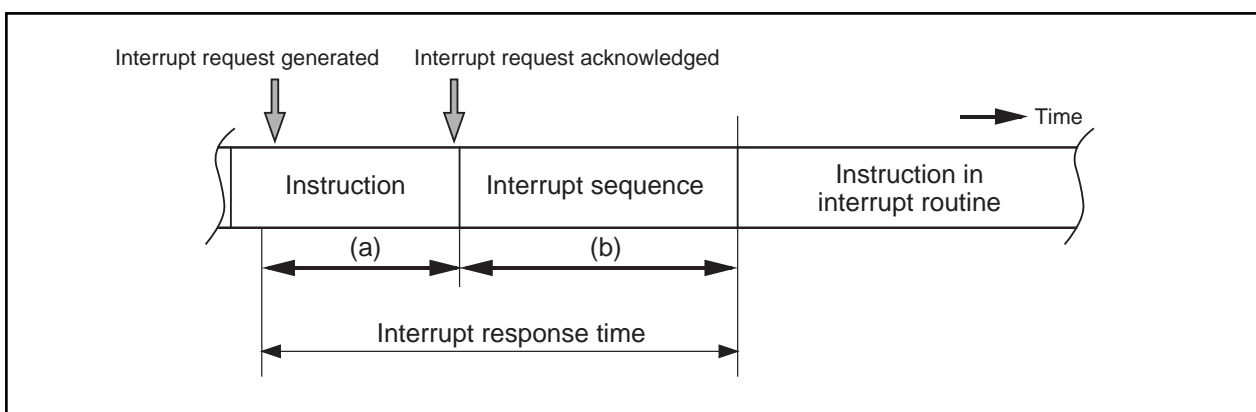


Figure 1.14.4. Interrupt response time

Interrupt

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

Time (b) is as shown in Table 1.14.5.

Table 1.14.5. Time required for executing the interrupt sequence

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

Note 1: Add 2 cycles in the case of a 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.

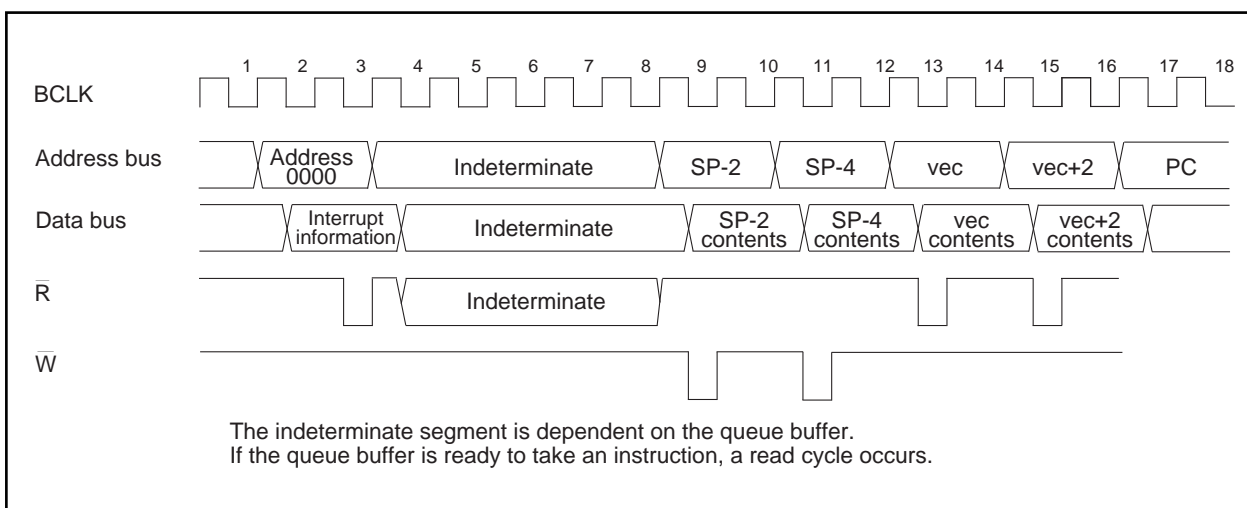


Figure 1.14.5. Time required for executing the interrupt sequence

Variation of IPL when Interrupt Request is Accepted

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

If an interrupt request, that does not have an interrupt priority level, is accepted, one of the values shown in Table 1.14.6 is set in the IPL.

Table 1.14.6. Relationship between interrupts without interrupt priority levels and IPL

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

Saving Registers

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

First, the processor saves the four higher-order bits of the program counter, and 4 upper-order bits and 8 lower-order bits of the FLG register, 16 bits in total, in the stack area, then saves 16 lower-order bits of the program counter. Figure 1.14.6 shows the state of the stack as it was before the acceptance of the interrupt request, and the state the stack after the acceptance of the interrupt request.

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

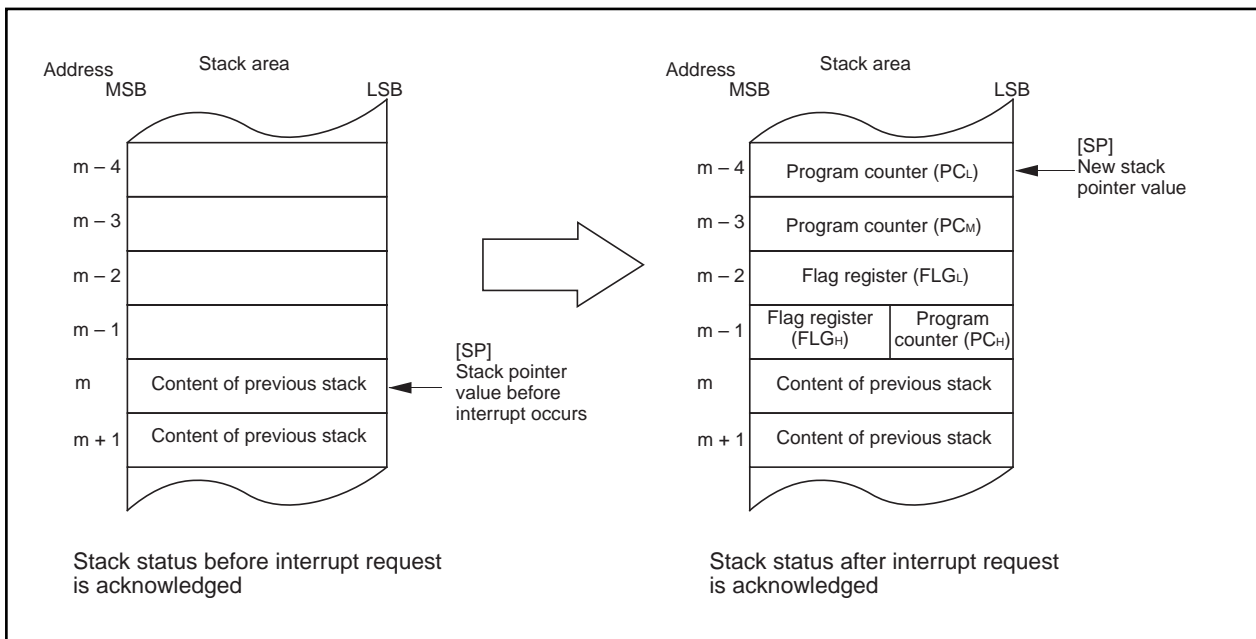


Figure 1.14.6. State of stack before and after acceptance of interrupt request

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 1.14.7 shows the operation of the saving registers.

Note: Stack pointer indicated by U flag.

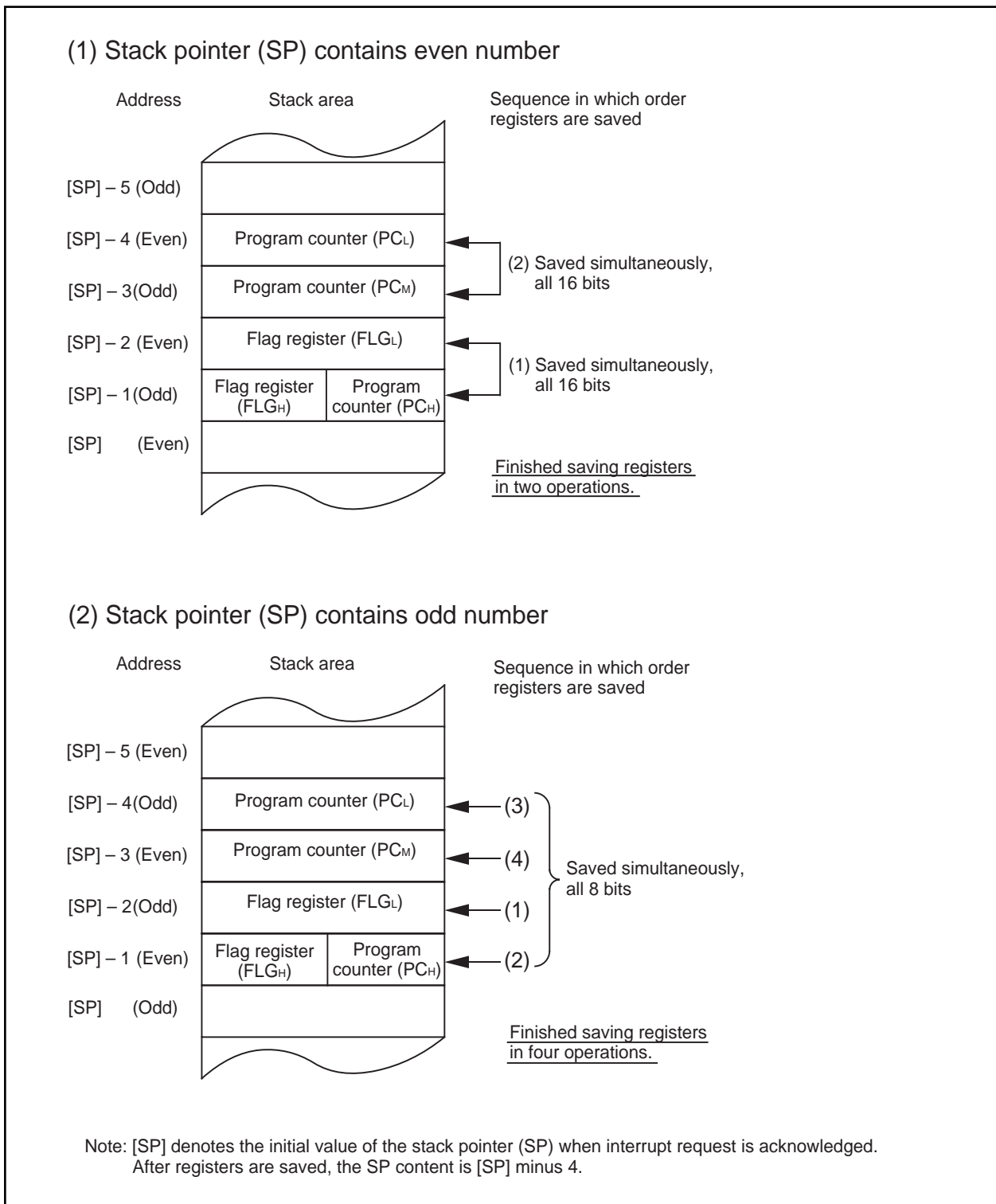


Figure 1.14.7. Operation of saving registers

Returning from an Interrupt Routine

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

Return the other registers saved by software within the interrupt routine using the POPM or similar instruction before executing the REIT instruction.

Interrupt Priority

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

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

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

Figure 1.14.8 shows the priorities of hardware interrupts.

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

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

Figure 1.14.8. Hardware interrupts priorities

Interrupt resolution circuit

When two or more interrupts are generated simultaneously, this circuit selects the interrupt with the highest priority level. Figure 1.14.9 shows the circuit that judges the interrupt priority level.

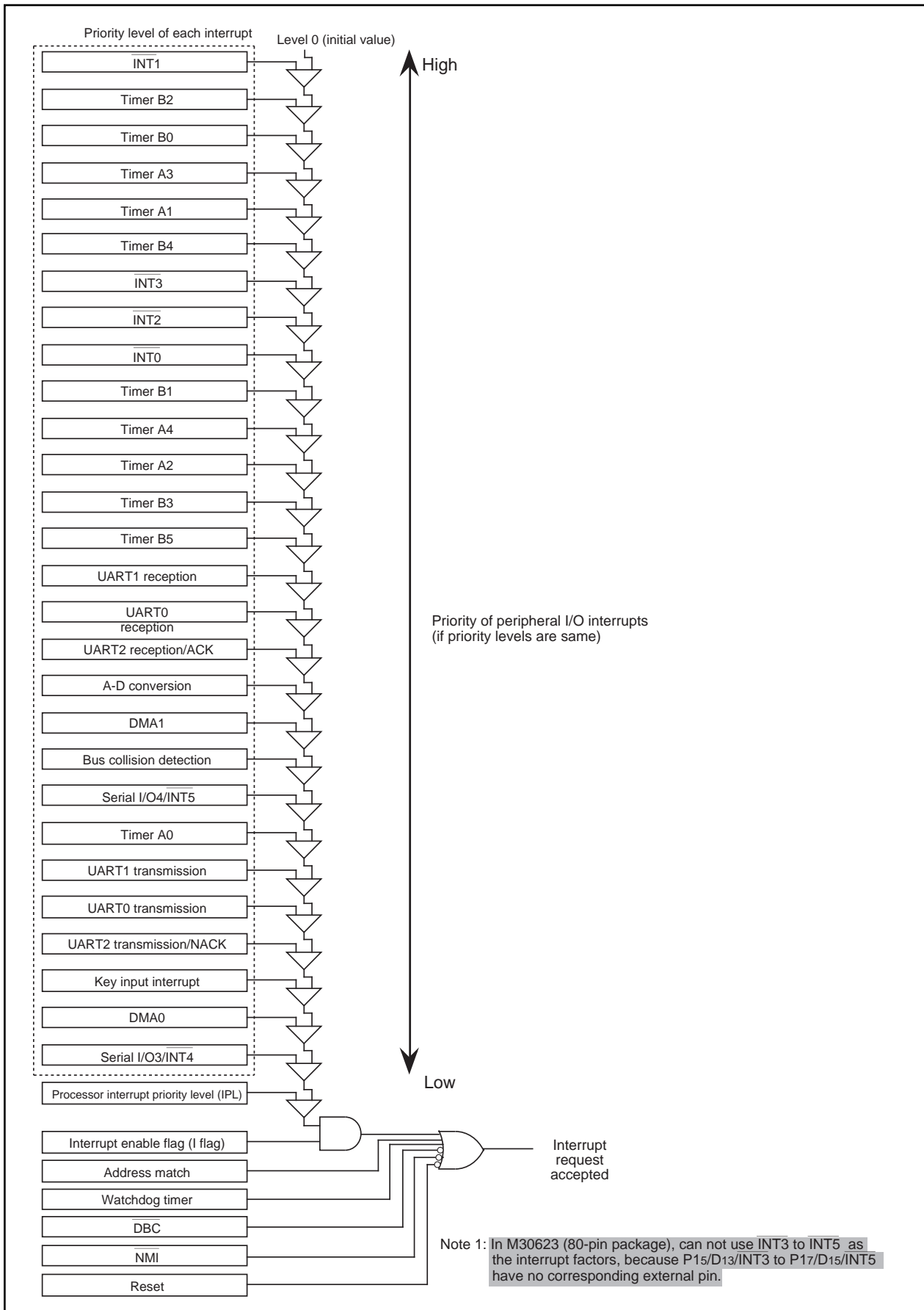


Figure 1.14.9. Maskable interrupts priorities (peripheral I/O interrupts)

INT Interrupt

INT Interrupt

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

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

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

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

Figure 1.14.10 shows the Interrupt request cause select register.

Note 1: In M30623(80-pin package), can not use INT3 to INT5 as the interrupt factor, because P15/D13/INT3 to P17/D15/INT5 have no corresponding external pin.

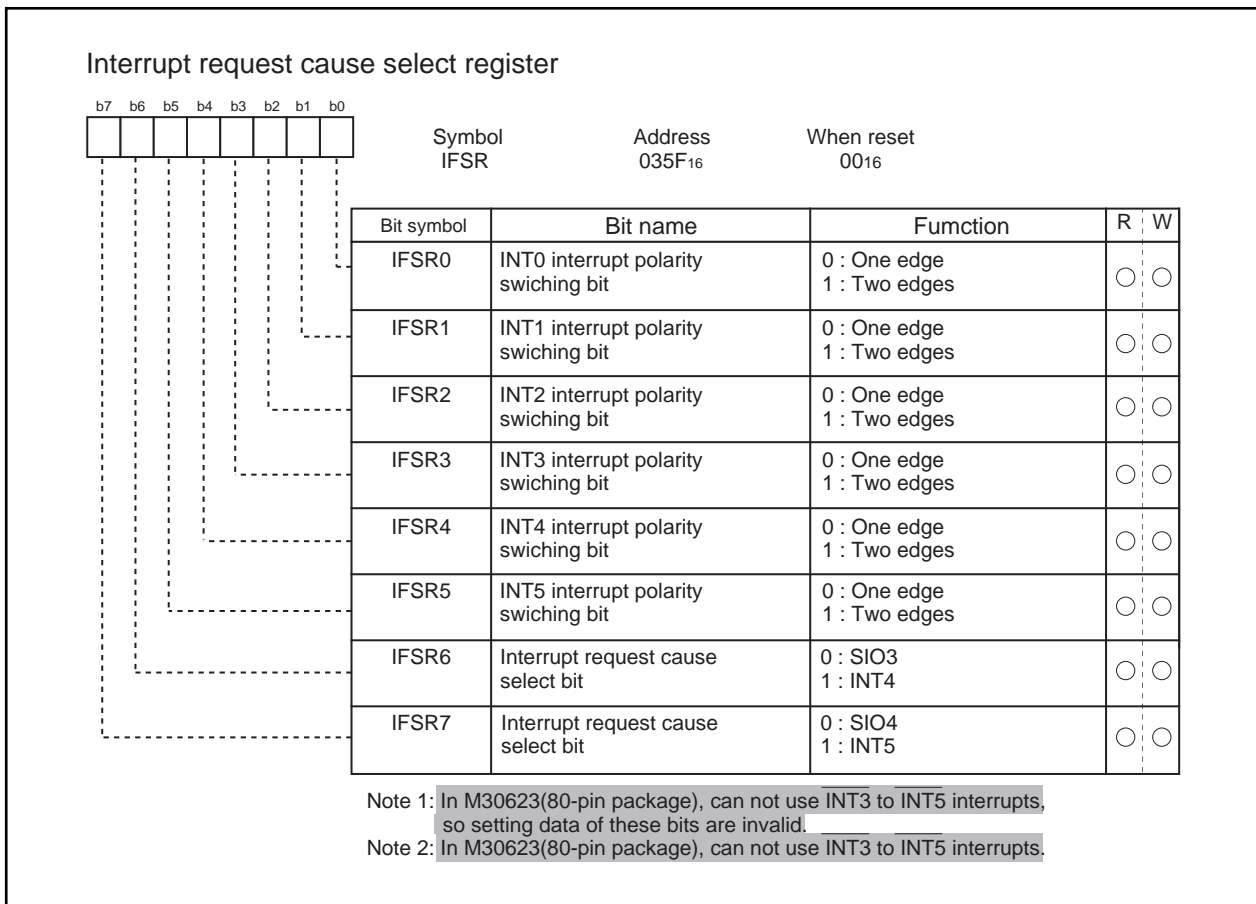


Figure 1.14.10. Interrupt request cause select register

NMI Interrupt

NMI Interrupt

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

This pin cannot be used as a normal port input.

Key Input Interrupt

If the direction register of any of P104 to P107 is set for input and a falling edge is input to that port, a key input interrupt is generated. A key input interrupt can also be used as a key-on wakeup function for canceling the wait mode or stop mode. However, if you intend to use the key input interrupt, do not use P104 to P107 as A-D input ports. Figure 1.14.11 shows the block diagram of the key input interrupt. Note that if an “L” level is input to any pin that has not been disabled for input, inputs to the other pins are not detected as an interrupt.

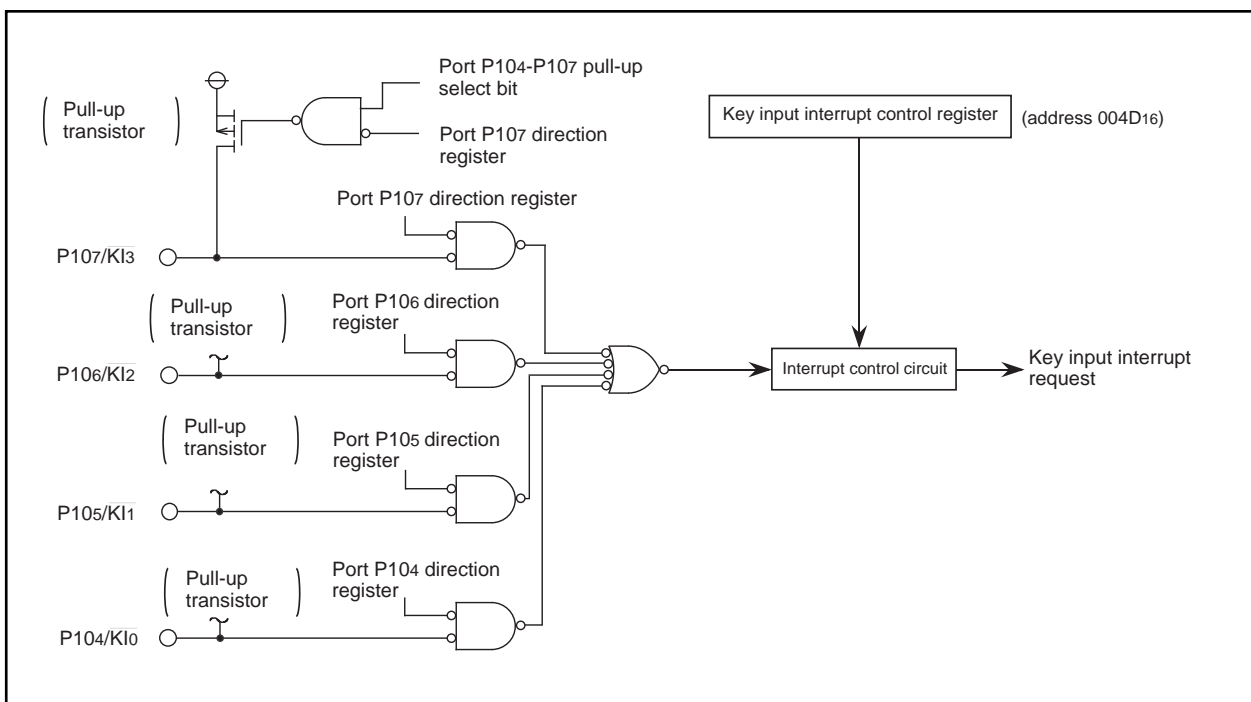


Figure 1.14.11. Block diagram of key input interrupt

Address Match 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 1.14.12 shows the address match interrupt-related registers.

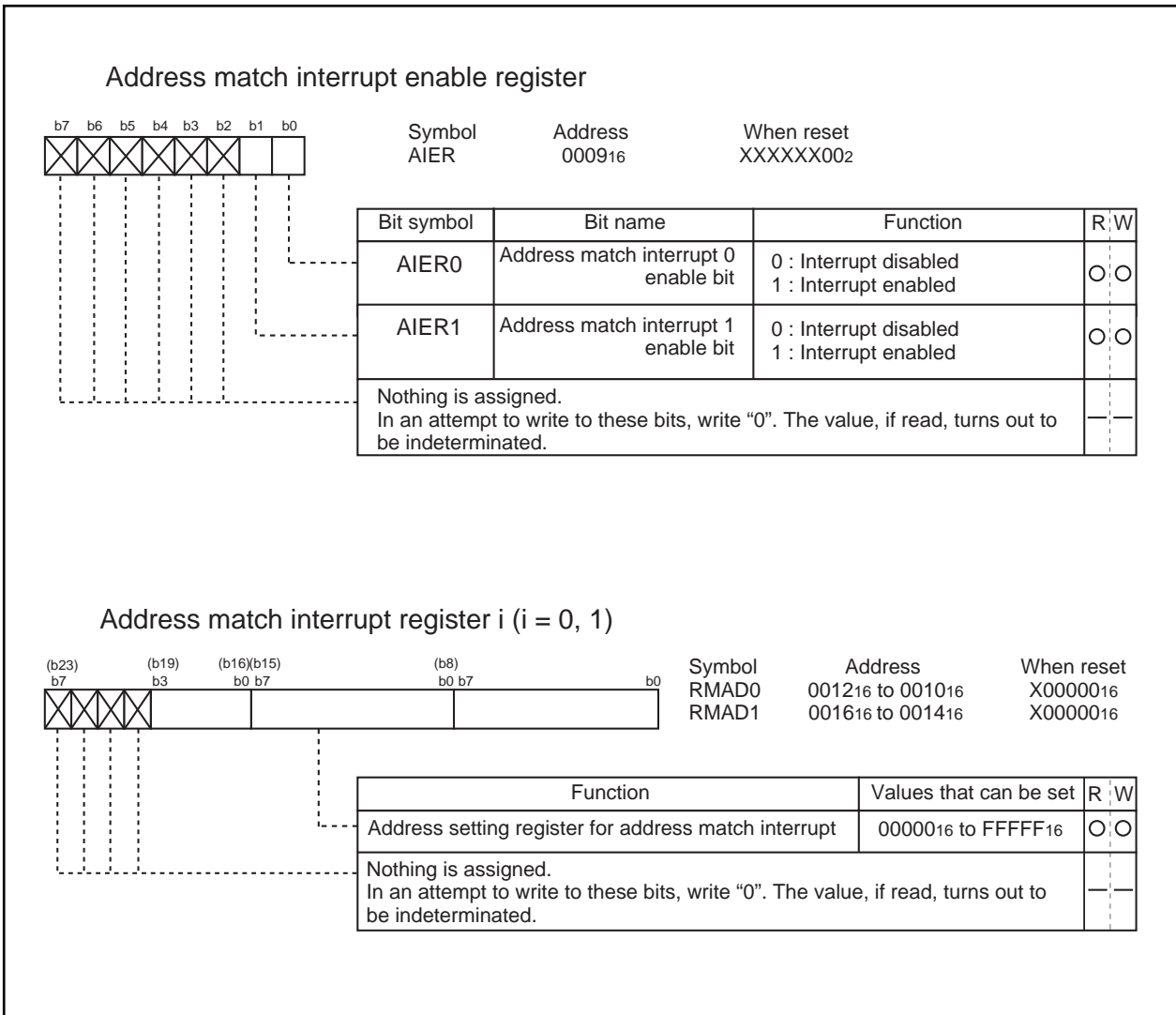


Figure 1.14.12. Address match interrupt-related registers

Precautions for Interrupts

(1) Reading address 00000₁₆

- 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 00000₁₆ will then be set to "0".

Reading address 00000₁₆ 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 00000₁₆ by software.

(2) Setting the stack pointer

- The value of the stack pointer immediately after reset is initialized to 0000₁₆. Accepting an interrupt before setting a value in the stack pointer may become a factor of runaway. Be sure to set a value in the stack pointer before accepting an interrupt. When using the $\overline{\text{NMI}}$ interrupt, initialize the stack 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 Vcc pin via a resistor (pull-up) if unused. Be sure to work on it.
- The $\overline{\text{NMI}}$ pin also serves as P8₅, which is exclusively input. Reading the contents of the P8 register allows reading the pin value. Use the reading of this pin only for establishing the pin level at the time when the $\overline{\text{NMI}}$ interrupt is input.
- Do not reset the CPU with the input to the $\overline{\text{NMI}}$ pin being in the "L" state.
- Do not attempt to go into stop mode with the input to the $\overline{\text{NMI}}$ pin being in the "L" state. With the input to the $\overline{\text{NMI}}$ being in the "L" state, the CM10 is fixed to "0", so attempting to go into stop mode is turned down.
- Do not attempt to go into wait mode with the input to the $\overline{\text{NMI}}$ pin being in the "L" state. With the input to the $\overline{\text{NMI}}$ pin being in the "L" state, the CPU stops but the oscillation does not stop, so no power is saved. In this instance, the CPU is returned to the normal state by a later interrupt.
- Signals input to the $\overline{\text{NMI}}$ pin require an "L" level of 1 clock or more, from the operation clock of the CPU.

(4) External interrupt

- Either an "L" level or an "H" level of at least 250 ns width is necessary for the signal input to pins $\overline{\text{INT0}}$ through $\overline{\text{INT5}}$ regardless of the CPU operation clock.
- When the polarity of the $\overline{\text{INT0}}$ to $\overline{\text{INT5}}$ pins is changed, the interrupt request bit is sometimes set to "1". After changing the polarity, set the interrupt request bit to "0". Figure 1.14.13 shows the procedure for changing the $\overline{\text{INT}}$ interrupt generate factor.

Note 1: In M30623(80-pin package), can not use $\overline{\text{INT3}}$ to $\overline{\text{INT5}}$ as the interrupt factor, because P15/D13/ $\overline{\text{INT3}}$ to P17/D15/ $\overline{\text{INT5}}$ have no corresponding external pin.

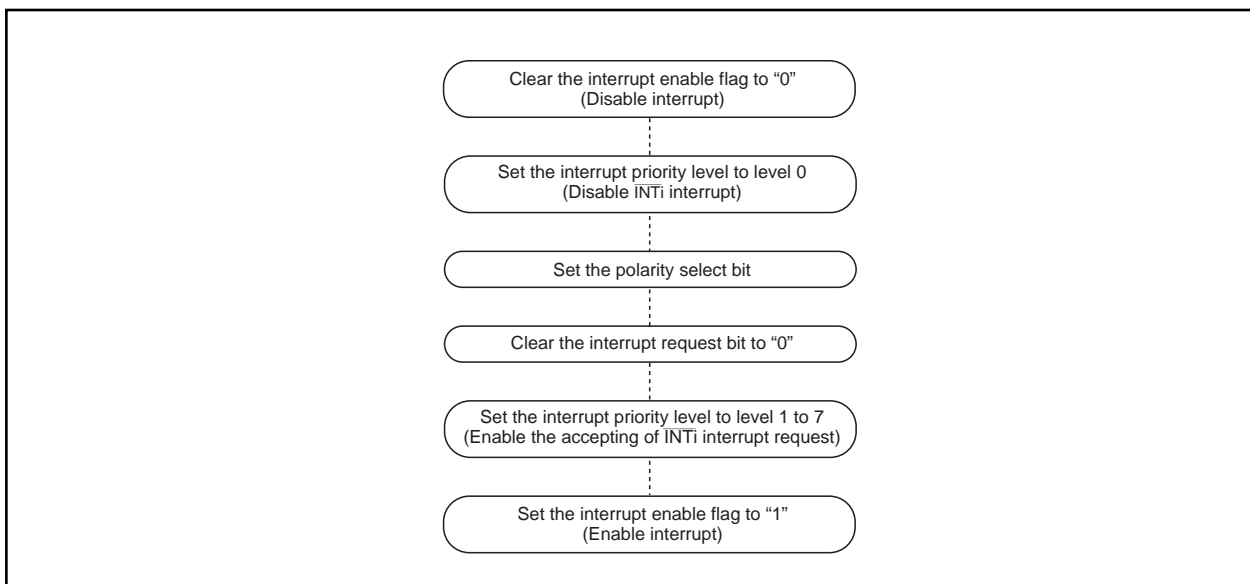


Figure 1.14.13. Switching condition of INT interrupt request

(5) Rewrite the interrupt control register

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

Example 1:

```

INT_SWITCH1:
  FCLR  I           ; Disable interrupts.
  AND.B #00h, 0055h ; Clear TA0IC int. priority level and int. request bit.
  NOP                               ; 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

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

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

With XCIN chosen for BCLK

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

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 1.15.1 shows the block diagram of the watchdog timer. Figure 1.15.2 shows the watchdog timer-related registers.

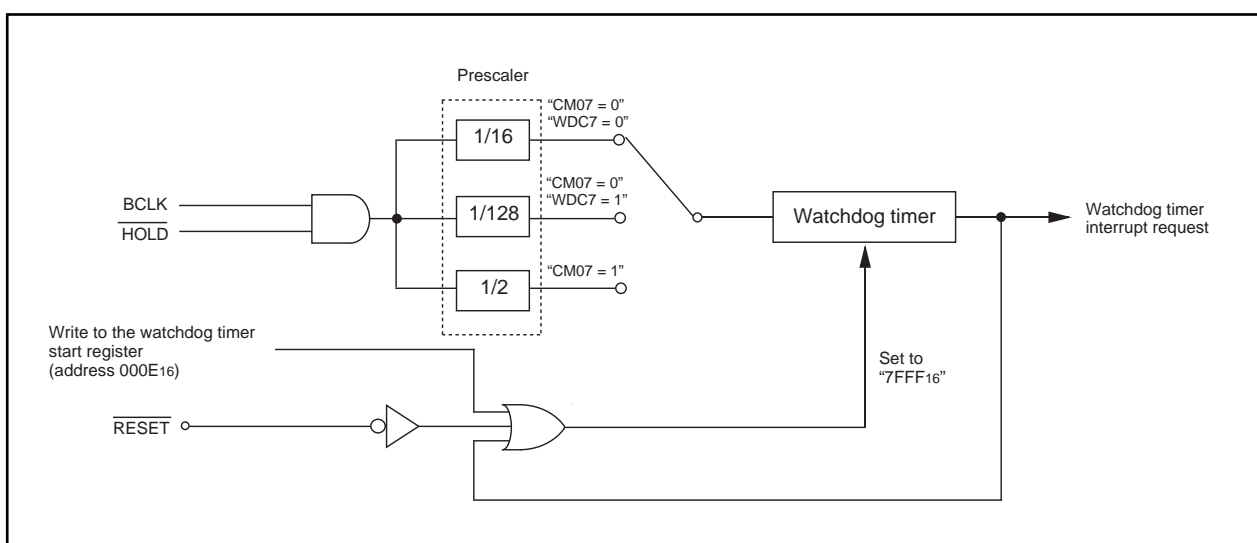


Figure 1.15.1. Block diagram of watchdog timer

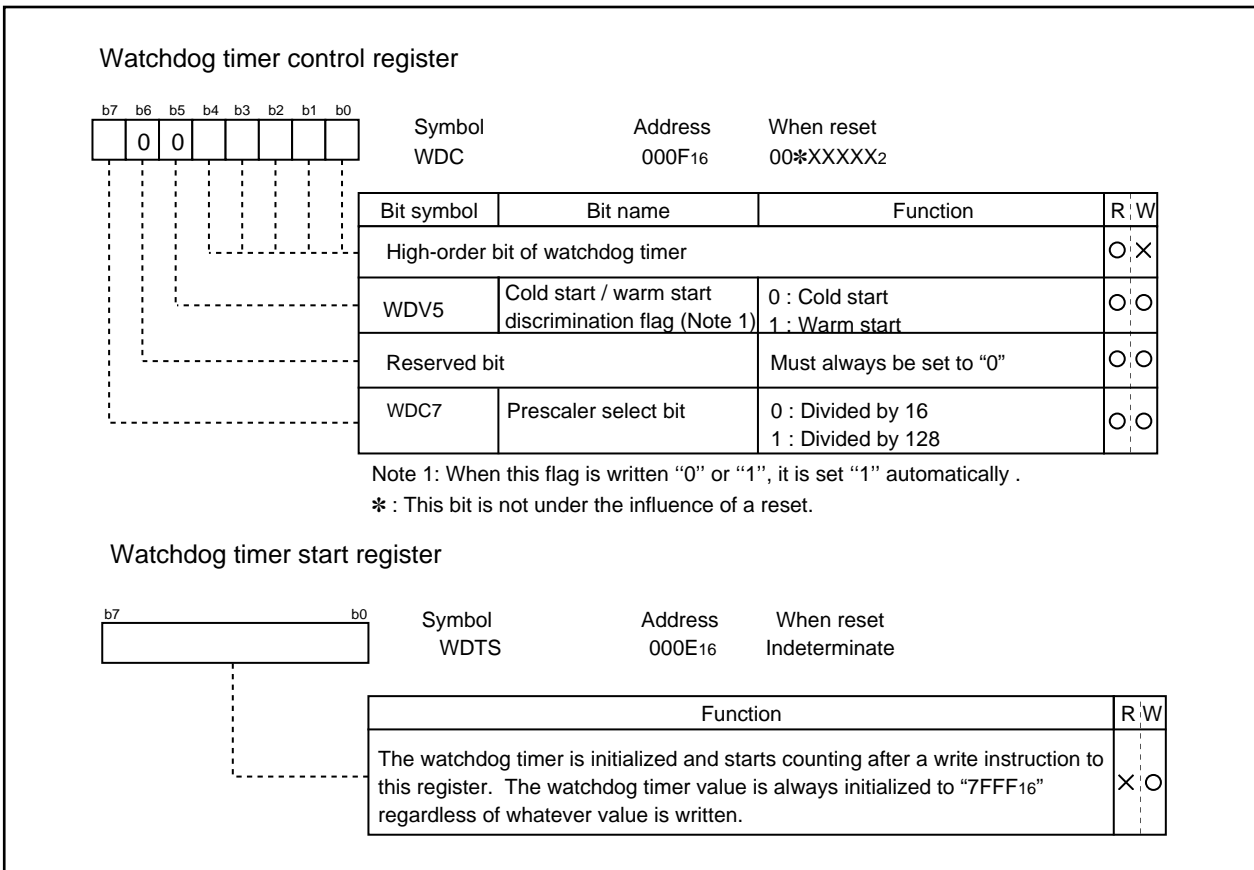


Figure 1.15.2. Watchdog timer control and start registers

Cold start / Warm start

The cold start/warm start discrimination flag(bit 5 at 000F₁₆) indicates the last reset by power on(cold start) or by reset signal(warm start).

The cold start/warm start discrimination flag is set "0" at power on, and is set "1" at writing any data to the watchdog timer control register(address is 000F₁₆). The flag is not set to "0" by the software reset and the input of reset signal.

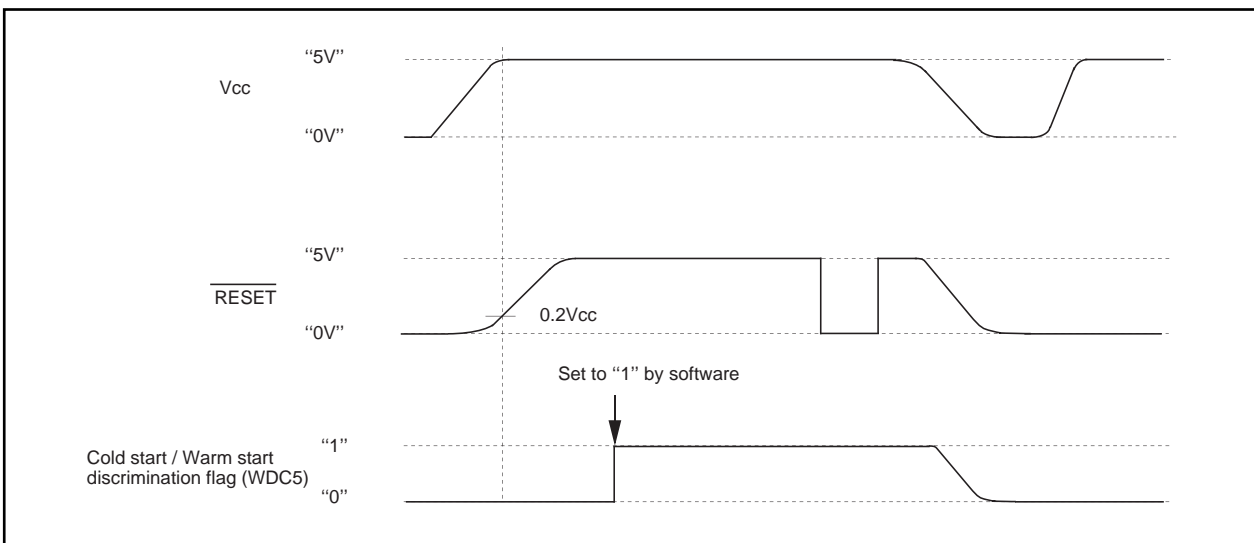


Figure 1.15.3. Cold start / Warm start

DMAC

DMAC

This microcomputer has two DMAC (direct memory access controller) channels that allow data to be sent to memory without using the CPU. DMAC shares the same data bus with the CPU. The DMAC is given a higher right of using the bus than the CPU, which leads to working the cycle stealing method. On this account, the operation from the occurrence of DMA transfer request signal to the completion of 1-word (16-bit) or 1-byte (8-bit) data transfer can be performed at high speed. Figure 1.16.1 shows the block diagram of the DMAC. Table 1.16.1 shows the DMAC specifications. Figures 1.16.2 to 1.16.4 show the registers used by the DMAC.

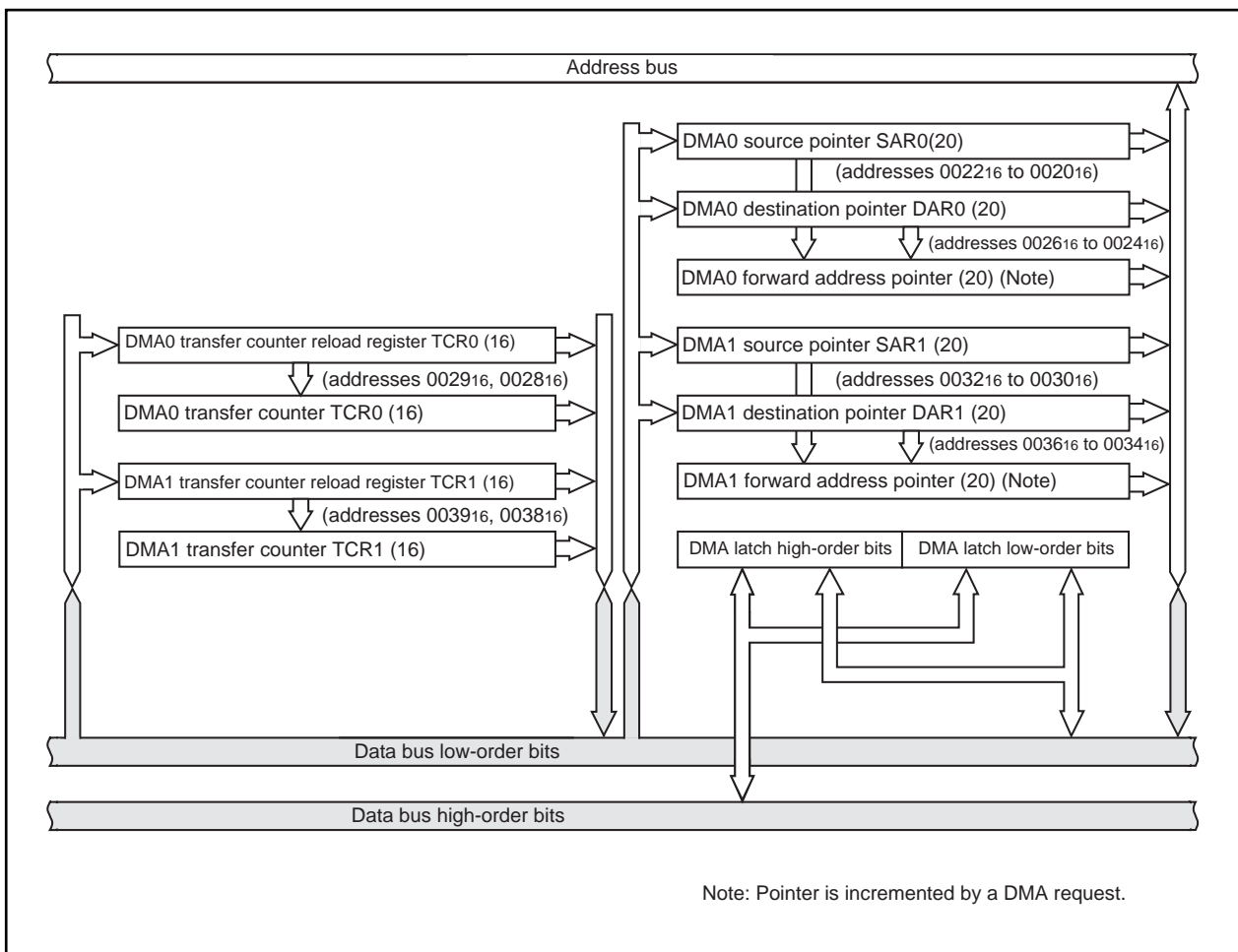


Figure 1.16.1. Block diagram of DMAC

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

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

Table 1.16.1. DMAC specifications

Item	Specification
No. of channels	2 (cycle steal method)
Transfer memory space	<ul style="list-style-type: none"> • From any address in the 1M bytes space to a fixed address • From a fixed address to any address in the 1M bytes space • From a fixed address to a fixed address (Note that DMA-related registers [0020 ₁₆ to 003F ₁₆] cannot be accessed)
Maximum No. of bytes transferred	128K bytes (with 16-bit transfers) or 64K bytes (with 8-bit transfers)
DMA request factors (Note)	Falling edge of $\overline{\text{INT0}}$ or $\overline{\text{INT1}}$ ($\overline{\text{INT0}}$ can be selected by DMA0, $\overline{\text{INT1}}$ by DMA1) or both edge Timer A0 to timer A4 interrupt requests Timer B0 to timer B5 interrupt requests UART0 transfer and reception interrupt requests UART1 transfer and reception interrupt requests UART2 transfer and reception interrupt requests Serial I/O3, 4 interrupt requests A-D conversion interrupt requests Software triggers
Channel priority	DMA0 takes precedence if DMA0 and DMA1 requests are generated simultaneously
Transfer unit	8 bits or 16 bits
Transfer address direction	forward/fixed (forward direction cannot be specified for both source and destination simultaneously)
Transfer mode	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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 reload timing for transfer counter	At the time of starting data transfer immediately after turning the DMAC active, the value of one of source pointer and destination pointer - the one specified for the forward direction - is reloaded to the forward direction address pointer, and the value of the transfer counter reload register is reloaded to the transfer counter.
Writing to register	Registers specified for forward direction transfer are always write enabled. Registers specified for fixed address transfer are write-enabled when the DMA enable bit is "0".
Reading the register	Can be read at any time. However, when the DMA enable bit is "1", reading the register set up as the forward register is the same as reading the value of the forward address pointer.

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

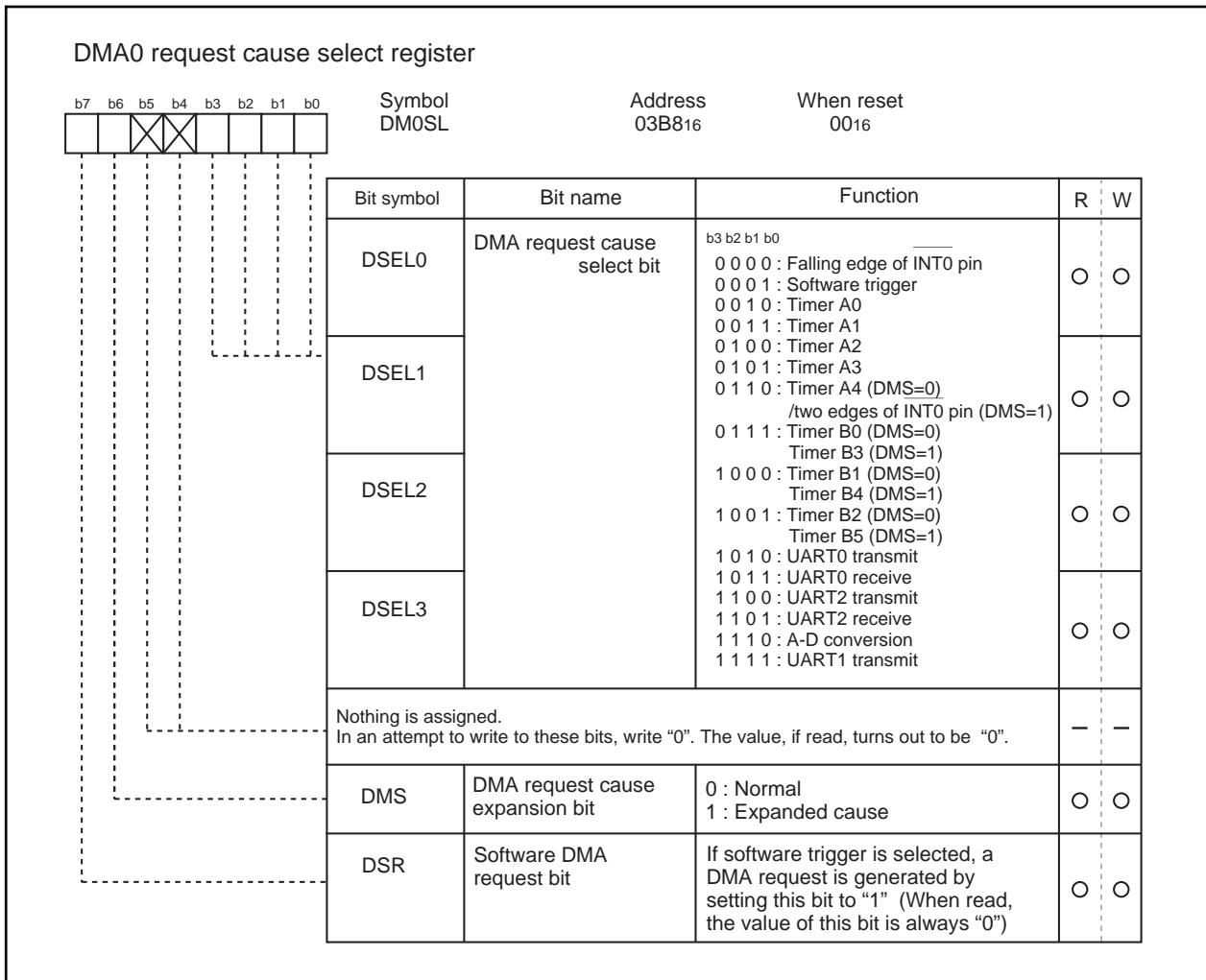


Figure 1.16.2. DMAC register (1)

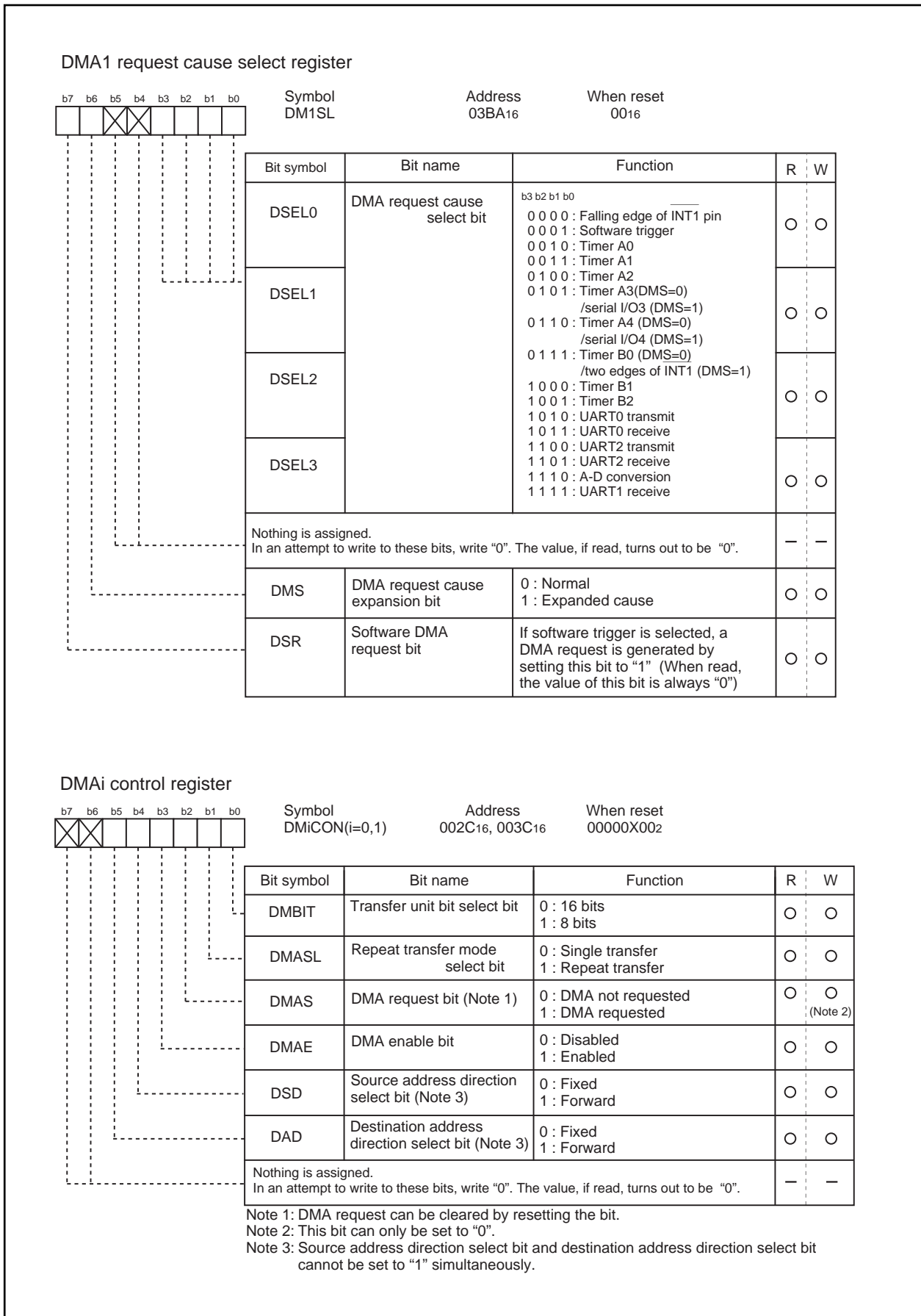


Figure 1.16.3. DMAC register (2)

DMAC

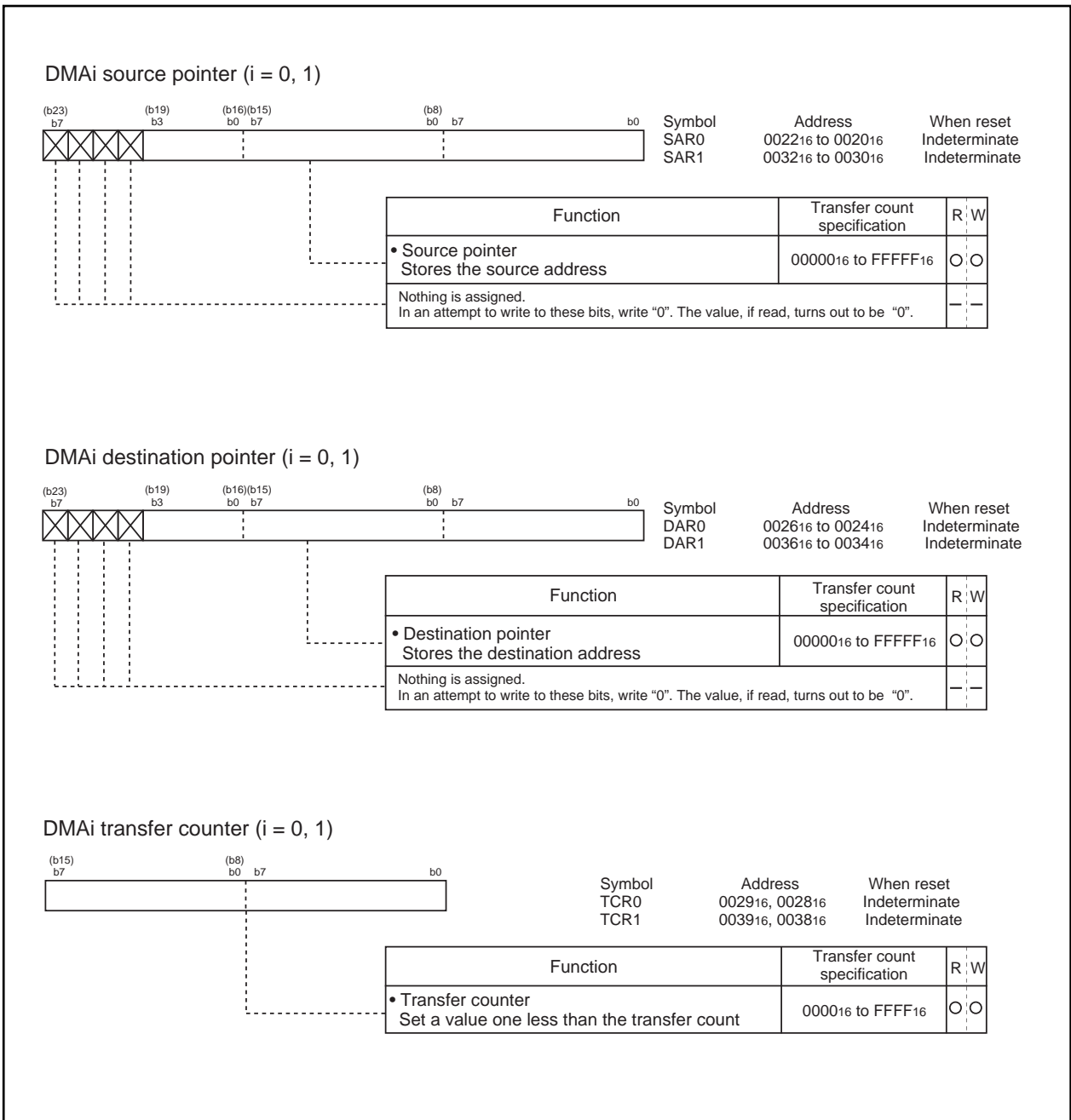


Figure 1.16.4. DMAC register (3)

(1) Transfer cycle

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

(a) Effect of source and destination addresses

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

(b) Effect of BYTE pin level

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

(c) Effect of software wait

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

Figure 1.16.5 shows the example of the transfer cycles for a source read. For convenience, the destination write cycle is shown as one cycle and the source read cycles for the different conditions are shown. In reality, the destination write cycle is subject to the same conditions as the source read cycle, with the transfer cycle changing accordingly. When calculating the transfer cycle, remember to apply the respective conditions to both the destination write cycle and the source read cycle. For example (2) in Figure 1.16.5, if data is being transferred in 16-bit units on an 8-bit bus, two bus cycles are required for both the source read cycle and the destination write cycle.

Note 1: M30623(80-pin package), in case of access to the external bus area, can be used only when 8-bit bus mode.

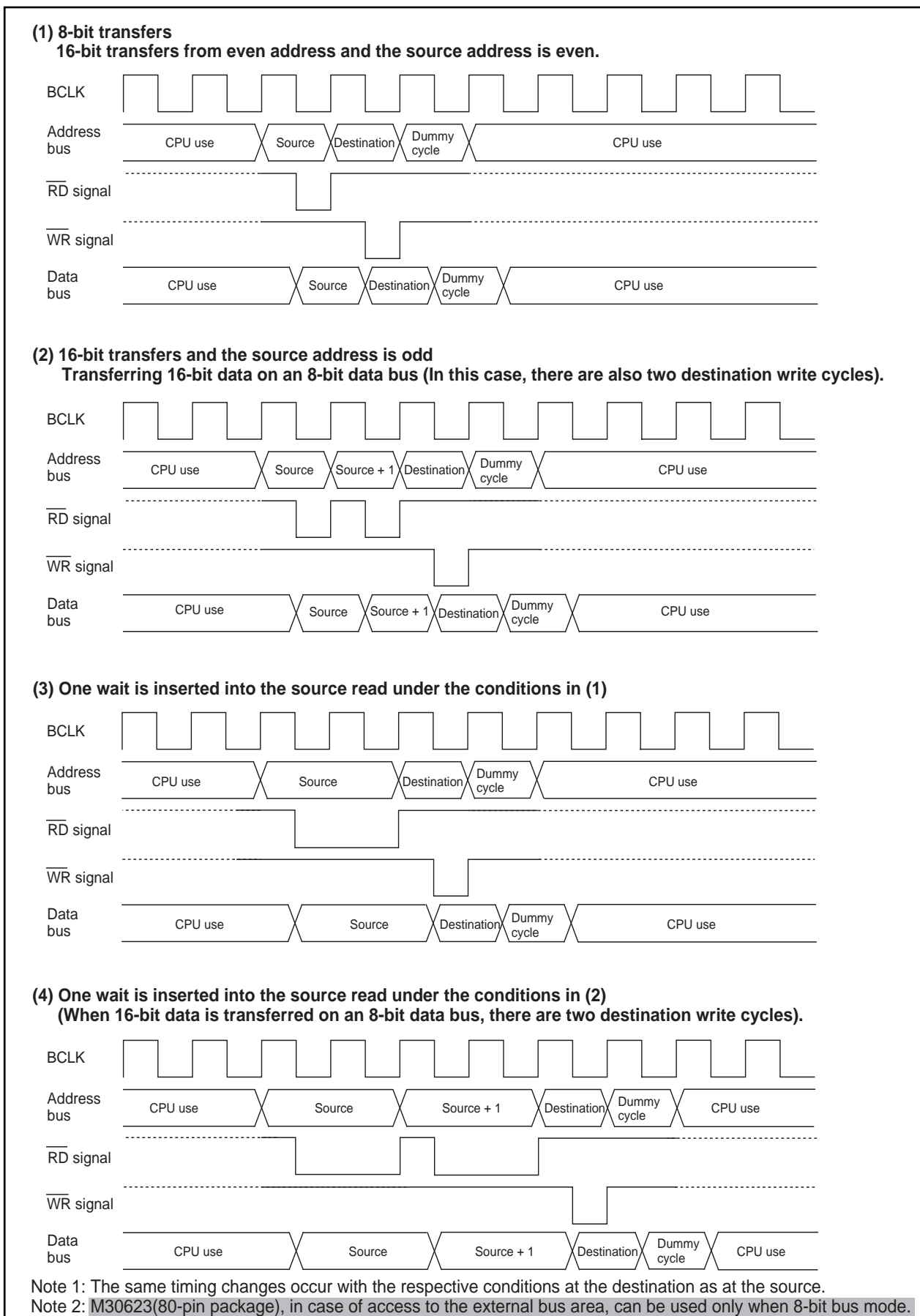


Figure 1.16.5. Example of the transfer cycles for a source read

(2) DMAC transfer cycles

Any combination of even or odd transfer read and write addresses is possible. Table 1.16.2 shows the number of DMAC transfer cycles.

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

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

Table 1.16.2. No. of DMAC transfer cycles

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

Coefficient j, k

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

Note 1: M30623(80-pin package), in case of access to the external bus area, can be used only when 8-bit bus mode.

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 DMA_i 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 INT_i pin (i depends on which DMAC channel is used).

Selecting the INT_i pins as external factors using the DMA request factor selection bit causes input from these pins to become the DMA transfer request signals.

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

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

(3) The priorities of channels and DMA transfer timing

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

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

Figure 1.16.6 An example of DMA transfer effected by external factors.

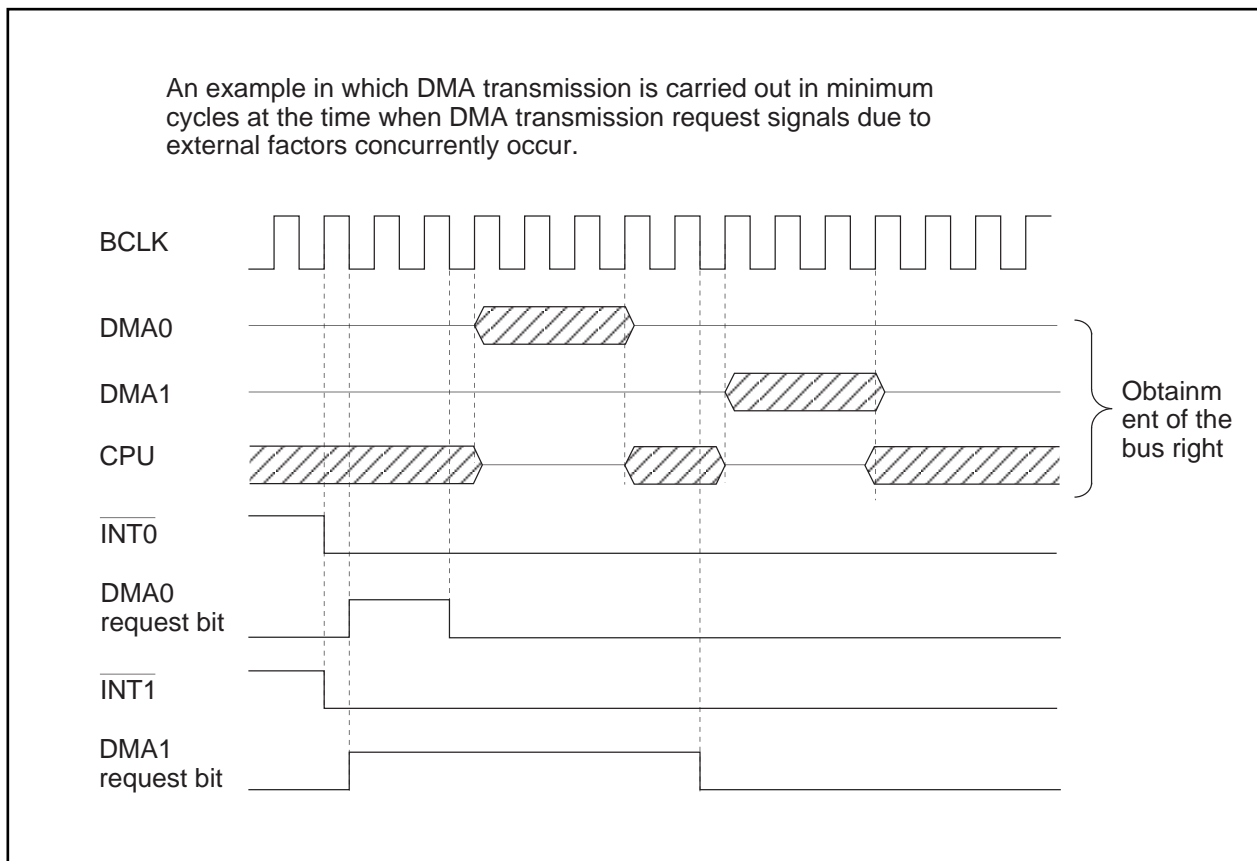


Figure 1.16.6. An example of DMA transfer effected by external factors

Timer

There are eleven 16-bit timers. These timers can be classified by function into timers A (five) and timers B (six). All these timers function independently. Figures 1.17.1 and 1.17.2 show the block diagram of timers.

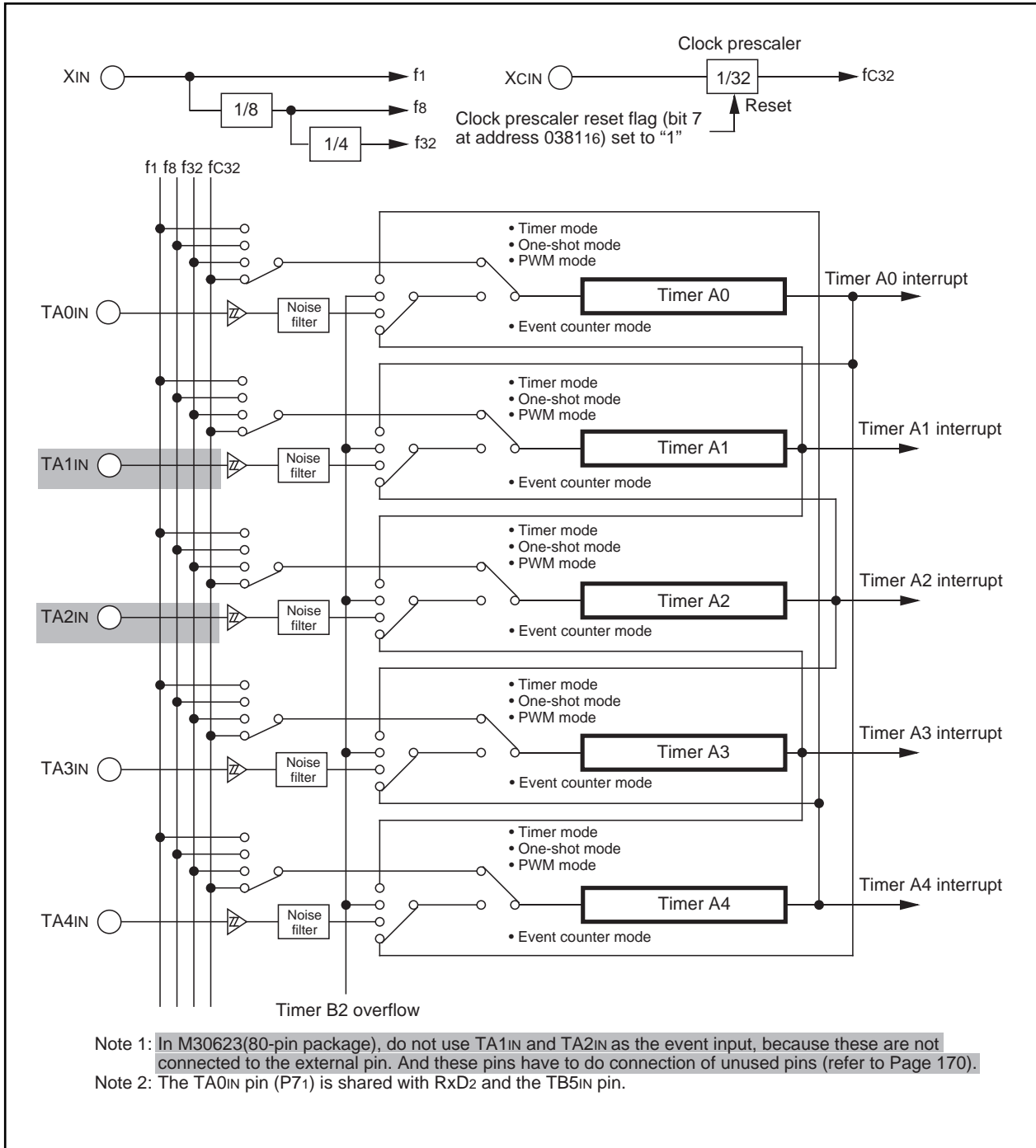


Figure 1.17.1. Timer A block diagram

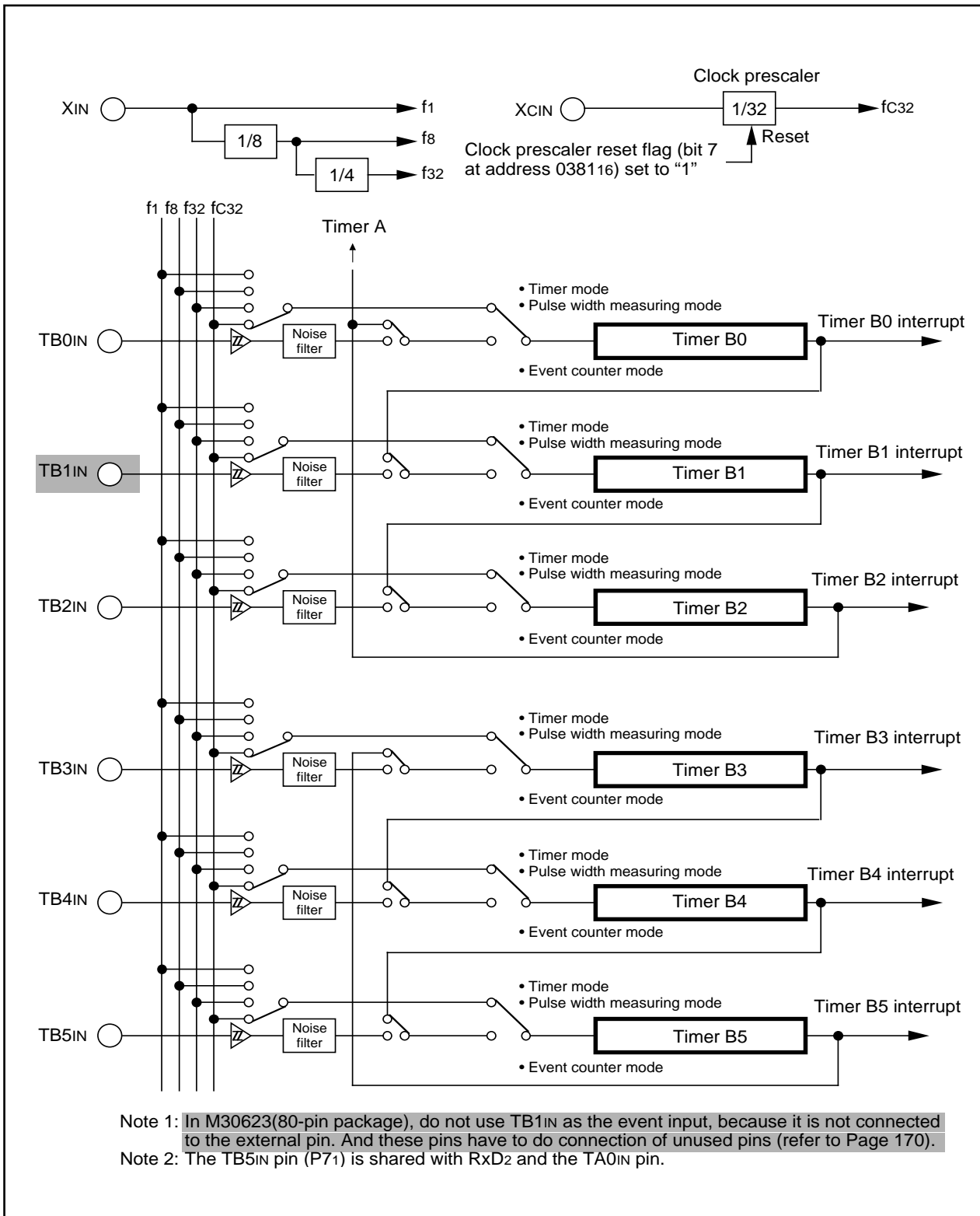


Figure 1.17.2. Timer B block diagram

Timer A

Timer A

Figure 1.17.3 shows the block diagram of timer A. Figures 1.17.4 to 1.17.6 show the timer A-related registers.

Except in event counter mode, timers A0 through A4 all have the same function. Use the timer Ai mode register (i = 0 to 4) bits 0 and 1 to choose the desired mode. But M30623(80-pin package), timer A1 and A2 have no I/O pin, so it operate as only internal timer.

Timer A has the four operation modes listed as follows:

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

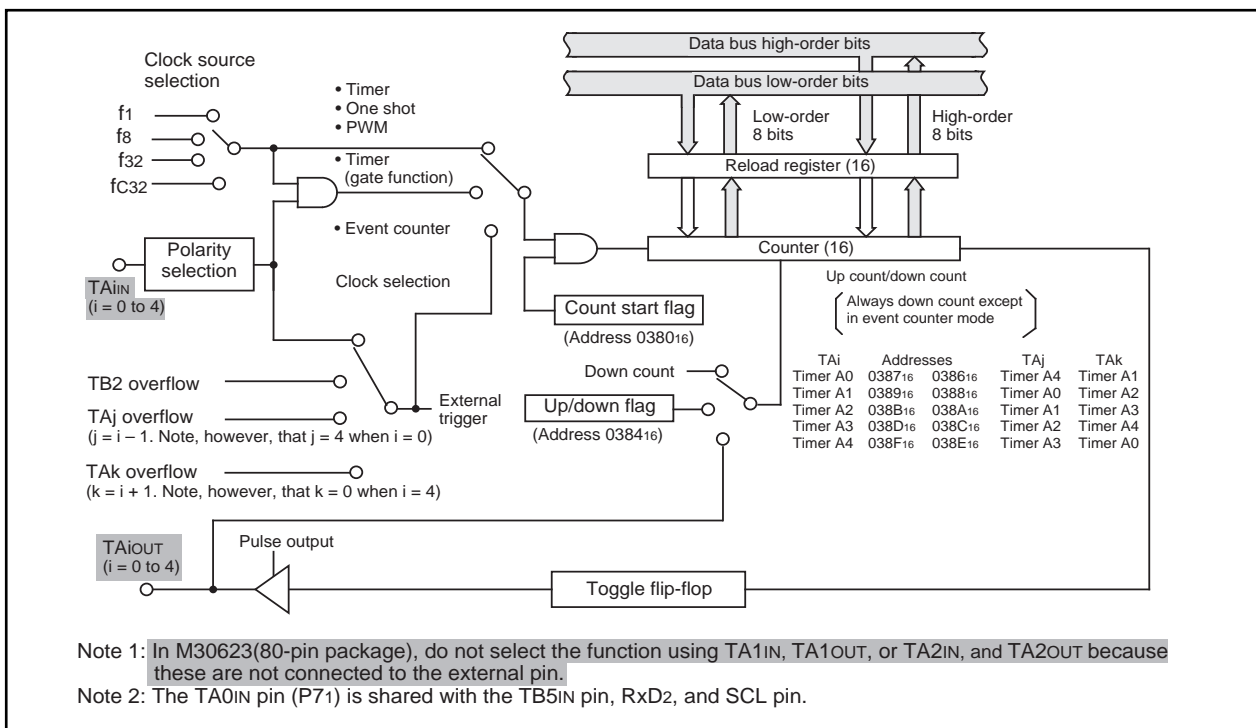


Figure 1.17.3. Block diagram of timer A

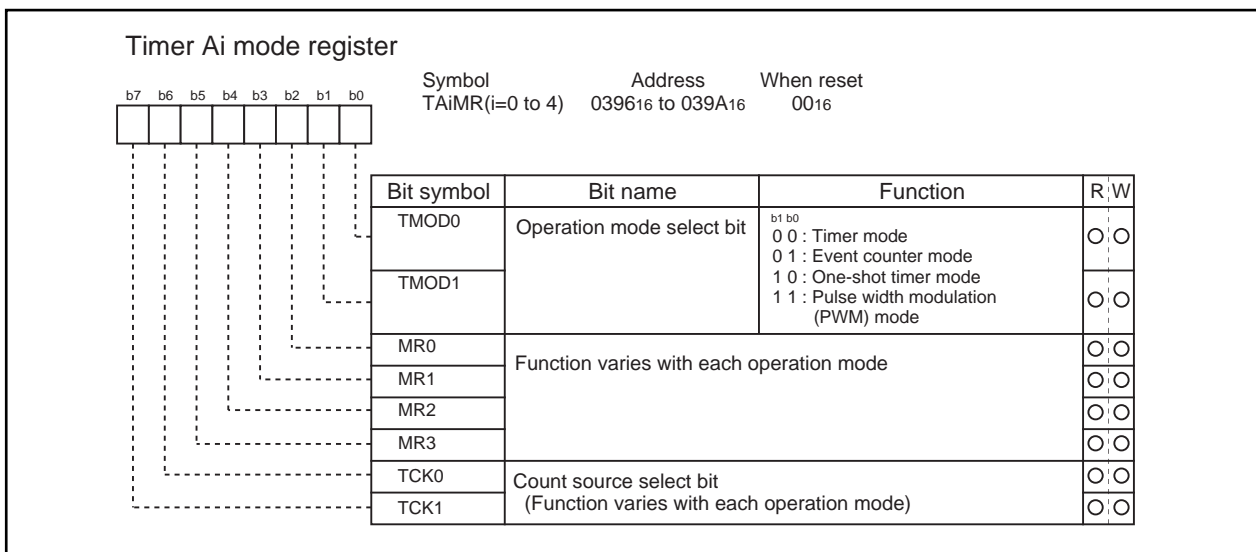


Figure 1.17.4. Timer A-related registers (1)

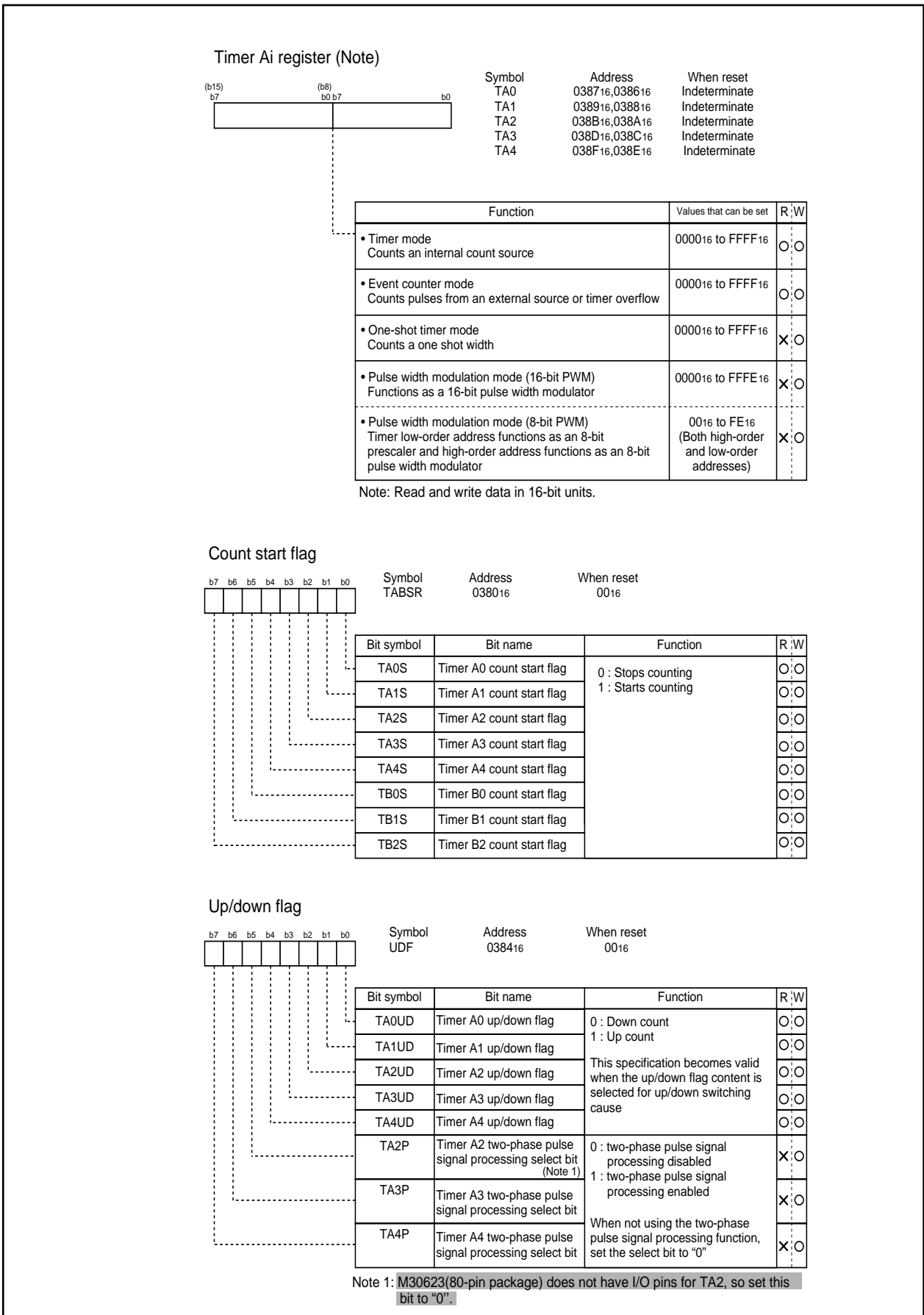
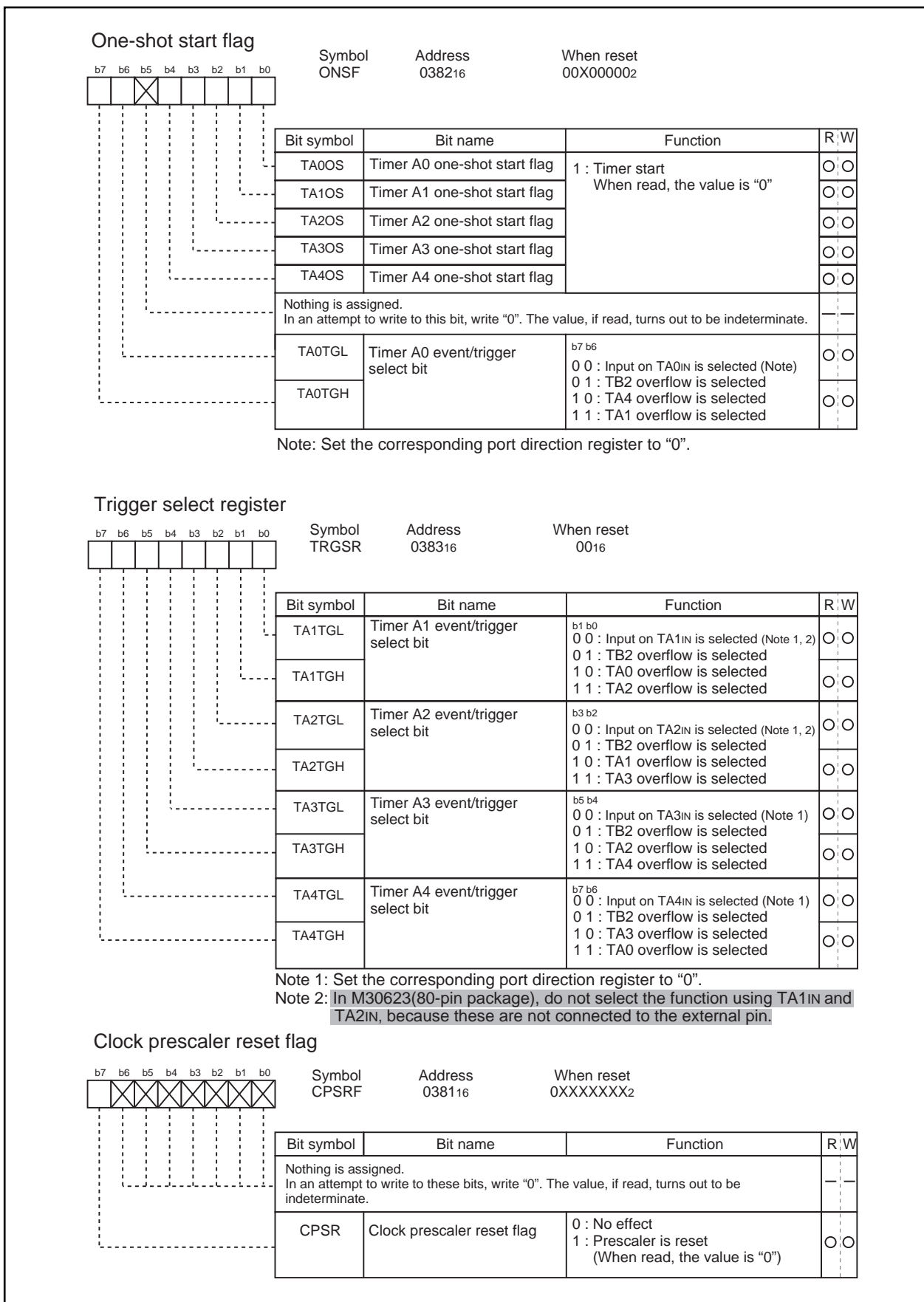


Figure 1.17.5. Timer A-related registers (2)



(1) Timer mode

In this mode, the timer counts an internally generated count source. (See Table 1.17.1.) Figure 1.17.7 shows the timer Ai mode register in timer mode.

Table 1.17.1. Specifications of timer mode

Item	Specification
Count source	f1, f8, f32, fC32
Count operation	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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

Note 1: M30623(80-pin package) does not have I/O pins(TAiIN,TAiOUT) for timer A1 and A2.

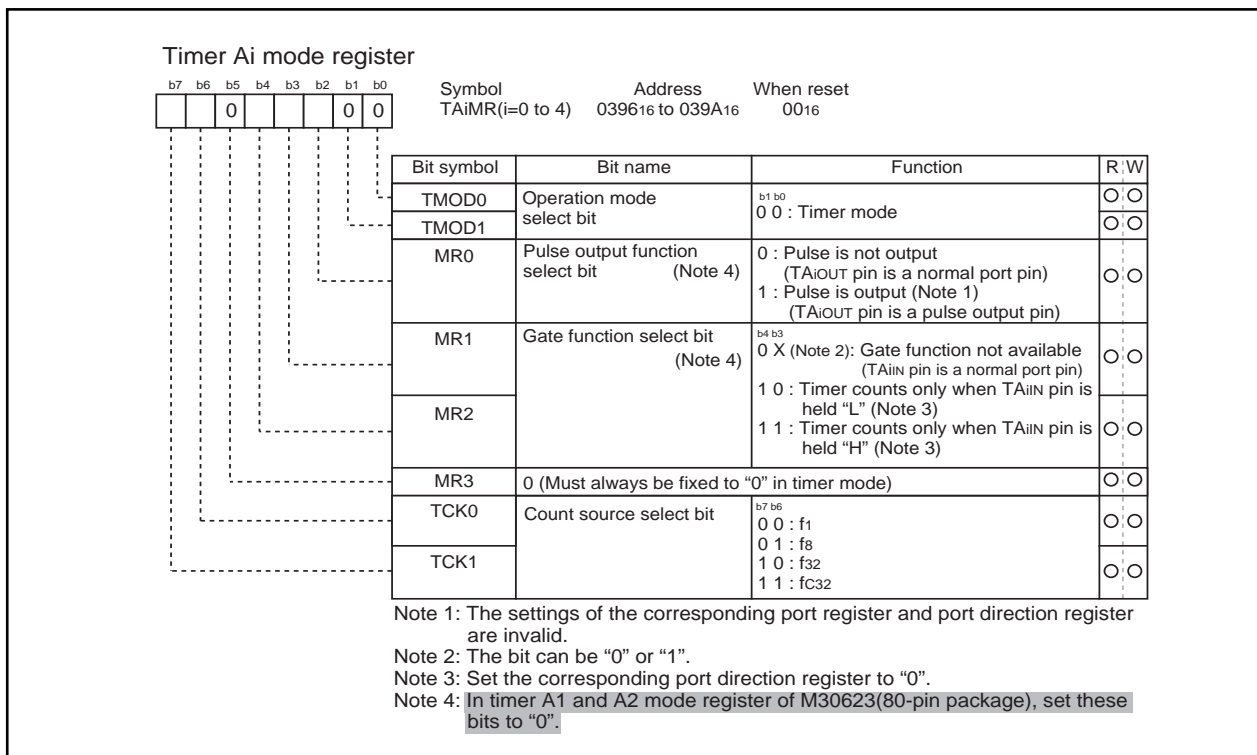


Figure 1.17.7. Timer Ai mode register in timer mode

(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 1.17.2 lists timer specifications when counting a single-phase external signal. Figure 1.17.8 shows the timer Ai mode register in event counter mode.

Table 1.17.3 lists timer specifications when counting a two-phase external signal. Figure 1.17.9 shows the timer Ai mode register in event counter mode.

Table 1.17.2. Timer specifications in event counter mode (when not processing two-phase pulse signal)

Item	Specification
Count source	<ul style="list-style-type: none"> External signals input to TAIIn pin (effective edge can be selected by software) TB2 overflow, TAJ overflow
Count operation	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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 1: This does not apply when the free-run function is selected.

Note 2: M30623(80-pin package) does not have I/O pins(TAIIn,TAiOUT) for timer A1 and A2.

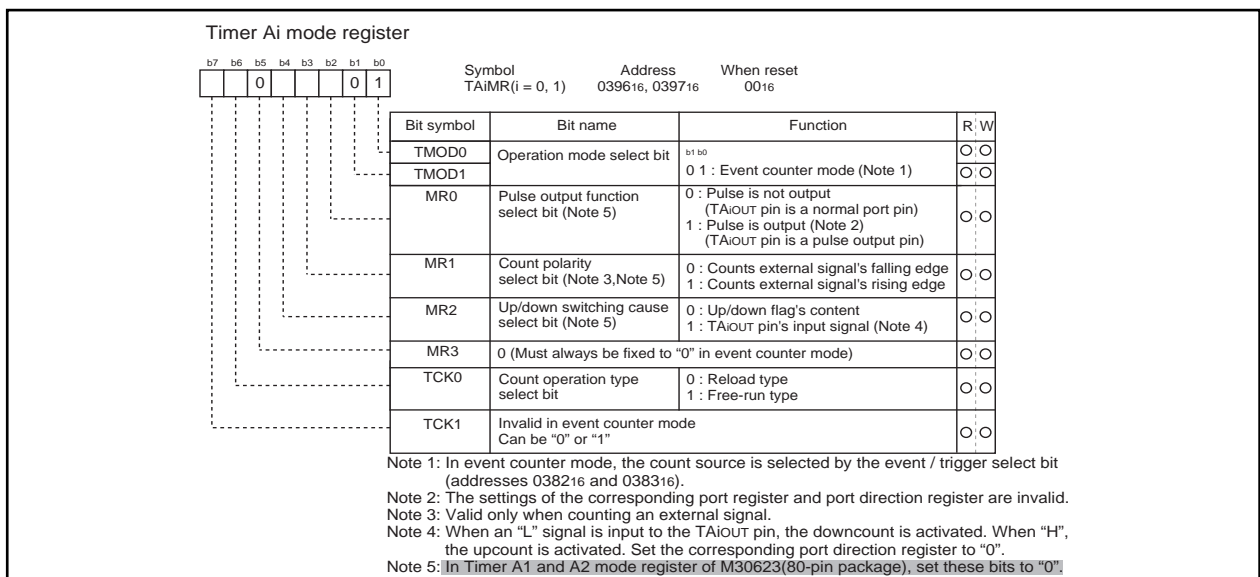
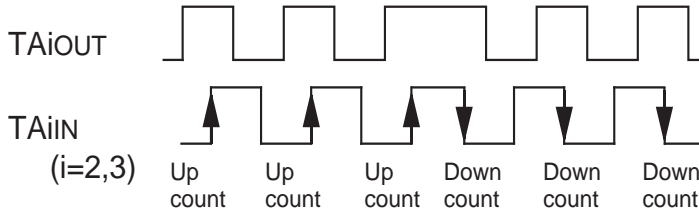
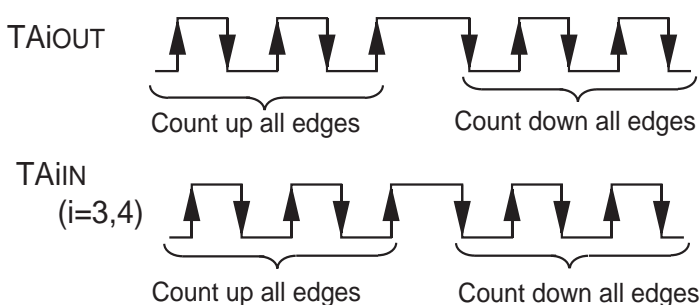


Figure 1.17.8. Timer Ai mode register in event counter mode

Table 1.17.3. Timer specifications in event counter mode (when processing two-phase pulse signal with timers A2, A3, and A4)

Item	Specification
Count source	• Two-phase pulse signals input to TAIiN or TAIoUT pin
Count operation	• Up count or down count can be selected by two-phase pulse signal • When the timer overflows or underflows, the reload register content is reloaded and the timer starts over again (Note)
Divide ratio	1/ (FFFF ₁₆ - n + 1) for up count 1/ (n + 1) for down count n : Set value
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	Timer overflows or underflows
TAiIN pin function	Two-phase pulse input
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	<ul style="list-style-type: none"> • 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"  <ul style="list-style-type: none"> • 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 1: This does not apply when the free-run function is selected.

Note 2: M30623(80-pin package) does not have I/O pins(TAIiN,TAIoUT) for timer A1 and A2.

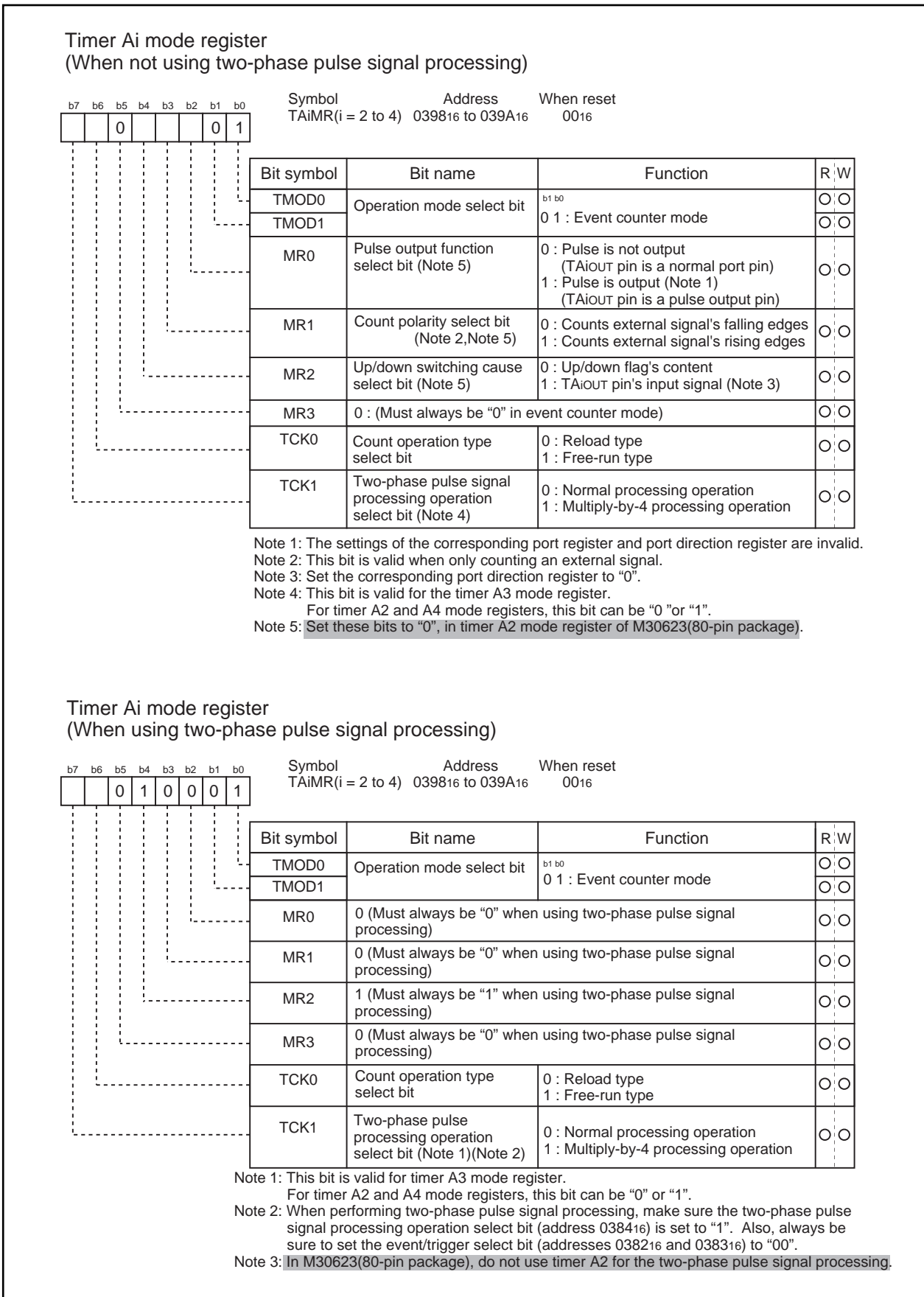


Figure 1.17.9. Timer Ai mode register in event counter mode

(3) One-shot timer mode

In this mode, the timer operates only once. (See Table 1.17.4.) When a trigger occurs, the timer starts up and continues operating for a given period. Figure 1.17.10 shows the timer Ai mode register in one-shot timer mode.

Table 1.17.4. Timer specifications in one-shot timer mode

Item	Specification
Count source	f1, f8, f32, fc32
Count operation	<ul style="list-style-type: none"> The timer counts down When the count reaches 0000₁₆, the timer stops counting after reloading a new count If a trigger occurs when counting, the timer reloads a new count and restarts counting
Divide ratio	1/n n : Set value
Count start condition	<ul style="list-style-type: none"> An external trigger is input The timer overflows The one-shot start flag is set (= 1)
Count stop condition	<ul style="list-style-type: none"> A new count is reloaded after the count has reached 0000₁₆ The count start flag is reset (= 0)
Interrupt request generation timing	The count reaches 0000 ₁₆
TAiIN pin function	Programmable I/O port or trigger input
TAiOUT pin function	Programmable I/O port or pulse output
Read from timer	When timer Ai register is read, it indicates an indeterminate value
Write to timer	<ul style="list-style-type: none"> 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)

Note 1: M30623(80-pin package) does not have I/O pins(TAiIN,TAiOUT) for timer A1 and A2.

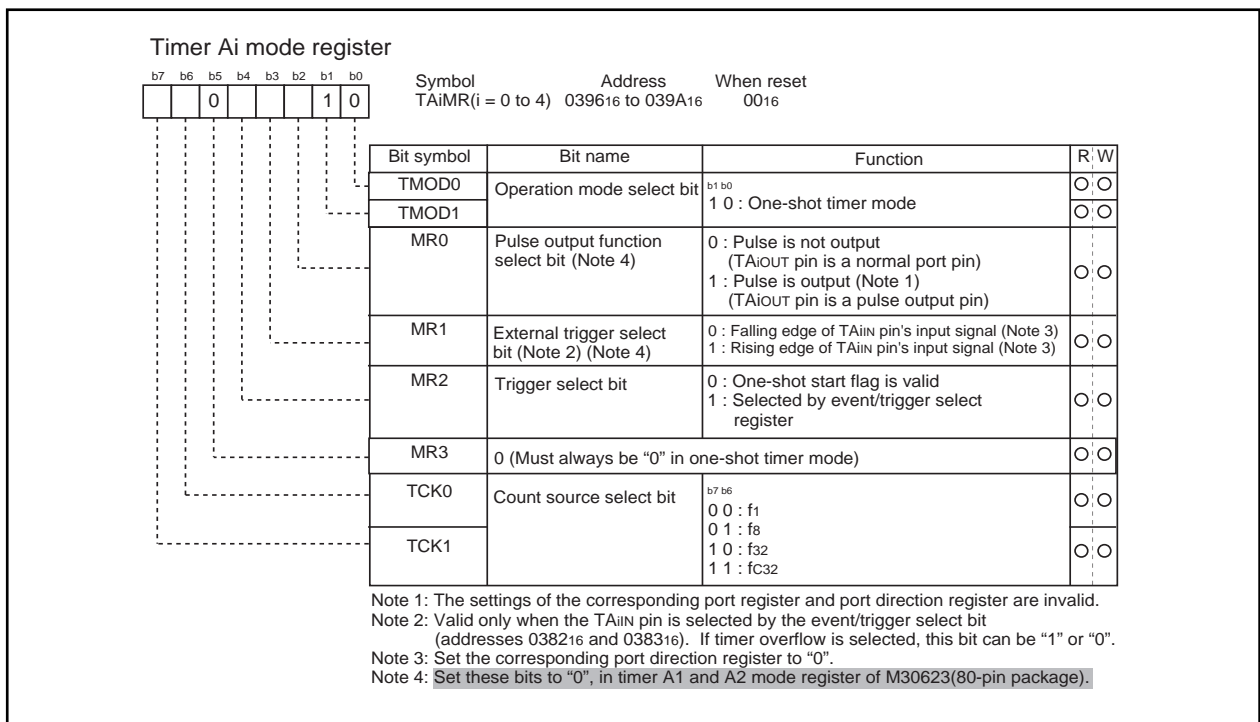


Figure 1.17.10. Timer Ai mode register in one-shot timer mode

(4) Pulse width modulation (PWM) mode

In this mode, the timer outputs pulses of a given width in succession. (See Table 1.17.5.) In this mode, the counter functions as either a 16-bit pulse width modulator or an 8-bit pulse width modulator. Figure 1.17.11 shows the timer Ai mode register in pulse width modulation mode. Figure 1.17.12 shows the example of how a 16-bit pulse width modulator operates. Figure 1.17.13 shows the example of how an 8-bit pulse width modulator operates.

Table 1.17.5. Timer specifications in pulse width modulation mode

Item	Specification
Count source	f1, f8, f32, fc32
Count operation	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> High level width n / f_i n : Set value Cycle time $(2^{16}-1) / f_i$ fixed
8-bit PWM	<ul style="list-style-type: none"> High level width $n \times (m+1) / f_i$ n : values set to timer Ai register's high-order address Cycle time $(2^8-1) \times (m+1) / f_i$ m : values set to timer Ai register's low-order address
Count start condition	<ul style="list-style-type: none"> External trigger is input The timer overflows The count start flag is set (= 1)
Count stop condition	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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)

Note 1: M30623(80-pin package) does not have I/O pins(TAiIN,TAiOUT) for timer A1 and A2.

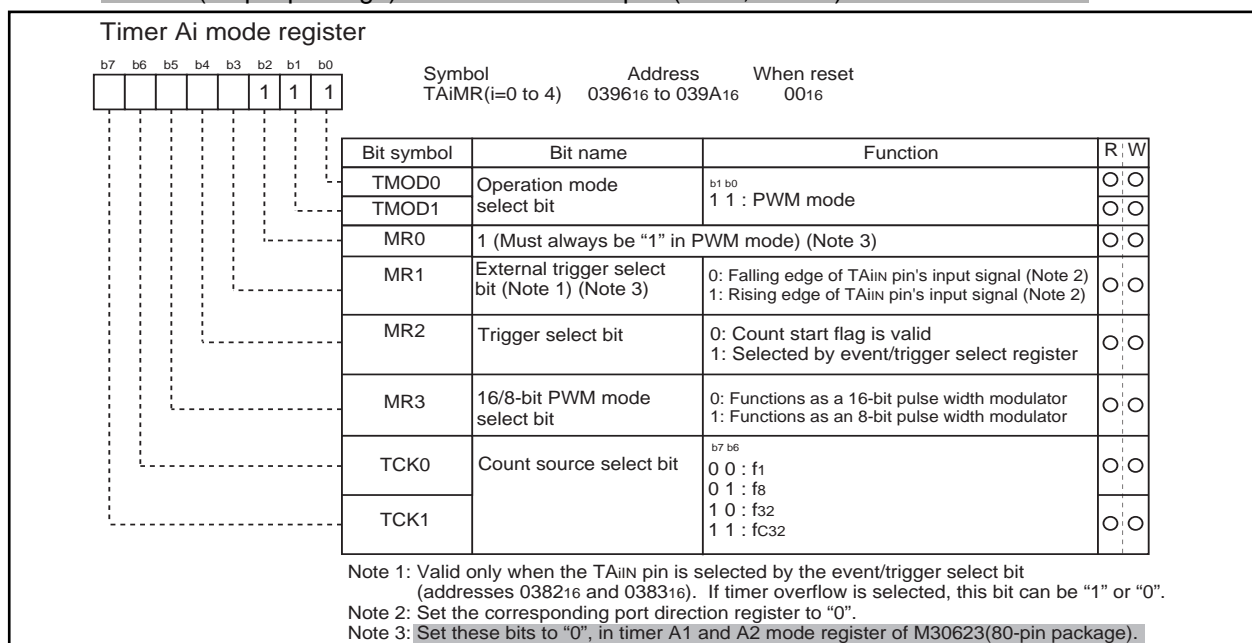


Figure 1.17.11. Timer Ai mode register in pulse width modulation mode

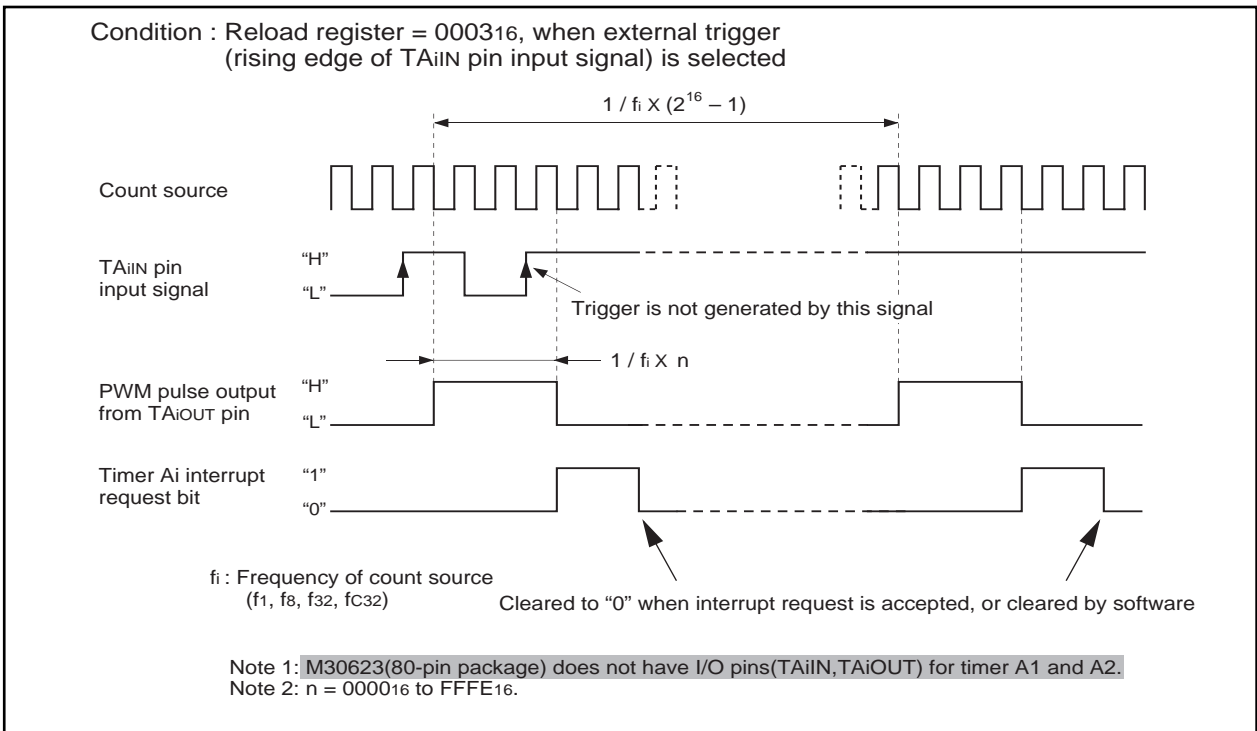


Figure 1.17.12. Example of how a 16-bit pulse width modulator operates

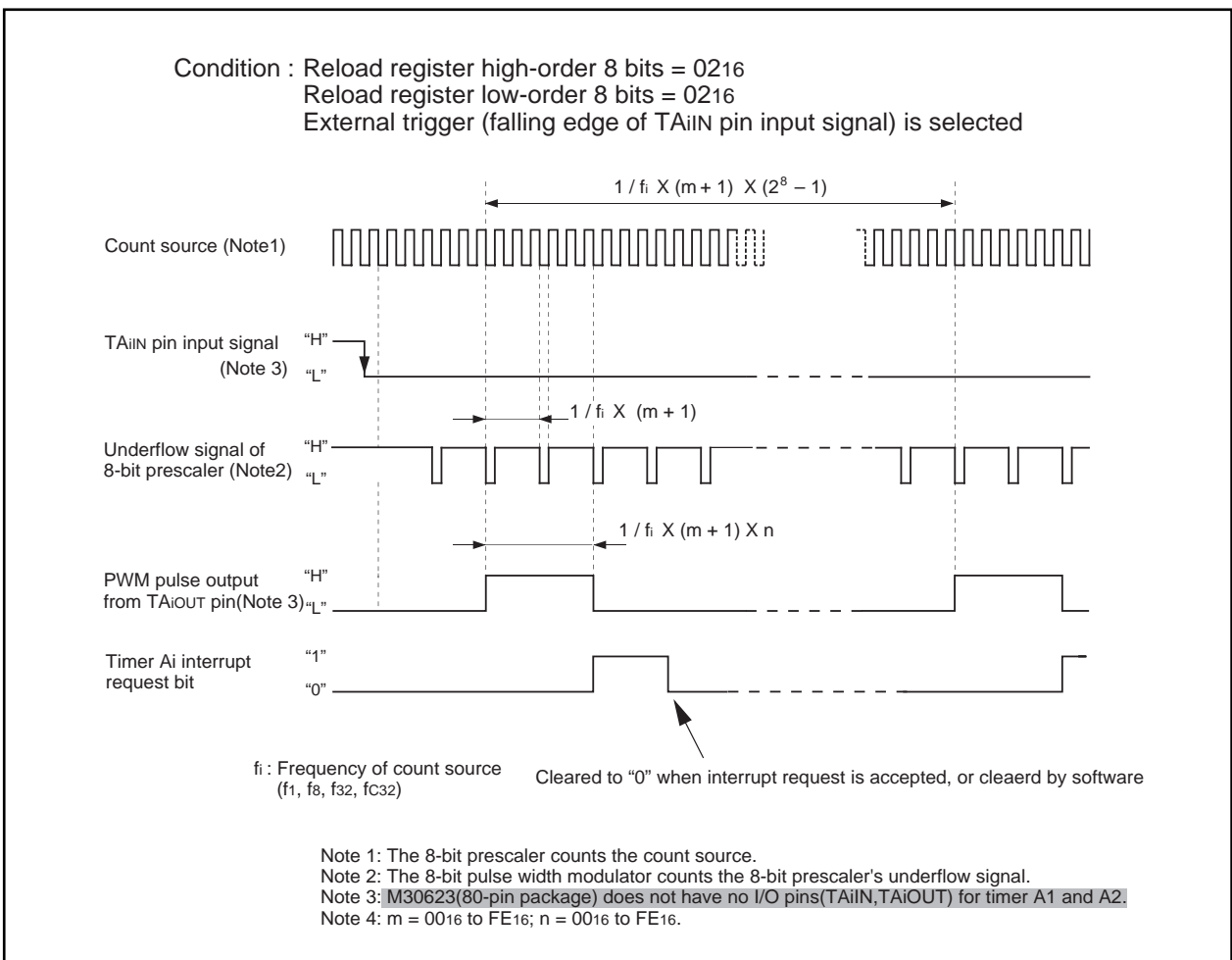


Figure 1.17.13. Example of how an 8-bit pulse width modulator operates

Timer B

Timer B

Figure 1.17.14 shows the block diagram of timer B. Figures 1.17.15 and 1.17.16 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.

But, M30623(80-pin package), timer B1 has no input pin, so funcns as the internal timer.

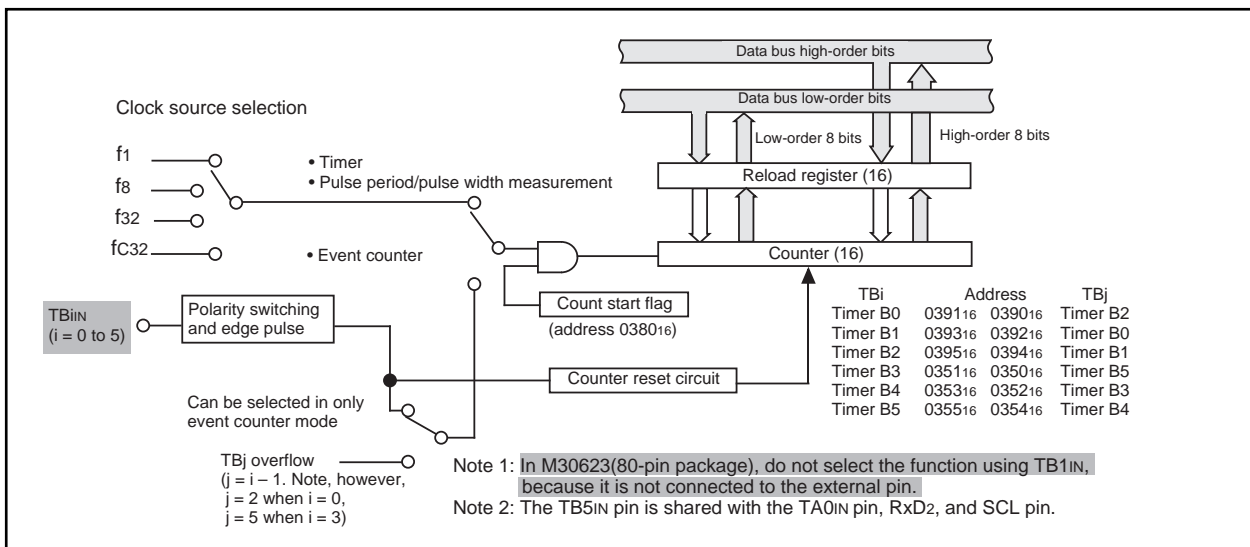


Figure 1.17.14. Block diagram of timer B

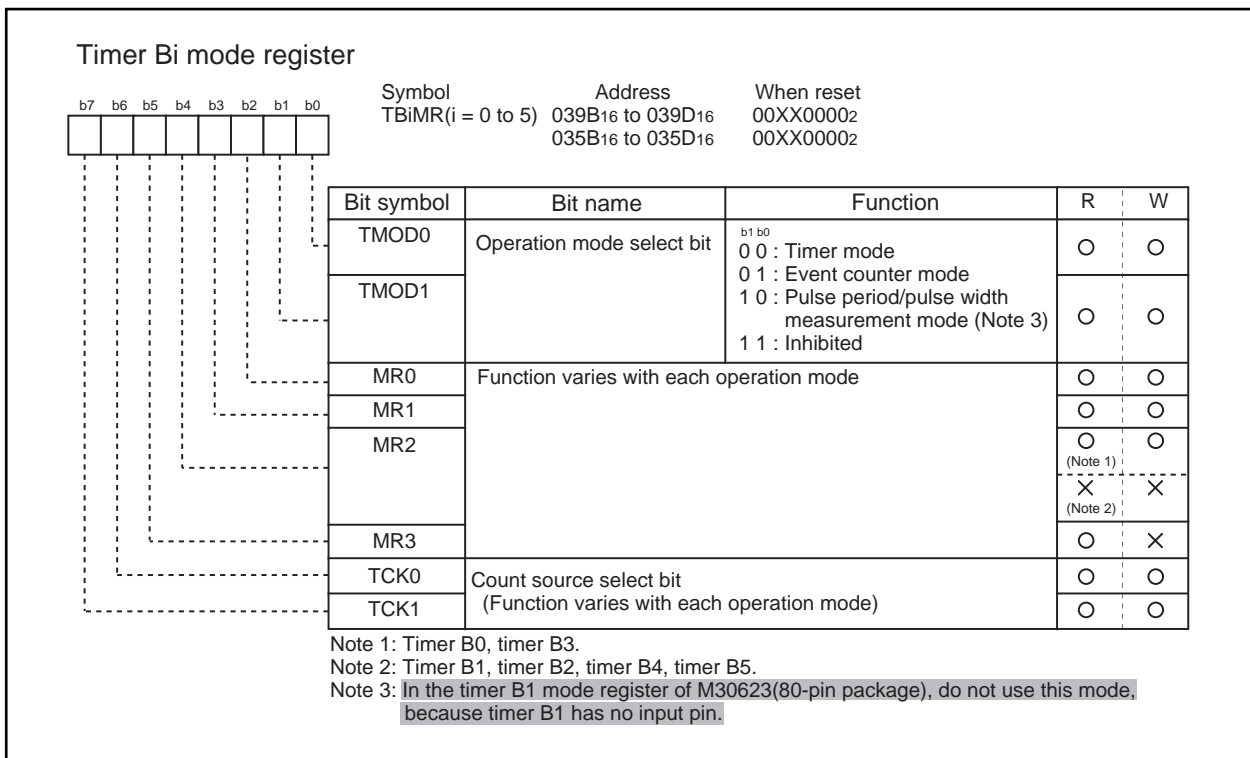


Figure 1.17.15. Timer B-related registers (1)

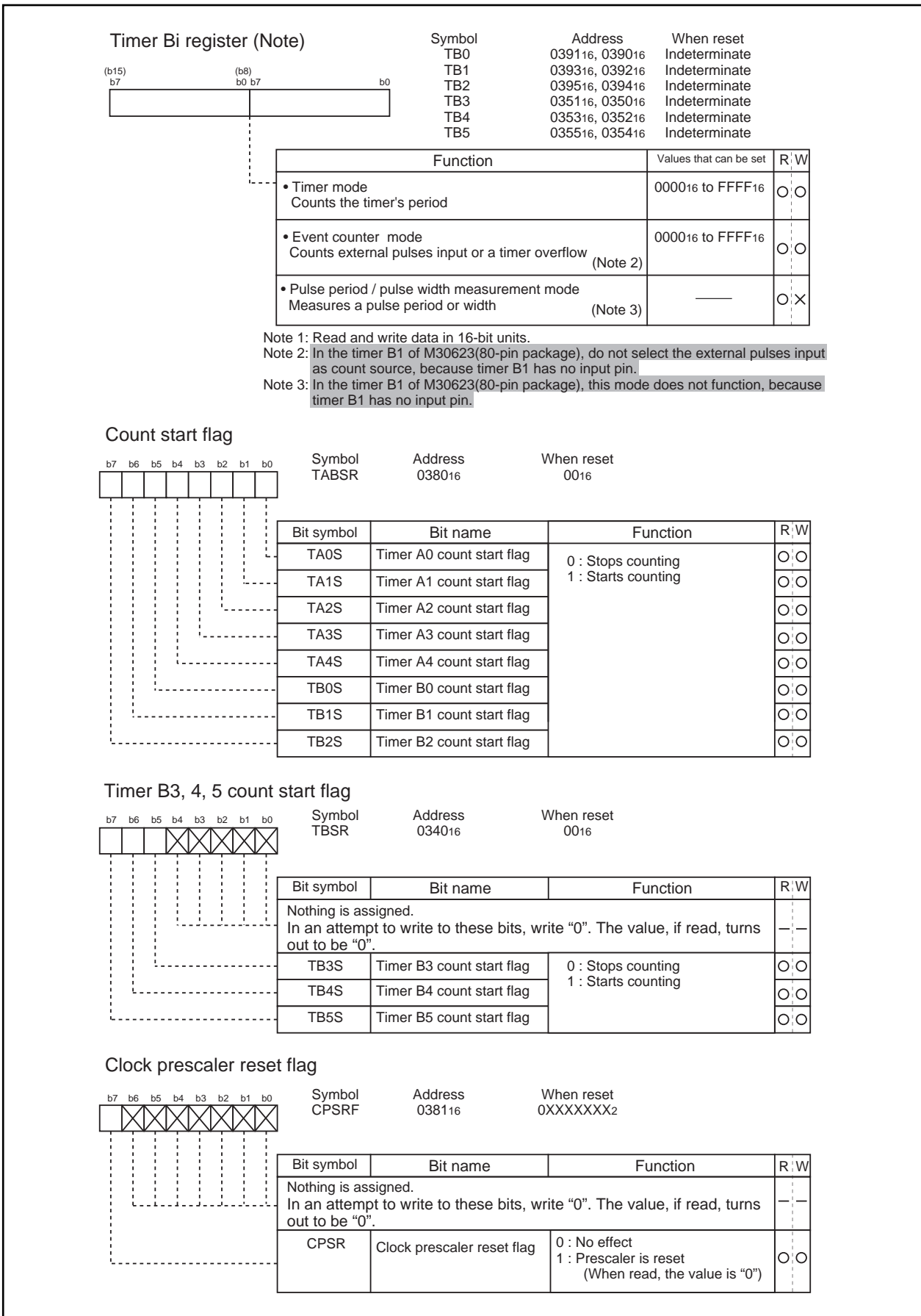


Figure 1.17.16. Timer B-related registers (2)

(1) Timer mode

In this mode, the timer counts an internally generated count source. (See Table 1.17.6.) Figure 1.17.17 shows the timer Bi mode register in timer mode.

Table 1.17.6. Timer specifications in timer mode

Item	Specification
Count source	f1, f8, f32, fc32
Count operation	<ul style="list-style-type: none"> Counts down When the timer underflows, it reloads the reload register contents before continuing counting
Divide ratio	1/(n+1) n : Set value
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	The timer underflows
TBiIN pin function	Programmable I/O port
Read from timer	Count value is read out by reading timer Bi register
Write to timer	<ul style="list-style-type: none"> 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)

Note 1: M30623(80-pin package) does not have the input pin(TB1IN) of timer B1.

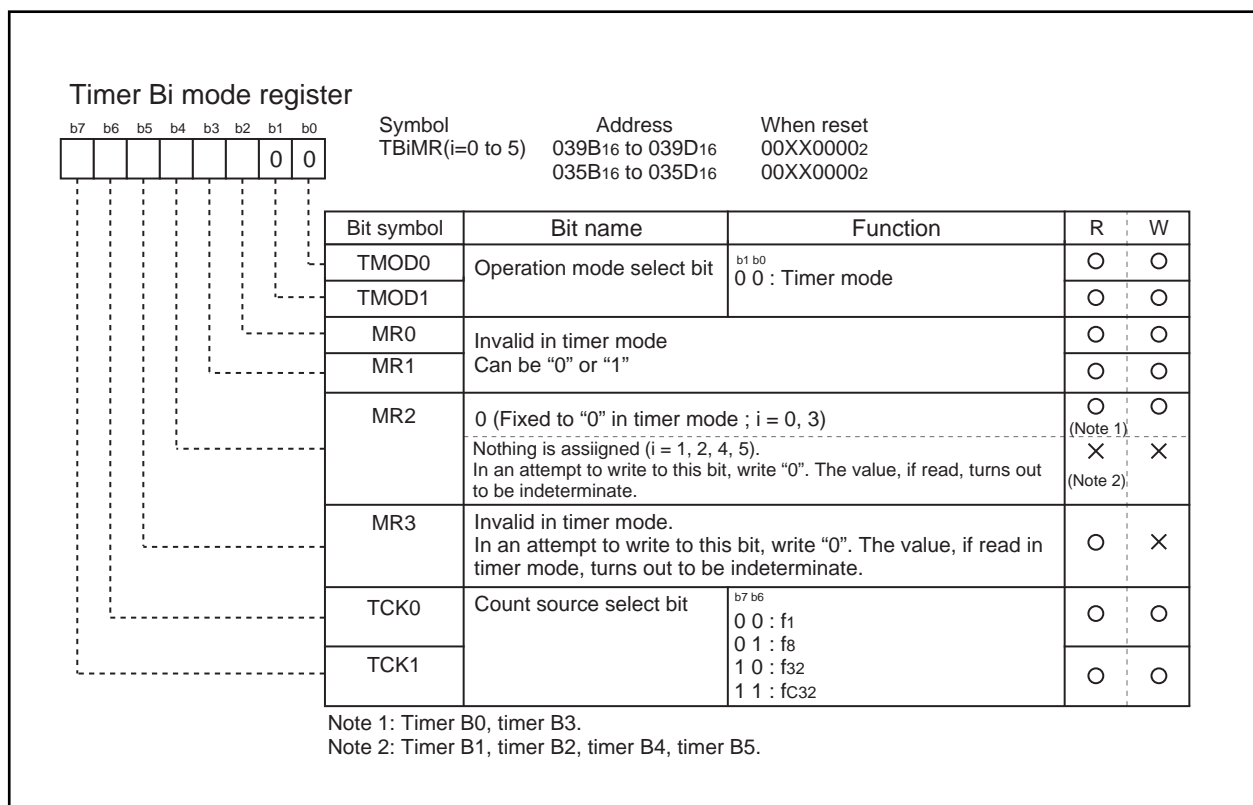


Figure 1.17.17. Timer Bi mode register in timer mode

(2) Event counter mode

In this mode, the timer counts an external signal or an internal timer's overflow. (See Table 1.17.7.)
Figure 1.17.18 shows the timer Bi mode register in event counter mode.

Table 1.17.7. Timer specifications in event counter mode

Item	Specification
Count source	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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)

Note 1: M30623(80-pin package) does not have the input pin(TB1IN) of timer B1.

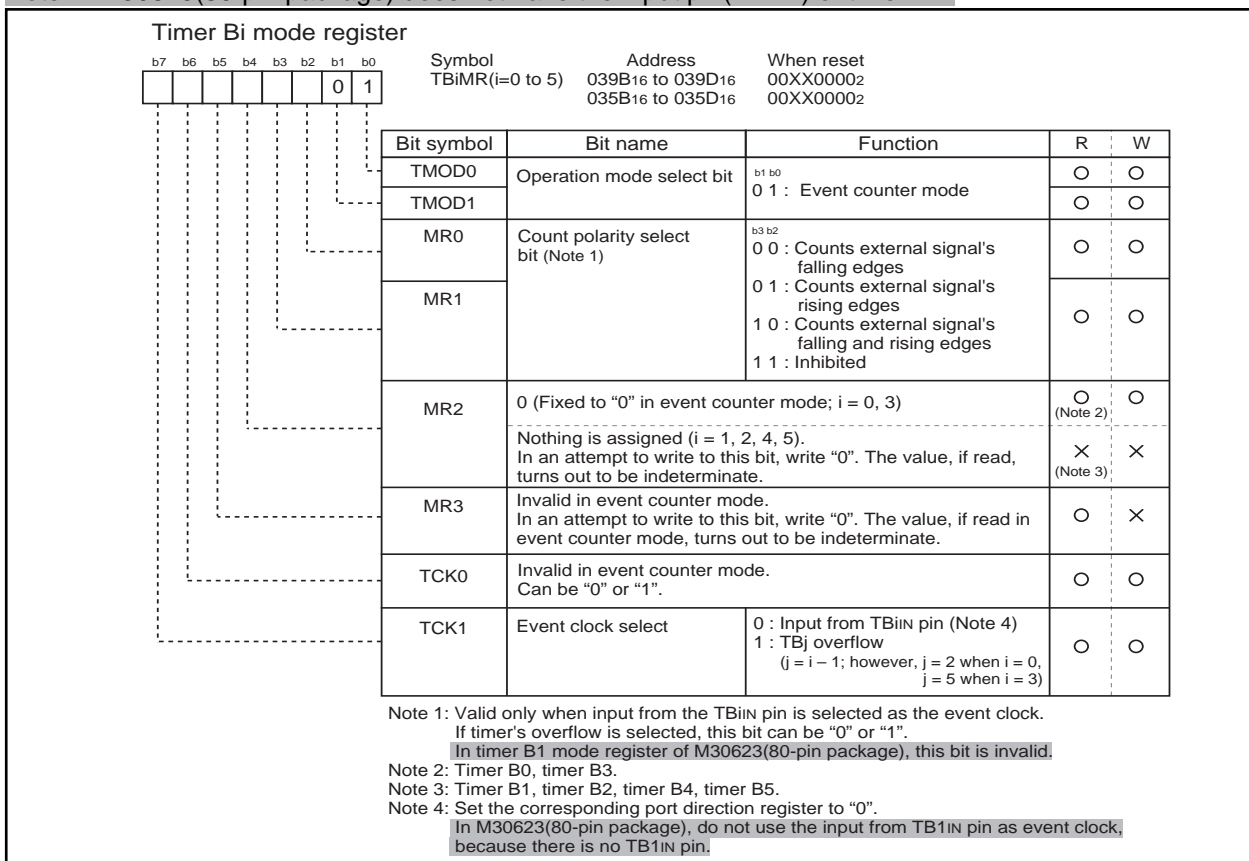


Figure 1.17.18. Timer Bi mode register in event counter mode

(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 1.17.8.) M30623(80-pin package), timer B1 has no input pin, so can not use this function.

Figure 1.17.19 shows the timer Bi mode register in pulse period/pulse width measurement mode. Figure 1.17.20 shows the operation timing when measuring a pulse period. Figure 1.17.21 shows the operation timing when measuring a pulse width

Table 1.17.8. Timer specifications in pulse period/pulse width measurement mode

Item	Specification
Count source	f1, f8, f32, fc32
Count operation	<ul style="list-style-type: none"> Up count Counter value "0000₁₆" is transferred to reload register at measurement pulse's effective edge and the timer continues counting
Count start condition	Count start flag is set (= 1)
Count stop condition	Count start flag is reset (= 0)
Interrupt request generation timing	<ul style="list-style-type: none"> When measurement pulse's effective edge is input (Note 1) When an overflow occurs. (Simultaneously, the timer Bi overflow flag changes to "1". The timer Bi overflow flag changes to "0" when the count start flag is "1" and a value is written to the timer Bi mode register.)
TBiIN pin function	Measurement pulse input
Read from timer	When timer Bi register is read, it indicates the reload register's content (measurement result) (Note 2)
Write to timer	Cannot be written to

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

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

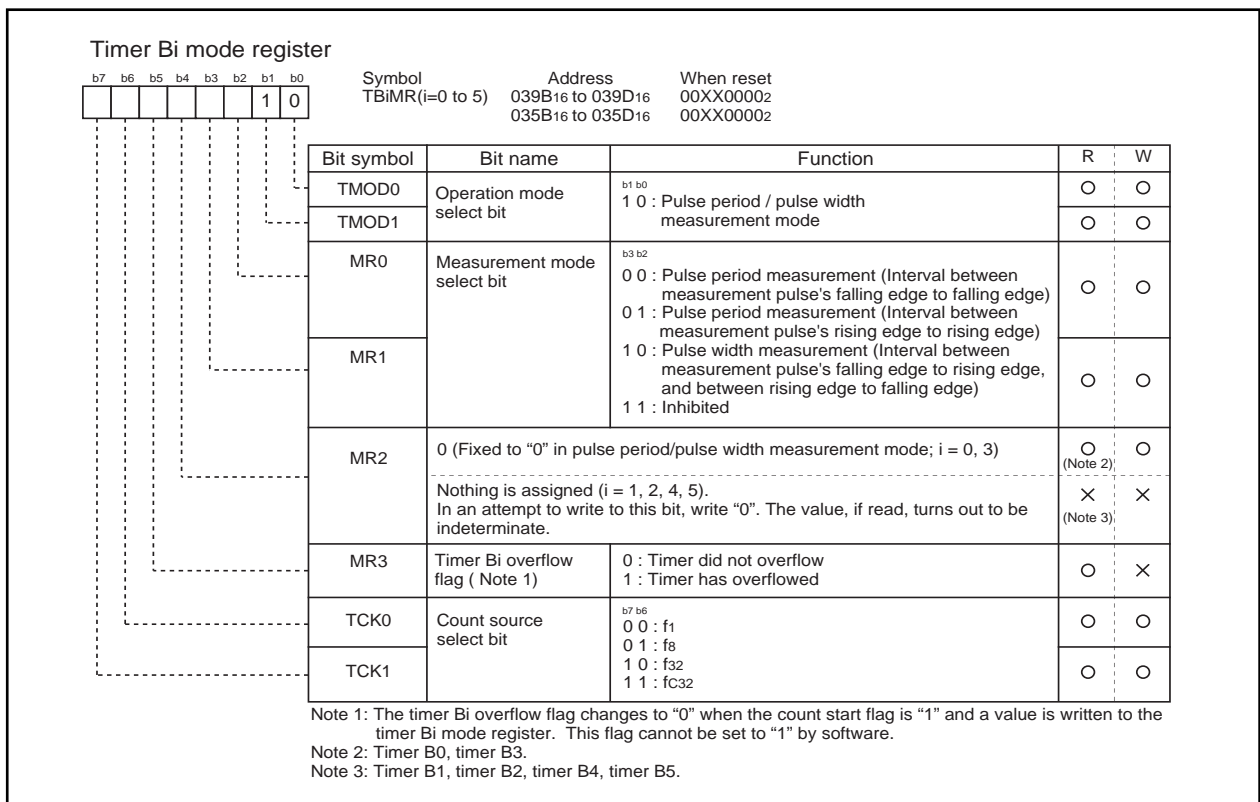


Figure 1.17.19. Timer Bi mode register in pulse period/pulse width measurement mode

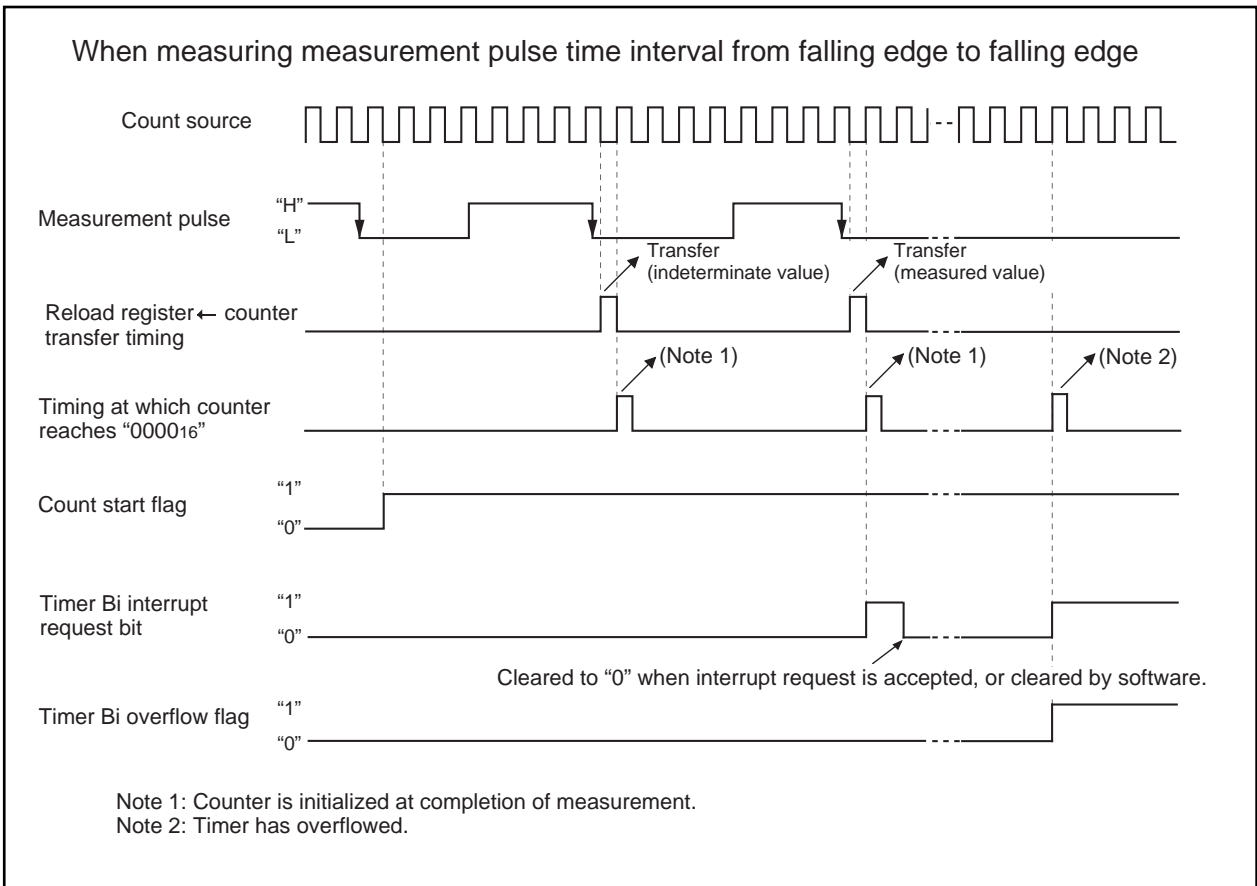


Figure 1.17.20. Operation timing when measuring a pulse period

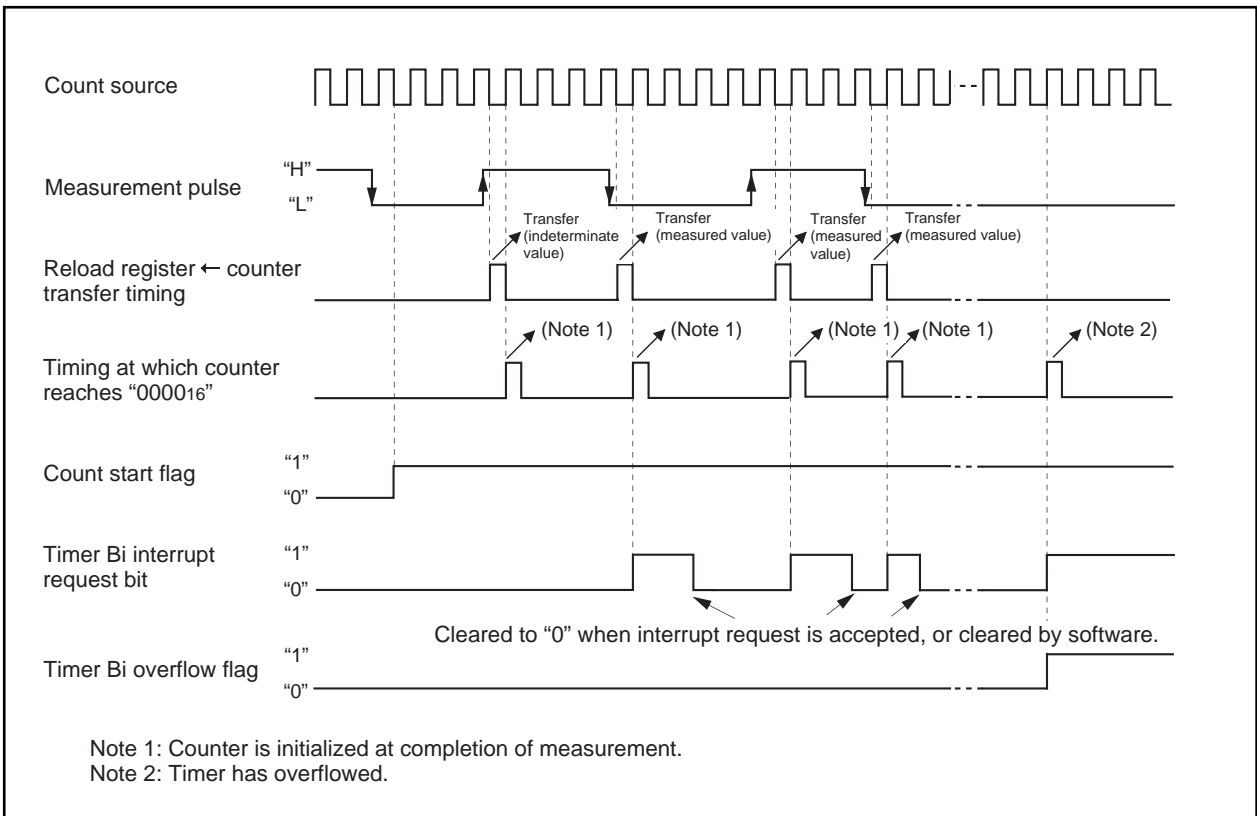


Figure 1.17.21. Operation timing when measuring a pulse width

Timers' functions for three-phase motor control

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

In M30623(80-pin package), the pins V, \bar{V} , W, and \bar{W} for three-phase motor control have no corresponding external pin. So, do not use this function.

Figures 1.18.1 to 1.18.3 show registers related to timers for three-phase motor control.

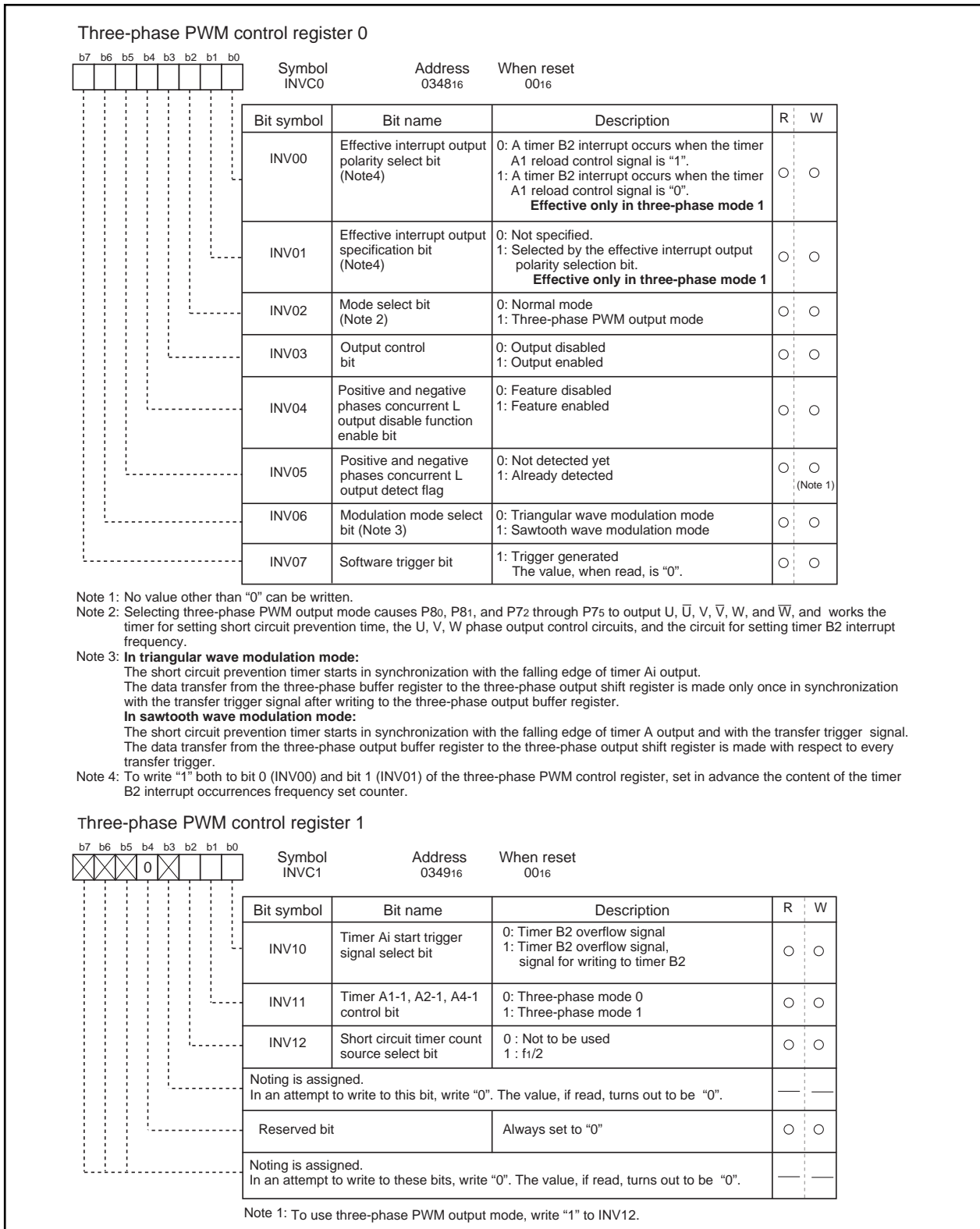


Figure1.18.1. Registers related to timers for three-phase motor control

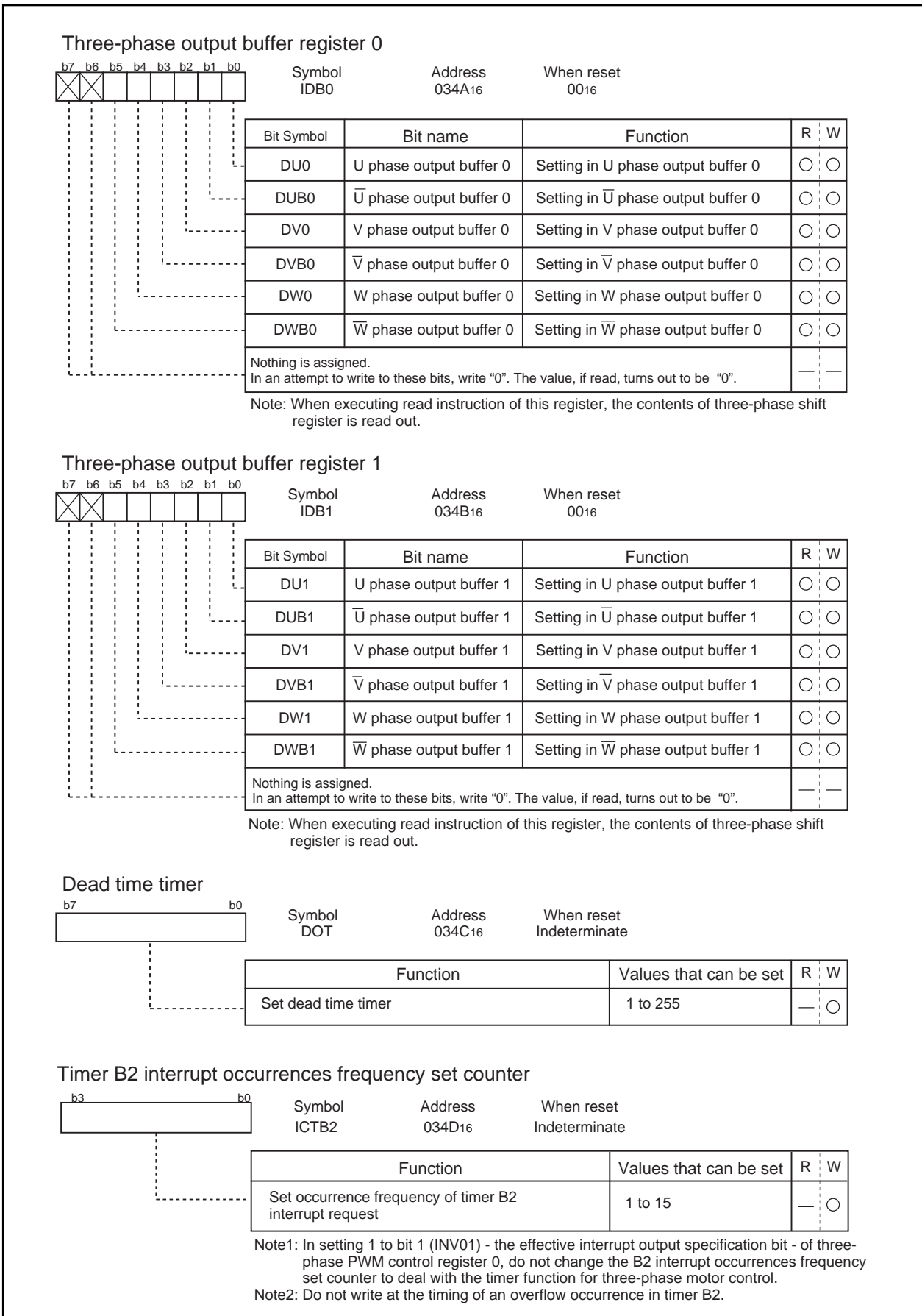


Figure 1.18.2. Registers related to timers for three-phase motor control

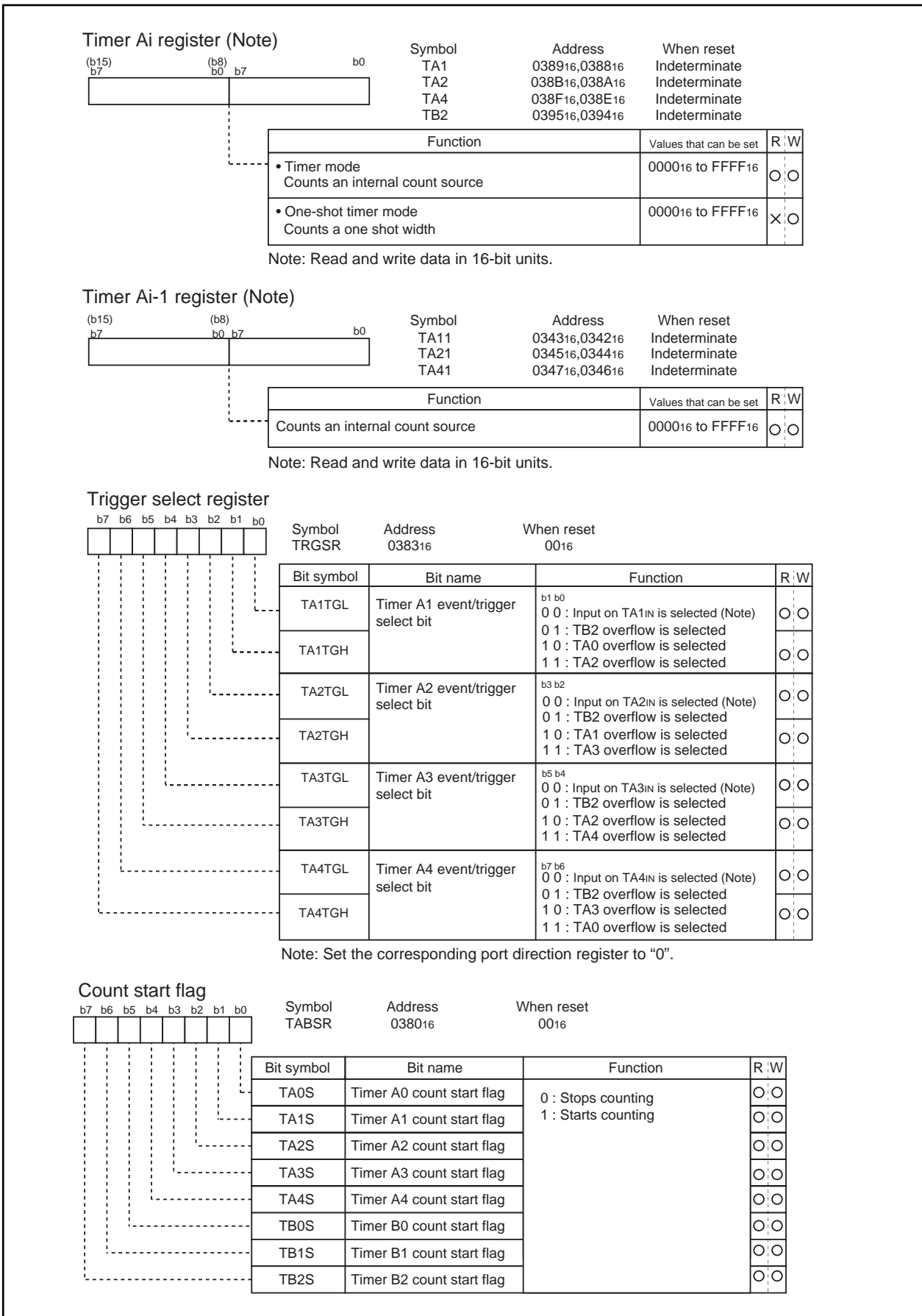


Figure 1.18.3. Registers related to timers for three-phase motor control

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

Setting "1" in the mode select bit (bit 2 at 034816) shown in Figure 1.18.1 - causes three-phase waveform mode that uses four timers A1, A2, A4, and B2 to be selected. As shown in Figure 1.18.4, set timers A1, A2, and A4 in one-shot timer mode, set the trigger in timer B2, and set timer B2 in timer mode using the respective timer mode registers.

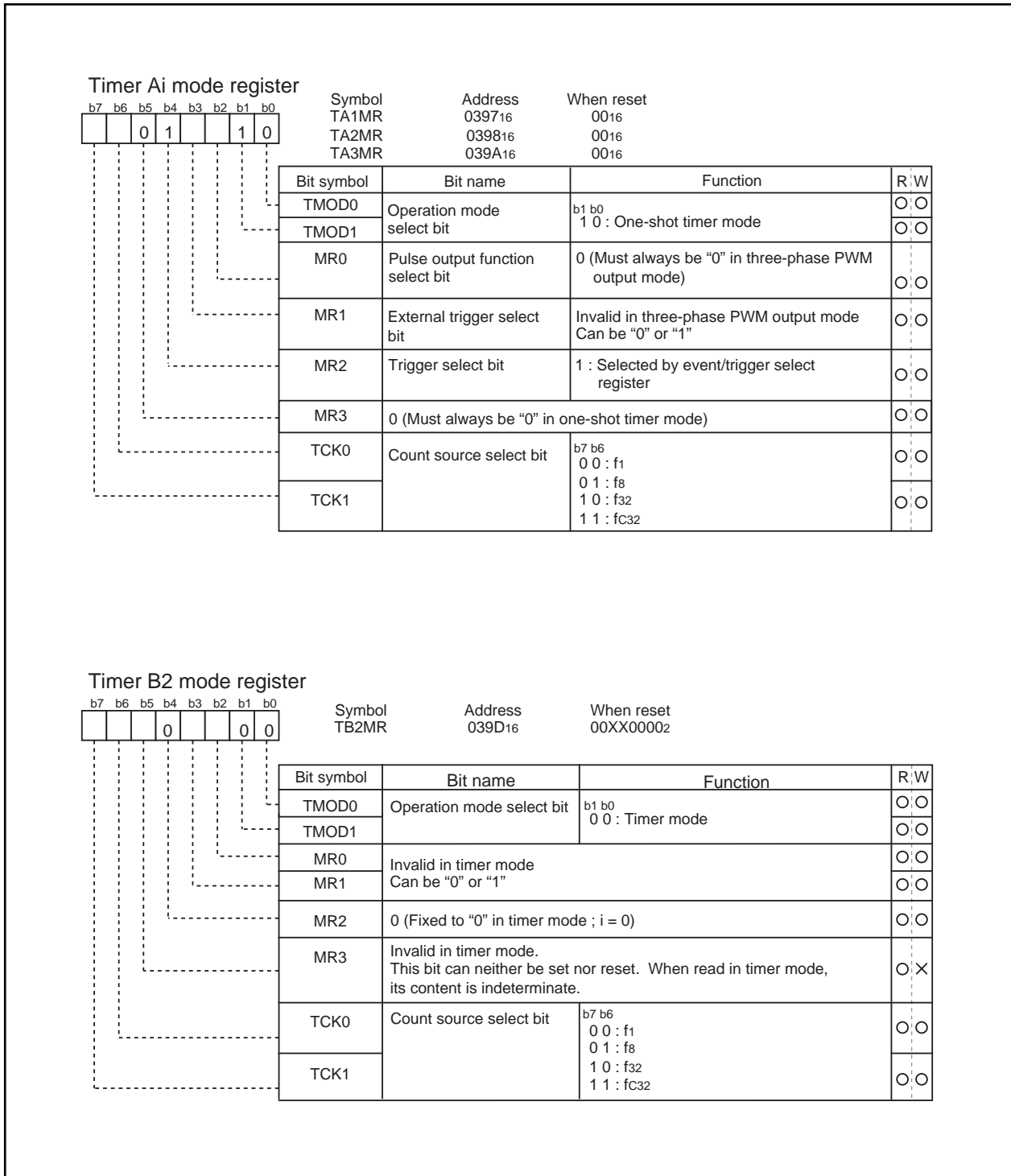


Figure 1.18.4. Timer mode registers in three-phase waveform mode

Figure 1.18.5 shows the block diagram for three-phase waveform mode. In three-phase waveform mode, the positive-phase waveforms (U phase, V phase, and W phase) and negative waveforms (\bar{U} phase, \bar{V} phase, and \bar{W} phase), six waveforms in total, are output from P80, P81, P72, P73, P74, and P75 as active on the "L" level. Of the timers used in this mode, timer A4 controls the U phase and \bar{U} phase, timer A1 controls the V phase and \bar{V} phase, and timer A2 controls the W phase and \bar{W} phase respectively; timer B2 controls the periods of one-shot pulse output from timers A4, A1, and A2.

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

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

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

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

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

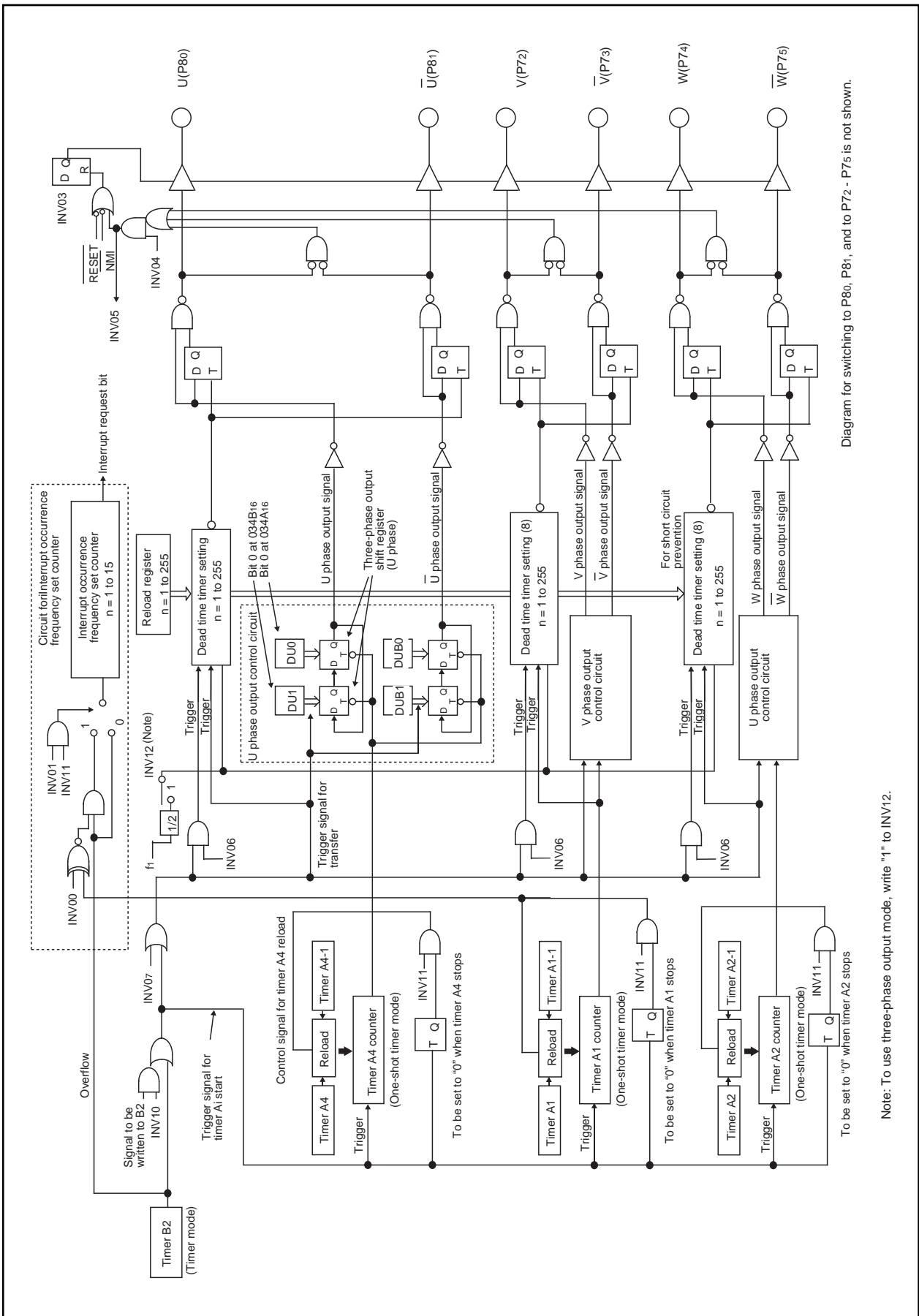


Diagram for switching to P80, P81, and to P72 - P75 is not shown.

Note: To use three-phase output mode, write "1" to INV12.

Figure 1.18.5. Block diagram for three-phase waveform mode

Triangular wave modulation

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

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

An example of U phase waveform is shown in Figure 1.18.6, and the description of waveform output workings is given below. Set "1" in DU0 (bit 0 at 034A₁₆). And set "0" in DUB0 (bit 1 at 034A₁₆). In addition, set "0" in DU1 (bit 0 at 034B₁₆) and set "1" in DUB1 (bit 1 at 034B₁₆). Also, set "0" in the effective interrupt output specification bit (bit 1 at 0348₁₆) to set a value in the timer B2 interrupt occurrence frequency set counter. By this setting, a timer B2 interrupt occurs when the timer B2 counter's content becomes 0000₁₆ as many as (setting) times. Furthermore, set "1" in the effective interrupt output specification bit (bit 1 at 0348₁₆), set in the effective interrupt polarity select bit (bit 0 at 0348₁₆) and set "1" in the interrupt occurrence frequency set counter(034D₁₆). These settings cause a timer B2 interrupt to occur every other interval when the U phase output goes to "H".

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

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

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

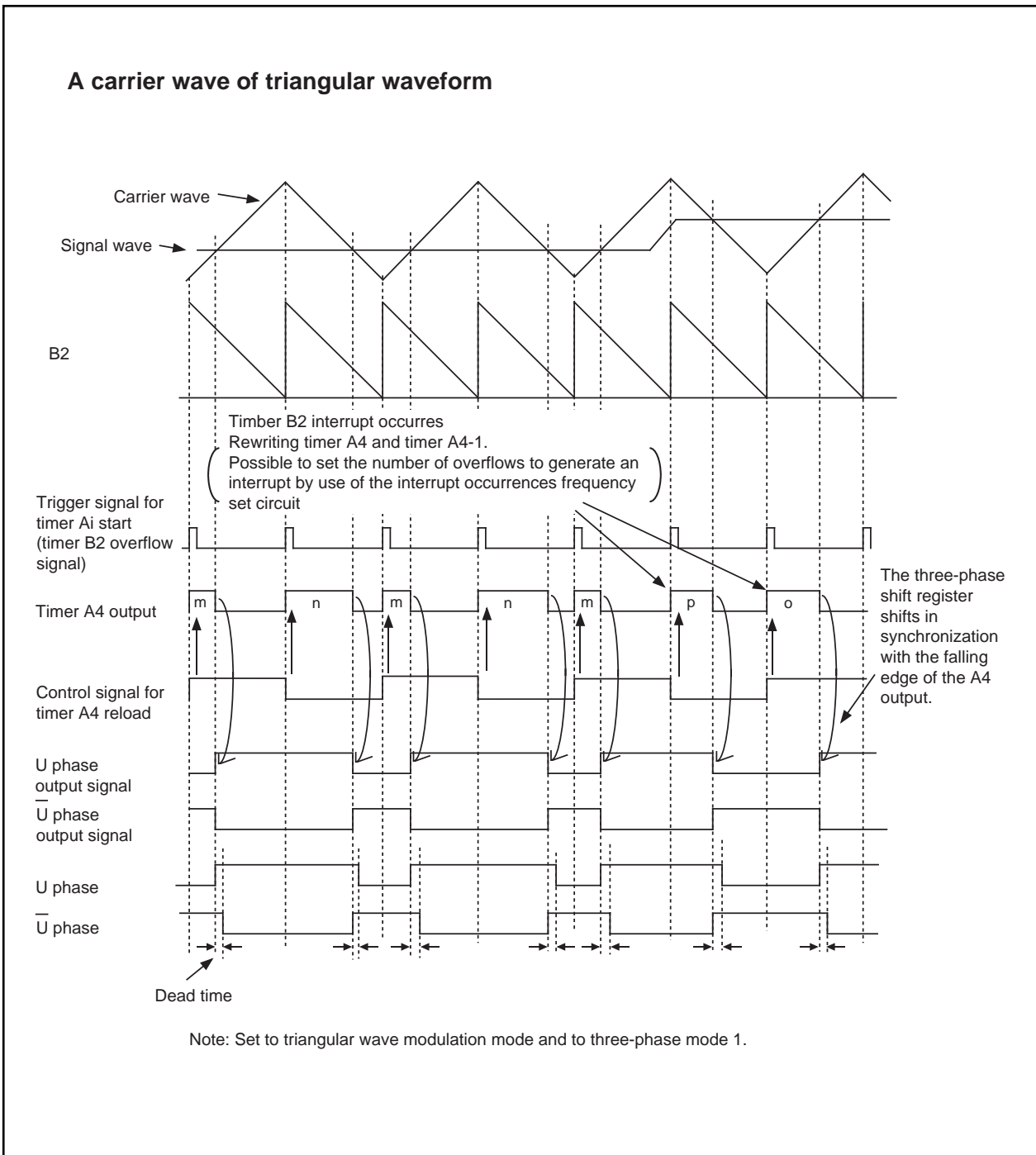


Figure 1.18.6. Timing chart of operation (1)

Assigning certain values to DU0 (bit 0 at 034A16) and DUB0 (bit 1 at 034A16), and to DU1 (bit 0 at 034B16) and DUB1 (bit 1 at 034B16) allows the user to output the waveforms as shown in Figure 1.18.7, that is, to output the U phase alone, to fix \bar{U} phase to "H", to fix the U phase to "H," or to output the \bar{U} phase alone.

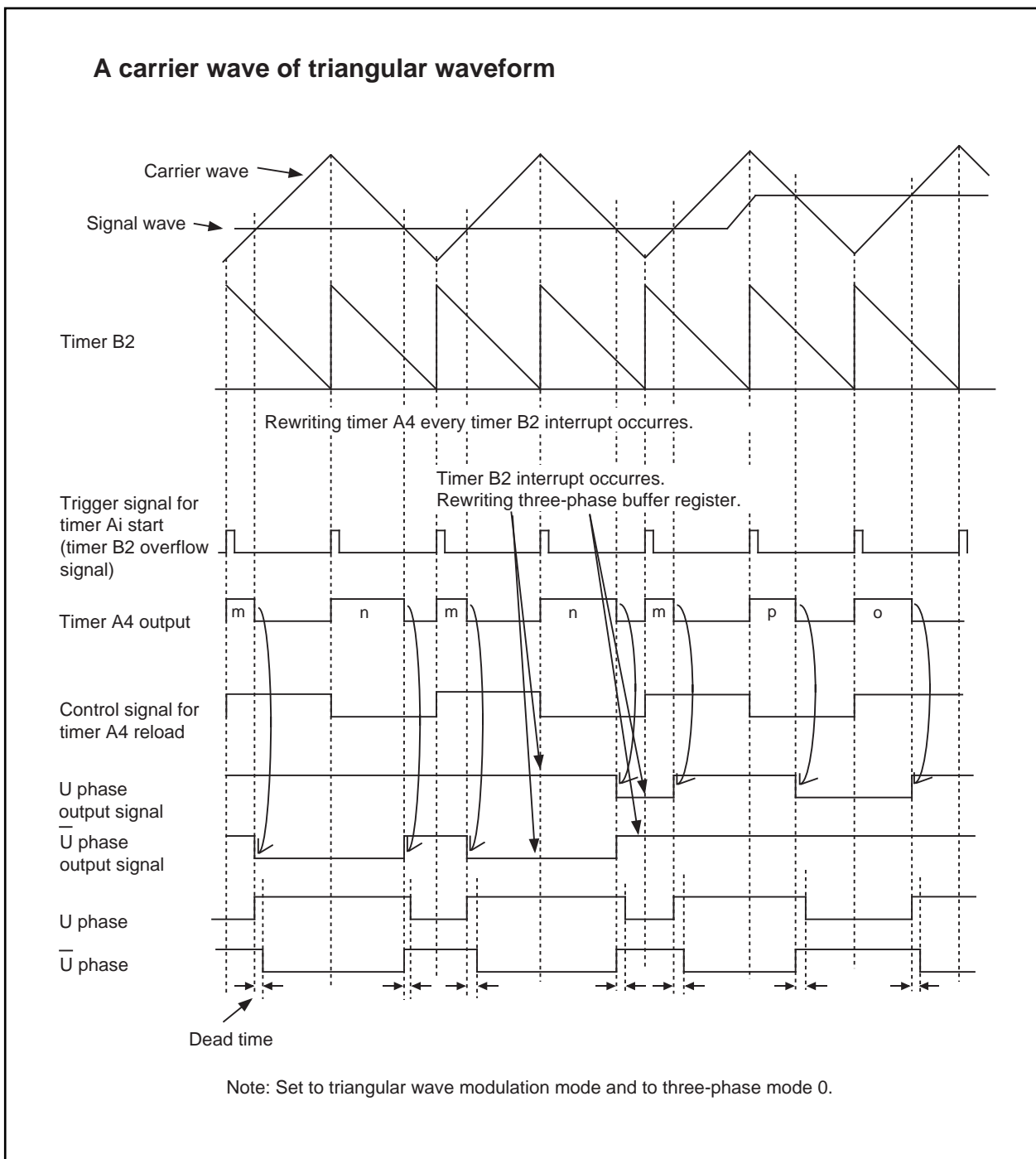


Figure 1.18.7. Timing chart of operation (2)

Sawtooth modulation

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

An example of U phase waveform is shown in Figure 75, and the description of waveform output workings is given below. Set "1" in DU0 (bit 0 at 034A₁₆), and set "0" in DUB0 (bit 1 at 034A₁₆). In addition, set "0" in DU1 (bit 0 at 034A₁₆) and set "1" in DUB1 (bit 1 at 034A₁₆).

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

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

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

Setting "1" both in DUB0 and in DUB1 provides a means to output the U phase alone and to fix the \bar{U} phase output to "H" as shown in Figure 1.18.8.

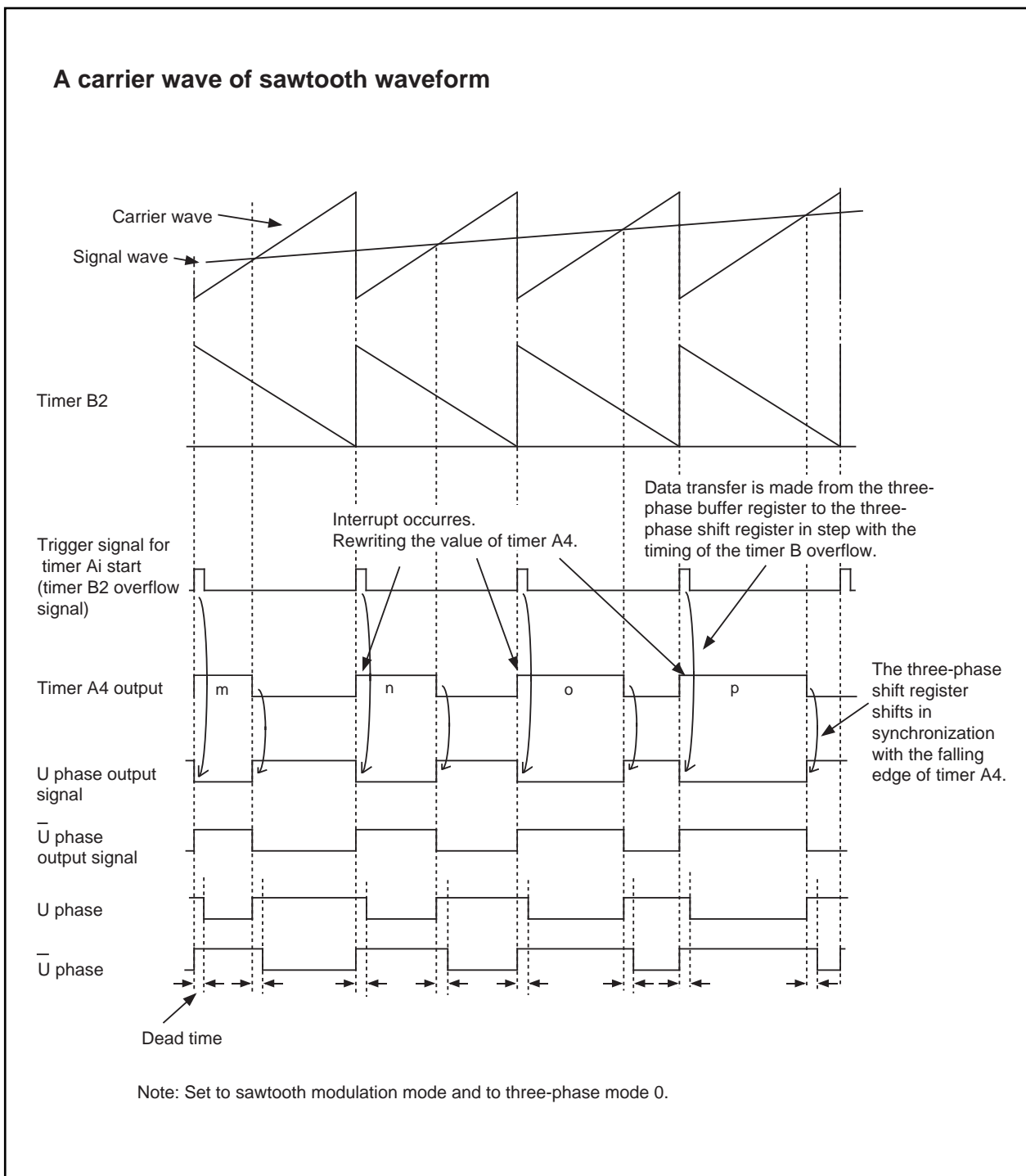


Figure 1.18.8. Timing chart of operation (3)

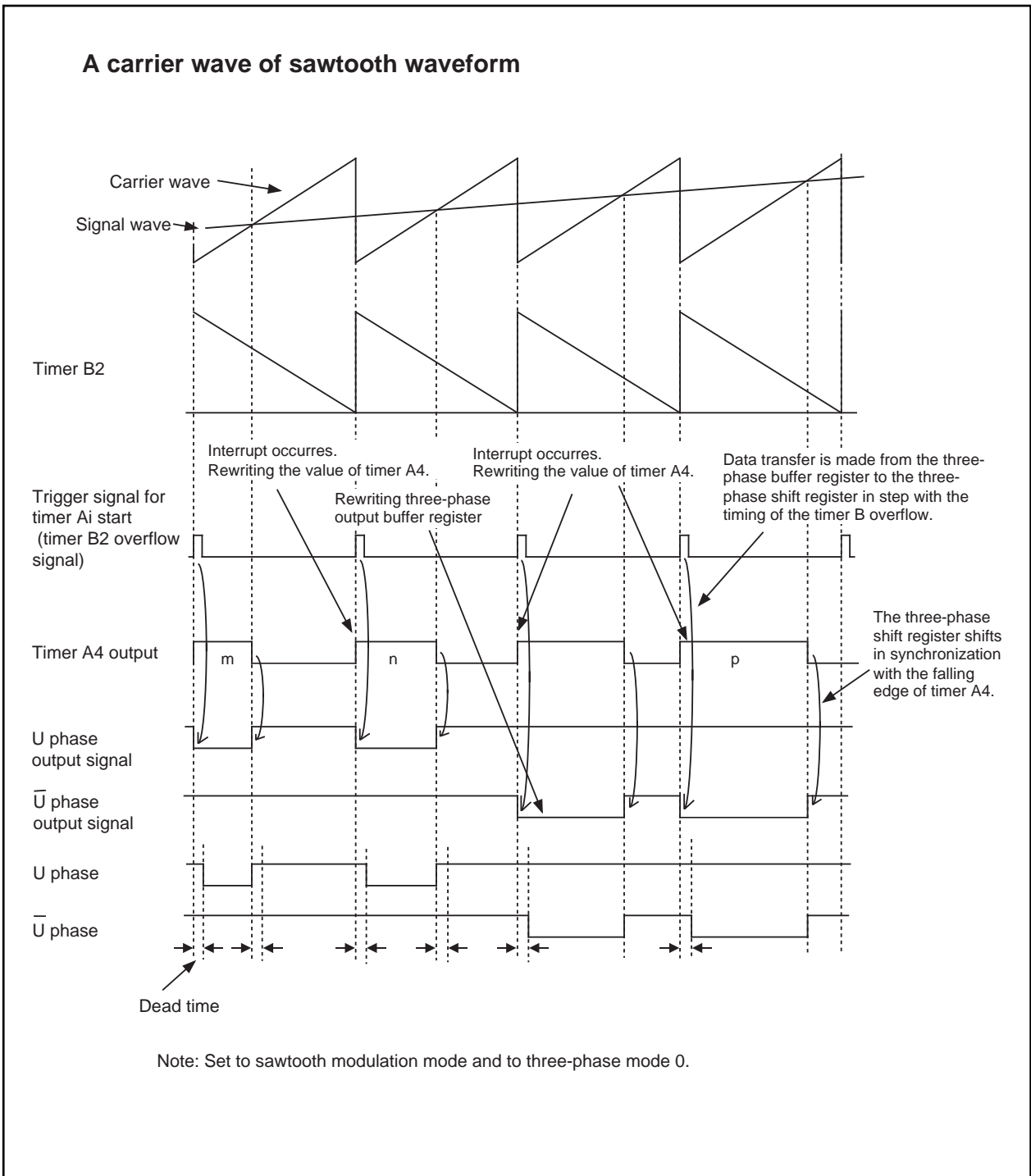


Figure 1.18.9. Timing chart of operation (4)

Serial I/O

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

UART0 to 2

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

Figure 1.19.1 shows the block diagram of UART0, UART1 and UART2. Figures 1.19.2 and 1.19.3 show the block diagram of the transmit/receive unit.

UART_i (i = 0 to 2) has two operation modes: a clock synchronous serial I/O mode and a clock asynchronous serial I/O mode (UART mode). The contents of the serial I/O mode select bits (bits 0 to 2 at addresses 03A0₁₆, 03A8₁₆ and 0378₁₆) determine whether UART_i 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.

In M30623(80-pin package), UART2 has the clock-asynchronous serial I/O mode and IIC mode.

Table 1.19.1 shows the comparison of functions of UART0 through UART2, and Figures 1.19.4 to 1.19.8 show the registers related to UART_i.

Note: SIM : Subscriber Identity Module

Table 1.19.1. Comparison of functions of UART0 through UART2

Function	UART0	UART1	UART2	
			M30622 (100pin-package)	M30623 (80pin-package)
CLK polarity selection	Possible (Note 1)	Possible (Note 1)	Possible (Note 1)	Impossible (Note 5)
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 $\overline{\text{CTS}}$ /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 (Note 6)	
Parity error signal output	Impossible	Impossible	Possible (Note 4)	
Bus collision detection	Impossible	Impossible	Possible (Note 7)	

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.

Note 5: In M30623(80-pin package), do not use this function, because CLK₂ and $\overline{\text{CTS}}_2$ /RTS₂ have no external pin.

Note 6: Connect via pull-up resistor to VCC outside.

Note 7: Generally, it use in case of IE bus-emulation.

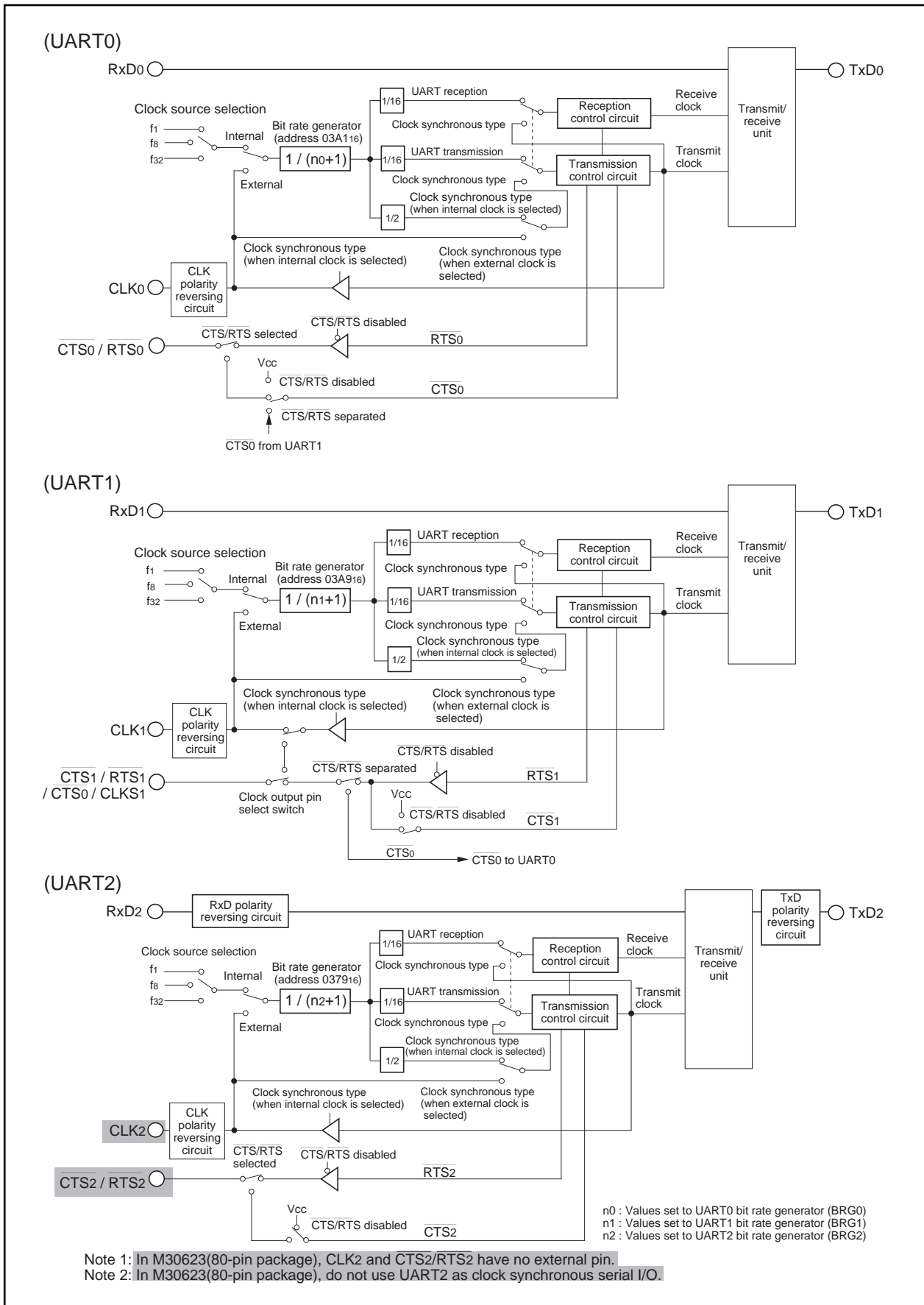


Figure 1.19.1. Block diagram of UARTi (i = 0 to 2)

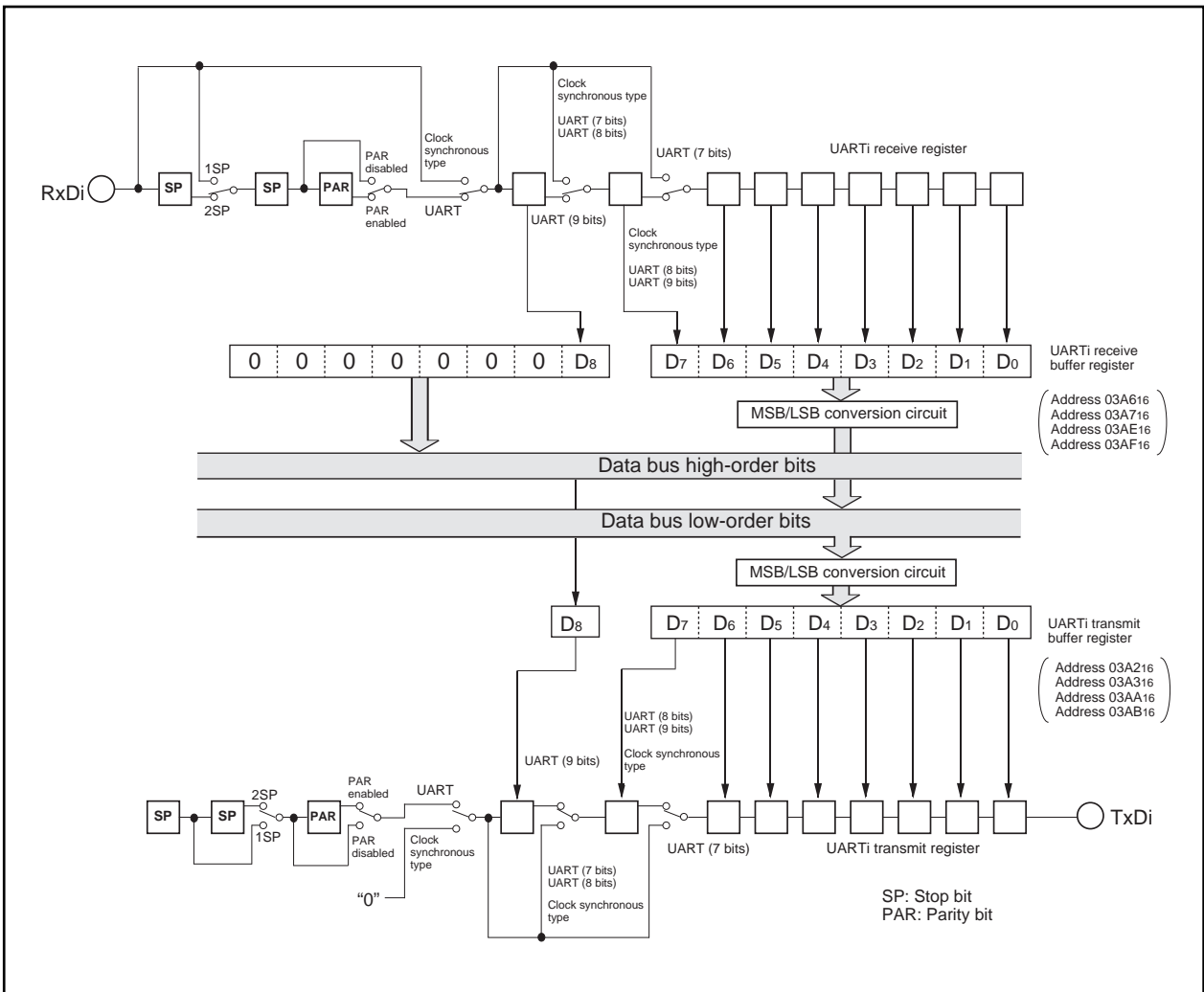


Figure 1.19.2. Block diagram of UARTi (i = 0, 1) transmit/receive unit

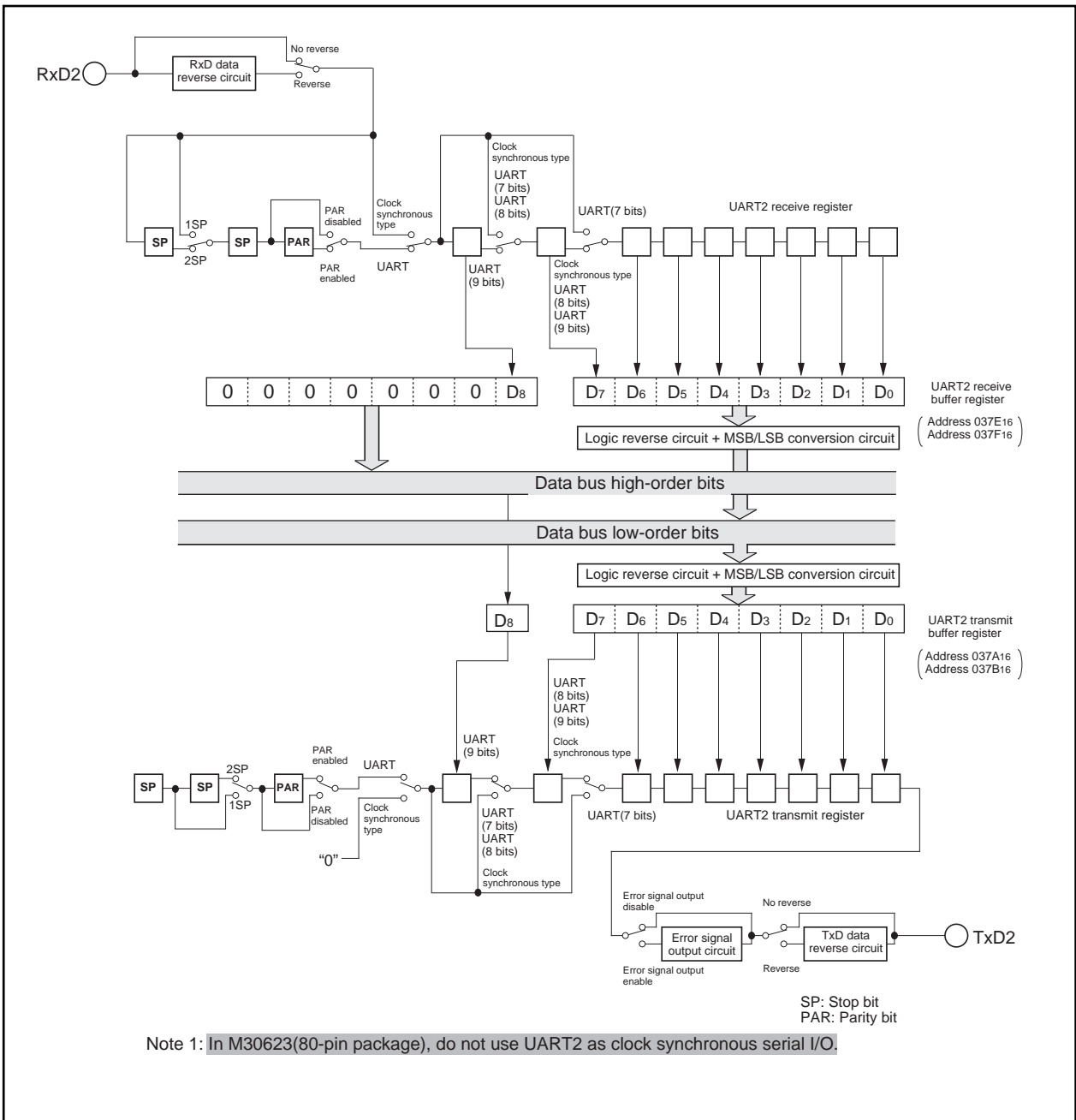


Figure 1.19.3. Block diagram of UART2 transmit/receive unit

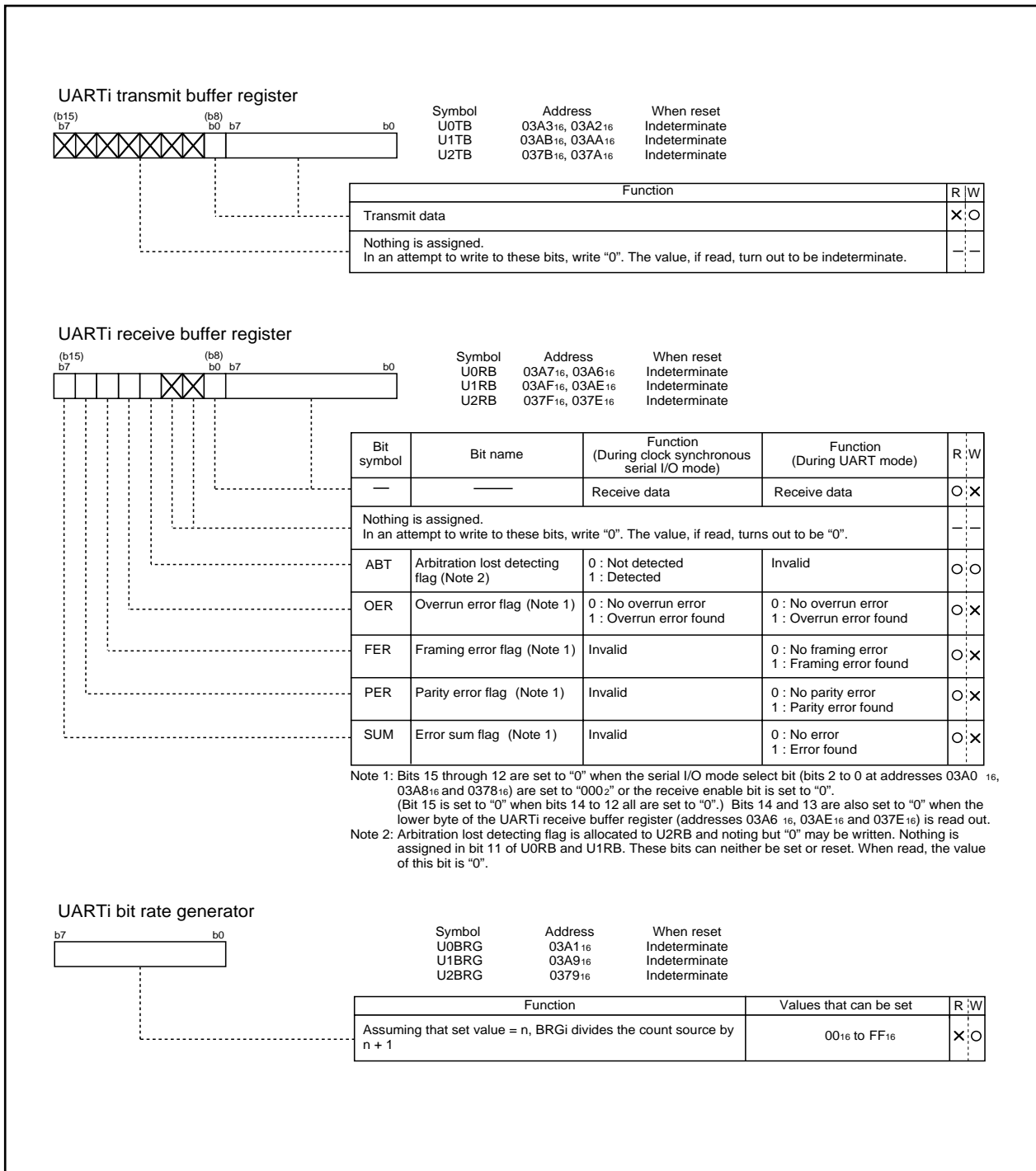


Figure 1.19.4. Serial I/O-related registers (1)

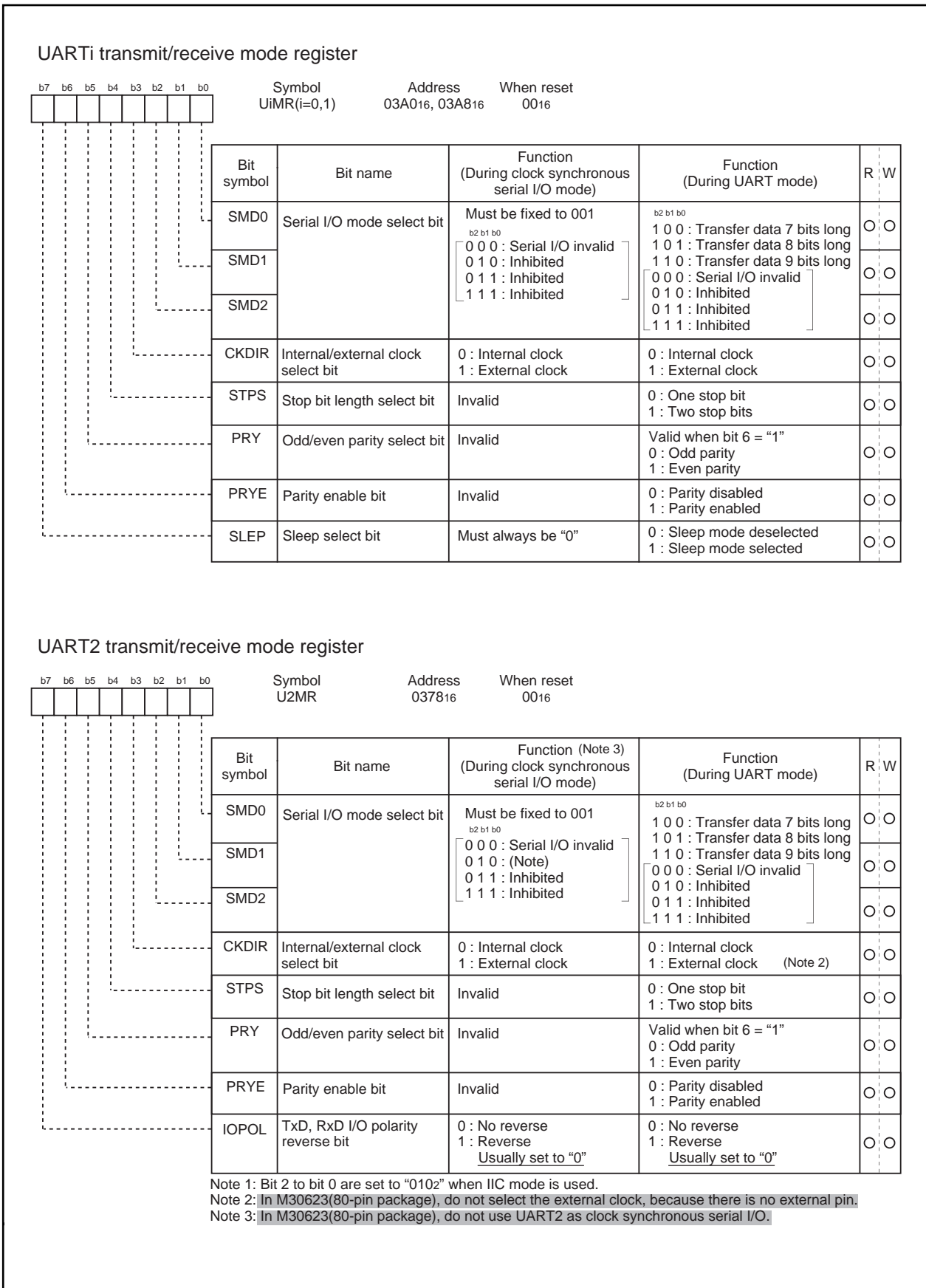


Figure 1.19.5. Serial I/O-related registers (2)

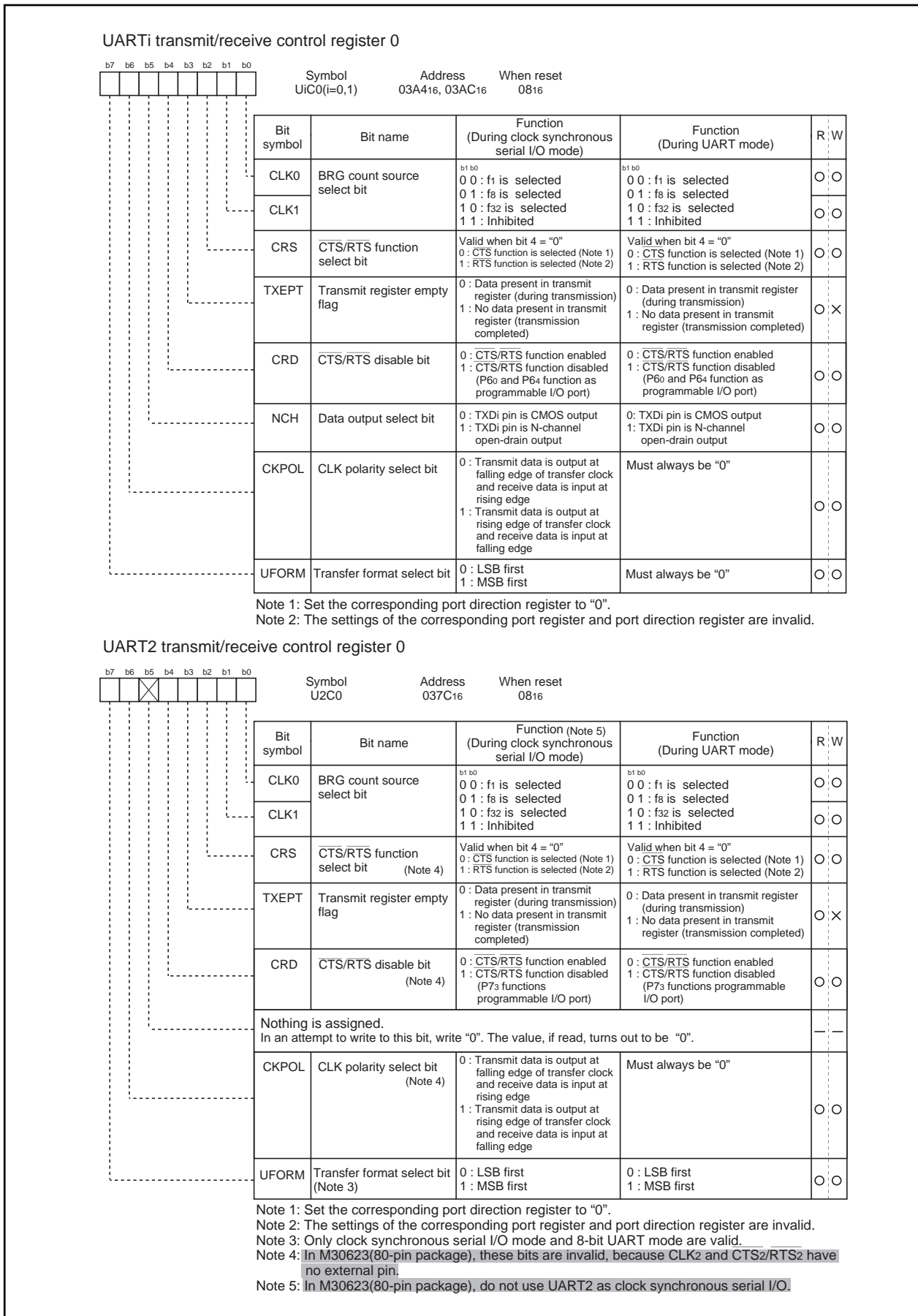


Figure 1.19.6. Serial I/O-related registers (3)

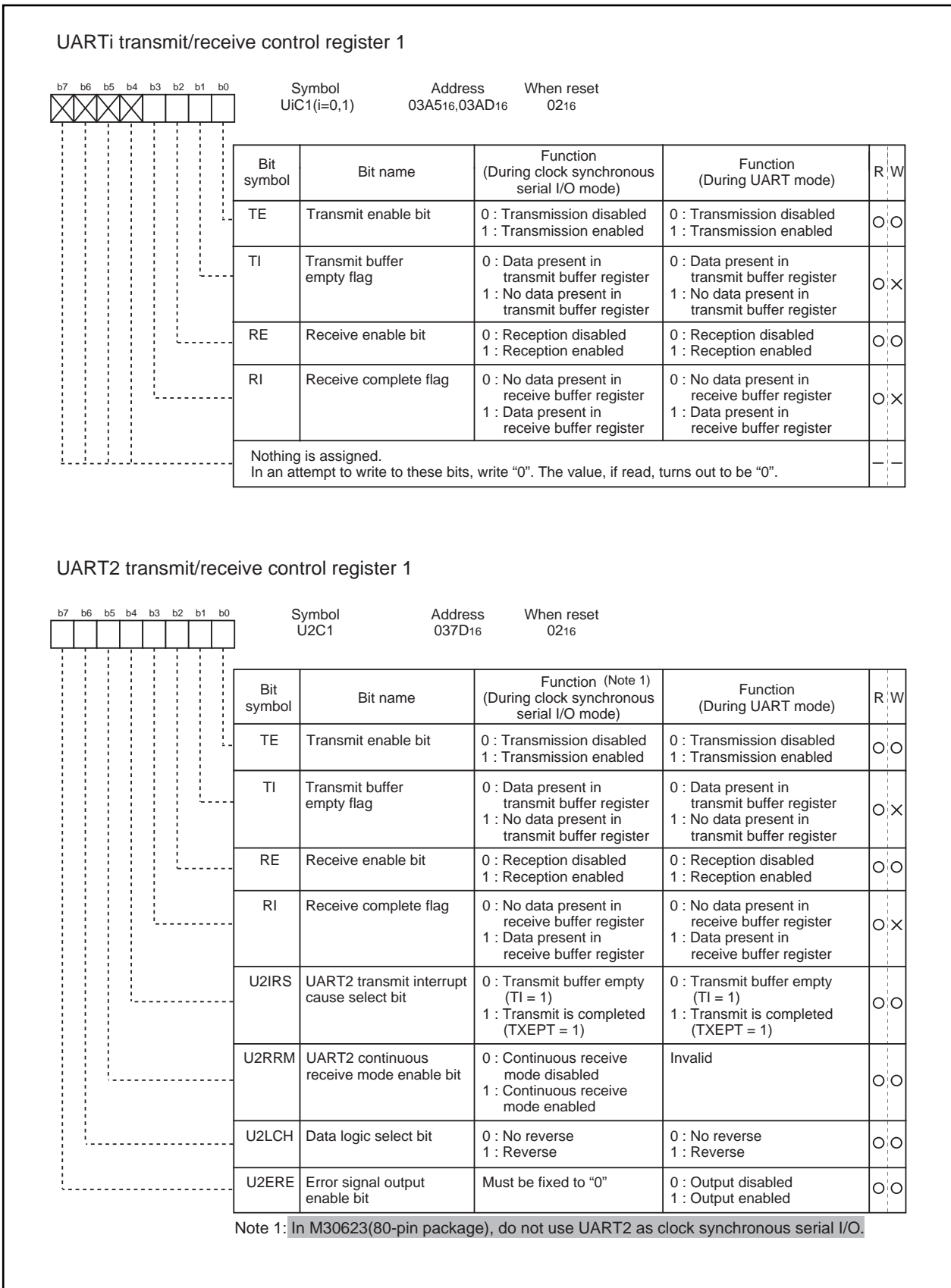


Figure 1.19.7. Serial I/O-related registers (4)

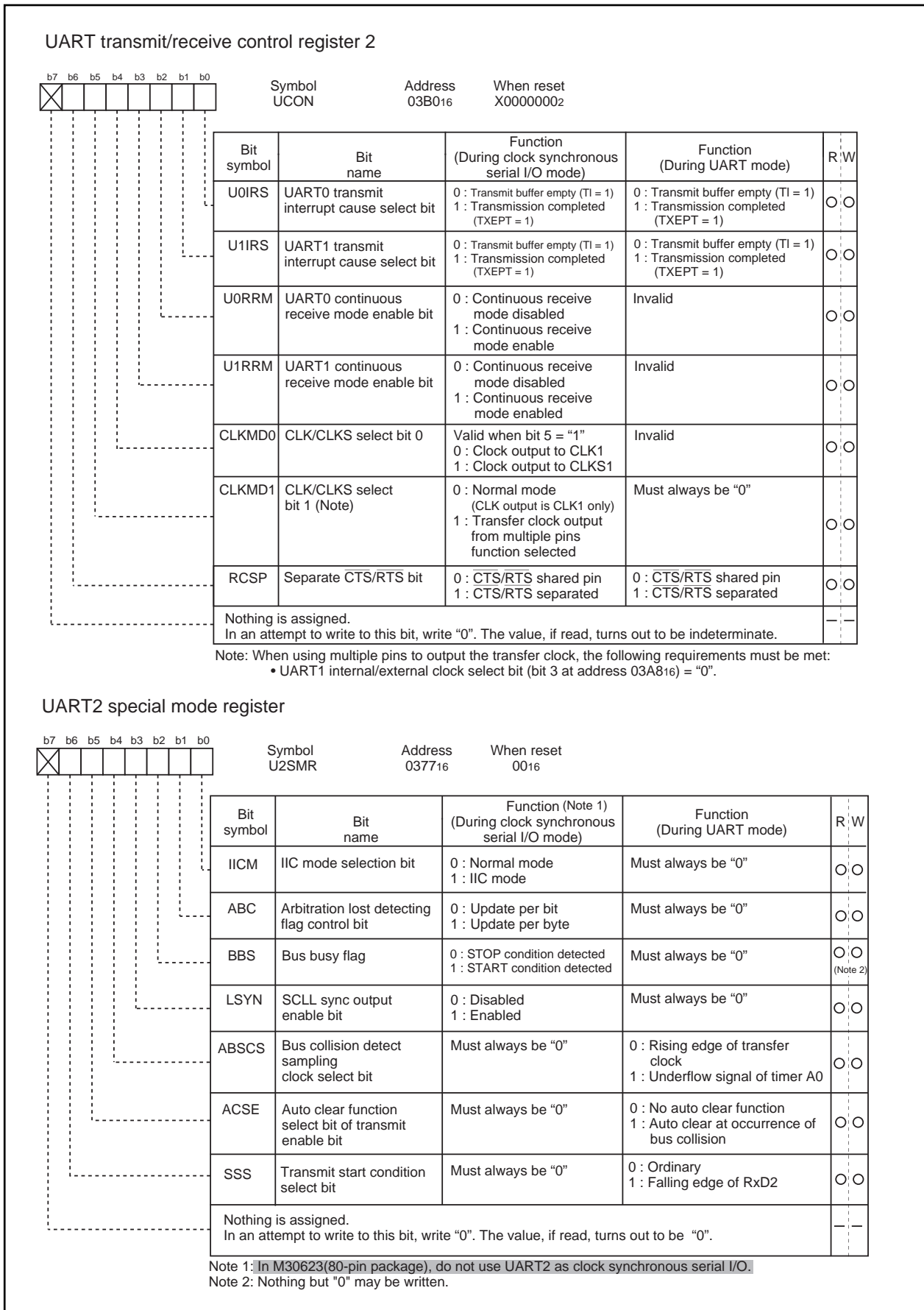


Figure 1.19.8. Serial I/O-related registers (5)

(1) Clock synchronous serial I/O mode

The clock synchronous serial I/O mode uses a transfer clock to transmit and receive data. Tables 1.19.2 and 1.19.3 list the specifications of the clock synchronous serial I/O mode. Figure 1.19.9 shows the UART_i transmit/receive mode register.

In M30623(80-pin package), do not use UART2 as clock synchronous serial I/O.

Table 1.19.2. Specifications of clock synchronous serial I/O mode (1)

Item	Specification
Transfer data format	<ul style="list-style-type: none"> Transfer data length: 8 bits
Transfer clock	<ul style="list-style-type: none"> When internal clock is selected (bit 3 at addresses 03A0₁₆, 03A8₁₆, 0378₁₆ = "0") : $f_i / 2(n+1)$ (Note 1) $f_i = f_1, f_8, f_{32}$ When external clock is selected (bit 3 at addresses 03A0₁₆, 03A8₁₆, 0378₁₆ = "1") : Input from CLK_i pin
Transmission/reception control	<ul style="list-style-type: none"> CTS function/RTS function/CTS, RTS function chosen to be invalid
Transmission start condition	<ul style="list-style-type: none"> To start transmission, the following requirements must be met: <ul style="list-style-type: none"> Transmit enable bit (bit 0 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" Transmit buffer empty flag (bit 1 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "0" When CTS function selected, CTS input level = "L" Furthermore, if external clock is selected, the following requirements must also be met: <ul style="list-style-type: none"> CLK_i polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "0": CLK_i input level = "H" CLK_i polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "1": CLK_i input level = "L"
Reception start condition	<ul style="list-style-type: none"> To start reception, the following requirements must be met: <ul style="list-style-type: none"> Receive enable bit (bit 2 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" Transmit enable bit (bit 0 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" Transmit buffer empty flag (bit 1 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "0" Furthermore, if external clock is selected, the following requirements must also be met: <ul style="list-style-type: none"> CLK_i polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "0": CLK_i input level = "H" CLK_i polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "1": CLK_i input level = "L"
Interrupt request generation timing	<ul style="list-style-type: none"> When transmitting <ul style="list-style-type: none"> Transmit interrupt cause select bit (bits 0, 1 at address 03B0₁₆, bit 4 at address 037D₁₆) = "0": Interrupts requested when data transfer from UART_i transfer buffer register to UART_i transmit register is completed Transmit interrupt cause select bit (bits 0, 1 at address 03B0₁₆, bit 4 at address 037D₁₆) = "1": Interrupts requested when data transmission from UART_i transfer register is completed When receiving <ul style="list-style-type: none"> Interrupts requested when data transfer from UART_i receive register to UART_i receive buffer register is completed
Error detection	<ul style="list-style-type: none"> Overrun error (Note 2) This error occurs when the next data is ready before contents of UART_i receive buffer register are read out

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

Note 2: If an overrun error occurs, the UART_i receive buffer will have the next data written in. Note also that the UART_i receive interrupt request bit is not set to "1".

Table 1.19.4. Specifications of clock synchronous serial I/O mode (2)

Item	Specification
Select function	<ul style="list-style-type: none"> • 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.

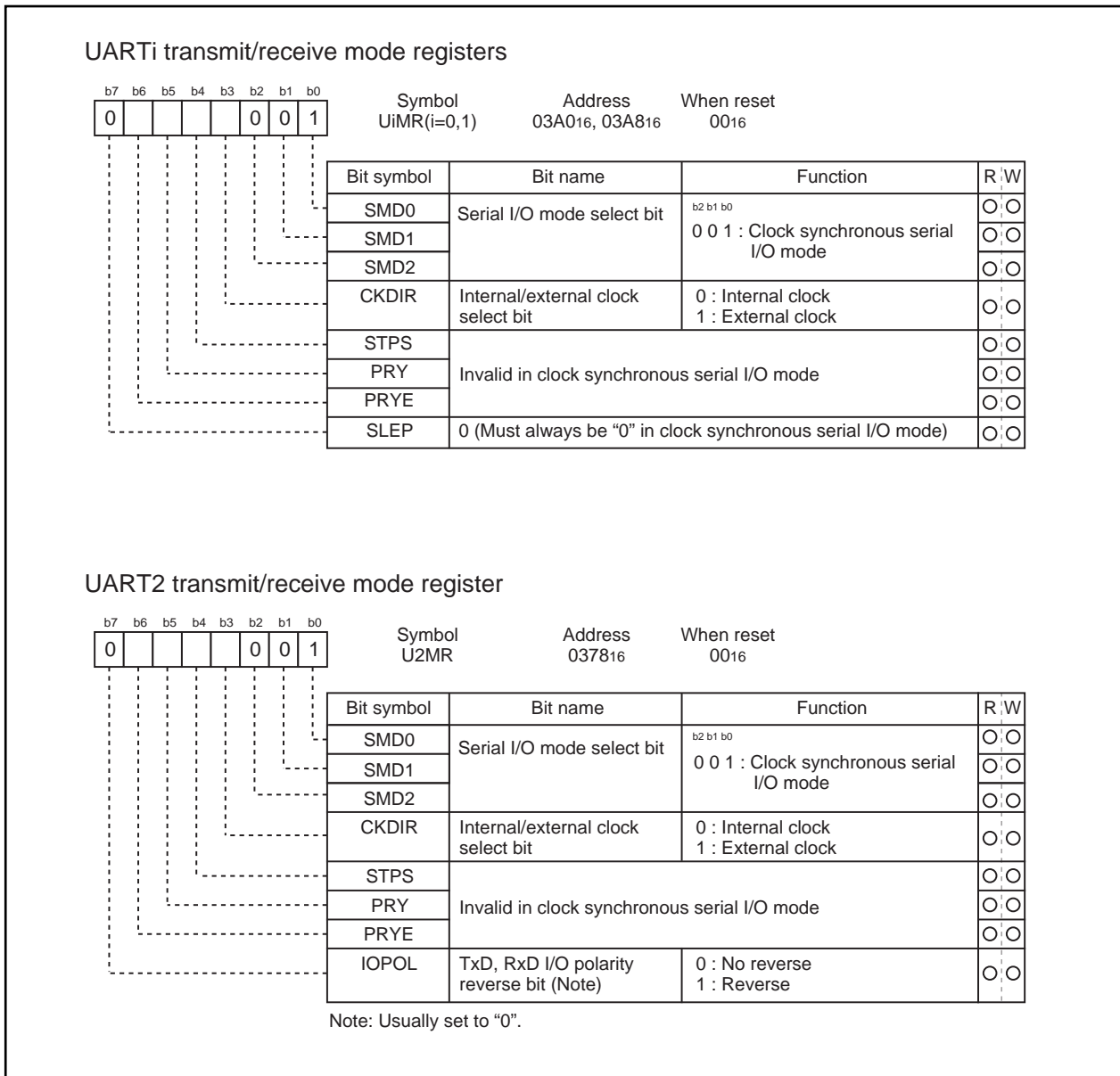


Figure 1.19.9. UARTi transmit/receive mode register in clock synchronous serial I/O mode

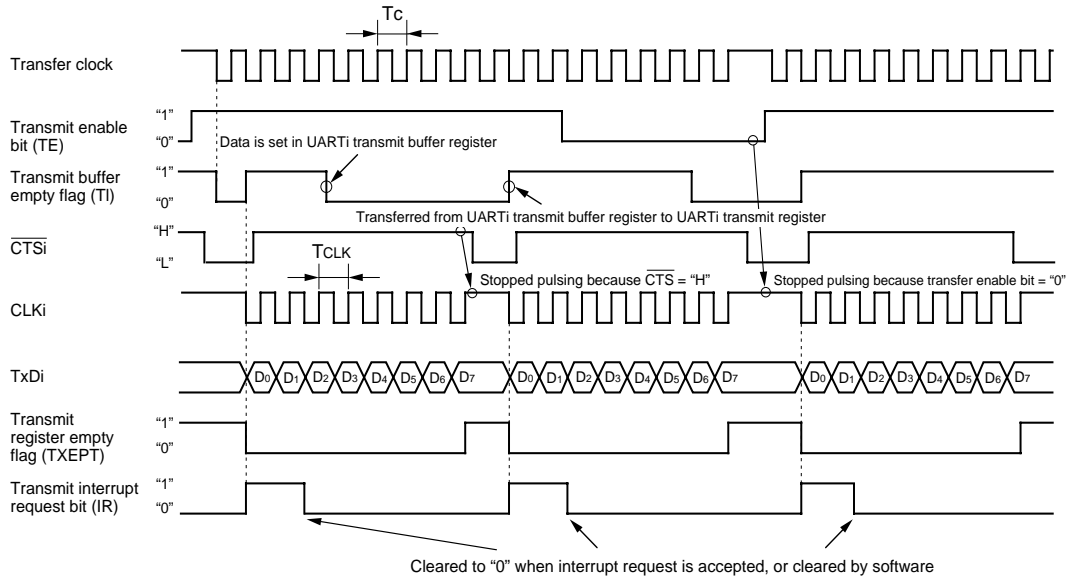
Table 1.19.4 lists the functions of the input/output pins during clock synchronous serial I/O mode. This table shows the pin functions when the transfer clock output from multiple pins and the separate $\overline{\text{CTS}}$ / $\overline{\text{RTS}}$ pins functions are not selected. Note that for a 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 1.19.4. Input/output pin functions in clock synchronous serial I/O mode

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

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

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



Shown in () are bit symbols.

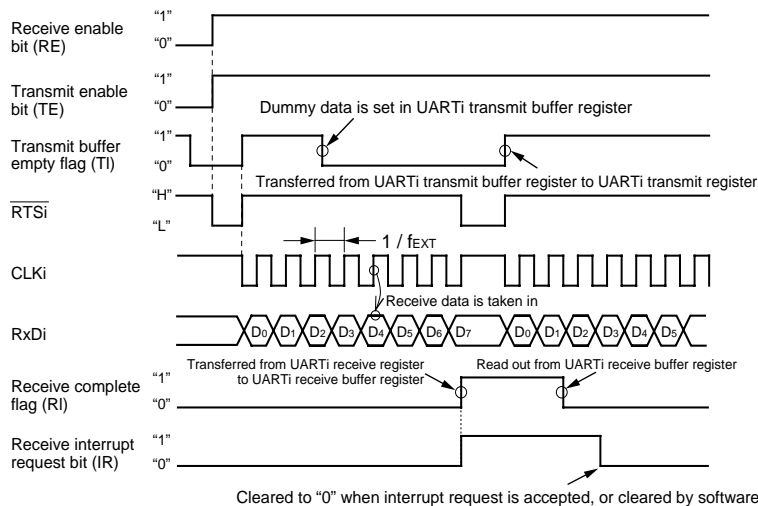
The above timing applies to the following settings:

- Internal clock is selected.
- CTS function is selected.
- CLK polarity select bit = "0".
- Transmit interrupt cause select bit = "0"

$$T_c = T_{CLK} = 2(n + 1) / f_i$$

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

f_{EXT} : 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 1.19.10. Typical transmit/receive timings in clock synchronous serial I/O mode

(a) Polarity select function

As shown in Figure 1.19.11, the CLK polarity select bit (bit 6 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) allows selection of the polarity of the transfer clock.

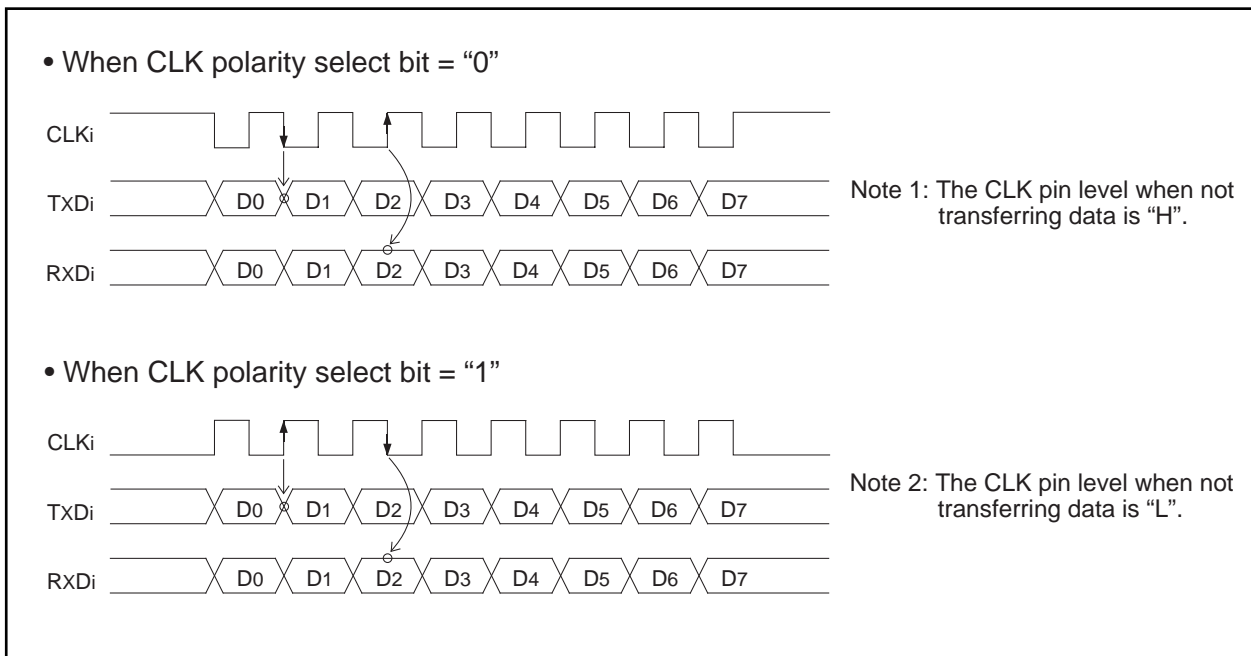


Figure 1.19.11. Polarity of transfer clock

(b) LSB first/MSB first select function

As shown in Figure 1.19.12, when the transfer format select bit (bit 7 at addresses 03A4₁₆, 03AC₁₆, 037C₁₆) = "0", the transfer format is "LSB first"; when the bit = "1", the transfer format is "MSB first".

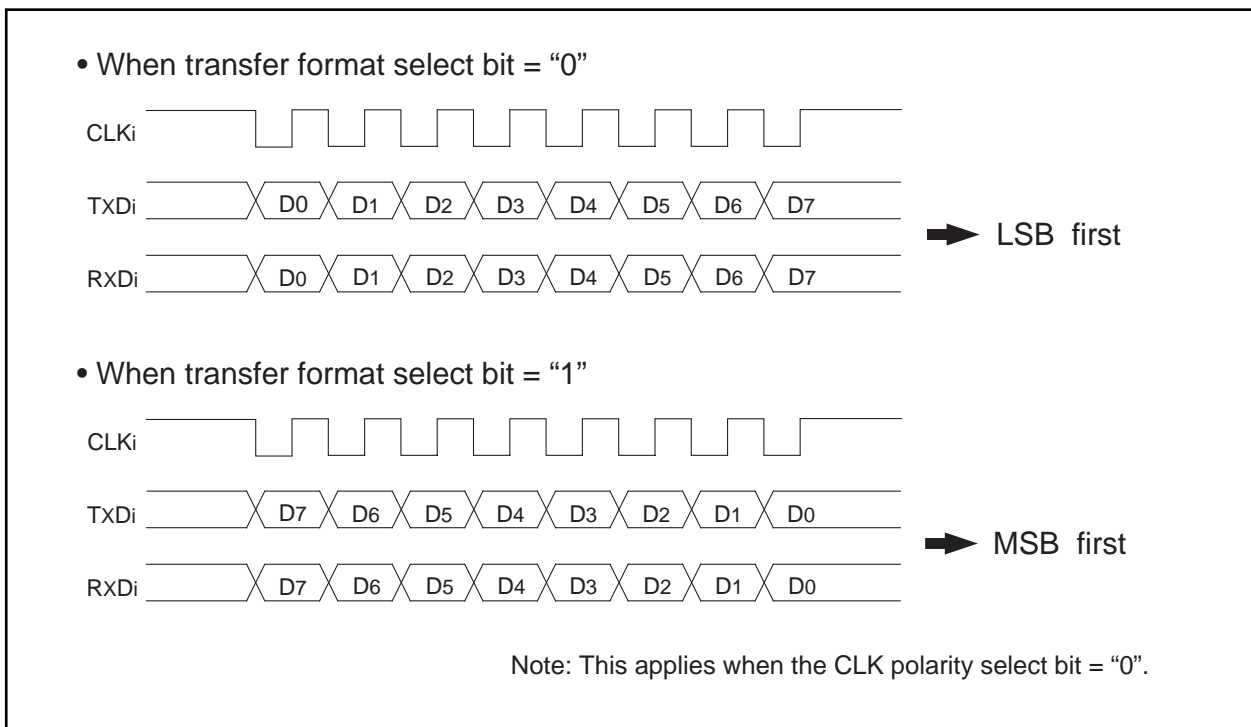


Figure 1.19.12. Transfer format

(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 03B016). (See Figure 1.19.3.) The multiple pins function is valid only when the internal clock is selected for UART1. Note that when this function is selected, UART1 $\overline{\text{CTS}}/\overline{\text{RTS}}$ function cannot be used.

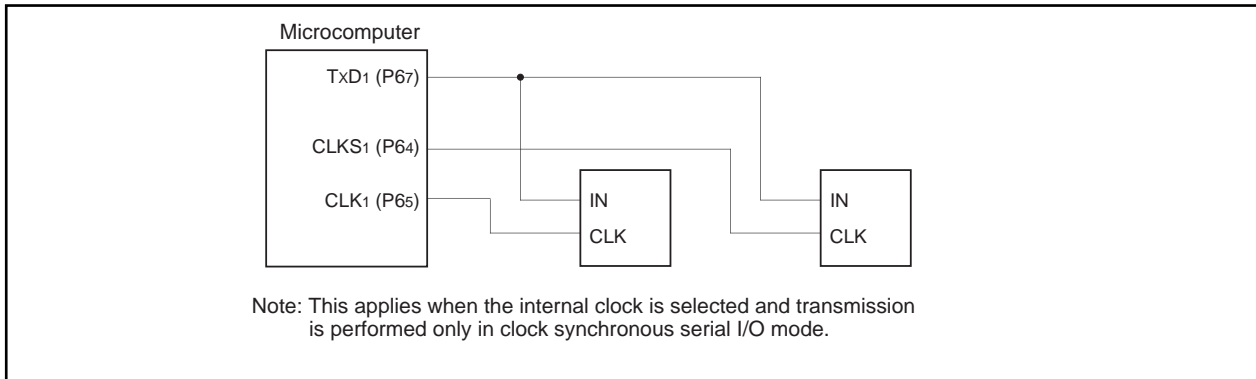


Figure 1.19.13. The transfer clock output from the multiple pins function usage

(d) Continuous receive mode

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

(e) Separate $\overline{\text{CTS}}/\overline{\text{RTS}}$ 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 037D16) = "1", and writing to transmit buffer register or reading from receive buffer register, data is reversed. Figure 1.19.14 shows the example of serial data logic switch timing.

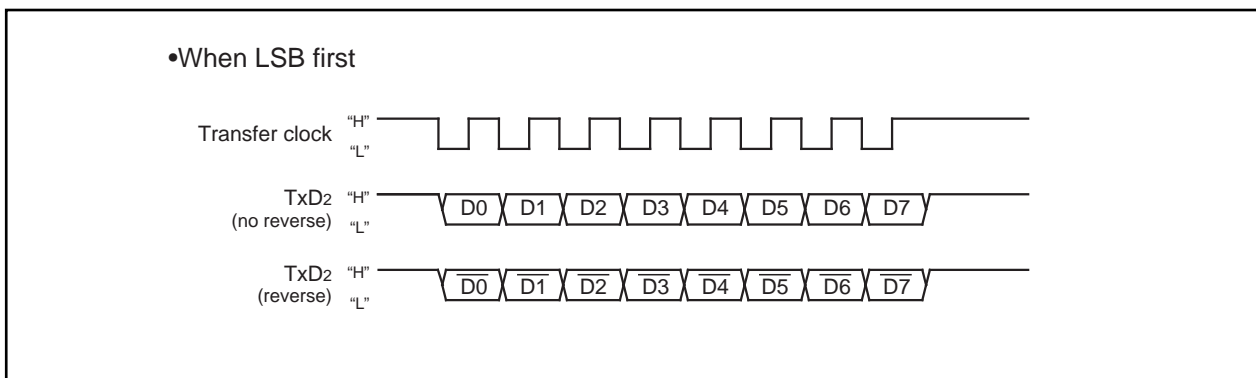


Figure 1.19.14. Serial data logic switch timing

(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. Tables 1.19.5 and 1.19.6 list the specifications of the UART mode. Figure 1.19.15 shows the UART_i transmit/receive mode register.

Table 1.19.5. Specifications of UART Mode (1)

Item	Specification
Transfer data format	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • When internal clock is selected (bit 3 at addresses 03A0₁₆, 03A8₁₆, 0378₁₆ = "0") : $f_i/16(n+1)$ (Note 1) $f_i = f_1, f_8, f_{32}$ • When external clock is selected (bit 3 at addresses 03A0₁₆, 03A8₁₆, 0378₁₆ = "1") : $f_{EXT}/16(n+1)$ (Note 1) (Note 2)
Transmission/reception control	<ul style="list-style-type: none"> • CTS function/$\overline{\text{RTS}}$ function/$\overline{\text{CTS}}$, $\overline{\text{RTS}}$ function chosen to be invalid (Note 4)
Transmission start condition	<ul style="list-style-type: none"> • To start transmission, the following requirements must be met: <ul style="list-style-type: none"> - Transmit enable bit (bit 0 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" - Transmit buffer empty flag (bit 1 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "0" - When CTS function selected, CTS input level = "L" (Note 4)
Reception start condition	<ul style="list-style-type: none"> • To start reception, the following requirements must be met: <ul style="list-style-type: none"> - Receive enable bit (bit 2 at addresses 03A5₁₆, 03AD₁₆, 037D₁₆) = "1" - Start bit detection
Interrupt request generation timing	<ul style="list-style-type: none"> • When transmitting <ul style="list-style-type: none"> - Transmit interrupt cause select bits (bits 0,1 at address 03B0₁₆, bit4 at address 037D₁₆) = "0": Interrupts requested when data transfer from UART_i transfer buffer register to UART_i transmit register is completed - Transmit interrupt cause select bits (bits 0, 1 at address 03B0₁₆, bit4 at address 037D₁₆) = "1": Interrupts requested when data transmission from UART_i transfer register is completed • When receiving <ul style="list-style-type: none"> - Interrupts requested when data transfer from UART_i receive register to UART_i receive buffer register is completed
Error detection	<ul style="list-style-type: none"> • Overrun error (Note 3) <p>This error occurs when the next data is ready before contents of UART_i receive buffer register are read out</p> • Framing error <p>This error occurs when the number of stop bits set is not detected</p> • Parity error <p>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</p> • Error sum flag <p>This flag is set (= 1) when any of the overrun, framing, and parity errors is encountered</p>

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

Note 2: f_{EXT} is input from the CLK_i pin. In M30623(80-pin package), do not select the external clock as transfer clock, because there is no external pin of CLK₂.

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

Note 4: In M30623(80-pin package), do not use these functions, because there is no external pin of CTS₂/RTS₂.

Table 1.19.6. Specifications of UART Mode (2)

Item	Specification
Select function	<ul style="list-style-type: none"><li data-bbox="507 342 1426 416">• Separate $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ pins (UART0) UART0 $\overline{\text{CTS}}$ and $\overline{\text{RTS}}$ pins each can be assigned to separate pins<li data-bbox="507 421 1426 533">• Sleep mode selection (UART0, UART1) This mode is used to transfer data to and from one of multiple slave micro-computers<li data-bbox="507 537 1426 649">• Serial data logic switch (UART2) This function is reversing logic value of transferring data. Start bit, parity bit and stop bit are not reversed.<li data-bbox="507 654 1426 768">• TxD, RxD I/O polarity switch This function is reversing TxD port output and RxD port input. All I/O data level is reversed.

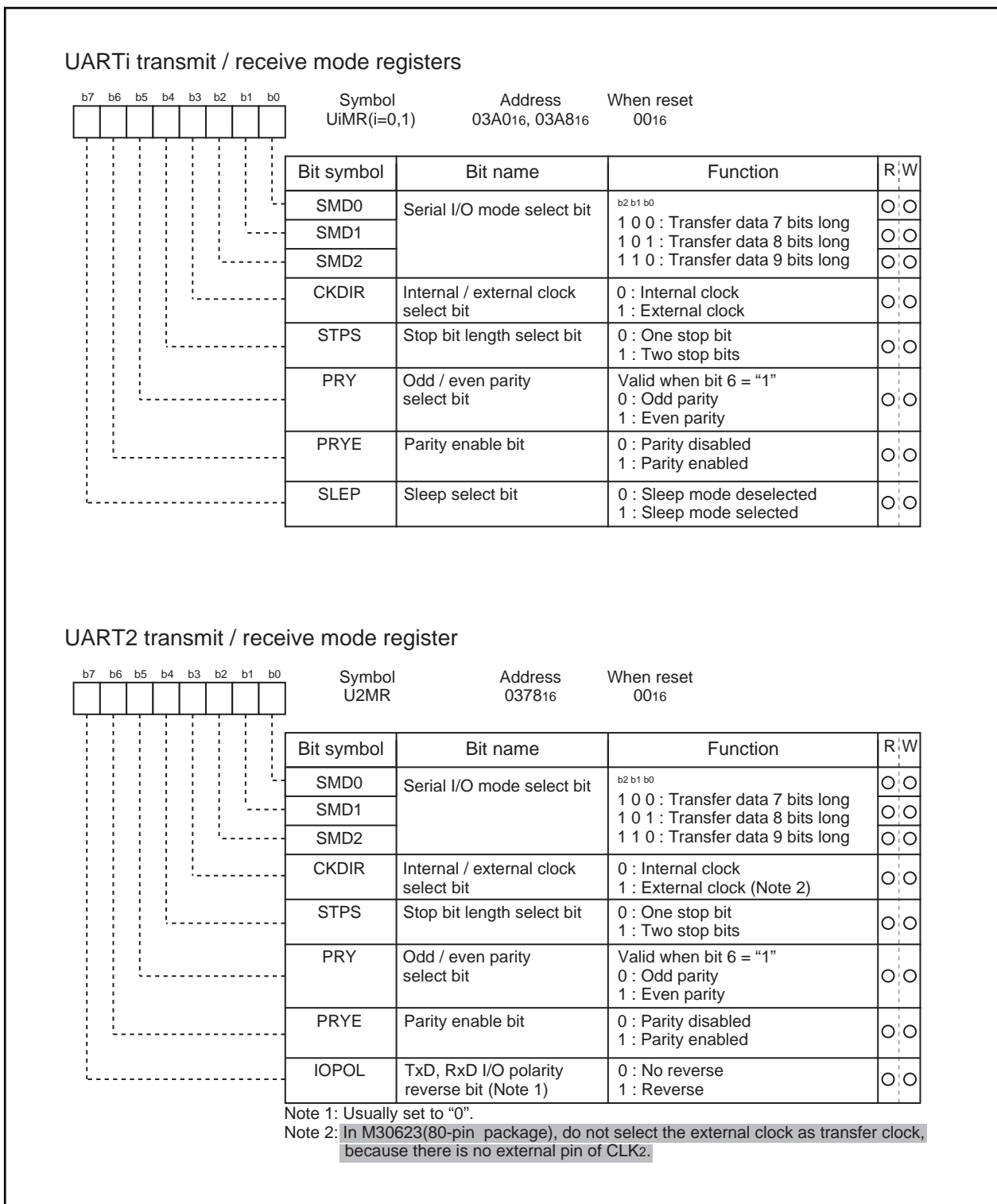


Figure 1.19.15. UARTi transmit/receive mode register in UART mode

Table 1.19.7 lists the functions of the input/output pins during UART mode. This table shows the pin functions when the separate $\overline{\text{CTS}}/\overline{\text{RTS}}$ 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 1.19.7. Input/output pin functions in UART mode

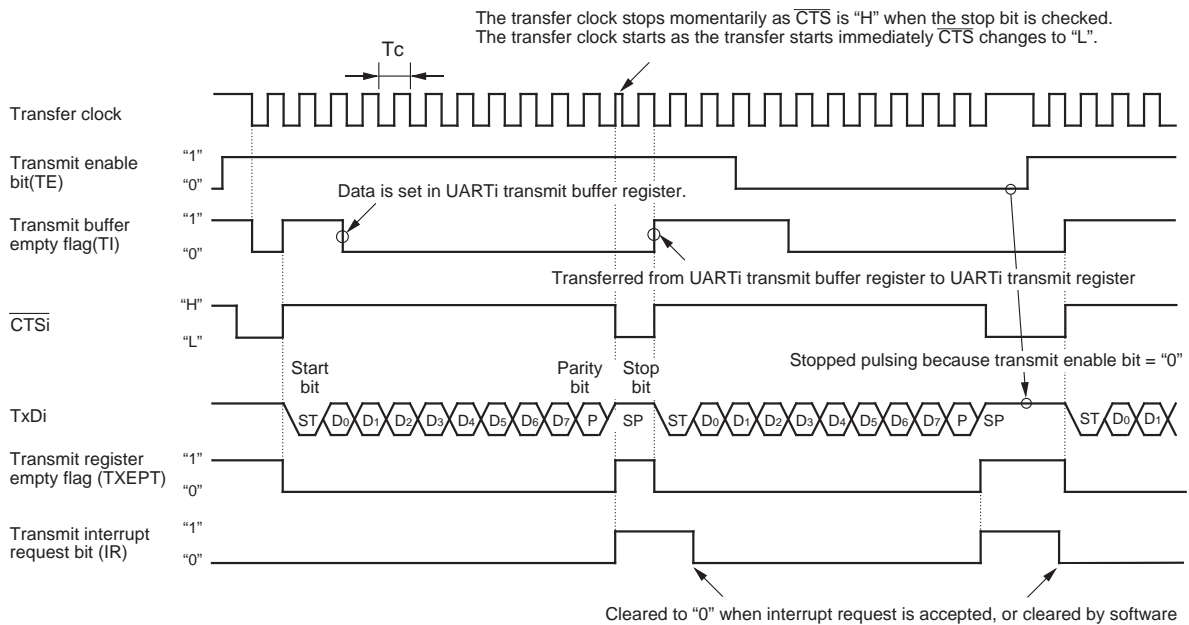
Pin name	Function	Method of selection
TxDi (P63, P67, P70)	Serial data output	
RxDi (P62, P66, P71)	Serial data input	Port P62, P66 and P71 direction register (bits 2 and 6 at address 03EE16, bit 1 at address 03EF16) = "0" (Can be used as an input port when performing transmission only)
CLKi (P61, P65,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

(when separate CTS/RTS pins function is not selected)

Note 1: In M30623(80-pin package), use the internal clock as transfer clock of UART2, because there is no external pin of CLK2(P72).

Note 2: In M30623(80-pin package), UART2 does not have these functions, because there is no external pin of $\overline{\text{CTS}}_2/\overline{\text{RTS}}_2$ (P73).

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



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

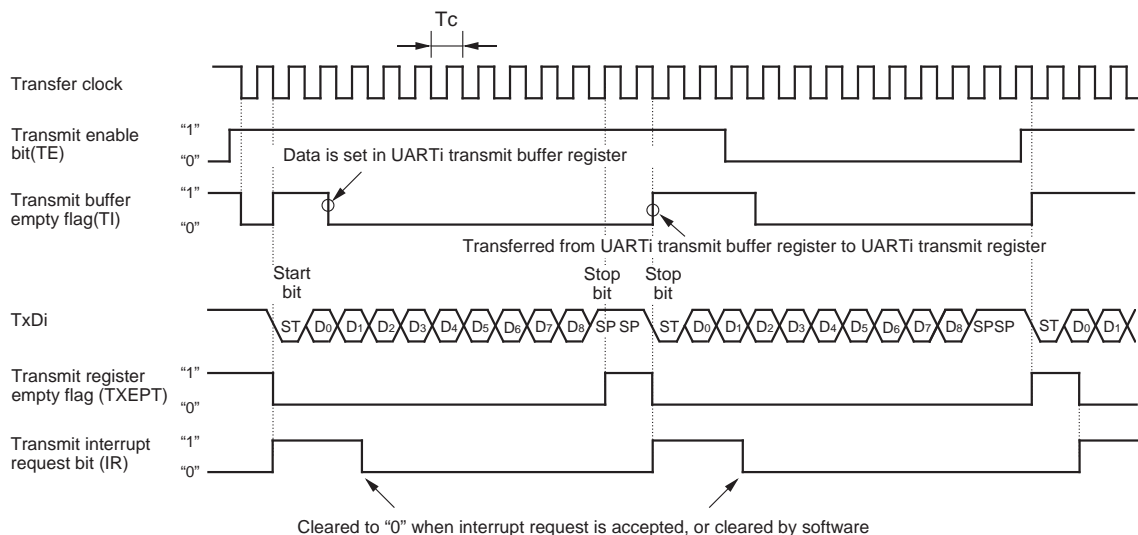


Figure 1.19.16. Typical transmit timings in UART mode

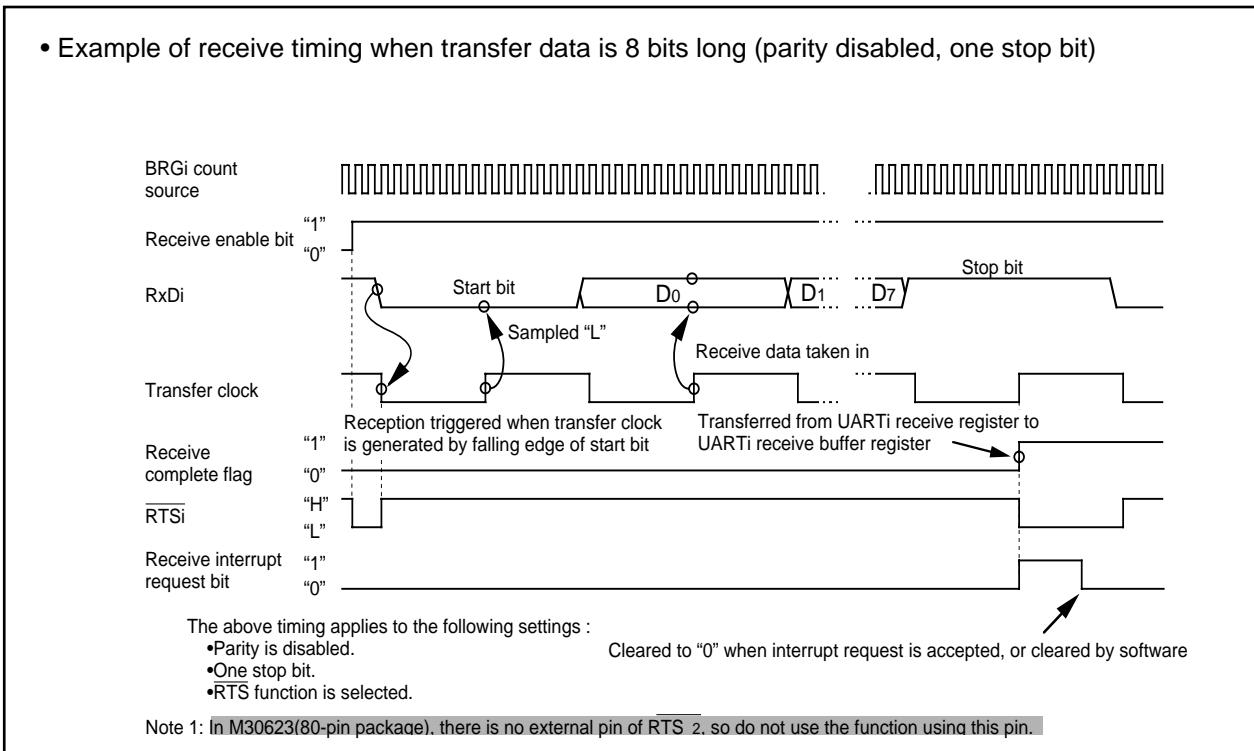


Figure 1.19.17. Typical receive timing in UART mode

(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 03B016) 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 03A416). 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 03AC16) and to the $\overline{\text{CTS}}$ / $\overline{\text{RTS}}$ disable bit (bit 4 of address 03AC16).

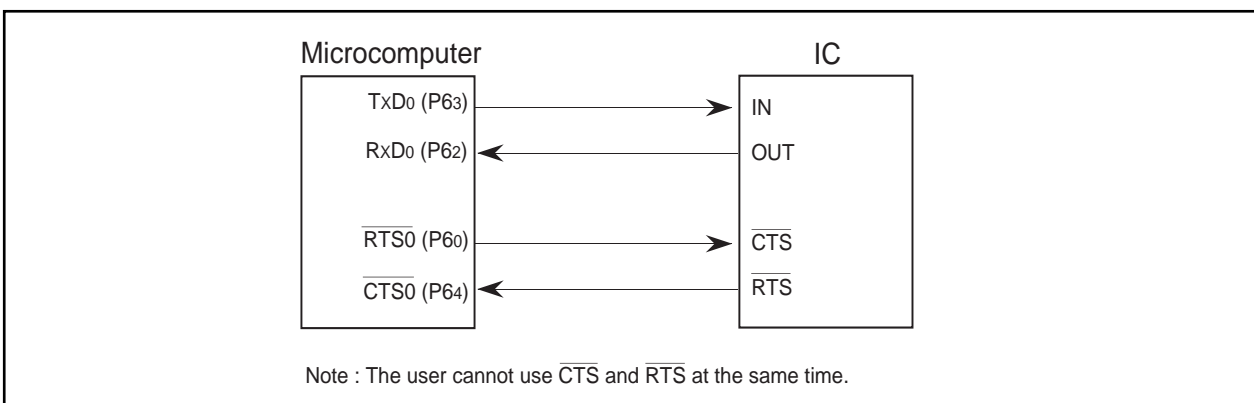


Figure 1.19.18. The separate $\overline{\text{CTS}}$ / $\overline{\text{RTS}}$ pins function usage

(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 03A016, 03A816) is set to "1" during reception. In this mode, the unit performs receive operation when the MSB of the received data = "1" and does not perform receive operation when the MSB = "0".

(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 1.19.19 shows the example of 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. Figure 1.19.19 shows the example of timing for I/O polarity reverse.

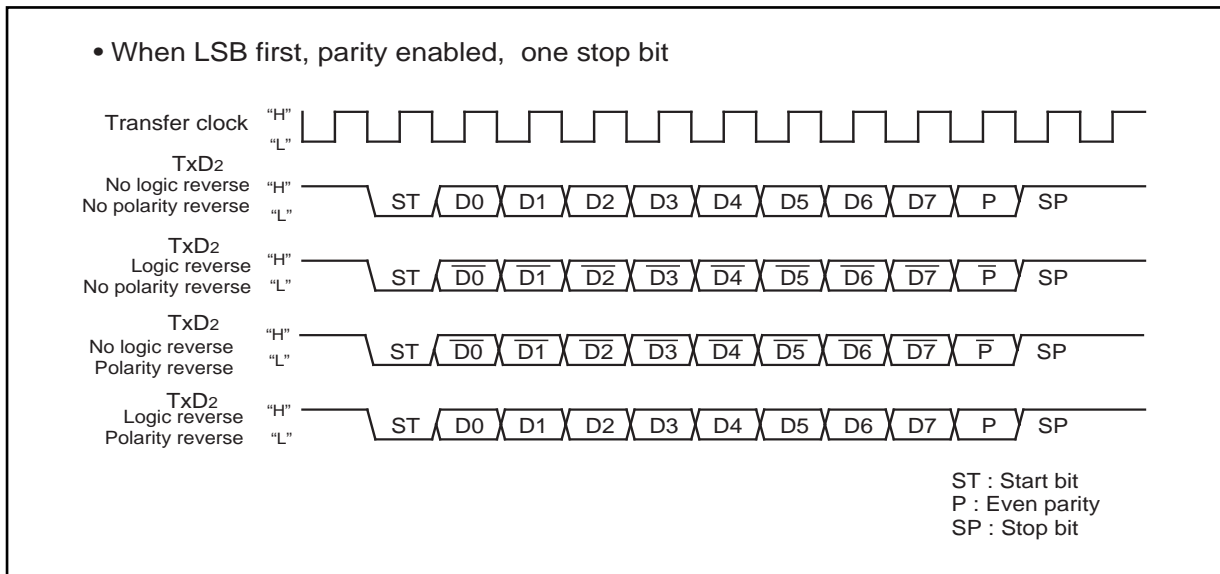


Figure 1.19.19. Timing for switching serial data logic, and I/O polarity reverse

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

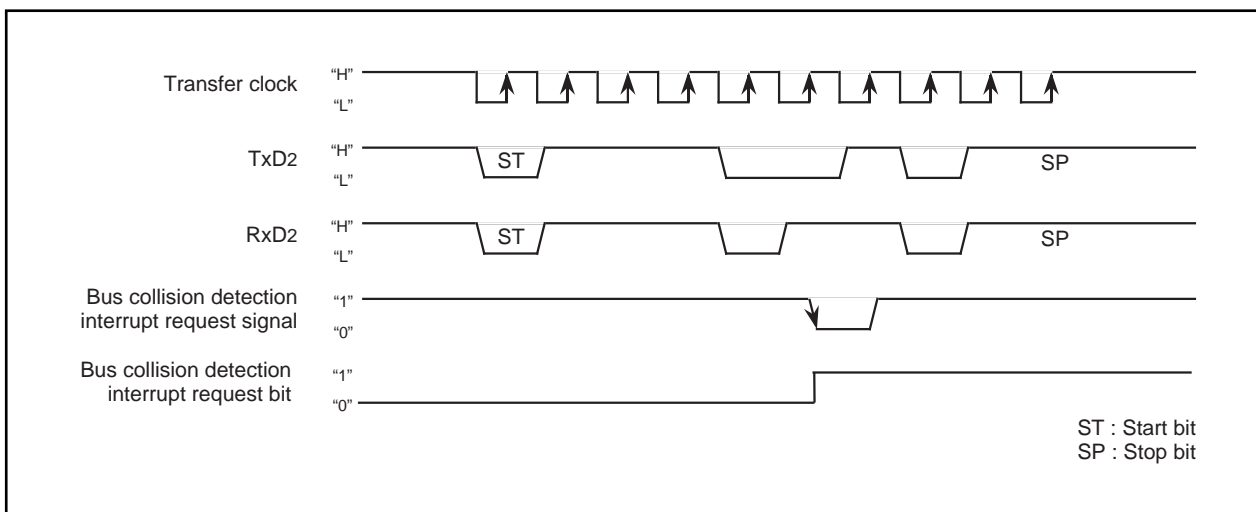


Figure 1.19.20. Detection timing of a bus collision (in UART mode)

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

Table 1.19.8. Specifications of clock-asynchronous serial I/O mode (compliant with the SIM interface)

Item	Specification
Transfer data format	<ul style="list-style-type: none"> • Transfer data 8-bit UART mode (bit 2 through bit 0 of address 0378₁₆ = "1012") • One stop bit (bit 4 of address 0378₁₆ = "0") • With the direct format chosen <ul style="list-style-type: none"> Set parity to "even" (bit 5 and bit 6 of address 0378₁₆ = "1" and "1" respectively) Set data logic to "direct" (bit 6 of address 037D₁₆ = "0"). Set transfer format to LSB (bit 7 of address 037C₁₆ = "0"). • With the inverse format chosen <ul style="list-style-type: none"> Set parity to "odd" (bit 5 and bit 6 of address 0378₁₆ = "0" and "1" respectively) Set data logic to "inverse" (bit 6 of address 037D₁₆ = "1") Set transfer format to MSB (bit 7 of address 037C₁₆ = "1")
Transfer clock	<ul style="list-style-type: none"> • With the internal clock chosen (bit 3 of address 0378₁₆ = "0") : $f_i / 16 (n + 1)$ (Note 1) : $f_i = f_1, f_8, f_{32}$ • With an external clock chosen (bit 3 of address 0378₁₆ = "1") : $f_{EXT} / 16 (n+1)$ (Note 1) (Note 2)
Transmission / reception control	<ul style="list-style-type: none"> • Disable the \overline{CTS} and \overline{RTS} function (bit 4 of address 037C₁₆ = "1")
Other settings	<ul style="list-style-type: none"> • The sleep mode select function is not available for UART2 • Set transmission interrupt factor to "transmission completed" (bit 4 of address 037D₁₆ = "1")
Transmission start condition	<ul style="list-style-type: none"> • To start transmission, the following requirements must be met: <ul style="list-style-type: none"> - Transmit enable bit (bit 0 of address 037D₁₆) = "1" - Transmit buffer empty flag (bit 1 of address 037D₁₆) = "0"
Reception start condition	<ul style="list-style-type: none"> • To start reception, the following requirements must be met: <ul style="list-style-type: none"> - Reception enable bit (bit 2 of address 037D₁₆) = "1" - Detection of a start bit
Interrupt request generation timing	<ul style="list-style-type: none"> • When transmitting <ul style="list-style-type: none"> When data transmission from the UART2 transfer register is completed (bit 4 of address 037D₁₆ = "1") • When receiving <ul style="list-style-type: none"> When data transfer from the UART2 receive register to the UART2 receive buffer register is completed
Error detection	<ul style="list-style-type: none"> • 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) <ul style="list-style-type: none"> - On the reception side, an "L" level is output from the TxD₂ pin by use of the parity error signal output function (bit 7 of address 037D₁₆ = "1") when a parity error is detected - On the transmission side, a parity error is detected by the level of input to the RxD₂ pin when a transmission interrupt occurs • The error sum flag (see the specifications of clock-asynchronous serial I/O)

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

Note 2: f_{EXT} is input from the CLK₂ pin. In M30623(80-pin package), do not select the external clock as transfer clock of UART₂, because there is no external pin of CLK₂.

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

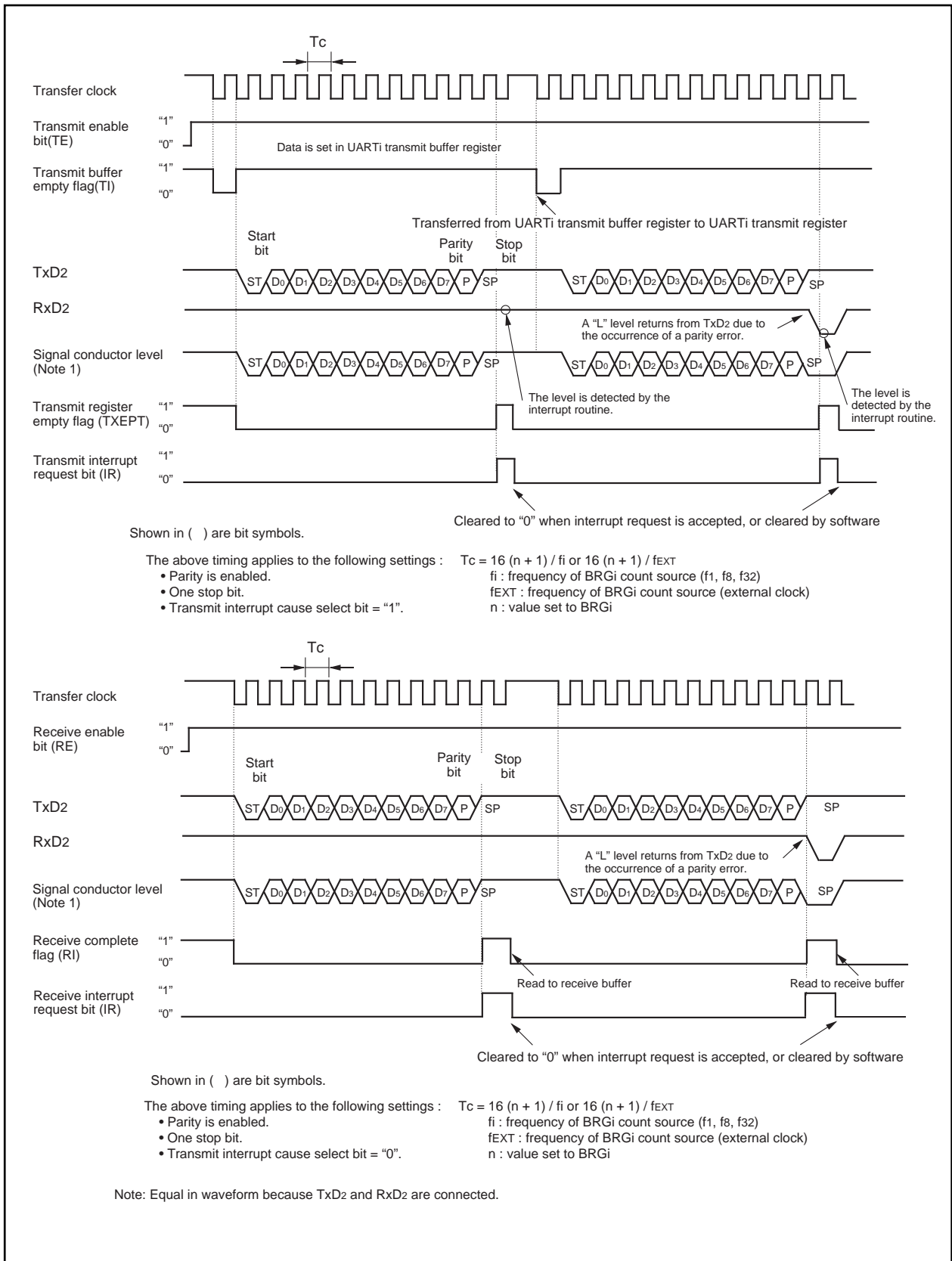


Figure 1.19.21. Typical transmit/receive timing in UART mode (compliant with the SIM interface)

(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 1.19.22 shows the output timing of the parity error signal.

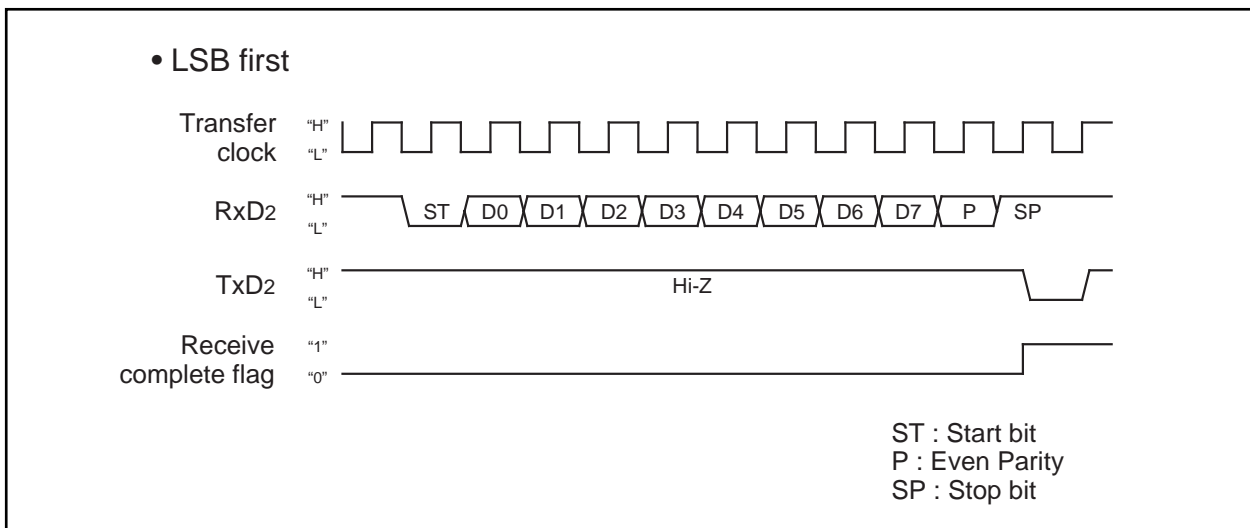


Figure 1.19.22. Output timing of the parity error signal

(b) Direct format/inverse format

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

Figure 1.19.23 shows the SIM interface format.

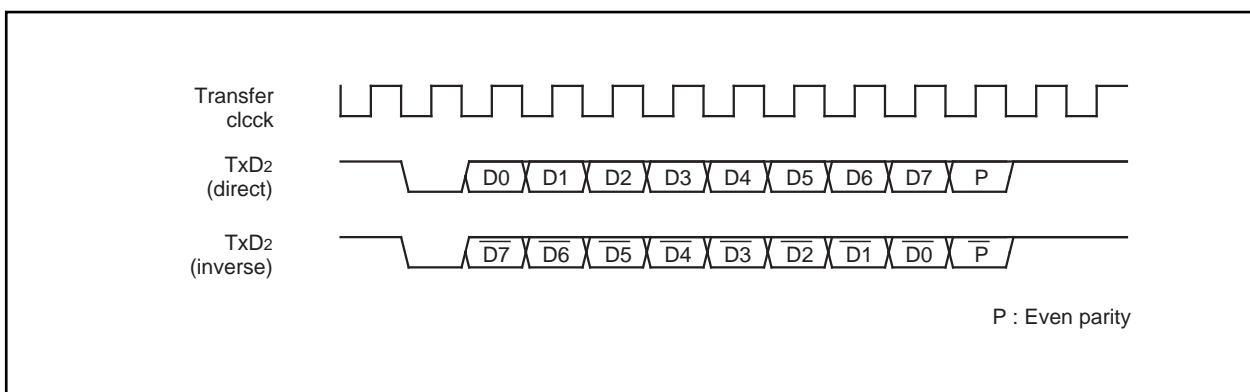


Figure 1.19.23. SIM interface format

Figure 1.19.24 shows the example of connecting the SIM interface. Connect TxD2 and RxD2 and apply pull-up.

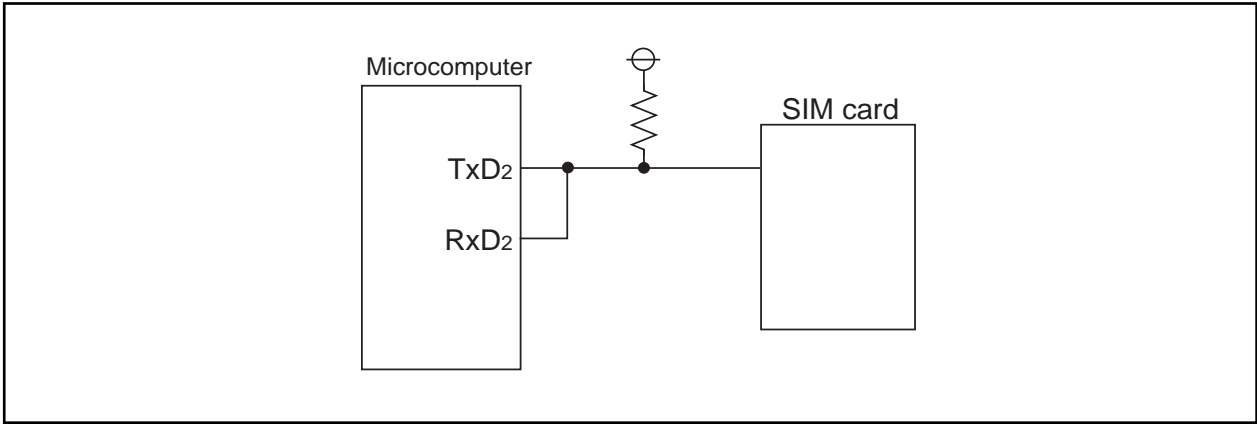


Figure 1.19.24. Connecting the SIM interface

UART2 Special Mode Register

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

Figure 1.19.25 shows the UART2 special mode register.

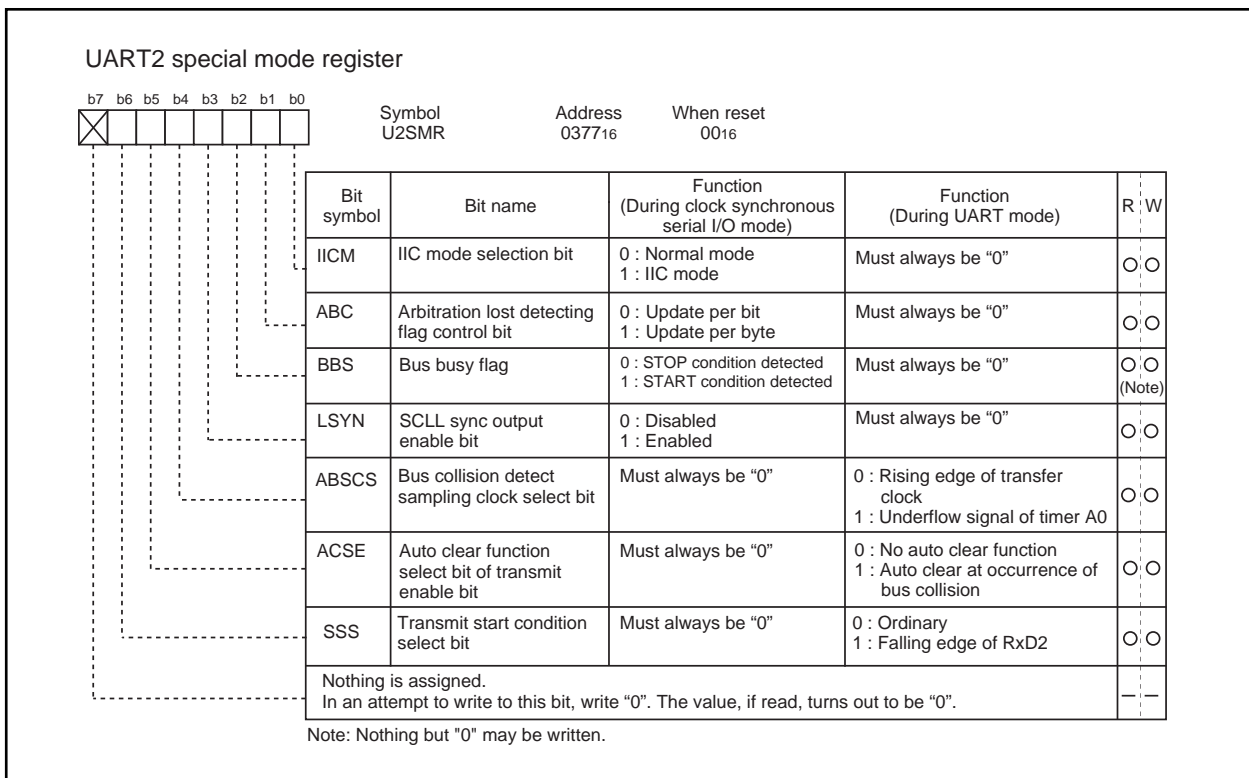


Figure 1.19.25. UART2 special mode register

Table 1.19.9. Features in IIC mode

	Function	Normal mode	IIC mode (Note 1)
1	Factor of interrupt number 10 (Note 2)	Bus collision detection	Start condition detection or stop condition detection
2	Factor of interrupt number 15 (Note 2)	UART2 transmission	No acknowledgment detection (NACK)
3	Factor of interrupt number 16 (Note 2)	UART2 reception	Acknowledgment detection (ACK)
4	UART2 transmission output delay	Not delayed	Delayed
5	P7 ₀ at the time when UART2 is in use	TxD ₂ (output)	SDA (input/output) (Note 3)
6	P7 ₁ at the time when UART2 is in use	RxD ₂ (input)	SCL (input/output)
7	P7 ₂ at the time when UART2 is in use (Note 4)	CLK ₂	P7 ₂
8	DMA1 factor at the time when 1 1 0 1 is assigned to the DMA request factor selection bits	UART2 reception	Acknowledgment detection (ACK)
9	Noise filter width	15ns	50ns
10	Reading P7 ₁	Reading the terminal when 0 is assigned to the direction register	Reading the terminal regardless of the value of the direction register
11	Initial value of UART2 output	H level (when 0 is assigned to the CLK polarity select bit)	The value set in latch P7 ₀ when the port is selected

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

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

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

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

1. Disable the interrupt of the corresponding number.
2. Switch from a factor to another.
3. Reset the interrupt request flag of the corresponding number.
4. Set an interrupt level of the corresponding number.

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

Note 4: In M30623(80-pin package), P7₂ is not connected to external pin.

In the first place, the control bits related to the IIC bus(simplified IIC bus) interface are explained.

Bit 0 of the UART special mode register (037716) is used as the IIC mode selection bit.

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

Table 1.19.9 shows the relation between the IIC mode select bit and respective control workings.

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

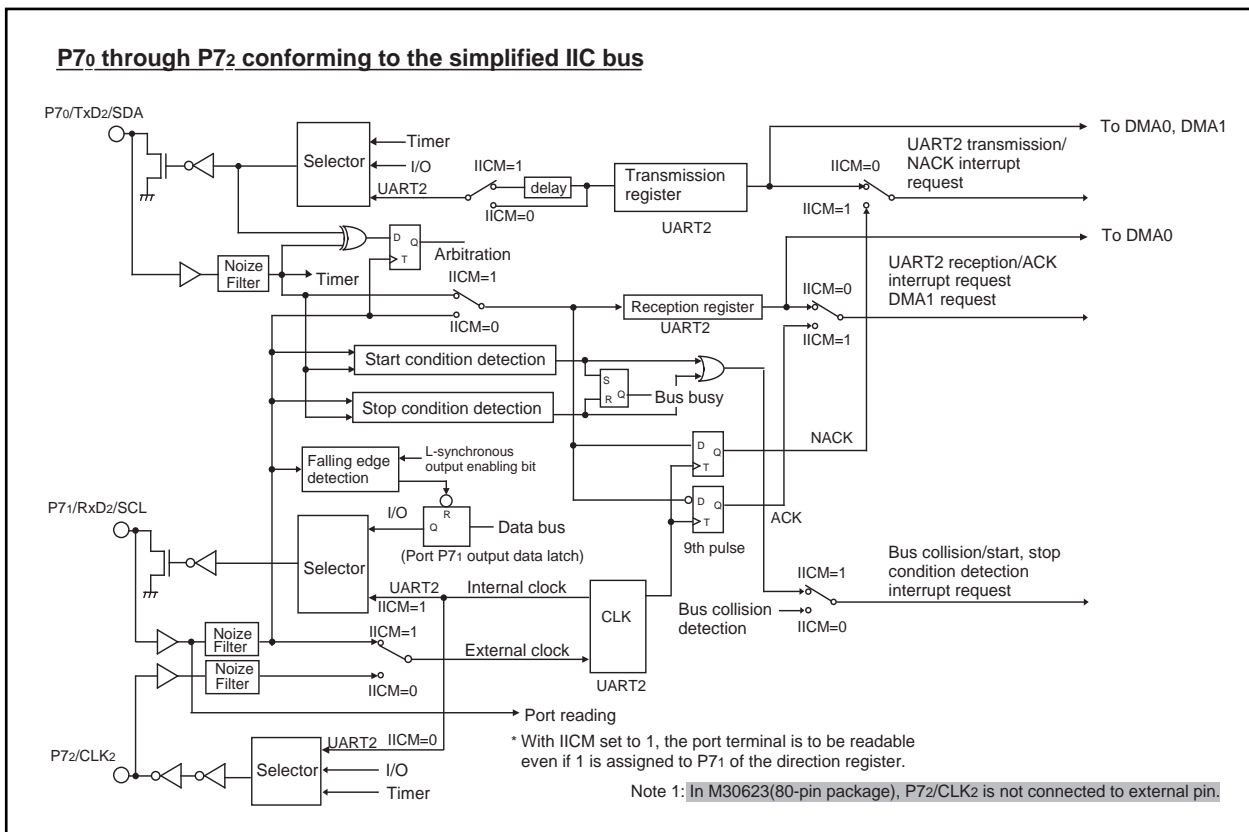


Figure 1.19.26. Functional block diagram for IIC mode

Figure 1.19.26 shows the functional block diagram for IIC mode. Setting "1" in the IIC mode selection bit (IICM) causes ports P70, P71, and P72 to work as data transmission-reception terminal SDA, clock input-output terminal SCL, and port P72 respectively. A delay circuit is added to the SDA transmission output, so the SDA output changes after SCL fully goes to "L". An attempt to read Port P71 (SCL) results in getting the terminal's level regardless of the content of the port direction register. The initial value of SDA transmission output in this mode goes to the value set in port P70. The interrupt factors of the bus collision detection interrupt, UART2 transmission interrupt, and of UART2 reception interrupt turn to the start/stop condition detection interrupt, acknowledgment non-detection interrupt, and acknowledgment detection interrupt respectively.

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

The acknowledgment non-detection interrupt refers to the interrupt that occurs when the SDA terminal level is detected still staying "H" at the rising edge of the 9th transmission clock. The acknowledgment detection interrupt refers to the interrupt that occurs when SDA terminal's level is detected already went to "L" at the 9th transmission clock. Also, assigning 1 1 0 1 (UART2 reception) to the DMA1 request factor select bits provides the means to start up the DMA transfer by the effect of acknowledgment detection. Bit 1 of the UART2 special mode register (0377₁₆) is used as the arbitration loss detecting flag control bit. Arbitration means the act of detecting the nonconformity between transmission data and SDA terminal data at the timing of the SCL rising edge. This detecting flag is located at bit 3 of the UART2 reception buffer register (037F₁₆), and "1" is set in this flag when nonconformity is detected. Use the arbitration lost detecting flag control bit to choose which way to use to update the flag, bit by bit or byte by byte. When setting this bit to "1" and updated the flag byte by byte if nonconformity is detected, the arbitration lost detecting flag is set to "1" at the falling edge of the 9th transmission clock.

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

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

Some other functions added are explained here. Figure 1.19.27 shows their workings.

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

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

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

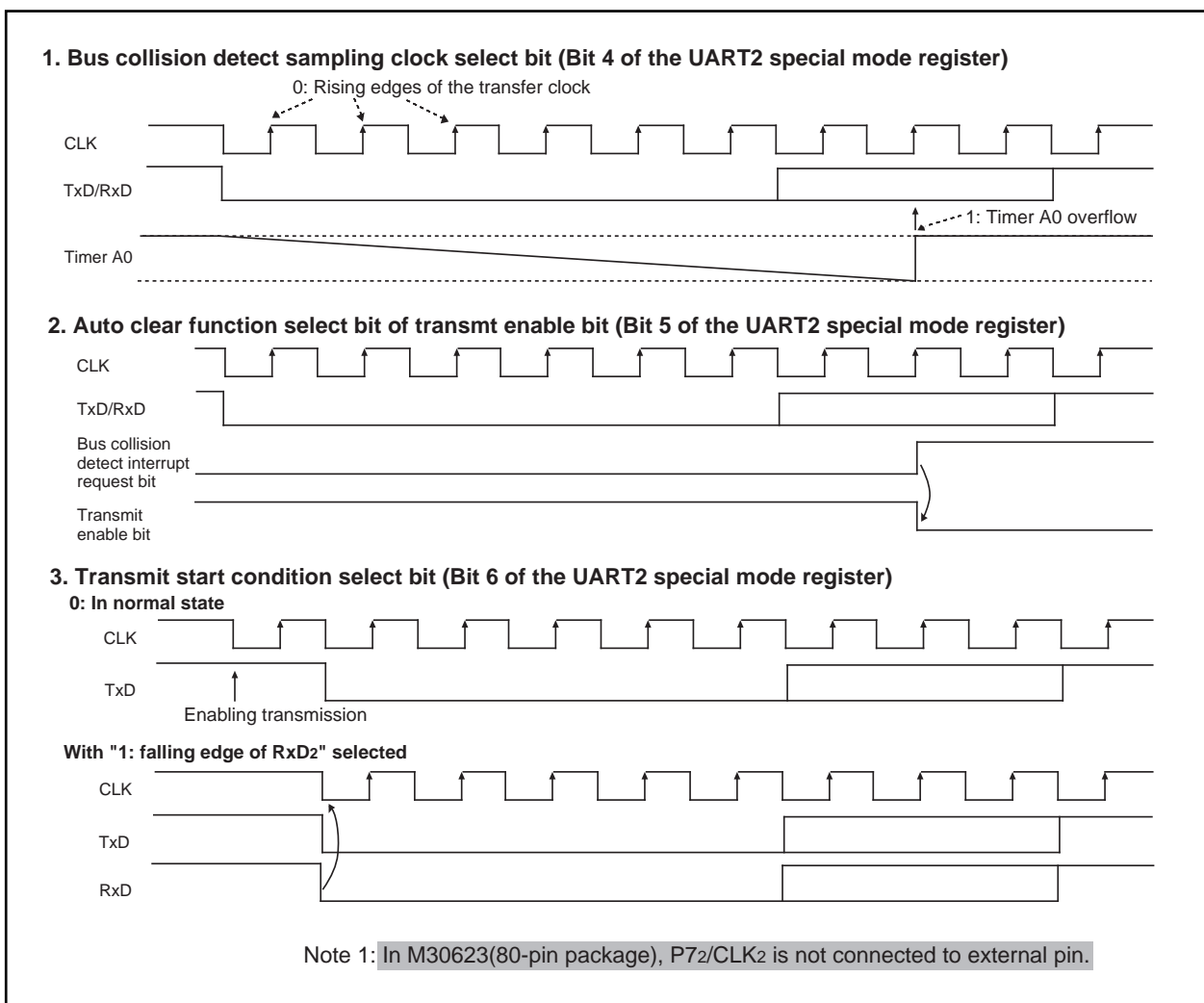


Figure 1.19.27. Some other functions added

S I/O3, 4

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

In M30623(80-pin package), SIN3 is not connected to external pin, so S I/O3 is exclusive transmission.

Figure 1.19.28 shows the S I/O3, 4 block diagram, and Figure 1.19.29 shows the S I/O3, 4 control register.

Table 1.19.10 shows the specifications of S I/O3, 4.

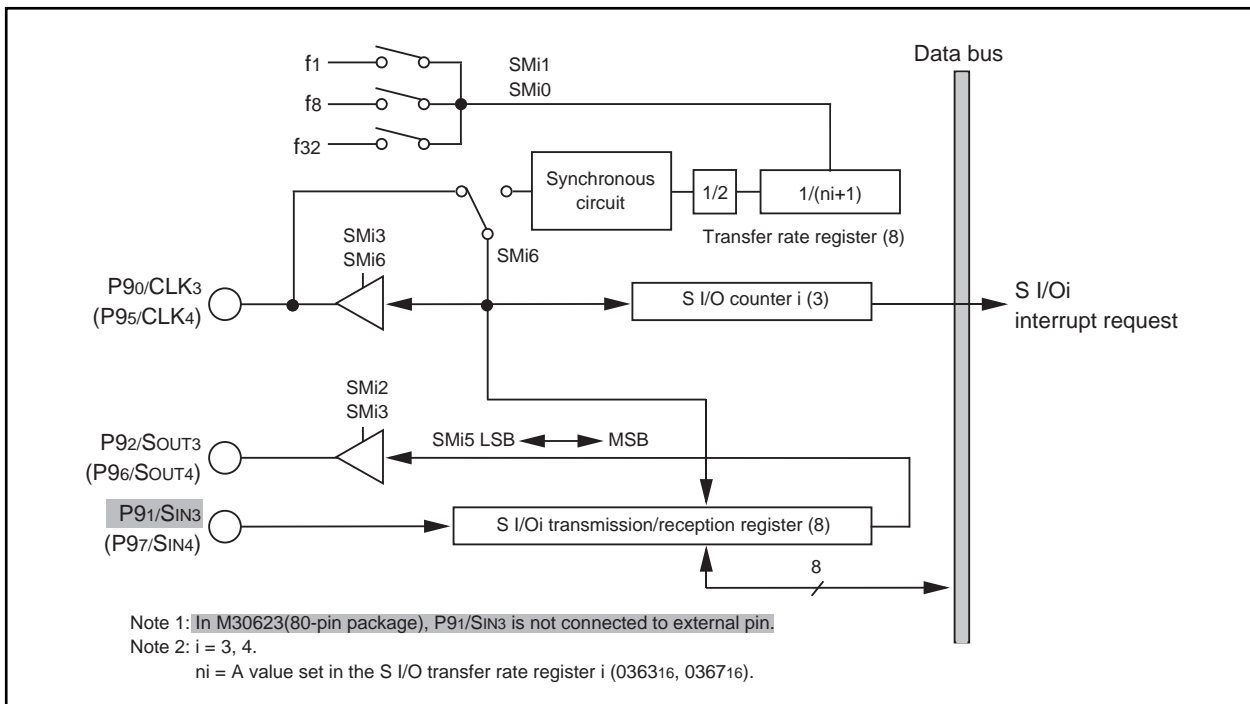


Figure 1.19.28. S I/O3, 4 block diagram

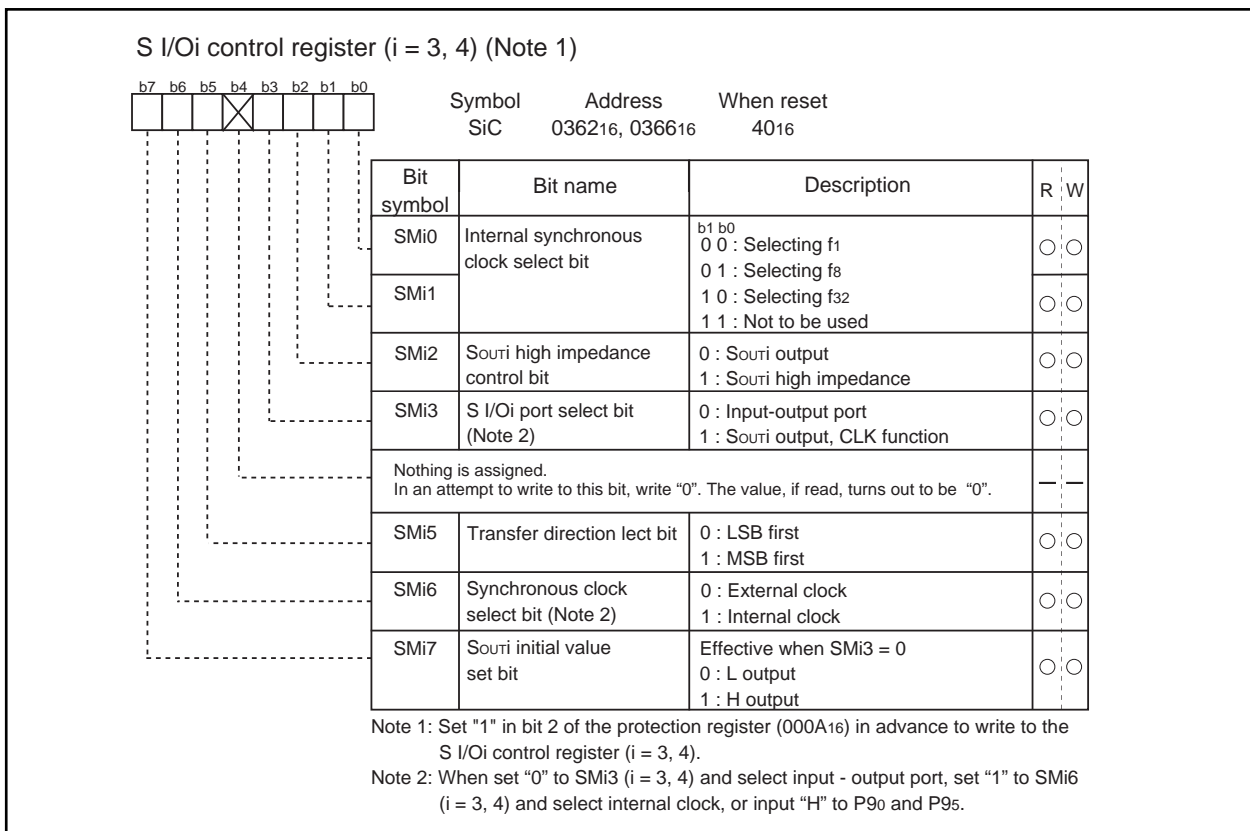


Figure 1.19.29. S I/O3, 4 control register

Table 1.19.10. Specifications of S I/O3, 4

Item	Specifications
Transfer data format	• Transfer data length: 8 bits
Transfer clock	• With the internal clock selected (bit 6 of 0362 ₁₆ , 0366 ₁₆ = "1"): f ₁ /2(ni+1), f ₈ /2(ni+1), f ₃₂ /2(ni+1) (Note 1) • With the external clock selected (bit 6 of 0362 ₁₆ , 0366 ₁₆ = 0): Input from the CLK _i terminal (Note 2)
Conditions for transmission/reception start	• To start transmit/reception, the following requirements must be met: - Select the synchronous clock (use bit 6 of 0362 ₁₆ , 0366 ₁₆). Select a frequency dividing ratio if the internal clock has been selected (use bits 0 and 1 of 0362 ₁₆ , 0366 ₁₆). - SOUT _i initial value set bit (use bit 7 of 0362 ₁₆ , 0366 ₁₆) = 1. - S I/O _i port select bit (bit 3 of 0362 ₁₆ , 0366 ₁₆) = 1. - Select the transfer direction (use bit 5 of 0362 ₁₆ , 0366 ₁₆) • To use S I/O _i interrupts, the following requirements must be met: - S I/O _i interrupt request bit (bit 3 of 0049 ₁₆ , 0048 ₁₆) = 0.
Interrupt request generation timing	• An interrupt occurs after counting eight transfer clock either in transmitting or receiving data. (Note 3) - In transmitting: At the time data transfer from the S I/O _i transmission/reception register finishes. - In receiving: At the time data reception to the S I/O _i transmission/reception register finishes.
Select function	• LSB first or MSB first selection Whether transmission/reception begins with bit 0 or bit 7 can be selected.

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

Note 2: With the external clock selected:

- To write to the S I/O_i transmission/reception register (0360₁₆, 0364₁₆), enter the "H" level to the CLK_i terminal. Also, to write to the bit 7 (SOUT_i initial value set bit) of SI/O_i control register (0362₁₆, 0366₁₆), enter the "H" level to the CLK_i terminal.
- The S I/O_i circuit keeps on with the shift operation as long as the synchronous clock is entered in it, so stop the synchronous clock at the instant when it counts to eight. The internal clock, if selected, automatically stops.

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

Note 4: In M30623(80-pin package), S I/O3 is exclusive transmission, because SIN₃ is not connected to external pin.

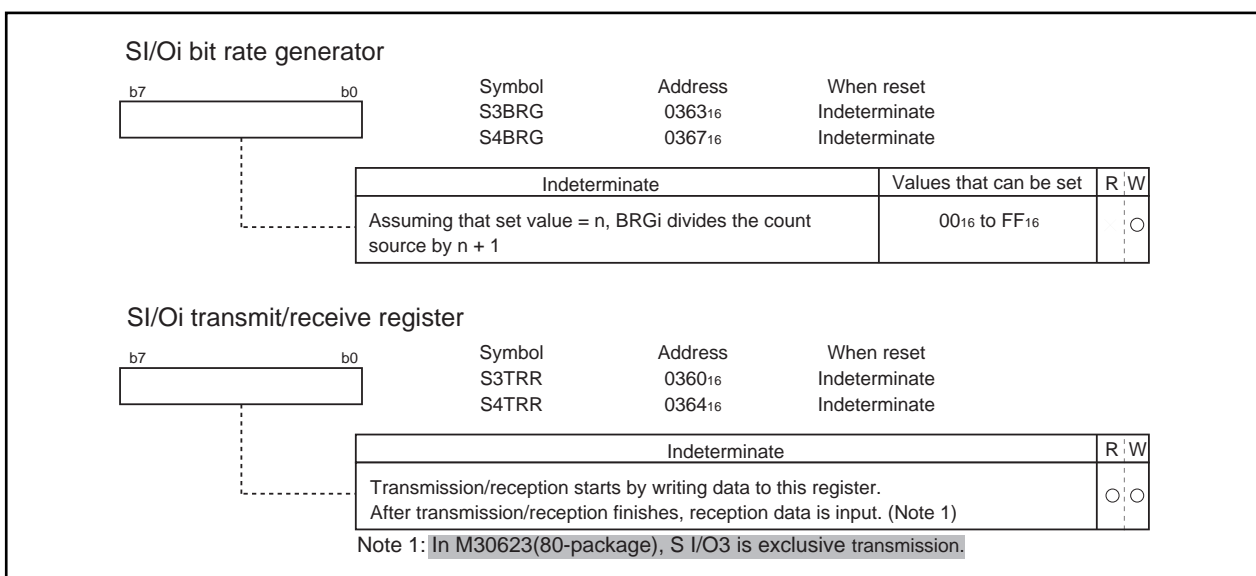


Figure 1.19.30. SI/O_i related register

■ Functions for setting an SOUTi initial value

In carrying out transmission, the output level of the SOUTi terminal as it is before transmitting 1-bit data can be set either to “H” or to “L”. Figure 1.19.31 shows the timing chart for setting an SOUTi initial value and how to set it.

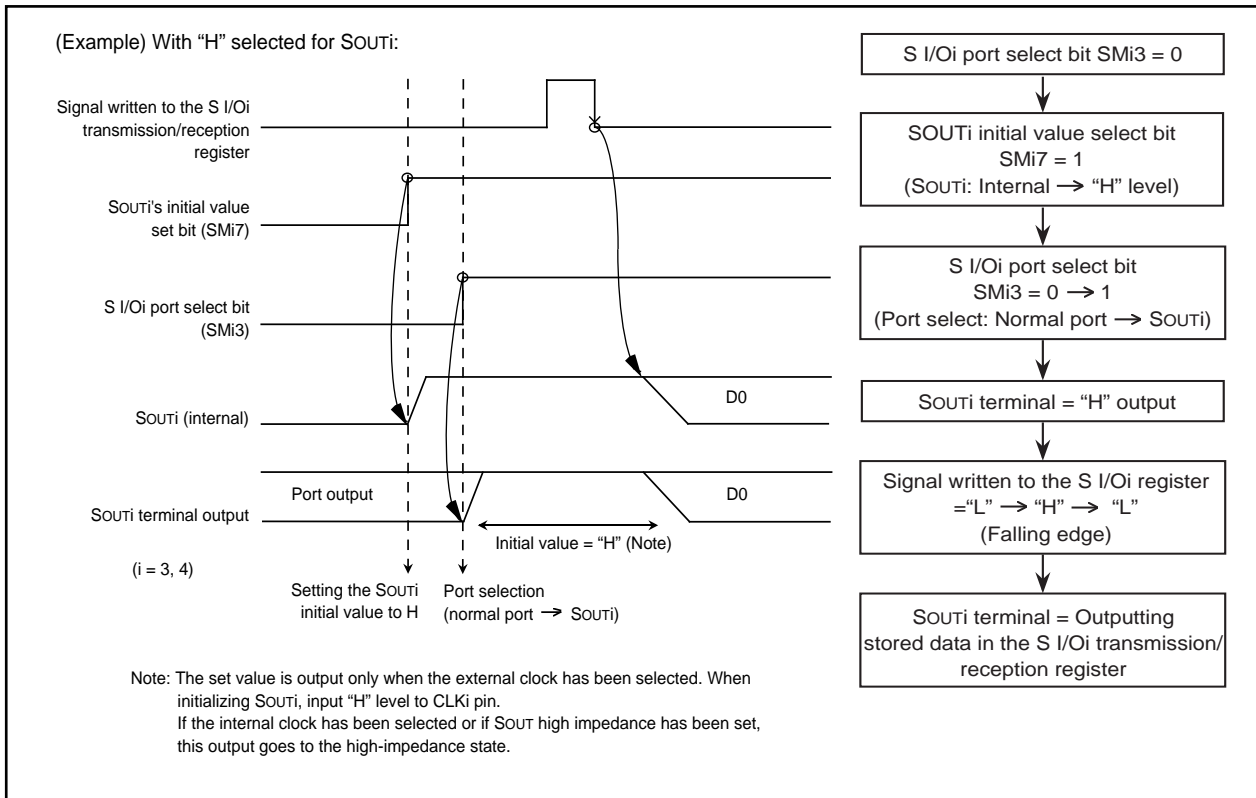


Figure 1.19.31. Timing chart for setting SOUTi’s initial value and how to set it

■ S I/Oi operation timing

Figure 1.19.32 shows the S I/Oi operation timing

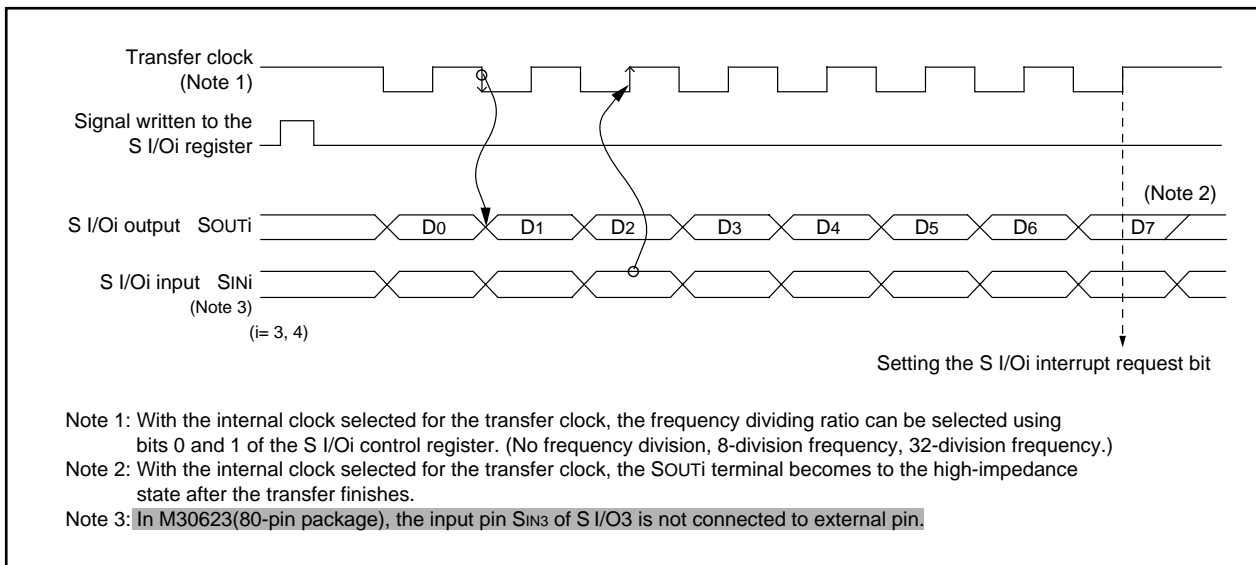


Figure 1.19.32. S I/Oi operation timing chart

A-D Converter

The A-D converter consists of one 10-bit successive approximation A-D converter circuit with a capacitive coupling amplifier. Pins P100 to P107, P95, P96, P00 to P07, and P20 to P27 also function as the analog signal input pins. The direction registers of these pins for A-D conversion must therefore be set to input. The Vref connect bit (bit 5 at address 03D716) can be used to isolate the resistance ladder of the A-D converter from the reference voltage input pin (VREF) when the A-D converter is not used. Doing so stops any current flowing into the resistance ladder from VREF, reducing the power dissipation. When using the A-D converter, start A-D conversion only after setting bit 5 of 03D716 to connect VREF.

The result of A-D conversion is stored in the A-D registers of the selected pins. When set to 10-bit precision, the low 8 bits are stored in the even addresses and the high 2 bits in the odd addresses. When set to 8-bit precision, the low 8 bits are stored in the even addresses.

Table 1.20.1 shows the performance of the A-D converter. Figure 1.20.1 shows the block diagram of the A-D converter, and Figures 1.20.2 and 1.20.3 show the A-D converter-related registers.

Table 1.20.1. Performance of A-D converter

Item	Performance
Method of A-D conversion	Successive approximation (capacitive coupling amplifier)
Analog input voltage (Note 1)	0V to AVCC (VCC)
Operating clock ϕ_{AD} (Note 2)	$f_{AD}/\text{divide-by-2}$ of $f_{AD}/\text{divide-by-4}$ of f_{AD} , $f_{AD}=f(XIN)$ (VCC = 5V)
Resolution	8-bit or 10-bit (selectable)
Absolute precision	<ul style="list-style-type: none"> ● 8-bit resolution $\pm 2\text{LSB}$ ● 10-bit resolution $\pm 3\text{LSB}$ When the extended analog input pins ANEX0, ANEX1, AN00 to AN07, and AN20 to AN27 are used as the external operation amp connection mode: $\pm 7\text{LSB}$
Operating modes	One-shot mode, repeat mode, single sweep mode, repeat sweep mode 0, and repeat sweep mode 1
Analog input pins	8 pins (AN0 to AN7) + 2 pins (ANEX0 and ANEX1) + 16 pins (AN00 to AN07, AN20 to AN27) (Note 3)
A-D conversion start condition	<ul style="list-style-type: none"> • 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 $\overline{ADTRG}/P97$ input changes from "H" to "L"
Conversion speed per pin	<ul style="list-style-type: none"> • Without sample and hold function 8-bit resolution: 49 ϕ_{AD} cycles, 10-bit resolution: 59 ϕ_{AD} cycles • With sample and hold function 8-bit resolution: 28 ϕ_{AD} cycles, 10-bit resolution: 33 ϕ_{AD} cycles

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

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

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

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

Note 3: The pins are not used as the analog input pins can be used as normal I/O ports, or I/O pins of each peripheral function.

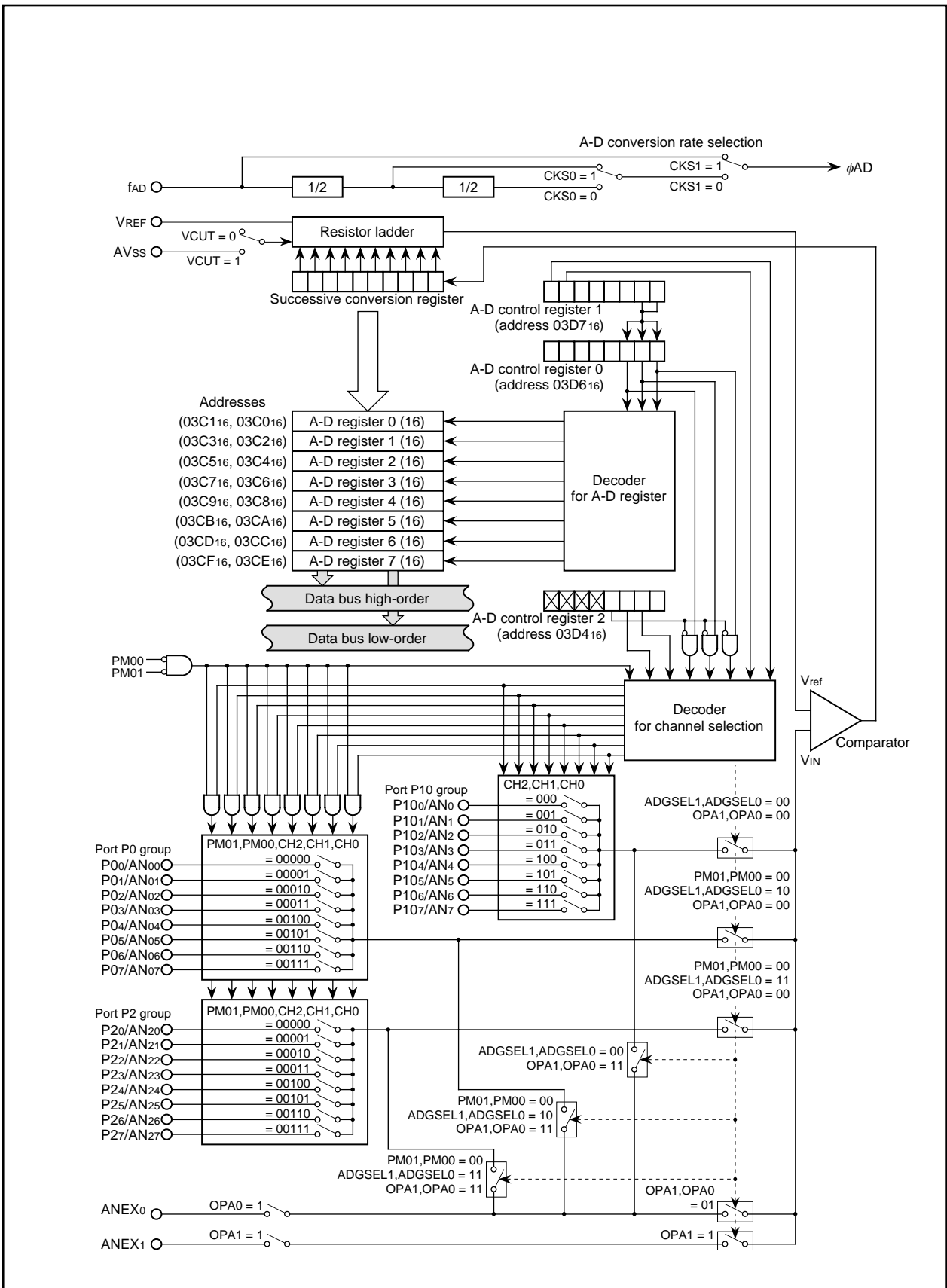


Figure 1.20.1. Block diagram of A-D converter

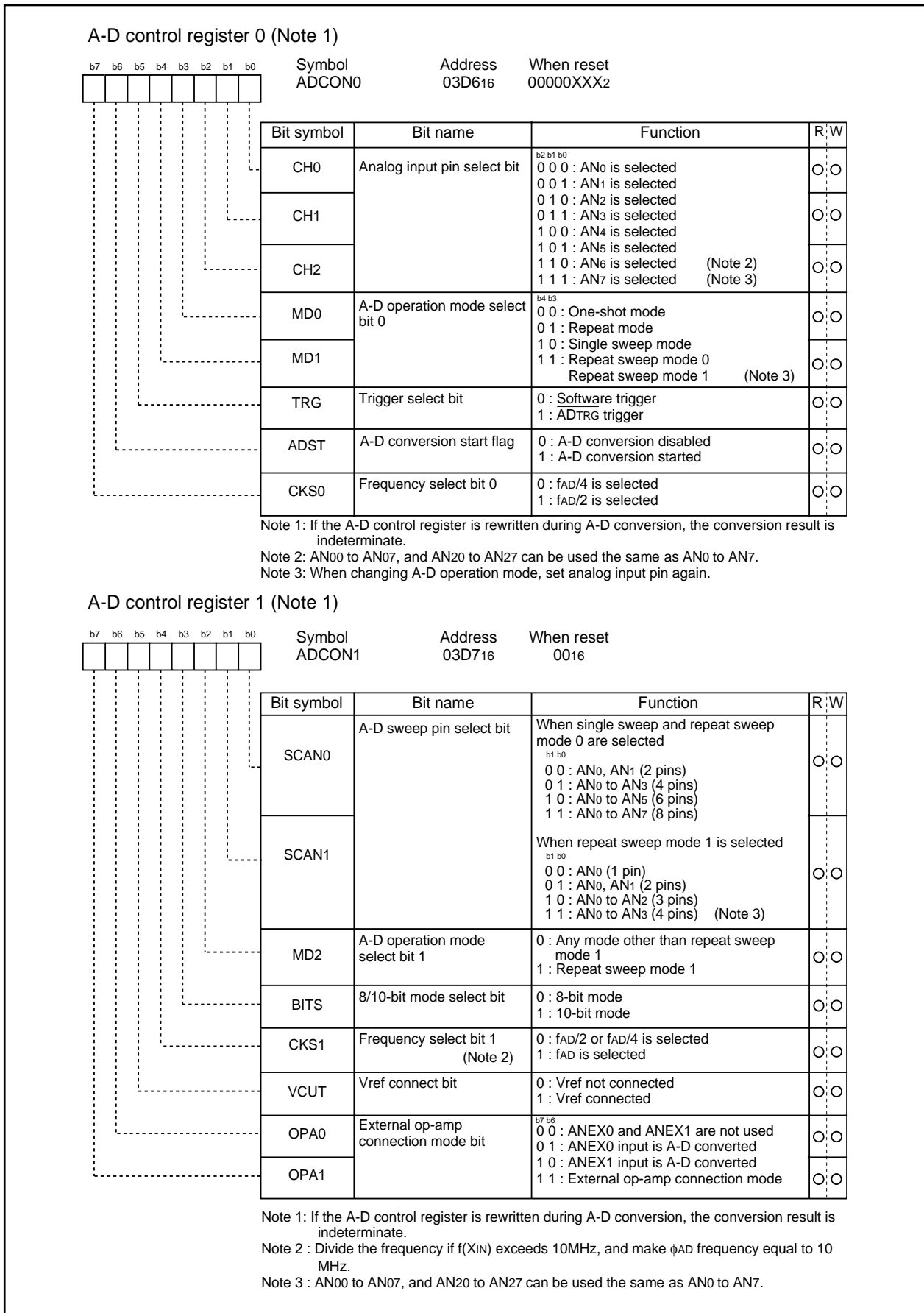


Figure 1.20.2. A-D converter-related registers (1)

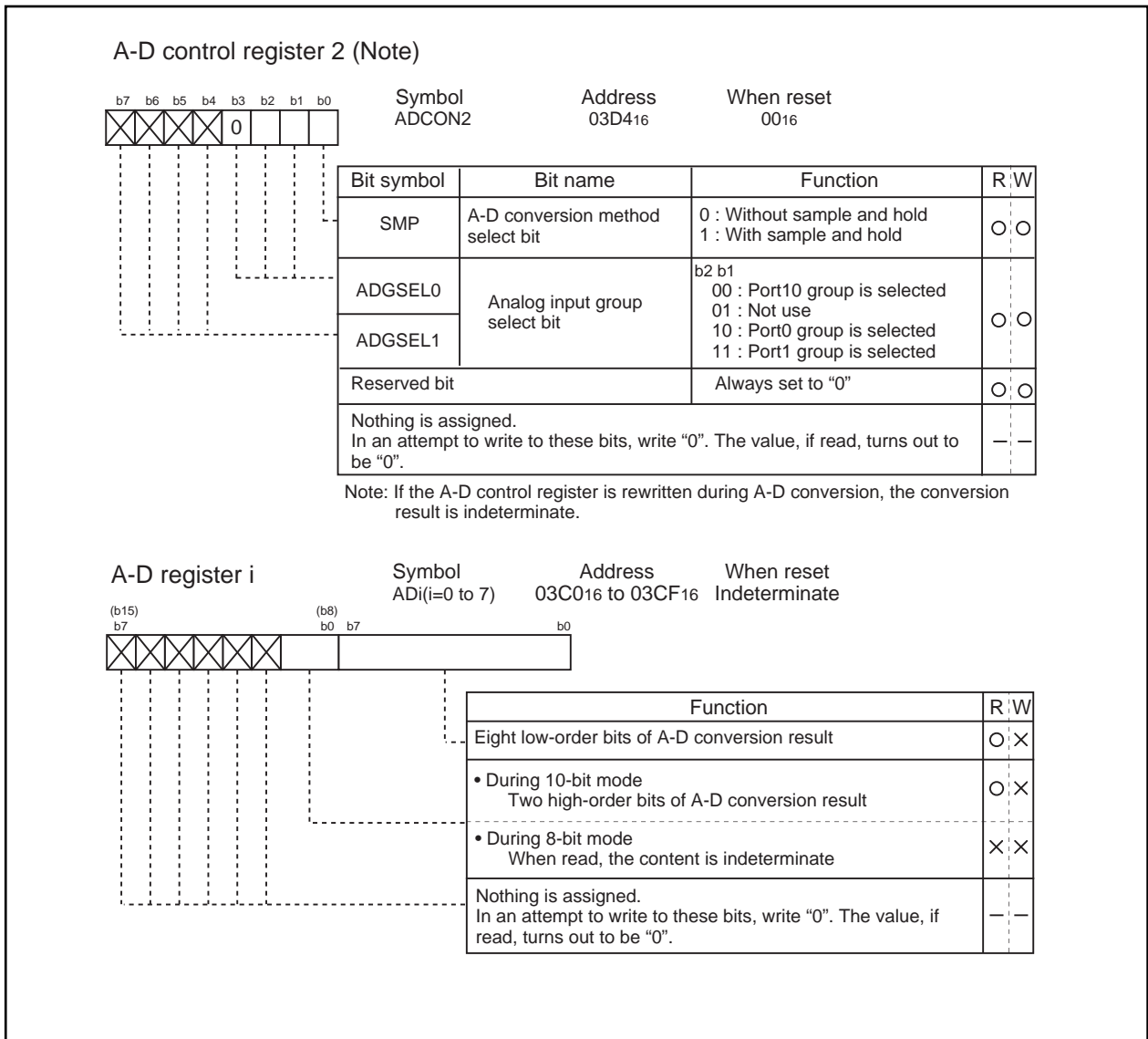


Figure 1.20.3. A-D converter-related registers (2)

(1) One-shot mode

In one-shot mode, the pin selected using the analog input pin select bit is used for one-shot A-D conversion. Table 1.20.2 shows the specifications of one-shot mode. Figure 1.20.4 shows the A-D control register in one-shot mode.

Table 1.20.2. One-shot mode specifications

Item	Specification
Function	The pin selected by the analog input pin select bit is used for one A-D conversion
Start condition	Writing "1" to A-D conversion start flag
Stop condition	<ul style="list-style-type: none"> 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 (Note 1)
Reading of result of A-D converter	Read A-D register corresponding to selected pin

Note 1: AN₀ to AN₇, and AN₂₀ to AN₂₇ can be used the same as AN₀ to AN₇.

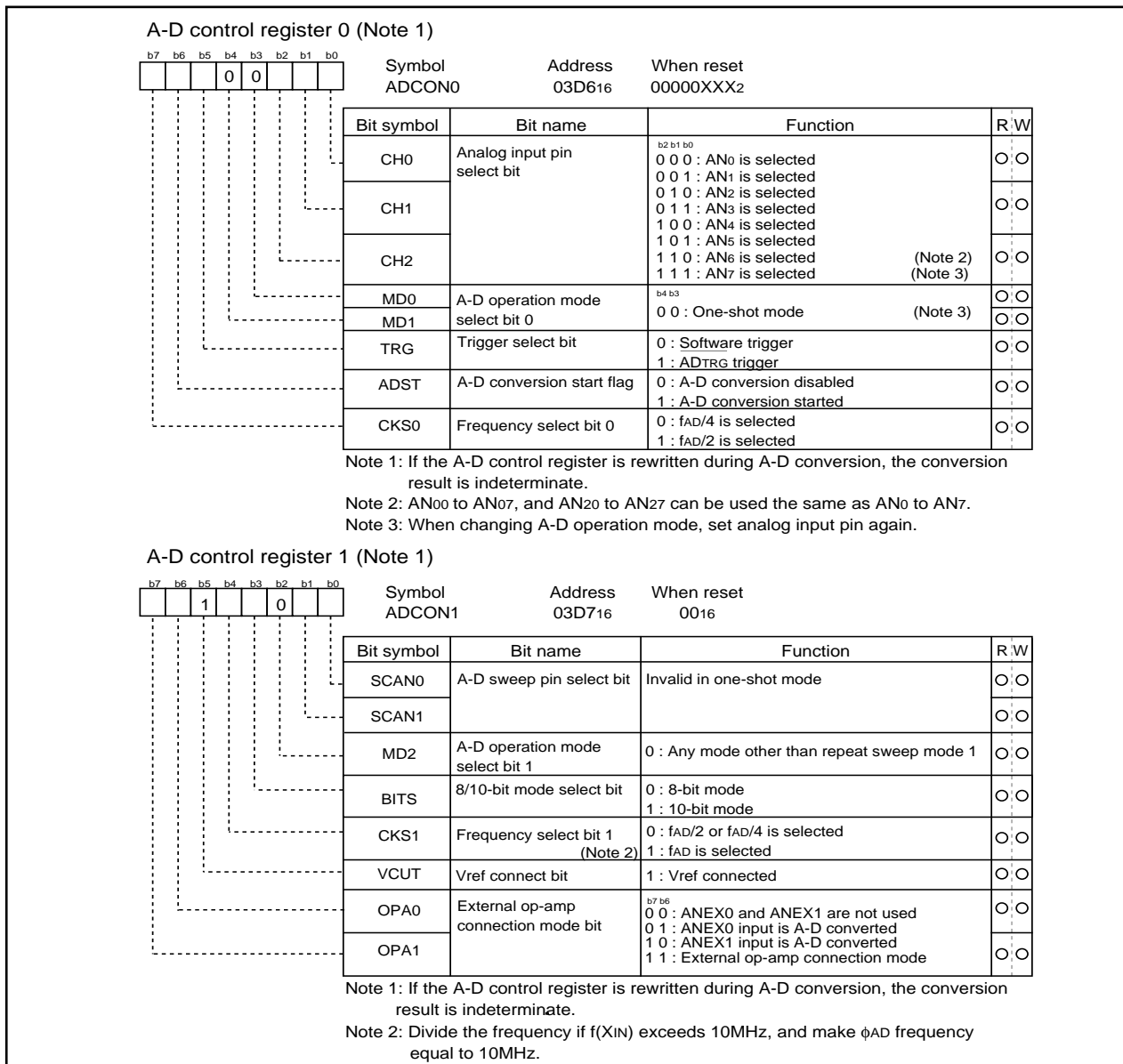


Figure 1.20.4. A-D conversion register in one-shot mode

(2) Repeat mode

In repeat mode, the pin selected using the analog input pin select bit is used for repeated A-D conversion. Table 1.20.3 shows the specifications of repeat mode. Figure 1.20.5 shows the A-D control register in repeat mode.

Table 1.20.3. Repeat mode specifications

Item	Specification
Function	The pin selected by the analog input pin select bit is used for repeated 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	One of AN0 to AN7, as selected (Note 1)
Reading of result of A-D converter	Read A-D register corresponding to selected pin

Note 1: AN0 to AN07, and AN20 to AN27 can be used the same as AN0 to AN7.

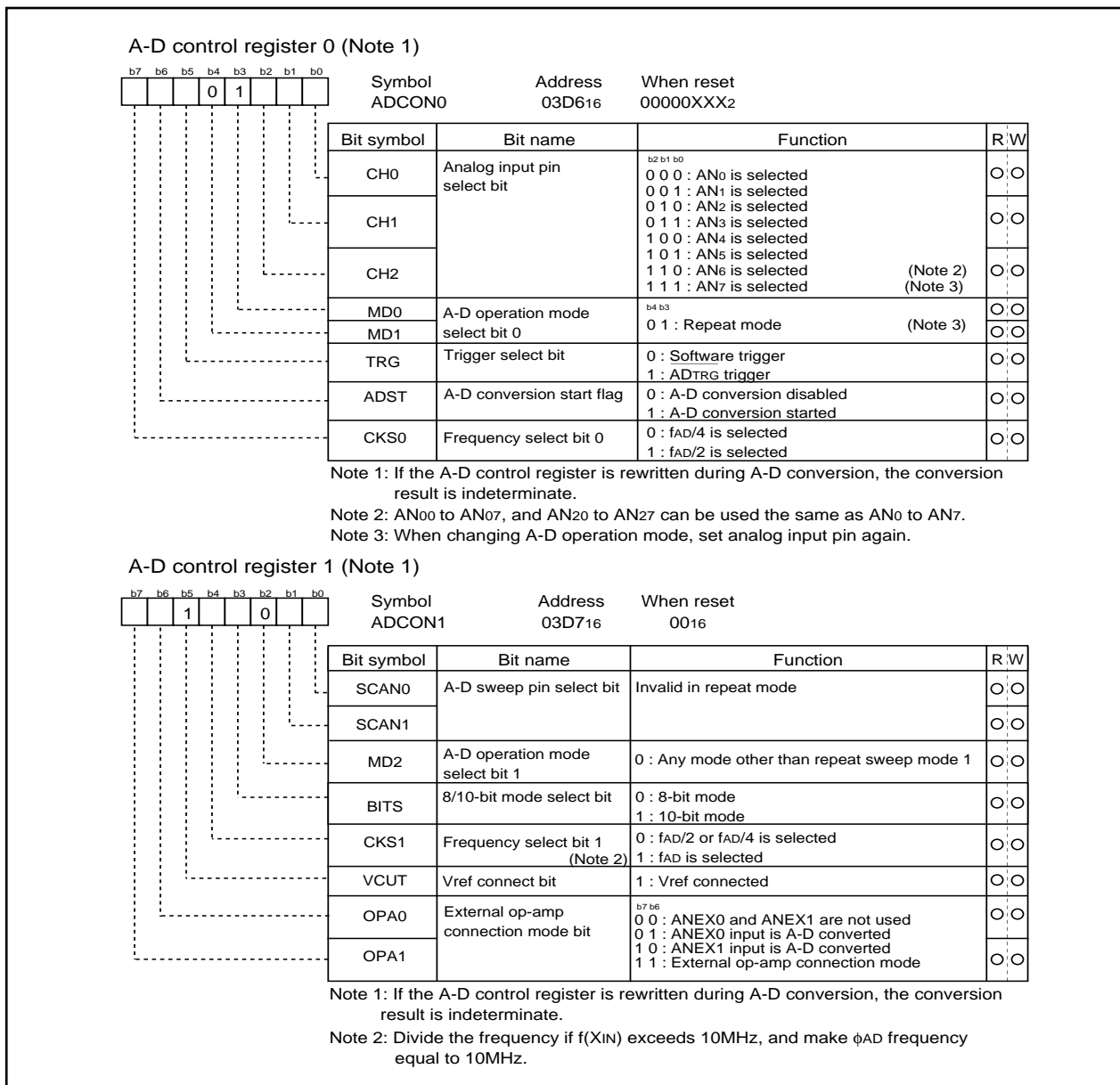


Figure 1.20.5. A-D conversion register in repeat mode

(3) Single sweep mode

In single sweep mode, the pins selected using the A-D sweep pin select bit are used for one-by-one A-D conversion. Table 1.20.4 shows the specifications of single sweep mode. Figure 1.20.6 shows the A-D control register in single sweep mode.

Table 1.20.4. Single sweep mode specifications

Item	Specification
Function	The pins selected by the A-D sweep pin select bit are used for one-by-one A-D conversion
Start condition	Writing "1" to A-D converter start flag
Stop condition	<ul style="list-style-type: none"> 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) (Note 1)
Reading of result of A-D converter	Read A-D register corresponding to selected pin

Note 1: AN₀₀ to AN₀₇, and AN₂₀ to AN₂₇ can be used the same as AN₀ to AN₇.

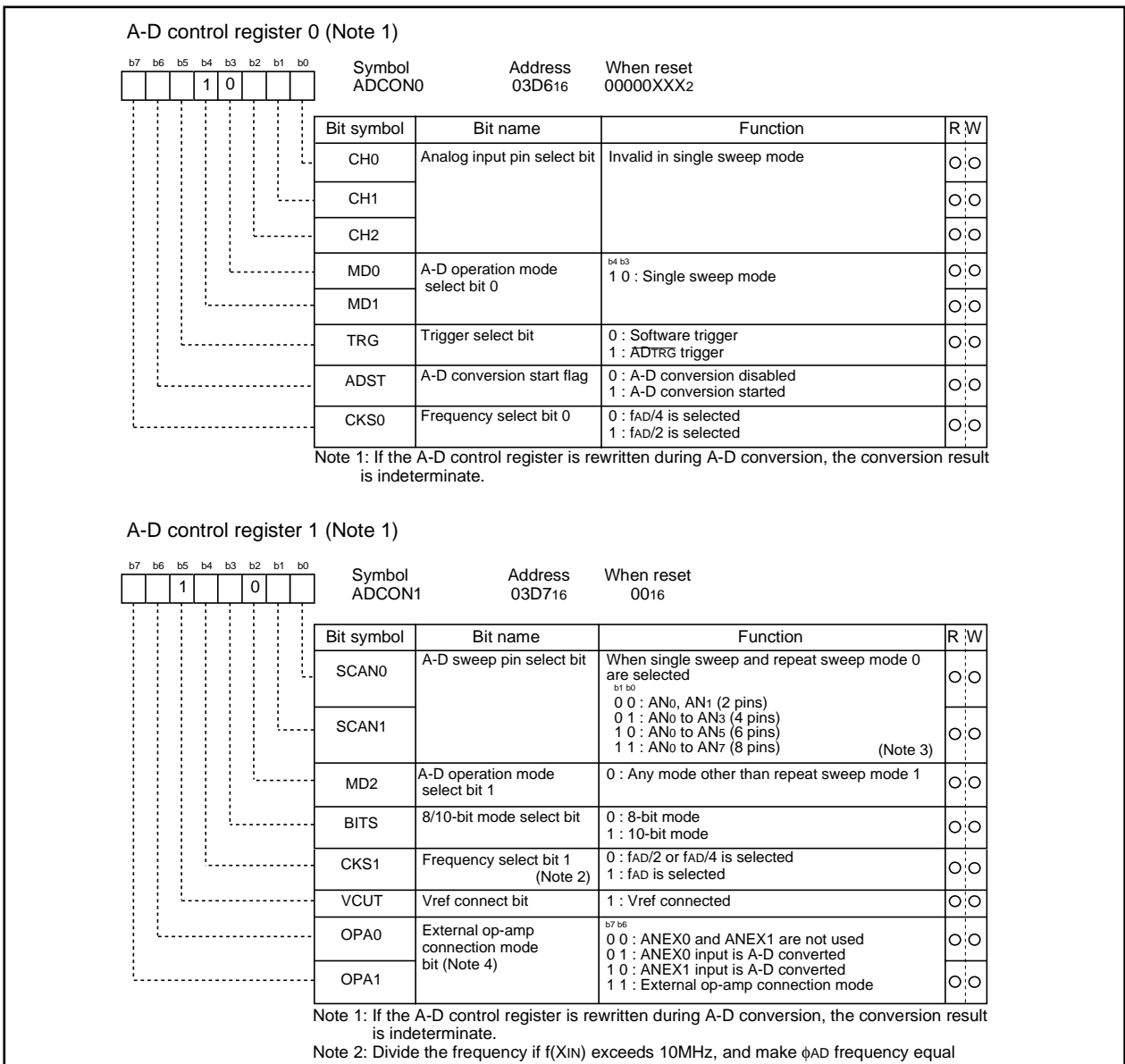


Figure 1.20.6. A-D conversion register in single sweep mode

(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 1.20.5 shows the specifications of repeat sweep mode 0. Figure 1.20.7 shows the A-D control register in repeat sweep mode 0.

Table 1.20.5. 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) (Note 1)
Reading of result of A-D converter	Read A-D register corresponding to selected pin (at any time)

Note 1: AN₀ to AN₇, and AN₂₀ to AN₂₇ can be used the same as AN₀ to AN₇.

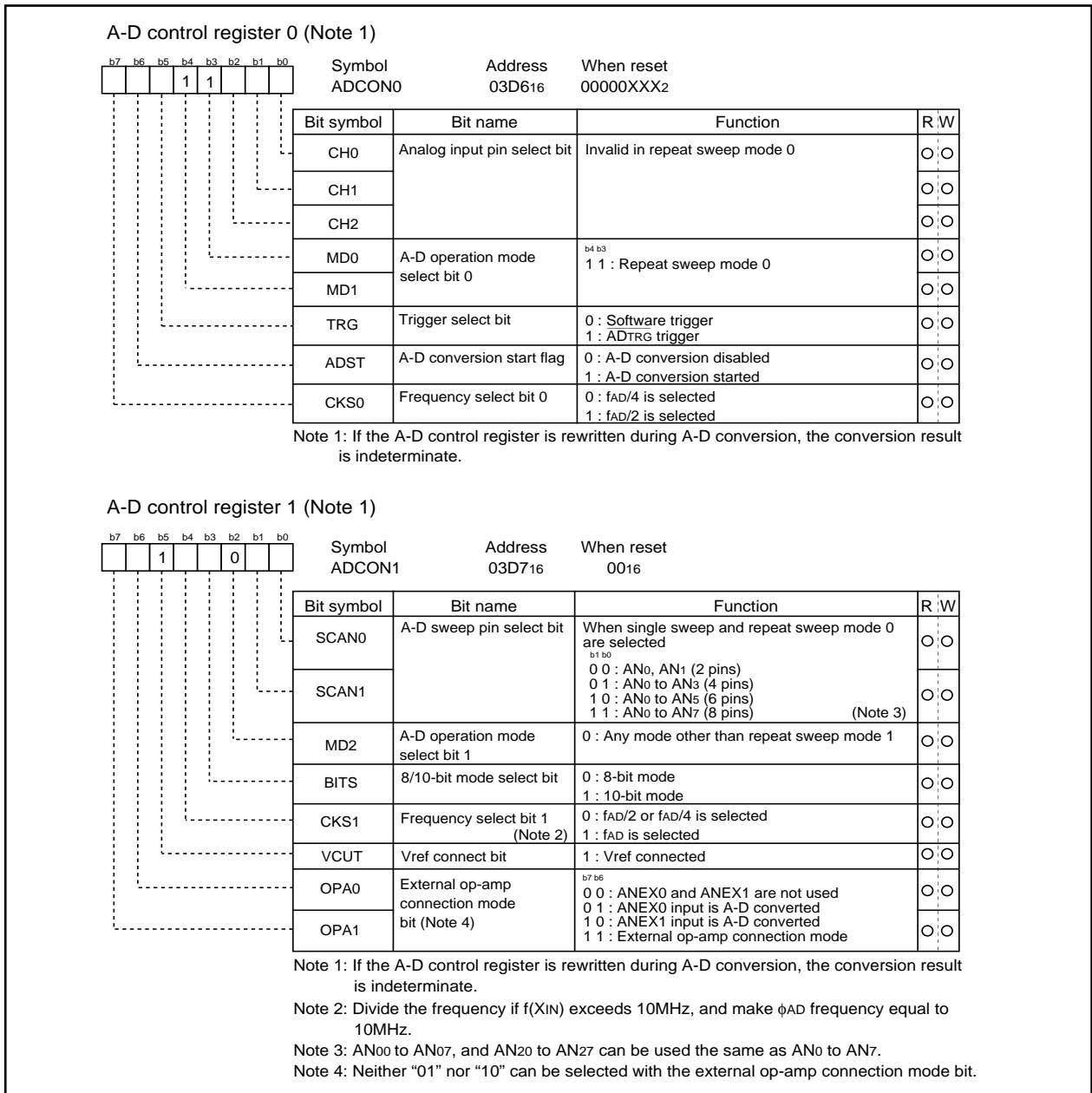


Figure 1.20.7. A-D conversion register in repeat sweep mode 0

(5) Repeat sweep mode 1

In repeat sweep mode 1, all pins are used for A-D conversion with emphasis on the pin or pins selected using the A-D sweep pin select bit. Table 1.20.6 shows the specifications of repeat sweep mode 1. Figure 1.20.8 shows the A-D control register in repeat sweep mode 1.

Table 1.20.6. 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 → AN ₁ → AN ₀ → AN ₂ → AN ₀ → AN ₃ , etc
Start condition	Writing "1" to A-D conversion start flag
Stop condition	Writing "0" to A-D conversion start flag
Interrupt request generation timing	None generated
Input pin	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) (Note 1)
Reading of result of A-D converter	Read A-D register corresponding to selected pin (at any time)

Note 1: AN₀₀ to AN₀₇, and AN₂₀ to AN₂₇ can be used the same as AN₀ to AN₇.

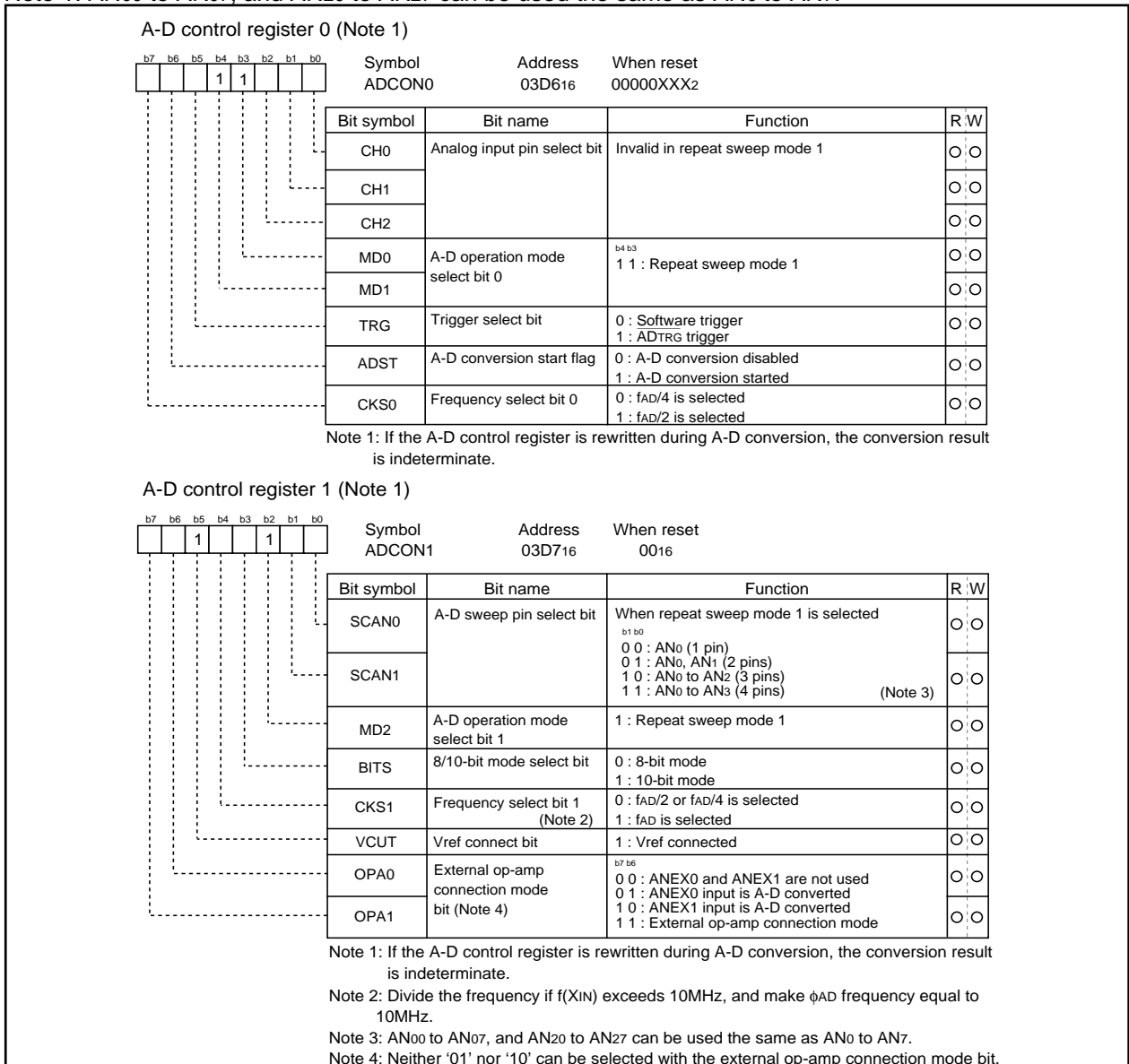


Figure 1.20.8. A-D conversion register in repeat sweep mode 1

(a) Sample and hold

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

(b) Extended analog input pins

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

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

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

Furthermore, the input via 16pins of the extended analog input pins AN00 to AN07, AN20 to AN27 can be converted from analog to digital. These pins can be used the same as AN0 to AN7.

Use the A-D control register 2 (address 03D416) bit 1 and bit 2 to select the pin group AN0 to AN7, AN00 to AN07, AN20 to AN27.

In the selected pin group, the pins is not used as the analog input pin, can be used as normal I/O ports, or I/O pins of each peripheral function.

(c) External operation amp connection mode

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

When bit 6 of the A-D control register 1 (address 03D716) is "1" and bit 7 is "1", input via AN0 to AN7(Note 1) is output from ANEX0. The input from ANEX1 is converted from analog to digital and the result stored in the corresponding A-D register. The speed of A-D conversion depends on the response of the external operation amp. Do not connect the ANEX0 and ANEX1 pins directly. Figure 1.20.9 is an example of how to connect the pins in external operation amp mode.

Note 1: AN00 to AN07, AN20 to AN27 can be used the same as AN0 to AN7.

(d) Caution of using A-D converter

- (1) Set the direction register of the following ports to input: the port corresponding to a pin to be used as an analog input pin and external trigger input pin(P97).
- (2) In using a key-input interrupt, none of 4 pins (AN4 through AN7) can be used as an A-D conversion port (if the A-D input voltage goes to "L" level, a key-input interrupt occurs).
- (3) Insert the capacitor between AVcc and AVss, between VREF and AVss, and between the analog input pin (ANi) and AVss, to prevent a malfunction or program runaway, and to reduce conversion error, due to noise. Figure 1.20.10 is an example connection of each pin.

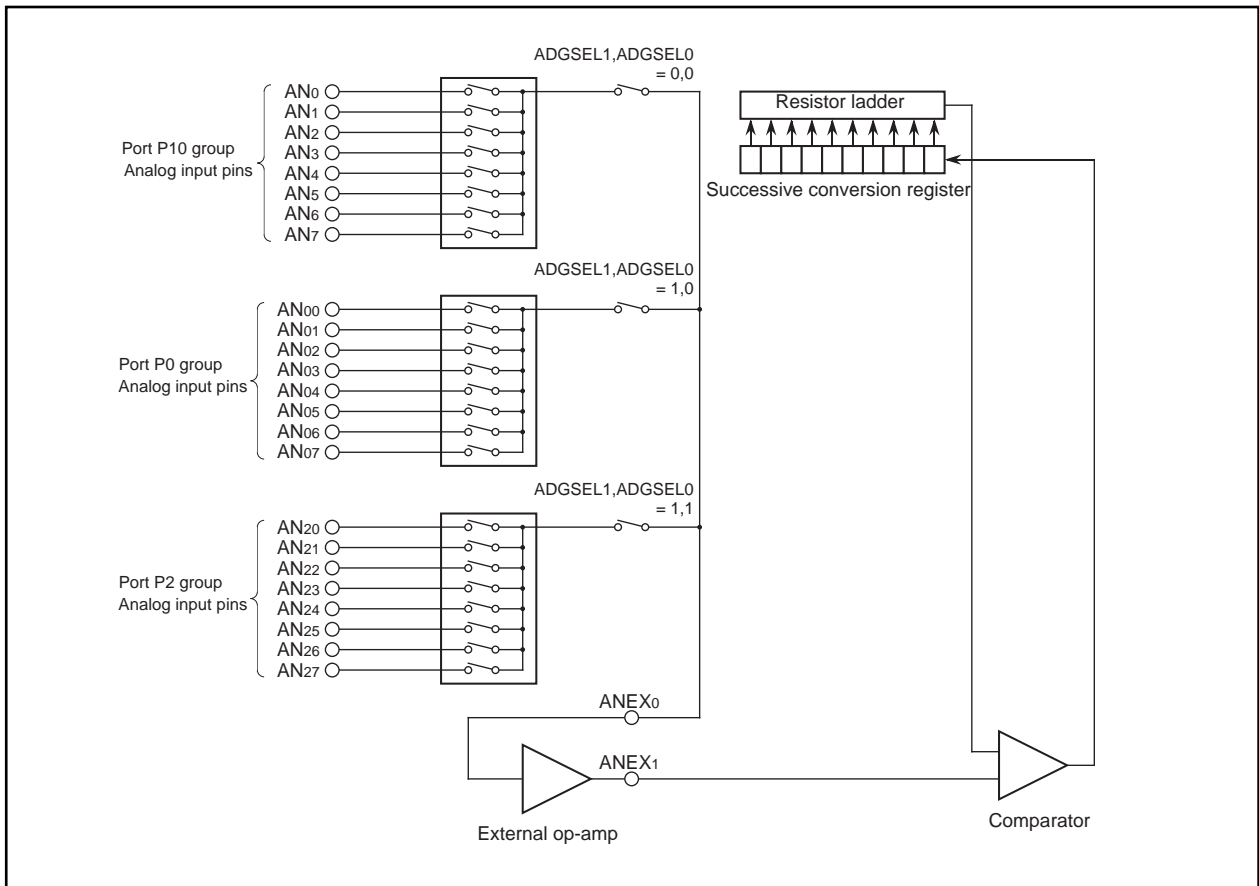


Figure 1.20.9. Example of external op-amp connection mode

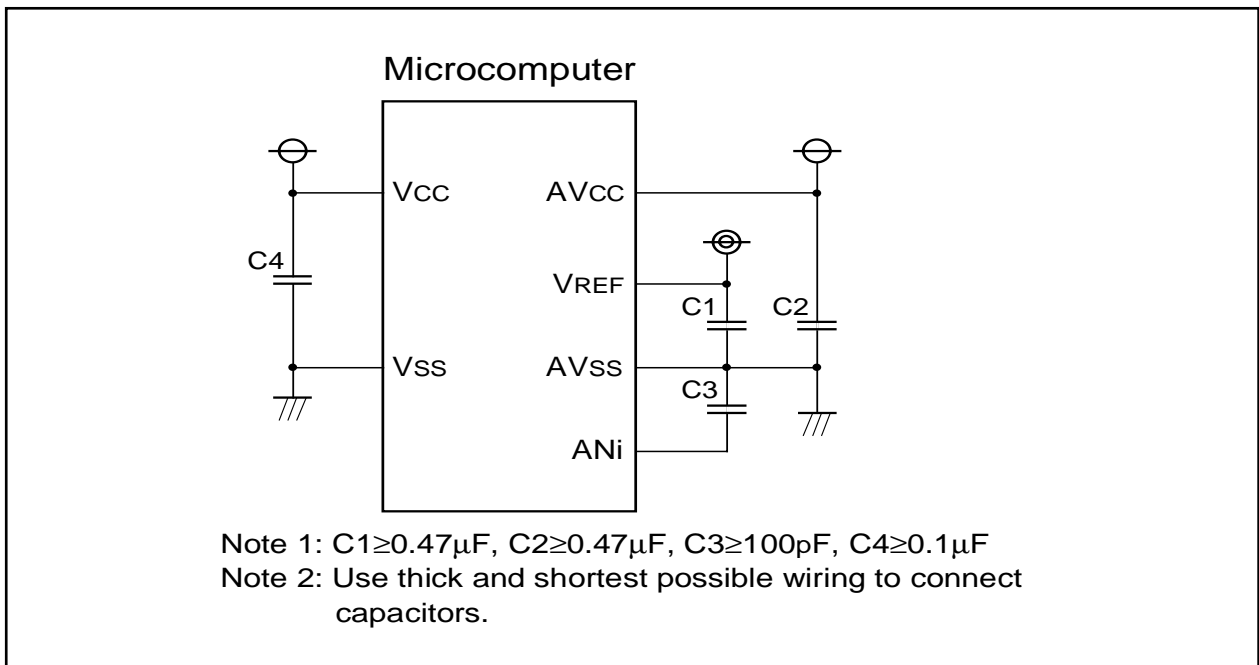


Figure 1.20.10. Example connection of Vcc, Vss, AVcc, AVss, VREF and ANi

D-A Converter

D-A Converter

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

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

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

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

V_{REF} : reference voltage

Table 1.21.1 lists the performance of the D-A converter. Figure 1.21.1 shows the block diagram of the D-A converter. Figure 1.21.2 shows the D-A control register. Figure 1.21.3 shows the D-A converter equivalent circuit.

Table 1.21.1. Performance of D-A converter

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

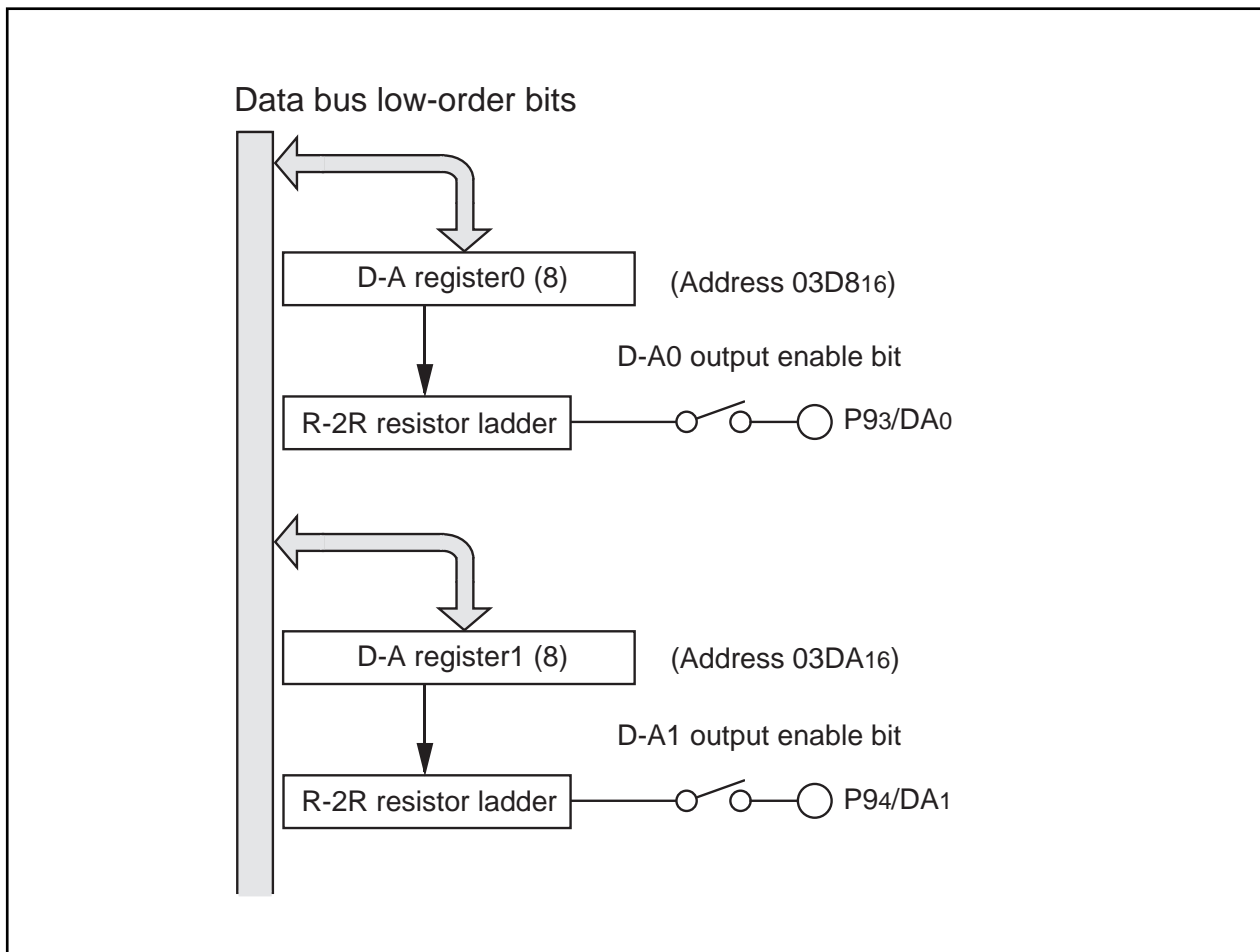


Figure 1.21.1. Block diagram of D-A converter

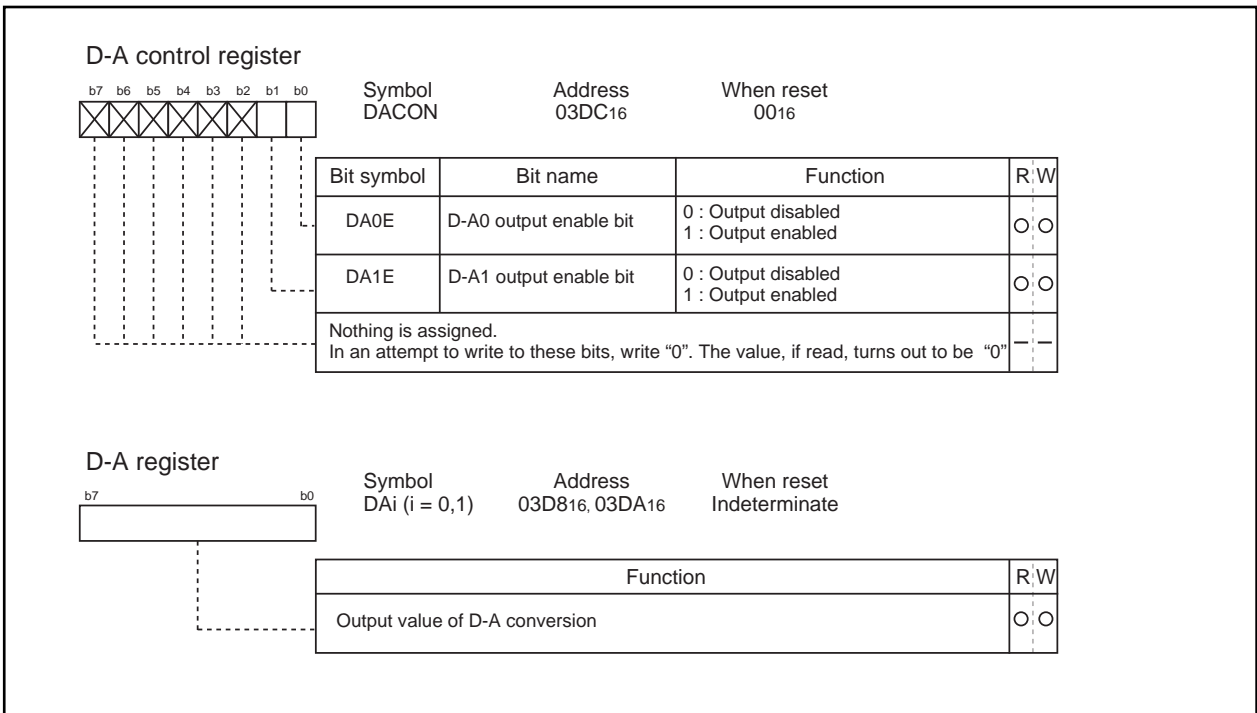


Figure 1.21.2. D-A control register

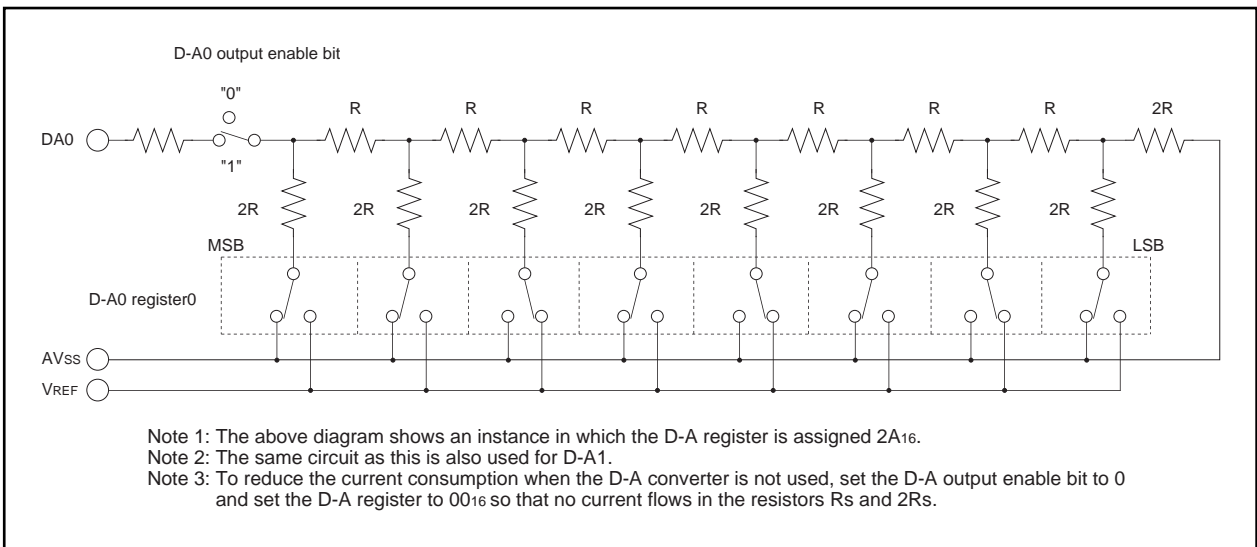


Figure 1.21.3. D-A converter equivalent circuit

CRC Calculation Circuit

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

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

Figure 1.22.1 shows the block diagram of the CRC circuit. Figure 1.22.2 shows the CRC-related registers. Figure 1.22.3 shows the calculation example using the CRC calculation circuit

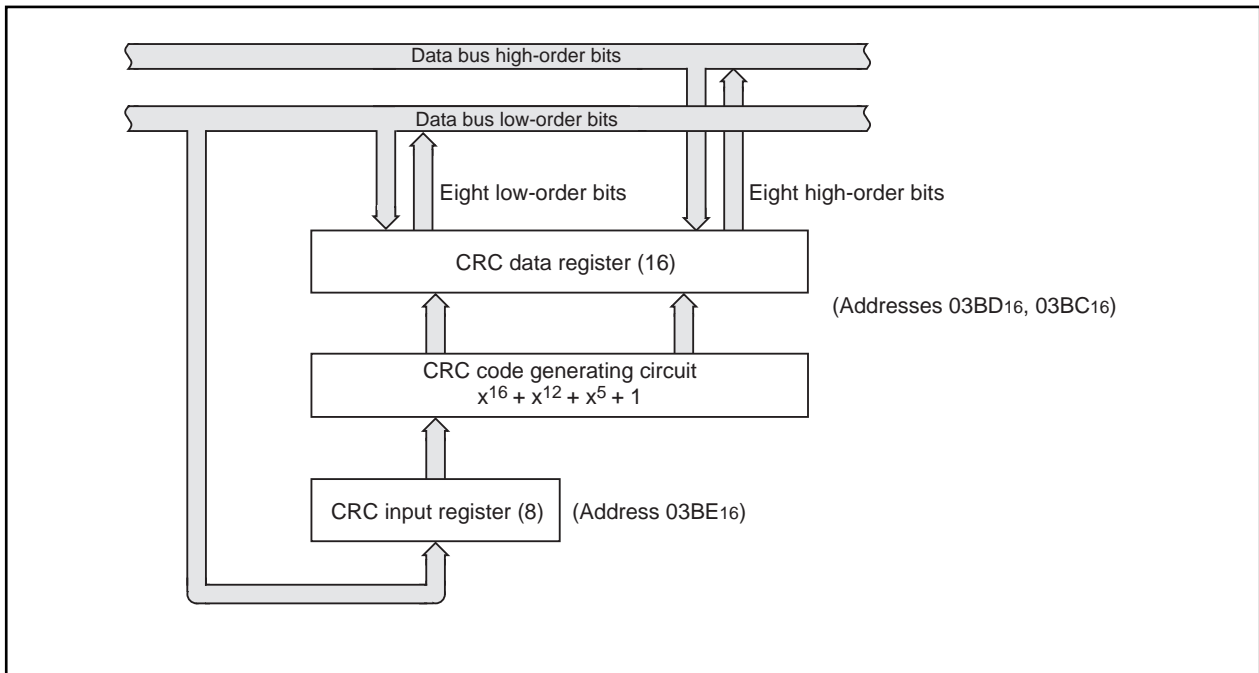


Figure 1.22.1. Block diagram of CRC circuit

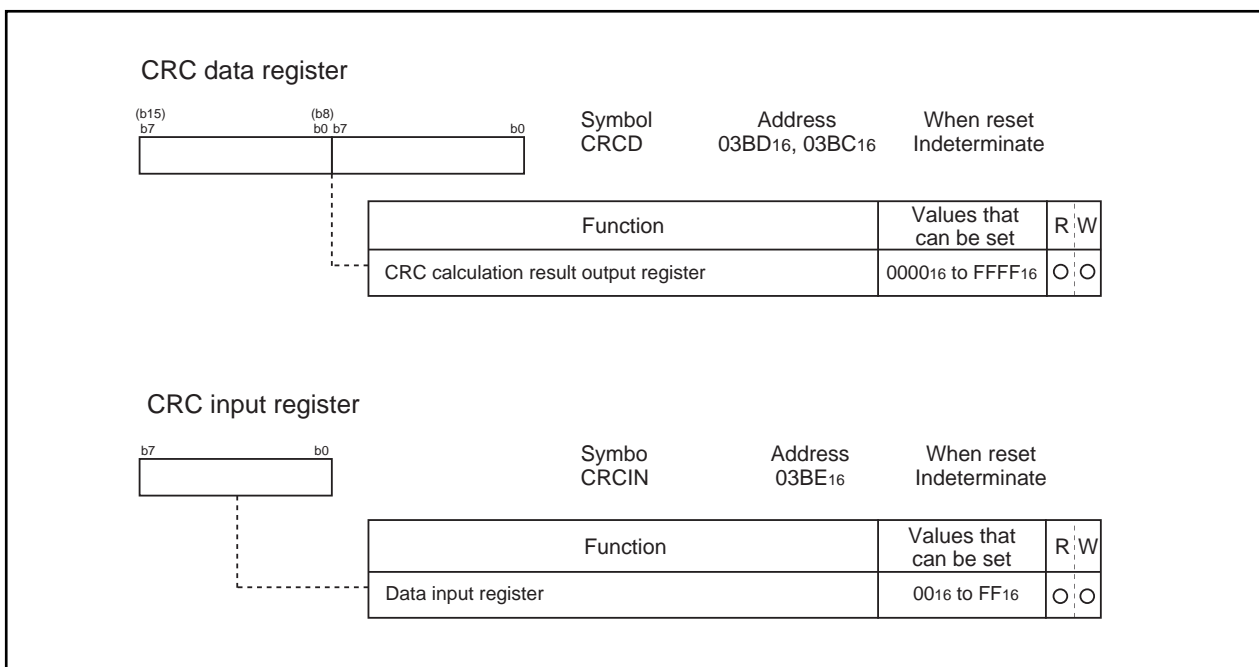


Figure 1.22.2. CRC-related registers

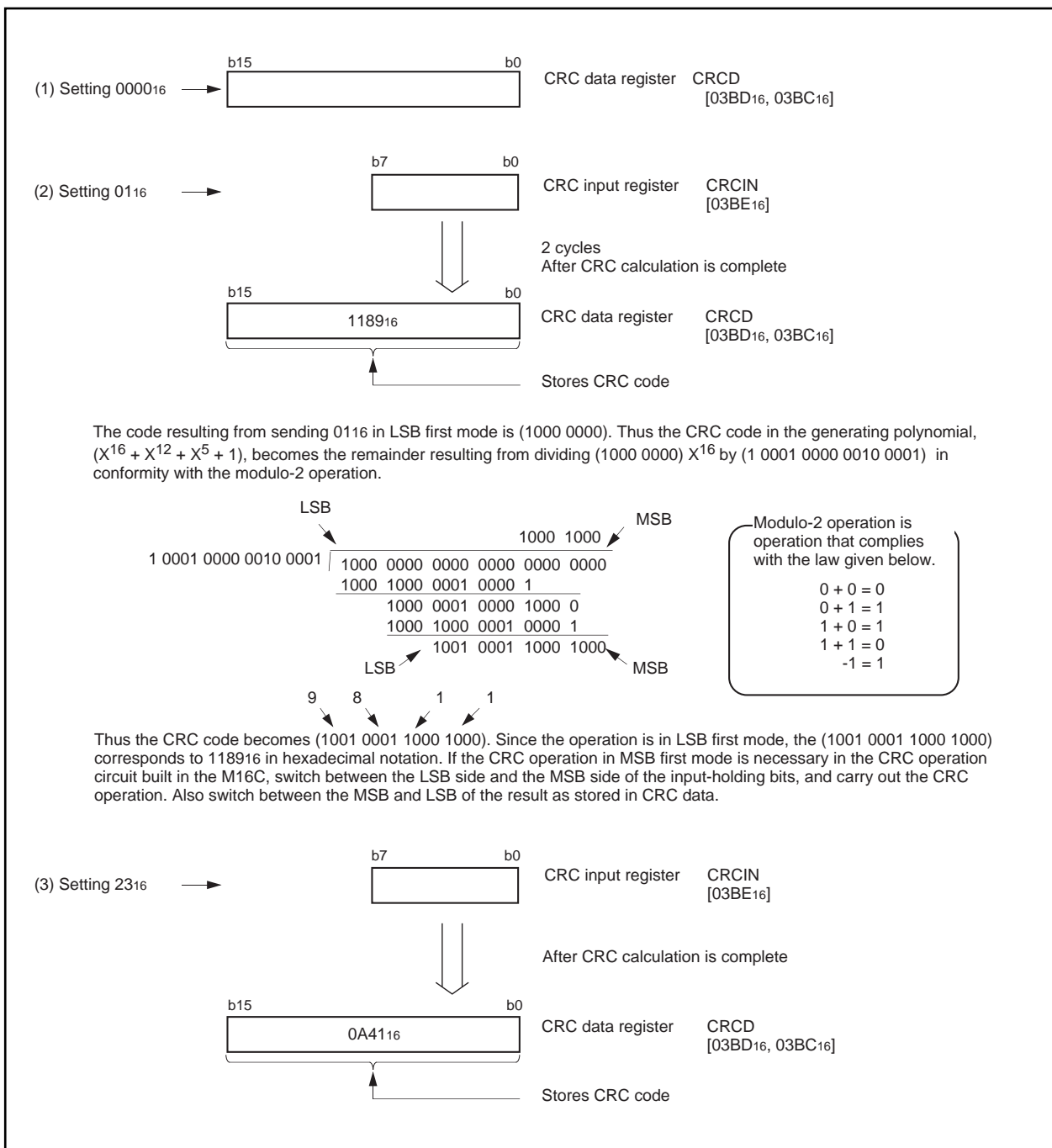


Figure 1.22.3. Calculation example using the CRC calculation circuit

Programmable I/O Ports

M30622(100-pin package) has 87 programmable I/O ports: P0 to P10 (excluding P85). M30623(80-pin package) has 70 (P1, P4₄ to P4₇, P7₂ to P7₅, P9₁ are not connected to external pin).

Each port can be set independently for input or output using the direction register. A pull-up resistance for each block of 4 ports can be set. P85 is an input-only port and has no built-in pull-up resistance.

Figures 1.23.1 to 1.23.3 show the programmable I/O ports. Figure 1.23.4 shows the I/O pins.

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

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

(1) Direction registers

Figure 1.23.5 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 P85.

(2) Port registers

Figure 1.23.6 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 1.23.7 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.

(4) Port control register

Figure 1.23.8 shows the port control register.

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

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

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

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

This register is valid in the following:

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

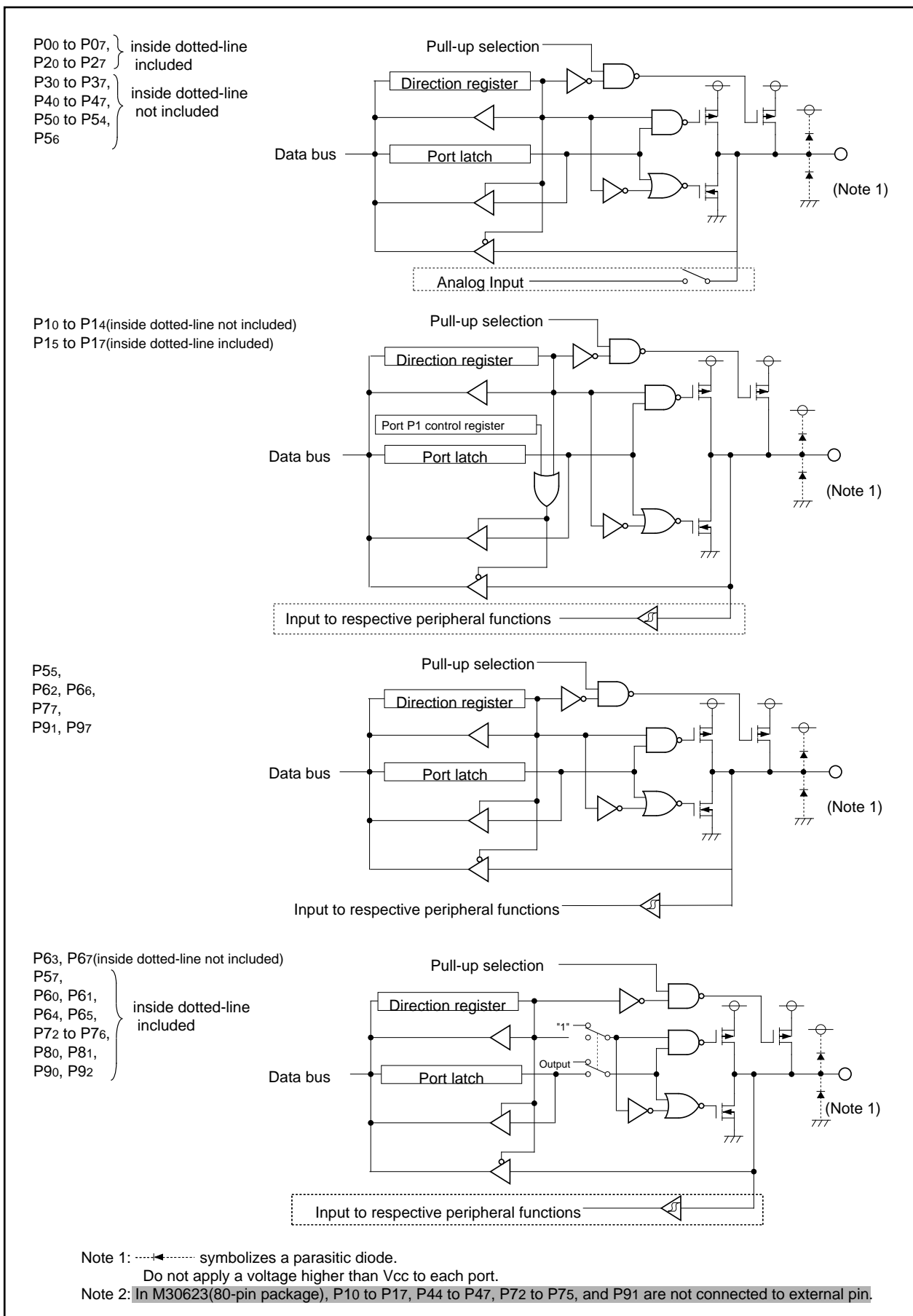


Figure 1.23.1. Programmable I/O ports (1)

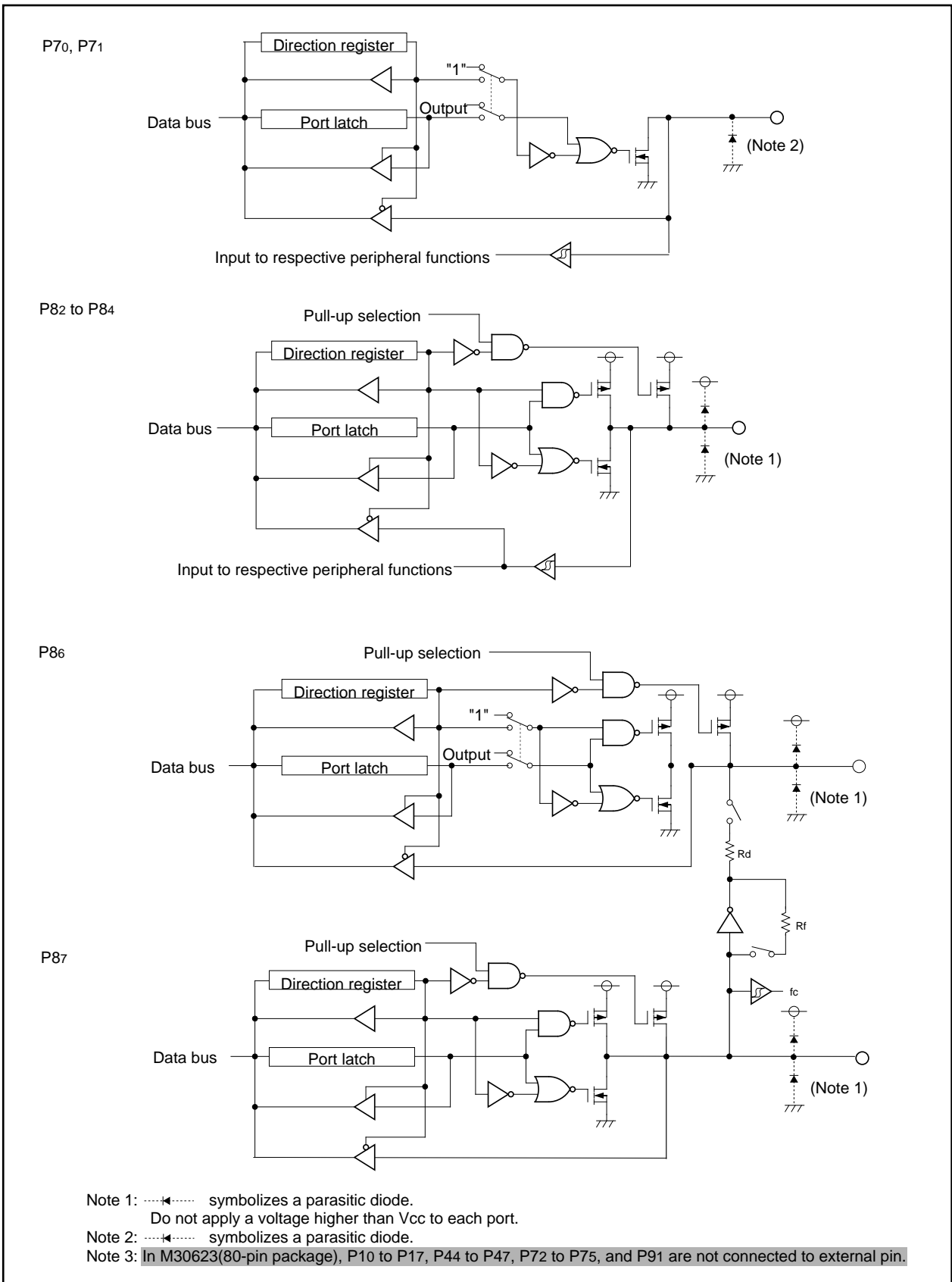


Figure 1.23.2. Programmable I/O ports (2)

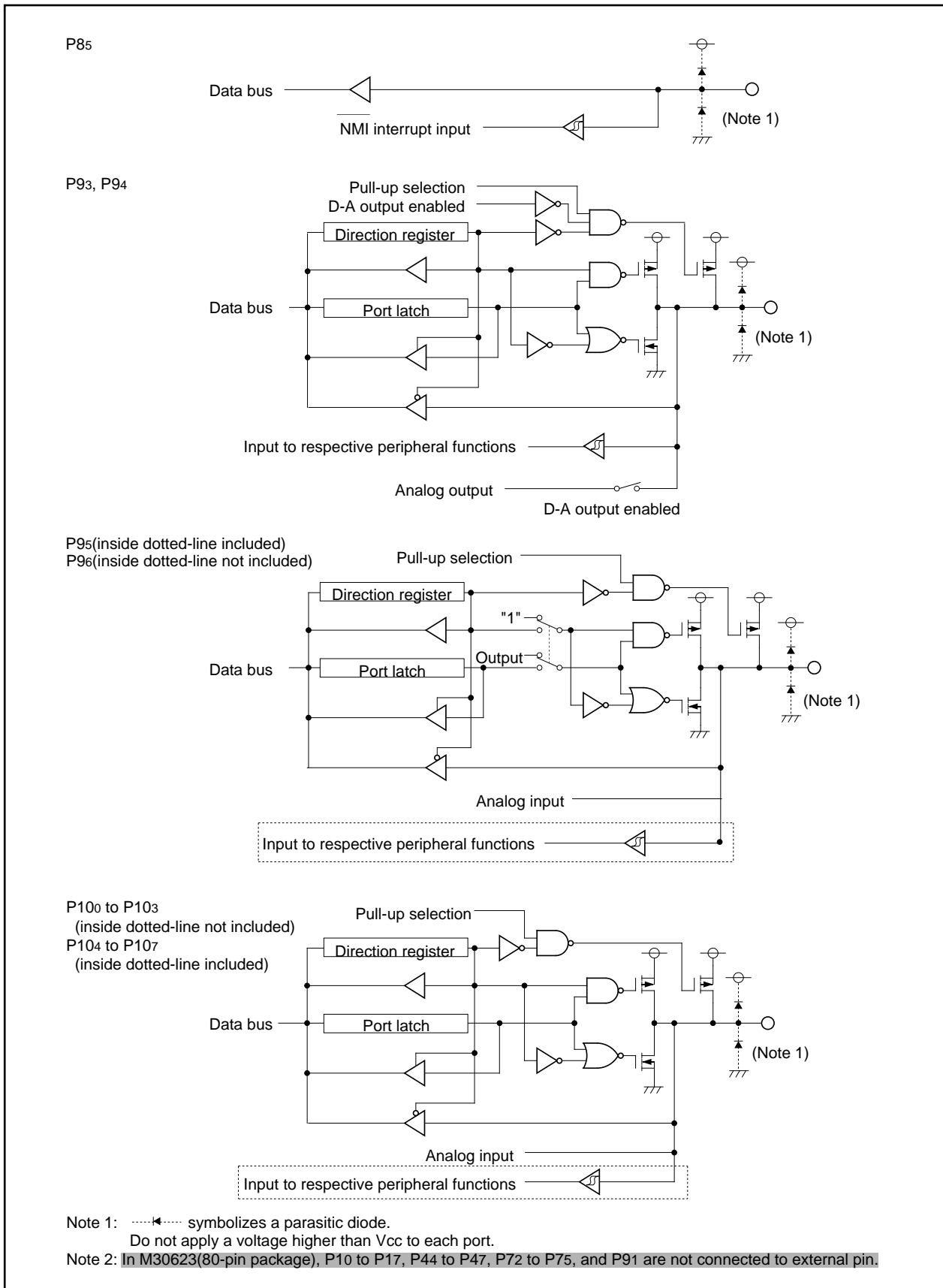


Figure 1.23.3. Programmable I/O ports (3)

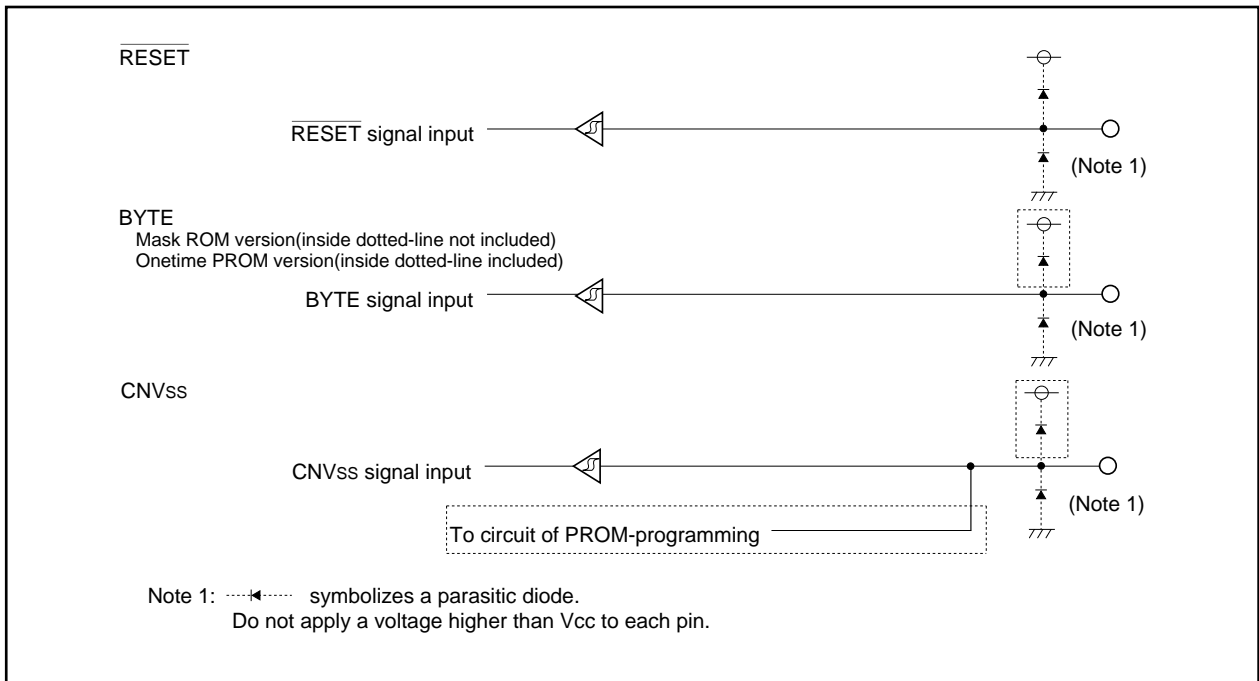


Figure 1.23.4. I/O pins

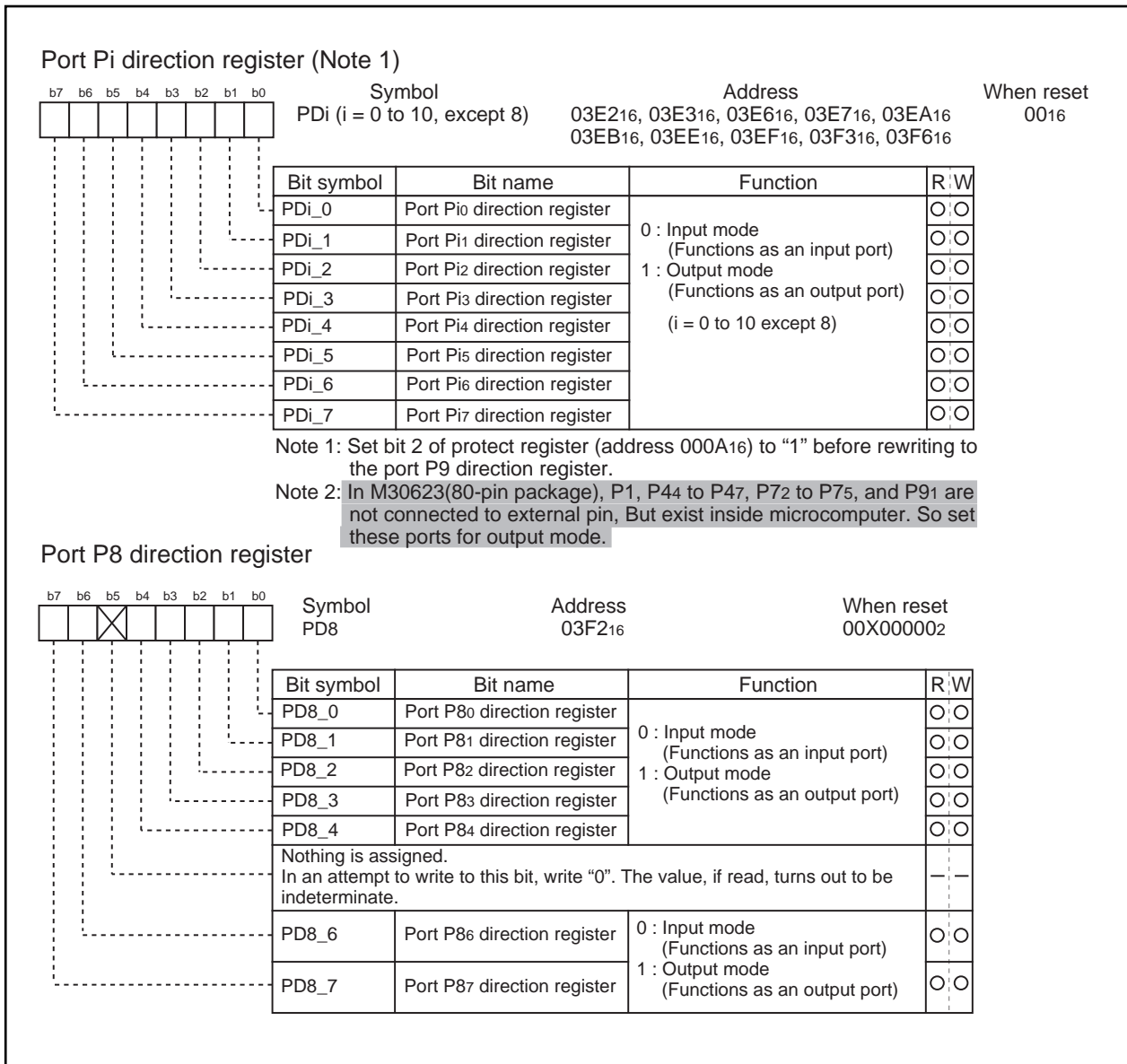


Figure 1.23.5. Direction register

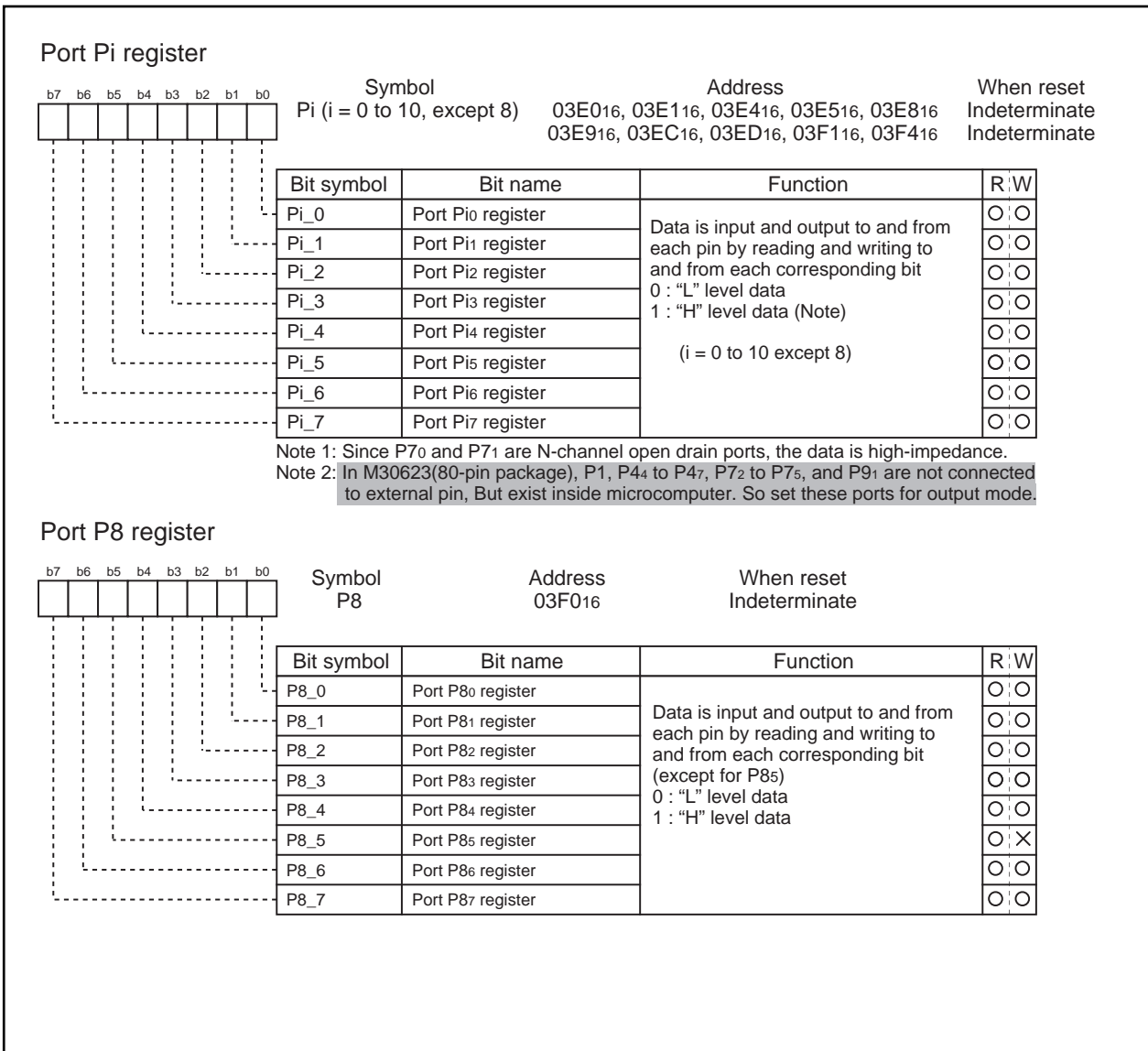


Figure 1.23.6. Port register

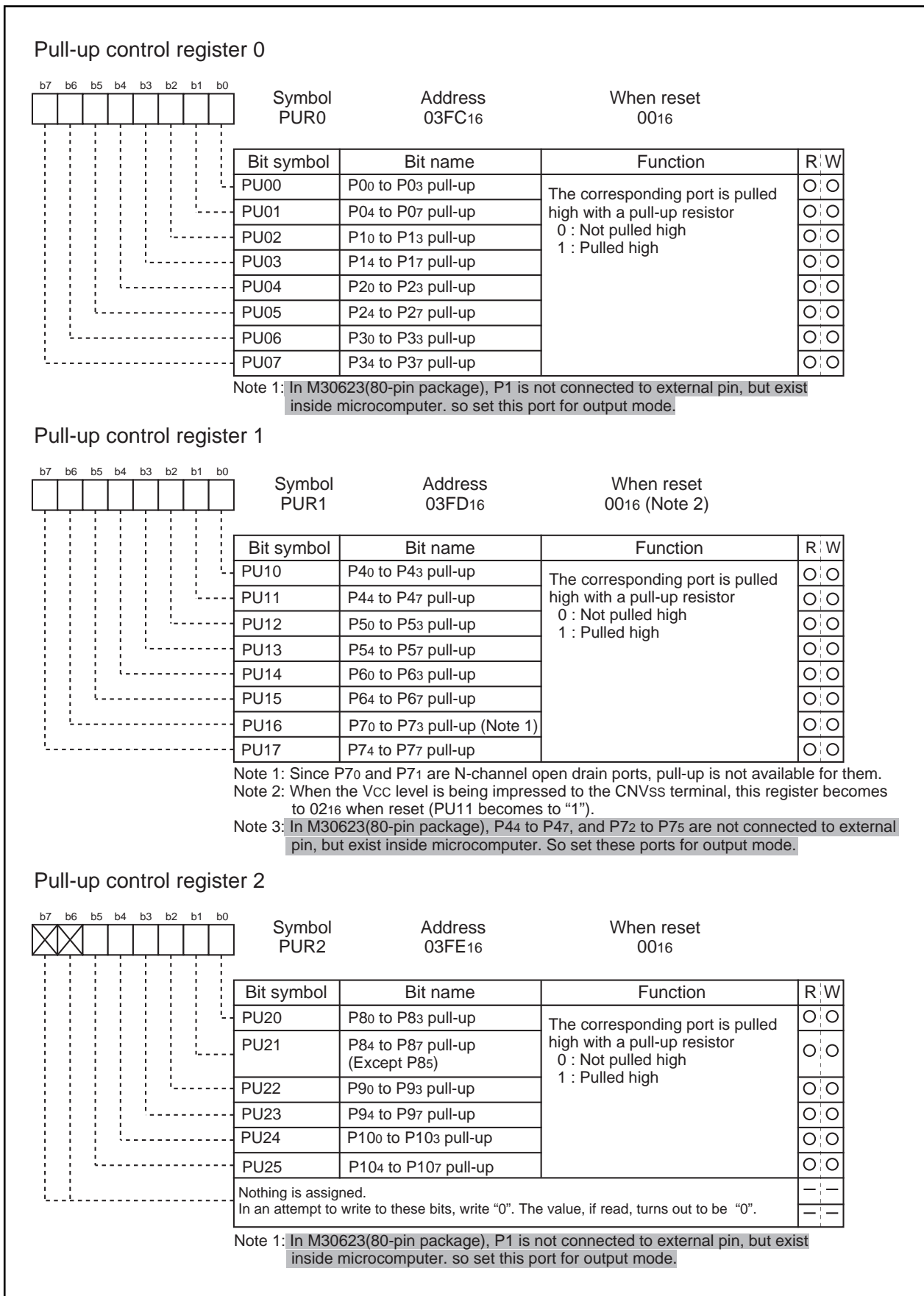


Figure 1.23.7. Pull-up control register

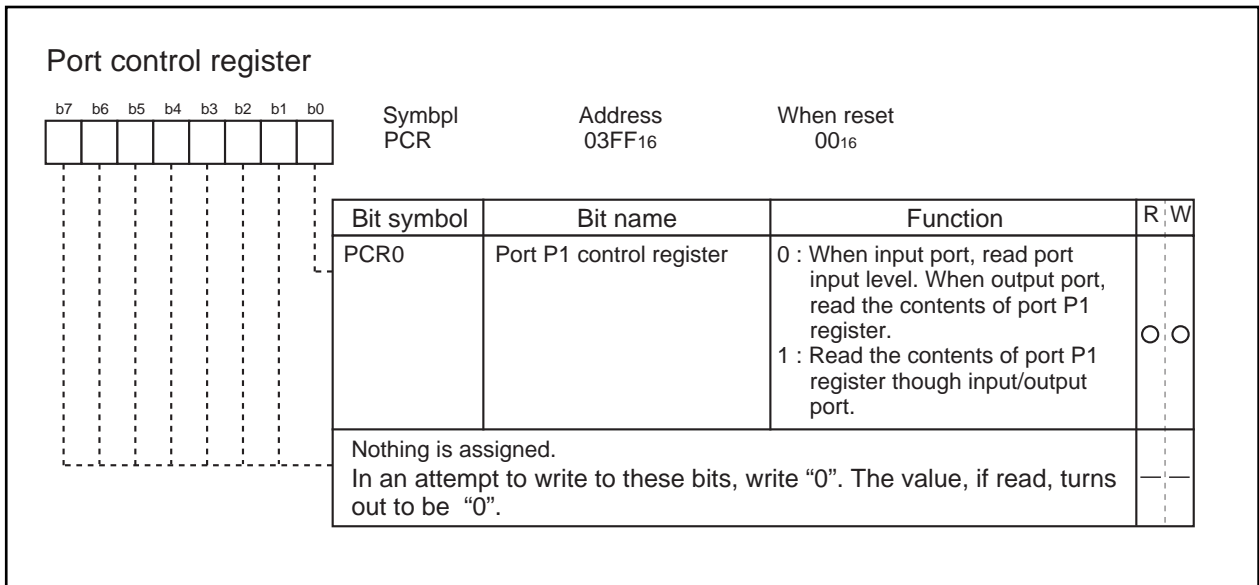


Figure 1.23.8. Port control register

Table 1.23.1. Example connection of unused pins in single-chip mode

Pin name	Connection
Ports P0 to P10 (excluding P85) (Note 1)	After setting for input mode, connect every pin to Vss or Vcc via a resistor; or after setting for output mode, leave these pins open.
XOUT (Note 2)	Open
NMI	Connect via resistor to Vcc (pull-up)
AVcc	Connect to Vcc
AVss, VREF, BYTE	Connect to Vss

Note 1: In M30623(80-pin package), P1, P44 to P47, P72 to P75, and P91 are not connected to external pin, but exist inside microcomputer. So set these ports for output mode.

Note 2: With external clock input to XIN pin.

Table 1.23.2. Example connection of unused pins in memory expansion mode and microprocessor mode

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

Note 1: In M30623(80-pin package), P72 to P75, P91 are not connected to external pin, but exist inside microcomputer. So set these ports for output mode.

Note 2: With external clock input to XIN pin.

Note 3: The M16C/62T group is not guaranteed to operate in memory expansion and microprocessor modes.

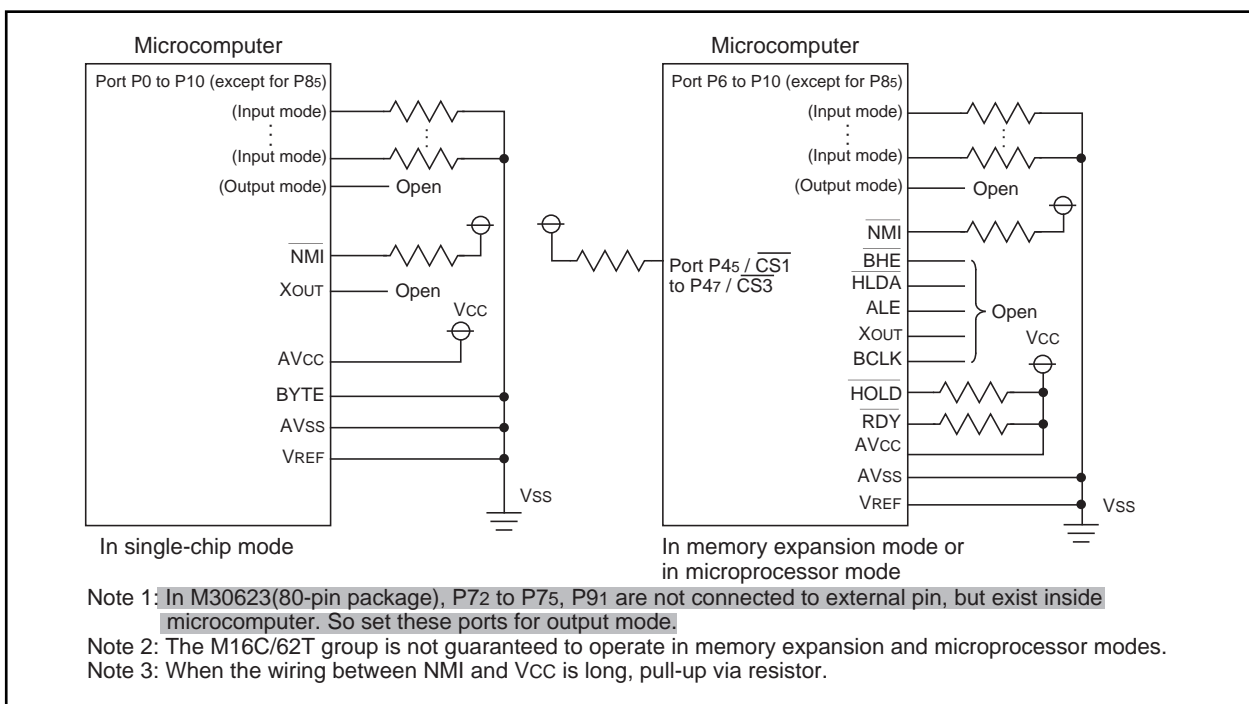


Figure 1.23.9. Example connection of unused pins

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 "FFFF₁₆". Reading the timer Ai register after setting a value in the timer Ai register with a count halted but before the counter starts counting gets a proper value.

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 "FFFF₁₆" by underflow or "0000₁₆" by overflow. Reading the timer Ai register after setting a value in the timer Ai register with a count halted but before the counter starts counting gets a proper value.
- (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 TAIOUT 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 TAIOUT pin is outputting an "H" level in this instance, the output level goes to "L", and the timer Ai interrupt request bit goes to "1". If the TAIOUT pin is outputting an "L" level in this instance, the level does not change, and the timer Ai interrupt request bit does not 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 "FFFF₁₆". Reading the timer Bi register after setting a value in the timer Bi register with a count halted but before the counter starts counting gets a proper value.

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 μ s 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 00000₁₆
 - 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 00000₁₆ will then be set to "0".
Reading address 00000₁₆ 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 00000₁₆ by software.
- (2) Setting the stack pointer
 - The value of the stack pointer immediately after reset is initialized to 0000₁₆. Accepting an interrupt before setting a value in the stack pointer may become a factor of runaway. Be sure to set a value in the stack pointer before accepting an interrupt.
When using the $\overline{\text{NMI}}$ interrupt, initialize the stack 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 Vcc pin via a resistor (pull-up) if unused. Be sure to work on it.
 - Do not get either into stop mode with the $\overline{\text{NMI}}$ pin set to "L".

(4) External interrupt

- When the polarity of the $\overline{\text{INT0}}$ to $\overline{\text{INT5}}$ pins is changed, the interrupt request bit is sometimes set to "1". After changing the polarity, set the interrupt request bit to "0".

Note 1: In M30623 (80-pin package), can not use $\overline{\text{INT3}}$ to $\overline{\text{INT5}}$ as the interrupt factors, because P15/D13/ $\overline{\text{INT3}}$ to P17/D15/ $\overline{\text{INT5}}$ have no corresponding external pin.

(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

Usage precaution of 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 (M30622ECTFP/ECVFP, M30623ECTGP/ECVGP), 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 1.24.1 before use.

But, in case of using as the test of cars loading, mass production, correspond to programming PROM, and screened shipped in programming, please require.

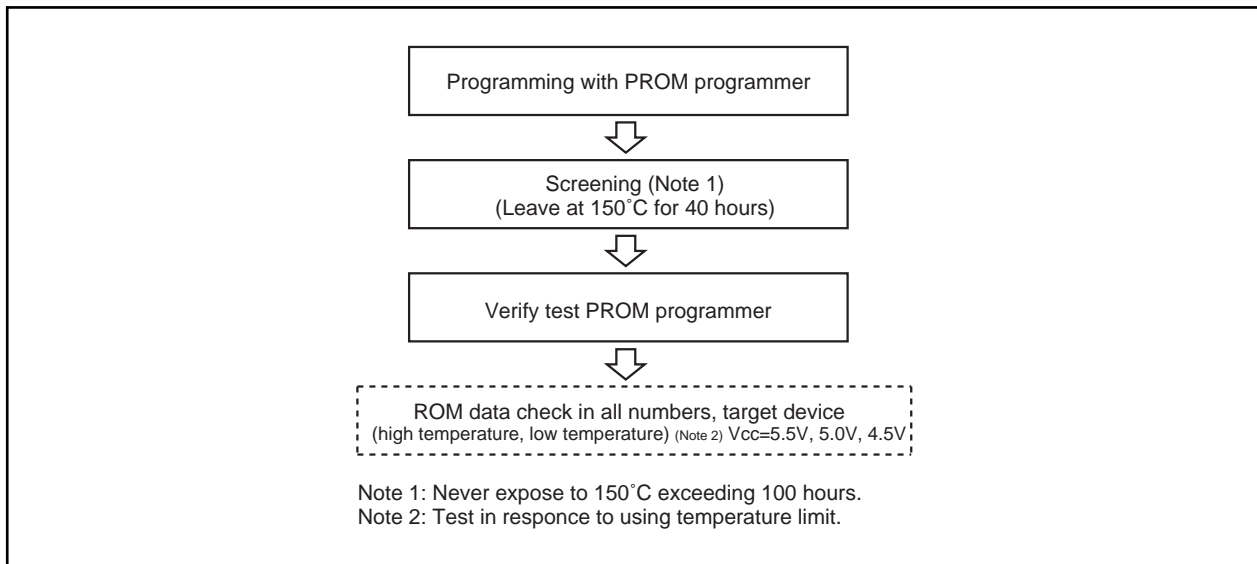


Figure 1.24.1. Programming and test flow for One Time PROM version

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 1.26.1. Absolute maximum ratings

Symbol	Parameter	Condition	Rated value		Unit
			One-time PROM version	Mask ROM version	
V _{cc}	Supply voltage	AV _{cc} =V _{cc} , AV _{ss} =V _{ss}	-0.3 to 7	-0.3 to 6.5	V
AV _{cc}	Analog supply voltage	AV _{cc} =V _{cc} , AV _{ss} =V _{ss}	-0.3 to 7	-0.3 to 6.5	V
V _i	Input voltage	RESET, V _{REF} , X _{IN} P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ , P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₃ , 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	-0.3 to V _{cc} +0.3	-0.3 to V _{cc} +0.3	V
		P7 ₀ , P7 ₁	-0.3 to 7	-0.3 to 6.5	V
		CNV _{ss} , BYTE	-0.3 to 7 (Note 1)	-0.3 to V _{cc} +0.3	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 ₃ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₂ to P7 ₇ , P8 ₀ to P8 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇ , X _{OUT}	-0.3 to V _{cc} +0.3	-0.3 to V _{cc} +0.3	V
		P7 ₀ , P7 ₁ ,	-0.3 to 7	-0.3 to 6.5	V
P _d	Power dissipation	-40°C < Ta ≤ 85°C	300	300	mW
		85°C < Ta ≤ 125°C	200	200	
T _{opr}	Operating ambient temperature		-40 to 125 (Note 2)	-40 to 125 (Note 2)	°C
T _{stg}	Storage temperature		-65 to 150	-65 to 150	°C

Note 1: When writing to EPROM, only CNV_{ss} is -0.3 to 13.5 (V).

Note 2: In case of 85°C guaranteed version, -40°C to 85°C. In case of 125°C guaranteed version, -40°C to 125°C.

Note 3: In M30623(80-pin package), P1₀ to P1₇, P4₄ to P4₇, P7₂ to P7₅, and P9₁ are not connected to the external pin.

Table 1.26.2. Recommended operating conditions (referenced to V_{CC} = 4.2V (Note 1) to 5.5V at Ta = -40°C to 125°C (Note 2) unless otherwise specified)

Symbol	Parameter	Standard			Unit	
		Min	Typ.	Max.		
V _{cc}	Supply voltage	4.2 (Note 1)	5.0	5.5	V	
AV _{cc}	Analog supply voltage		V _{cc}		V	
V _{ss}	Supply voltage		0		V	
AV _{ss}	Analog supply voltage		0		V	
V _{IH}	HIGH input voltage	P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₀ to P7 ₇ , P8 ₀ to P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇ , X _{IN} , RESET, CNV _{ss} , BYTE	0.8V _{cc}		V _{cc}	V
V _{IH}	HIGH input voltage	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ (during single-chip mode)	0.8V _{cc}		V _{cc}	V
V _{IL}	LOW input voltage	P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₀ to P7 ₇ , P8 ₀ to P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇ , X _{IN} , RESET, CNV _{ss} , BYTE	0		0.2V _{cc}	V
V _{IL}	LOW input voltage	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ (during single-chip mode)	0		0.2V _{cc}	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 (Note 4)			-10	mA
I _{OH} (avg)	HIGH average output current	P0 ₀ to P0 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	mA
I _{OL} (peak)	LOW peak output current	P0 ₀ to P0 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 (Note 4)			10	mA
I _{OL} (avg)	LOW average output current	P0 ₀ to P0 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	mA
f (X _{IN})	Main clock input oscillation frequency	V _{cc} =4.2V (Note 1) to 5.5V			16	MHz
f (X _{CIN})	Subclock oscillation frequency		32.768	50		kHz

Note 1: In case of One-time PROM version, 4.5V.

Note 2: In case of 85°C guaranteed version, -40°C to 85°C. In case of 125°C guaranteed version, -40°C to 125°C.

Note 3: The mean output current is the mean value within 100ms.

Note 4: In M30622(100-pin package), the total I_{OL} (peak) and the total I_{OH} (peak) for ports P0, P1, P2, P8₆, P8₇, P9, and P10 and the total I_{OL} (peak) and the total I_{OH} (peak) for ports P3, P4, P5, P6, P7, and P8₀ to P8₄ severally must be 80mA max.
In M30623(80-pin package), V_{cc} pin and V_{ss} pin are each one pin, so the total I_{OL} (peak) and the total I_{OH} (peak) for all ports must be 80mA max.

Note 5: The loss power effect of the whole part-port (the output port transistor and the pull-up resistor) must be 50mW max, so that power dissipation at Ta=125°C (include Ta >85°C) doesn't exceed absolute maximum ratings.

Note 6: In M30623(80-pin package), P1₀ to P1₇, P4₄ to P4₇, P7₂ to P7₅, and P9₁ are not connected to the external pin.

Table 1.26.3. Electrical characteristics (referenced to V_{CC} = 5V, V_{SS} = 0V at Ta = -40°C to 125°C(Note 1), f(X_{IN}) = 16MHz unless otherwise specified)

Symbol	Parameter		Measuring condition	Standard			Unit
				Min	Typ.	Max.	
V _{OH}	HIGH output voltage	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ , P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₂ to P7 ₇ , P8 ₀ to P8 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	I _{OH} = -5mA V _{CC} =4.0V to 5.5V	0.6V _{CC}			V
V _{OH}	HIGH output voltage	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ , P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₂ to P7 ₇ , P8 ₀ to P8 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	I _{OH} = -200μA V _{CC} =4.0V to 5.5V	0.9V _{CC}			V
V _{OH}	HIGH output voltage	X _{OUT}	HIGHPOWER	I _{OH} = -1mA	3.0		V
			LOWPOWER	I _{OH} = -0.5mA	3.0		
	HIGH output voltage	X _{COUT}	HIGHPOWER	With no load applied		3.0	V
			LOWPOWER	With no load applied		1.6	
V _{OL}	LOW output voltage	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ , P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₀ to P7 ₇ , P8 ₀ to P8 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	I _{OL} =5mA V _{CC} =4.0V to 5.5V			0.4V _{CC}	V
V _{OL}	LOW output voltage	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ , P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₀ to P7 ₇ , P8 ₀ to P8 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	I _{OL} =200μA V _{CC} =4.0V to 5.5V			0.1V _{CC}	V
V _{OL}	LOW output voltage	X _{OUT}	HIGHPOWER	I _{OL} =1mA		2.0	V
			LOWPOWER	I _{OL} =0.5mA		2.0	
	LOW output voltage	X _{COUT}	HIGHPOWER	With no load applied		0	V
			LOWPOWER	With no load applied		0	
V _{T+} -V _{T-}	Hysteresis	TA0 _{IN} to TA4 _{IN} , TA0 _{OUT} to TA4 _{OUT} , TB0 _{IN} to TB5 _{IN} , INT ₀ to INT ₅ , P8 ₂ to P8 ₄ , AD _{TRG} , CTS ₀ to CTS ₂ , CLK ₀ to CLK ₄ , RXD ₀ to RXD ₂ , SIN ₃ , SIN ₄ , KI ₀ to KI ₃ , NMI		0.2		0.8	V
V _{T+} -V _{T-}	Hysteresis	RESET, CNV _{SS} , BYTE		0.5		1.5	V
V _{T+} -V _{T-}	Hysteresis	X _{IN}		0.2		0.8	V
I _{IH}	HIGH input current	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ , P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₀ to P7 ₇ , P8 ₀ to P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇ , X _{IN} , RESET, CNV _{SS} , BYTE	V _I =5V			5	μA
I _{IL}	LOW input current	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ , P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₀ to P7 ₇ , P8 ₀ to P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇ , X _{IN} , RESET, CNV _{SS} , BYTE	No pull-up resistance V _I =0V			-5	μA
I _{IL}	LOW input current	P0 ₀ to P0 ₇ , P1 ₀ to P1 ₇ , P2 ₀ to P2 ₇ , P3 ₀ to P3 ₇ , P4 ₀ to P4 ₇ , P5 ₀ to P5 ₇ , P6 ₀ to P6 ₇ , P7 ₂ to P7 ₇ , P8 ₀ to P8 ₄ , P8 ₆ , P8 ₇ , P9 ₀ to P9 ₇ , P10 ₀ to P10 ₇	Pull-up resistance V _I =0V	-70	-100	-150	μA
R _{FXIN}	Feedback resistance	X _{IN}				1.0	MΩ
R _{FXCIN}	Feedback resistance	X _{CIN}				6.0	MΩ
V _{RAM}	RAM retention voltage		When clock is stopped	2			V
I _{CC}	Power supply current	In single-chip mode, the output pins are open and other pins are V _{SS}	f(X _{IN})=16MHz, Square wave, divide-by-1, no-wait		28	38	mA
			f(X _{IN})=16kHz, Square wave, divide-by-1, 1-wait		24		mA
			f(X _{IN})=16kHz, Square wave, divide-by-8, no-wait		6.7		mA
			f(X _{CIN})=32kHz When a WAIT instruction is executed, Ta=25°C		4.0		μA
			Ta=25°C when clock is stopped			2	μA
			Ta=85°C when clock is stopped			20	
Ta=125°C when clock is stopped			50				

Note 1: In case of 85°C guaranteed version, -40°C to 85°C. In case of 125°C guaranteed version, -40°C to 125°C.

Note 2: In M30623(80-pin package), P1₀ to P1₇, P4₄ to P4₇, P7₂ to P7₅, and P9₁ are not connected to the external pin.

Table 1.26.4. A-D conversion characteristics (referenced to $V_{CC} = AV_{CC} = 5V$, $V_{SS} = AV_{SS} = 0V$, $T_a = 25^\circ C$, $f(X_{IN}) = 16MHz$ unless otherwise specified)

Symbol	Parameter	Measuring condition	Standard			Unit		
			Min.	Typ.	Max.			
-	Resolution	$V_{REF} = V_{CC} = 5V$			10	Bits		
-	Absolute accuracy(8bit)	$V_{REF} = AV_{CC} = V_{CC} = 5V$, $\phi_{AD} \leq 10MHz$			± 2	LSB		
-	Absolute accuracy (10bit)	Sample & hold function not available	$V_{REF} = AV_{CC} = V_{CC} = 5V$, $\phi_{AD} \leq 10MHz$			± 3	LSB	
		Sample & hold function available	$V_{REF} = AV_{CC} = V_{CC} = 5V$	AN0 to AN7, AN00 to AN07, AN20 to AN27, ANEX0, ANEX1 input			± 3	LSB
			$\phi_{AD} \leq 10MHz$	External op-amp connection mode			± 7	LSB
RLADDER	Ladder resistance	$V_{REF} = V_{CC} = 5V$	10		40	k Ω		
t _{CONV}	Conversion time(10bit)	$f(X_{IN}) = 16MHz$, $\phi_{AD} = f_{AD}/2 = 8MHz$	4.125			μs		
		$f(X_{IN}) = 10MHz$, $\phi_{AD} = f_{AD} = 10MHz$	3.3					
t _{CONV}	Conversion time(8bit)	$f(X_{IN}) = 16MHz$, $\phi_{AD} = f_{AD}/2 = 8MHz$	3.5			μs		
		$f(X_{IN}) = 10MHz$, $\phi_{AD} = f_{AD} = 10MHz$	2.8					
t _{SAMP}	Sampling time	$f(X_{IN}) = 16MHz$, $\phi_{AD} = f_{AD}/2 = 8MHz$	0.375			μs		
		$f(X_{IN}) = 10MHz$, $\phi_{AD} = f_{AD} = 10MHz$	0.3					
V _{REF}	Reference voltage		2		V _{CC}	V		
V _{IA}	Analog input voltage		0		V _{REF}	V		

Note 1: Divide the frequency if $f(X_{IN})$ exceeds 10 MHz, and make ϕ_{AD} equal to or lower than 10 MHz.

Table 1.26.5. D-A conversion characteristics (referenced to $V_{CC} = 5V$, $V_{SS} = AV_{SS} = 0V$, $V_{REF} = 5V$ at $T_a = 25^\circ C$, $f(X_{IN}) = 16MHz$ unless otherwise specified)

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

Note 1: This applies when using one D-A converter, with the D-A register for the unused D-A converter set to "0016". The A-D converter's ladder resistance is not included.

Note 2: When the Vref is unconnected at the A-D control register, I_{VREF} is sent. When not using D-A converter, with the D-A register for the unused D-A converter set to "0016", so that prevent dissipation of unnecessary reference power supply current.

Timing requirements

Referenced to $V_{CC} = 5V$, $V_{SS} = 0V$ at $T_a = -40^{\circ}C$ to $85^{\circ}C$ ($85^{\circ}C$ guaranteed version), or $T_a = -40^{\circ}C$ to $125^{\circ}C$ ($125^{\circ}C$ guaranteed version) unless otherwise specified.

Table 1.26.6. External clock input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t_c	External clock input cycle time	62.5		ns
$t_w(H)$	External clock input HIGH pulse width	25		ns
$t_w(L)$	External clock input LOW pulse width	25		ns
t_r	External clock rise time		15	ns
t_f	External clock fall time		15	ns

Table 1.26.7. External interrupt \overline{INT}_i inputs

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_w(INH)$	\overline{INT}_i input HIGH pulse width	250		ns
$t_w(INL)$	\overline{INT}_i input LOW pulse width	250		ns

Table 1.26.8. Timer A input (counter input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_c(TA)$	TA_{iIN} input cycle time	150		ns
$t_w(TAH)$	TA_{iIN} input HIGH pulse width	60		ns
$t_w(TAL)$	TA_{iIN} input LOW pulse width	60		ns

Table 1.26.9. Timer A input (gating input in timer mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_c(TA)$	TA_{iIN} input cycle time	400		ns
$t_w(TAH)$	TA_{iIN} input HIGH pulse width	200		ns
$t_w(TAL)$	TA_{iIN} input LOW pulse width	200		ns

Table 1.26.10. Timer A input (external trigger input in one-shot timer mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_c(TA)$	TA_{iIN} input cycle time	200		ns
$t_w(TAH)$	TA_{iIN} input HIGH pulse width	100		ns
$t_w(TAL)$	TA_{iIN} input LOW pulse width	100		ns

Table 1.26.11. Timer A input (external trigger input in pulse width modulation mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_w(TAH)$	TA_{iIN} input HIGH pulse width	100		ns
$t_w(TAL)$	TA_{iIN} input LOW pulse width	100		ns

Table 1.26.12. Timer A input (up/down input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_c(UP)$	TA_{iOUT} input cycle time	2000		ns
$t_w(UPH)$	TA_{iOUT} input HIGH pulse width	1000		ns
$t_w(UPL)$	TA_{iOUT} input LOW pulse width	1000		ns
$t_{su}(UP-TIN)$	TA_{iOUT} input setup time	400		ns
$t_h(TIN-UP)$	TA_{iOUT} input hold time	400		ns

Timing requirements

Referenced to $V_{CC} = 5V$, $V_{SS} = 0V$ at $T_a = -40^{\circ}C$ to $85^{\circ}C$ ($85^{\circ}C$ guaranteed version), or $T_a = -40^{\circ}C$ to $125^{\circ}C$ ($125^{\circ}C$ guaranteed version) unless otherwise specified.

Table 1.26.13. Timer B input (counter input in event counter mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiIN input cycle time (counted on one edge)	150		ns
$t_{w(TBH)}$	TBiIN input HIGH pulse width (counted on one edge)	60		ns
$t_{w(TBL)}$	TBiIN input LOW pulse width (counted on one edge)	60		ns
$t_{c(TB)}$	TBiIN input cycle time (counted on both edges)	300		ns
$t_{w(TBH)}$	TBiIN input HIGH pulse width (counted on both edges)	120		ns
$t_{w(TBL)}$	TBiIN input LOW pulse width (counted on both edges)	120		ns

Table 1.26.14. 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 1.26.15. 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 1.26.16. Serial I/O

Symbol	Parameter		Standard		Unit
			Min.	Max.	
$t_{c(CK)}$	CLKi input cycle time		250		ns
$t_{w(CKH)}$	CLKi input HIGH pulse width		125		ns
$t_{w(CKL)}$	CLKi input LOW pulse width		125		ns
$t_{d(C-Q)}$	TxDi / Souti output delay time			100	ns
$t_{h(C-Q)}$	TxDi / Souti hold time		0		ns
$t_{su(D-C)}$	RxDi / Sini input setup time	When external clock is selected	45		ns
		When external clock is selected	120		ns
$t_{h(C-D)}$	RxDi / Sini input hold time	When external clock is selected	120		ns
		When external clock is selected	45		ns

Table 1.26.17. 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

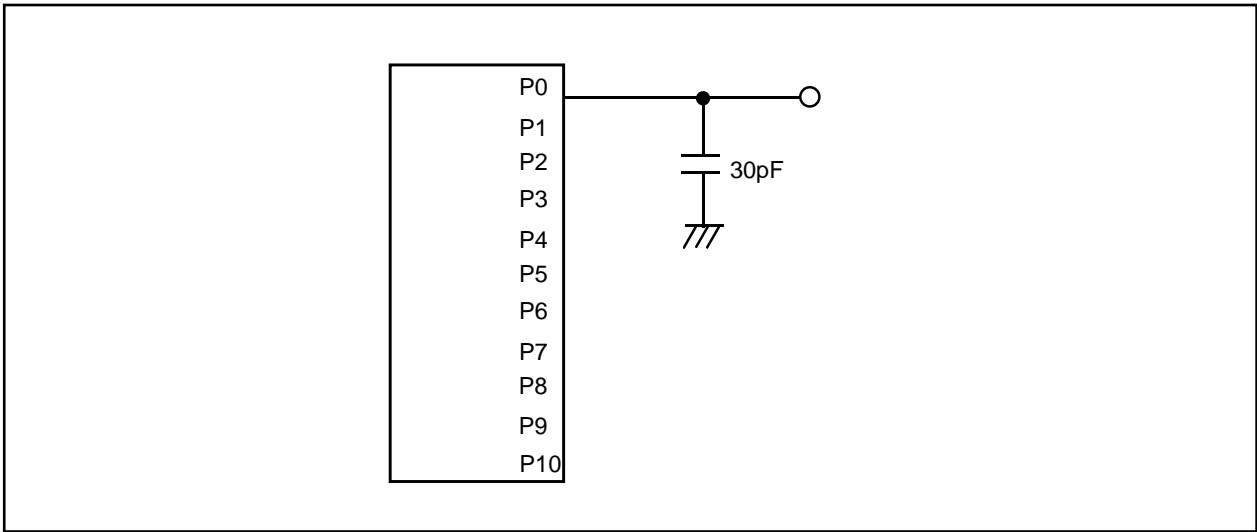


Figure 1.26.1. Port P0 to P10 measurement circuit

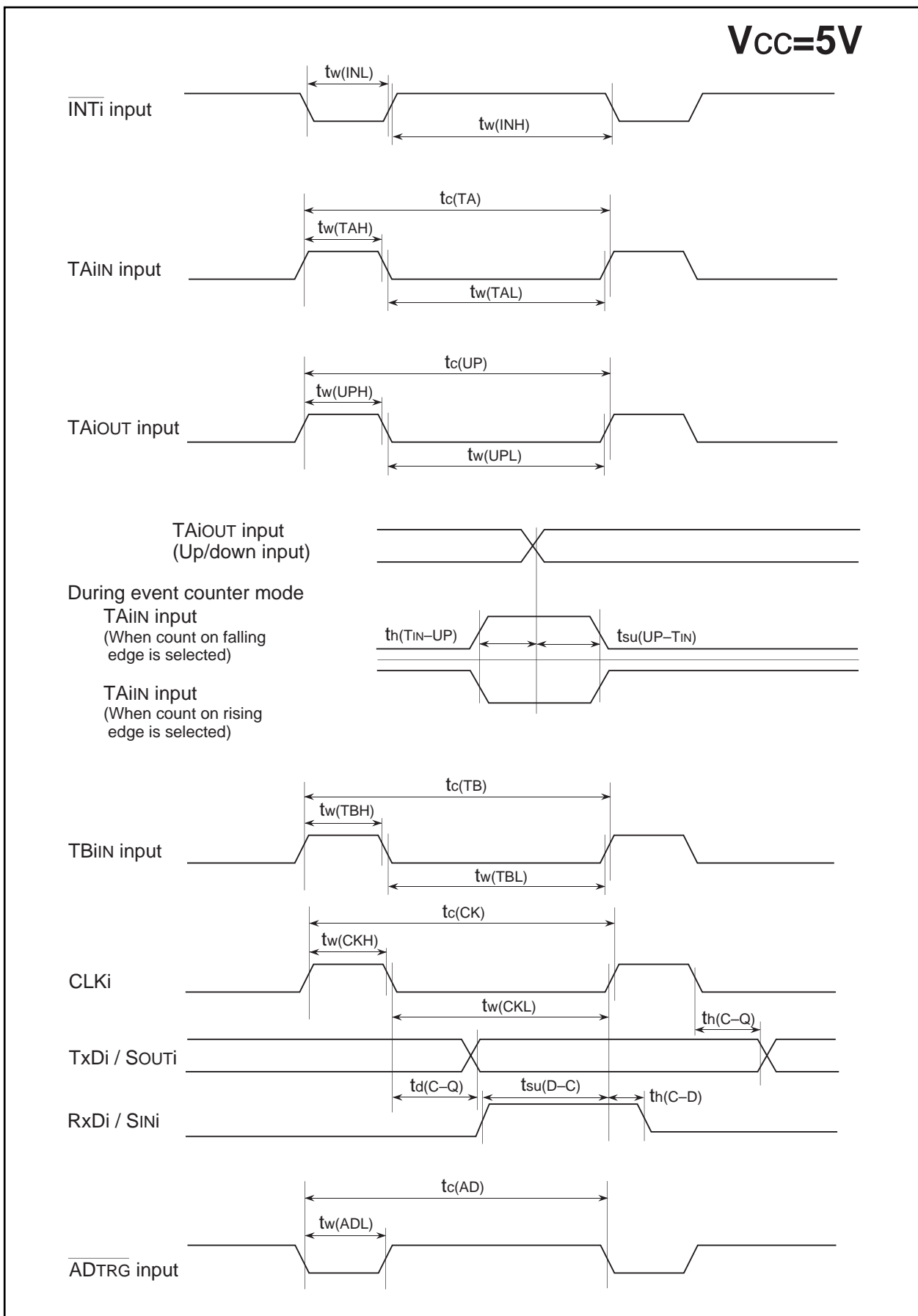


Figure 1.26.2. Timing

Differences between M16C/62T group and M16C/61T group

Group	M16C/62T group	M16C/61T group
Memory space (Note 1)	Memory expansion is possible 1.2M bytes mode 4M bytes mode	1M byte fixed
Timer B	6 channels	3 channels
Serial I/O	UART/clocked SI/O 3 channel (80-pin package: One of exclusive UART) Clocked SI/O 2 channel (80-pin package: One of exclusive transmission)	UART/clocked SI/O 3 channels (80-pin package: One of exclusive UART)
IIC bus mode	UART2 used IIC bus interface can be performed with software	Impossible
Port function	P90 TB0IN/CLK3 P91 TB1IN/SIN3 P92 TB2IN/SOUT3 P93 TB3IN/DA0 P94 TB4IN/DA1 P95 ANEX0/CLK4 P96 ANEX1/SOUT4 P97 ADTRG/SIN4 P15 D13/INT3 (Note 2) P16 D14/INT4 (Note 2) P17 D15/INT5 (Note 2) P71 RxD2/TA0IN/TB5IN	P90 TB0IN P91 TB1IN P92 TB2IN P93 DA0 P94 DA1 P95 ANEX0 P96 ANEX1 P97 ADTRG P15 D13 (Note 2) P16 D14 (Note 2) P17 D15 (Note 2) P71 RxD2/TA0IN
Interrupt cause	Internal 25 sources, External 8 sources (80-pin package: 5 sources), Software 4 sources (Added 2 Serial I/O, 3 timers and 3external interrupts (Note 2))	Internal 20 sources External 5 sources Software 4 sources
Chip select (Note 1) (Note 2)	M16C/61T type (writing the right) and the type as below can be switched (Besides 4M-byte mode is possible.) CS0 : 04000 ₁₆ to 3FFFF ₁₆ (fetch) 40000 ₁₆ to FFFFF ₁₆ (data/facth) CS1 : 28000 ₁₆ to 2FFFF ₁₆ (data) CS2 : 08000 ₁₆ to 27FFF ₁₆ (data) CS3 : 04000 ₁₆ to 07FFF ₁₆ (data)	CS0 : 30000 ₁₆ to FFFFF ₁₆ CS1 : 28000 ₁₆ to 2FFFF ₁₆ CS2 : 08000 ₁₆ to 27FFF ₁₆ CS3 : 04000 ₁₆ to 07FFF ₁₆
Three-phase inverter control circuit (Note 2)	PWM output for three-phase inverter can be performed using timer A4, A1 and A2. Output port is arranged to P72 to P75, P80 and P81.	Impossible
Read port P1 (Note 2)	By setting to register, the state of port register can be read always.	The state of port when input mode. The state of port register when output mode.
P44/ $\overline{CS0}$ - P47/ $\overline{CS3}$ (Note 1) (Note 2)	If a Vcc level is applied to the CNVss pin, bit 2 (PU11) of pull-up control register 1 turns to "1" when reset, and P44/ $\overline{CS0}$ - P47/ $\overline{CS3}$ turn involved in pull-up.	Bit 2 (PU11) of the pull-up control register 1 turns to "0" when reset, and P44/ $\overline{CS0}$ - P47/ $\overline{CS3}$ turn free from pull- up.

Note 1: M16C/61T group, and M16C/62T group are not guaranteed operating of memory expansion, but it is mentioned in the table for clear the difference of capacity.

Note 2: In 80-pin package(M30613, M30623), pins of a part are not connected to the external pin, so do not use these functions and pins.

MITSUBISHI SEMICONDUCTORS
M16C/62T Group Tentative Specification REV.A

Jan First Edition 1999

Edited by
Committee of editing of Mitsubishi Semiconductor

Published by
Mitsubishi Electric Corp., Kitaitami Works

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