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7540 Group

User's Manual

RENESAS 8-BIT CISC SINGLE-CHIP
MICROCOMPUTER
740 FAMILY / 740 SERIES

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REVISION HISTORY

7540 Group User's Manual

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| 1.00 | Sep. 17, 2002 | – | First edition issued |
| 1.10 | May 28, 2003 | 1-17 1-19 1-34 1-45 2-49 2-52 2-53 2-61 3-86 | [Pull-up control register] PULL; Note added. Fig.15; Note 2 eliminated. Fig.17; (2) Ports P01,P02 revised. Fig.29; Port P03 direction register block, Port P01 direction register block and Port P02 direction register block revised. (3) RC oscillation revised. Fig.2.4.12; RTI → RTS Fig.2.4.16; Prescaler X 1/4 → <u>1/2</u> , CNTR0 pin output 4 MHz → <u>4 kHz</u> Fig.2.4.17; The second CPUM setting 00000X002 → <u>11000X002</u> Prescaler X 0316 → <u>0116</u> , Note 2 revised. Fig.2.4.26; The followings are revised. The second setting of CNTR0 interrupt enable bit and Timer X interrupt enable bit. The second setting of timer X mode register. Fig.3.3.5; NOP added. |
| 2.00 | Jun. 21, 2004 | All pages 1-9 1-10 1-11 1-17 1-19 1-34 1-42 1-45 1-51 1-52 2-5 2-14 2-35 2-36 2-66 2-134 2-145 3-82 3-83 3-91 | Words standardized: On-chip oscillator, A/D converter Fig. 8: "Under development" eliminated. Table 2: "Under development" eliminated. CPU: Description revised. [Pull-up control register] PULL: Note added Fig.17 (2) Ports P01, P02 revised. Fig. 29 P03/TXOUT, P01/TYOUT, P02/TZOUT revised. Note on A/D converter added. Fig. 49 revised. Note on A/D converter added. Notes on clock generating circuit: On-chip oscillator operation added. Note on Power Source Voltage, and Electrical Characteristic Difference Among Mask ROM and One Time PROM Version MCUs added. Fig.2.1.6: Note 2 eliminated. Fig.2.2.3: Note 2 eliminated. 2.2.7 Notes on timer A, (2): Register name revised. Fig.2.3.2: Description revised. Fig.2.5.7: Description revised. 2.8.4 Notes on A/D converter: (3) added. 2.9.6 Notes on oscillation stop detection circuit, (1): Ⓜ added. 3.3.10 Notes on A/D converter: (3) added. 3.3.11 Notes on oscillation stop detection circuit, (1): Ⓜ added. 3.3.19 Note on Power Source Voltage and 3.3.20 Electrical Characteristic Difference Among Mask ROM and One Time PROM Version MCUs added. |

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| | | 3-106 | Fig.3.5.15: Description revised. |
| | | 3-108 | Fig.3.5.19: Description revised. |
| | | 3-120 | 32P6U-A revised. |
| | | 3-140 | Fig.3.11.1: Memory address of 7531 Group revised. |
| | | | |

BEFORE USING THIS MANUAL

This user's manual consists of the following three chapters. Refer to the chapter appropriate to your conditions, such as hardware design or software development. Chapter 3 also includes necessary information for systems development. You must refer to that chapter.

1. Organization

● CHAPTER 1 HARDWARE

This chapter describes features of the microcomputer and operation of each peripheral function.

● CHAPTER 2 APPLICATION

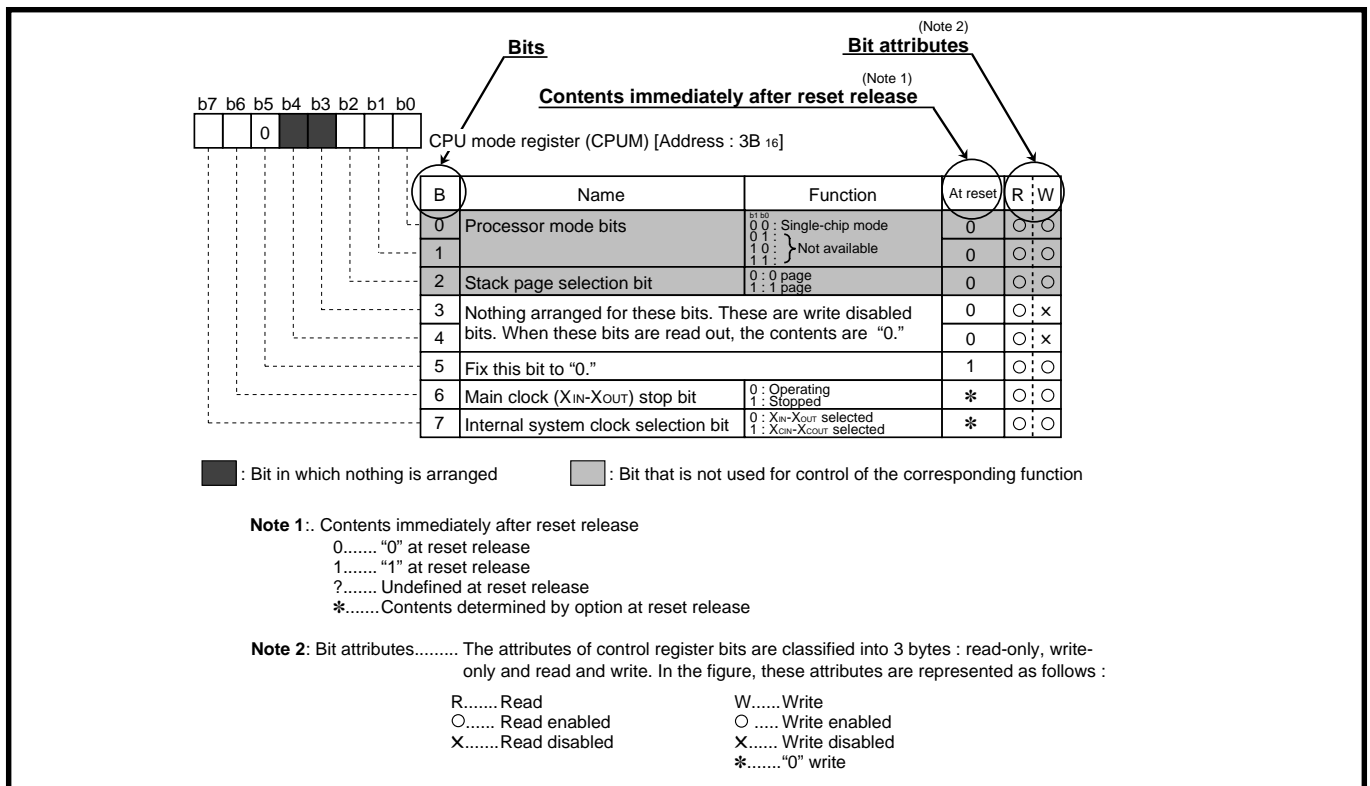
This chapter describes usage and application examples of peripheral functions, based mainly on setting examples of relevant registers.

● CHAPTER 3 APPENDIX

This chapter includes necessary information for systems development using the microcomputer, such as the electrical characteristics, the list of registers.

2. Structure of register

The figure of each register structure describes its functions, contents at reset, and attributes as follows :



3. Supplementation

For details of software, refer to the "740 FAMILY SOFTWARE MANUAL."

For development tools, refer to the "Renesas Technology tool Index for 740 Family." Homepage (http://www.renesas.com/eng/products/mpumcu/toolhp/mcu/740_e.htm).

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CHAPTER 1

HARDWARE

DESCRIPTION

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DESCRIPTION

The 7540 Group is the 8-bit microcomputer based on the 740 family core technology.

The 7540 Group has a serial I/O, 8-bit timers, a 16-bit timer, and an A/D converter, and is useful for control of home electric appliances and office automation equipment.

FEATURES

- Basic machine-language instructions 71
- The minimum instruction execution time 0.34 μ s
(at 6 MHz oscillation frequency, double-speed mode for the shortest instruction)
- Memory size ROM 8 K to 32 K bytes
RAM 384 to 768 bytes
- Programmable I/O ports 29 (25 in 32-pin version)
- Interrupts 15 sources, 15 vectors
..... (14 sources, 14 vectors for 32-pin version)
- Timers 8-bit X 4
..... 16-bit X 1
- Serial I/O1 8-bit X 1 (UART or Clock-synchronized)
- Serial I/O2 (**Note 1**) 8-bit X 1 (Clock-synchronized)
- A/D converter 10-bit X 8 channels
..... (6 channels for 32-pin version)
- Clock generating circuit Built-in type
(low-power dissipation by an on-chip oscillator enabled)
(connect to external ceramic resonator or quartz-crystal oscillator permitting RC oscillation)
- Watchdog timer 16-bit X 1
- Power source voltage
 - XIN oscillation frequency at ceramic oscillation, in double-speed mode
 - At 6 MHz 4.5 to 5.5 V
 - XIN oscillation frequency at ceramic oscillation, in high-speed mode
 - At 8 MHz 4.0 to 5.5 V
 - At 4 MHz 2.4 to 5.5 V
 - At 2 MHz 2.2 to 5.5 V
 - XIN oscillation frequency at RC oscillation in high-speed mode or middle-speed mode
 - At 4 MHz 4.0 to 5.5 V
 - At 2 MHz 2.4 to 5.5 V
 - At 1 MHz 2.2 to 5.5 V
- Power dissipation
 - Mask ROM version 22.5 mW (standard)
 - One Time PROM version 30 mW (standard)
- Operating temperature range -20 to 85 °C
(-40 to 85 °C for extended operating temperature version)
(-40 to 125 °C for extended operating temperature 125 °C version (**Note 2**))

APPLICATION

Office automation equipment, factory automation equipment, home electric appliances, consumer electronics, car, etc.

Notes 1: Serial I/O2 can be used in the following cases;

- (1) Serial I/O1 is not used,
- (2) Serial I/O1 is used as UART and BRG output divided by 16 is selected as the synchronized clock.

2: In this version, the operating temperature range and total time are limited as follows;

- 55 °C to 85 °C: within total 6000 hours,
- 85 °C to 125 °C: within total 1000 hours.

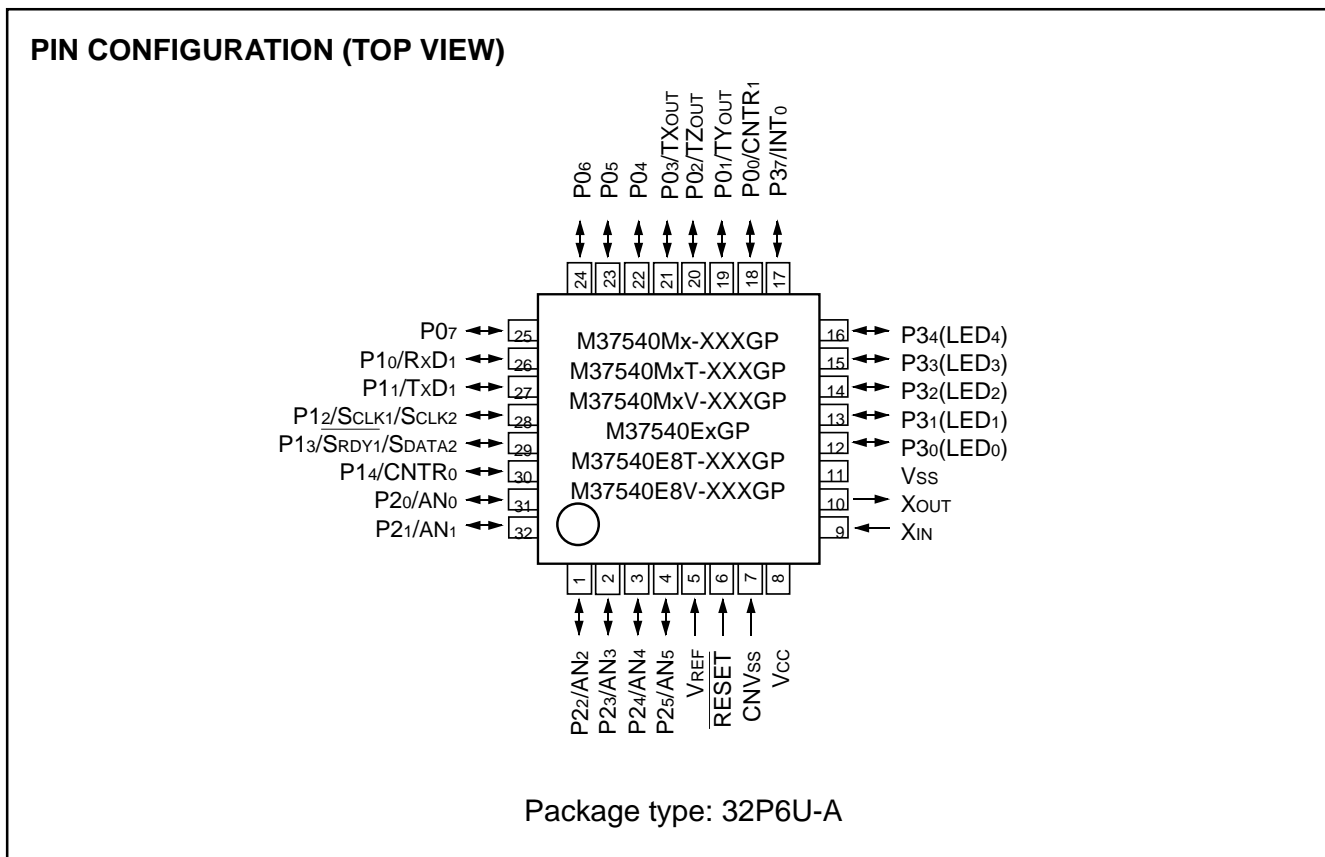


Fig. 1 Pin configuration (32P6U-A type)

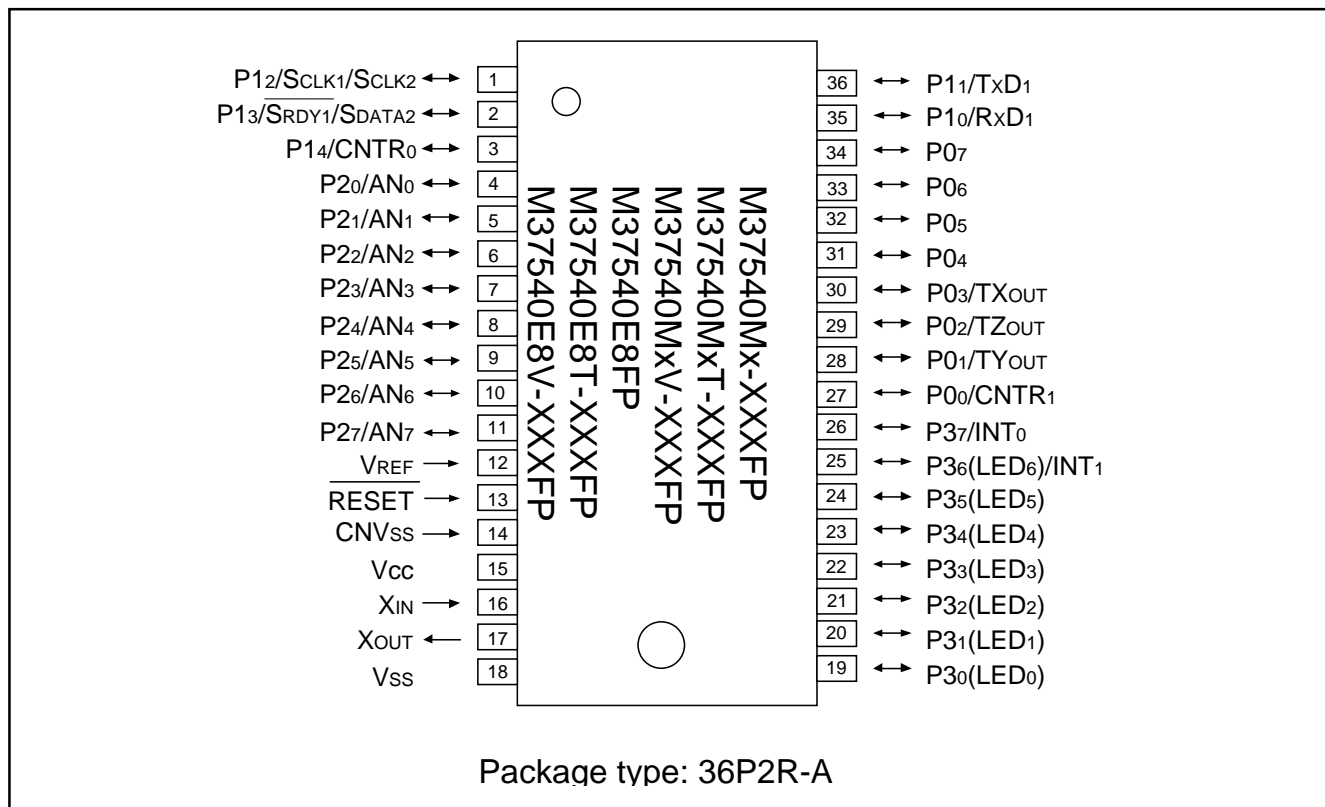


Fig. 2 Pin configuration (36P2R-A type)

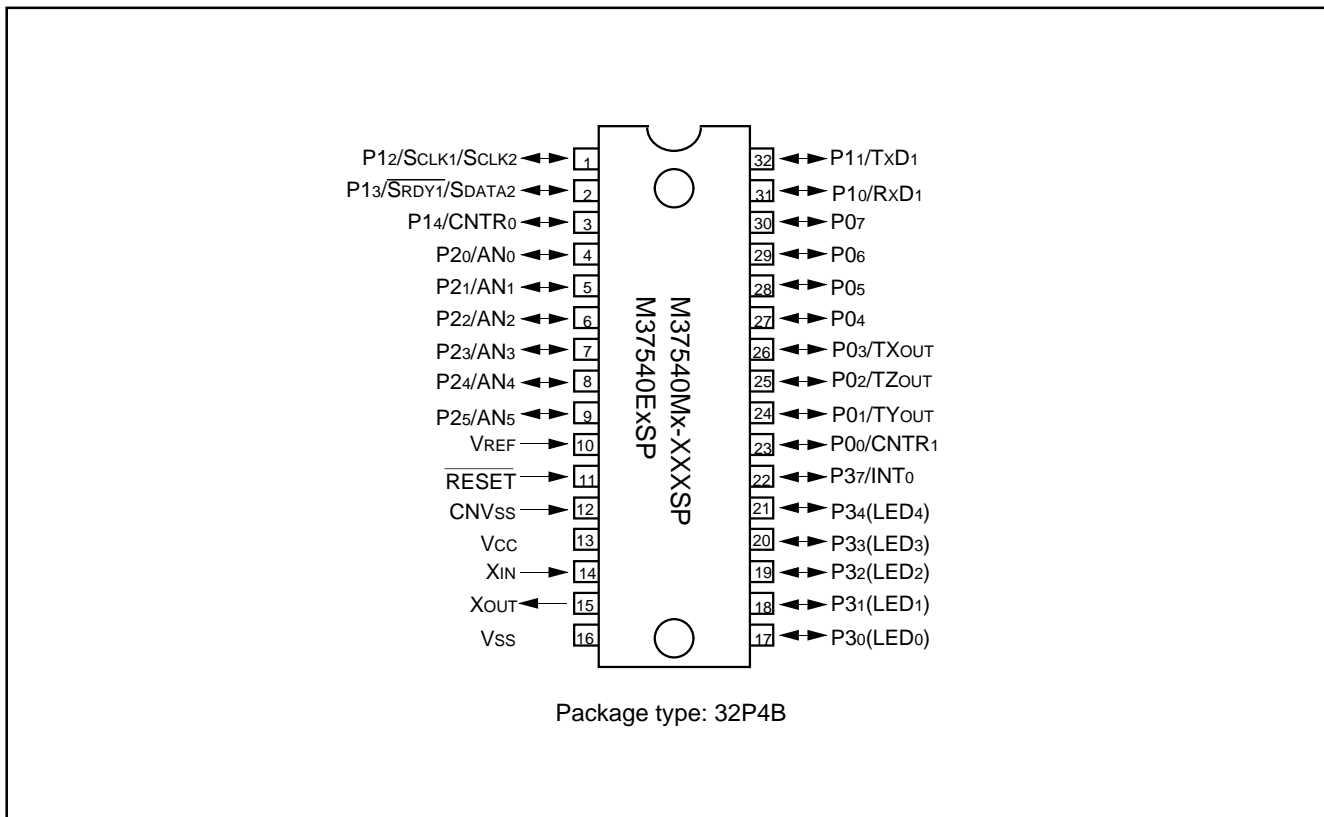


Fig. 3 Pin configuration (32P4B-A type)

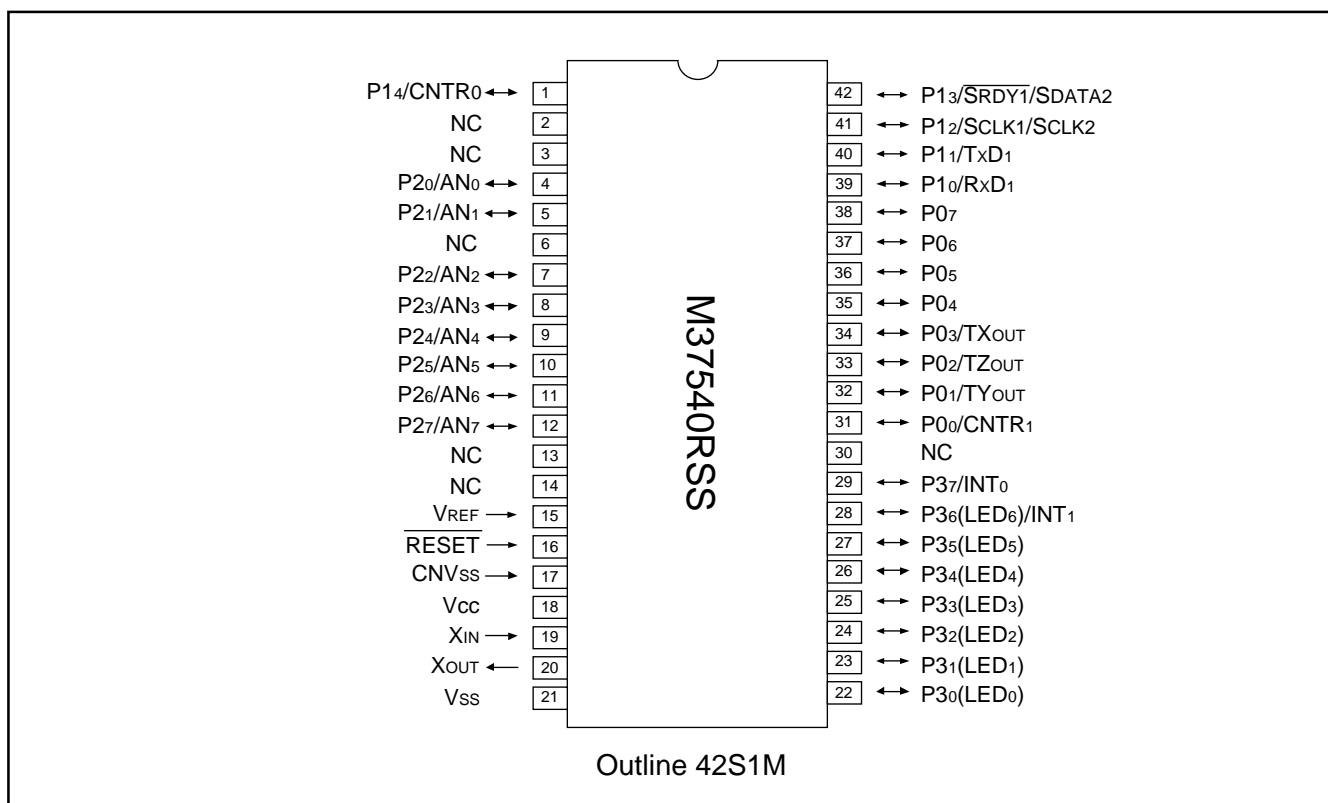
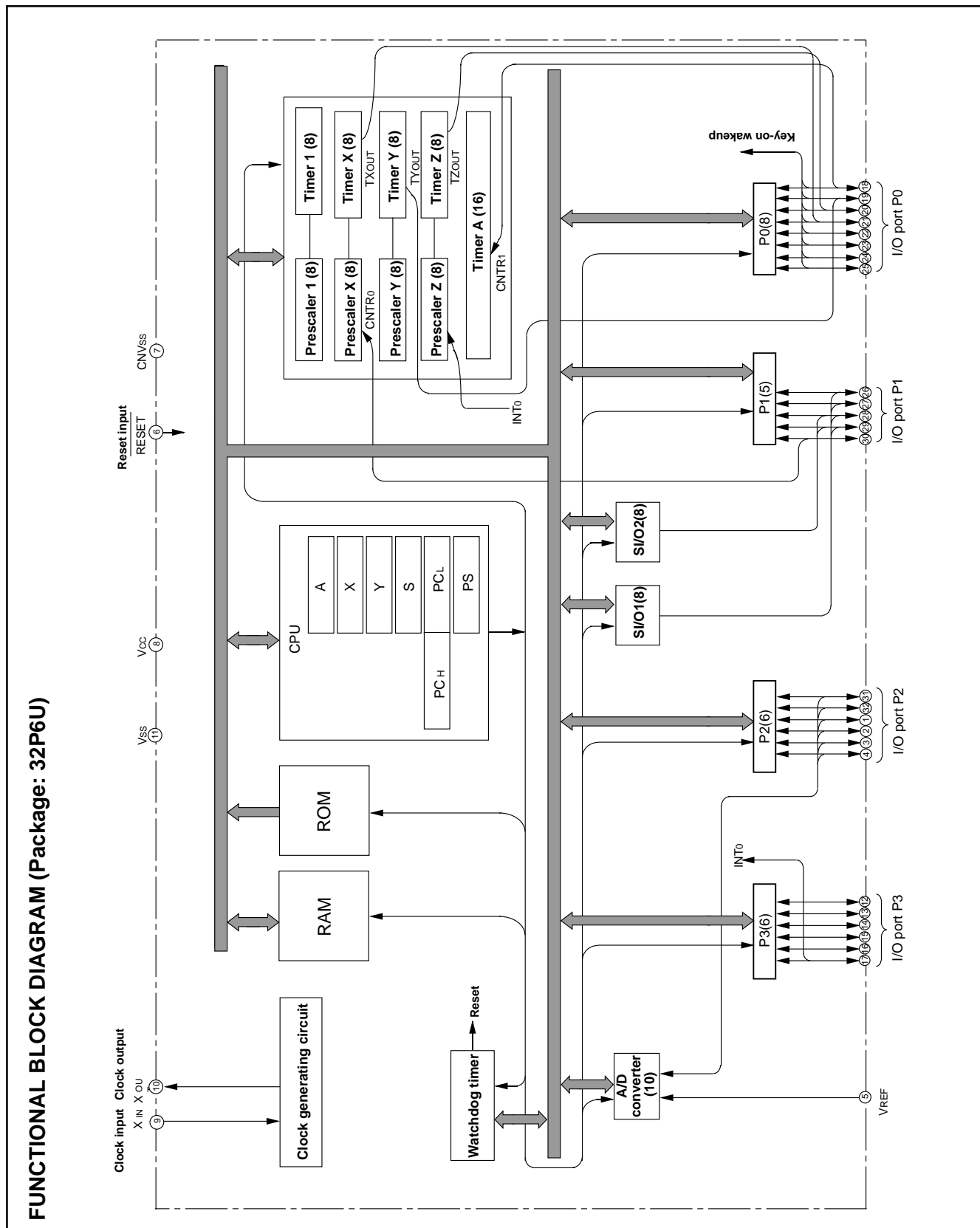


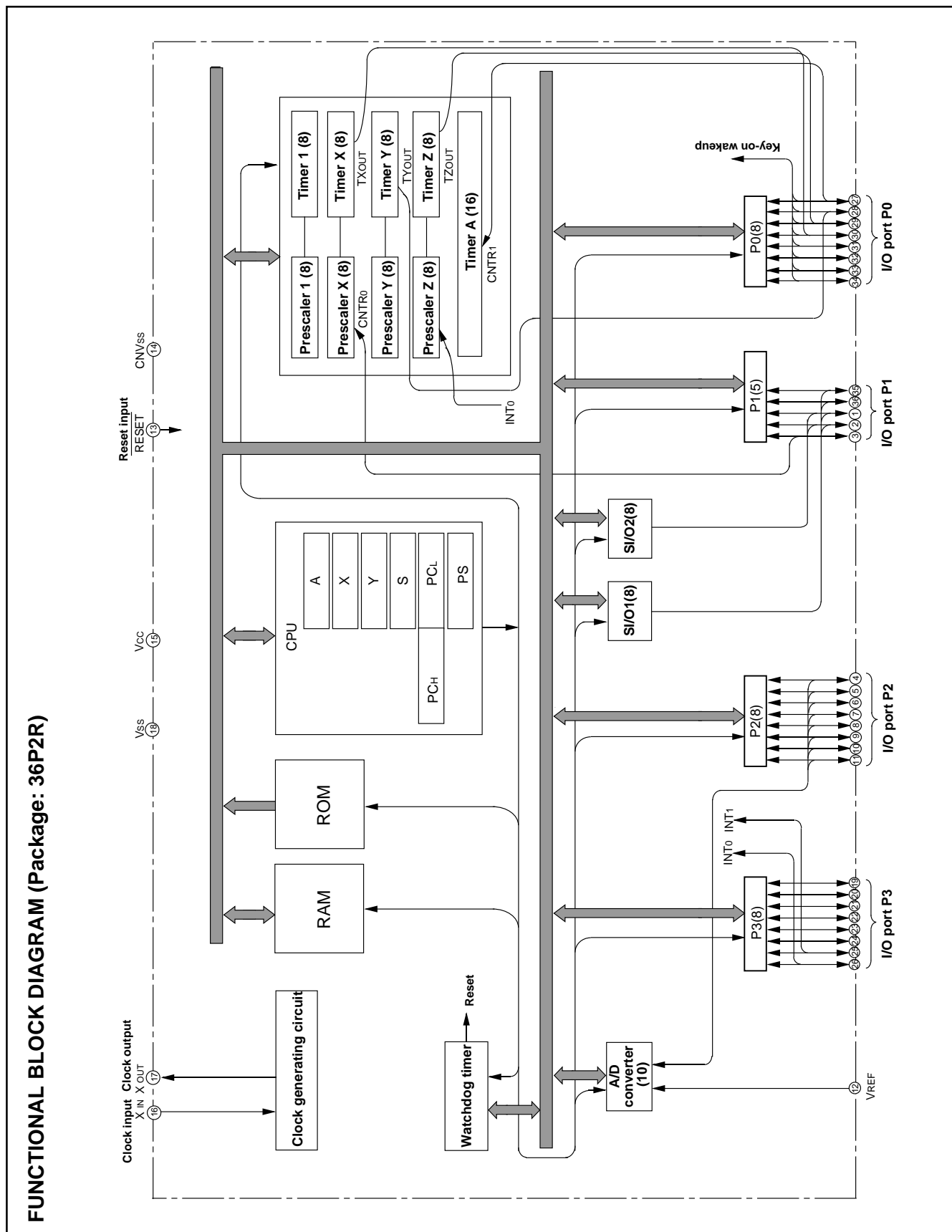
Fig. 4 Pin configuration (42S1M type)

FUNCTIONAL BLOCK



FUNCTIONAL BLOCK DIAGRAM (Package: 32P6U)

Fig. 5 Functional block diagram (32P6U package)



FUNCTIONAL BLOCK DIAGRAM (Package: 36P2R)

Fig. 6 Functional block diagram (36P2R package)

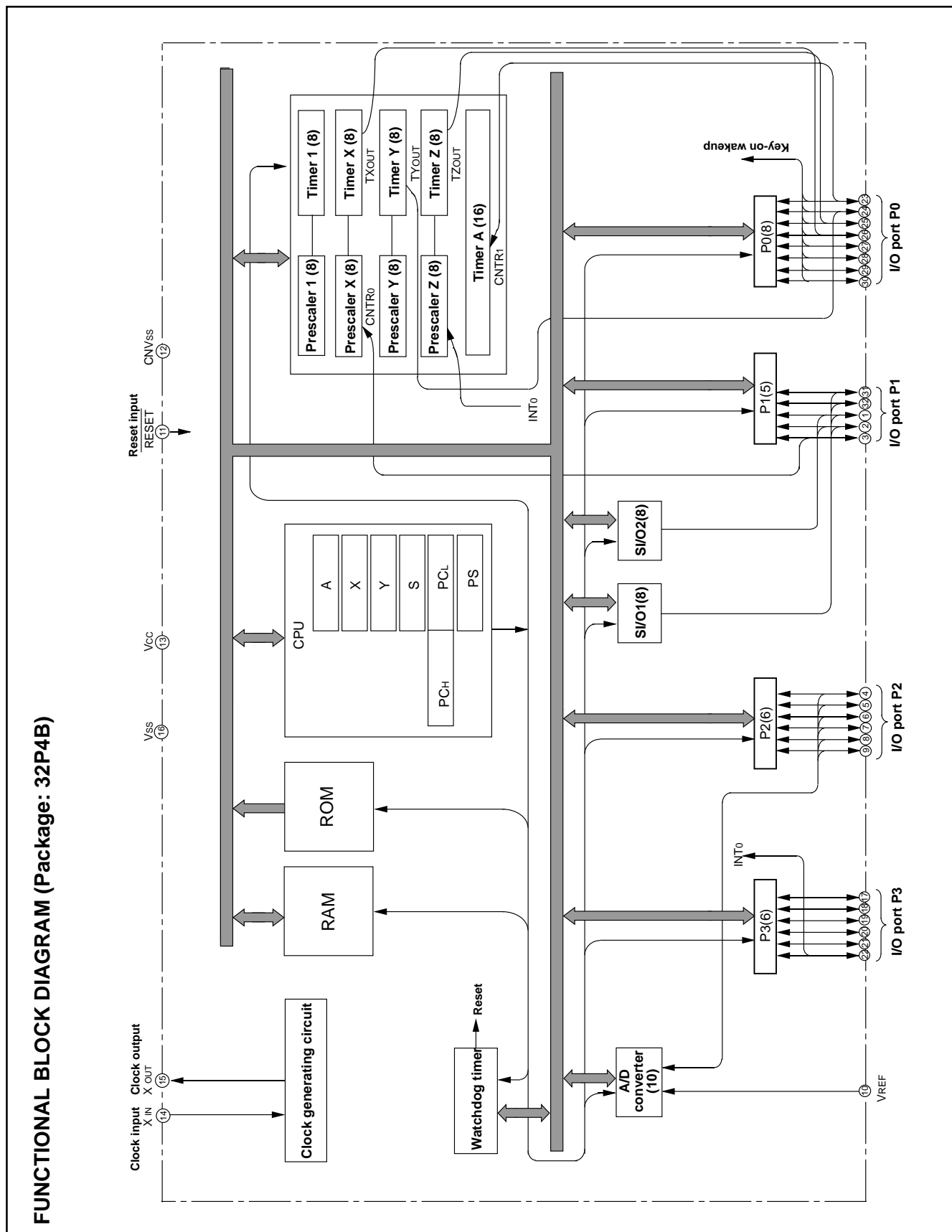


Fig. 7 Functional block diagram (32P4B package)

PIN DESCRIPTION

Table 1 Pin description

| Pin | Name | Function | Function expect a port function |
|---|--------------------------|--|---|
| Vcc, Vss | Power source (Note 1) | •Apply voltage of 2.2 to 5.5 V to Vcc, and 0 V to Vss. | |
| VREF | Analog reference voltage | •Reference voltage input pin for A/D converter | |
| CNVss | CNVss | •Chip operating mode control pin, which is always connected to Vss. | |
| RESET | Reset input | •Reset input pin for active "L" | |
| XIN | Clock input | <ul style="list-style-type: none"> •Input and output pins for main clock generating circuit •Connect a ceramic resonator or quartz crystal oscillator between the XIN and XOUT pins. | |
| XOUT | Clock output | <ul style="list-style-type: none"> •For using RC oscillator, short between the XIN and XOUT pins, and connect the capacitor and resistor. •If an external clock is used, connect the clock source to the XIN pin and leave the XOUT pin open. •When the on-chip oscillator is selected as the main clock, connect XIN pin to Vss and leave XOUT open. | |
| P00/CNTR1 P01/TYOUT P02/TZOUT P03/TXOUT P04–P07 | I/O port P0 | <ul style="list-style-type: none"> •8-bit I/O port. •I/O direction register allows each pin to be individually programmed as either input or output. •CMOS compatible input level •CMOS 3-state output structure •Whether a built-in pull-up resistor is to be used or not can be determined by program. | <ul style="list-style-type: none"> • Key-input (key-on wake up interrupt input) pins • Timer Y, timer Z, timer X and timer A function pin |
| P10/RxD1 P11/TxD1 | I/O port P1 | <ul style="list-style-type: none"> •5-bit I/O port •I/O direction register allows each pin to be individually programmed as either input or output. | <ul style="list-style-type: none"> • Serial I/O1 function pin |
| P12/SCLK1/SCLK2 P13/SRDY1/SDATA2 | | <ul style="list-style-type: none"> •CMOS compatible input level •CMOS 3-state output structure | <ul style="list-style-type: none"> • Serial I/O1 function pin • Serial I/O2 function pin |
| P14/CNTR0 | | <ul style="list-style-type: none"> •CMOS/TTL level can be switched for P10, P12 and P13 | <ul style="list-style-type: none"> • Timer X function pin |
| P20/AN0–P27/AN7 | I/O port P2 (Note 2) | <ul style="list-style-type: none"> •8-bit I/O port having almost the same function as P0 •CMOS compatible input level •CMOS 3-state output structure | <ul style="list-style-type: none"> • Input pins for A/D converter |
| P30–P35 | I/O port P3 (Note 3) | <ul style="list-style-type: none"> •8-bit I/O port •I/O direction register allows each pin to be individually programmed as either input or output. •CMOS compatible input level (CMOS/TTL level can be switched for P36 and P37). •CMOS 3-state output structure •P30 to P36 can output a large current for driving LED. | |
| P36/INT1 P37/INT0 | | <ul style="list-style-type: none"> •Whether a built-in pull-up resistor is to be used or not can be determined by program. | <ul style="list-style-type: none"> • Interrupt input pins |

Notes 1: VCC = 2.4 to 5.5 V for the extended operating temperature version and the extended operating temperature 125 °C version.

2: P26/AN6 and P27/AN7 do not exist for the 32-pin version, so that Port P2 is a 6-bit I/O port.

3: P35 and P36/INT1 do not exist for the 32-pin version, so that Port P3 is a 6-bit I/O port.

GROUP EXPANSION

We plan to expand the 7540 group as follow:

Memory type

Support for Mask ROM version, One Time PROM version, and Emulator MCU .

Memory size

ROM/PROM size 8 K to 32 K bytes
 RAM size 384 to 768 bytes

Package

32P4B 32-pin plastic molded SDIP
 32P6U-A 0.8 mm-pitch 32-pin plastic molded LQFP
 36P2R-A 0.8 mm-pitch 36-pin plastic molded SSOP
 42S1M 42-pin shrink ceramic PIGGY BACK

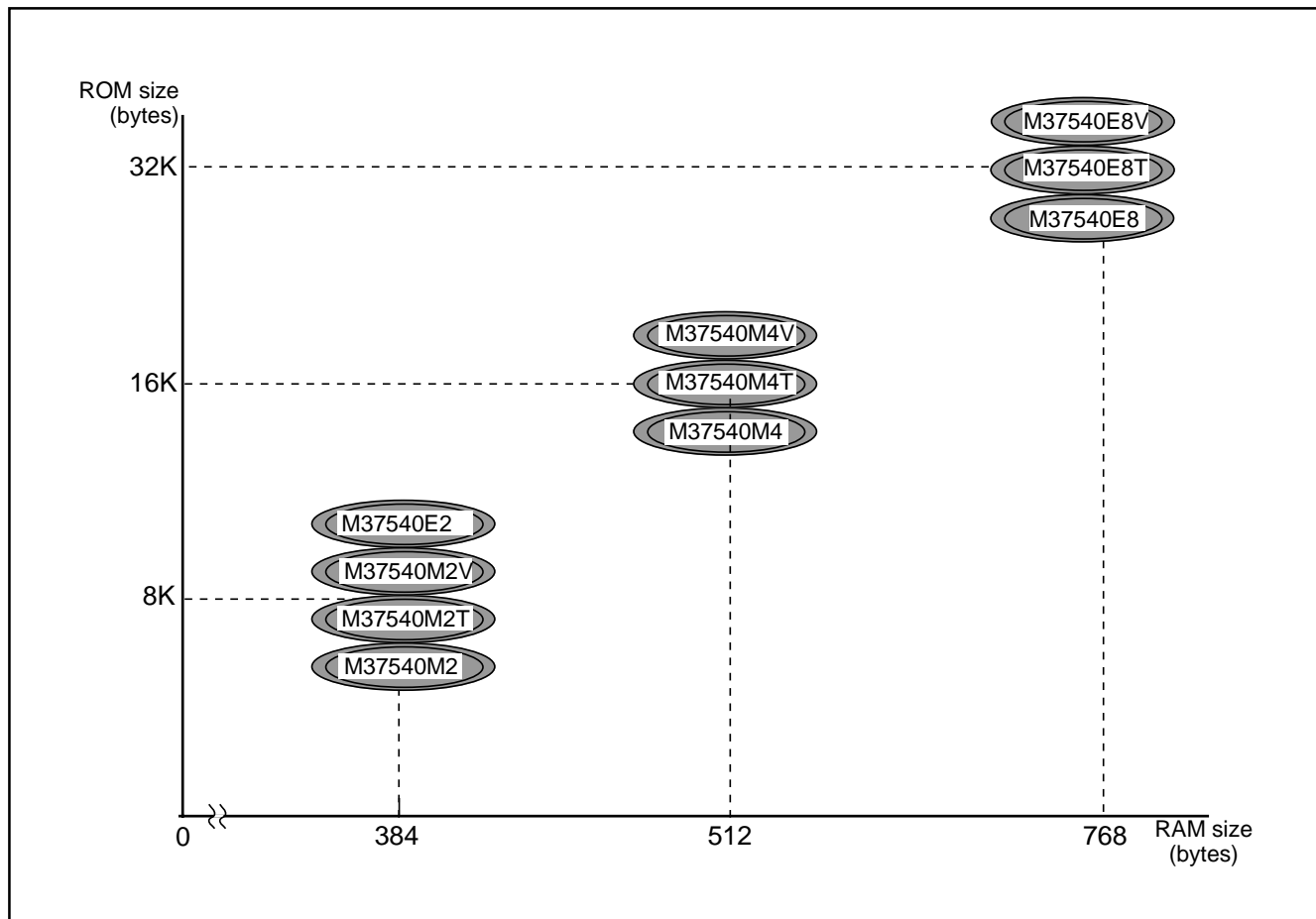


Fig. 8 Memory expansion plan

Currently supported products are listed below.

Table 2 List of supported products

| Part Number | (P) ROM size (bytes) ROM size for User () | RAM size (bytes) | Package | Remarks |
|-----------------|---|---------------------|--|--|
| M37540M2-XXXSP | 8192 (8062) | 384 | 32P4B | Mask ROM version |
| M37540M2-XXXFP | | | 36P2R-A | Mask ROM version |
| M37540M2T-XXXFP | | | | Mask ROM version (extended operating temperature version) |
| M37540M2V-XXXFP | | | 32P6U-A | Mask ROM version (extended operating temperature 125 °C version) |
| M37540M2-XXXGP | | | | Mask ROM version |
| M37540M2T-XXXGP | | | | Mask ROM version (extended operating temperature version) |
| M37540M2V-XXXGP | | | Mask ROM version (extended operating temperature 125 °C version) | |
| M37540M4-XXXSP | 16384 (16254) | 512 | 32P4B | Mask ROM version |
| M37540M4-XXXFP | | | 36P2R-A | Mask ROM version |
| M37540M4T-XXXFP | | | | Mask ROM version (extended operating temperature version) |
| M37540M4V-XXXFP | | | 32P6U-A | Mask ROM version (extended operating temperature 125 °C version) |
| M37540M4-XXXGP | | | | Mask ROM version |
| M37540M4T-XXXGP | | | | Mask ROM version (extended operating temperature version) |
| M37540M4V-XXXGP | | | Mask ROM version (extended operating temperature 125 °C version) | |
| M37540E2SP | 8192 (8062) | 384 | 32P4B | One Time PROM version (blank) |
| M37540E2FP | | | 36P2R-A | One Time PROM version (blank) |
| M37540E2GP | | | 32P6U-A | One Time PROM version (blank) |
| M37540E8SP | 32768 (32638) | 768 | 32P4B | One Time PROM version (blank) |
| M37540E8FP | | | 36P2R-A | One Time PROM version (blank) |
| M37540E8T-XXXFP | | | | One Time PROM version (shipped after programming, extended operating temperature version) |
| M37540E8V-XXXFP | | | 32P6U-A | One Time PROM version (shipped after programming, extended operating temperature 125 °C version) |
| M37540E8GP | | | | One Time PROM version (blank) |
| M37540E8T-XXXGP | | | | One Time PROM version (shipped after programming, extended operating temperature version) |
| M37540E8V-XXXGP | | | One Time PROM version (shipped after programming, extended operating temperature 125 °C version) | |
| M37540RSS | ————— | 768 | 42S1M | Emulator MCU |

FUNCTIONAL DESCRIPTION

Central Processing Unit (CPU)

The MCU uses the standard 740 family instruction set. Refer to the table of 740 family addressing modes and machine-language instructions or the SERIES 740 <SOFTWARE> USER'S MANUAL for details on each instruction set.

Machine-resident 740 family instructions are as follows:

1. The FST and SLW instructions cannot be used.
2. The MUL and DIV instructions can be used.
3. The WIT instruction can be used.
4. The STP instruction can be used. (This instruction cannot be used while an on-chip oscillator is operating.)

Accumulator (A)

The accumulator is an 8-bit register. Data operations such as data transfer, etc., are executed mainly through the accumulator.

Index register X (X), Index register Y (Y)

Both index register X and index register Y are 8-bit registers. In the index addressing modes, the value of the OPERAND is added to the contents of register X or register Y and specifies the real address.

When the T flag in the processor status register is set to "1", the value contained in index register X becomes the address for the second OPERAND.

Stack pointer (S)

The stack pointer is an 8-bit register used during subroutine calls and interrupts. The stack is used to store the current address data and processor status when branching to subroutines or interrupt routines.

The lower eight bits of the stack address are determined by the contents of the stack pointer. The upper eight bits of the stack address are determined by the Stack Page Selection Bit. If the Stack Page Selection Bit is "0", then the RAM in the zero page is used as the stack area. If the Stack Page Selection Bit is "1", then RAM in page 1 is used as the stack area.

The Stack Page Selection Bit is located in the SFR area in the zero page. Note that the initial value of the Stack Page Selection Bit varies with each microcomputer type. Also some microcomputer types have no Stack Page Selection Bit and the upper eight bits of the stack address are fixed. The operations of pushing register contents onto the stack and popping them from the stack are shown in Fig. 10.

Program counter (PC)

The program counter is a 16-bit counter consisting of two 8-bit registers PCH and PCL. It is used to indicate the address of the next instruction to be executed.

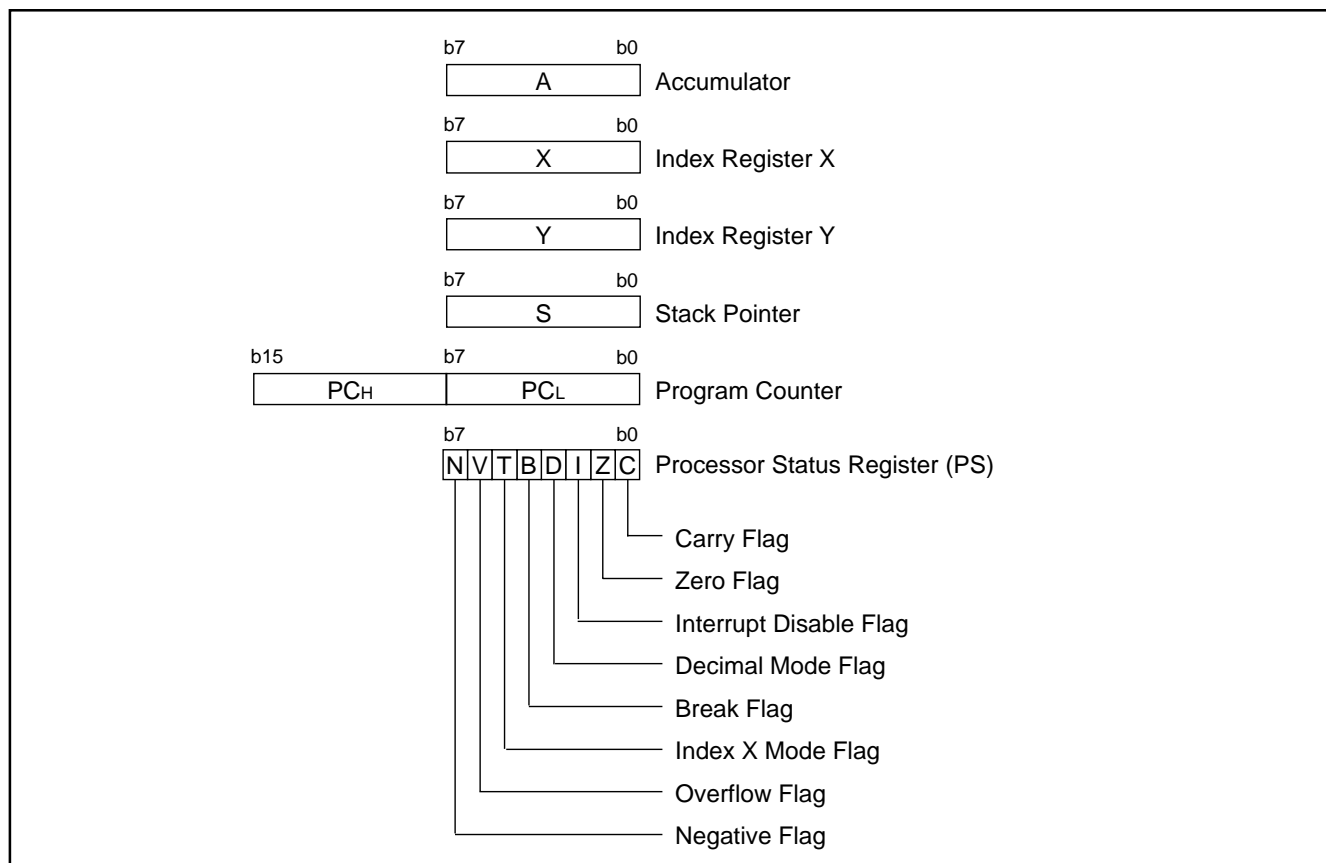


Fig. 9 740 Family CPU register structure

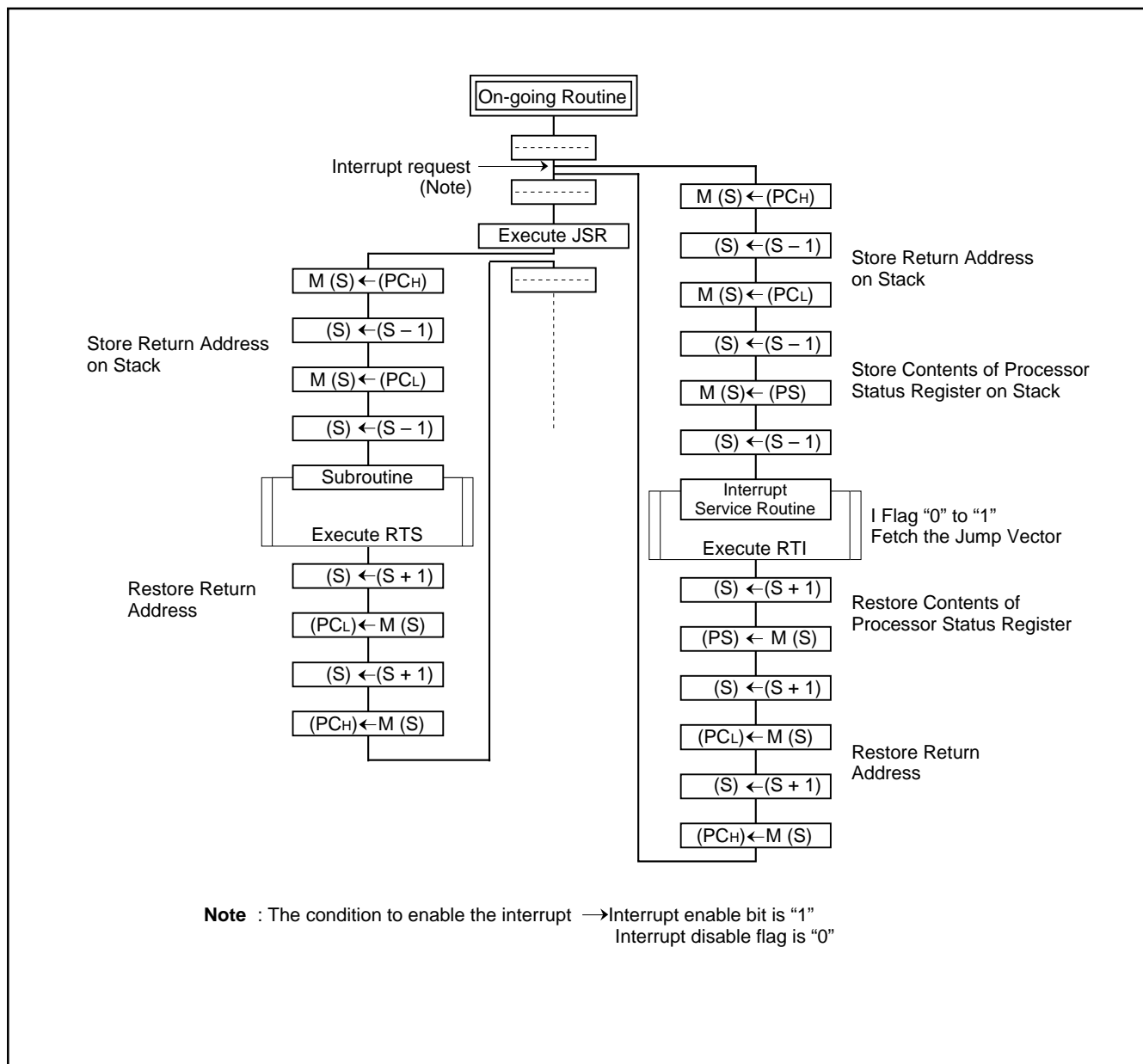


Fig. 10 Register push and pop at interrupt generation and subroutine call

Table 3 Push and pop instructions of accumulator or processor status register

| | Push instruction to stack | Pop instruction from stack |
|---------------------------|---------------------------|----------------------------|
| Accumulator | PHA | PLA |
| Processor status register | PHP | PLP |

Processor status register (PS)

The processor status register is an 8-bit register consisting of flags which indicate the status of the processor after an arithmetic operation. Branch operations can be performed by testing the Carry (C) flag, Zero (Z) flag, Overflow (V) flag, or the Negative (N) flag. In decimal mode, the Z, V, N flags are not valid.

After reset, the Interrupt disable (I) flag is set to "1", but all other flags are undefined. Since the Index X mode (T) and Decimal mode (D) flags directly affect arithmetic operations, they should be initialized in the beginning of a program.

(1) Carry flag (C)

The C flag contains a carry or borrow generated by the arithmetic logic unit (ALU) immediately after an arithmetic operation. It can also be changed by a shift or rotate instruction.

(2) Zero flag (Z)

The Z flag is set if the result of an immediate arithmetic operation or a data transfer is "0", and cleared if the result is anything other than "0".

(3) Interrupt disable flag (I)

The I flag disables all interrupts except for the interrupt generated by the BRK instruction. Interrupts are disabled when the I flag is "1".

When an interrupt occurs, this flag is automatically set to "1" to prevent other interrupts from interfering until the current interrupt is serviced.

(4) Decimal mode flag (D)

The D flag determines whether additions and subtractions are executed in binary or decimal. Binary arithmetic is executed when this flag is "0"; decimal arithmetic is executed when it is "1".

Decimal correction is automatic in decimal mode. Only the ADC and SBC instructions can be used for decimal arithmetic.

(5) Break flag (B)

The B flag is used to indicate that the current interrupt was generated by the BRK instruction. The BRK flag in the processor status register is always "0". When the BRK instruction is used to generate an interrupt, the processor status register is pushed onto the stack with the break flag set to "1". The saved processor status is the only place where the break flag is ever set.

(6) Index X mode flag (T)

When the T flag is "0", arithmetic operations are performed between accumulator and memory, e.g. the results of an operation between two memory locations is stored in the accumulator. When the T flag is "1", direct arithmetic operations and direct data transfers are enabled between memory locations, i.e. between memory and memory, memory and I/O, and I/O and I/O. In this case, the result of an arithmetic operation performed on data in memory location 1 and memory location 2 is stored in memory location 1. The address of memory location 1 is specified by index register X, and the address of memory location 2 is specified by normal addressing modes.

(7) Overflow flag (V)

The V flag is used during the addition or subtraction of one byte of signed data. It is set if the result exceeds +127 to -128. When the BIT instruction is executed, bit 6 of the memory location operated on by the BIT instruction is stored in the overflow flag.

(8) Negative flag (N)

The N flag is set if the result of an arithmetic operation or data transfer is negative. When the BIT instruction is executed, bit 7 of the memory location operated on by the BIT instruction is stored in the negative flag.

Table 4 Set and clear instructions of each bit of processor status register

| | C flag | Z flag | I flag | D flag | B flag | T flag | V flag | N flag |
|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Set instruction | SEC | – | SEI | SED | – | SET | – | – |
| Clear instruction | CLC | – | CLI | CLD | – | CLT | CLV | – |

[CPU mode register] CPUM

The CPU mode register contains the stack page selection bit. This register is allocated at address 003B16.

Switching method of CPU mode register

Switch the CPU mode register (CPUM) at the head of program after releasing Reset in the following method.

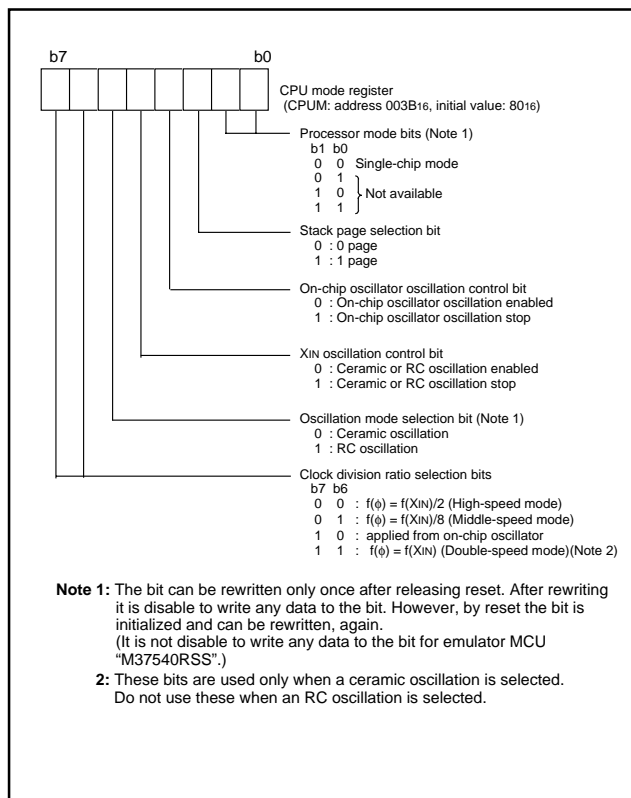


Fig. 11 Structure of CPU mode register

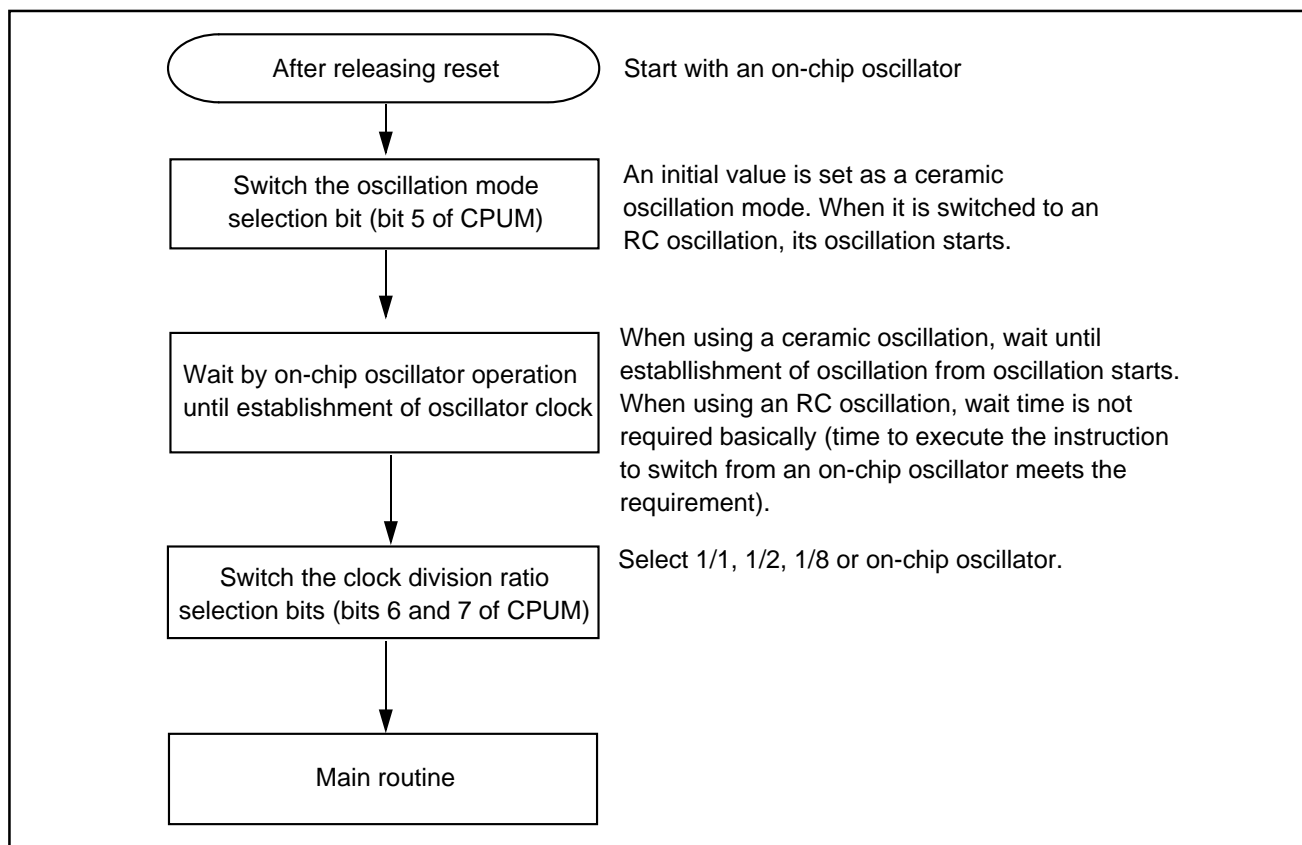


Fig. 12 Switching method of CPU mode register

Memory

Special function register (SFR) area

The SFR area in the zero page contains control registers such as I/O ports and timers.

RAM

RAM is used for data storage and for a stack area of subroutine calls and interrupts.

ROM

The first 128 bytes and the last 2 bytes of ROM are reserved for device testing and the rest is a user area for storing programs.

Interrupt vector area

The interrupt vector area contains reset and interrupt vectors.

Zero page

The 256 bytes from addresses 0000₁₆ to 00FF₁₆ are called the zero page area. The internal RAM and the special function registers (SFR) are allocated to this area.

The zero page addressing mode can be used to specify memory and register addresses in the zero page area. Access to this area with only 2 bytes is possible in the zero page addressing mode.

Special page

The 256 bytes from addresses FF00₁₆ to FFFF₁₆ are called the special page area. The special page addressing mode can be used to specify memory addresses in the special page area. Access to this area with only 2 bytes is possible in the special page addressing mode.

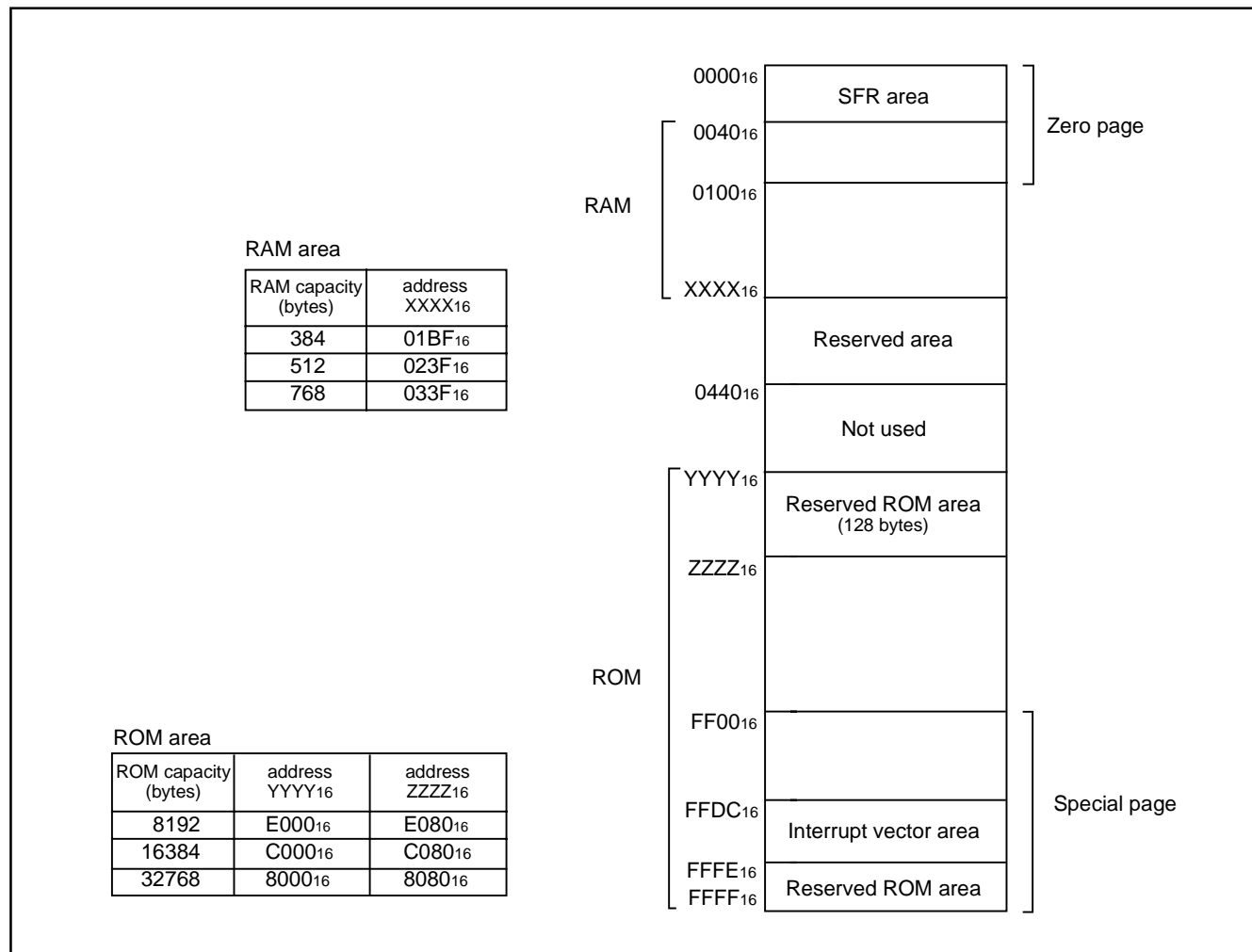


Fig. 13 Memory map diagram

| | | | |
|--------------------|--|--------------------|---|
| 0000 ₁₆ | Port P0 (P0) | 0020 ₁₆ | Timer Y, Z mode register (TYZM) |
| 0001 ₁₆ | Port P0 direction register (P0D) | 0021 ₁₆ | Prescaler Y (PREY) |
| 0002 ₁₆ | Port P1 (P1) | 0022 ₁₆ | Timer Y secondary (TYS) |
| 0003 ₁₆ | Port P1 direction register (P1D) | 0023 ₁₆ | Timer Y primary (TYP) |
| 0004 ₁₆ | Port P2 (P2) | 0024 ₁₆ | Timer Y, Z waveform output control register (PUM) |
| 0005 ₁₆ | Port P2 direction register (P2D) | 0025 ₁₆ | Prescaler Z (PREZ) |
| 0006 ₁₆ | Port P3 (P3) | 0026 ₁₆ | Timer Z secondary (TZS) |
| 0007 ₁₆ | Port P3 direction register (P3D) | 0027 ₁₆ | Timer Z primary (TZP) |
| 0008 ₁₆ | | 0028 ₁₆ | Prescaler 1 (PRE1) |
| 0009 ₁₆ | | 0029 ₁₆ | Timer 1 (T1) |
| 000A ₁₆ | | 002A ₁₆ | One-shot start register (ONS) |
| 000B ₁₆ | | 002B ₁₆ | Timer X mode register (TXM) |
| 000C ₁₆ | | 002C ₁₆ | Prescaler X (PREX) |
| 000D ₁₆ | | 002D ₁₆ | Timer X (TX) |
| 000E ₁₆ | | 002E ₁₆ | Timer count source set register (TCSS) |
| 000F ₁₆ | | 002F ₁₆ | |
| 0010 ₁₆ | | 0030 ₁₆ | Serial I/O2 control register (SIO2CON) |
| 0011 ₁₆ | | 0031 ₁₆ | Serial I/O2 register (SIO2) |
| 0012 ₁₆ | | 0032 ₁₆ | |
| 0013 ₁₆ | | 0033 ₁₆ | |
| 0014 ₁₆ | | 0034 ₁₆ | A/D control register (ADCON) |
| 0015 ₁₆ | | 0035 ₁₆ | A/D conversion register (low-order) (ADL) |
| 0016 ₁₆ | Pull-up control register (PULL) | 0036 ₁₆ | A/D conversion register (high-order) (ADH) |
| 0017 ₁₆ | Port P1P3 control register (P1P3C) | 0037 ₁₆ | |
| 0018 ₁₆ | Transmit/Receive buffer register (TB/RB) | 0038 ₁₆ | MISRG |
| 0019 ₁₆ | Serial I/O1 status register (SIO1STS) | 0039 ₁₆ | Watchdog timer control register (WDTCN) |
| 001A ₁₆ | Serial I/O1 control register (SIO1CON) | 003A ₁₆ | Interrupt edge selection register (INTEDGE) |
| 001B ₁₆ | UART control register (UARTCON) | 003B ₁₆ | CPU mode register (CPUM) |
| 001C ₁₆ | Baud rate generator (BRG) | 003C ₁₆ | Interrupt request register 1 (IREQ1) |
| 001D ₁₆ | Timer A mode register (TAM) | 003D ₁₆ | Interrupt request register 2 (IREQ2) |
| 001E ₁₆ | Timer A (low-order) (TAL) | 003E ₁₆ | Interrupt control register 1 (ICON1) |
| 001F ₁₆ | Timer A (high-order) (TAH) | 003F ₁₆ | Interrupt control register 2 (ICON2) |

Note : Do not access to the SFR area including nothing.

Fig. 14 Memory map of special function register (SFR)

I/O Ports

[Direction registers] PiD

The I/O ports have direction registers which determine the input/output direction of each pin. Each bit in a direction register corresponds to one pin, and each pin can be set to be input or output. When "1" is set to the bit corresponding to a pin, this pin becomes an output port. When "0" is set to the bit, the pin becomes an input port.

When data is read from a pin set to output, not the value of the pin itself but the value of port latch is read. Pins set to input are floating, and permit reading pin values.

If a pin set to input is written to, only the port latch is written to and the pin remains floating.

[Pull-up control register] PULL

By setting the pull-up control register (address 0016₁₆), ports P0 and P3 can exert pull-up control by program. However, pins set to output are disconnected from this control and cannot exert pull-up control.

Note: P26/AN6, P27/AN7, P35 and P36 do not exist for the 32-pin version.

Accordingly, the following settings are required;

- Set direction registers of ports P26 and P27 to output.
- Set direction registers of ports P35 and P36 to output.

[Port P1P3 control register] P1P3C

By setting the port P1P3 control register (address 0017₁₆), a CMOS input level or a TTL input level can be selected for ports P10, P12, P13, P36, and P37 by program.

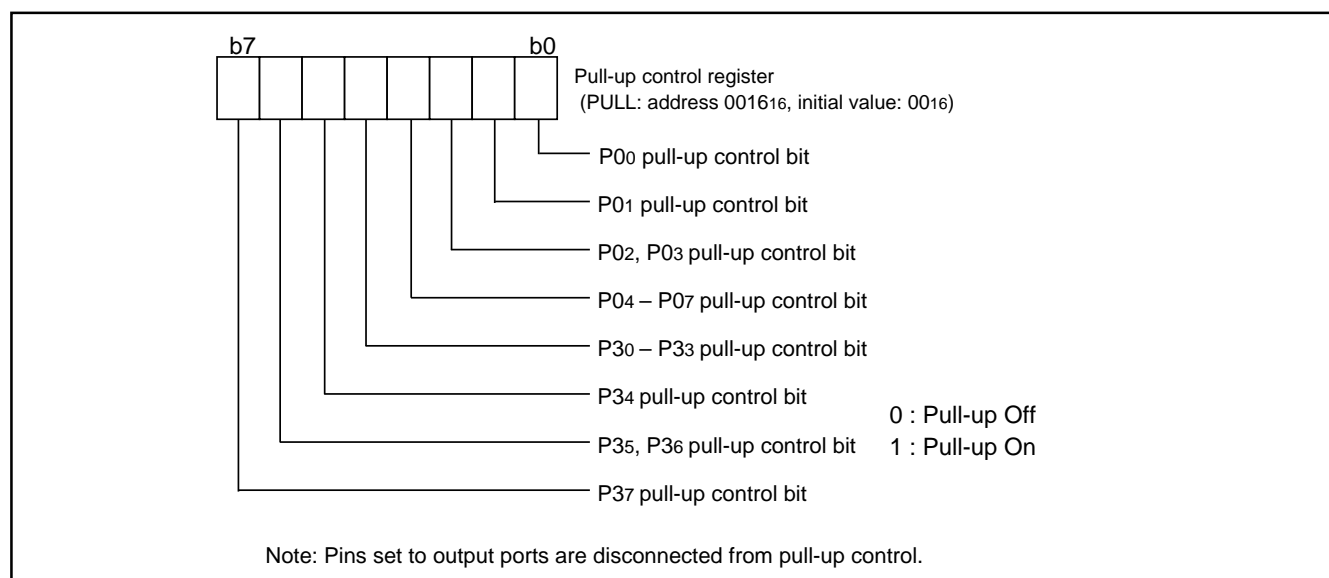


Fig. 15 Structure of pull-up control register

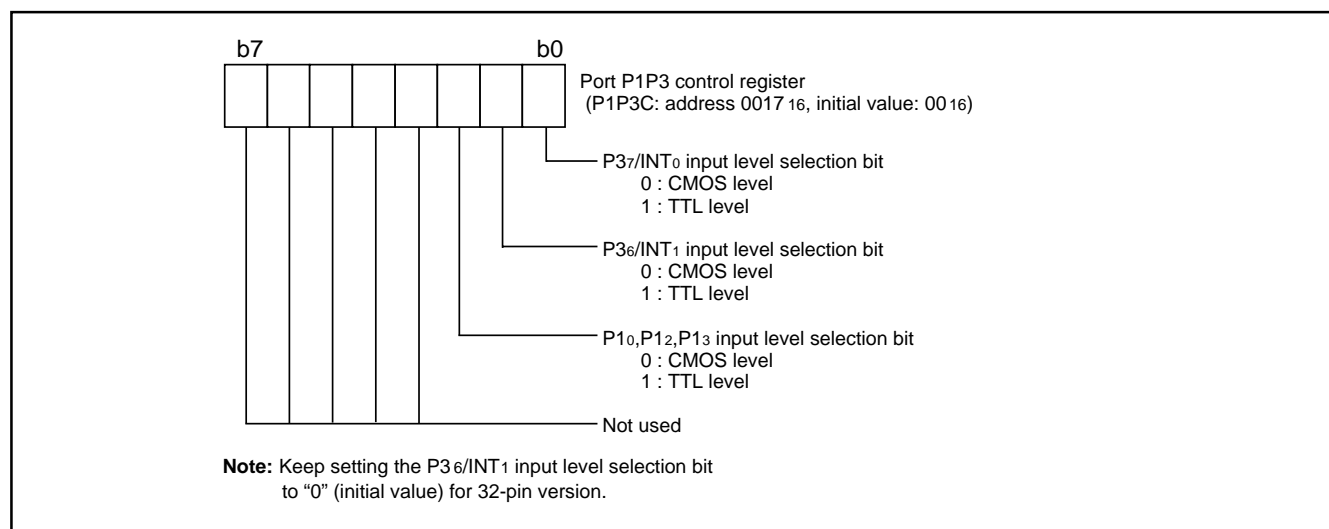


Fig. 16 Structure of port P1P3 control register

Table 5 I/O port function table

| Pin | Name | Input/output | I/O format | Non-port function | Related SFRs | Diagram No. |
|---|-------------------------|---------------------|---|--|--|--------------------------|
| P00/CNTR1 P01/TYOUT P02/TZOUT P03/TXOUT P04–P07 | I/O port P0 | I/O individual bits | <ul style="list-style-type: none"> •CMOS compatible input level •CMOS 3-state output (Note 1) | Key input interrupt Timer X function output Timer Y function output Timer Z function output Timer A function input | Pull-up control register Timer Y mode register Timer Z mode register Timer X mode register Timer Y,Z waveform output control register Timer A mode register | (1) (2) (3) (4) |
| P10/RxD1 P11/TxD1 | I/O port P1 | | | Serial I/O1 function input/output | Serial I/O1 control register | (5) (6) |
| P12/SCLK1/SCLK2 P13/SRDY1/SDATA2 | | | | Serial I/O2 function input/output | Serial I/O1 control register Serial I/O2 control register | (7) (8) |
| P14/CNTR0 | | | | Timer X function input/output | Timer X mode register | (9) |
| P20/AN0– P27/AN7 | I/O port P2 (Note 2) | | | A/D conversion input | A/D control register | (10) |
| P30–P35 | I/O port P3 | | | | | (11) |
| P36/INT1 P37/INT0 | (Note 3) | | | External interrupt input | Interrupt edge selection register | (12) |

Notes 1: Ports P10, P12, P13, P36, and P37 are CMOS/TTL level.

2: P26/AN6 and P27/AN7 do not exist for the 32-pin version.

3: P35 and P36/INT1 do not exist for the 32-pin version.

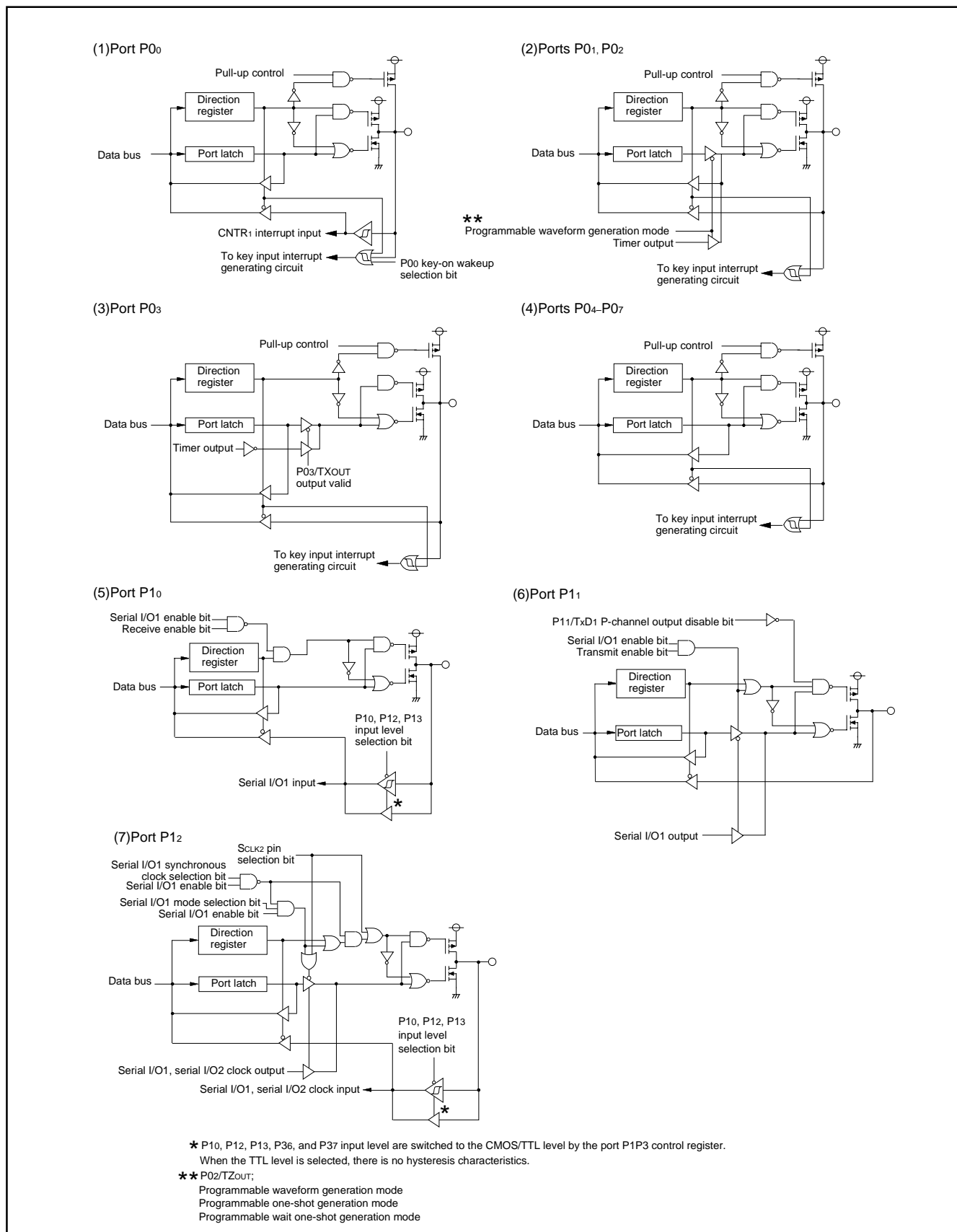


Fig. 17 Block diagram of ports (1)

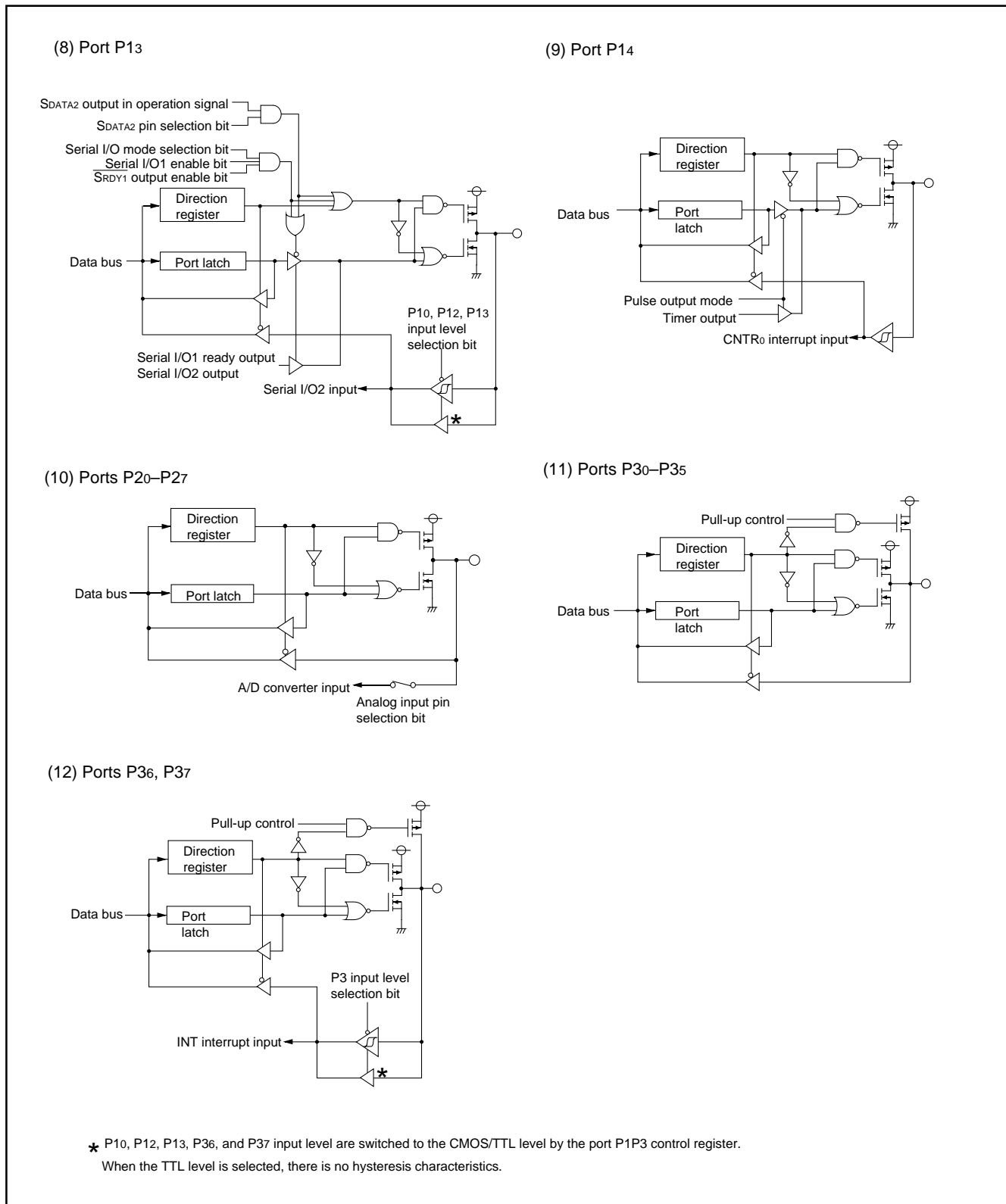


Fig. 18 Block diagram of ports (2)

Interrupts

Interrupts occur by 15 different sources : 5 external sources, 9 internal sources and 1 software source.

Interrupt control

All interrupts except the BRK instruction interrupt have an interrupt request bit and an interrupt enable bit, and they are controlled by the interrupt disable flag. When the interrupt enable bit and the interrupt request bit are set to "1" and the interrupt disable flag is set to "0", an interrupt is accepted.

The interrupt request bit can be cleared by program but not be set. The interrupt enable bit can be set and cleared by program.

The reset and BRK instruction interrupt can never be disabled with any flag or bit. All interrupts except these are disabled when the interrupt disable flag is set.

When several interrupts occur at the same time, the interrupts are received according to priority.

Interrupt operation

Upon acceptance of an interrupt the following operations are automatically performed:

1. The processing being executed is stopped.
2. The contents of the program counter and processor status register are automatically pushed onto the stack.
3. The interrupt disable flag is set and the corresponding interrupt request bit is cleared.
4. Concurrently with the push operation, the interrupt destination address is read from the vector table into the program counter.

■ Notes on use

When setting the followings, the interrupt request bit may be set to "1".

•When switching external interrupt active edge

Related register: Interrupt edge selection register (address 003A16)

Timer X mode register (address 2B16)

Timer A mode register (address 1D16)

When not requiring the interrupt occurrence synchronized with these setting, take the following sequence.

- ① Set the corresponding interrupt enable bit to "0" (disabled).
- ② Set the interrupt edge select bit (active edge switch bit).
- ③ Set the corresponding interrupt request bit to "0" after 1 or more instructions have been executed.
- ④ Set the corresponding interrupt enable bit to "1" (enabled).

Table 6 Interrupt vector address and priority

| Interrupt source | Priority | Vector addresses (Note 1) | | Interrupt request generating conditions | Remarks |
|----------------------|----------|---------------------------|-----------|--|---|
| | | High-order | Low-order | | |
| Reset (Note 2) | 1 | FFFD16 | FFFC16 | At reset input | Non-maskable |
| Serial I/O1 receive | 2 | FFFB16 | FFFA16 | At completion of serial I/O1 data receive | Valid only when serial I/O1 is selected |
| Serial I/O1 transmit | 3 | FFF916 | FFF816 | At completion of serial I/O1 transmit shift or when transmit buffer is empty | Valid only when serial I/O1 is selected |
| INT0 | 4 | FFF716 | FFF616 | At detection of either rising or falling edge of INT0 input | External interrupt (active edge selectable) |
| INT1 (Note 3) | 5 | FFF516 | FFF416 | At detection of either rising or falling edge of INT1 input | External interrupt (active edge selectable) |
| Key-on wake-up | 6 | FFF316 | FFF216 | At falling of conjunction of input logical level for port P0 (at input) | External interrupt (valid at falling) |
| CNTR0 | 7 | FFF116 | FFF016 | At detection of either rising or falling edge of CNTR0 input | External interrupt (active edge selectable) |
| CNTR1 | 8 | FFEF16 | FFEE16 | At detection of either rising or falling edge of CNTR1 input | External interrupt (active edge selectable) |
| Timer X | 9 | FFED16 | FFEC16 | At timer X underflow | |
| Timer Y | 10 | FFEB16 | FFEA16 | At timer Y underflow | |
| Timer Z | 11 | FFE916 | FFE816 | At timer Z underflow | |
| Timer A | 12 | FFE716 | FFE616 | At timer A underflow | |
| Serial I/O2 | 13 | FFE516 | FFE416 | At completion of transmit/receive shift | |
| A/D conversion | 14 | FFE316 | FFE216 | At completion of A/D conversion | |
| Timer 1 | 15 | FFE116 | FFE016 | At timer 1 underflow | STP release timer underflow |
| Reserved area | 16 | FFDF16 | FFDE16 | Not available | |
| BRK instruction | 17 | FFDD16 | FFDC16 | At BRK instruction execution | Non-maskable software interrupt |

Note 1: Vector addresses contain internal jump destination addresses.

2: Reset function in the same way as an interrupt with the highest priority.

3: It is an interrupt which can use only for 36 pin version.

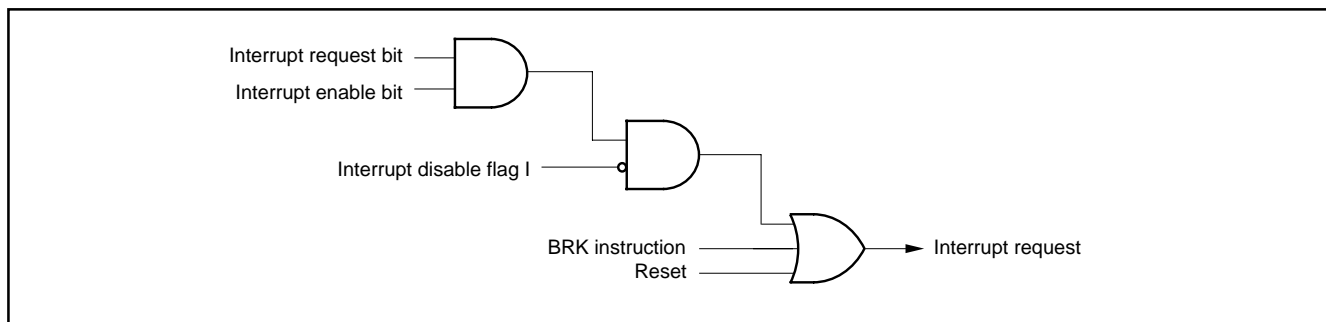


Fig. 19 Interrupt control

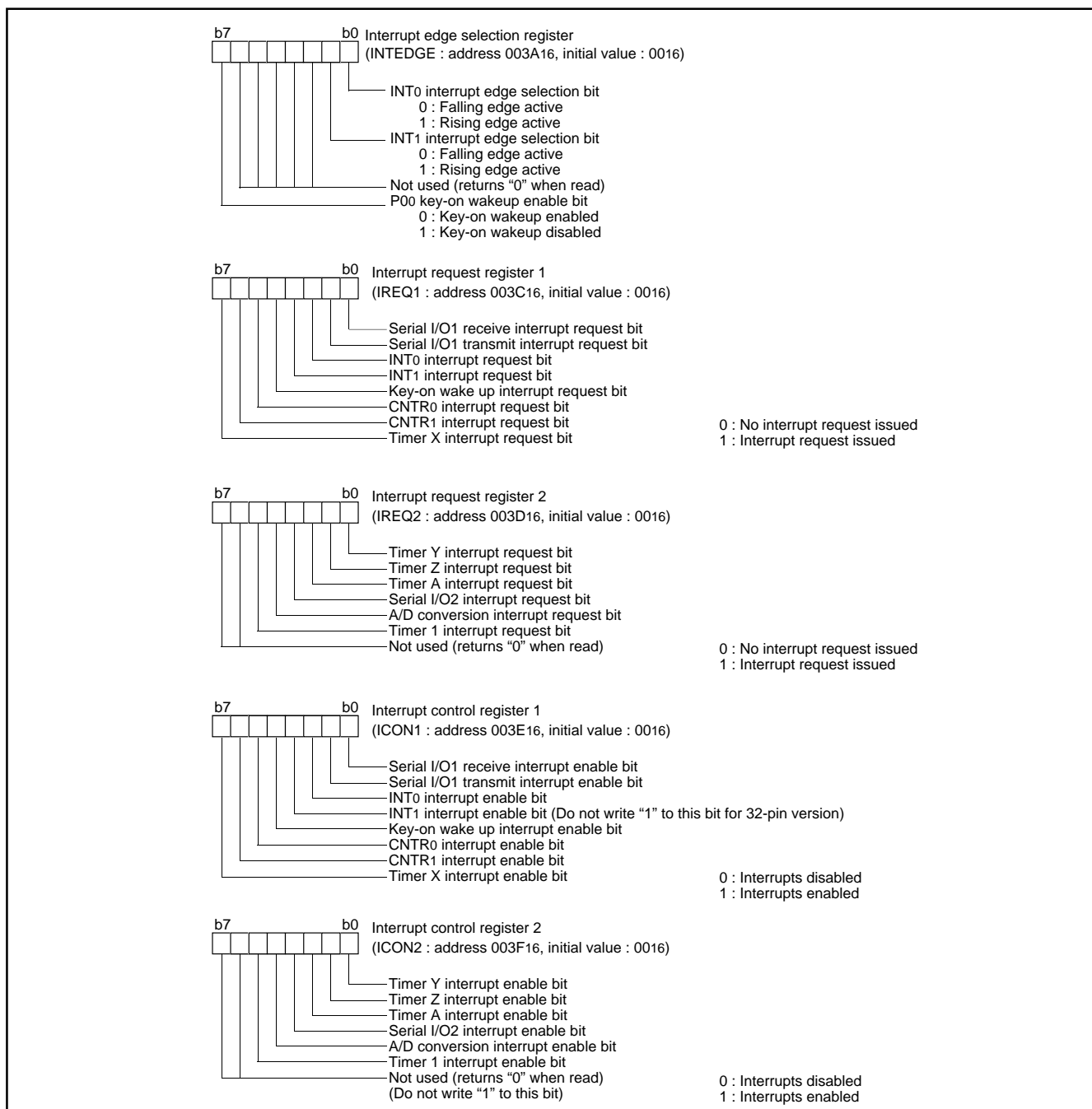


Fig. 20 Structure of Interrupt-related registers

Key Input Interrupt (Key-On Wake-Up)

A key-on wake-up interrupt request is generated by applying "L" level to any pin of port P0 that has been set to input mode.

In other words, it is generated when the AND of input level goes from "1" to "0". An example of using a key input interrupt is shown in Figure 21, where an interrupt request is generated by pressing one of the keys provided as an active-low key matrix which uses ports P00 to P03 as input ports.

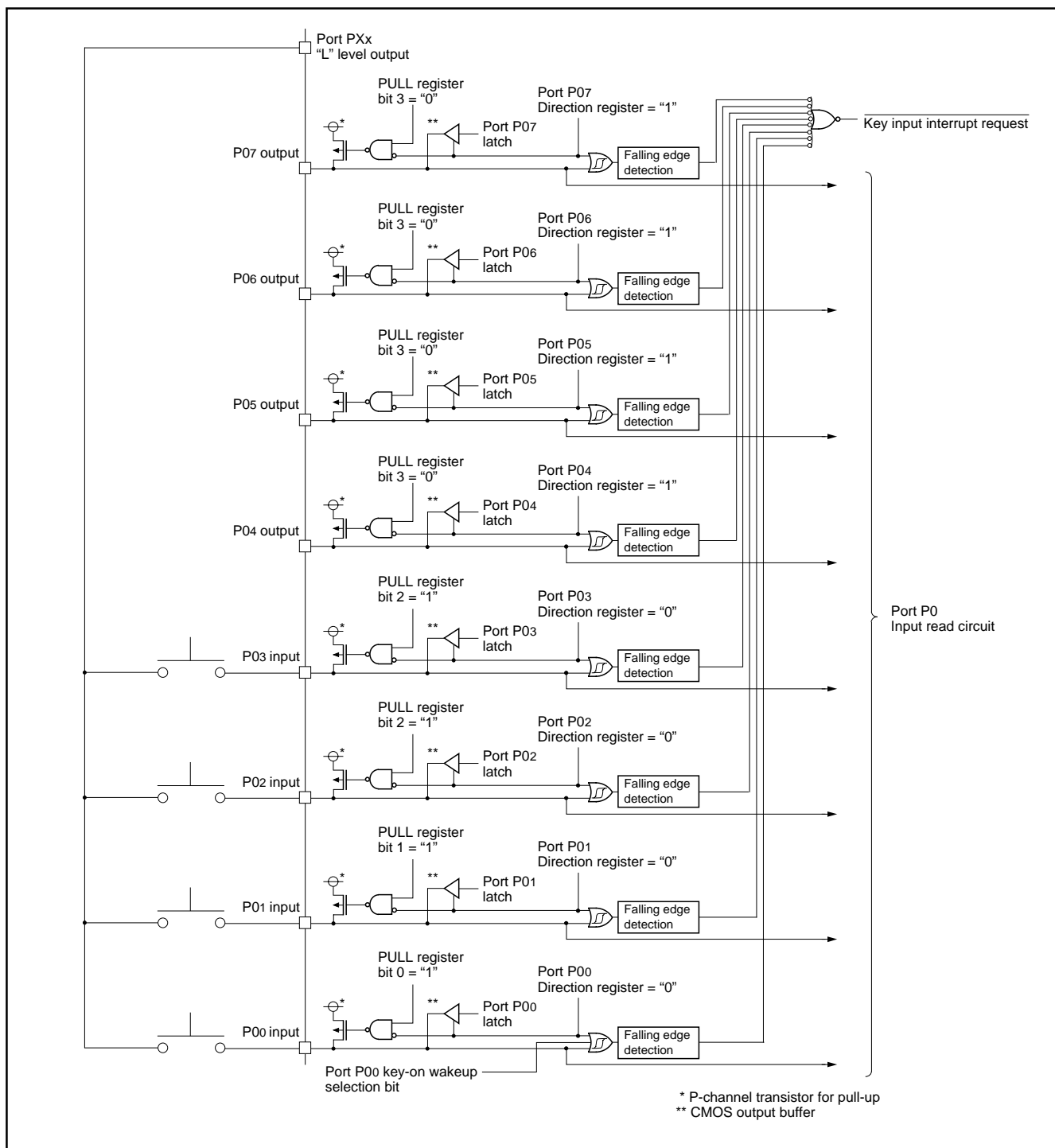


Fig. 21 Connection example when using key input interrupt and port P0 block diagram

Timers

The 7540 Group has 5 timers: timer 1, timer A, timer X, timer Y and timer Z.

The division ratio of every timer and prescaler is $1/(n+1)$ provided that the value of the timer latch or prescaler is n .

All the timers are down count timers. When a timer reaches "0", an underflow occurs at the next count pulse, and the corresponding timer latch is reloaded into the timer. When a timer underflows, the interrupt request bit corresponding to each timer is set to "1".

●Timer 1

Timer 1 is an 8-bit timer and counts the prescaler output.

When Timer 1 underflows, the timer 1 interrupt request bit is set to "1".

Prescaler 1 is an 8-bit prescaler and counts the signal which is the oscillation frequency divided by 16.

Prescaler 1 and Timer 1 have the prescaler 1 latch and the timer 1 latch to retain the reload value, respectively. The value of prescaler 1 latch is set to Prescaler 1 when Prescaler 1 underflows. The value of timer 1 latch is set to Timer 1 when Timer 1 underflows.

When writing to Prescaler 1 (PRE1) is executed, the value is written to both the prescaler 1 latch and Prescaler 1.

When writing to Timer 1 (T1) is executed, the value is written to both the timer 1 latch and Timer 1.

When reading from Prescaler 1 (PRE1) and Timer 1 (T1) is executed, each count value is read out.

Timer 1 always operates in the timer mode.

Prescaler 1 counts the signal which is the oscillation frequency divided by 16. Each time the count clock is input, the contents of Prescaler 1 is decremented by 1. When the contents of Prescaler 1 reach "00₁₆", an underflow occurs at the next count clock, and the prescaler 1 latch is reloaded into Prescaler 1 and count continues. The division ratio of Prescaler 1 is $1/(n+1)$ provided that the value of Prescaler 1 is n .

The contents of Timer 1 is decremented by 1 each time the underflow signal of Prescaler 1 is input. When the contents of Timer 1 reach "00₁₆", an underflow occurs at the next count clock, and the timer 1 latch is reloaded into Timer 1 and count continues. The division ratio of Timer 1 is $1/(m+1)$ provided that the value of Timer 1 is m . Accordingly, the division ratio of Prescaler 1 and Timer 1 is $1/((n+1) \times (m+1))$ provided that the value of Prescaler 1 is n and the value of Timer 1 is m .

Timer 1 cannot stop counting by software.

●Timer A

Timer A is a 16-bit timer and counts the signal which is the oscillation frequency divided by 16. When Timer A underflows, the timer A interrupt request bit is set to "1".

Timer A consists of the low-order of Timer A (TAL) and the high-order of Timer A (TAH).

Timer A has the timer A latch to retain the reload value. The value of timer A latch is set to Timer A at the timing shown below.

- When Timer A underflows.
- When an active edge is input from CNTR1 pin (valid only when period measurement mode and pulse width HL continuously measurement mode).

When writing to both the low-order of Timer A (TAL) and the high-order of Timer A (TAH) is executed, the value is written to both the timer A latch and Timer A.

When reading from the low-order of Timer A (TAL) and the high-order of Timer A (TAH) is executed, the following values are read out according to the operating mode.

- In timer mode, event counter mode:
The count value of Timer A is read out.
- In period measurement mode, pulse width HL continuously measurement mode:
The measured value is read out.

Be sure to write to/read out the low-order of Timer A (TAL) and the high-order of Timer A (TAH) in the following order;

Read

Read the high-order of Timer A (TAH) first, and the low-order of Timer A (TAL) next and be sure to read out both TAH and TAL.

Write

Write to the low-order of Timer A (TAL) first, and the high-order of Timer A (TAH) next and be sure to write to both TAL and TAH.

Timer A can be selected in one of 4 operating modes by setting the timer A mode register.

(1) Timer mode

Timer A counts the oscillation frequency divided by 16. Each time the count clock is input, the contents of Timer A is decremented by 1. When the contents of Timer A reach "0000₁₆", an underflow occurs at the next count clock, and the timer A latch is reloaded into Timer A. The division ratio of Timer A is $1/(n+1)$ provided that the value of Timer A is n .

(2) Period measurement mode

In the period measurement mode, the pulse period input from the P00/CNTR1 pin is measured.

CNTR1 interrupt request is generated at rising/falling edge of CNTR1 pin input signal. Simultaneously, the value in the timer A latch is reloaded into Timer A and count continues. The active edge of CNTR1 pin input signal can be selected from rising or falling by the CNTR1 active edge switch bit. The count value when trigger input from CNTR1 pin is accepted is retained until Timer A is read once.

(3) Event counter mode

Timer A counts signals input from the P00/CNTR1 pin.

Except for this, the operation in event counter mode is the same as in timer mode.

The active edge of CNTR1 pin input signal can be selected from rising or falling by the CNTR1 active edge switch bit .

(4) Pulse width HL continuously measurement mode

In the pulse width HL continuously measurement mode, the pulse width (“H” and “L” levels) input to the P00/CNTR1 pin is measured. CNTR1 interrupt request is generated at both rising and falling edges of CNTR1 pin input signal. Except for this, the operation in pulse width HL continuously measurement mode is the same as in period measurement mode.

The count value when trigger input from the CNTR1 pin is accepted is retained until Timer A is read once.

Timer A can stop counting by setting “1” to the timer A count stop bit in any mode.

Also, when Timer A underflows, the timer A interrupt request bit is set to “1”.

Note on Timer A is described below;

■ Note on Timer A

CNTR1 interrupt active edge selection

CNTR1 interrupt active edge depends on the CNTR1 active edge switch bit.

When this bit is “0”, the CNTR1 interrupt request bit is set to “1” at the falling edge of the CNTR1 pin input signal. When this bit is “1”, the CNTR1 interrupt request bit is set to “1” at the rising edge of the CNTR1 pin input signal.

However, in the pulse width HL continuously measurement mode, CNTR1 interrupt request is generated at both rising and falling edges of CNTR1 pin input signal regardless of the setting of CNTR1 active edge switch bit.

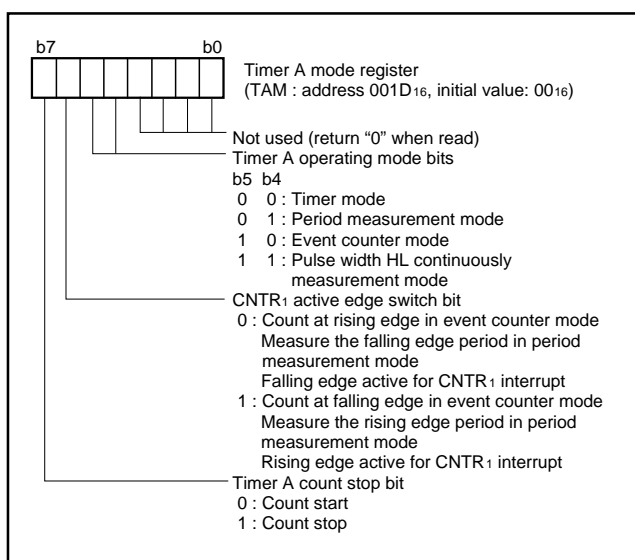


Fig. 22 Structure of timer A mode register

●Timer X

Timer X is an 8-bit timer and counts the prescaler X output.

When Timer X underflows, the timer X interrupt request bit is set to “1”.

Prescaler X is an 8-bit prescaler and counts the signal selected by the timer X count source selection bit.

Prescaler X and Timer X have the prescaler X latch and the timer X latch to retain the reload value, respectively. The value of prescaler X latch is set to Prescaler X when Prescaler X underflows. The value of timer X latch is set to Timer X when Timer X underflows.

When writing to Prescaler X (PREX) is executed, the value is written to both the prescaler X latch and Prescaler X.

When writing to Timer X (TX) is executed, the value is written to both the timer X latch and Timer X.

When reading from Prescaler X (PREX) and Timer X (TX) is executed, each count value is read out.

Timer X can be selected in one of 4 operating modes by setting the timer X operating mode bits of the timer X mode register.

(1) Timer mode

Prescaler X counts the count source selected by the timer X count source selection bits. Each time the count clock is input, the contents of Prescaler X is decremented by 1. When the contents of Prescaler X reach “00₁₆”, an underflow occurs at the next count clock, and the prescaler X latch is reloaded into Prescaler X and count continues. The division ratio of Prescaler X is 1/(n+1) provided that the value of Prescaler X is n.

The contents of Timer X is decremented by 1 each time the underflow signal of Prescaler X is input. When the contents of Timer X reach “00₁₆”, an underflow occurs at the next count clock, and the timer X latch is reloaded into Timer X and count continues. The division ratio of Timer X is 1/(m+1) provided that the value of Timer X is m. Accordingly, the division ratio of Prescaler X and Timer X is 1/((n+1)X(m+1)) provided that the value of Prescaler X is n and the value of Timer X is m.

(2) Pulse output mode

In the pulse output mode, the waveform whose polarity is inverted each time timer X underflows is output from the CNTR0 pin.

The output level of CNTR0 pin can be selected by the CNTR0 active edge switch bit. When the CNTR0 active edge switch bit is “0”, the output of CNTR0 pin is started at “H” level. When this bit is “1”, the output is started at “L” level.

Also, the inverted waveform of pulse output from CNTR0 pin can be output from TXOUT pin by setting “1” to the P03/TXOUT output valid bit.

When using a timer in this mode, set the port P14 and P03 direction registers to output mode.

(3) Event counter mode

The timer A counts signals input from the P14/CNTR0 pin.

Except for this, the operation in event counter mode is the same as in timer mode.

The active edge of CNTR0 pin input signal can be selected from rising or falling by the CNTR0 active edge switch bit .

(4) Pulse width measurement mode

In the pulse width measurement mode, the pulse width of the signal input to P14/CNTR0 pin is measured.

The operation of Timer X can be controlled by the level of the signal input from the CNTR0 pin.

When the CNTR0 active edge switch bit is "0", the signal selected by the timer X count source selection bit is counted while the input signal level of CNTR0 pin is "H". The count is stopped while the pin is "L". Also, when the CNTR0 active edge switch bit is "1", the signal selected by the timer X count source selection bit is counted while the input signal level of CNTR0 pin is "L". The count is stopped while the pin is "H".

Timer X can stop counting by setting "1" to the timer X count stop bit in any mode.

Also, when Timer X underflows, the timer X interrupt request bit is set to "1".

Note on Timer X is described below;

■ Note on Timer X

CNTR0 interrupt active edge selection

CNTR0 interrupt active edge depends on the CNTR0 active edge switch bit.

When this bit is "0", the CNTR0 interrupt request bit is set to "1" at the falling edge of CNTR0 pin input signal. When this bit is "1", the CNTR0 interrupt request bit is set to "1" at the rising edge of CNTR0 pin input signal.

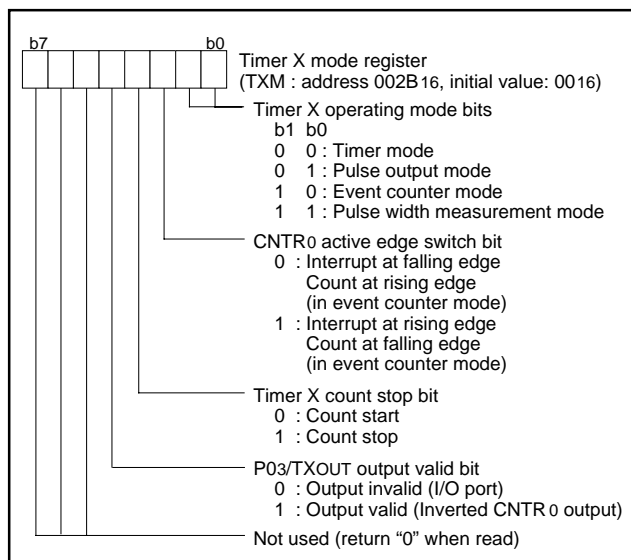


Fig. 23 Structure of timer X mode register

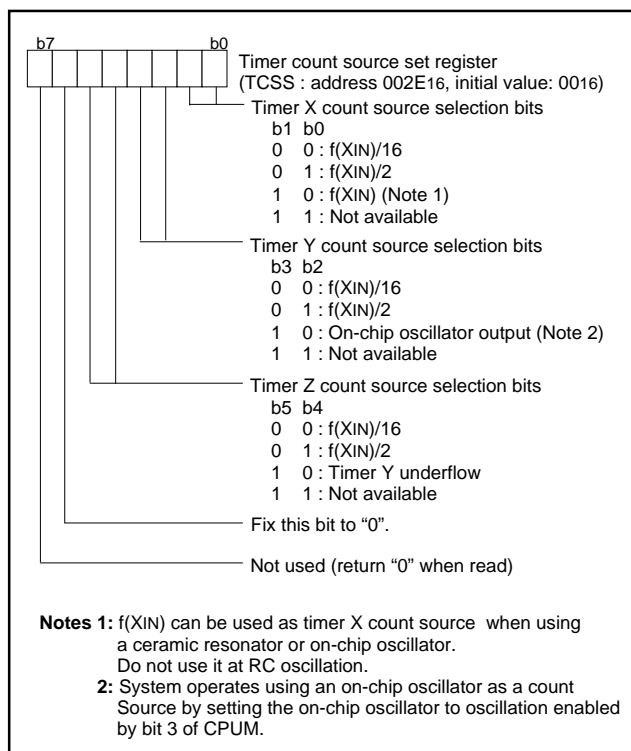


Fig. 24 Timer count source set register

●Timer Y

Timer Y is an 8-bit timer and counts the prescaler Y output. When Timer Y underflows, the timer Y interrupt request bit is set to "1".

Prescaler Y is an 8-bit prescaler and counts the signal selected by the timer Y count source selection bit.

Prescaler Y has the prescaler Y latch to retain the reload value. Timer Y has the timer Y primary latch and timer Y secondary latch to retain the reload value.

The value of prescaler Y latch is set to Prescaler Y when Prescaler Y underflows. The value of timer Y primary latch or timer Y secondary latch are set to Timer Y when Timer Y underflows.

As for the value to transfer to Timer Y, either of timer Y primary or timer Y secondary is selected depending on the timer Y operating mode.

When writing to Prescaler Y (PREY), timer Y primary (TYP) or timer Y secondary (TYS) is executed, writing to "latch only" or "latch and prescaler (timer)" can be selected by the setting value of the timer Y write control bit. Be sure to set the timer Y write control bit because there are some notes according to the operating mode.

When reading from Prescaler Y (PREY) is executed, the count value of Prescaler Y is read out. When reading from timer Y primary (TYP) is executed, the count value of Timer Y is read out. The count value of Timer Y can be read out by reading from the timer Y primary (TYP) even when the value of timer Y primary latch or timer Y secondary latch is counted. When reading the timer Y secondary (TYS) is executed, the undefined value is read out.

Timer Y can be selected in one of 2 operating modes by setting the timer Y operating mode bits of the timer Y, Z mode register.

(1) Timer mode

Prescaler Y counts the count source selected by the timer Y count source selection bits. Each time the count clock is input, the contents of Prescaler Y is decremented by 1. When the contents of Prescaler Y reach "0016", an underflow occurs at the next count clock, and the prescaler Y latch is reloaded into Prescaler Y. The division ratio of Prescaler Y is $1/(n+1)$ provided that the value of Prescaler Y is n.

The contents of Timer Y is decremented by 1 each time the underflow signal of Prescaler Y is input. When the contents of Timer Y reach "0016", an underflow occurs at the next count clock, and the timer Y primary latch is reloaded into Timer Y and count continues. (In the timer mode, the contents of timer Y primary latch is counted. Timer Y secondary latch is not used in this mode.)

The division ratio of Timer Y is $1/(m+1)$ provided that the value of Timer Y is m. Accordingly, the division ratio of Prescaler Y and Timer Y is $1/((n+1) \times (m+1))$ provided that the value of Prescaler Y is n and the value of Timer Y is m.

In the timer mode, writing to "latch only" or "latches and Prescaler Y and timer Y primary" can be selected by the setting value of the timer Y write control bit.

(2) Programmable waveform generation mode

In the programmable waveform generation mode, timer counts the setting value of timer Y primary and the setting value of timer Y secondary alternately, the waveform inverted each time Timer Y underflows is output from TYOUT pin.

When using this mode, be sure to set "1" to the timer Y write control bit to select "write to latch only". Also, set the port P01 direction registers to output mode.

The active edge of output waveform is set by the timer Y output level latch (b5) of the timer Y, Z waveform output control register (PUM). When "0" is set to b5 of PUM, "H" interval by the setting value of TYP or "L" interval by the setting value of TYS is output alternately. When "1" is set to b5 of PUM, "L" interval by the setting value of TYP or "H" interval by the setting value of TYS is output alternately.

Also, in this mode, the primary interval and the secondary interval of the output waveform can be extended respectively for 0.5 cycle of timer count source clock by setting the timer Y primary waveform extension control bit (b2) and the timer Y secondary waveform extension control bit (b3) of PUM to "1". As a result, the waveforms of more accurate resolution can be output.

When b2 and b3 of PUM are used, the frequency and duty of the output waveform are as follows;

Waveform frequency:

$$FYOUT = \frac{2XTMYCL}{2X(TYP+1)+2X(TYS+1)+(EXPYP+EXPYS)}$$

Duty:

$$DYOUT = \frac{2X(TYP+1)+EXPYP}{(2X(TYP+1)+EXPYP)+(2X(TYS+1)+EXPYS)}$$

TMYCL: Timer Y count source (frequency)

TYP: Timer Y primary (8bit)

TYS: Timer Y secondary (8bit)

EXPYP: Timer Y primary waveform extension control bit (1bit)

EXPYS: Timer Y secondary waveform extension control bit (1bit)

In the programmable waveform generation mode, when values of the TYP, TYS, EXPYP and EXPYS are changed, the output waveform is changed at the beginning (timer Y primary waveform interval) of waveform period.

When the count values are changed, set values to the TYS, EXPYP and EXPYS first. After then, set the value to TYP. The values are set all at once at the beginning of the next waveform period when the value is set to TYP. (When writing at timer stop is executed, writing to TYP at last is required.)

Notes on programmable waveform generation mode is described below;

■ Notes on programmable generation waveform mode**• Count set value**

In the programmable waveform generation mode, values of TYS, EXPYP, and EXPYS are valid by writing to TYP because the setting to them is executed all at once by writing to TYP. Even when changing TYP is not required, write the same value again.

• Write timing to TYP

In the programmable waveform generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TYP and the timing of timer underflow during the secondary interval simultaneously.

• Usage of waveform extension function

The waveform extension function by the timer Y waveform extension control bit can be used only when "0016" is set to Prescaler Y. When the value other than "0016" is set to Prescaler Y, be sure to set "0" to EXPYP and EXPYS.

• Timer Y write mode

When using this mode, be sure to set "1" to the timer Y write control bit to select "write to latch only".

Timer Y can stop counting by setting "1" to the timer Y count stop bit in any mode.

Also, when Timer Y underflows, the timer Y interrupt request bit is set to "1".

Timer Y reloads the value of latch when counting is stopped by the timer Y count stop bit. (When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

●Timer Z

Timer Z is an 8-bit timer and counts the prescaler Z output. When Timer Z underflows, the timer Z interrupt request bit is set to "1".

Prescaler Z is an 8-bit prescaler and counts the signal selected by the timer Z count source selection bit.

Prescaler Z has the prescaler Z latch to retain the reload value. Timer Z has the timer Z primary latch and timer Z secondary latch to retain the reload value.

The value of prescaler Z latch is set to Prescaler Z when Prescaler Z underflows. The value of timer Z primary latch or timer Z secondary latch are set to Timer Z when Timer Z underflows.

As for the value to transfer to Timer Z, either of timer Z primary or timer Z secondary is selected depending on the timer Z operating mode.

When writing to Prescaler Z (PREZ), timer Z primary (TZP) or timer Z secondary (TZS) is executed, writing to "latch only" or "latches and Prescaler Z and Timer Z" can be selected by the setting value of the timer Z write control bit. Be sure to set the write control bit because there are some notes according to the operating mode.

When reading from Prescaler Z (PREZ) is executed, the count value of Prescaler Z is read out. When reading from timer Z primary (TZP) is executed, the count value of Timer Z is read out. The count value of Timer Z can be read out by reading from the timer Z primary (TZP) even when the value of timer Z primary latch or timer Z secondary latch is counted. When reading the timer Z secondary (TZS) is executed, the undefined value is read out.

Timer Z can be selected in one of 4 operating modes by setting the timer Z operating mode bits of the timer Y, Z mode register.

(1) Timer mode

Prescaler Z counts the count source selected by the timer Z count source selection bits. Each time the count clock is input, the contents of Prescaler Z is decremented by 1. When the contents of Prescaler Z reach "0016", an underflow occurs at the next count clock, and the prescaler Z latch is reloaded into Prescaler Z. The division ratio of Prescaler Z is $1/(n+1)$ provided that the value of Prescaler Z is n.

The contents of Timer Z is decremented by 1 each time the underflow signal of Prescaler Z is input. When the contents of Timer Z reach "0016", an underflow occurs at the next count clock, and the timer Z primary latch is reloaded into Timer Z and count continues. (In the timer mode, the contents of timer Z primary latch is counted. Timer Z secondary latch is not used in this mode.)

The division ratio of Timer Z is $1/(m+1)$ provided that the value of Timer Z is m. Accordingly, the division ratio of Prescaler Z and Timer Z is $1/((n+1) \times (m+1))$ provided that the value of Prescaler Z is n and the value of Timer Z is m.

In the timer mode, writing to "latch only" or "latches and Prescaler Z and timer Z primary" can be selected by the setting value of the timer Z write control bit.

(2) Programmable waveform generation mode

In the programmable waveform generation mode, timer counts the setting value of timer Z primary and the setting value of timer Z secondary alternately, the waveform inverted each time Timer Z underflows is output from TZOUT pin.

When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only". Also, set the port P02 direction registers to output mode.

The active edge of output waveform is set by the timer Z output level latch (b4) of the timer Y, Z waveform output control register (PUM). When "0" is set to b4 of PUM, "H" interval by the setting value of TZP or "L" interval by the setting value of TZS is output alternately. When "1" is set to b4 of PUM, "L" interval by the setting value of TZP or "H" interval by the setting value of TZS is output alternately.

Also, in this mode, the primary interval and the secondary interval of the output waveform can be extended respectively for 0.5 cycle of timer count source clock by setting the timer Z primary waveform extension control bit (b0) and the timer Z secondary waveform extension control bit (b1) of PUM to "1". As a result, the waveforms of more accurate resolution can be output.

When b0 and b1 of PUM are used, the frequency and duty of the output waveform are as follows;

Waveform frequency:

$$FZOUT = \frac{2 \times TMZCL}{2 \times (TZP+1) + 2 \times (TZS+1) + (EXPZP+EXPZS)}$$

Duty:

$$DZOUT = \frac{2 \times (TZP+1) + EXPZP}{(2 \times (TZP+1) + EXPZP) + (2 \times (TZS+1) + EXPZS)}$$

TMZCL: Timer Z count source (frequency)

TZP: Timer Z primary (8bit)

TZS: Timer Z secondary (8bit)

EXPZP: Timer Z primary waveform extension control bit (1bit)

EXPZS: Timer Z secondary waveform extension control bit (1bit)

In the programmable waveform generation mode, when values of the TZP, TZS, EXPZP and EXPZS are changed, the output waveform is changed at the beginning (timer Z primary waveform interval) of waveform period.

When the count values are changed, set values to the TZS, EXPZP and EXPZS first. After then, set the value to TZP. The values are set all at once at the beginning of the next waveform period when the value is set to TZP. (When writing at timer stop is executed, writing to TZP at last is required.)

Notes on the programmable waveform generation mode are described below;

■ **Notes on programmable waveform generation mode**

• Count set value

In the programmable waveform generation mode, values of TZS, EXPZP, and EXPZS are valid by writing to TZP because the setting to them is executed all at once by writing to TZP. Even when changing TZP is not required, write the same value again.

• Write timing to TZP

In the programmable waveform generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow during the secondary interval simultaneously.

• Usage of waveform extension function

The waveform extension function by the timer Z waveform extension control bit can be used only when "0016" is set to Prescaler Z. When the value other than "0016" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the count source, the waveform extension function cannot be used.

• Timer Z write mode

When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".

(3) Programmable one-shot generation mode

In the programmable one-shot generation mode, the one-shot pulse by the setting value of timer Z primary can be output from TZOUT pin by software or external trigger. When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only". Also, set the port P02 direction registers to output mode. In this mode, TZS is not used.

The active edge of output waveform is set by the timer Z output level latch (b5) of the timer Y, Z waveform output control register (PUM). When "0" is set to b5 of PUM, "H" pulse during the interval of the TZP setting value is output. When "1" is set to b5 of PUM, "L" pulse during the interval of the TZP setting value is output.

Also, in this mode, the interval of the one-shot pulse output can be extended for 0.5 cycle of timer count source clock by setting the timer Z primary waveform extension control bit (b2) of PUM to "1". As a result, the waveforms of more accurate resolution can be output.

In the programmable one-shot generation mode, the trigger by software or the external INT0 pin can be accepted by writing "0" to the timer Z count stop bit after the count value is set. (At the time when "0" is written to the timer Z count stop bit, Timer Z stops.)

By writing "1" to the timer Z one-shot start bit, or by inputting the valid trigger to the INT0 pin after the trigger to the INT0 pin becomes valid by writing "1" to the INT0 pin one-shot trigger control bit, Timer Z starts counting, at the same time, the output of TZOUT pin is inverted. When Timer Z underflows, the output of TZOUT pin is inverted again and Timer Z stops. When also the trigger of INT0 pin is accepted, the contents of the one-shot start bit is changed to "1" by hardware.

The falling or rising can be selected as the edge of the valid trigger of INT0 pin by the INT0 pin one-shot trigger edge selection bit. During the one-shot pulse output interval, the one-shot pulse output can be stopped forcibly by writing "0" to the timer Z one-shot start bit.

In the programmable one-shot generation mode, when the count values are changed, set value to the EXPZP first. After then, set the value to TZP. The values are set all at once at the beginning of the next one-shot pulse when the value is set to TZP. (When writing at timer stop is executed, writing to TZP at last is required.)

Notes on the programmable one-shot generation mode are described below;

■ **Notes on programmable one-shot generation mode**

• Count set value

In the programmable one-shot generation mode, the value of EXPZP becomes valid by writing to TZP. Even when changing TZP is not required, write the same value again.

• Write timing to TZP

In the programmable one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow simultaneously.

• Usage of waveform extension function

The waveform extension function by the timer Z waveform extension control bit can be used only when "0016" is set to Prescaler Z. When the value other than "0016" is set to Prescaler Z, be sure to set "0" to EXPZP. Also, when the timer Y underflow is selected as the count source, the waveform extension function cannot be used.

• Timer Z write mode

When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".

(4) Programmable wait one-shot generation mode

In the programmable wait one-shot generation mode, the one-shot pulse by the setting value of timer Z secondary can be output from TZOUT pin by software or external trigger to INT0 pin after the wait by the setting value of the timer Z primary. When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only". Also, set the port P02 direction registers to output mode.

The active edge of output waveform is set by the timer Z output level latch (b5) of the timer Y, Z waveform output control register (PUM). When "0" is set to b5 of PUM, after the wait during the interval of the TZP setting value, "H" pulse during the interval of the TZS setting value is output. When "1" is set to b5 of PUM, after the wait during the interval of the TZP setting value, "L" pulse during the interval of the TZS setting value is output.

Also, in this mode, the intervals of the wait and the one-shot pulse output can be extended for 0.5 cycle of timer count source clock by setting EXPZP and EXPZS of PUM to "1". As a result, the waveforms of more accurate resolution can be output.

In the programmable one-shot generation mode, the trigger by software or the external INT0 pin can be accepted by writing "0" to the timer Z count stop bit after the count value is set. (At the time when "0" is written to the timer Z count stop bit, Timer Z stops.)

By writing "1" to the timer Z one-shot start bit, or by inputting the valid trigger to the INT0 pin after the trigger to the INT0 pin becomes valid by writing "1" to the INT0 pin one-shot trigger control bit, Timer Z starts counting.

While Timer Z counts the TZP, the initial value of the TZOUT pin output is retained. When Timer Z underflows, the value of TZS is reloaded, at the same time, the output of TZOUT pin is inverted.

When Timer Z underflows, the output of TZOUT pin is inverted again and Timer Z stops. When also the trigger of INT0 pin is accepted, the contents of the one-shot start bit is changed to "1" by hardware.

The falling or rising can be selected as the edge of the valid trigger of INT0 pin by the INT0 pin one-shot trigger edge selection bit. During the wait interval and the one-shot pulse output interval, the one-shot pulse output can be stopped forcibly by writing "0" to the timer Z one-shot start bit.

In the programmable wait one-shot generation mode, when the count values are changed, set values to the TZS, EXPZP and EXPZS first. After then, set the value to TZP. The values are set all at once at the beginning of the next wait interval when the value is set to TZP. (When writing at timer stop is executed, writing to TZP at last is required.)

Notes on the programmable wait one-shot generation mode are described below;

■ Notes on programmable wait one-shot generation mode

- Count set value

In the programmable wait one-shot generation mode, values of TZS, EXPZP and EXPZS are valid by writing to TZP. Even when changing TZP is not required, write the same value again.

- Write timing to TZP

In the programmable wait one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow during the secondary interval simultaneously.

- Usage of waveform extension function

The waveform extension function by the timer Z waveform extension control bit can be used only when "0016" is set to Prescaler Z. When the value other than "0016" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the count source, the waveform extension function cannot be used.

- Timer Z write mode

When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".

Timer Z can stop counting by setting "1" to the timer Z count stop bit in any mode.

Also, when Timer Z underflows, the timer Z interrupt request bit is set to "1".

Timer Z reloads the value of latch when counting is stopped by the timer Z count stop bit. (When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

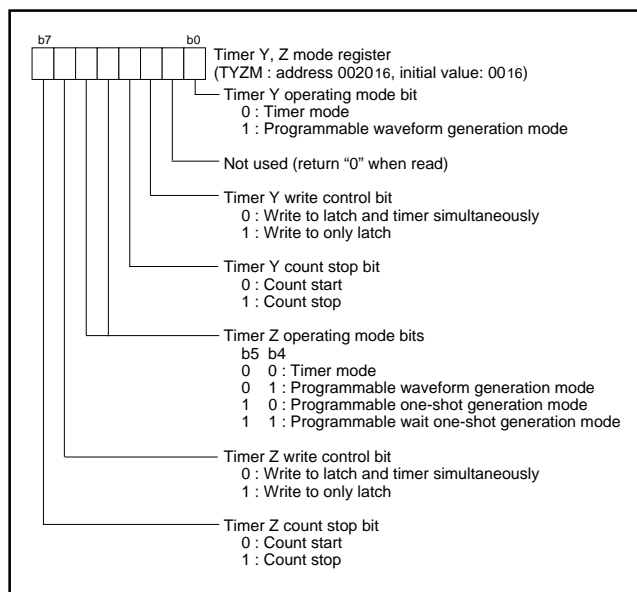


Fig. 25 Structure of timer Y, Z mode register

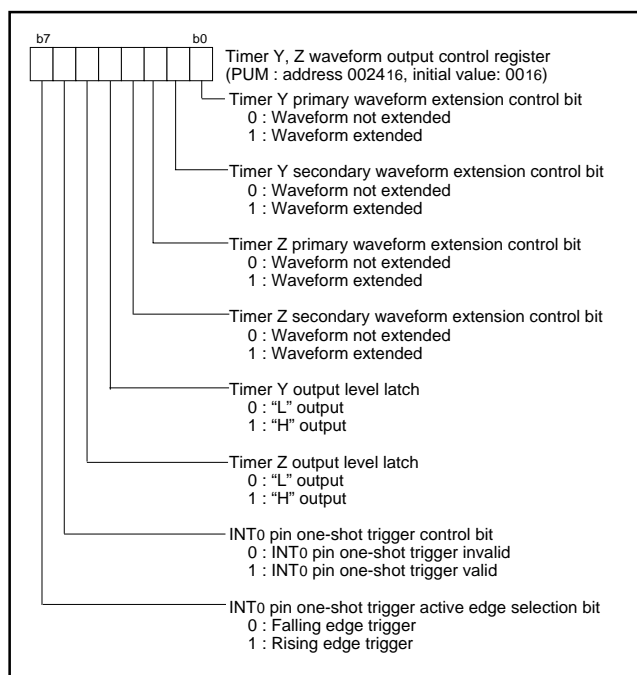


Fig. 26 Structure of timer Y, Z waveform output control register

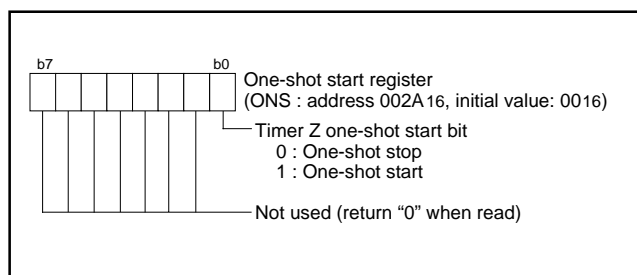


Fig. 27 Structure of one-shot start register

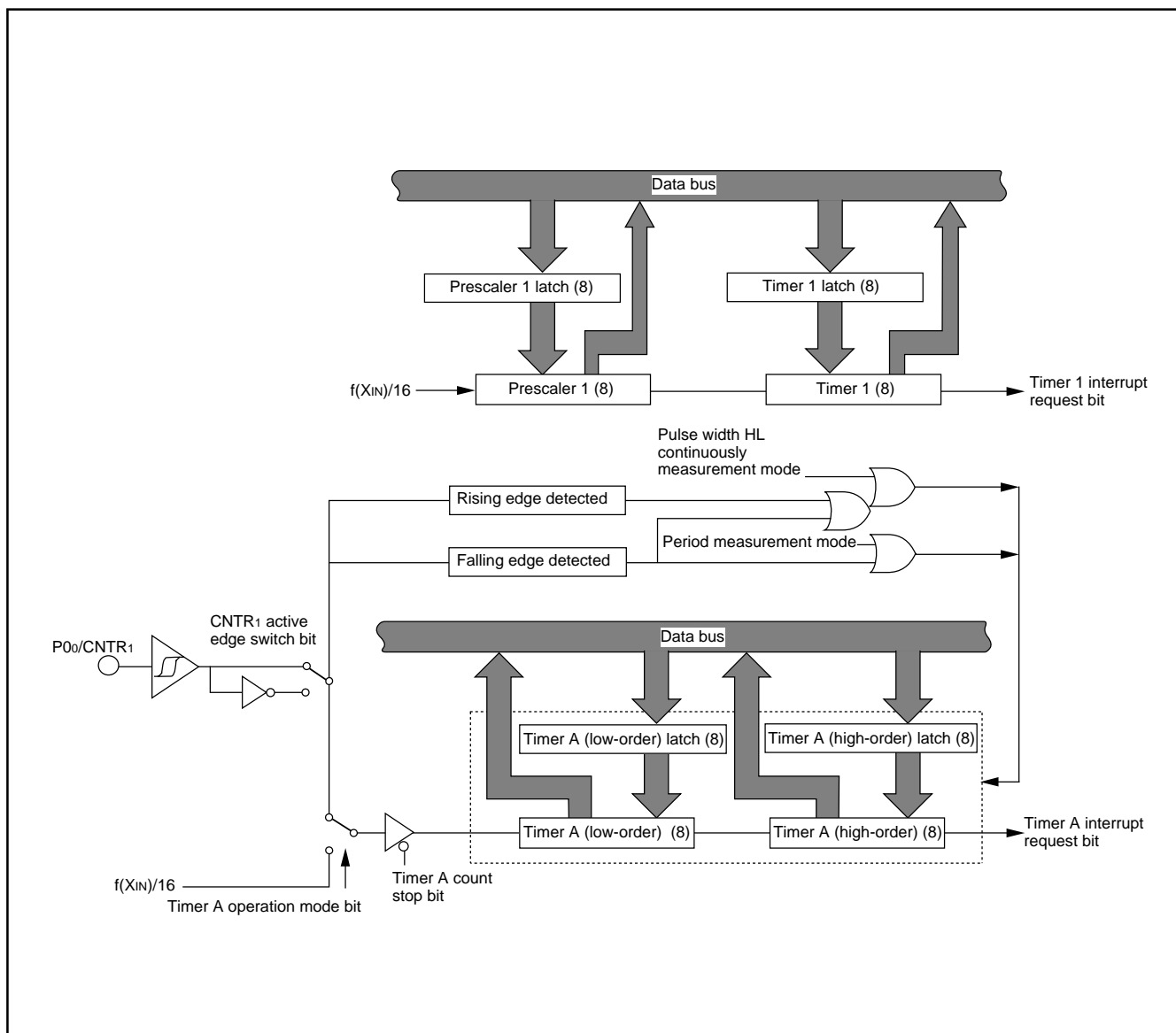


Fig. 28 Block diagram of timer 1 and timer A

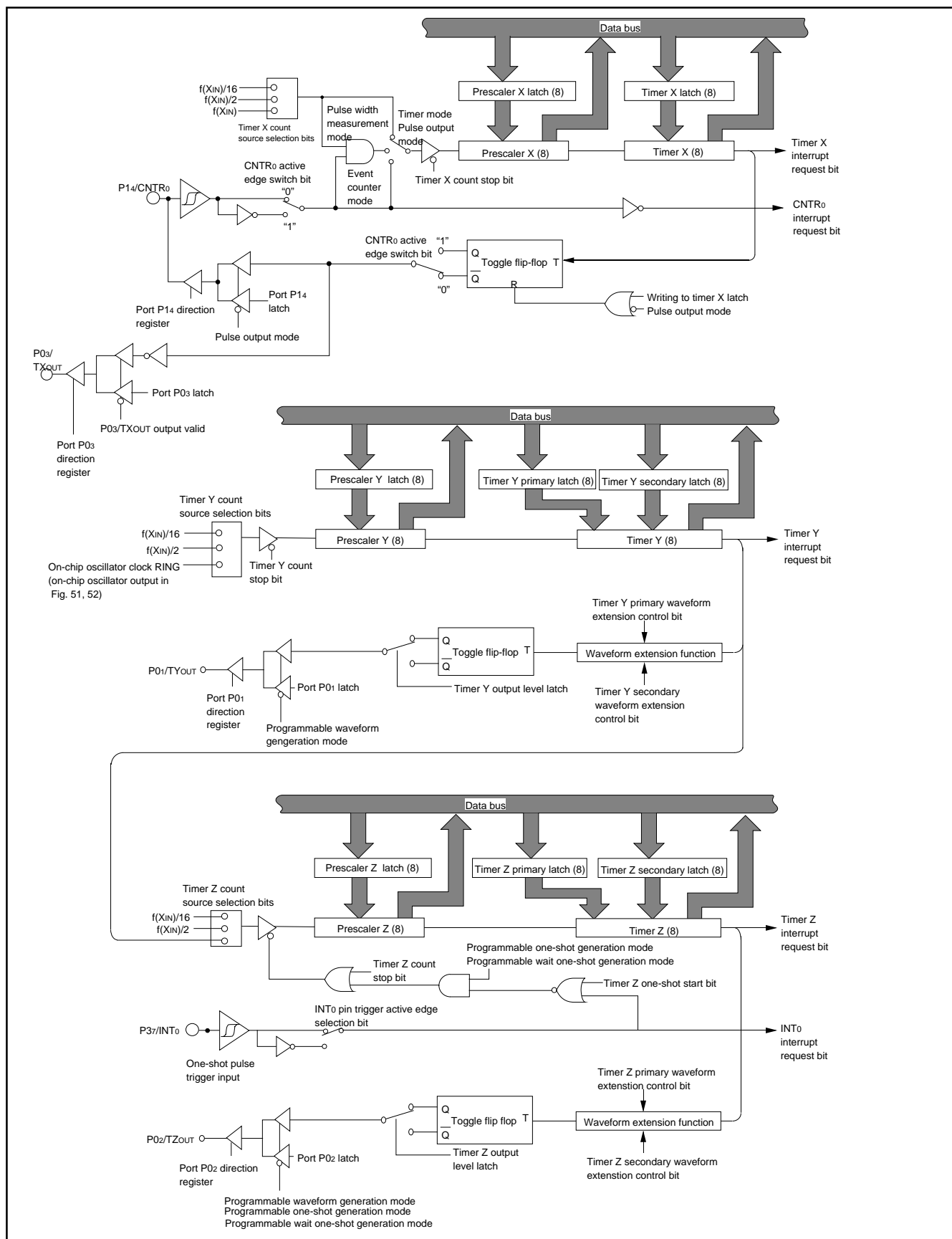


Fig. 29 Block diagram of timer X, timer Y and timer Z

Serial I/O
●Serial I/O1

Serial I/O1 can be used as either clock synchronous or asynchronous (UART) serial I/O. A dedicated timer is also provided for baud rate generation.

(1) Clock Synchronous Serial I/O Mode

Clock synchronous serial I/O1 mode can be selected by setting the serial I/O1 mode selection bit of the serial I/O1 control register (bit 6) to "1".

For clock synchronous serial I/O1, the transmitter and the receiver must use the same clock. If an internal clock is used, transfer is started by a write signal to the TB/RB.

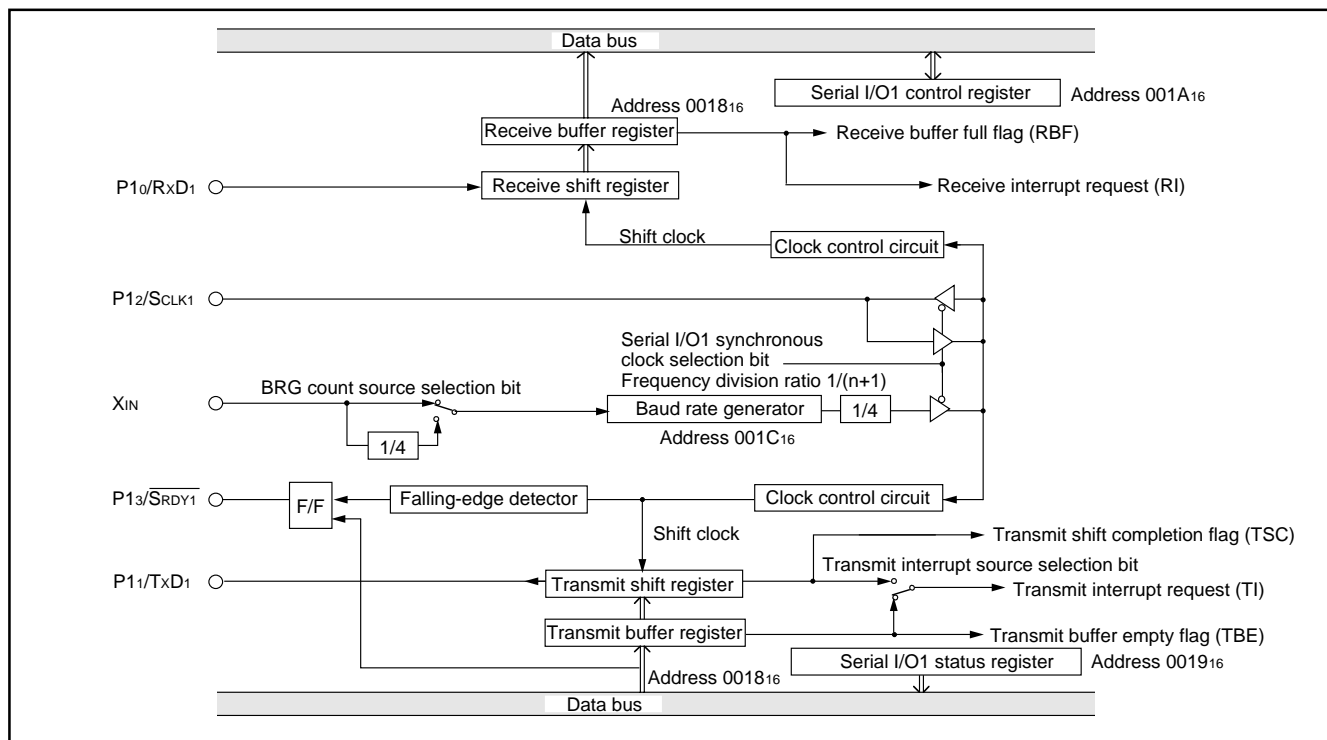


Fig. 30 Block diagram of clock synchronous serial I/O1

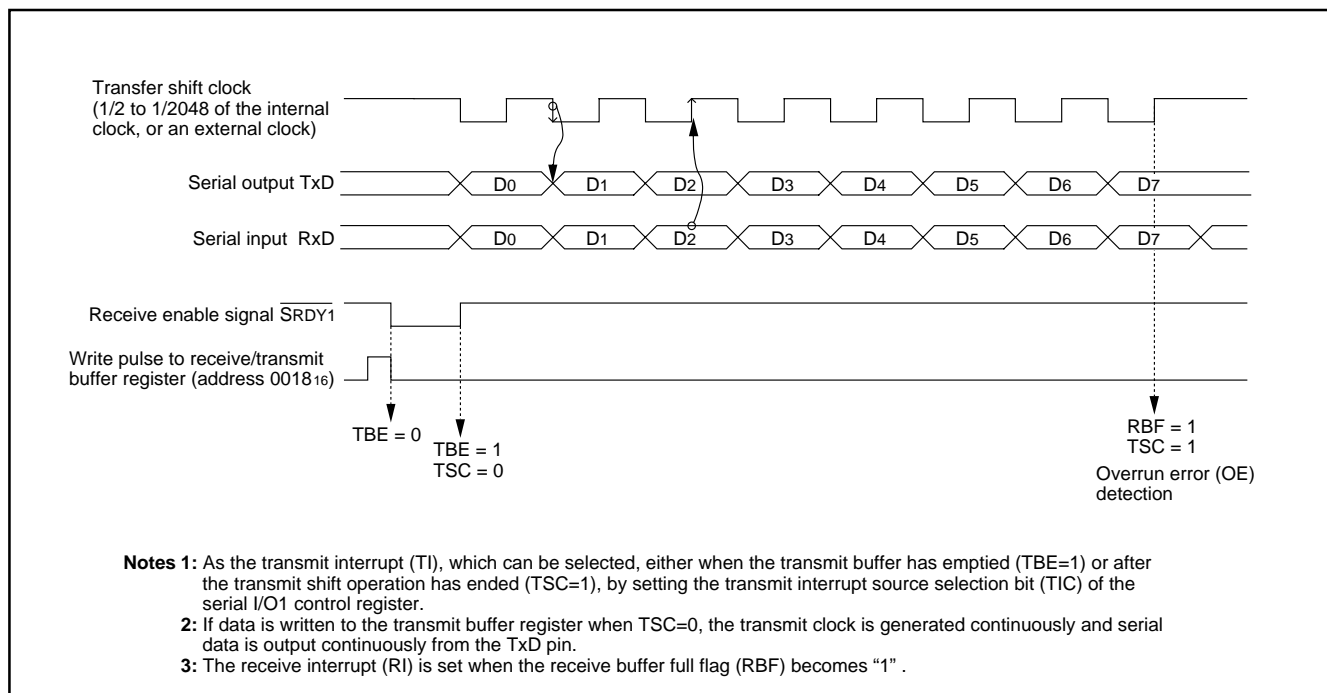


Fig. 31 Operation of clock synchronous serial I/O1 function

(2) Asynchronous Serial I/O (UART) Mode

Clock asynchronous serial I/O mode (UART) can be selected by clearing the serial I/O1 mode selection bit of the serial I/O1 control register to "0".

Eight serial data transfer formats can be selected, and the transfer formats used by a transmitter and receiver must be identical.

The transmit and receive shift registers each have a buffer, but the two buffers have the same address in memory. Since the shift register cannot be written to or read from directly, transmit data is written to the transmit buffer register, and receive data is read from the receive buffer register.

The transmit buffer register can also hold the next data to be transmitted, and the receive buffer register can hold a character while the next character is being received.

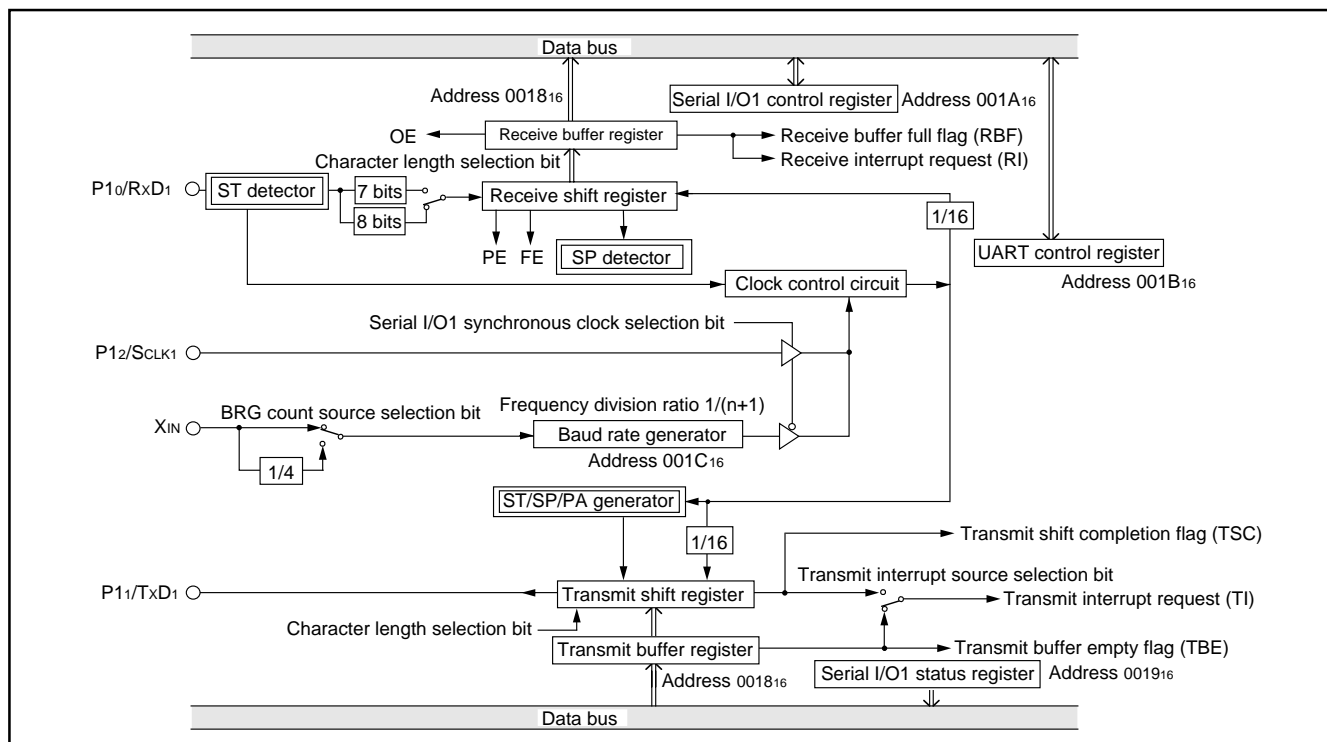


Fig. 32 Block diagram of UART serial I/O1

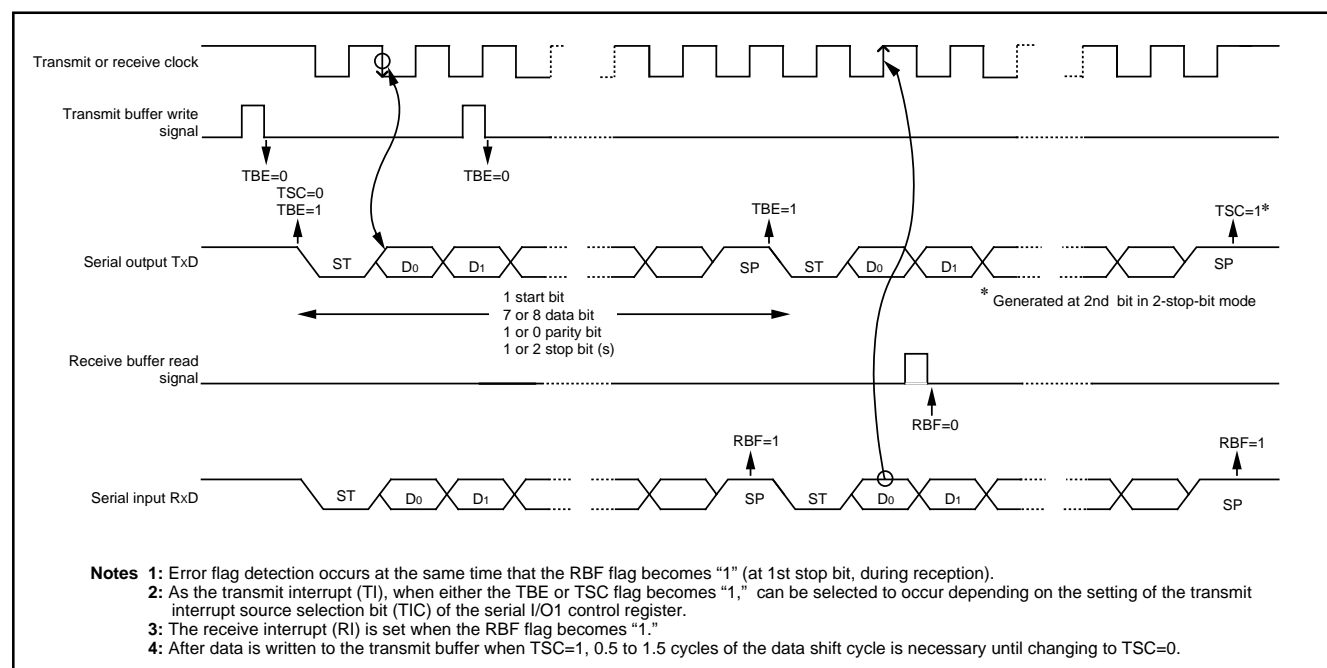


Fig. 33 Operation of UART serial I/O1 function

[Transmit buffer register/receive buffer register (TB/RB)] 001816

The transmit buffer register and the receive buffer register are located at the same address. The transmit buffer is write-only and the receive buffer is read-only. If a character bit length is 7 bits, the MSB of data stored in the receive buffer is "0".

[Serial I/O1 status register (SIO1STS)] 001916

The read-only serial I/O1 status register consists of seven flags (bits 0 to 6) which indicate the operating status of the serial I/O1 function and various errors.

Three of the flags (bits 4 to 6) are valid only in UART mode.

The receive buffer full flag (bit 1) is cleared to "0" when the receive buffer register is read.

If there is an error, it is detected at the same time that data is transferred from the receive shift register to the receive buffer register, and the receive buffer full flag is set. A write to the serial I/O1 status register clears all the error flags OE, PE, FE, and SE (bit 3 to bit 6, respectively). Writing "0" to the serial I/O1 enable bit SIOE (bit 7 of the serial I/O1 control register) also clears all the status flags, including the error flags.

Bits 0 to 6 of the serial I/O1 status register are initialized to "0" at reset, but if the transmit enable bit of the serial I/O1 control register has been set to "1", the transmit shift completion flag (bit 2) and the transmit buffer empty flag (bit 0) become "1".

[Serial I/O1 control register (SIO1CON)] 001A16

The serial I/O1 control register consists of eight control bits for the serial I/O1 function.

[UART control register (UARTCON)] 001B16

The UART control register consists of four control bits (bits 0 to 3) which are valid when asynchronous serial I/O is selected and set the data format of a data transfer and one bit (bit 4) which is always valid and sets the output structure of the P11/TXD1 pin.

[Baud rate generator (BRG)] 001C16

The baud rate generator determines the baud rate for serial transfer. The baud rate generator divides the frequency of the count source by $1/(n + 1)$, where n is the value written to the baud rate generator.

■ Notes on serial I/O**• Serial I/O interrupt**

When setting the transmit enable bit to "1", the serial I/O transmit interrupt request bit is automatically set to "1". When not requiring the interrupt occurrence synchronized with the transmission enabled, take the following sequence.

- ① Set the serial I/O transmit interrupt enable bit to "0" (disabled).
- ② Set the transmit enable bit to "1".
- ③ Set the serial I/O transmit interrupt request bit to "0" after 1 or more instructions have been executed.
- ⑤ Set the serial I/O transmit interrupt enable bit to "1" (enabled).

• I/O pin function when serial I/O1 is enabled.

The functions of P12 and P13 are switched with the setting values of a serial I/O1 mode selection bit and a serial I/O1 synchronous clock selection bit as follows.

(1) Serial I/O1 mode selection bit → "1" :

Clock synchronous type serial I/O is selected.

Setup of a serial I/O1 synchronous clock selection bit

"0" : P12 pin turns into an output pin of a synchronous clock.

"1" : P12 pin turns into an input pin of a synchronous clock.

Setup of a SRDY1 output enable bit (SRDY)

"0" : P13 pin can be used as a normal I/O pin.

"1" : P13 pin turns into a SRDY output pin.

(2) Serial I/O1 mode selection bit → "0" :

Clock asynchronous (UART) type serial I/O is selected.

Setup of a serial I/O1 synchronous clock selection bit

"0" : P12 pin can be used as a normal I/O pin.

"1" : P12 pin turns into an input pin of an external clock.

When clock asynchronous (UART) type serial I/O is selected, it is P13 pin. It can be used as a normal I/O pin.

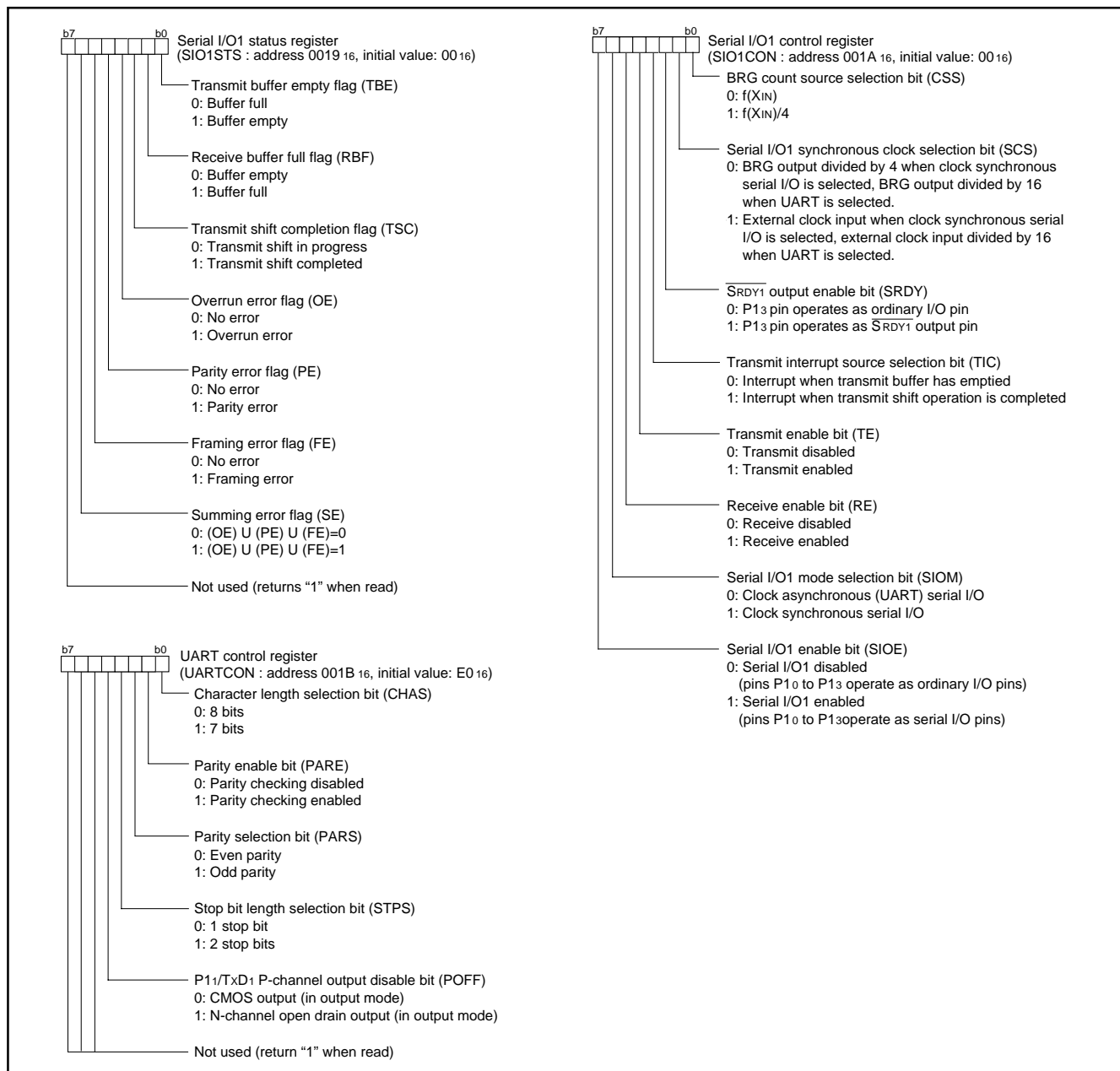


Fig. 34 Structure of serial I/O1-related registers

●Serial I/O2

The serial I/O2 function can be used only for clock synchronous serial I/O.

For clock synchronous serial I/O2 the transmitter and the receiver must use the same clock. When the internal clock is used, transfer is started by a write signal to the serial I/O2 register.

Note: Serial I/O2 can be used in the following cases;

- (1) Serial I/O1 is not used,
- (2) Serial I/O1 is used as UART and BRG output divided by 16 is selected as the synchronized clock.

[Serial I/O2 control register] SIO2CON

The serial I/O2 control register contains 8 bits which control various serial I/O functions.

- Set "0" to bit 3 to receive.
- At reception, clear bit 7 to "0" by writing a dummy data to the serial I/O2 register after completion of shift.

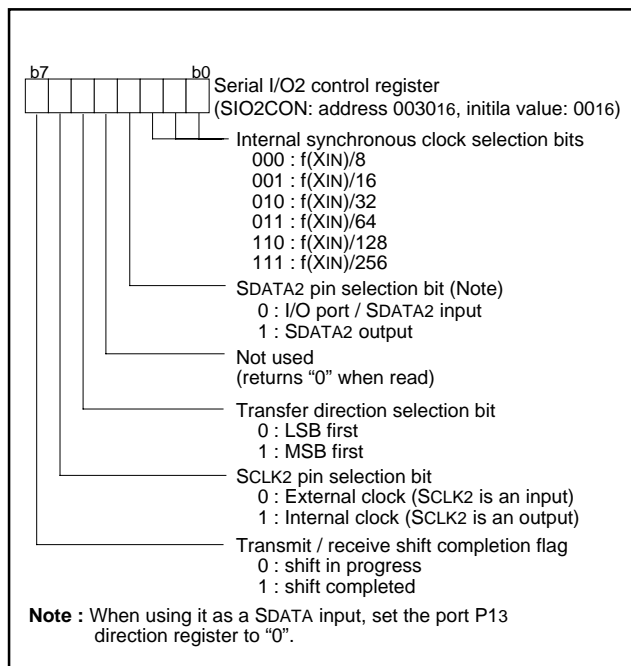


Fig. 35 Structure of serial I/O2 control registers

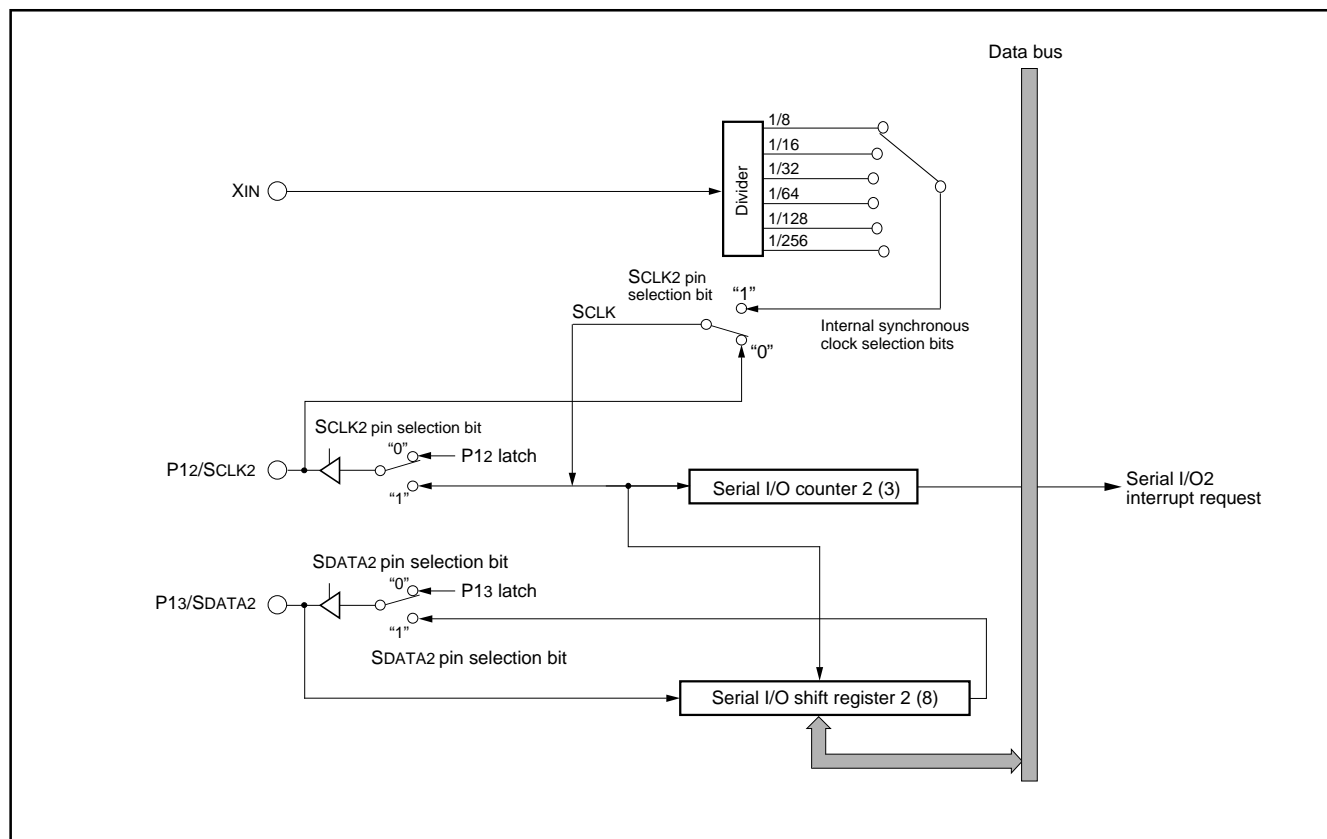


Fig. 36 Block diagram of serial I/O2

Serial I/O2 operation

By writing to the serial I/O2 register (address 003116) the serial I/O2 counter is set to "7".

After writing, the SDATA2 pin outputs data every time the transfer clock shifts from "H" to "L". And, as the transfer clock shifts from "L" to "H", the SDATA2 pin reads data, and at the same time the contents of the serial I/O2 register are shifted by 1 bit.

When the internal clock is selected as the transfer clock source, the following operations execute as the transfer clock counts up to 8.

- Serial I/O2 counter is cleared to "0".
- Transfer clock stops at an "H" level.
- Interrupt request bit is set.
- Shift completion flag is set.

Also, the SDATA2 pin is in a high impedance state after the data transfer is completed (refer to Fig.37).

When the external clock is selected as the transfer clock source, the interrupt request bit is set as the transfer clock counts up to 8, but external control of the clock is required since it does not stop. Notice that the SDATA2 pin is not in a high impedance state on the completion of data transfer.

Also, after the receive operation is completed, the transmit/receive shift completion flag is cleared by reading the serial I/O2 register. At transmit, the transmit/receive shift completion flag is cleared and the transmit operation is started by writing to serial I/O2 register.

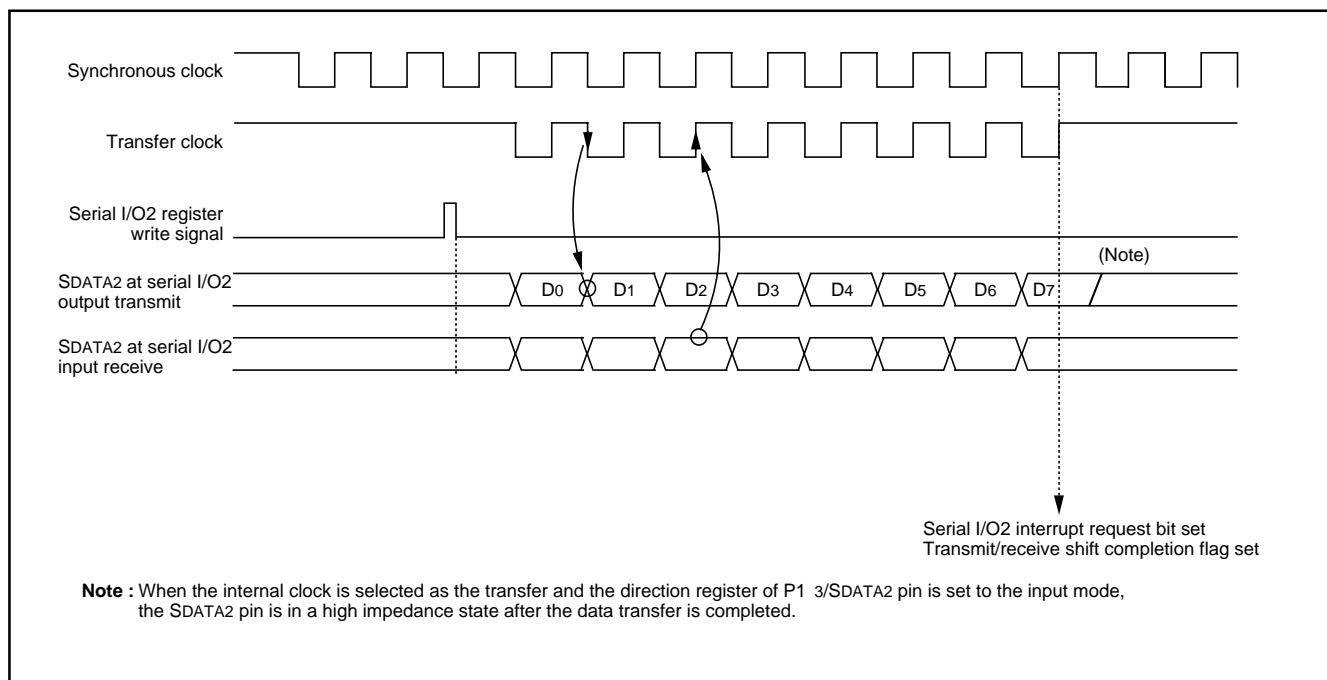


Fig. 37 Serial I/O2 timing (LSB first)

A/D Converter

The functional blocks of the A/D converter are described below.

[A/D conversion register] AD

The A/D conversion register is a read-only register that stores the result of A/D conversion. Do not read out this register during an A/D conversion.

[A/D control register] ADCON

The A/D control register controls the A/D converter. Bit 2 to 0 are analog input pin selection bits. Bit 4 is the AD conversion completion bit. The value of this bit remains at "0" during A/D conversion, and changes to "1" at completion of A/D conversion.

A/D conversion is started by setting this bit to "0".

[Comparison voltage generator]

The comparison voltage generator divides the voltage between AVSS and VREF by 1024, and outputs the divided voltages.

[Channel selector]

The channel selector selects one of ports P27/AN7 to P20/AN0, and inputs the voltage to the comparator.

[Comparator and control circuit]

The comparator and control circuit compares an analog input voltage with the comparison voltage and stores its result into the A/D conversion register. When A/D conversion is completed, the control circuit sets the AD conversion completion bit and the AD interrupt request bit to "1". Because the comparator is constructed linked to a capacitor, set f(XIN) to 500 kHz or more during A/D conversion.

■ Note on A/D converter

As for AD translation accuracy, on the following operating conditions, accuracy may become low.

- (1) Since the analog circuit inside a microcomputer becomes sensitive to noise when VREF voltage is set up lower than Vcc voltage, accuracy may become low rather than the case where VREF voltage and Vcc voltage are set up to the same value.

- (2) When VREF voltage is lower than [3.0 V], the accuracy at the low temperature may become extremely low compared with that at room temperature. When the system would be used at low temperature, the use at VREF=3.0 V or more is recommended.

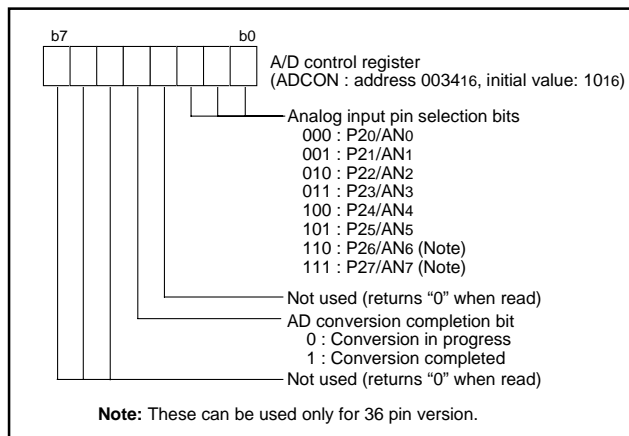


Fig. 38 Structure of A/D control register

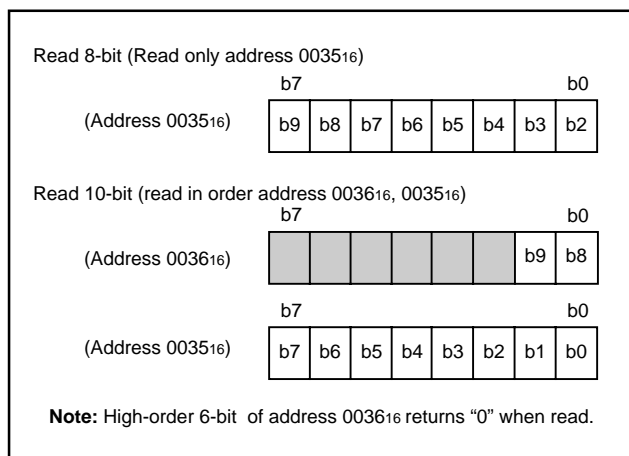


Fig. 39 Structure of A/D conversion register

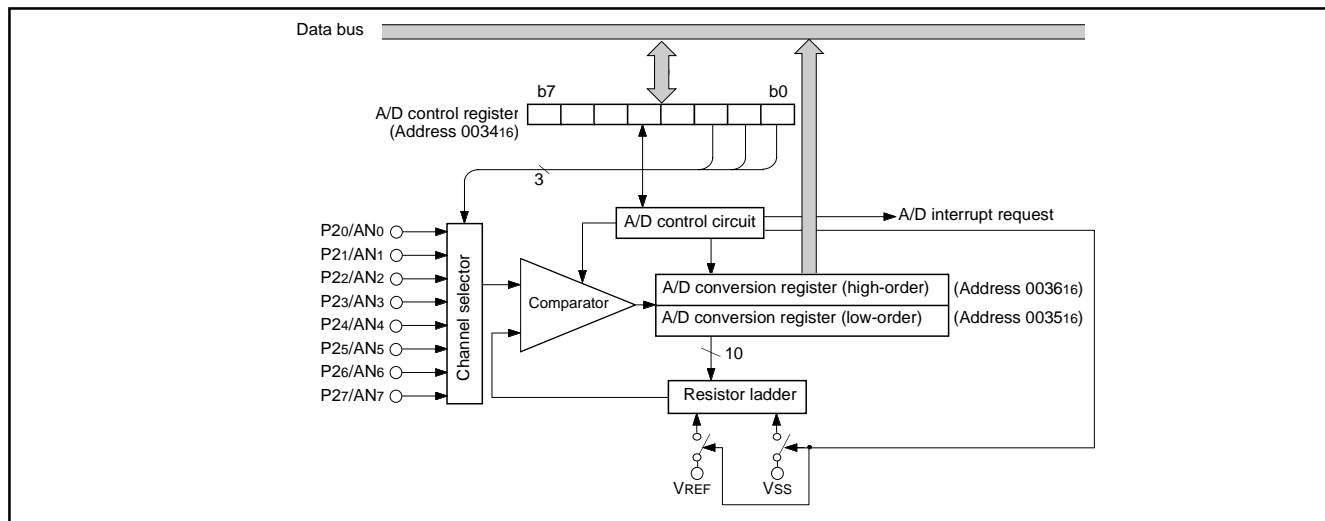


Fig. 40 Block diagram of A/D converter

Watchdog Timer

The watchdog timer gives a means for returning to a reset status when the program fails to run on its normal loop due to a runaway. The watchdog timer consists of an 8-bit watchdog timer H and an 8-bit watchdog timer L, being a 16-bit counter.

Standard operation of watchdog timer

The watchdog timer stops when the watchdog timer control register (address 0039₁₆) is not set after reset. Writing an optional value to the watchdog timer control register (address 0039₁₆) causes the watchdog timer to start to count down. When the watchdog timer H underflows, an internal reset occurs. Accordingly, it is programmed that the watchdog timer control register (address 0039₁₆) can be set before an underflow occurs.

When the watchdog timer control register (address 0039₁₆) is read, the values of the high-order 6-bit of the watchdog timer H, STP instruction disable bit and watchdog timer H count source selection bit are read.

Initial value of watchdog timer

By a reset or writing to the watchdog timer control register (address 0039₁₆), the watchdog timer H is set to "FF₁₆" and the watchdog timer L is set to "FF₁₆".

Operation of watchdog timer H count source selection bit

A watchdog timer H count source can be selected by bit 7 of the watchdog timer control register (address 0039₁₆). When this bit is "0", the count source becomes a watchdog timer L underflow signal. The detection time is 131.072 ms at $f(XIN)=8$ MHz. When this bit is "1", the count source becomes $f(XIN)/16$. In this case, the detection time is 512 μ s at $f(XIN)=8$ MHz. This bit is cleared to "0" after reset.

Operation of STP instruction disable bit

When the watchdog timer is in operation, the STP instruction can be disabled by bit 6 of the watchdog timer control register (address 0039₁₆).

When this bit is "0", the STP instruction is enabled.

When this bit is "1", the STP instruction is disabled, and an internal reset occurs if the STP instruction is executed.

Once this bit is set to "1", it cannot be changed to "0" by program. This bit is cleared to "0" after reset.

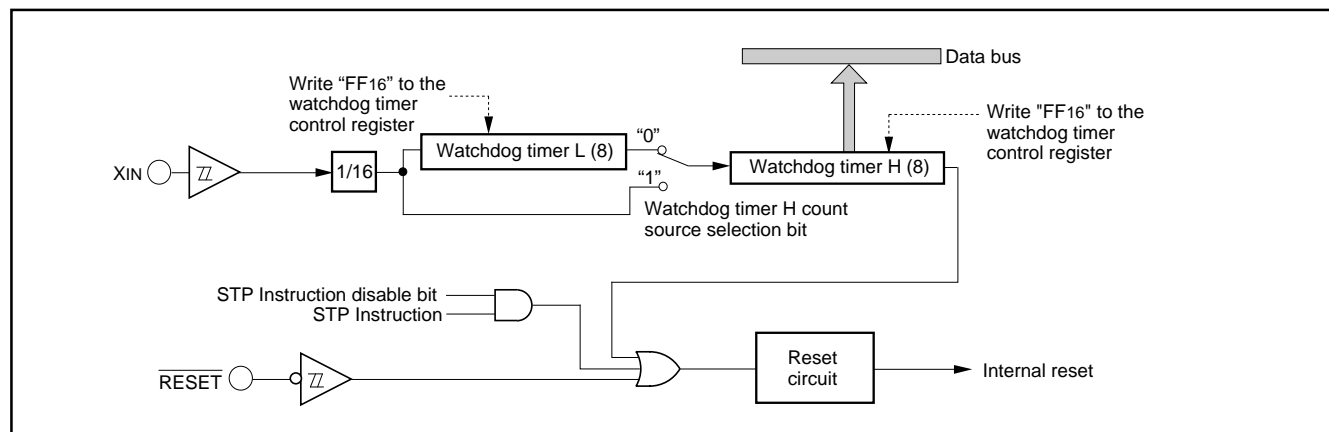


Fig. 41 Block diagram of watchdog timer

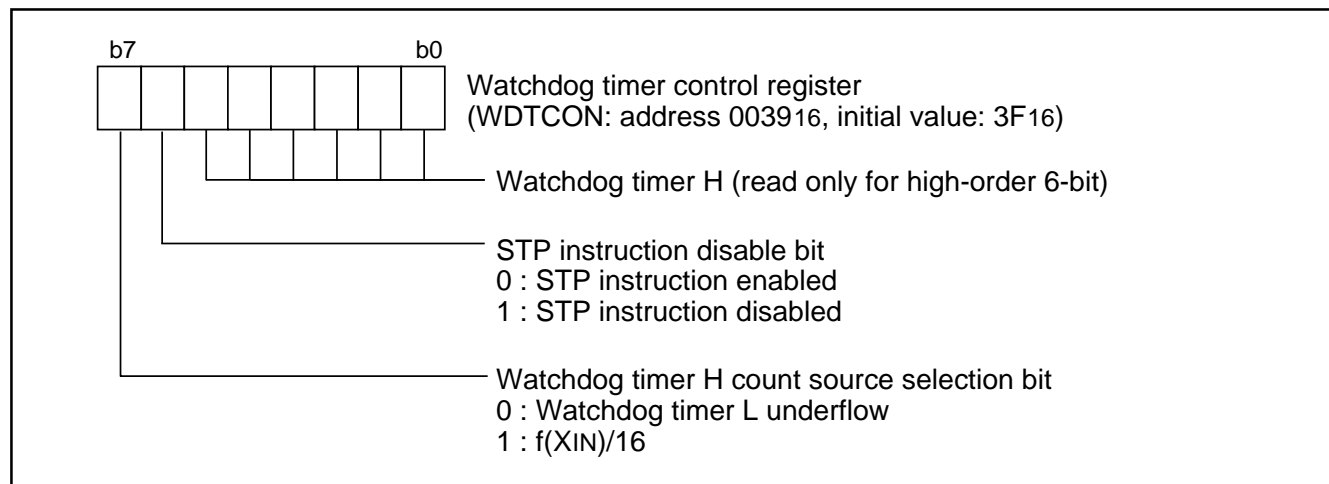


Fig. 42 Structure of watchdog timer control register

Reset Circuit

The microcomputer is put into a reset status by holding the $\overline{\text{RESET}}$ pin at the "L" level for 2 μs or more when the power source voltage is 2.2 to 5.5 V and XIN is in stable oscillation.

After that, this reset status is released by returning the $\overline{\text{RESET}}$ pin to the "H" level. The program starts from the address having the contents of address FFFD₁₆ as high-order address and the contents of address FFFC₁₆ as low-order address.

In the case of $f(\phi) \leq 6$ MHz, the reset input voltage must be 0.9 V or less when the power source voltage passes 4.5 V.

In the case of $f(\phi) \leq 4$ MHz, the reset input voltage must be 0.8 V or less when the power source voltage passes 4.0 V.

In the case of $f(\phi) \leq 2$ MHz, the reset input voltage must be 0.48 V or less when the power source voltage passes 2.4 V.

In the case of $f(\phi) \leq 1$ MHz, the reset input voltage must be 0.44 V or less when the power source voltage passes 2.2 V.

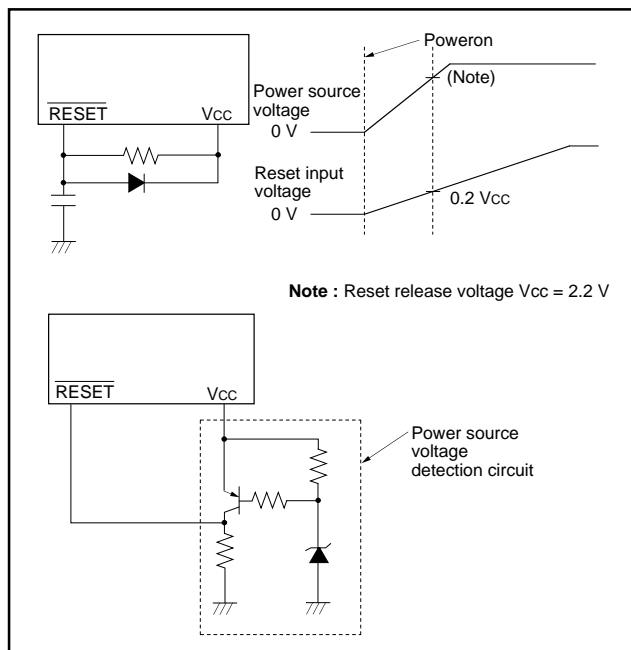


Fig. 43 Example of reset circuit

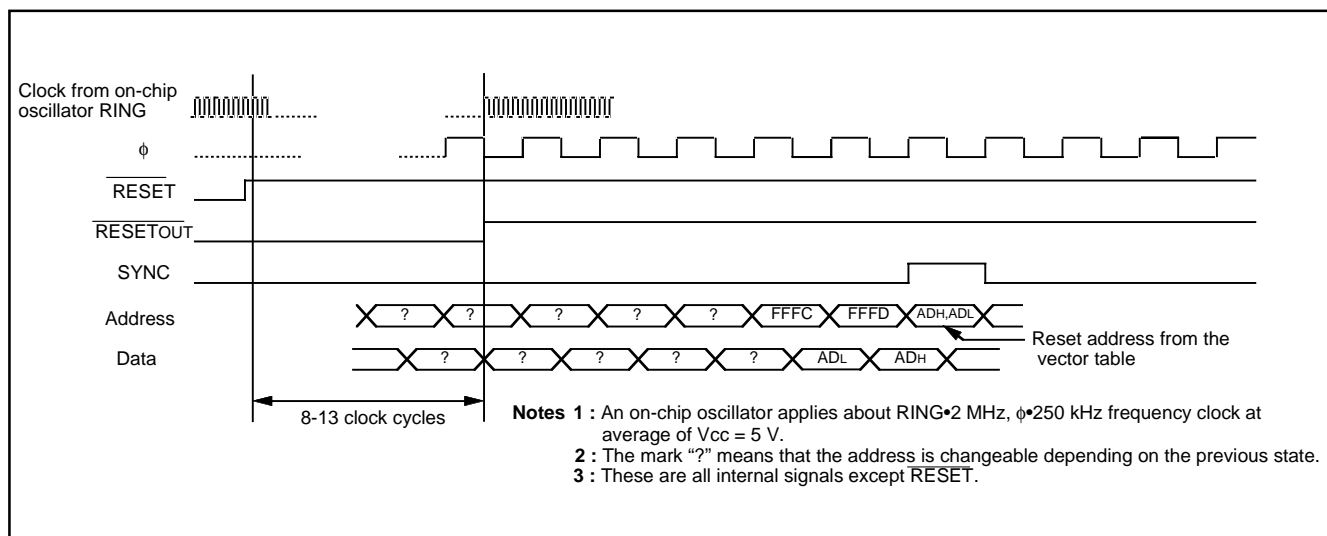


Fig. 44 Timing diagram at reset

| | Address | Register contents |
|--|--------------------|--|
| (1) Port P0 direction register | 0001 ₁₆ | 00 ₁₆ |
| (2) Port P1 direction register | 0003 ₁₆ | X X X 0 0 0 0 0 |
| (3) Port P2 direction register | 0005 ₁₆ | 00 ₁₆ |
| (4) Port P3 direction register | 0007 ₁₆ | 00 ₁₆ |
| (5) Pull-up control register | 0016 ₁₆ | 00 ₁₆ |
| (6) Port P1P3 control register | 0017 ₁₆ | 00 ₁₆ |
| (7) Serial I/O1 status register | 0019 ₁₆ | 1 0 0 0 0 0 0 0 |
| (8) Serial I/O1 control register | 001A ₁₆ | 00 ₁₆ |
| (9) UART control register | 001B ₁₆ | 1 1 1 0 0 0 0 0 |
| (10) Timer A mode register | 001D ₁₆ | 00 ₁₆ |
| (11) Timer A (low-order) | 001E ₁₆ | FF ₁₆ |
| (12) Timer A (high-order) | 001F ₁₆ | FF ₁₆ |
| (13) Timer Y, Z mode register | 0020 ₁₆ | 00 ₁₆ |
| (14) Prescaler Y | 0021 ₁₆ | FF ₁₆ |
| (15) Timer Y secondary | 0022 ₁₆ | FF ₁₆ |
| (16) Timer Y primary | 0023 ₁₆ | FF ₁₆ |
| (17) Timer Y, Z waveform output control register | 0024 ₁₆ | 00 ₁₆ |
| (18) Prescaler Z | 0025 ₁₆ | FF ₁₆ |
| (19) Timer Z secondary | 0026 ₁₆ | FF ₁₆ |
| (20) Timer Z primary | 0027 ₁₆ | FF ₁₆ |
| (21) Prescaler 1 | 0028 ₁₆ | FF ₁₆ |
| (22) Timer 1 | 0029 ₁₆ | 01 ₁₆ |
| (23) One-shot start register | 002A ₁₆ | 00 ₁₆ |
| (24) Timer X mode register | 002B ₁₆ | 00 ₁₆ |
| (25) Prescaler X | 002C ₁₆ | FF ₁₆ |
| (26) Timer X | 002D ₁₆ | FF ₁₆ |
| (27) Timer count source set register | 002E ₁₆ | 00 ₁₆ |
| (28) Serial I/O2 control register | 0030 ₁₆ | 00 ₁₆ |
| (29) Serial I/O2 register | 0031 ₁₆ | 00 ₁₆ |
| (30) A/D control register | 0034 ₁₆ | 10 ₁₆ |
| (31) MISRG | 0038 ₁₆ | 00 ₁₆ |
| (32) Watchdog timer control register | 0039 ₁₆ | 0 0 1 1 1 1 1 1 |
| (33) Interrupt edge selection register | 003A ₁₆ | 00 ₁₆ |
| (34) CPU mode register | 003B ₁₆ | 1 0 0 0 0 0 0 0 |
| (35) Interrupt request register 1 | 003C ₁₆ | 00 ₁₆ |
| (36) Interrupt request register 2 | 003D ₁₆ | 00 ₁₆ |
| (37) Interrupt control register 1 | 003E ₁₆ | 00 ₁₆ |
| (38) Interrupt control register 2 | 003F ₁₆ | 00 ₁₆ |
| (39) Processor status register | (PS) | X X X X X 1 X X |
| (40) Program counter | (PCH) | Contents of address FFFD ₁₆ |
| | (PCL) | Contents of address FFFC ₁₆ |

Note X : Undefined

Fig. 45 Internal status of microcomputer at reset

Clock Generating Circuit

An oscillation circuit can be formed by connecting a resonator between XIN and XOUT, and an RC oscillation circuit can be formed by connecting a resistor and a capacitor.

Use the circuit constants in accordance with the resonator manufacturer's recommended values.

(1) On-chip oscillator operation

When the MCU operates by the on-chip oscillator for the main clock, connect XIN pin to VSS and leave XOUT pin open.

The clock frequency of the on-chip oscillator depends on the supply voltage and the operation temperature range.

Be careful that variable frequencies when designing application products.

(2) Ceramic resonator

When the ceramic resonator is used for the main clock, connect the ceramic resonator and the external circuit to pins XIN and XOUT at the shortest distance. A feedback resistor is built in between pins XIN and XOUT.

(3) RC oscillation

When the RC oscillation is used for the main clock, connect the XIN pin and XOUT pin to the external circuit of resistor R and the capacitor C at the shortest distance.

The frequency is affected by a capacitor, a resistor and a micro-computer.

So, set the constants within the range of the frequency limits.

(4) External clock

When the external signal clock is used for the main clock, connect the XIN pin to the clock source and leave XOUT pin open.

Select "ceramic resonance" by setting "0" to the Oscillation mode selection bit of CPU mode register (address 003B16).

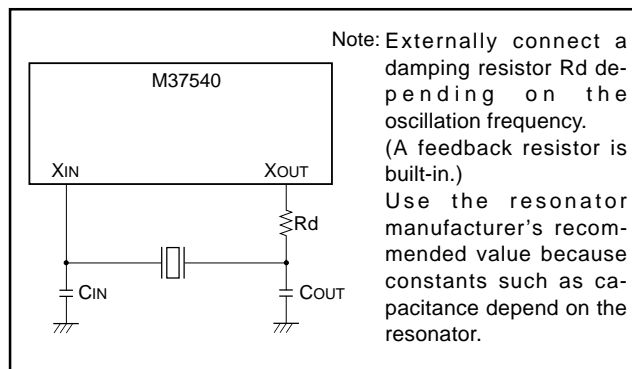


Fig. 46 External circuit of ceramic resonator

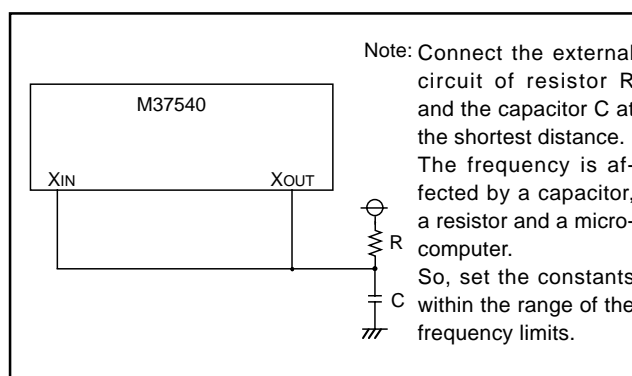


Fig. 47 External circuit of RC oscillation

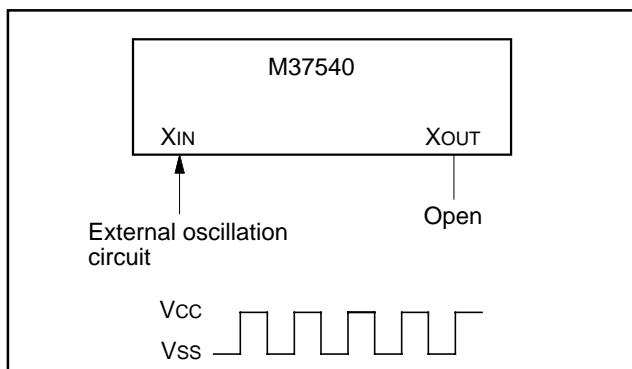


Fig. 48 External clock input circuit

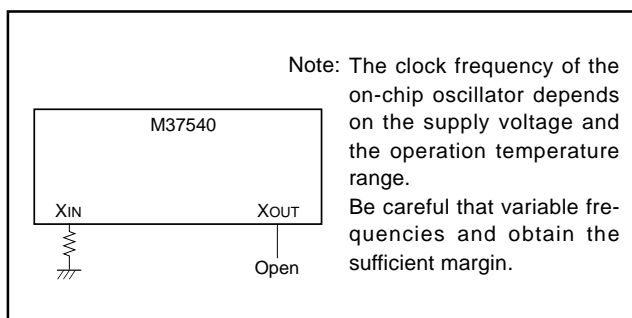


Fig. 49 Processing of XIN and XOUT pins at on-chip oscillator operation

(1) Oscillation control**• Stop mode**

When the STP instruction is executed, the internal clock ϕ stops at an "H" level and the XIN oscillator stops. At this time, timer 1 is set to "0116" and prescaler 1 is set to "FF16" when the oscillation stabilization time set bit after release of the STP instruction is "0". On the other hand, timer 1 and prescaler 1 are not set when the above bit is "1". Accordingly, set the wait time fit for the oscillation stabilization time of the oscillator to be used. $f(XIN)/16$ is forcibly connected to the input of prescaler 1. When an external interrupt is accepted, oscillation is restarted but the internal clock ϕ remains at "H" until timer 1 underflows. As soon as timer 1 underflows, the internal clock ϕ is supplied. This is because when a ceramic oscillator is used, some time is required until a start of oscillation. In case oscillation is restarted by reset, no wait time is generated. So apply an "L" level to the RESET pin while oscillation becomes stable.

Also, the STP instruction cannot be used while CPU is operating by an on-chip oscillator.

• Wait mode

If the WIT instruction is executed, the internal clock ϕ stops at an "H" level, but the oscillator does not stop. The internal clock restarts if a reset occurs or when an interrupt is received. Since the oscillator does not stop, normal operation can be started immediately after the clock is restarted. To ensure that interrupts will be received to release the STP or WIT state, interrupt enable bits must be set to "1" before the STP or WIT instruction is executed.

■ Notes on clock generating circuit

For use with the oscillation stabilization set bit after release of the STP instruction set to "1", set values in timer 1 and prescaler 1 after fully appreciating the oscillation stabilization time of the oscillator to be used.

• Switch of ceramic and RC oscillations

After releasing reset the operation starts by starting an on-chip oscillator. Then, a ceramic oscillation or an RC oscillation is selected by setting bit 5 of the CPU mode register.

• Double-speed mode

When a ceramic oscillation is selected, a double-speed mode can be used. Do not use it when an RC oscillation is selected.

• CPU mode register

Bits 5, 1 and 0 of CPU mode register are used to select oscillation mode and to control operation modes of the microcomputer. In order to prevent the dead-lock by error-writing (ex. program run-away), these bits can be rewritten only once after releasing reset. After rewriting it is disable to write any data to the bit. (The emulator MCU "M37540RSS" is excluded.)

Also, when the read-modify-write instructions (SEB, CLB) are executed to bits 2 to 4, 6 and 7, bits 5, 1 and 0 are locked.

• Clock division ratio, XIN oscillation control, on-chip oscillator control

The state transition shown in Fig. 52 can be performed by setting the clock division ratio selection bits (bits 7 and 6), XIN oscillation control bit (bit 4), on-chip oscillator oscillation control bit (bit 3) of CPU mode register. Be careful of notes on use in Fig. 52.

● Oscillation stop detection circuit (Note)

The oscillation stop detection circuit is used for reset occurrence when a ceramic resonator or an oscillation circuit stops by disconnection. When internal reset occurs, reset because of oscillation stop can be detected by setting "1" to the oscillation stop detection status bit.

Also, when using the oscillation stop detection circuit, an on-chip oscillator is required.

Figure 53 shows the state transition.

Note: The oscillation stop detection circuit is not included in the emulator MCU "M37540RSS".

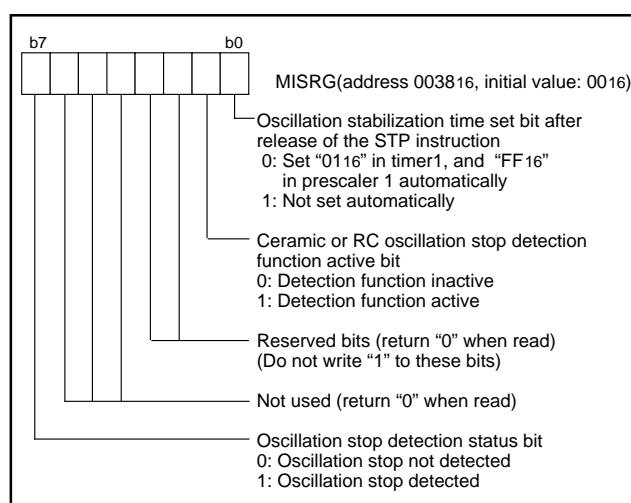


Fig. 50 Structure of MISRG

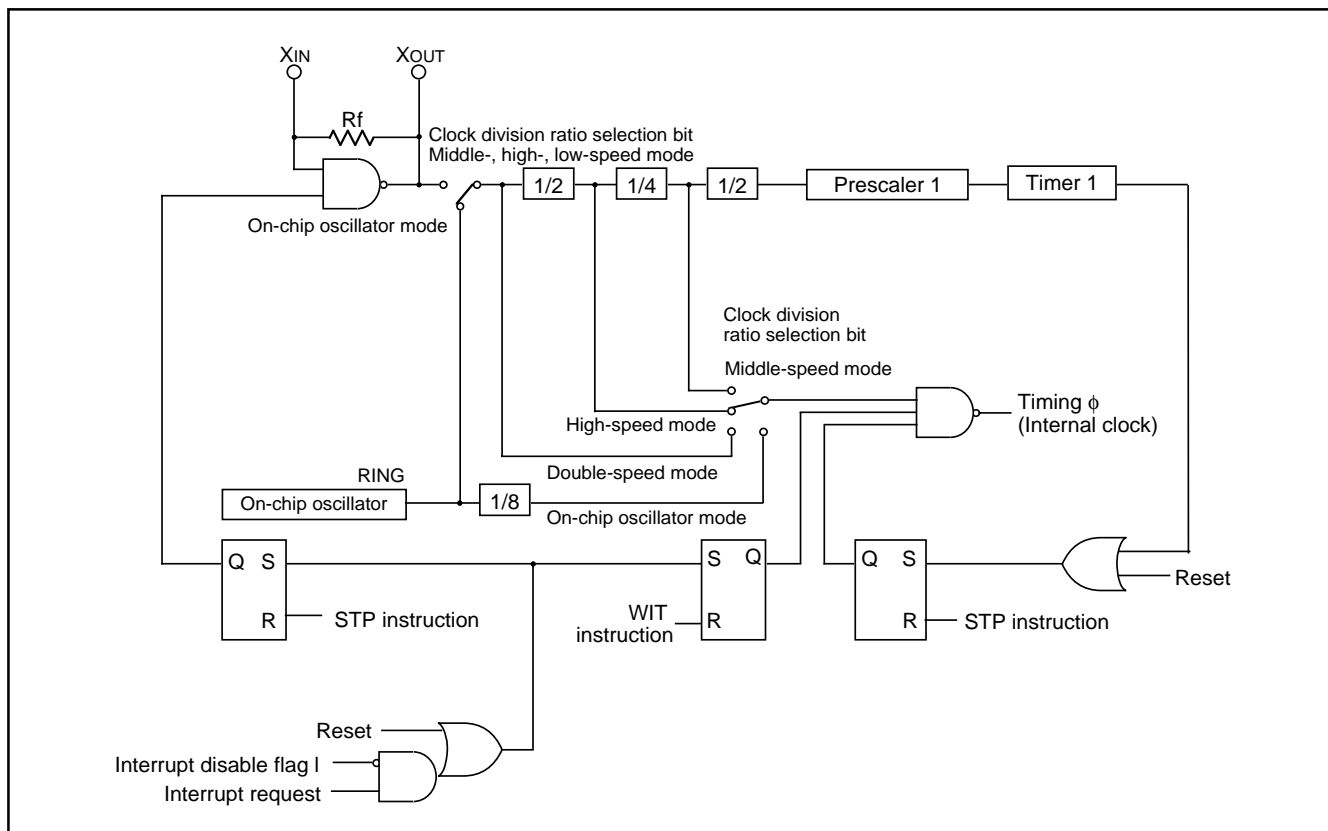


Fig. 51 Block diagram of internal clock generating circuit (for ceramic resonator)

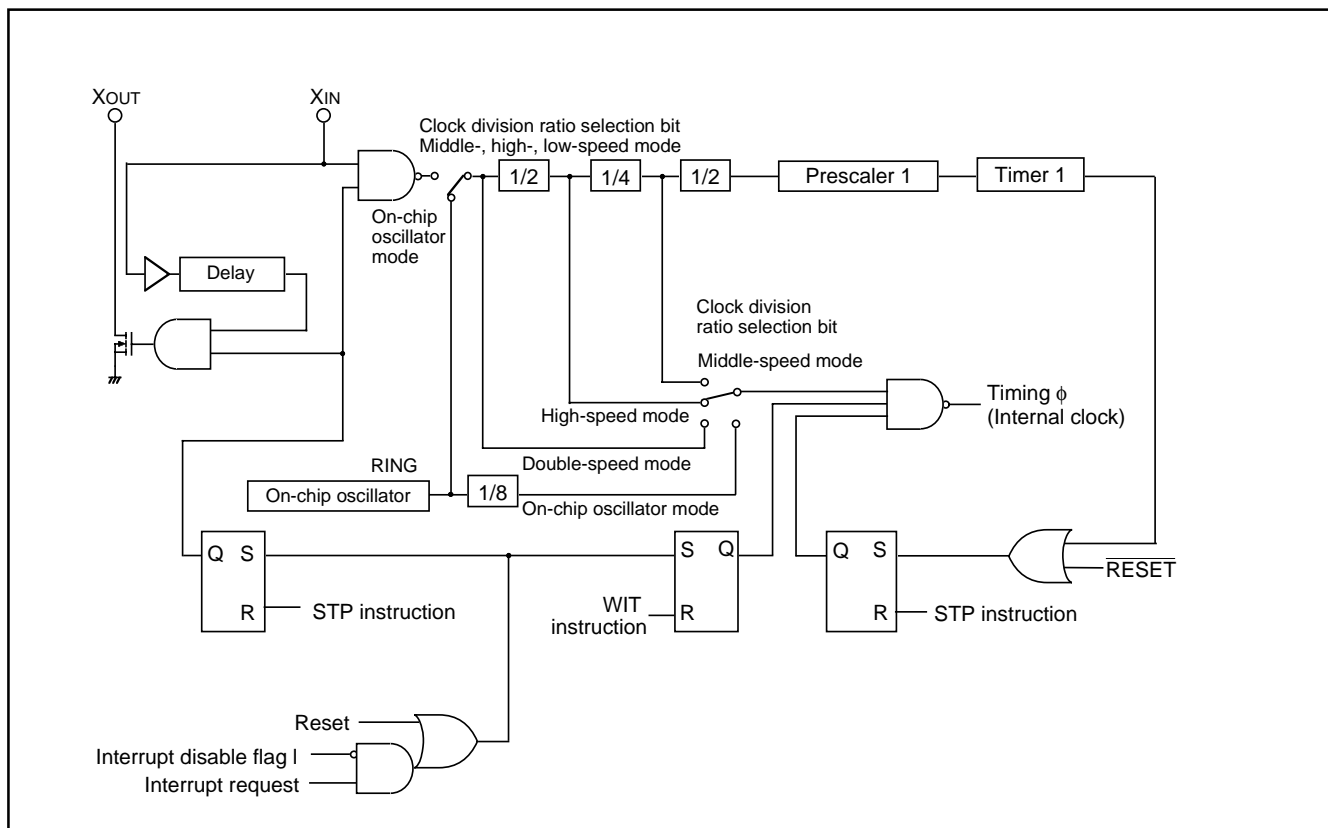


Fig. 52 Block diagram of internal clock generating circuit (for RC oscillation)

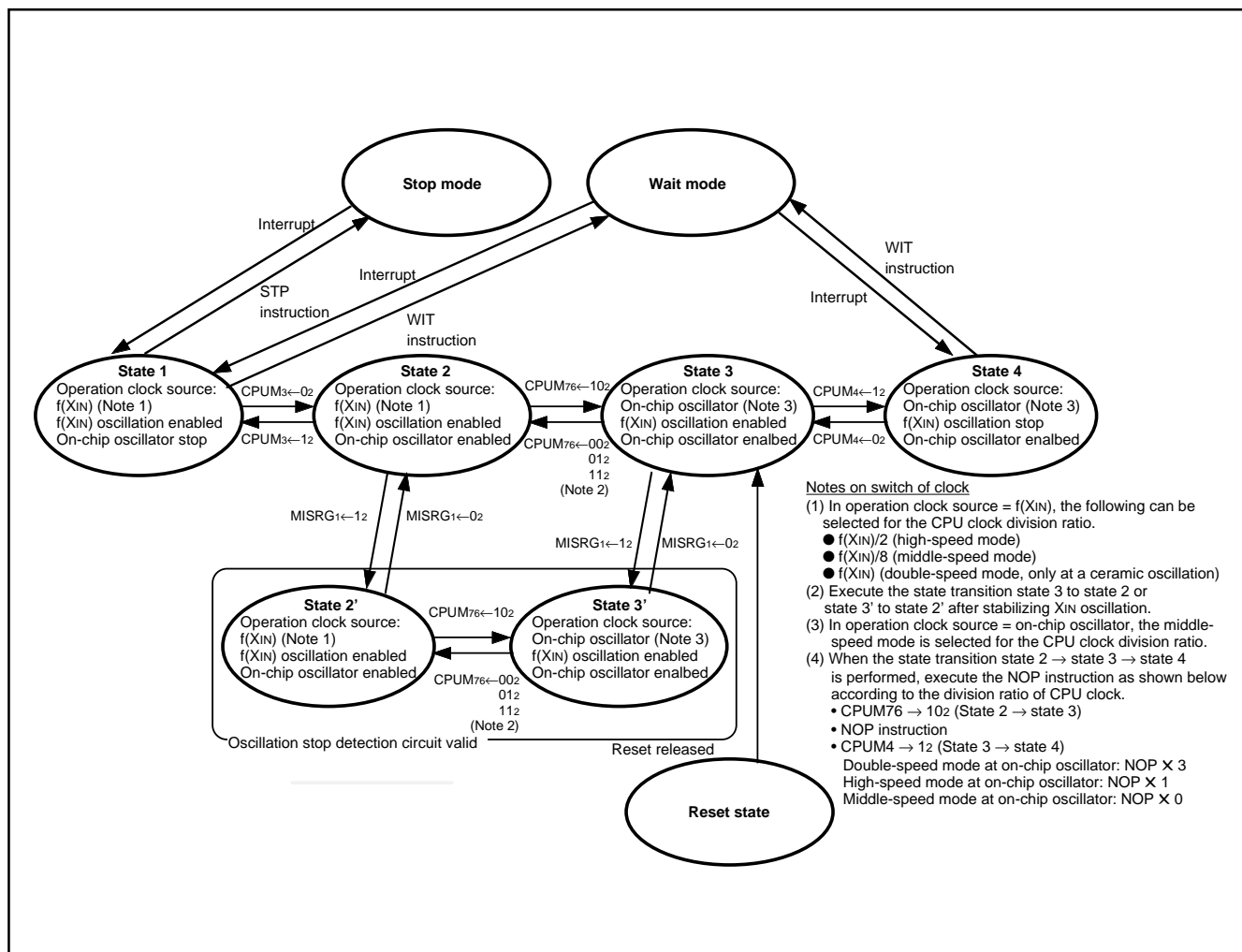


Fig. 53 State transition

NOTES ON PROGRAMMING

Processor Status Register

The contents of the processor status register (PS) after reset are undefined except for the interrupt disable flag I which is "1". After reset, initialize flags which affect program execution. In particular, it is essential to initialize the T flag and the D flag because of their effect on calculations.

Interrupts

The contents of the interrupt request bit do not change even if the BBC or BBS instruction is executed immediately after they are changed by program because this instruction is executed for the previous contents. For executing the instruction for the changed contents, execute one instruction before executing the BBC or BBS instruction.

Decimal Calculations

- For calculations in decimal notation, set the decimal mode flag D to "1", then execute the ADC instruction or SBC instruction. In this case, execute SEC instruction, CLC instruction or CLD instruction after executing one instruction before the ADC instruction or SBC instruction.
- In the decimal mode, the values of the N (negative), V (overflow) and Z (zero) flags are invalid.

Ports

- The values of the port direction registers cannot be read. That is, it is impossible to use the LDA instruction, memory operation instruction when the T flag is "1", addressing mode using direction register values as qualifiers, and bit test instructions such as BBC and BBS.
- It is also impossible to use bit operation instructions such as CLB and SEB and read/modify/write instructions of direction registers for calculations such as ROR.
- For setting direction registers, use the LDM instruction, STA instruction, etc.

A/D Conversion

Do not execute the STP instruction during A/D conversion.

Instruction Execution Timing

The instruction execution time can be obtained by multiplying the frequency of the internal clock ϕ by the number of cycles mentioned in the machine-language instruction table.

The frequency of the internal clock ϕ is the same as that of the X_{IN} in double-speed mode, twice the X_{IN} cycle in high-speed mode and 8 times the X_{IN} cycle in middle-speed mode.

CPU Mode Register

The oscillation mode selection bit and processor mode bits can be rewritten only once after releasing reset. However, after rewriting it is disable to write any value to the bit. (Emulator MCU is excluded.)

When a ceramic oscillation is selected, a double-speed mode of the clock division ratio selection bits can be used. Do not use it when an RC oscillation is selected.

State transition

Do not stop the clock selected as the operation clock because of setting of CM3, 4.

NOTES ON HARDWARE

Handling of Power Source Pin

In order to avoid a latch-up occurrence, connect a capacitor suitable for high frequencies as bypass capacitor between power source pin (V_{cc} pin) and GND pin (V_{ss} pin). Besides, connect the capacitor to as close as possible. For bypass capacitor which should not be located too far from the pins to be connected, a ceramic capacitor of 0.01 μ F to 0.1 μ F is recommended.

One Time PROM Version

The CNV_{ss} pin is connected to the internal memory circuit block by a low-ohmic resistance, since it has the multiplexed function to be a programmable power source pin (V_{PP} pin) as well.

To improve the noise reduction, connect a track between CNV_{ss} pin and V_{ss} pin with 1 to 10 k Ω resistance.

The mask ROM version track of CNV_{ss} pin has no operational interference even if it is connected via a resistor.

NOTES ON PERIPHERAL FUNCTIONS

■ Interrupt

When setting the followings, the interrupt request bit may be set to "1".

- When switching external interrupt active edge

Related register: Interrupt edge selection register (address 003A₁₆)

Timer X mode register (address 2B₁₆)

Timer A mode register (address 1D₁₆)

When not requiring the interrupt occurrence synchronized with these setting, take the following sequence.

- ① Set the corresponding interrupt enable bit to "0" (disabled).
- ② Set the interrupt edge select bit (active edge switch bit).
- ③ Set the corresponding interrupt request bit to "0" after 1 or more instructions have been executed.
- ④ Set the corresponding interrupt enable bit to "1" (enabled).

■ Timers

- When n (0 to 255) is written to a timer latch, the frequency division ratio is 1/(n+1).
- When a count source of timer X, timer Y or timer Z is switched, stop a count of timer X.

■ Timer A

CNTR₁ interrupt active edge selection

CNTR₁ interrupt active edge depends on the CNTR₁ active edge switch bit.

When this bit is "0", the CNTR₁ interrupt request bit is set to "1" at the falling edge of the CNTR₁ pin input signal. When this bit is "1", the CNTR₁ interrupt request bit is set to "1" at the rising edge of the CNTR₁ pin input signal.

However, in the pulse width HL continuously measurement mode, CNTR₁ interrupt request is generated at both rising and falling edges of CNTR₁ pin input signal regardless of the setting of CNTR₁ active edge switch bit.

■ Timer X

CNTR₀ interrupt active edge selection

CNTR₀ interrupt active edge depends on the CNTR₀ active edge switch bit.

When this bit is "0", the CNTR₀ interrupt request bit is set to "1" at the falling edge of CNTR₀ pin input signal. When this bit is "1", the CNTR₀ interrupt request bit is set to "1" at the rising edge of CNTR₀ pin input signal.

■ Timer Y: Programmable Generation Waveform Mode

- Count set value

In the programmable waveform generation mode, values of TYS, EXPYP, and EXPYS are valid by writing to TYP because the setting to them is executed all at once by writing to TYP. Even when changing TYP is not required, write the same value again.

- Write timing to TYP

In the programmable waveform generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TYP and the timing of timer underflow during the secondary interval simultaneously.

- Usage of waveform extension function

The waveform extension function by the timer Y waveform extension control bit can be used only when "00₁₆" is set to Prescaler Y. When the value other than "00₁₆" is set to Prescaler Y, be sure to set "0" to EXPYP and EXPYS.

- Timer Y write mode

When using this mode, be sure to set "1" to the timer Y write control bit to select "write to latch only".

Timer Y can stop counting by setting "1" to the timer Y count stop bit in any mode.

Also, when Timer Y underflows, the timer Y interrupt request bit is set to "1".

Timer Y reloads the value of latch when counting is stopped by the timer Y count stop bit. (When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

■ Timer Z: Programmable Waveform Generation Mode

- Count set value

In the programmable waveform generation mode, values of TZS, EXPZP, and EXPZS are valid by writing to TZP because the setting to them is executed all at once by writing to TZP. Even when changing TZP is not required, write the same value again.

- Write timing to TZP

In the programmable waveform generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow during the secondary interval simultaneously.

- Usage of waveform extension function

The waveform extension function by the timer Z waveform extension control bit can be used only when "00₁₆" is set to Prescaler Z. When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the count source, the waveform extension function cannot be used.

- Timer Z write mode

When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".

■ Timer Z: Programmable One-shot Generation Mode

- Count set value

In the programmable one-shot generation mode, the value of EXPZP becomes valid by writing to TZP. Even when changing TZP is not required, write the same value again.

- Write timing to TZP

In the programmable one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow simultaneously.

- Usage of waveform extension function

The waveform extension function by the timer Z waveform extension control bit can be used only when "0016" is set to Prescaler Z. When the value other than "0016" is set to Prescaler Z, be sure to set "0" to EXPZP. Also, when the timer Y underflow is selected as the count source, the waveform extension function cannot be used.

- Timer Z write mode

When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".

■ Timer Z: Programmable Wait One-shot Generation Mode

- Count set value

In the programmable wait one-shot generation mode, values of TZS, EXPZP and EXPZS are valid by writing to TZP. Even when changing TZP is not required, write the same value again.

- Write timing to TZP

In the programmable wait one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow during the secondary interval simultaneously.

- Usage of waveform extension function

The waveform extension function by the timer Z waveform extension control bit can be used only when "0016" is set to Prescaler Z. When the value other than "0016" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the count source, the waveform extension function cannot be used.

- Timer Z write mode

When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".

Timer Z can stop counting by setting "1" to the timer Z count stop bit in any mode.

Also, when Timer Z underflows, the timer Z interrupt request bit is set to "1".

Timer Z reloads the value of latch when counting is stopped by the timer Z count stop bit. (When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

■ Serial I/O

- Serial I/O interrupt

When setting the transmit enable bit to "1", the serial I/O transmit interrupt request bit is automatically set to "1". When not requiring the interrupt occurrence synchronized with the transmission enabled, take the following sequence.

① Set the serial I/O transmit interrupt enable bit to "0" (disabled).

② Set the transmit enable bit to "1".

③ Set the serial I/O transmit interrupt request bit to "0" after 1 or more instructions have been executed.

⑤ Set the serial I/O transmit interrupt enable bit to "1" (enabled).

- I/O pin function when serial I/O is enabled.

The functions of P12 and P13 are switched with the setting values of a serial I/O1 mode selection bit and a serial I/O1 synchronous clock selection bit as follows.

(1) Serial I/O1 mode selection bit → "1" :

Clock synchronous type serial I/O is selected.

Setup of a serial I/O1 synchronous clock selection bit

"0" : P12 pin turns into an output pin of a synchronous clock.

"1" : P12 pin turns into an input pin of a synchronous clock.

Setup of a SRDY1 output enable bit (SRDY)

"0" : P13 pin can be used as a normal I/O pin.

"1" : P13 pin turns into a SRDY output pin.

(2) Serial I/O1 mode selection bit → "0" :

Clock asynchronous (UART) type serial I/O is selected.

Setup of a serial I/O1 synchronous clock selection bit

"0" : P12 pin can be used as a normal I/O pin.

"1" : P12 pin turns into an input pin of an external clock.

When clock asynchronous (UART) type serial I/O is selected, it is P13 pin. It can be used as a normal I/O pin.

■ A/D Converter

- The comparator uses internal capacitors whose charge will be lost if the clock frequency is too low.

Make sure that $f(X_{IN})$ is 500kHz or more during A/D conversion.

- As for AD translation accuracy, on the following operating conditions, accuracy may become low.

(1) Since the analog circuit inside a microcomputer becomes sensitive to noise when V_{REF} voltage is set up lower than V_{CC} voltage, accuracy may become low rather than the case where V_{REF} voltage and V_{CC} voltage are set up to the same value.

(2) When V_{REF} voltage is lower than [3.0 V], the accuracy at the low temperature may become extremely low compared with that at room temperature. When the system would be used at low temperature, the use at $V_{REF}=3.0$ V or more is recommended.

■ Notes on clock generating circuit

For use with the oscillation stabilization set bit after release of the STP instruction set to "1", set values in timer 1 and prescaler 1 after fully appreciating the oscillation stabilization time of the oscillator to be used.

- Switch of ceramic and RC oscillations

After releasing reset the operation starts by starting an on-chip oscillator. Then, a ceramic oscillation or an RC oscillation is selected by setting bit 5 of the CPU mode register.

- Double-speed mode

When a ceramic oscillation is selected, a double-speed mode can be used. Do not use it when an RC oscillation is selected.

- CPU mode register

Bits 5, 1 and 0 of CPU mode register are used to select oscillation mode and to control operation modes of the microcomputer. In order to prevent the dead-lock by error-writing (ex. program run-away), these bits can be rewritten only once after releasing reset. After rewriting it is disable to write any data to the bit. (The emulator MCU "M37540RSS" is excluded.)

Also, when the read-modify-write instructions (SEB, CLB) are executed to bits 2 to 4, 6 and 7, bits 5, 1 and 0 are locked.

- Clock division ratio, XIN oscillation control, on-chip oscillator control
The state transition shown in Fig. 53 can be performed by setting the clock division ratio selection bits (bits 7 and 6), XIN oscillation control bit (bit 4), on-chip oscillator oscillation control bit (bit 3) of CPU mode register. Be careful of notes on use in Fig. 53.

- On-chip oscillator operation

The clock frequency of the on-chip oscillator depends on the supply voltage and the operation temperature range.

Be careful that variable frequencies when designing application products.

■ Electric Characteristic Differences Among Mask ROM and One Time PROM Version MCUs

There are differences in electric characteristics, operation margin, noise immunity, and noise radiation among mask ROM and One Time PROM version MCUs due to the differences in the manufacturing processes.

When manufacturing an application system with One Time PROM version and then switching to use of the mask ROM version, perform sufficient evaluations for the commercial samples of the mask ROM version.

■ Note on Power Source Voltage

When the power source voltage value of a microcomputer is less than the value which is indicated as the recommended operating conditions, the microcomputer does not operate normally and may perform unstable operation.

In a system where the power source voltage drops slowly when the power source voltage drops or the power supply is turned off, reset a microcomputer when the supply voltage is less than the recommended operating conditions and design a system not to cause errors to the system by this unstable operation.

DATA REQUIRED FOR MASK ORDERS

The following are necessary when ordering a mask ROM production:

- 1.Mask ROM Order Confirmation Form *
- 2.Mark Specification Form *
- 3.Data to be written to ROM, in EPROM form (three identical copies) or one floppy disk.

DATA REQUIRED FOR ROM PROGRAMMING ORDERS

The following are necessary when ordering a One Time PROM production:

- 1.ROM Programming Order Confirmation Form *
- 2.Mark Specification Form *
- 3.Data to be written to ROM, in EPROM form (three identical copies) or one floppy disk.

* For the mask ROM confirmation ROM programming order confirmation and the mark specifications, refer to the "Renesas Technology Corp" Homepage (<http://www.renesas.com/en/rom>).

ROM PROGRAMMING METHOD

The built-in PROM of the blank One Time PROM version can be read or programmed with a general-purpose PROM programmer using a special programming adapter. Set the address of PROM programmer in the user ROM area.

Table 7 Special programming adapter

| Package | Name of Programming Adapter |
|---------|-----------------------------|
| 32P4B | PCA7435SPG02 |
| 32P6U-A | PCA7435GPG03 |
| 36P2R-A | PCA7435FPG02 |

The PROM of the blank One Time PROM version is not tested or screened in the assembly process and following processes. To ensure proper operation after programming, the procedure shown in Figure 54 is recommended to verify programming.

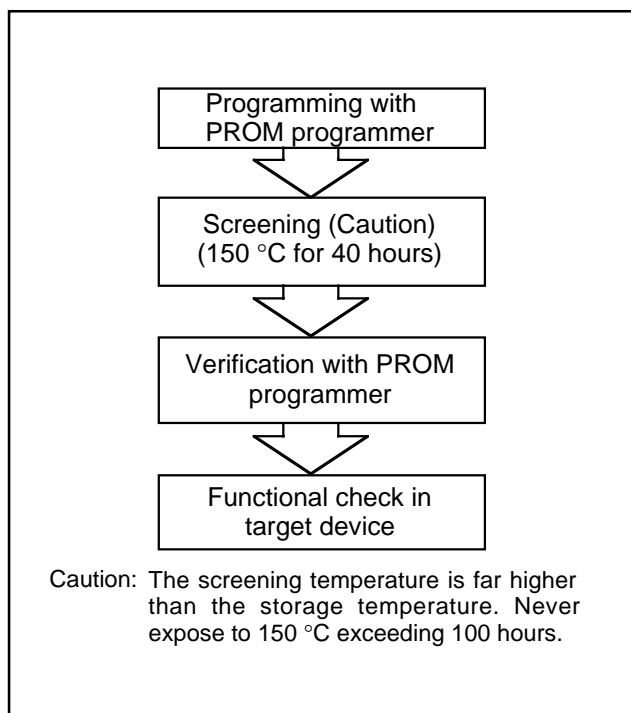


Fig. 54 Programming and testing of One Time PROM version

FUNCTIONAL DESCRIPTION SUPPLEMENT

Interrupt

7540 group permits interrupts on the 14 sources for 42-pin version, 13 sources for 36-pin version and 12 sources for 32-pin version. It is vector interrupts with a fixed priority system. Accordingly,

when two or more interrupt requests occur during the same sampling, the higher-priority interrupt is accepted first. This priority is determined by hardware, but variety of priority processing can be performed by software, using an interrupt enable bit and an interrupt disable flag.

For interrupt sources, vector addresses and interrupt priority, refer to “Table 8.”

Table 8 Interrupt sources, vector addresses and interrupt priority

| Interrupt source | Priority | Vector addresses (Note 1) | | Interrupt request generating conditions | Remarks |
|---------------------------|----------|---------------------------|--------------------|--|---|
| | | High-order | Low-order | | |
| Reset (Note 2) | 1 | FFFD ₁₆ | FFFC ₁₆ | At reset input | Non-maskable |
| Serial I/O1 receive | 2 | FFFB ₁₆ | FFFA ₁₆ | At completion of serial I/O1 data receive | Valid only when serial I/O1 is selected |
| Serial I/O1 transmit | 3 | FFF9 ₁₆ | FFF8 ₁₆ | At completion of serial I/O1 transmit shift or when transmit buffer is empty | Valid only when serial I/O1 is selected |
| INT ₀ | 4 | FFF7 ₁₆ | FFF6 ₁₆ | At detection of either rising or falling edge of INT ₀ input | External interrupt (active edge selectable) |
| INT ₁ (Note 3) | 5 | FFF5 ₁₆ | FFF4 ₁₆ | At detection of either rising or falling edge of INT ₁ input | External interrupt (active edge selectable) |
| Key-on wake-up | 6 | FFF3 ₁₆ | FFF2 ₁₆ | At falling of conjunction of input logical level for port P0 (at input) | External interrupt (valid at falling) |
| CNTR ₀ | 7 | FFF1 ₁₆ | FFF0 ₁₆ | At detection of either rising or falling edge of CNTR ₀ input | External interrupt (active edge selectable) |
| CNTR ₁ | 8 | FFEF ₁₆ | FFEE ₁₆ | At detection of either rising or falling edge of CNTR ₁ input | External interrupt (active edge selectable) |
| Timer X | 9 | FFED ₁₆ | FFEC ₁₆ | At timer X underflow | |
| Timer Y | 10 | FFEB ₁₆ | FFEA ₁₆ | At timer Y underflow | |
| Timer Z | 11 | FFE9 ₁₆ | FFE8 ₁₆ | At timer Z underflow | |
| Timer A | 12 | FFE7 ₁₆ | FFE6 ₁₆ | At timer A underflow | |
| Serial I/O2 | 13 | FFE5 ₁₆ | FFE4 ₁₆ | At completion of transmit/receive shift | |
| A/D conversion | 14 | FFE3 ₁₆ | FFE2 ₁₆ | At completion of A/D conversion | |
| Timer 1 | 15 | FFE1 ₁₆ | FFE0 ₁₆ | At timer 1 underflow | STP release timer underflow |
| Reserved area | 16 | FFDF ₁₆ | FFDE ₁₆ | Not available | |
| BRK instruction | 17 | FFDD ₁₆ | FFDC ₁₆ | At BRK instruction execution | Non-maskable software interrupt |

Note 1: Vector addresses contain internal jump destination addresses.

2: Reset function in the same way as an interrupt with the highest priority.

3: It is an interrupt which can use only for 36 pin version.

Timing After Interrupt

The interrupt processing routine begins with the machine cycle following the completion of the

instruction that is currently in execution.

Figure 55 shows a timing chart after an interrupt occurs, and Figure 56 shows the time up to execution of the interrupt processing routine.

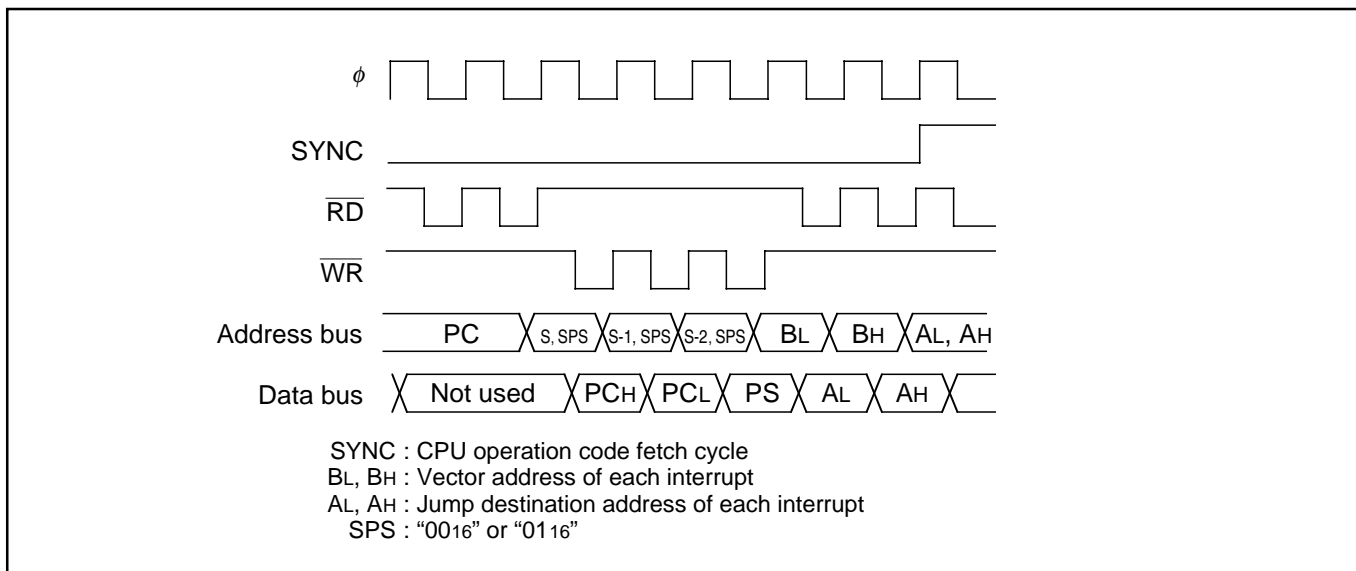


Fig. 55 Timing chart after an interrupt occurs

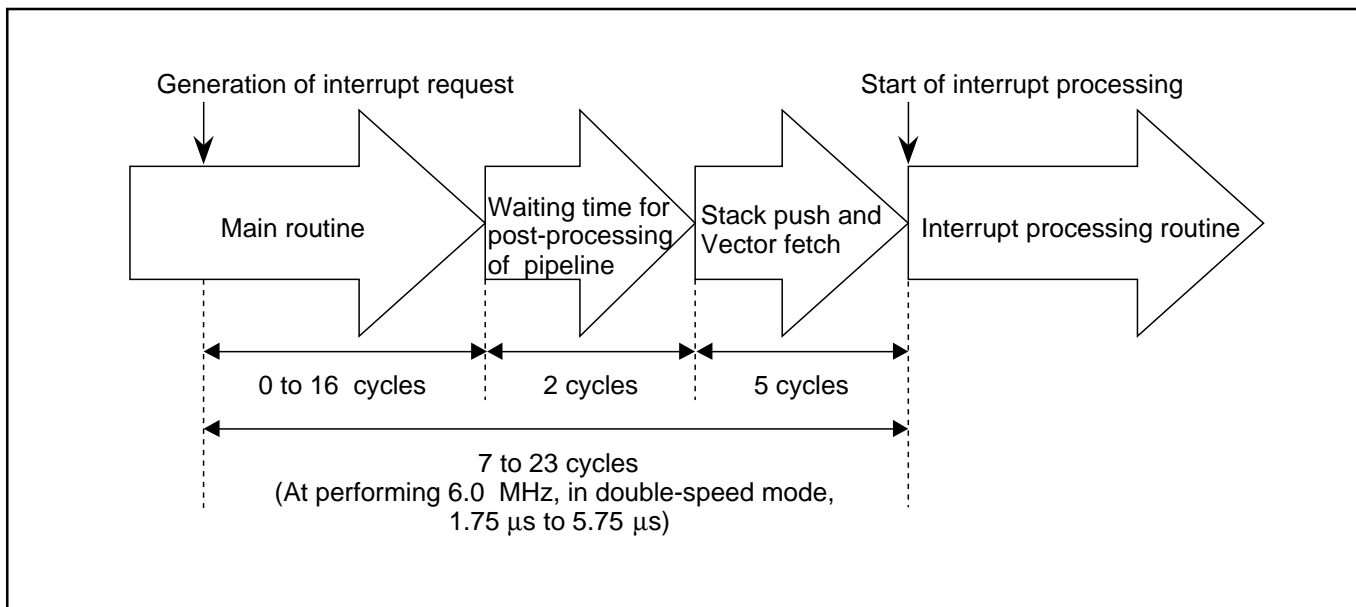


Fig. 56 Time up to execution of the interrupt processing routine

A/D Converter

A/D conversion is started by setting AD conversion completion bit to "0." During A/D conversion, internal operations are performed as follows.

1. After the start of A/D conversion, A/D conversion register goes to "0016."
2. The highest-order bit of A/D conversion register is set to "1," and the comparison voltage V_{ref} is input to the comparator. Then, V_{ref} is compared with analog input voltage V_{IN} .
3. As a result of comparison, when $V_{ref} < V_{IN}$, the highest-order bit of A/D conversion register becomes "1." When $V_{ref} > V_{IN}$, the highest-order bit becomes "0."

By repeating the above operations up to the lowest-order bit of the A/D conversion register, an analog value converts into a digital value.

A/D conversion completes at 122 clock cycles (20.34 μ s at $f(X_{IN}) = 6.0$ MHz) after it is started, and the result of the conversion is stored into the A/D conversion register.

Concurrently with the completion of A/D conversion, A/D conversion interrupt request occurs, so that the AD conversion interrupt request bit is set to "1."

Relative formula for a reference voltage V_{REF} of A/D converter and V_{ref}

When $n = 0$

$$V_{ref} = 0$$

$$\text{When } n = 1 \text{ to } 1023 \quad V_{ref} = \frac{V_{REF}}{1024} \times n$$

n : the value of A/D converter (decimal numeral)

Table 9 Change of A/D conversion register during A/D conversion

| | Change of A/D conversion register | Value of comparison voltage (V_{ref}) |
|--------------------------------------|--|--|
| At start of conversion | 0 0 0 0 0 0 0 0 0 0 0 | 0 |
| First comparison | 1 0 0 0 0 0 0 0 0 0 0 | $\frac{V_{REF}}{2}$ |
| Second comparison | *1 1 0 0 0 0 0 0 0 0 0 | $\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4}$ |
| Third comparison | *1 *2 1 0 0 0 0 0 0 0 0 | $\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4} \pm \frac{V_{REF}}{8}$ |
| ⋮ | ⋮ | ⋮ |
| After completion of tenth comparison | A result of A/D conversion *1 *2 *3 *4 *5 *6 *7 *8 *9 *10 | $\frac{V_{REF}}{2} \pm \frac{V_{REF}}{4} \pm \dots \pm \frac{V_{REF}}{1024}$ |

*1–*10: A result of the first to tenth comparison

Figure 56 shows A/D conversion equivalent circuit, and Figure 57 shows A/D conversion timing chart.

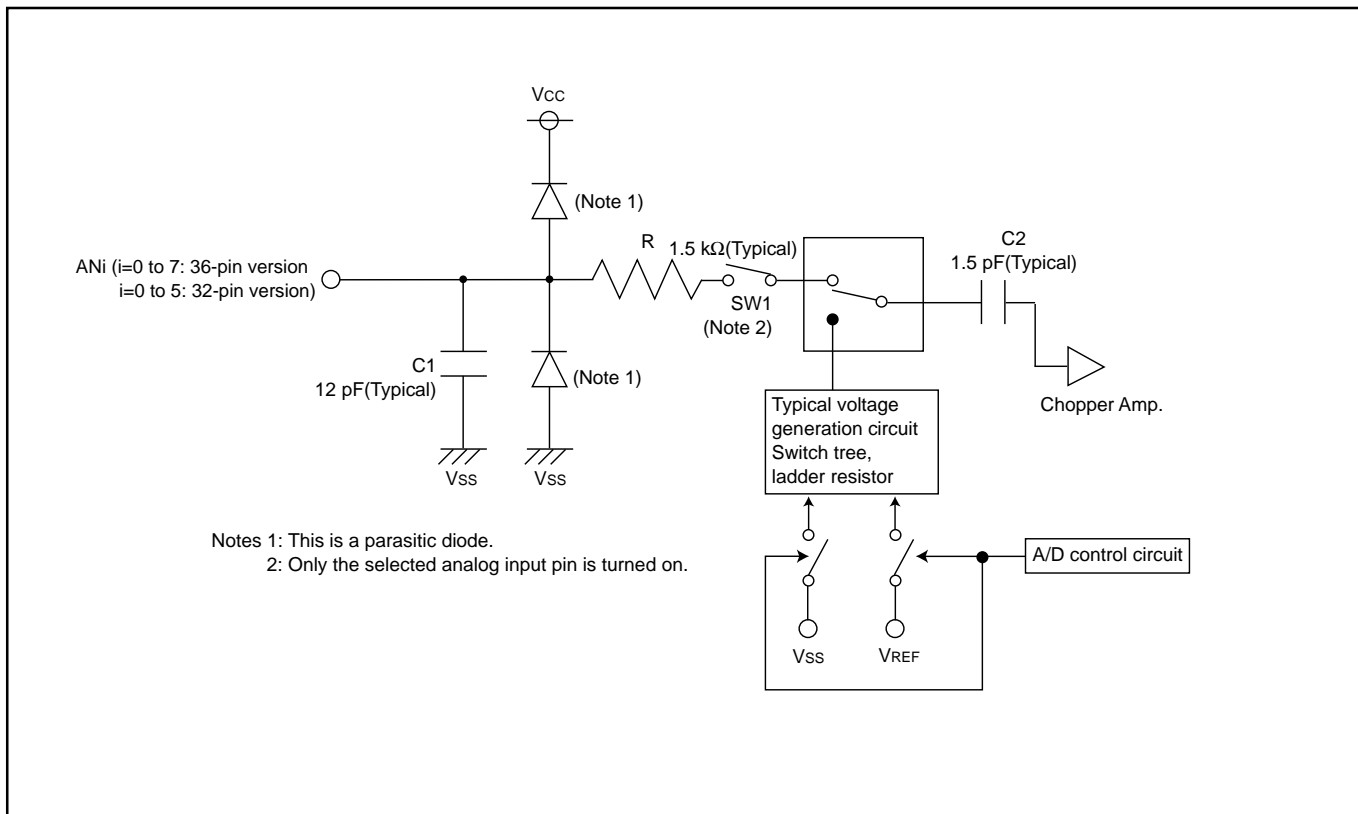


Fig. 57 A/D conversion equivalent circuit

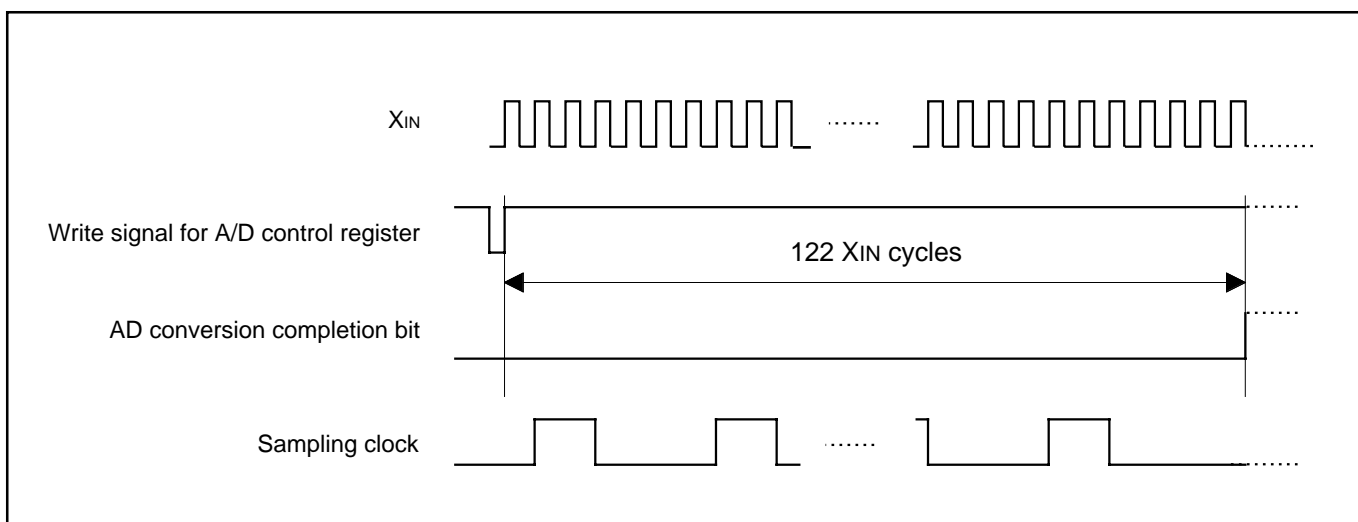


Fig. 58 A/D conversion timing chart

CHAPTER 2

APPLICATION

- 2.1 I/O port**
- 2.2 Timer A**
- 2.3 Timer 1**
- 2.4 Timer X**
- 2.5 Timer Y and timer Z**
- 2.6 Serial I/O1**
- 2.7 Serial I/O2**
- 2.8 A/D converter**
- 2.9 Reset**

2.1 I/O port

This paragraph explains the registers setting method and the notes relevant to the I/O ports.

2.1.1 Memory map

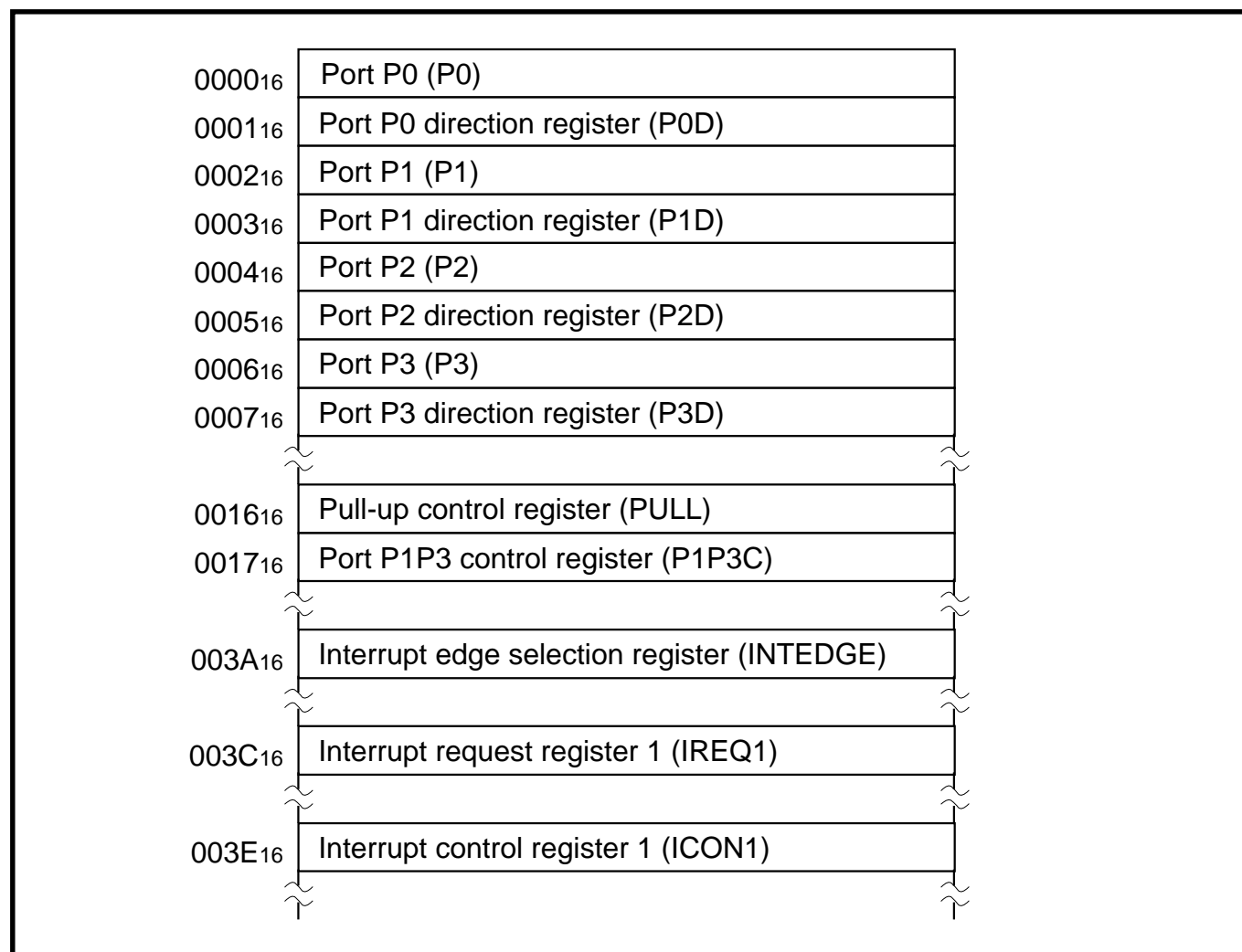


Fig. 2.1.1 Memory map of registers relevant to I/O port

2.1.2 Relevant registers

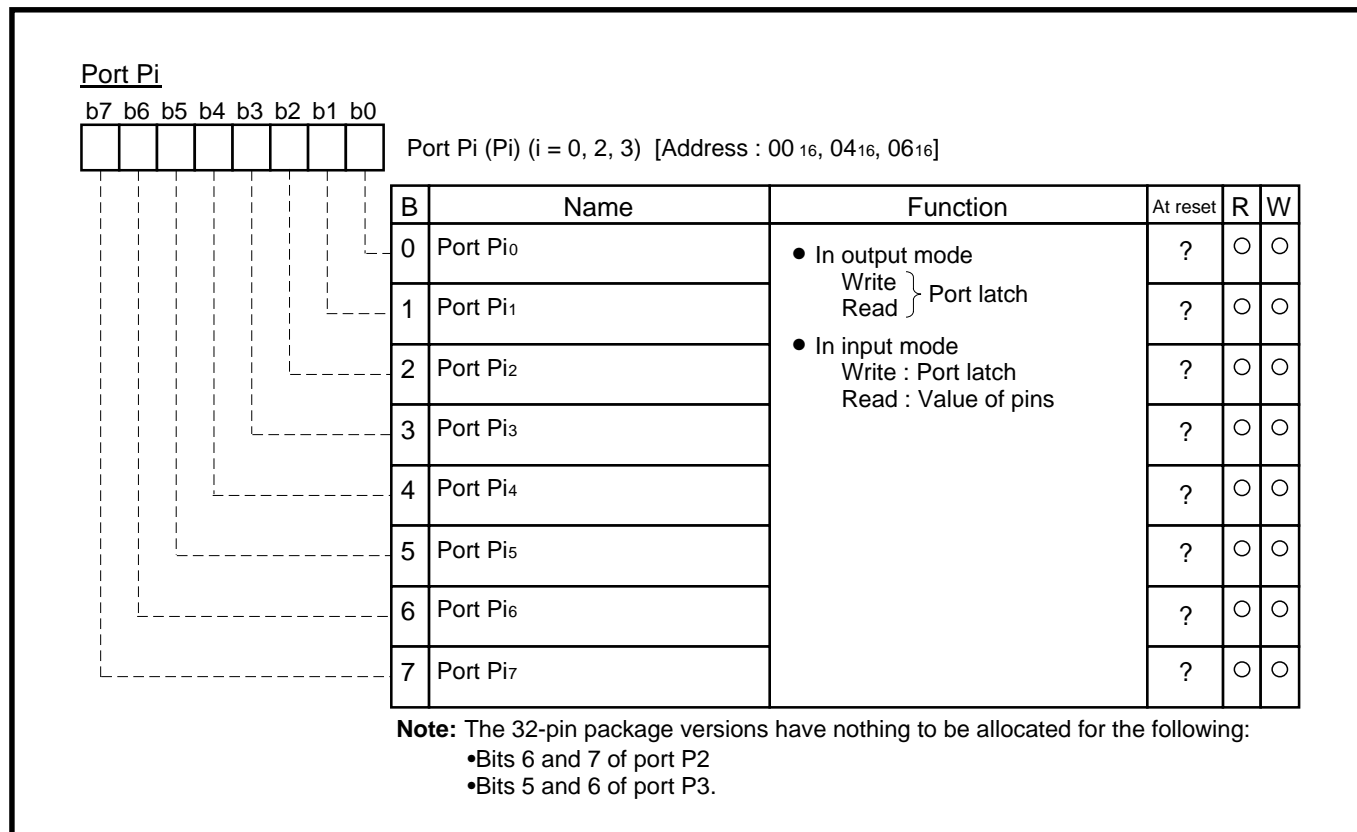


Fig. 2.1.2 Structure of Port Pi (i = 0, 2, 3)

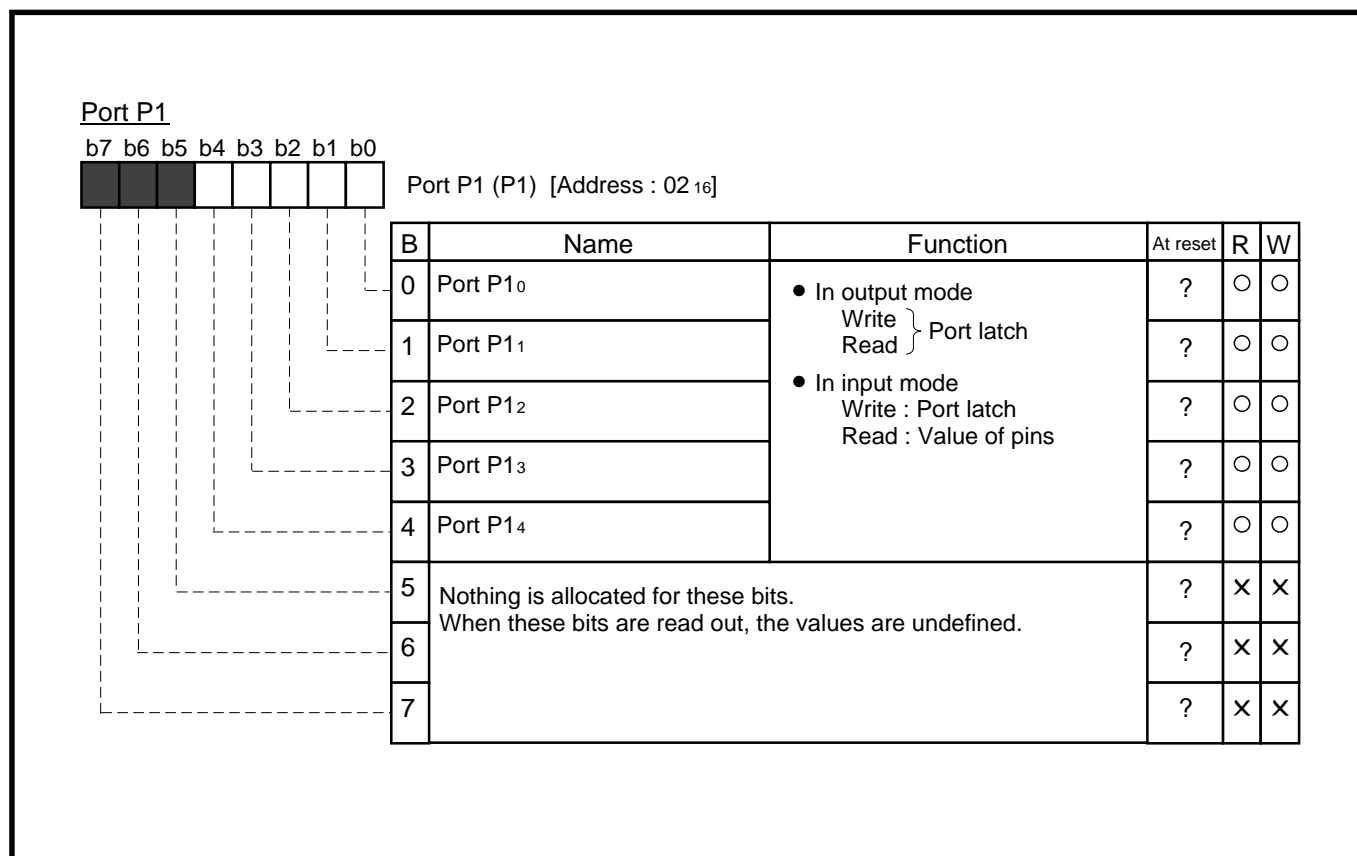


Fig. 2.1.3 Structure of Port P1

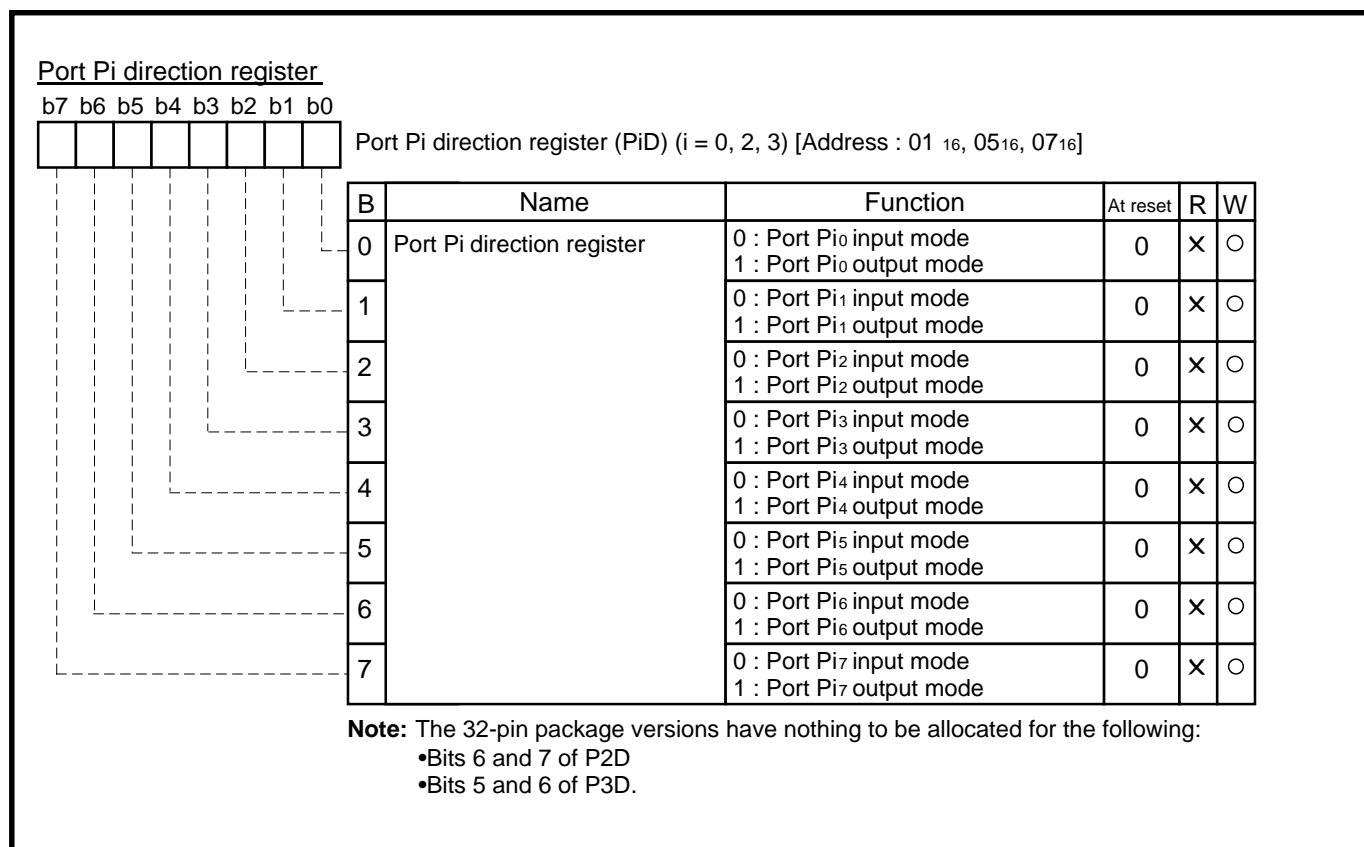


Fig. 2.1.4 Structure of Port Pi direction register (i = 0, 2, 3)

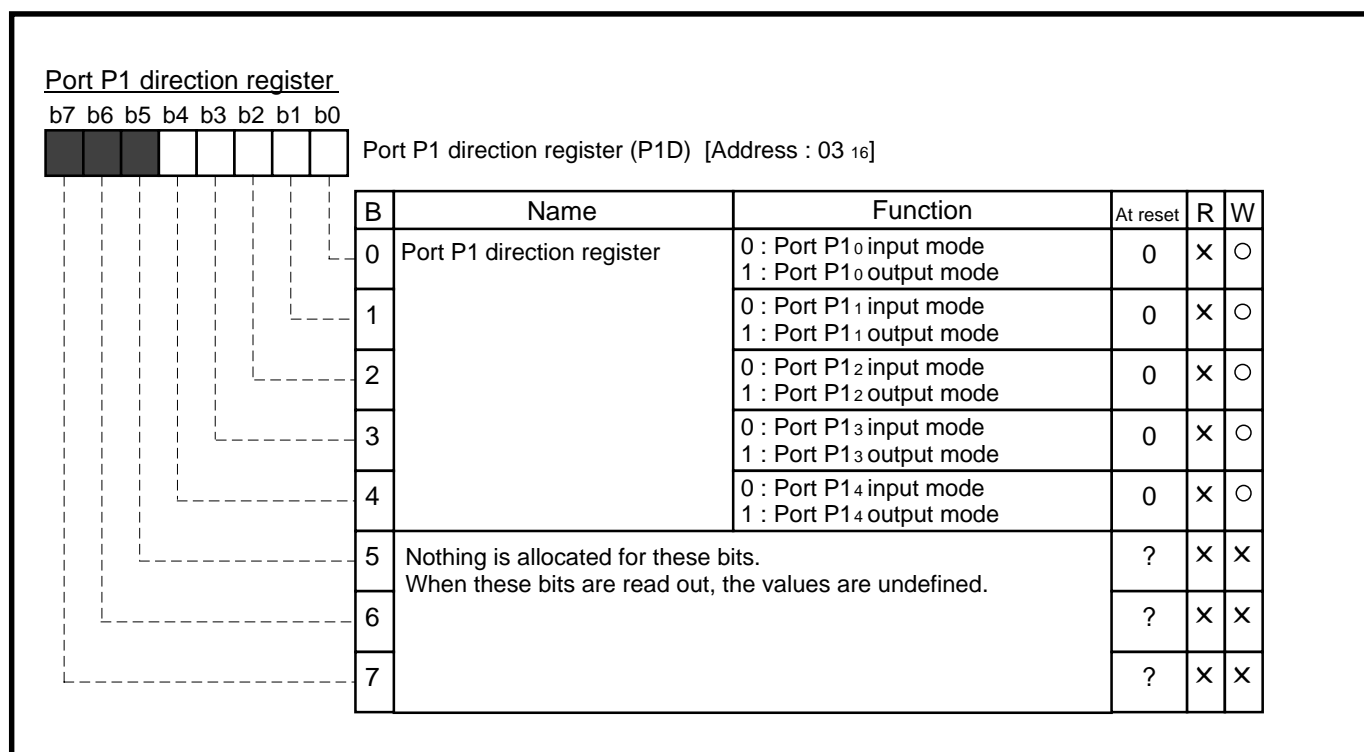


Fig. 2.1.5 Structure of Port P1 direction register

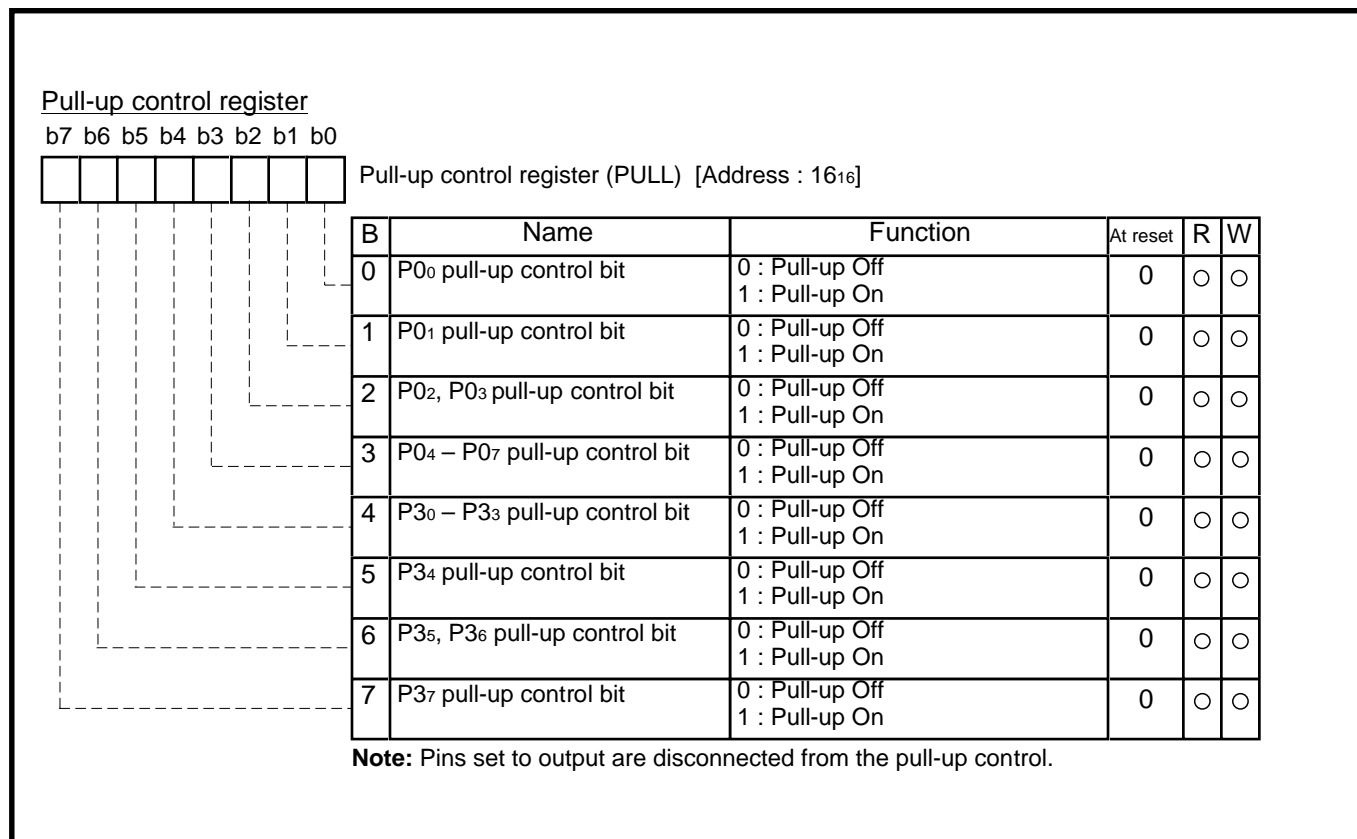


Fig. 2.1.6 Structure of Pull-up control register

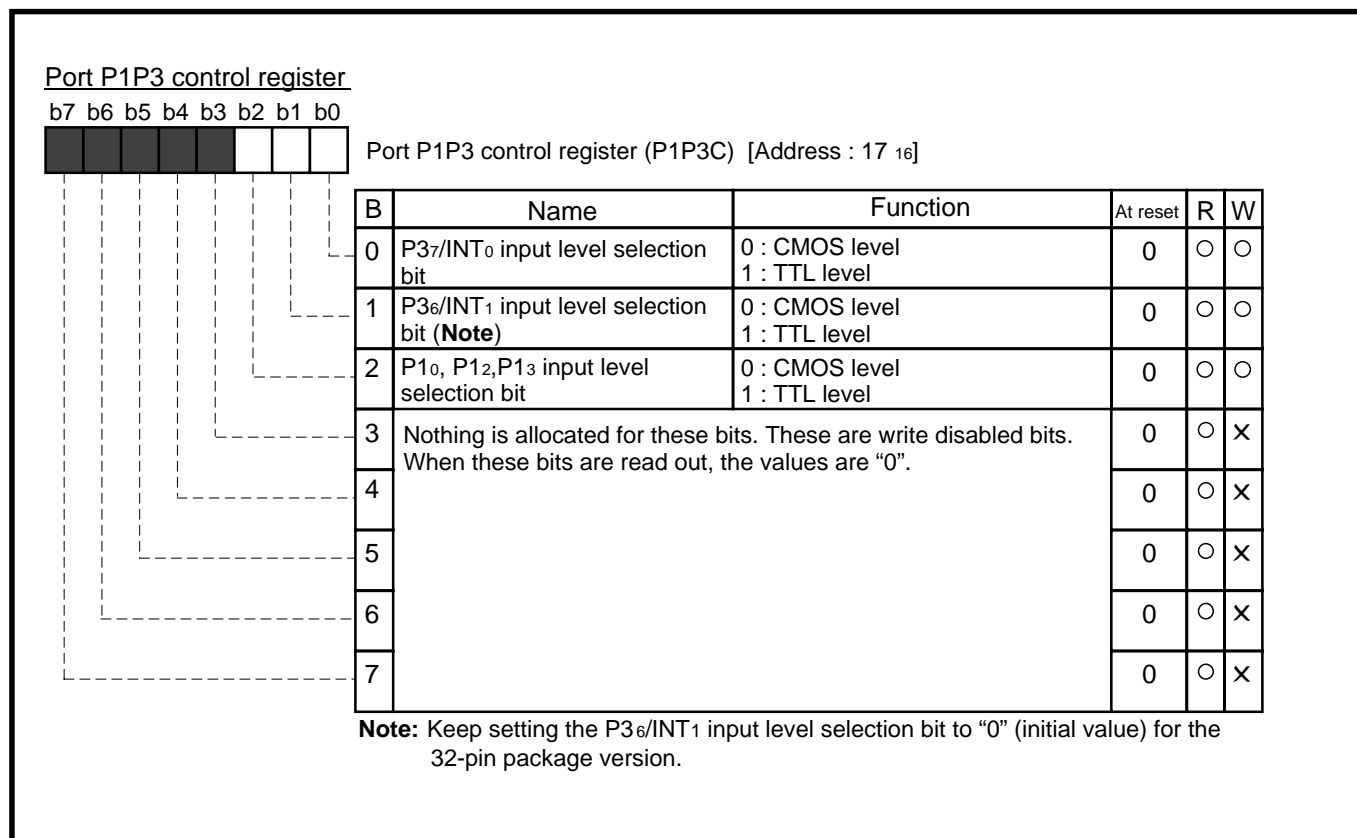


Fig. 2.1.7 Structure of Port P1P3 control register

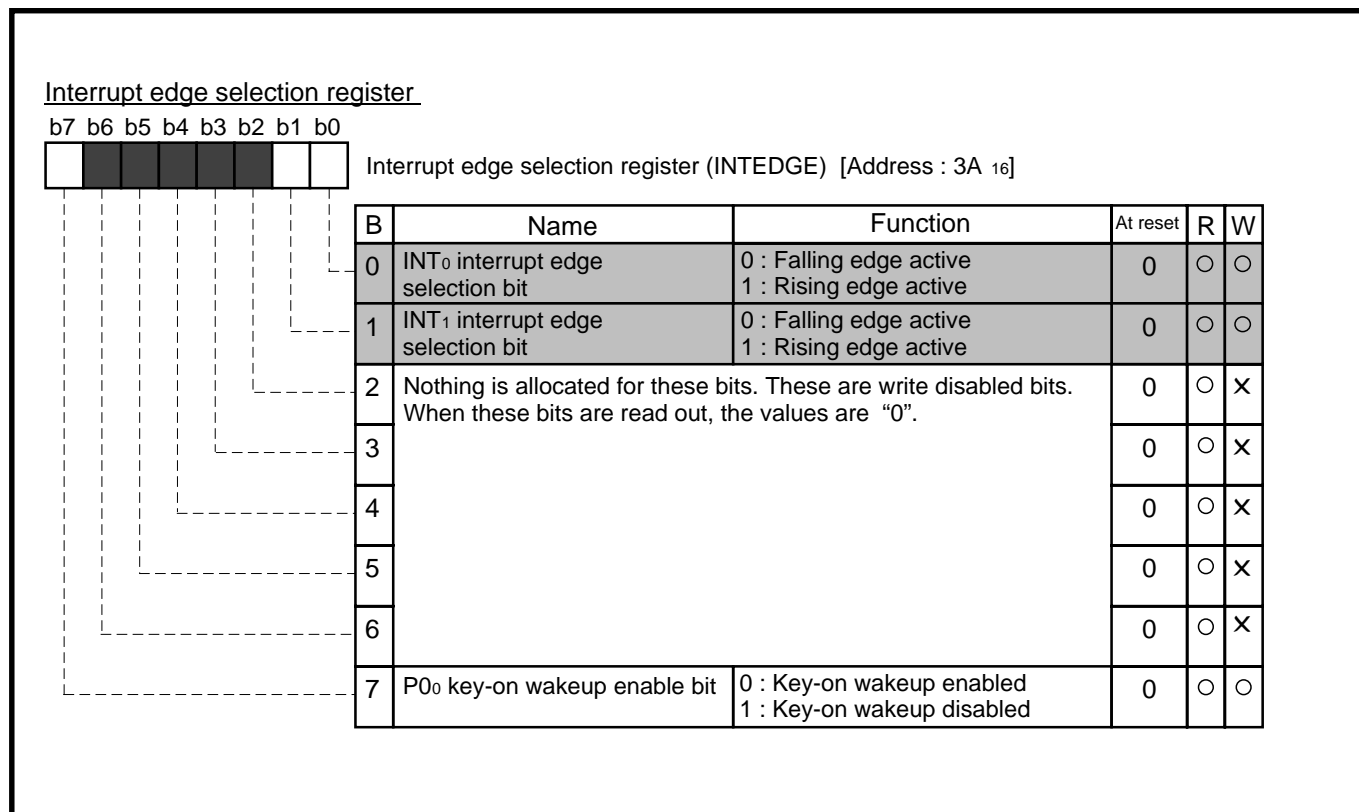


Fig. 2.1.8 Structure of Interrupt edge selection register

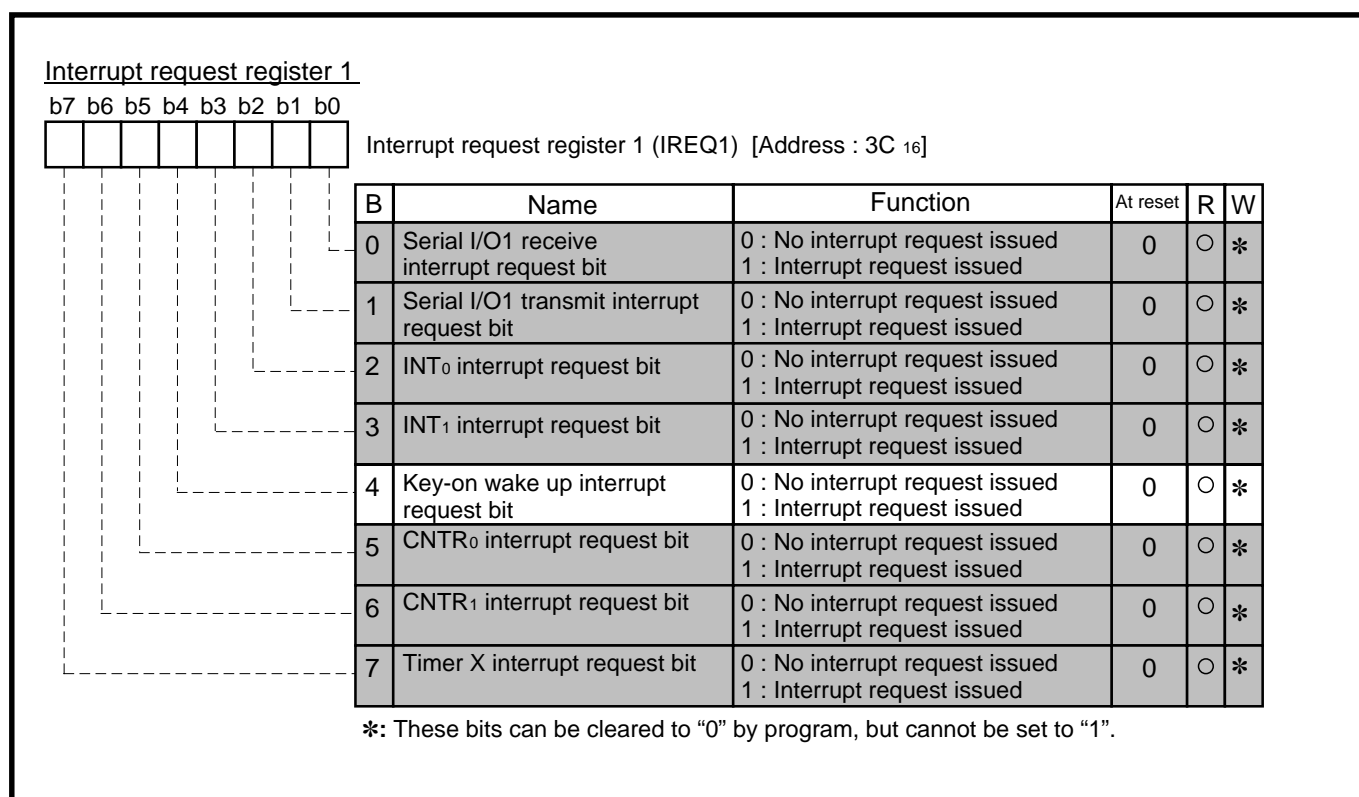


Fig. 2.1.9 Structure of Interrupt request register 1

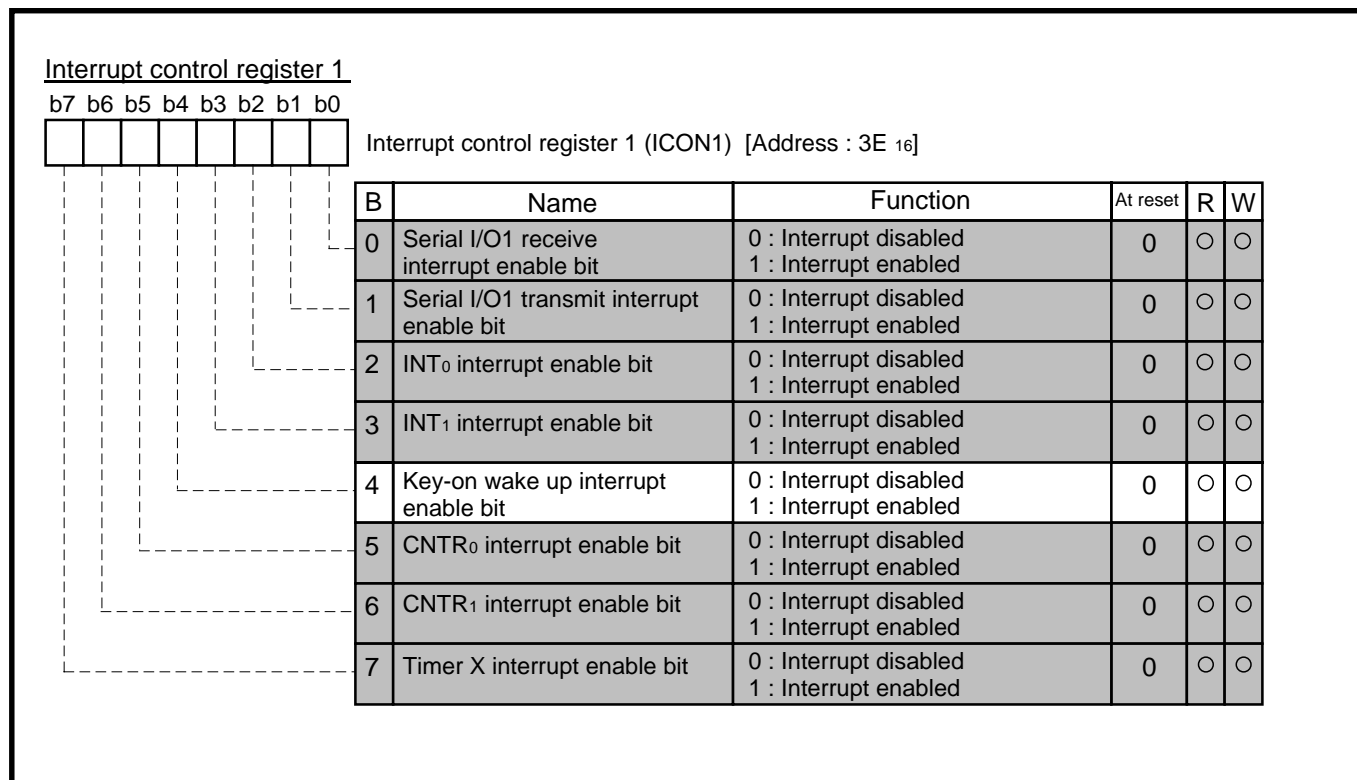


Fig. 2.1.10 Structure of Interrupt control register 1

2.1.3 Application example of key-on wake up (1)

Outline: The built-in pull-up resistor is used.

Specifications: System is returned from the wait mode when the key-on wakeup interrupt occurs by input of the falling edge to port P0i.

Note: Only the falling edge is active for the key-on wakeup interrupt.

Figure 2.1.11 shows an example of application circuit, and Figure 2.1.12 shows an example of control procedure.

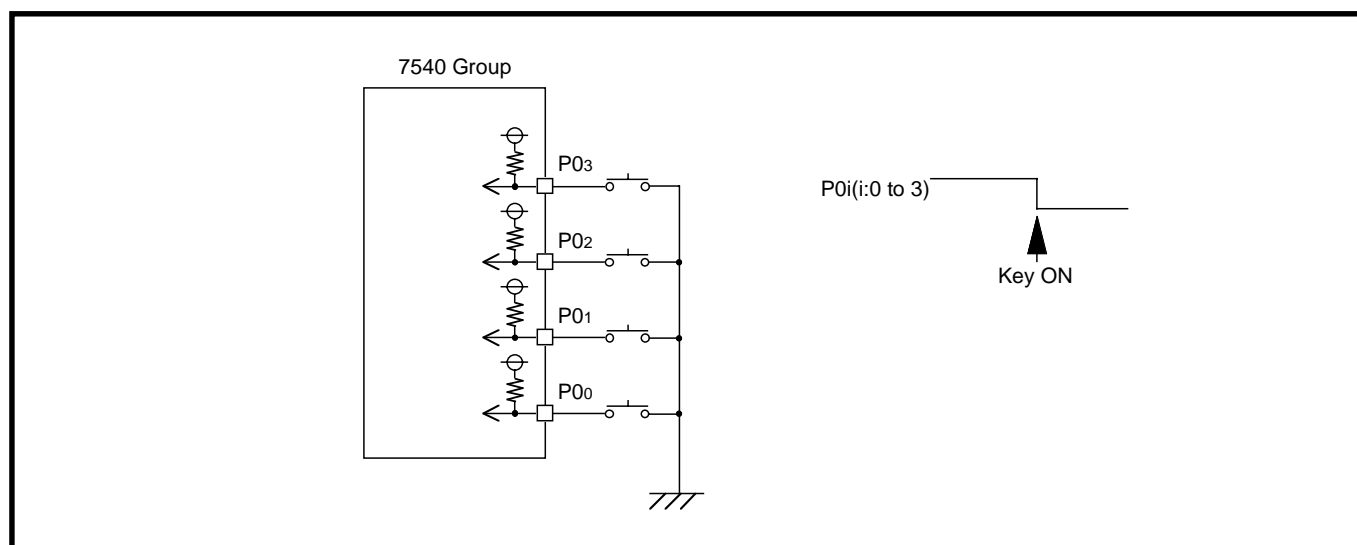


Fig. 2.1.11 Example of application circuit

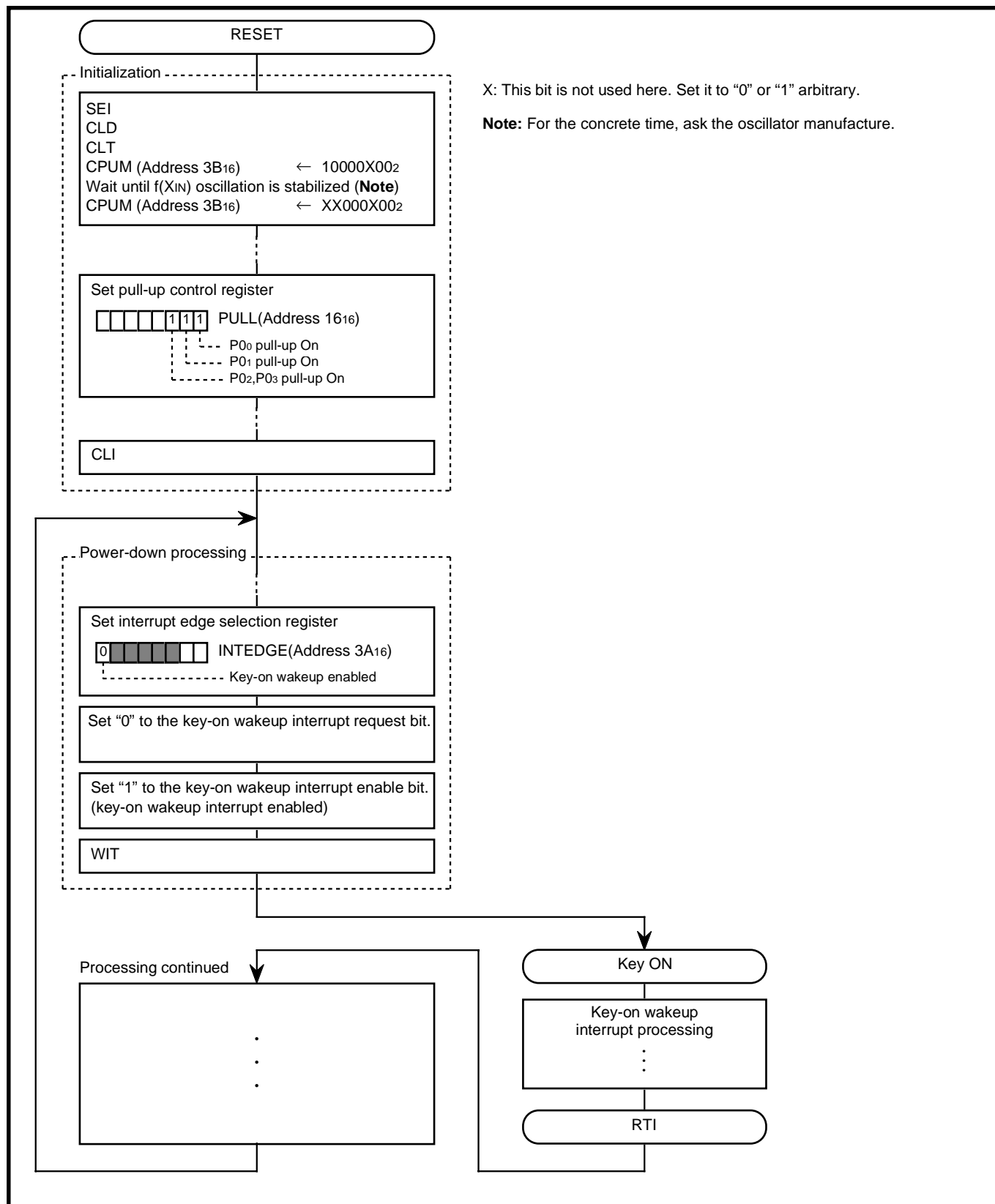


Fig. 2.1.12 Example of control procedure (1)

2.1.4 Application example of key-on wake up (2)

Outline: The key-on wakeup interrupt is used as the normal external interrupt.

Specifications: The key-on wakeup interrupt occurs by input of the falling edge to port P0i. If necessary, the built-in pull-up resistor is used.

Note: Only the falling edge is active for the key-on wakeup interrupt.

Figure 2.1.13 shows an example of control procedure.

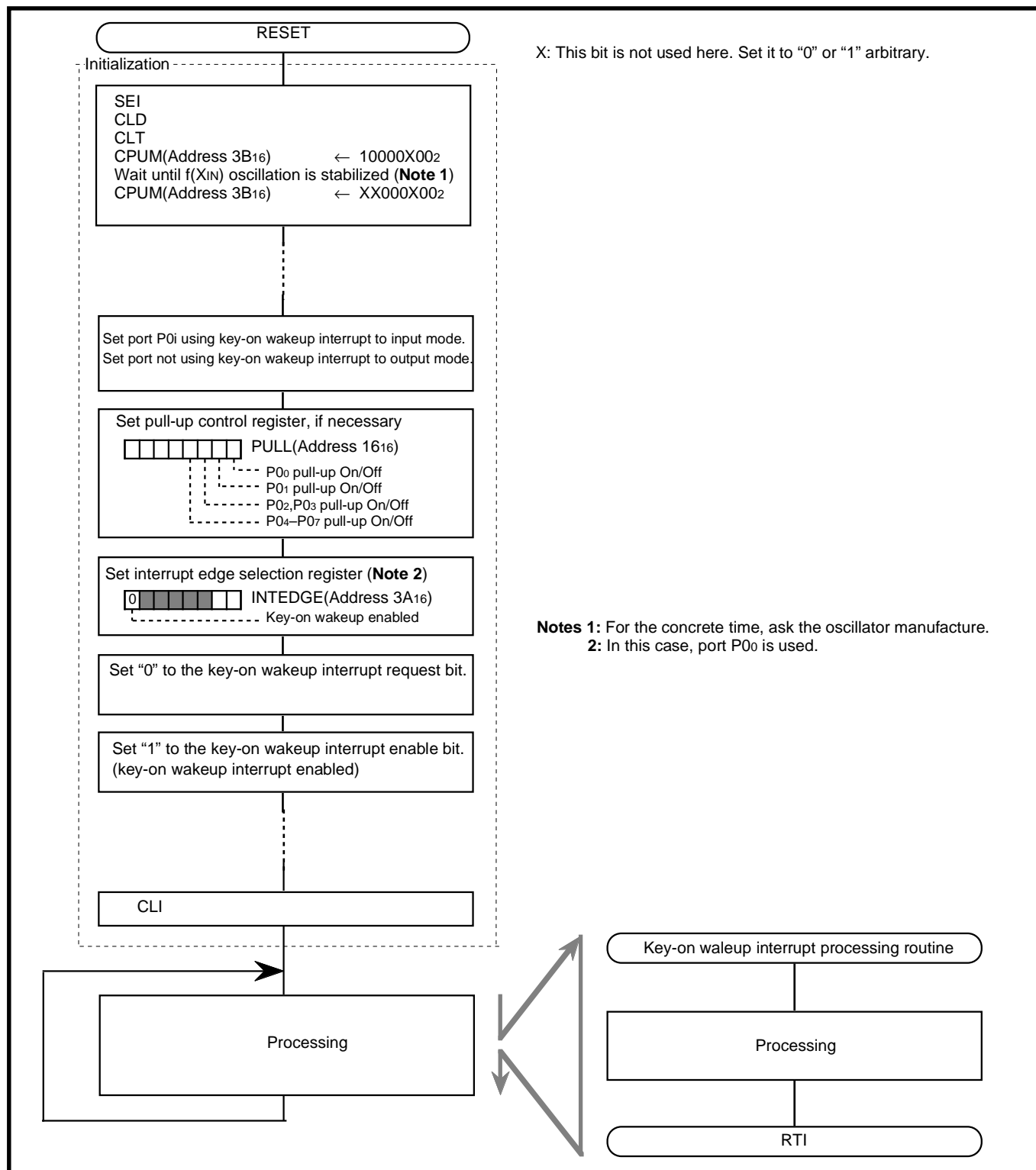


Fig. 2.1.13 Example of control procedure (2)

2.1.5 Handling of unused pins

Table 2.1.1 Handling of unused pins

| Pins/Ports name | Handling |
|------------------|--|
| P0, P1, P2, P3 | <ul style="list-style-type: none">•Set to the input mode and connect each to Vcc or Vss through a resistor of 1 kΩ to 10 kΩ.•Set to the output mode and open at “L” or “H” level. |
| V _{REF} | <ul style="list-style-type: none">•Connect to Vss (GND). |
| X _{IN} | <ul style="list-style-type: none">•Connect to V_{SS} (GND) when using an on-chip oscillator for main clock. |
| X _{OUT} | <ul style="list-style-type: none">•Open when using an external clock.•Open when using an on-chip oscillator for main clock. |

2.1.6 Notes on input and output ports

Notes on using input and output ports are described below.

(1) Notes in stand-by state

In stand-by state*¹ for low-power dissipation, do not make input levels of an input port and an I/O port “undefined”.

Pull-up (connect the port to VCC) or pull-down (connect the port to VSS) these ports through a resistor.

When determining a resistance value, note the following points:

- External circuit
- Variation of output levels during the ordinary operation

When using a built-in pull-up resistor, note on varied current values:

- When setting as an input port : Fix its input level
- When setting as an output port : Prevent current from flowing out to external.

● Reason

The output transistor becomes the OFF state, which causes the ports to be the high-impedance state. Note that the level becomes “undefined” depending on external circuits.

Accordingly, the potential which is input to the input buffer in a microcomputer is unstable in the state that input levels of a input port and an I/O port are “undefined”. This may cause power source current.

*¹ stand-by state : the stop mode by executing the **STP** instruction
the wait mode by executing the **WIT** instruction

(2) Modifying output data with bit managing instruction

When the port latch of an I/O port is modified with the bit managing instruction*², the value of the unspecified bit may be changed.

● Reason

The bit managing instructions are read-modify-write form instructions for reading and writing data by a byte unit. Accordingly, when these instructions are executed on a bit of the port latch of an I/O port, the following is executed to all bits of the port latch.

- As for a bit which is set for an input port :
The pin state is read in the CPU, and is written to this bit after bit managing.
- As for a bit which is set for an output port :
The bit value of the port latch is read in the CPU, and is written to this bit after bit managing.

Note the following :

- Even when a port which is set as an output port is changed for an input port, its port latch holds the output data.
- As for a bit of the port latch which is set for an input port, its value may be changed even when not specified with a bit managing instruction in case where the pin state differs from its port latch contents.

*² bit managing instructions : **SEB**, and **CLB** instructions

(3) Usage for the 32-pin version

- ① Fix the P3₅, P3₆ pull-up control bit of the pull-up control register to “1”.
- ② Keep the P3₆/INT₁ input level selection bit of the port P1P3 control register “0” (initial state).

2.1.7 Termination of unused pins

(1) Terminate unused pins

① I/O ports :

- Set the I/O ports for the input mode and connect them to VCC or VSS through each resistor of 1 k Ω to 10 k Ω .

Ports that permit the selecting of a built-in pull-up resistor can also use this resistor. Set the I/O ports for the output mode and open them at "L" or "H".

- When opening them in the output mode, the input mode of the initial status remains until the mode of the ports is switched over to the output mode by the program after reset. Thus, the potential at these pins is undefined and the power source current may increase in the input mode. With regard to an effects on the system, thoroughly perform system evaluation on the user side.
- Since the direction register setup may be changed because of a program runaway or noise, set direction registers by program periodically to increase the reliability of program.

(2) Termination remarks

① Input ports and I/O ports :

Do not open in the input mode.

● Reason

- The power source current may increase depending on the first-stage circuit.
- An effect due to noise may be easily produced as compared with proper termination ② and ③ shown on the above.

② I/O ports :

When setting for the input mode, do not connect to VCC or VSS directly.

● Reason

If the direction register setup changes for the output mode because of a program runaway or noise, a short circuit may occur between a port and VCC (or VSS).

③ I/O ports :

When setting for the input mode, do not connect multiple ports in a lump to VCC or VSS through a resistor.

● Reason

If the direction register setup changes for the output mode because of a program runaway or noise, a short circuit may occur between ports.

- At the termination of unused pins, perform wiring at the shortest possible distance (20 mm or less) from microcomputer pins.

2.2 Timer A

This paragraph explains the registers setting method and the notes relevant to the timer A.

2.2.1 Memory map

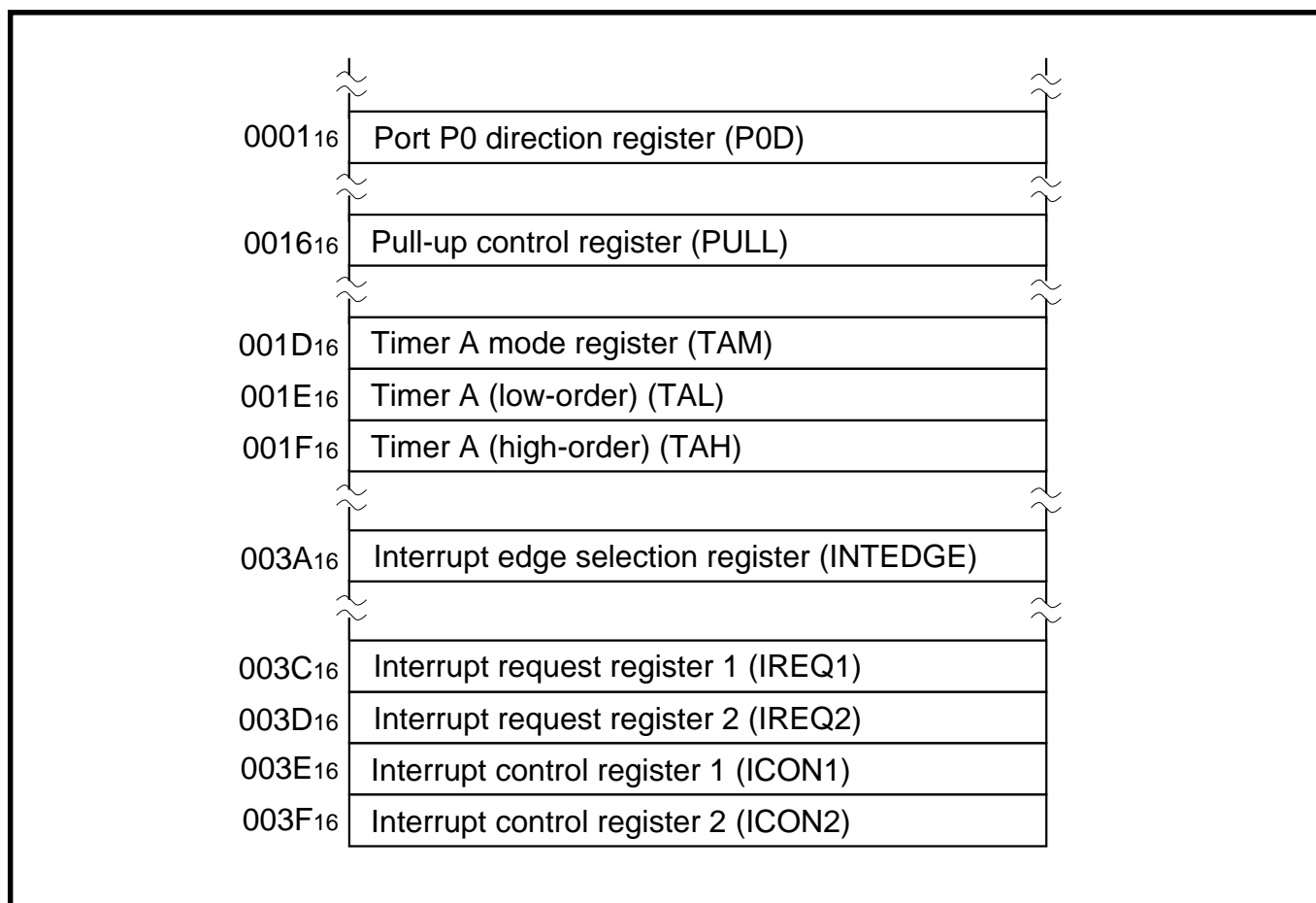


Fig. 2.2.1 Memory map of registers relevant to timer A

2.2.2 Relevant registers

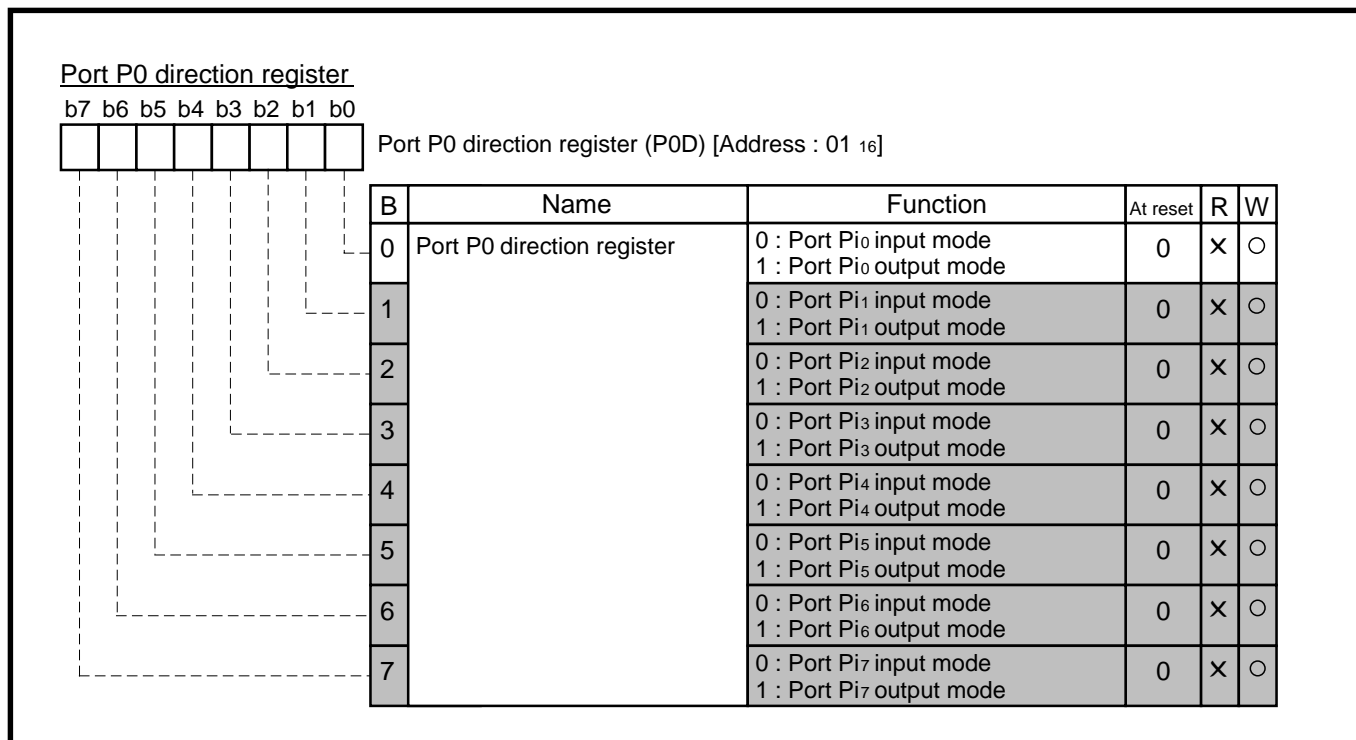


Fig. 2.2.2 Structure of Port P0 direction register

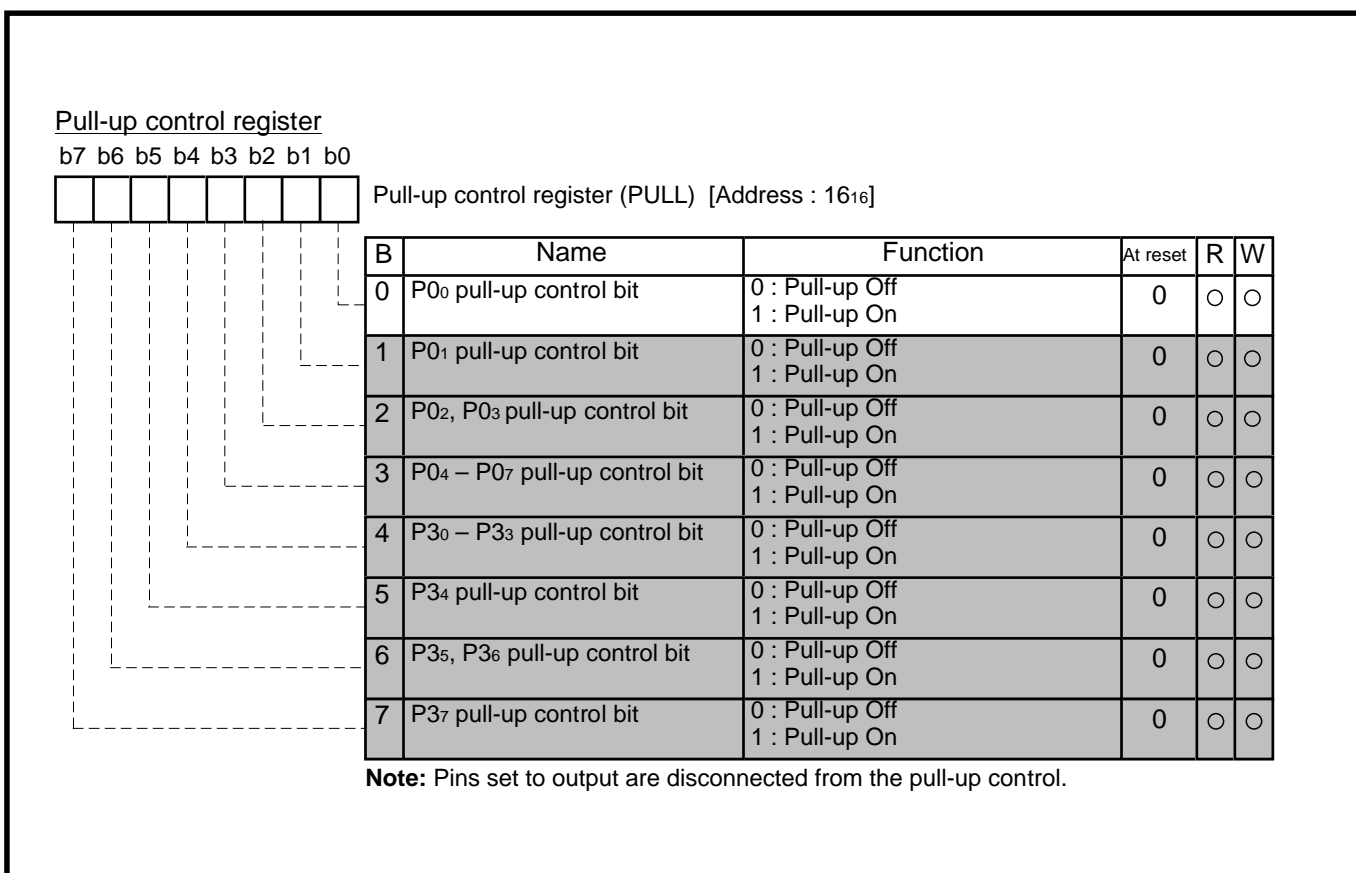


Fig. 2.2.3 Structure of Pull-up control register

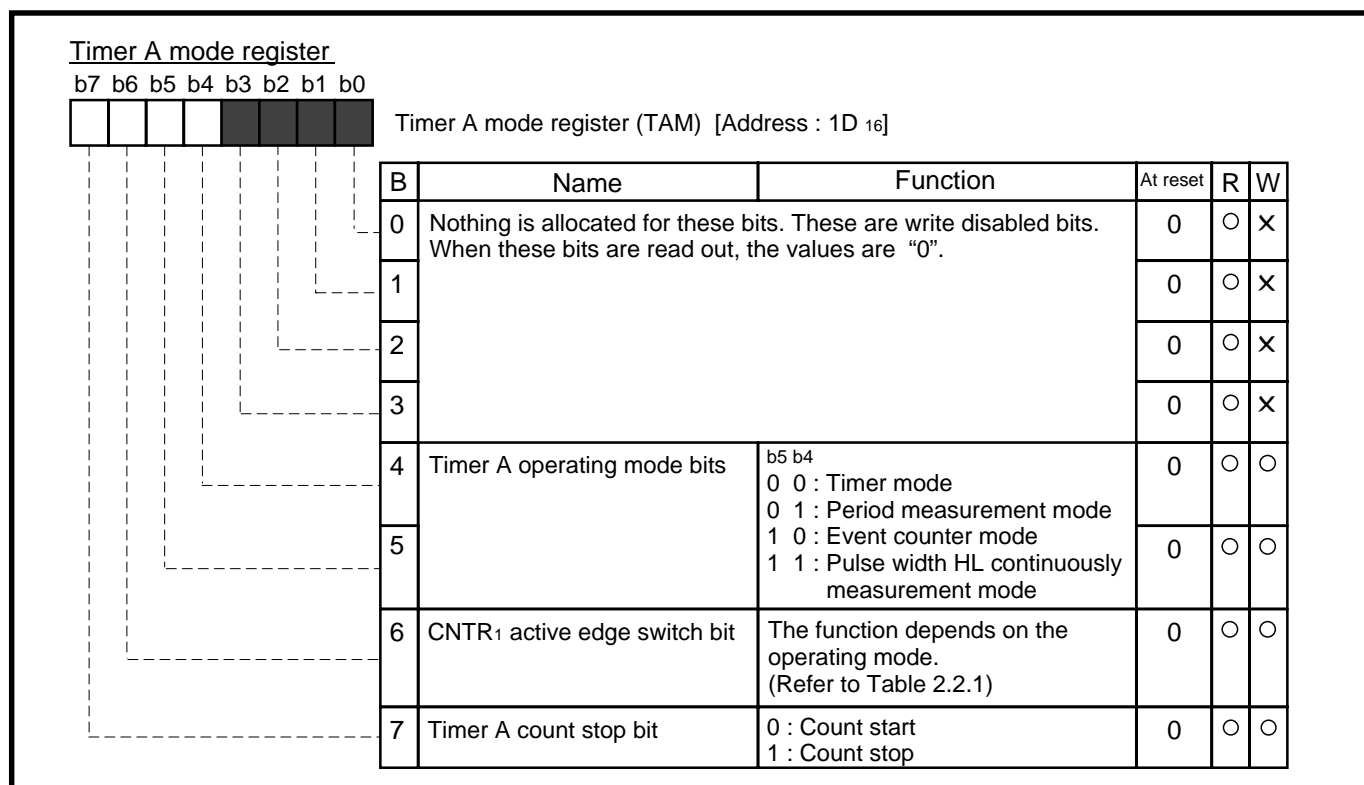


Fig. 2.2.4 Structure of Timer A mode register

Table 2.2.1 CNTR₁ active edge switch bit function

| Timer A operating modes | CNTR ₁ active edge switch bit (bit 6 of address 1D ₁₆) contents | |
|--|--|--|
| Timer mode | "0" | CNTR ₁ interrupt request occurrence: Falling edge ; No influence to timer count |
| | "1" | CNTR ₁ interrupt request occurrence: Rising edge ; No influence to timer count |
| Period measurement mode | "0" | Period measurement: Falling period measurement CNTR ₁ interrupt request occurrence: Falling edge |
| | "1" | Period measurement: Rising period measurement CNTR ₁ interrupt request occurrence: Rising edge |
| Event counter mode | "0" | Timer A: Rising edge count CNTR ₁ interrupt request occurrence: Falling edge |
| | "1" | Timer A: Falling edge count CNTR ₁ interrupt request occurrence: Rising edge |
| Pulse width HL continuously measurement mode | "0" | CNTR ₁ interrupt request occurrence: Rising edge and Falling edge |
| | "1" | CNTR ₁ interrupt request occurrence: Rising edge and Falling edge |

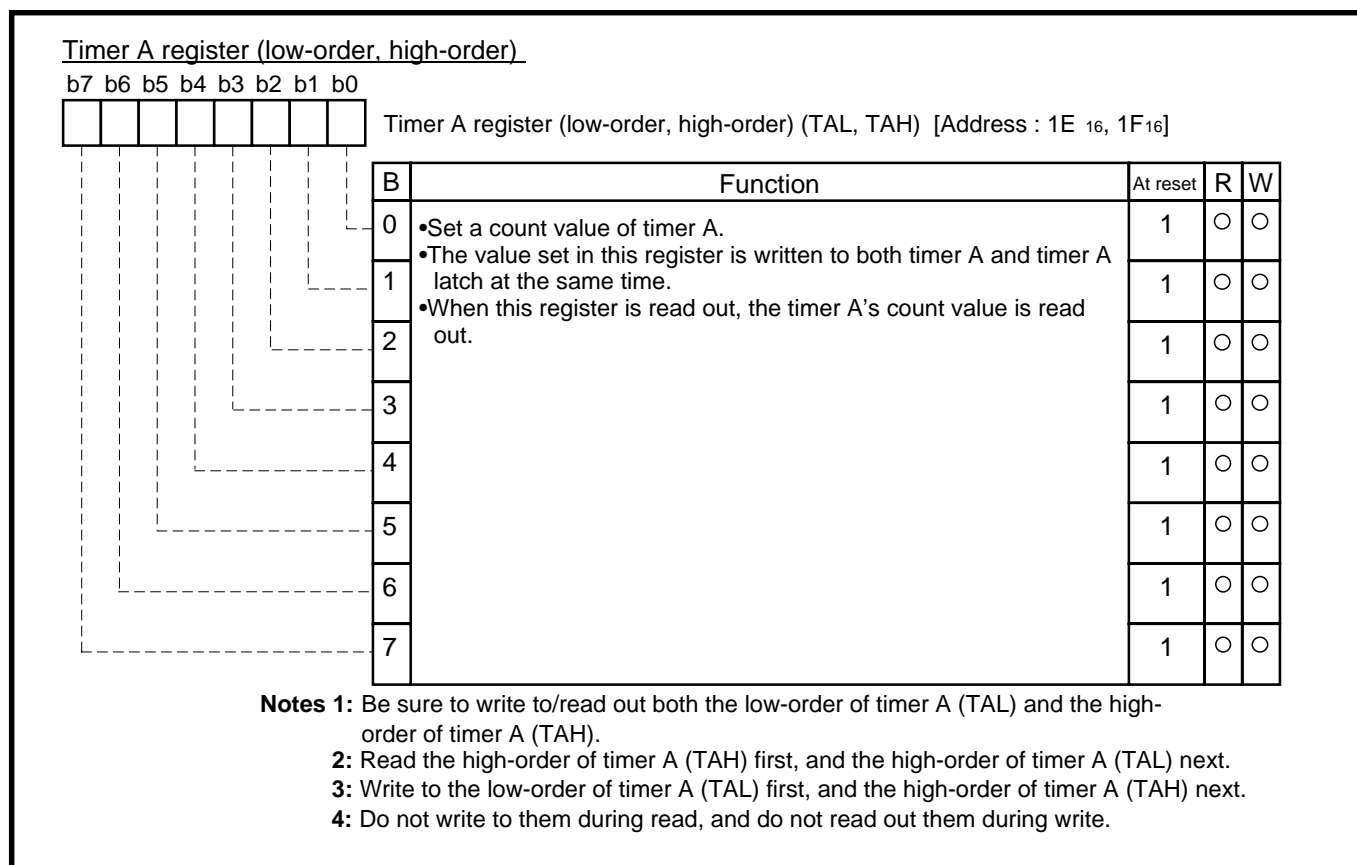


Fig. 2.2.5 Structure of Timer A register

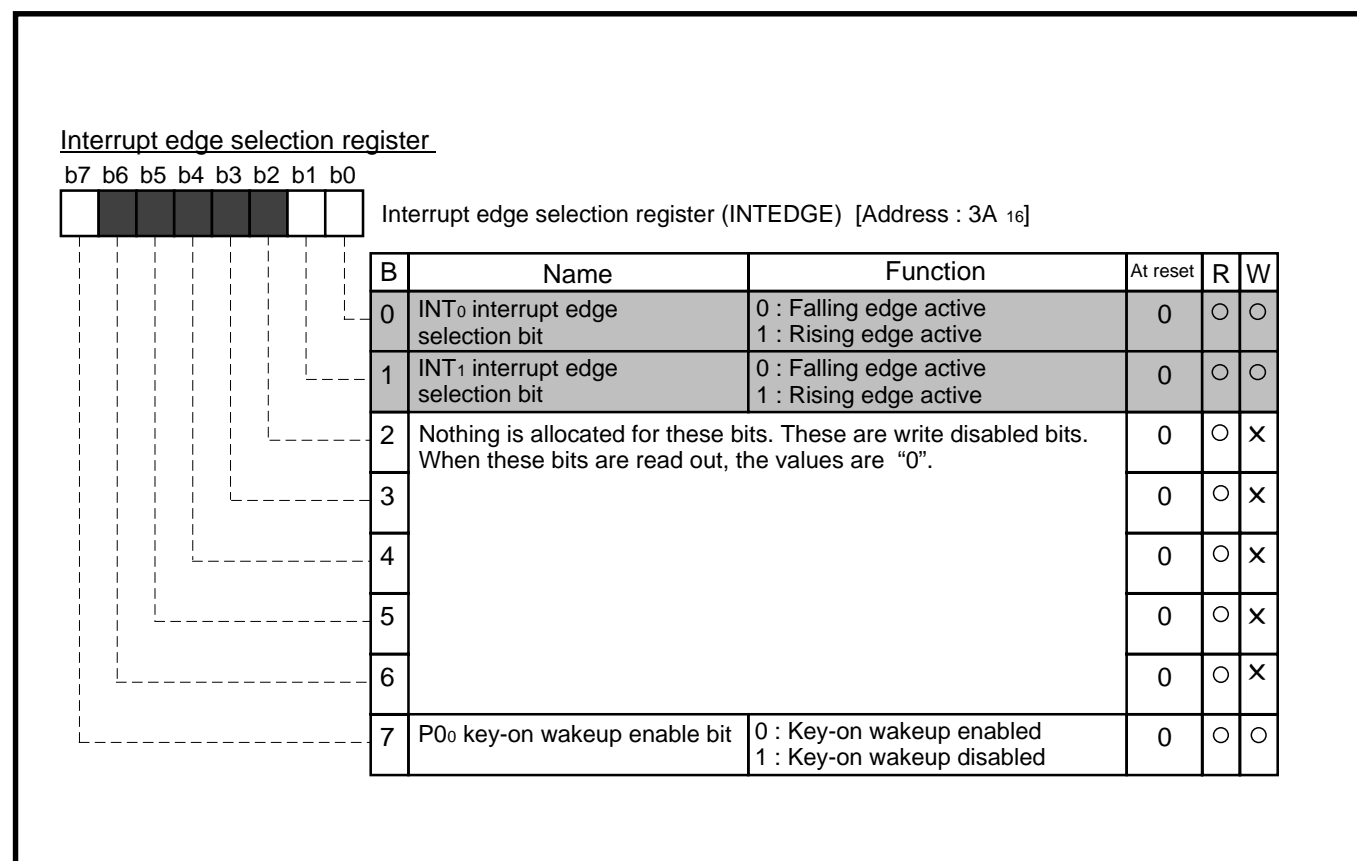


Fig. 2.2.6 Structure of Interrupt edge selection register

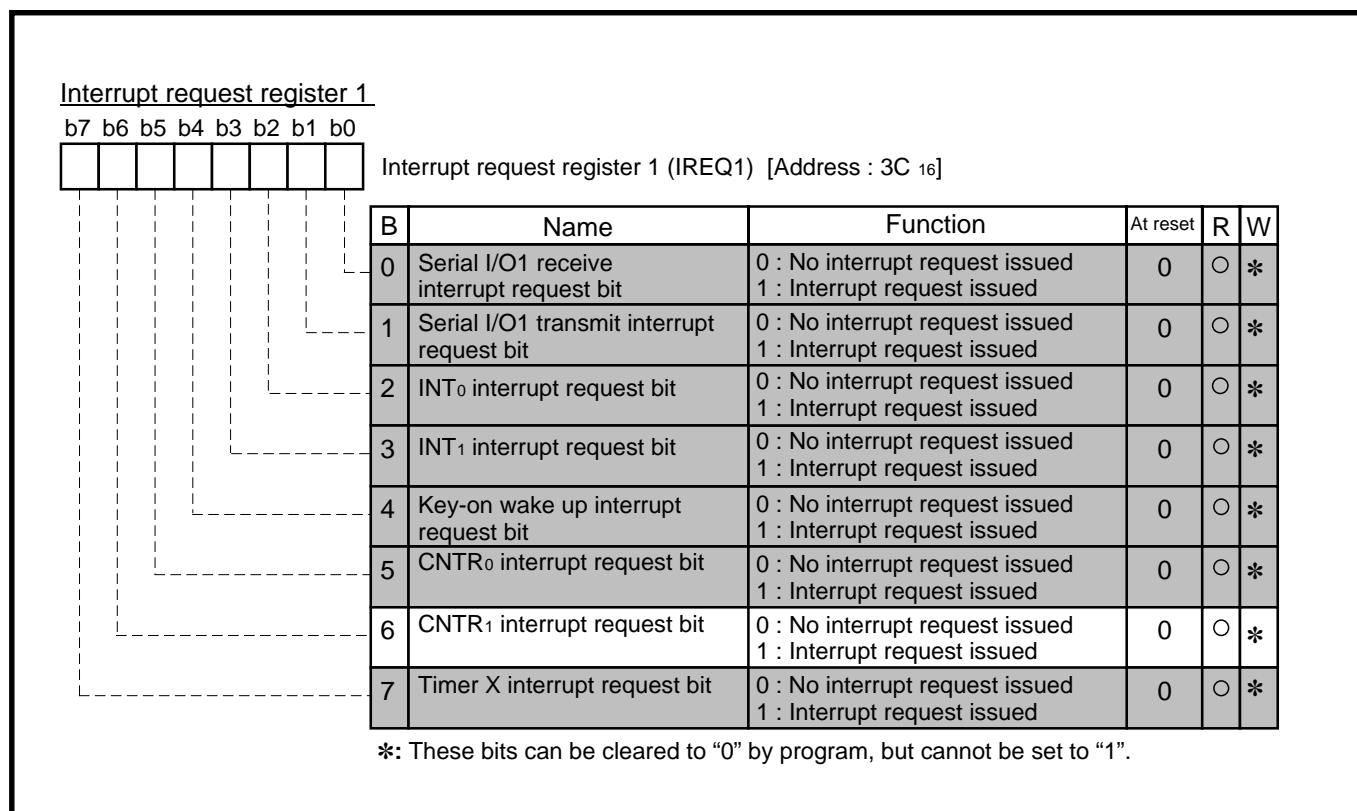


Fig. 2.2.7 Structure of Interrupt request register 1

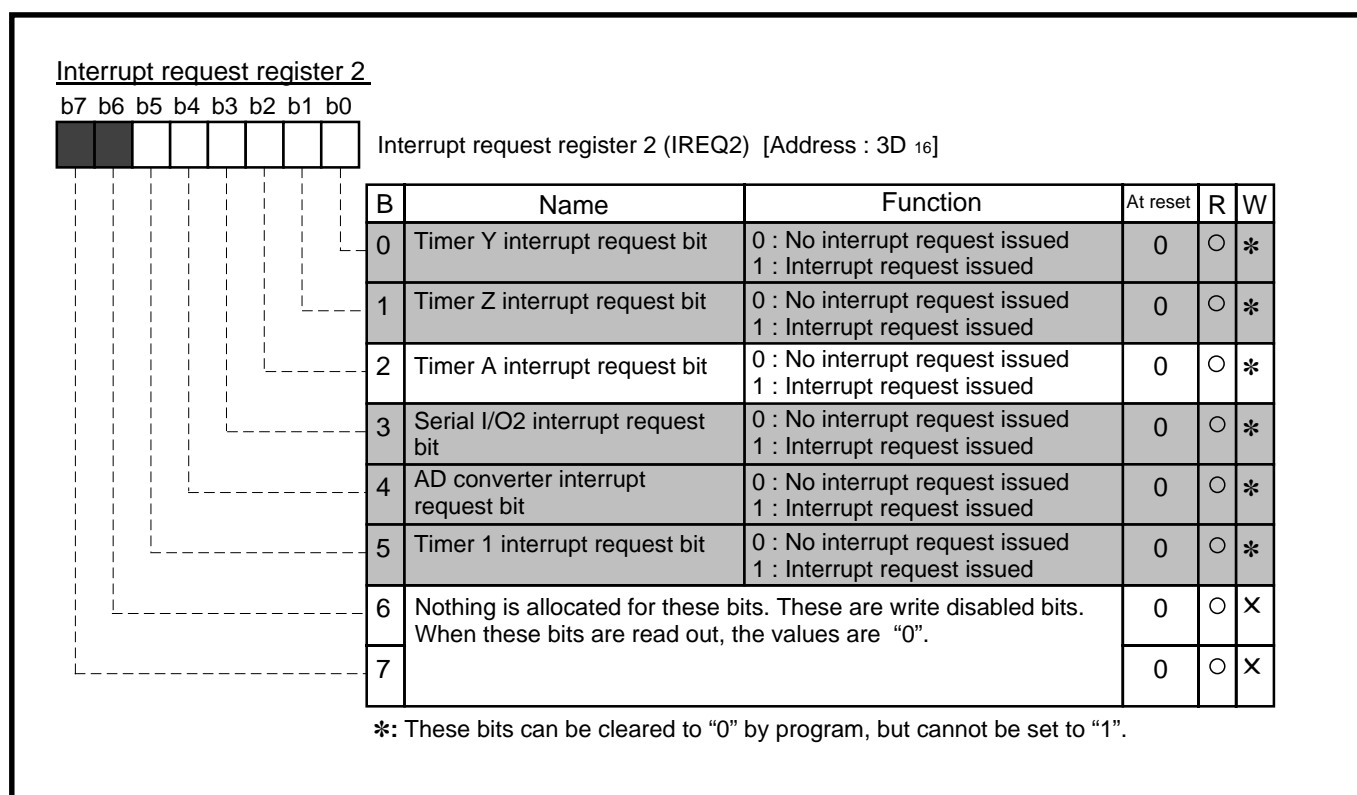


Fig. 2.2.8 Structure of Interrupt request register 2

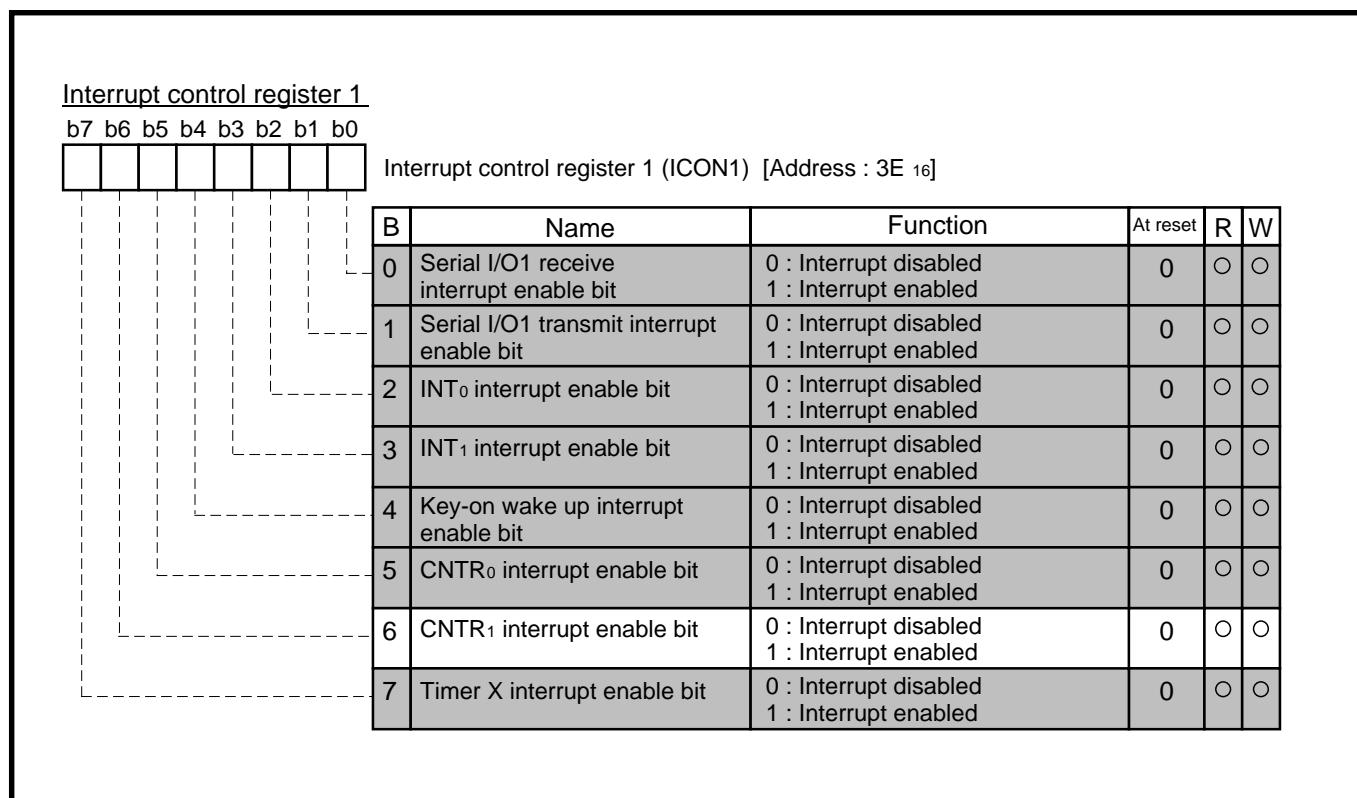


Fig. 2.2.9 Structure of Interrupt control register 1

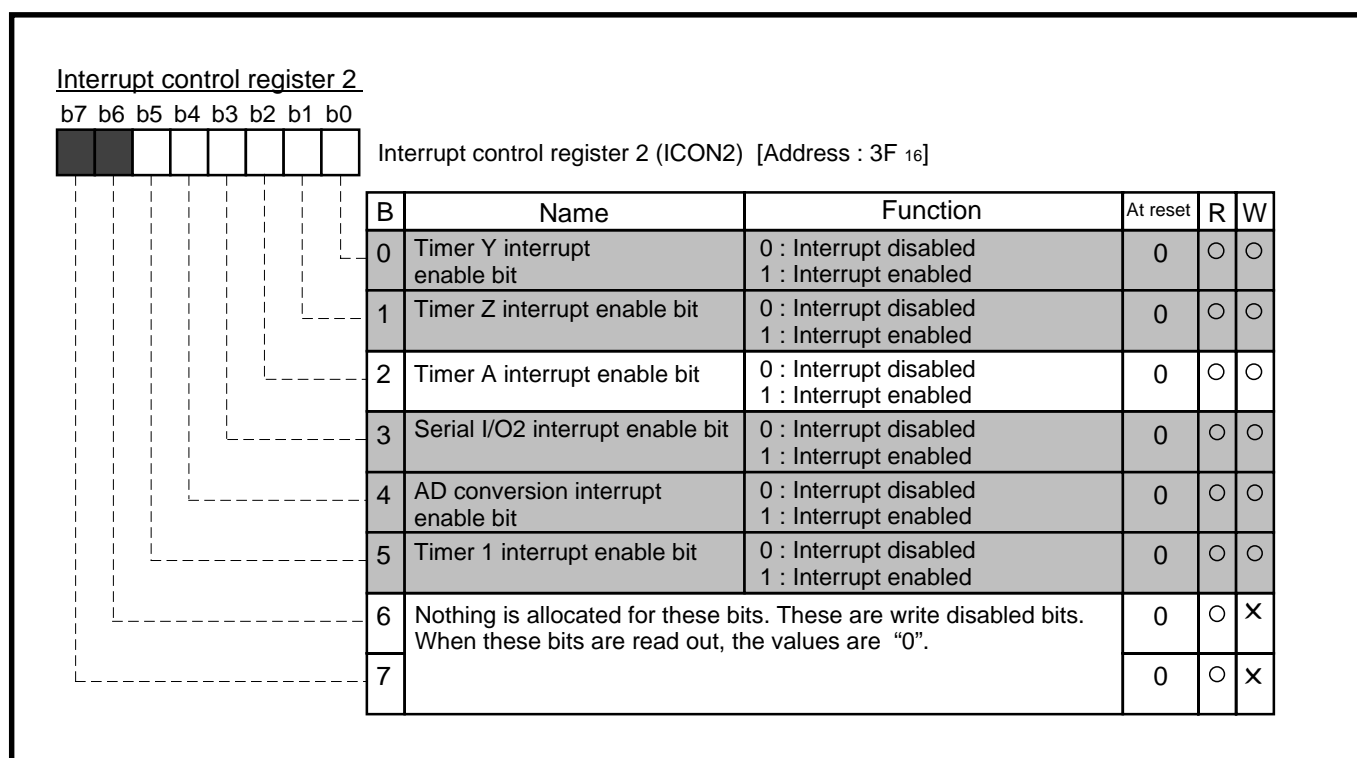


Fig. 2.2.10 Structure of Interrupt control register 2

2.2.3 Timer mode

(1) Operation description

Timer A counts the oscillation frequency divided by 16. Each time the count clock is input, the contents of Timer A is decremented by 1. When the contents of Timer A reach "0000₁₆", an underflow occurs at the next count clock, and the timer A latch is reloaded into Timer A. The division ratio of Timer A is $1/(n+1)$ provided that the value of Timer A is n .

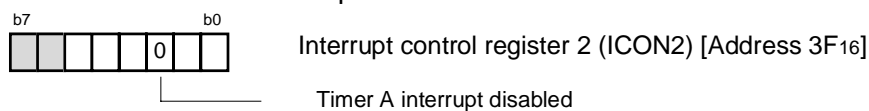
Timer A can stop counting by setting "1" to the timer A count stop bit.

Also, when Timer A underflows, the timer A interrupt request bit is set to "1".

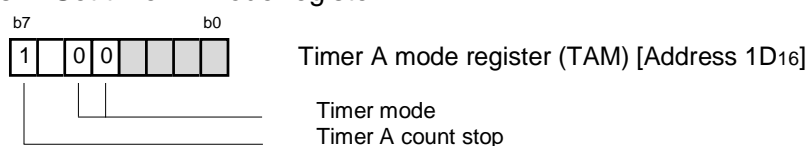
(2) Timer mode setting method

Figure 2.2.11 shows the setting method for timer mode of timer A.

Process 1: Disable timer A interrupt.

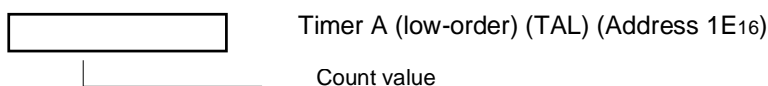


Process 2: Set timer A mode register.

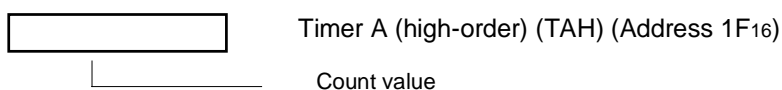


Process 3: Set the count value to Timer A (**Note**).

- Set the count value to timer A (low-order)

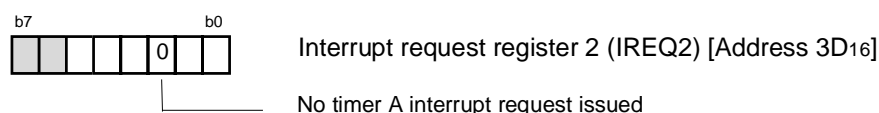


- Set the count value to timer A (high-order)

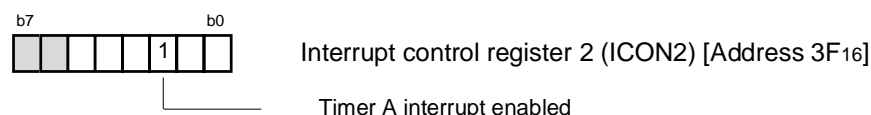


Note: Write both registers in order of timer X (low-order) and timer X (high-order) following, certainly.

Process 4: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer A interrupt request bit.



Process 5: When Timer A interrupt is used, set "1" (interrupt enabled) to the timer A interrupt enable bit.



Process 6: Start counting of Timer A.

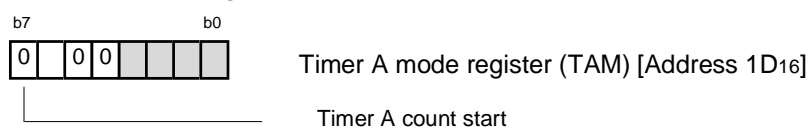


Fig. 2.2.11 Setting method for timer mode

(3) Application example of timer mode

Outline: The input clock is divided by the timer so that the period processing is executed every 25 ms intervals.

- Specifications:**
- The $f(X_{IN}) = 8$ MHz is divided by timer A to detect 25 ms.
 - The timer A interrupt request is confirmed in the main routine. When 25 ms has elapsed, the period processing is executed in the timer A interrupt processing routine.
 - Operation clock: $f(X_{IN}) = 8$ MHz, high-speed mode

Figure 2.2.12 shows an example of control procedure.

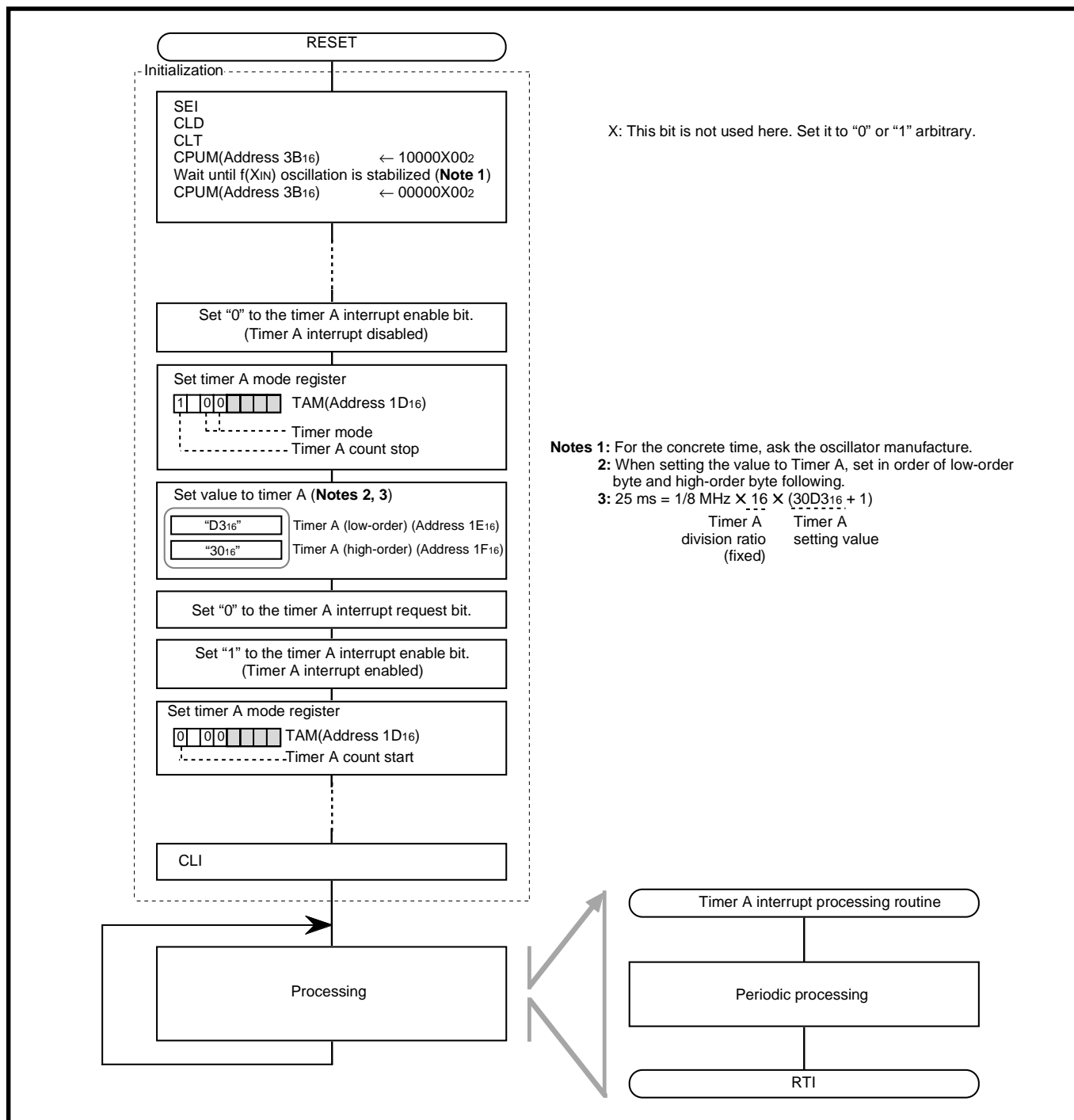


Fig. 2.2.12 Example of control procedure

2.2.4 Period measurement mode

(1) Operation description

In the period measurement mode, the pulse period input from the P0₀/CNTR₁ pin is measured. CNTR₁ interrupt request is generated at rising/falling edge of CNTR₁ pin input signal. Simultaneously, the value in the timer A latch is reloaded in Timer A and count continues. The active edge of CNTR₁ pin input signal can be selected from rising or falling by the CNTR₁ active edge switch bit. The count value when trigger input from CNTR₁ pin is accepted is retained until Timer A is read once. Timer A can stop counting by setting "1" to the timer A count stop bit. Also, when Timer A underflows, the timer A interrupt request bit is set to "1".

(2) Period measurement mode setting method

Figure 2.2.13 and Figure 2.2.14 show the setting method for period measurement mode of timer A.

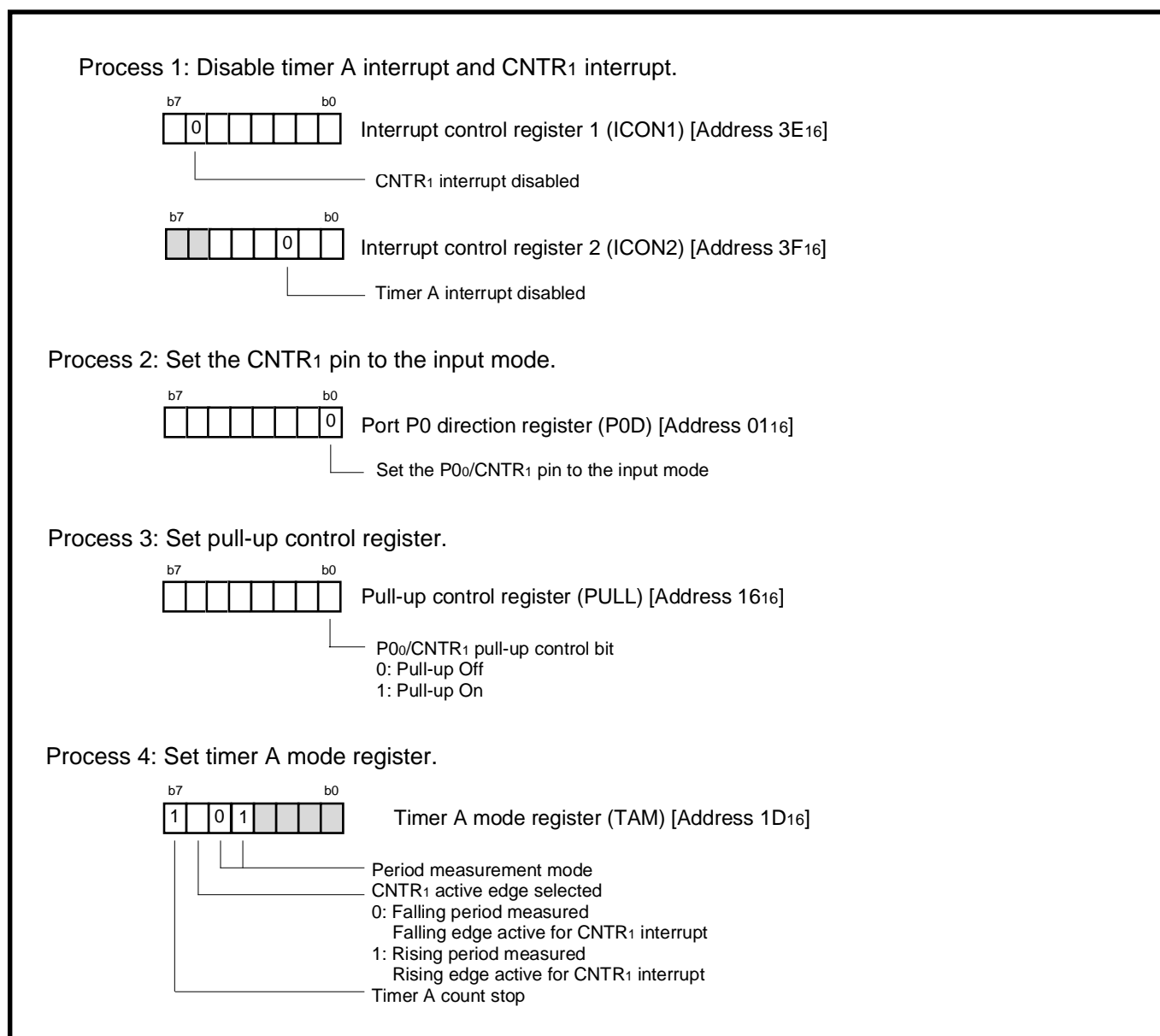
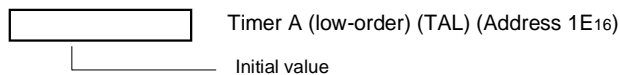


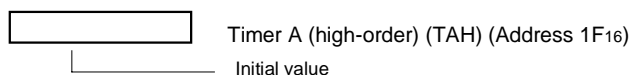
Fig. 2.2.13 Setting method for period measurement mode (1)

Process 5: Set the count value to timer A (**Note**).

- Set the initial value to timer A (low-order)

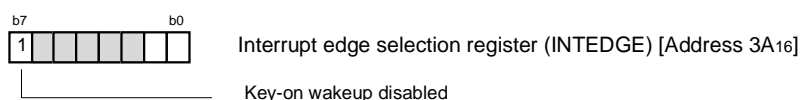


- Set the initial value to timer A (high-order)

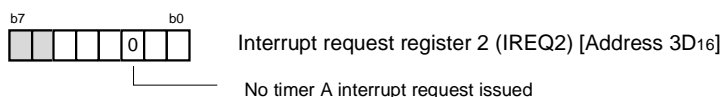
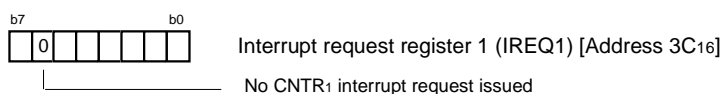


Note: Write both registers in order of timer X (low-order) and timer X (high-order) following, certainly.

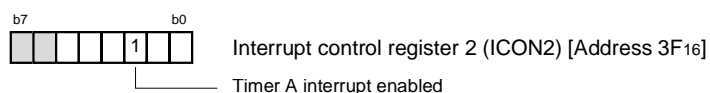
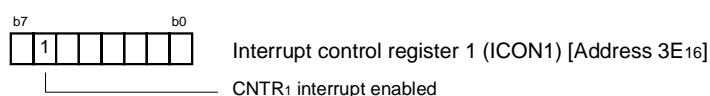
Process 6: In order to use the CNTR₁ pin function of the P0₀/CNTR₁ pin, disable the P0₀ key-on wakeup function.



Process 7: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer A interrupt request bit and CNTR₁ interrupt request bit.



Process 8: When the interrupt is used, set "1" (interrupt enabled) to the timer A interrupt enable bit or CNTR₁ interrupt enable bit.



Process 9: Start counting of timer A.

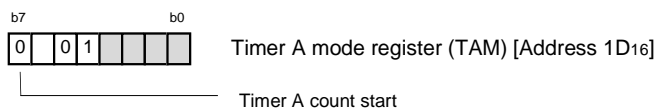


Fig. 2.2.14 Setting method for period measurement mode (2)

(3) Application example of period measurement mode

Outline: The phase control signal is adjusted by using the period measurement mode.

- Specifications:**
- The phase control signal is output to a load, and that controls the phase of a load.
 - The period of the pulse input to the P0₀/CNTR₁ pin from the load as a feedback signal is measured. The correct of the phase control signal to the load is executed using this result. The input pulse period is set to be less than the period of timer A. When timer A underflows, the period is recognized as not corrected, and error processing is executed in the timer A interrupt processing routine.
 - Operation clock: $f(X_{IN}) = 8 \text{ MHz}$, high-speed mode

Figure 2.2.15 shows an example of a peripheral circuit, and Figure 2.2.16 shows an example of control procedure.

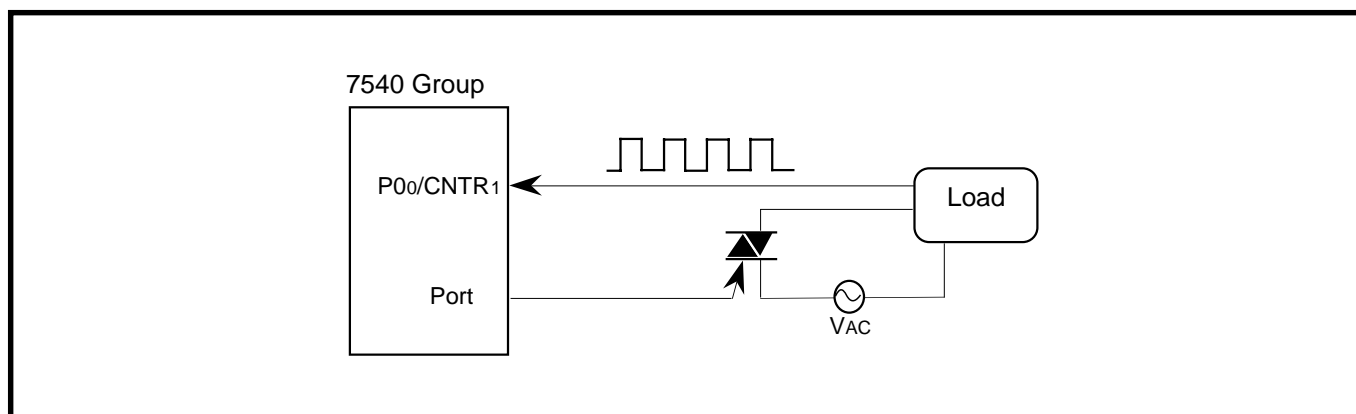


Fig. 2.2.15 Example of peripheral circuit

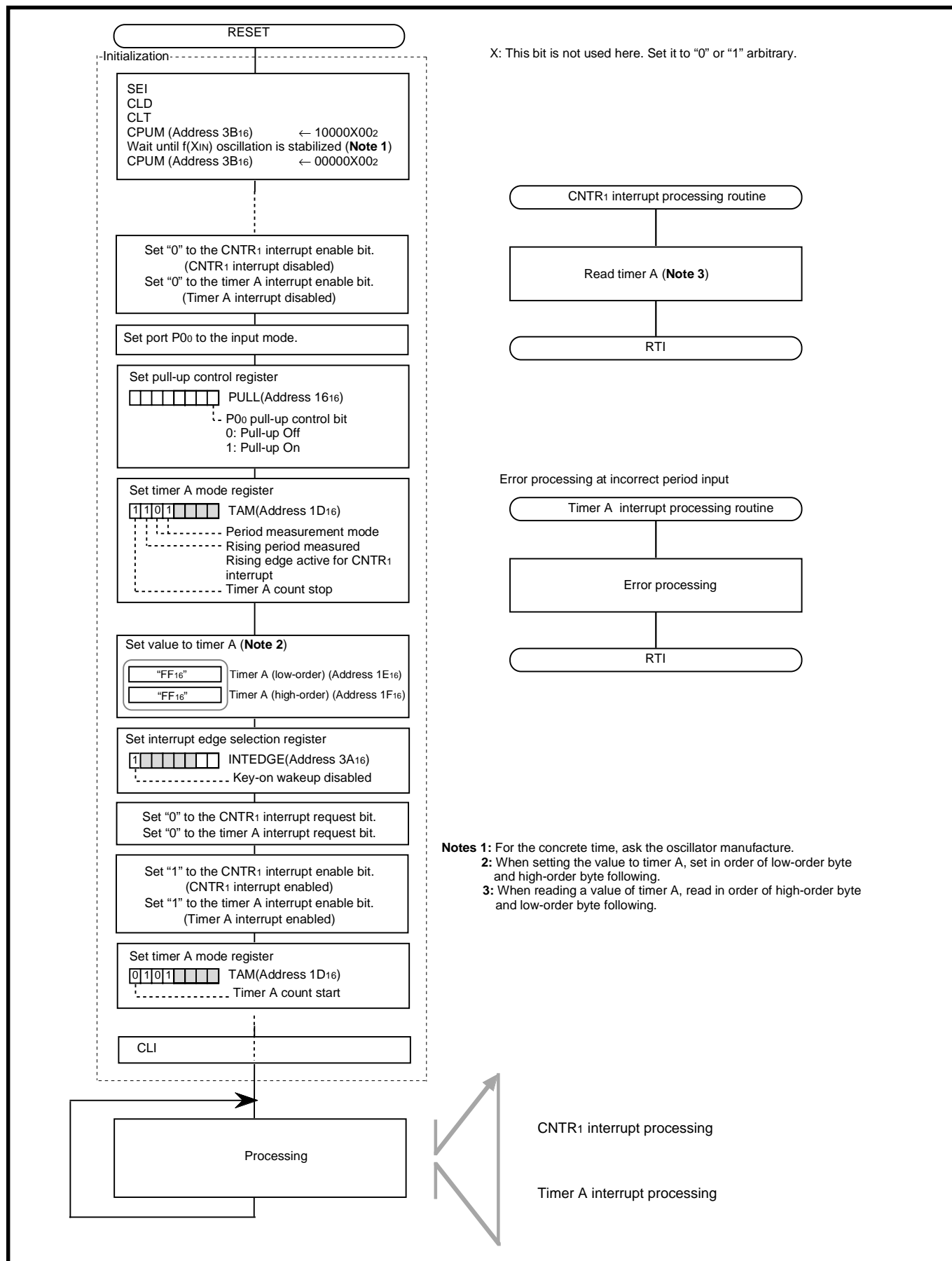


Fig. 2.2.16 Example of control procedure

2.2.5 Event counter mode

(1) Operation description

Timer A counts signals input from the P0₀/CNTR₁ pin.

Except for this, the operation in event counter mode is the same as in timer mode.

The active edge of CNTR₁ pin input signal can be selected from rising or falling by the CNTR₁ active edge switch bit.

Timer A can stop counting by setting "1" to the timer A count stop bit.

Also, when Timer A underflows, the timer A interrupt request bit is set to "1".

(2) Event counter mode setting method

Figure 2.2.17 and Figure 2.2.18 show the setting method for event counter mode of timer A.

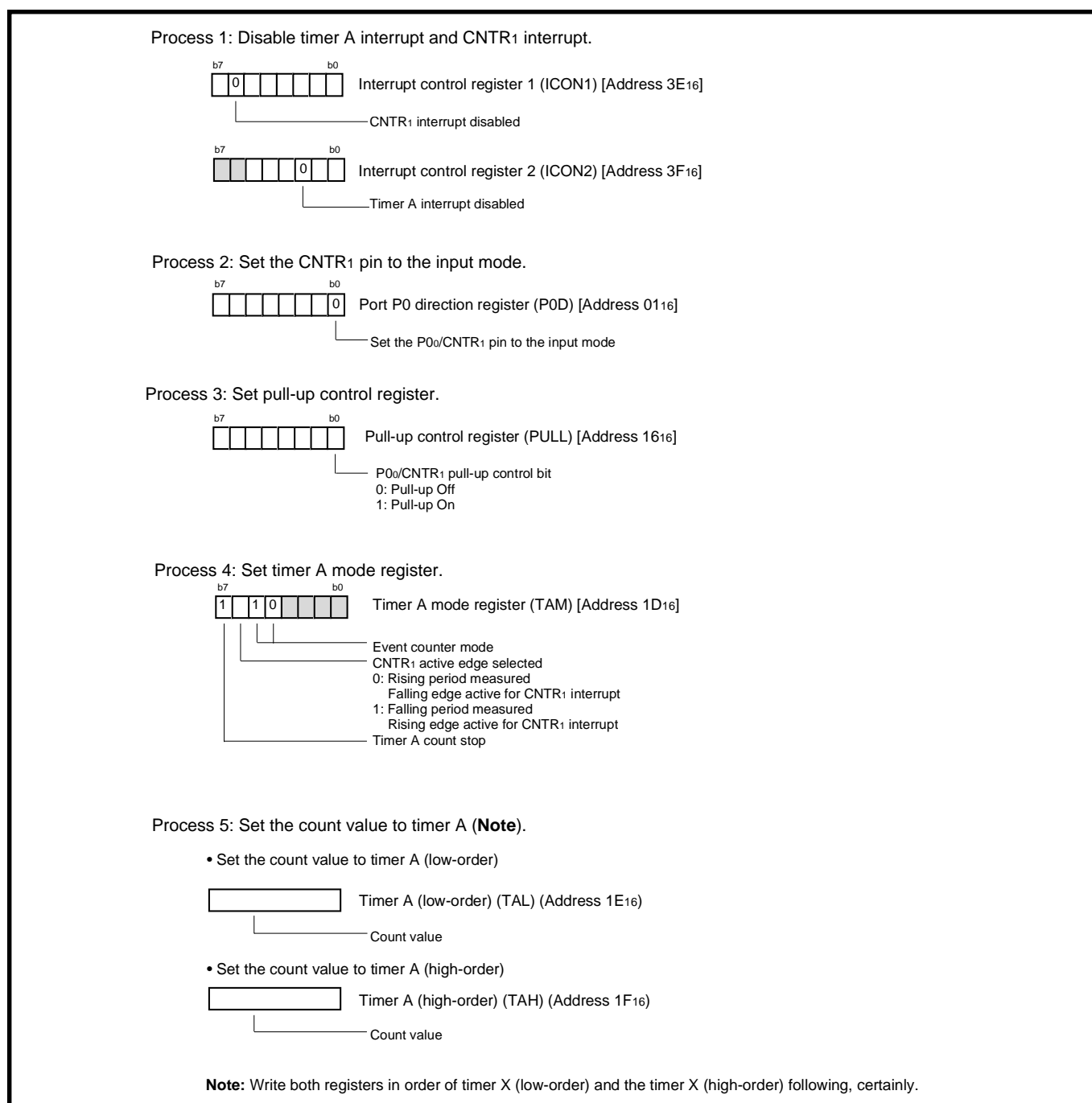
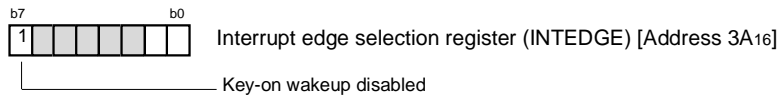
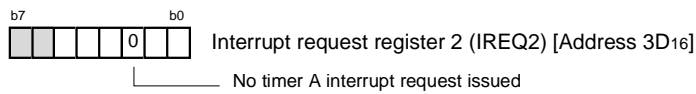
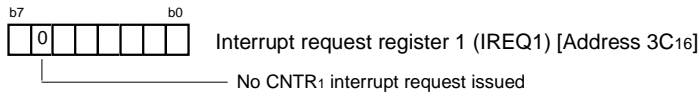


Fig. 2.2.17 Setting method for event counter mode (1)

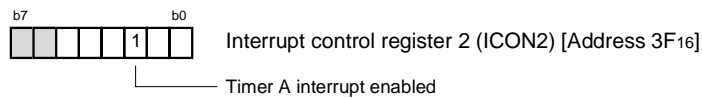
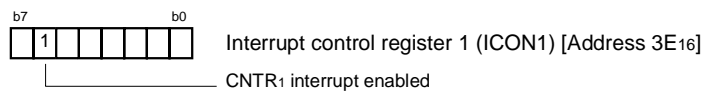
Process 6: In order to use the CNTR1 pin function of the P00/CNTR1 pin, disable the P00 key-on wakeup function.



Process 7: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer A interrupt request bit and CNTR1 interrupt request bit.



Process 8: When the interrupt is used, set "1" (interrupt enabled) to the timer A interrupt enable bit or CNTR1 interrupt enable bit.



Process 9: Start counting of timer A.

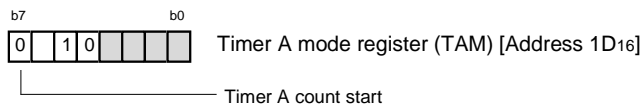


Fig. 2.2.18 Setting method for event counter mode (2)

(3) Application example of event counter mode

Outline: The frequency of the pulse which is input to the P0₀/CNTR₁ pin ("H" active) is measured by the number of events in a certain period.

Specifications: The count source of timer A is input from the P0₀/CNTR₁ pin, and the timer A starts counting the count source. Clock ($f(X_{IN}) = 8 \text{ MHz}$) is divided by timer X to detect 1 ms. The frequency of the pulse input to the P0₀/CNTR₁ pin is calculated by the number of events counted within 1 ms.

Operation clock: $f(X_{IN}) = 8 \text{ MHz}$, high-speed mode

Figure 2.2.19 shows an example of measurement method of frequency, and Figure 2.2.20 shows an example of control procedure.

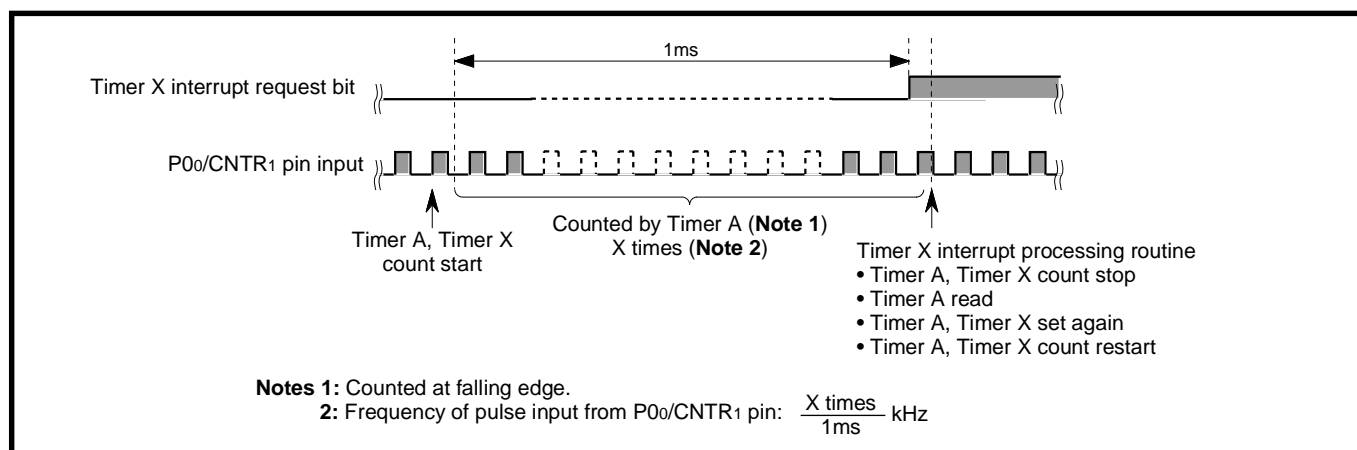


Fig. 2.2.19 Example of measurement method of frequency

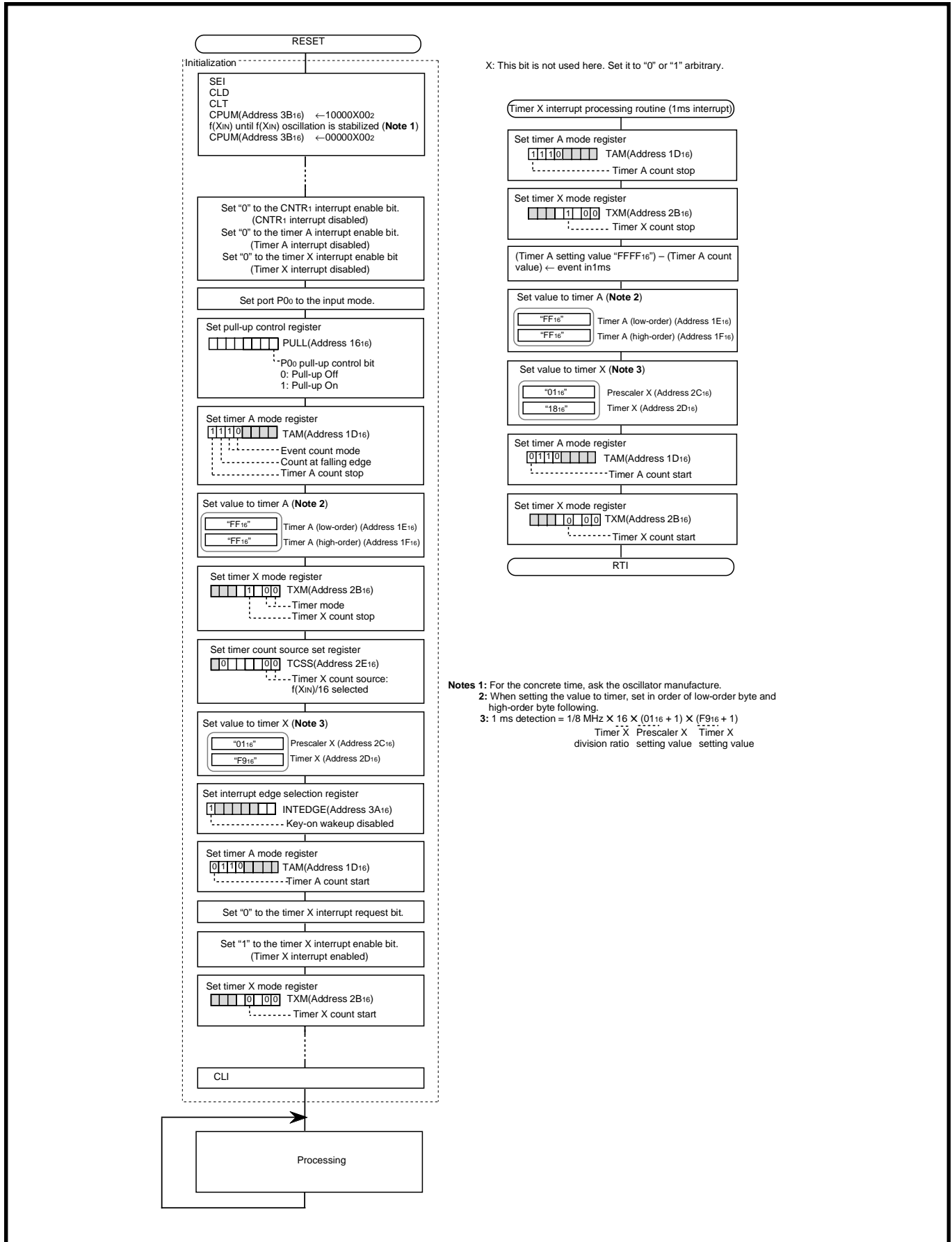


Fig. 2.2.20 Example of control procedure

2.2.6 Pulse width HL continuously measurement mode

(1) Operation description

In the pulse width HL continuously measurement mode, the pulse width (“H” and “L” levels) input to the P0₀/CNTR₁ pin is measured.

CNTR₁ interrupt request is generated at both rising and falling edges of CNTR₁ pin input signal. Except for this, the operation in pulse width HL continuously measurement mode is the same as in period measurement mode.

The count value when trigger input from the CNTR₁ pin is accepted is retained until Timer A is read once. Timer A can stop counting by setting “1” to the timer A count stop bit.

Also, when Timer A underflows, the timer A interrupt request bit is set to “1”.

(2) Pulse width HL continuously measurement mode setting method

Figure 2.2.21 and Figure 2.2.22 show the setting method for pulse width HL continuously measurement mode of timer A.

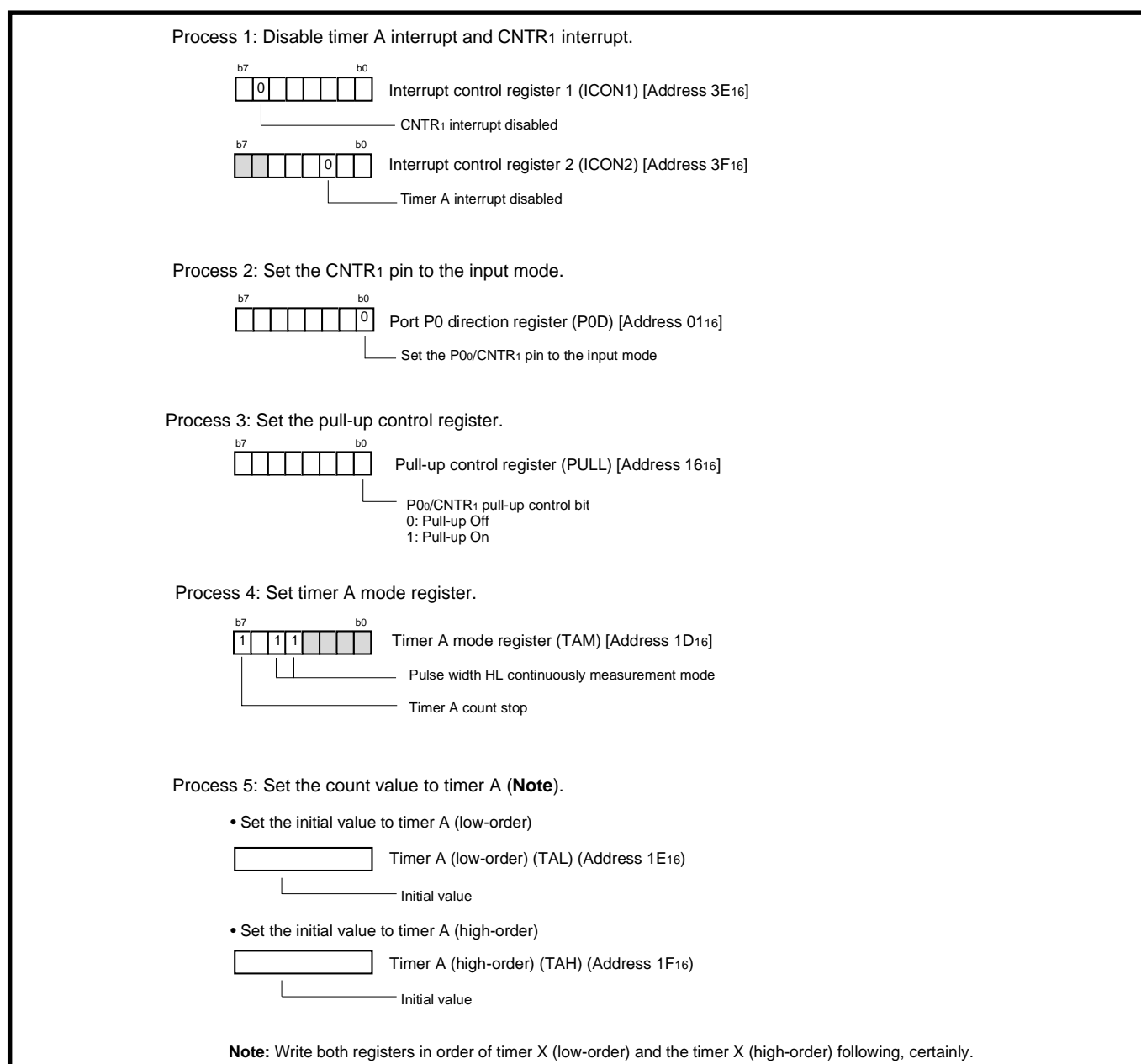
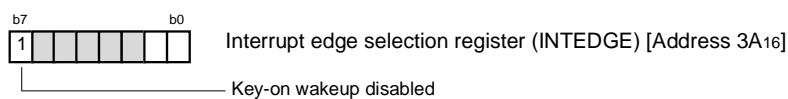
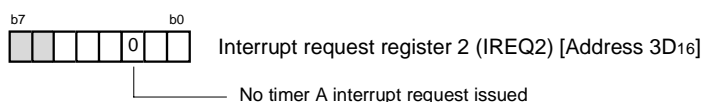
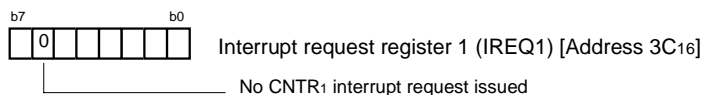


Fig. 2.2.21 Setting method for pulse width HL continuously measurement mode (1)

Process 6: In order to use the CNTR1 pin function of the P00/CNTR1 pin, disable the P00 key-on wakeup function.

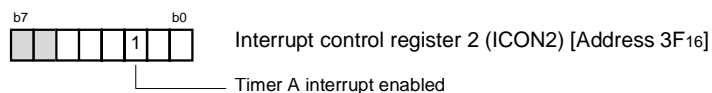
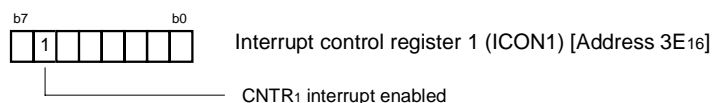


Process 7: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer A interrupt request bit and CNTR1 interrupt request bit (**Note**).



Note: In the pulse width HL continuously measurement mode, the CNTR1 interrupt request occurs at the rising edge and falling edge of the P00/CNTR1 pin regardless of the value of the P00/CNTR1 active edge switch bit of the timer A mode register.

Process 8: When the interrupt is used, set "1" (interrupt enabled) to the timer A interrupt enable bit or CNTR1 interrupt enable bit.



Process 9: Start counting of timer A.

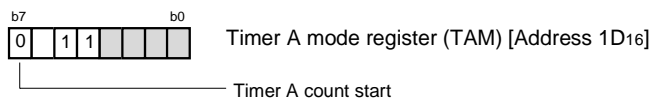


Fig. 2.2.22 Setting method for pulse width HL continuously measurement mode (2)

(3) Application example of pulse width HL continuously measurement mode

Outline: A telephone ringing (calling) pulse* is detected by using the pulse width HL continuously measurement mode.

* Signal which is sent by turning on/off (make/break) the telephone line.

Each country has a different standard. In this case, Japanese domestic standard is adopted as an example.

Specifications: Whether a telephone call exists or not is judged by measuring a pulse width output from the ringing signal detection circuit.

$f(X_{IN})/16$ ($f(X_{IN}) = 6.4 \text{ MHz}$) is used as the count source, and "H" and "L" pulse width of the ringing pulse are measured by using the pulse width HL continuously measurement mode. When the following conditions are satisfied, it is recognized as a normal value. When the following conditions are not satisfied, it is recognized as an unusual value.

$200 \text{ ms} \leq \text{"H" pulse width of ringing pulse} < 1.2 \text{ s}$

$600 \text{ ms} \leq \text{"L" pulse width of ringing pulse} < 2.2 \text{ s}$

$1.0 \text{ s} \leq \text{one period ("H" pulse width + "L" pulse width)} < 3.0 \text{ s}$

Operation clock: $f(X_{IN}) = 6.4 \text{ MHz}$, high-speed mode

Figure 2.2.23 shows an example of a peripheral circuit, and Figure 2.2.24 shows an operation timing when a ringing pulse is input. Figures 2.2.25 and 2.2.26 show an example of control procedure.

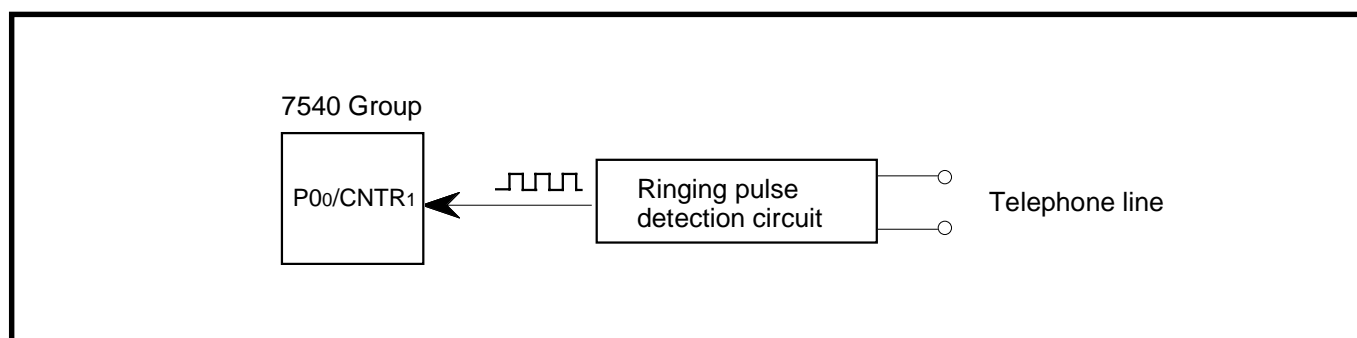


Fig. 2.2.23 Example of peripheral circuit

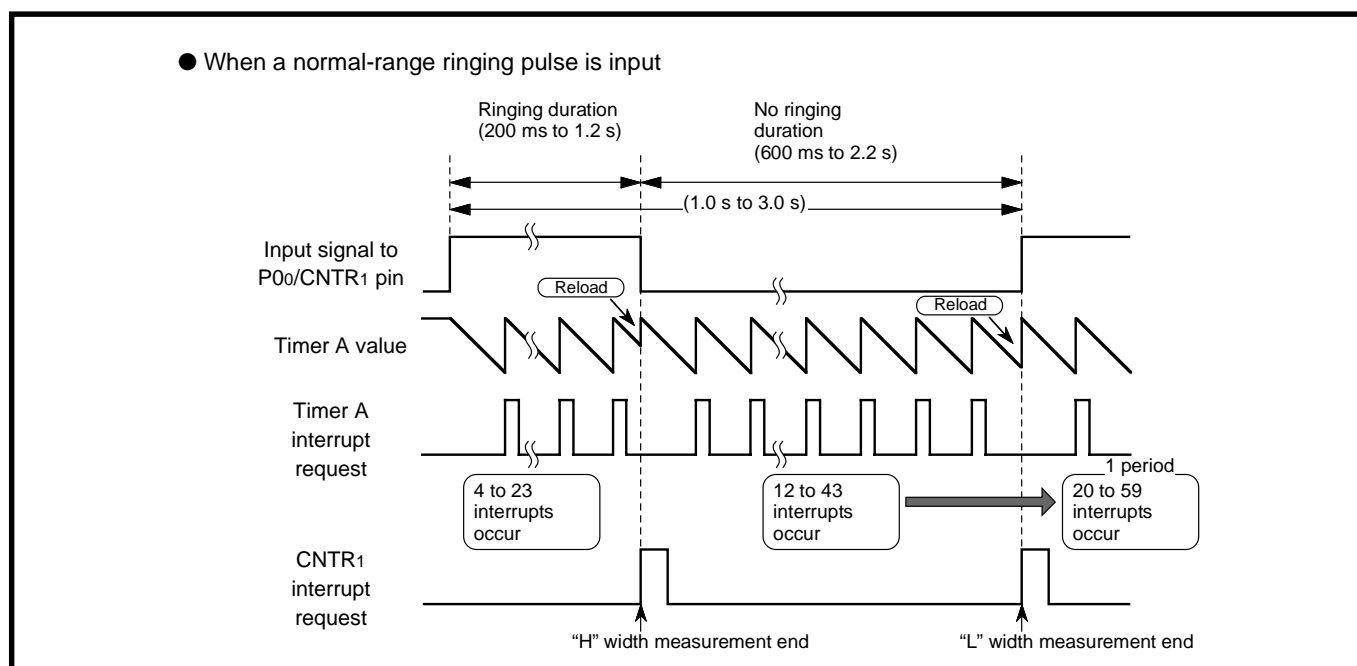


Fig. 2.2.24 Operation timing when ringing pulse is input

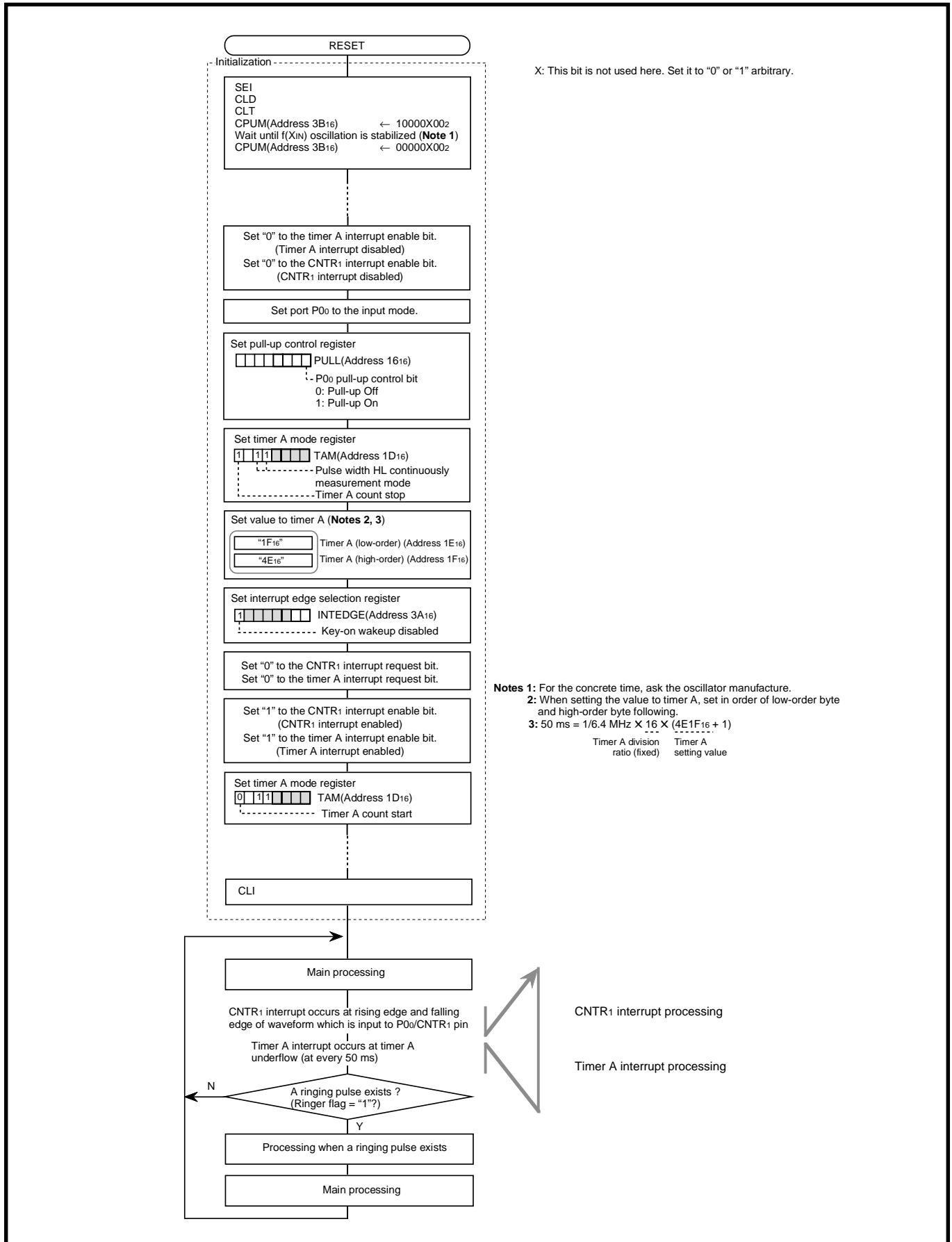


Fig. 2.2.25 Example of control procedure (1)

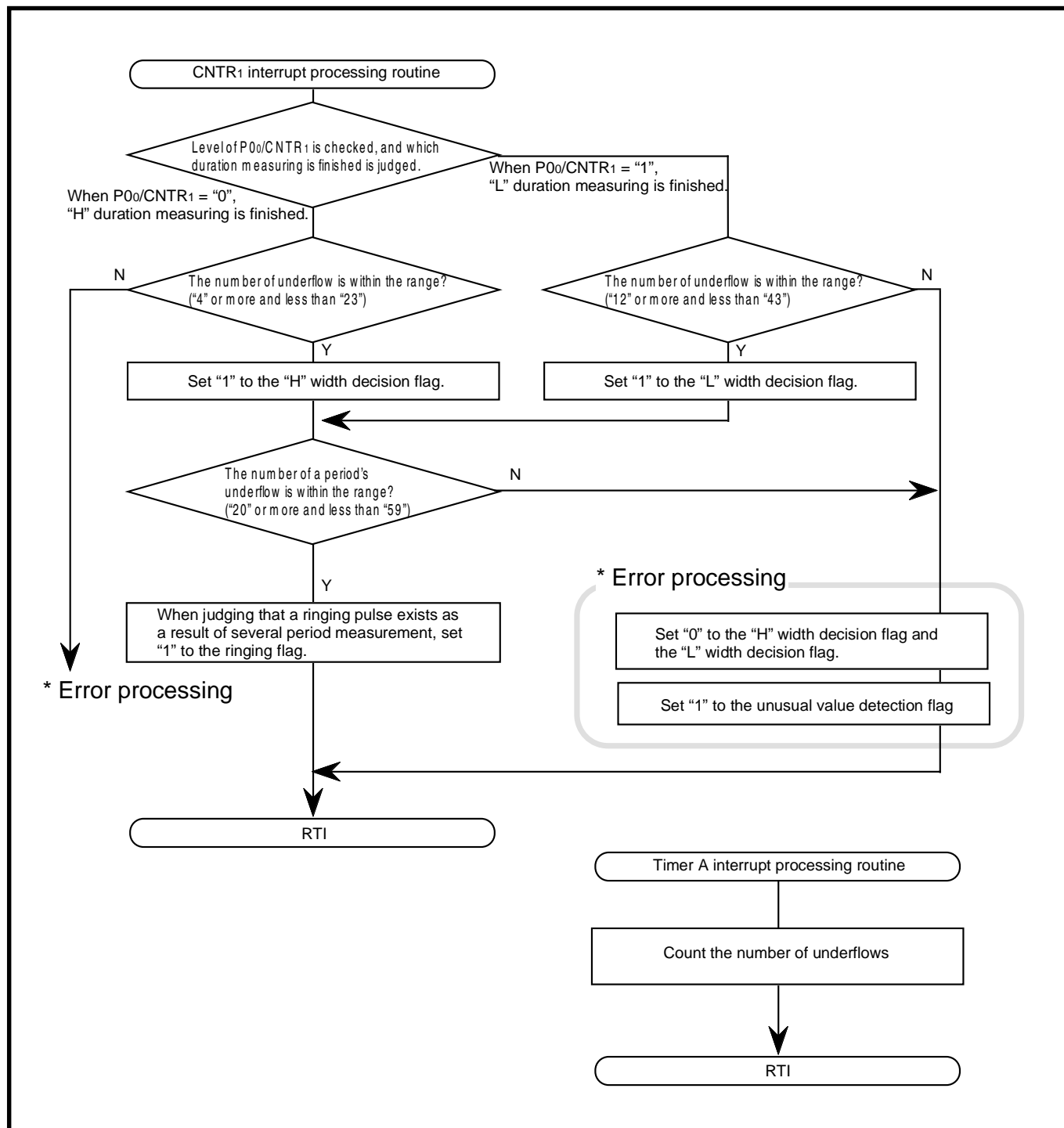


Fig. 2.2.26 Example of control procedure (2)

2.2.7 Notes on timer A

Notes on using timer A are described below.

(1) Common to all modes

- ① When reading timer A (high-order) (TAH) and timer A (low-order) (TAL), the contents of timer A is read out. Read both registers in order of TAH and TAL following, certainly.
TAH and TAL keep the values until they are read out.
Also, do not write to them during read. In this case, unexpected operation may occur.
- ② When writing data to TAL and TAH when timer A is operating or stopped, the data are set to timer A and timer A latch simultaneously. Write both registers in order of TAL and TAH following, certainly.
Also, do not read them during write. In this case, unexpected operation may occur.

(2) Period measurement mode, event counter mode, and pulse width HL continuously measurement mode

- ① In order to use CNTR₁ pin, set "0" to bit 0 of the port P0 direction register (input mode).
- ② In order to use CNTR₁ pin, set "1" to bit 7 of the interrupt edge selection register to disable the P0₀ key-on wakeup function.
- ③ CNTR₁ interrupt active edge depends on the CNTR₁ active edge switch bit. When this bit is "0", the CNTR₁ interrupt request bit is set to "1" at the falling edge of the CNTR₁ pin input signal. When this bit is "1", the CNTR₁ interrupt request bit is set to "1" at the rising edge of the CNTR₁ pin input signal.
However, in the pulse width HL continuously measurement mode, CNTR₁ interrupt request is generated at both rising and falling edges of CNTR₁ pin input signal regardless of the setting of CNTR₁ active edge switch bit.

2.3 Timer 1

This paragraph explains the registers setting method and the notes relevant to the timer 1.

2.3.1 Memory map

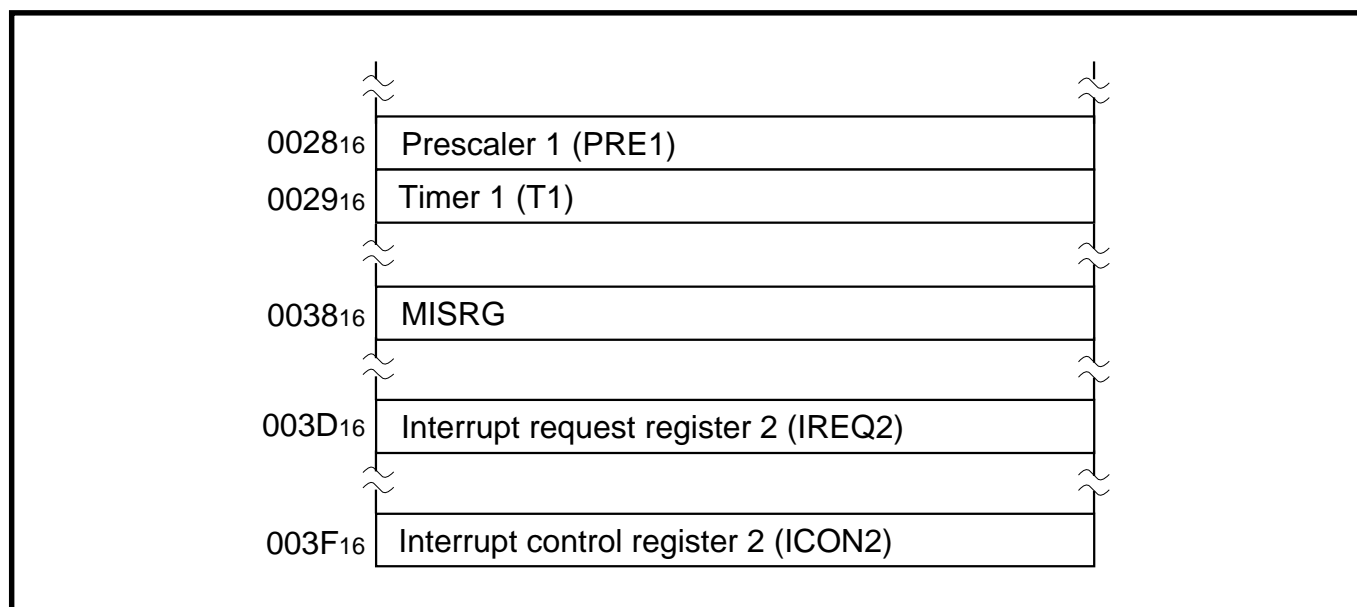


Fig. 2.3.1 Memory map of registers relevant to timer 1

2.3.2 Relevant registers

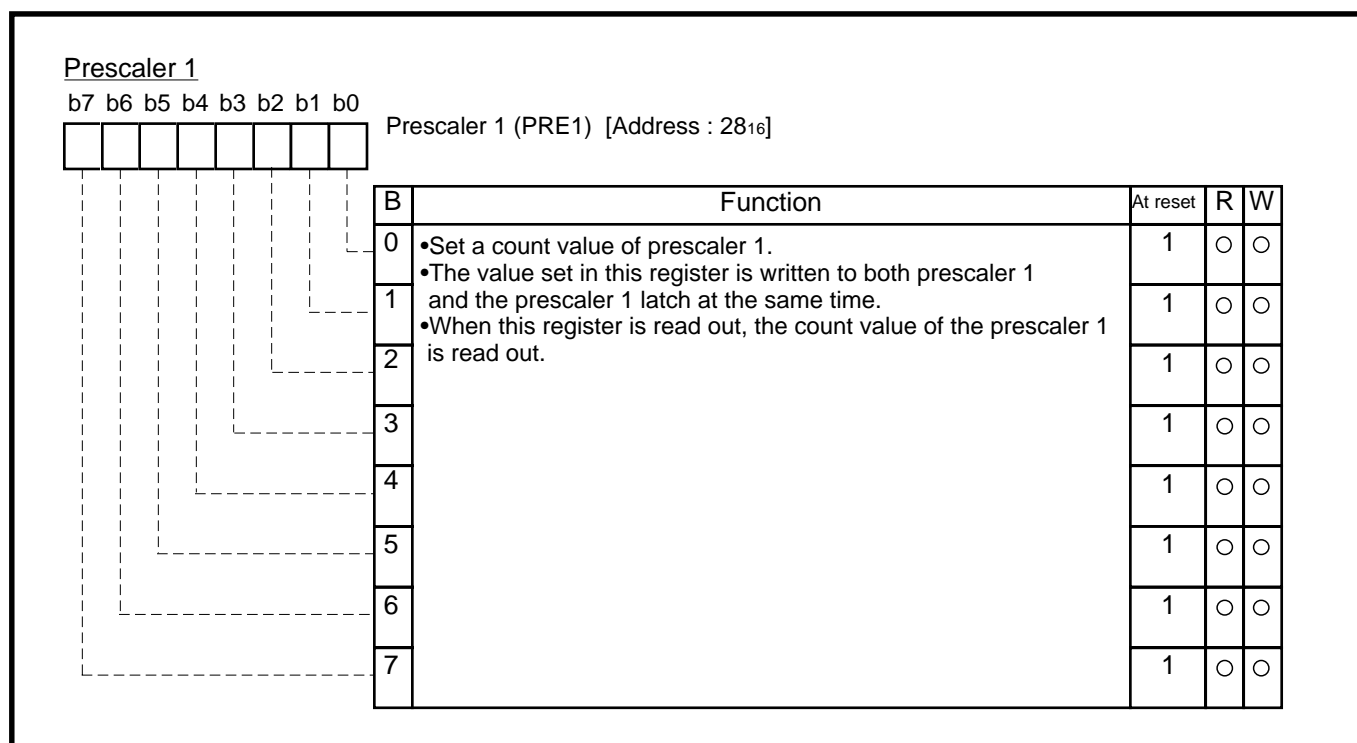


Fig. 2.3.2 Structure of Prescaler 1

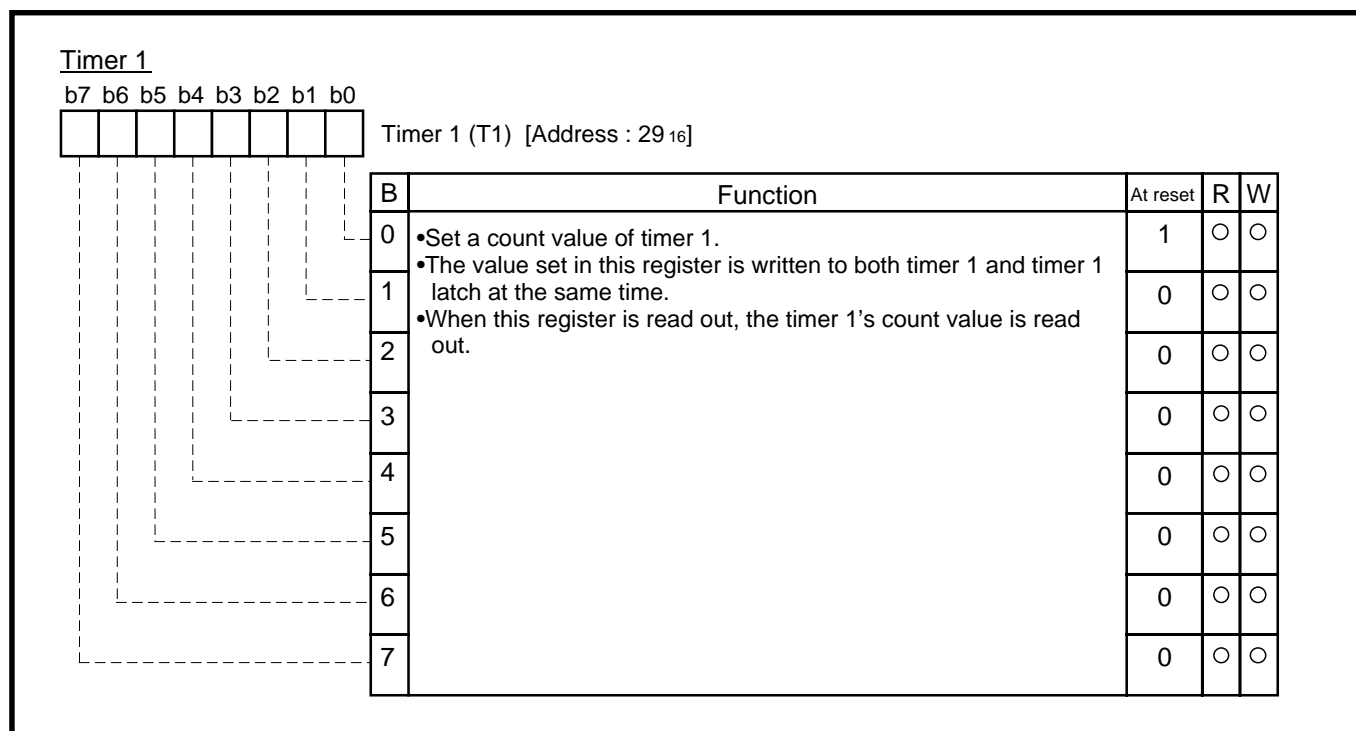


Fig. 2.3.3 Structure of Timer 1

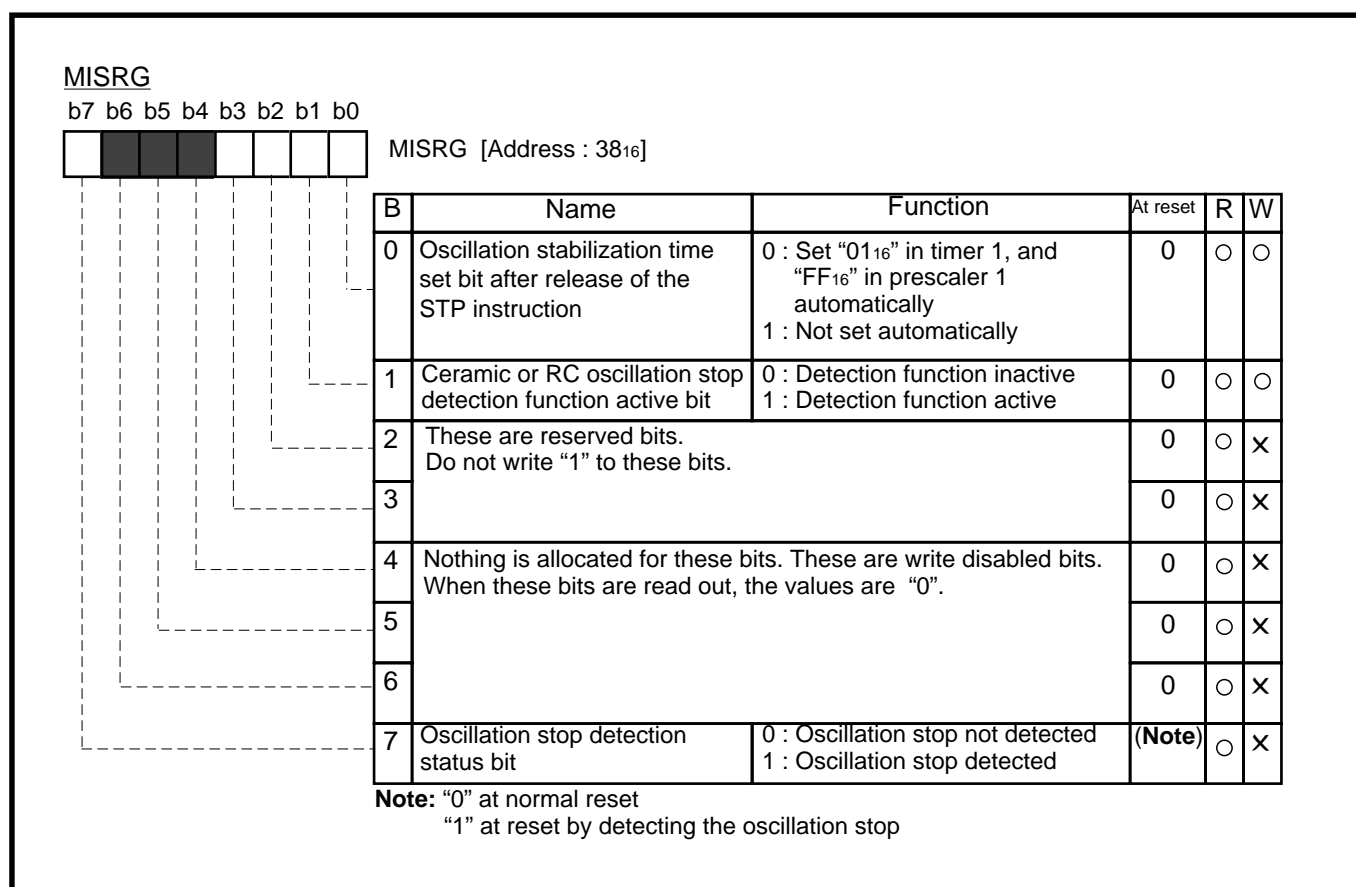


Fig. 2.3.4 Structure of MISRG

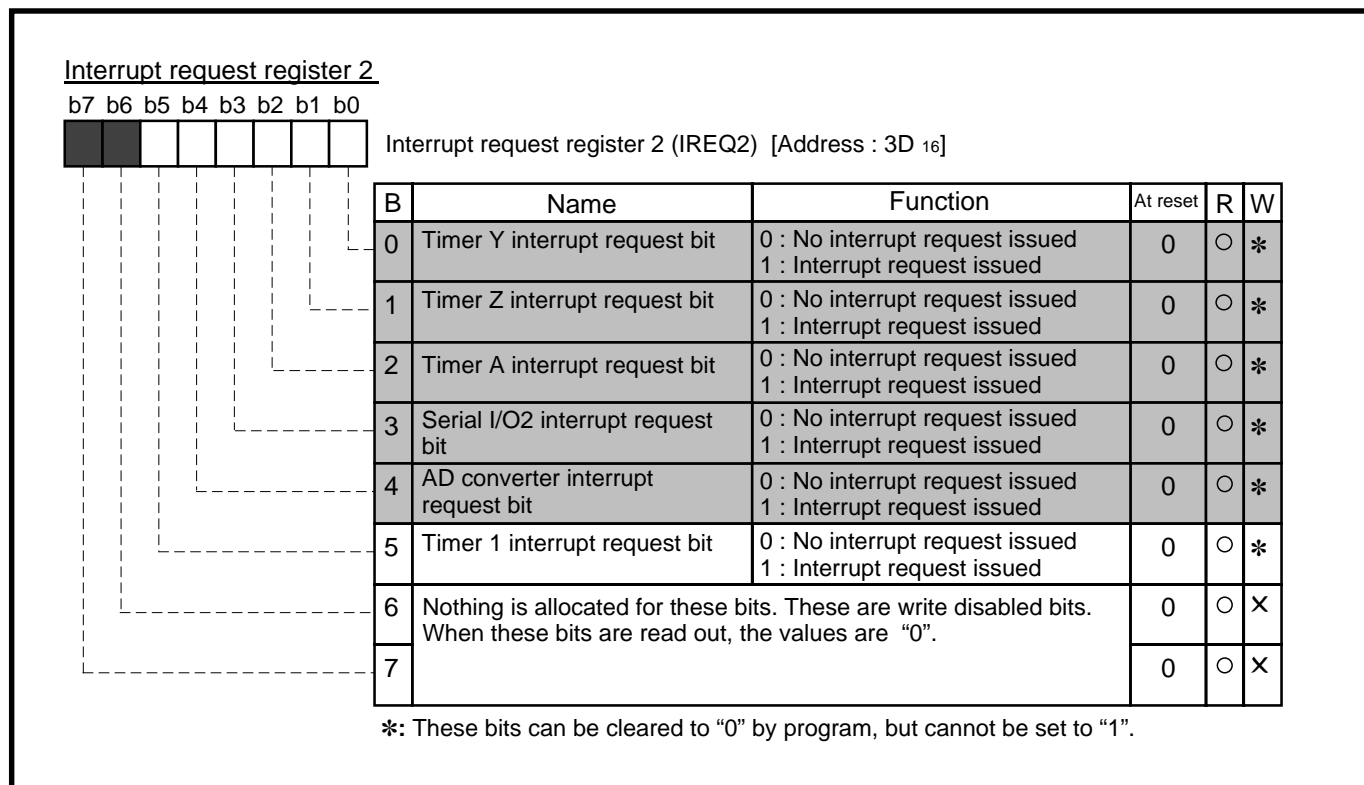


Fig. 2.3.5 Structure of Interrupt request register 2

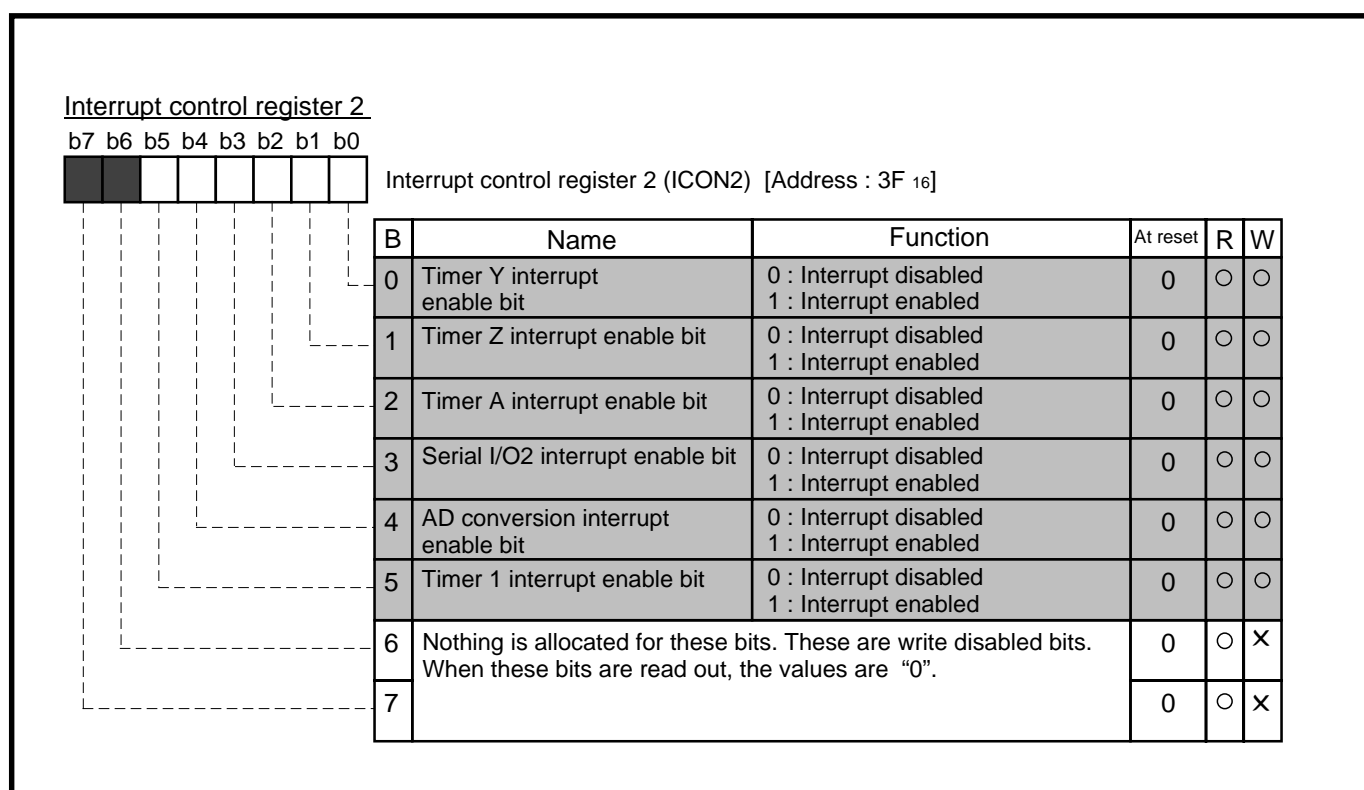


Fig. 2.3.6 Structure of Interrupt control register 2

2.3.3 Timer 1 operation description

Timer 1 always operates in the timer mode.

Prescaler 1 counts the selected count source. Each time the count clock is input, the contents of Prescaler 1 is decremented by 1.

When the contents of Prescaler 1 reach "00₁₆", an underflow occurs at the next count clock, and the prescaler 1 latch is reloaded into Prescaler 1 and count continues. The division ratio of Prescaler 1 is 1/(n+1) provided that the value of Prescaler 1 is n.

The contents of Timer 1 is decremented by 1 each time the underflow signal of Prescaler 1 is input. When the contents of Timer 1 reach "00₁₆", an underflow occurs at the next count clock, and the timer 1 latch is reloaded into Timer 1 and count continues. The division ratio of Timer 1 is 1/(m+1) provided that the value of Timer 1 is m. Accordingly, the division ratio of Prescaler 1 and Timer 1 is provided as follows that the value of Prescaler 1 is n and the value of Timer 1 is m.

$$\text{Division ratio} = \frac{1}{(n+1) \times (m+1)}$$

Timer 1 cannot stop counting by software.

Also, when timer 1 underflows, the timer 1 interrupt request bit is set to "1".

2.3.4 Notes on timer 1

Note on using timer 1 is described below.

(1) Notes on set of the oscillation stabilizing time

Timer 1 can be used to set the oscillation stabilizing time after release of the **STP** instruction. The oscillation stabilizing time after release of **STP** instruction can be selected from "set automatically"/"not set automatically" by the oscillation stabilizing time set bit after release of the **STP** instruction of MISRG. When "0" is set to this bit, "01₁₆" is set to timer 1 and "FF₁₆" is set to prescaler 1 automatically. When "1" is set to this bit, nothing is set to timer 1 and prescaler 1. Therefore, set the wait time according to the oscillation stabilizing time of the oscillation. Also, when timer 1 is used, set values again to timer 1 and prescaler 1 after system is returned from the stop mode.

2.4 Timer X

This paragraph explains the registers setting method and the notes relevant to the timer X.

2.4.1 Memory map

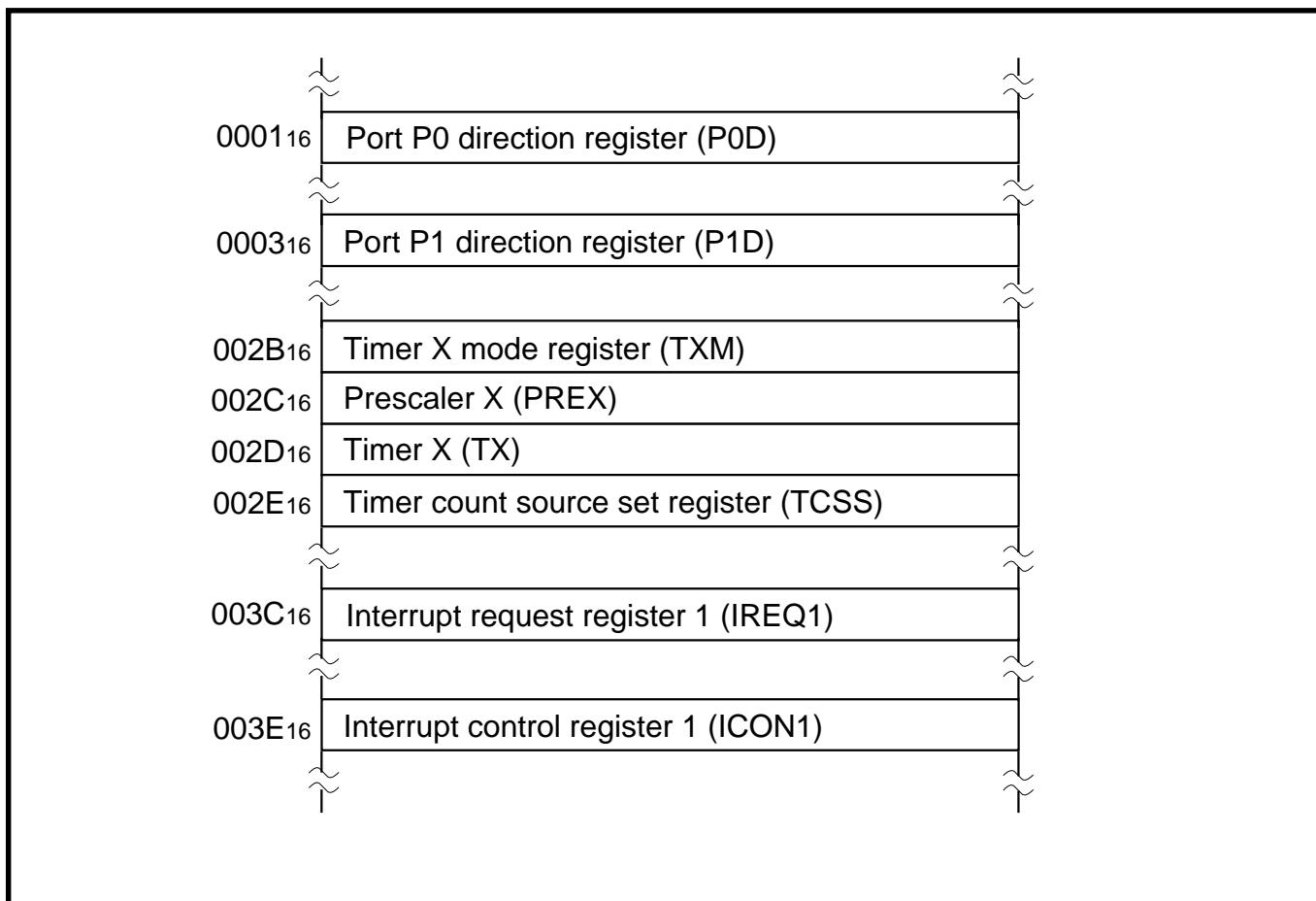


Fig. 2.4.1 Memory map of registers relevant to timer X

2.4.2 Relevant registers

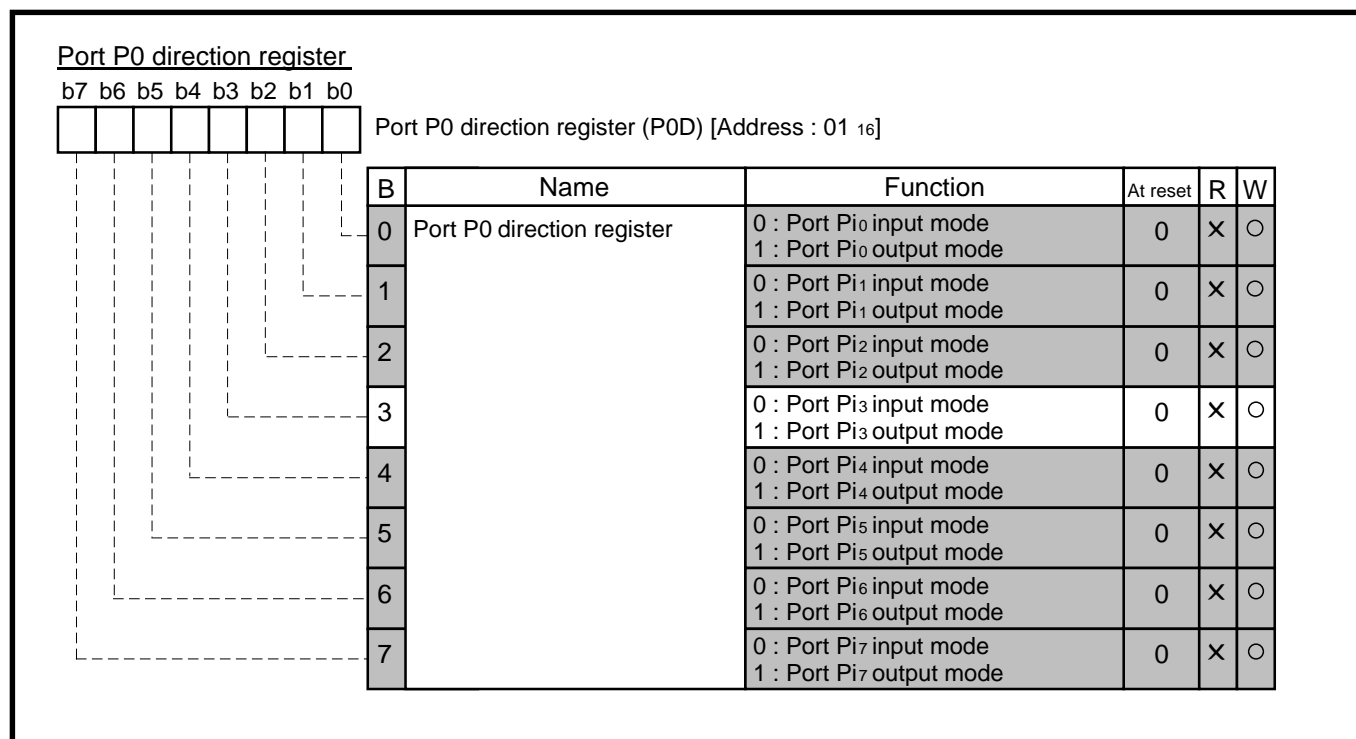


Fig. 2.4.2 Structure of Port P0 direction register

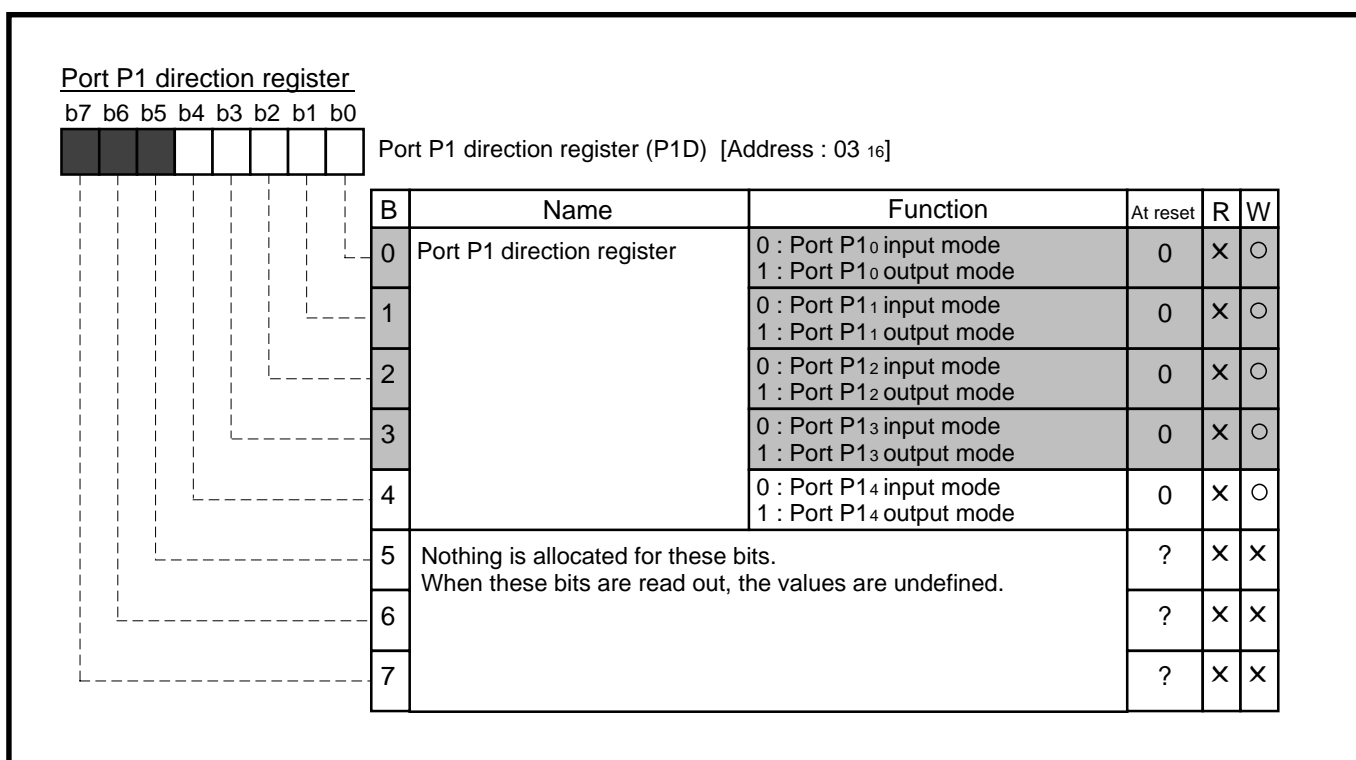


Fig. 2.4.3 Structure of Port P1 direction register

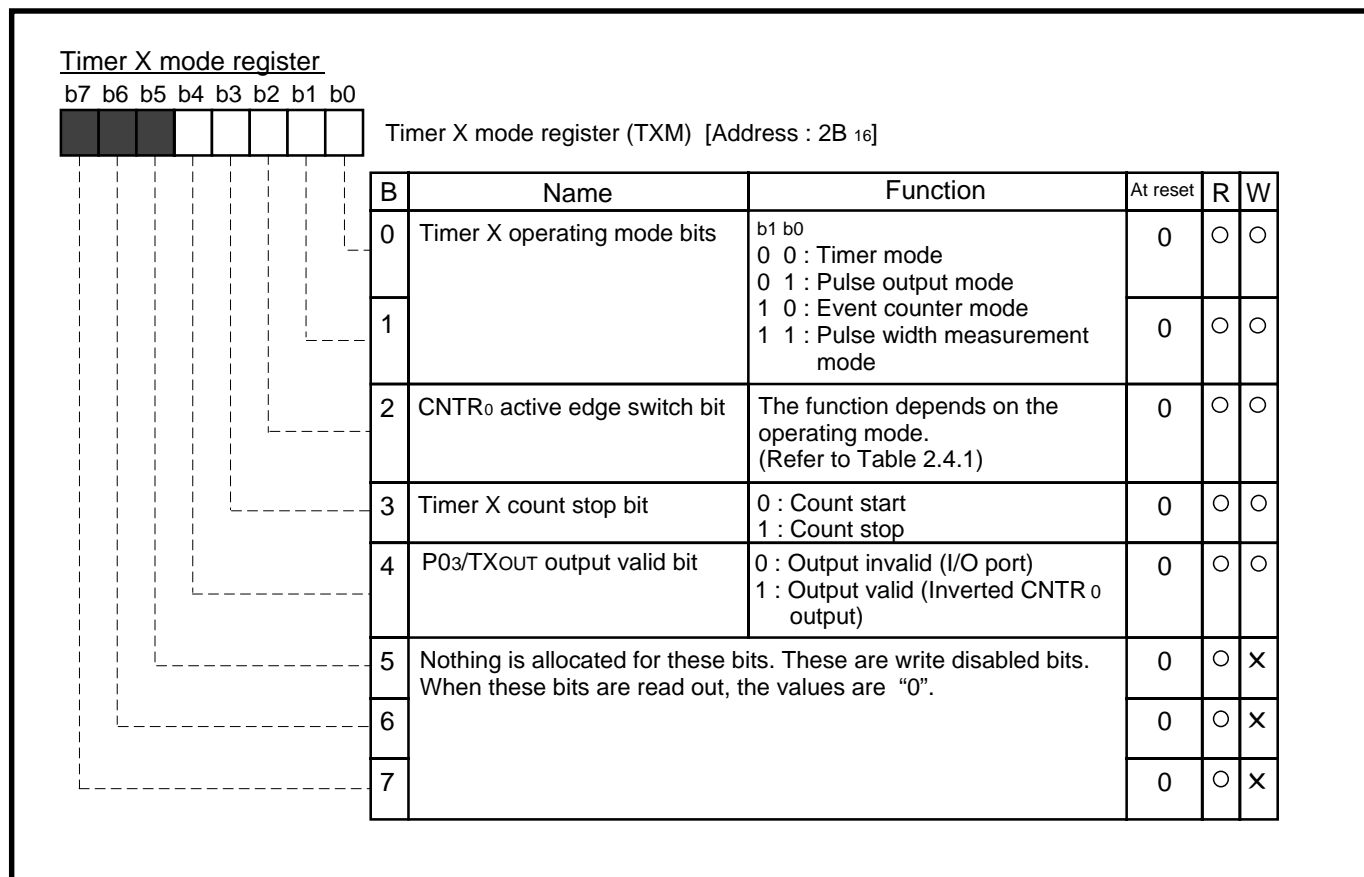


Fig. 2.4.4 Structure of Timer X mode register

Table 2.4.1 CNTR₀ active edge switch bit function

| Timer X operating modes | CNTR ₀ active edge switch bit (bit 2 of address 2B ₁₆) contents |
|------------------------------|--|
| Timer mode | "0" CNTR ₀ interrupt request occurrence: Falling edge ; No influence to timer count |
| | "1" CNTR ₀ interrupt request occurrence: Rising edge ; No influence to timer count |
| Pulse output mode | "0" Pulse output start: Beginning at "H" level CNTR ₀ interrupt request occurrence: Falling edge |
| | "1" Pulse output start: Beginning at "L" level CNTR ₀ interrupt request occurrence: Rising edge |
| Event counter mode | "0" Timer X: Rising edge count CNTR ₀ interrupt request occurrence: Falling edge |
| | "1" Timer X: Falling edge count CNTR ₀ interrupt request occurrence: Rising edge |
| Pulse width measurement mode | "0" Timer X: "H" level width measurement CNTR ₀ interrupt request occurrence: Falling edge |
| | "1" Timer X: "L" level width measurement CNTR ₀ interrupt request occurrence: Rising edge |

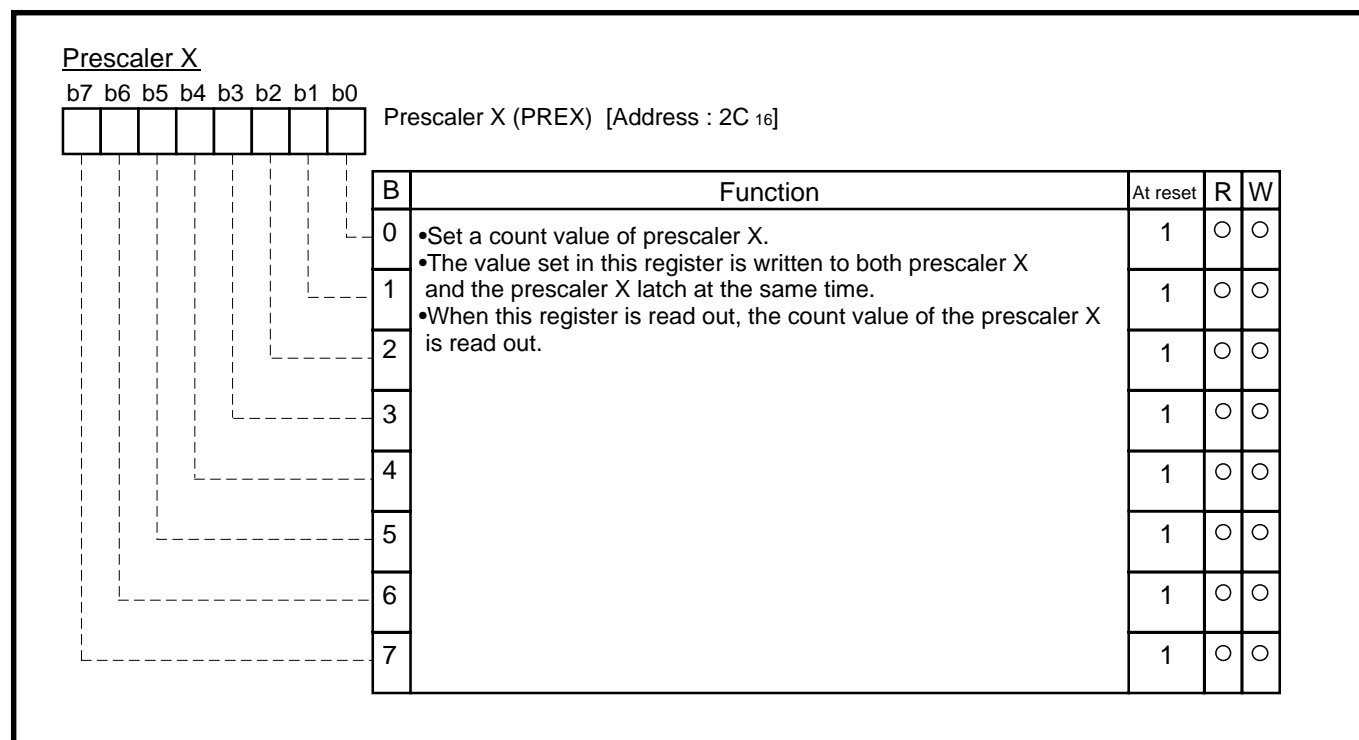


Fig. 2.4.5 Structure of Prescaler X

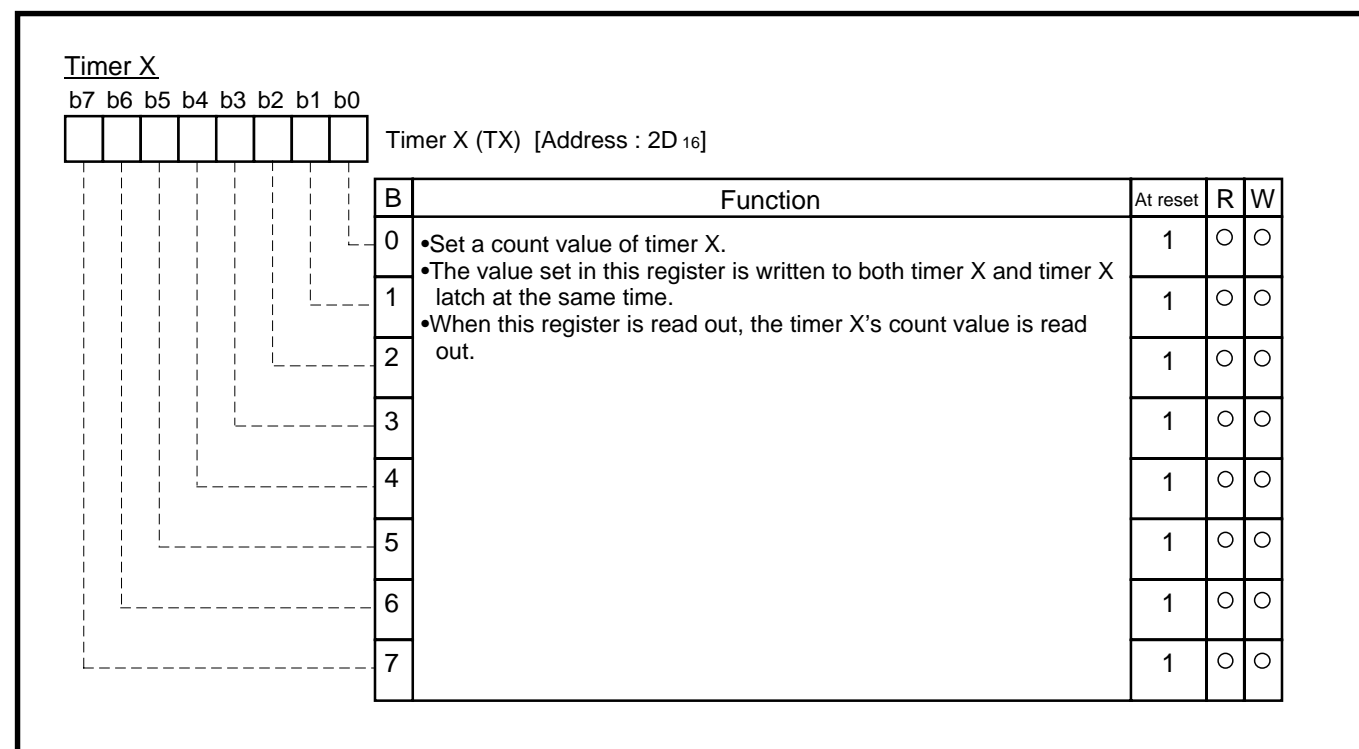


Fig. 2.4.6 Structure of Timer X

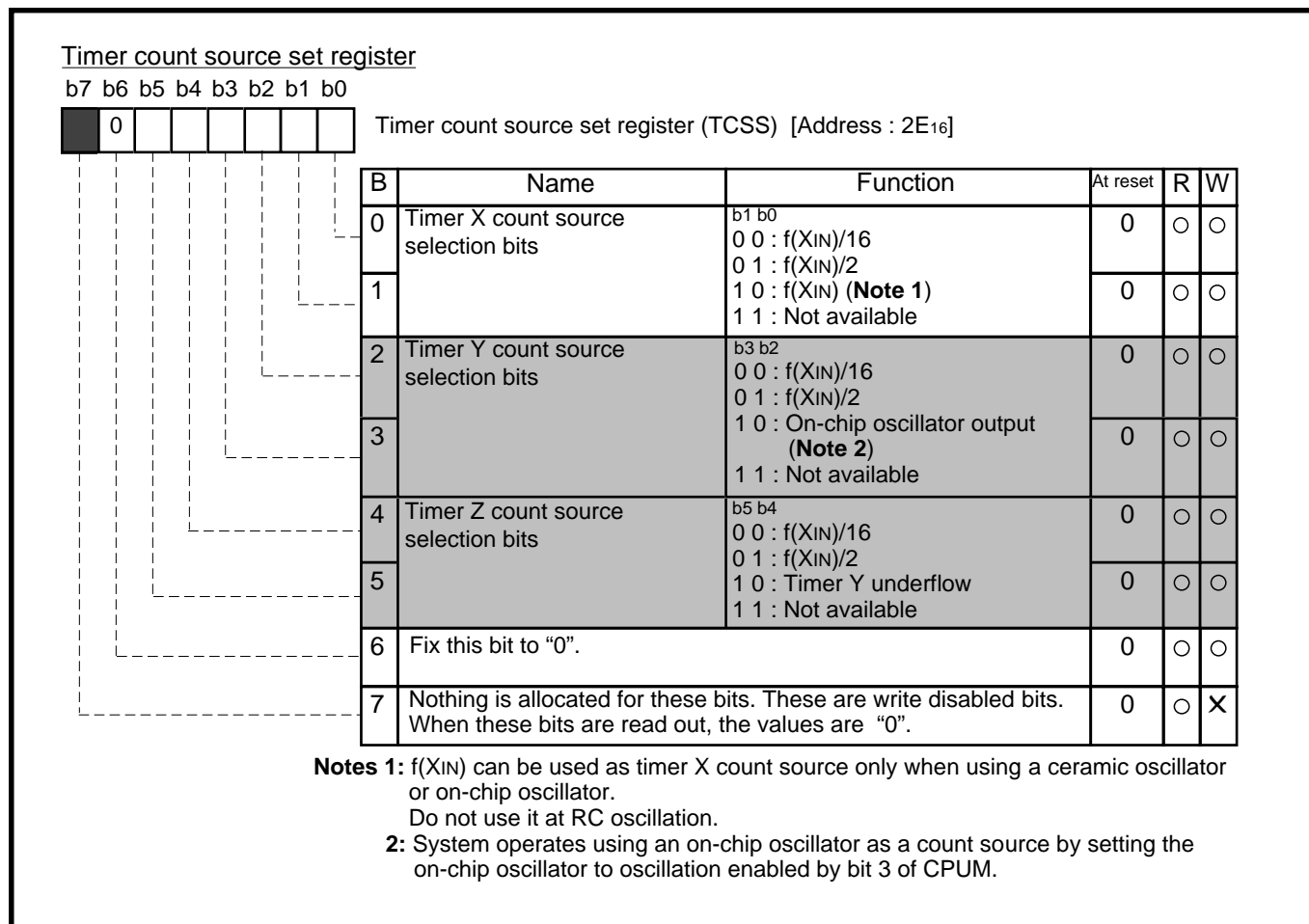


Fig. 2.4.7 Structure of Timer count source set register

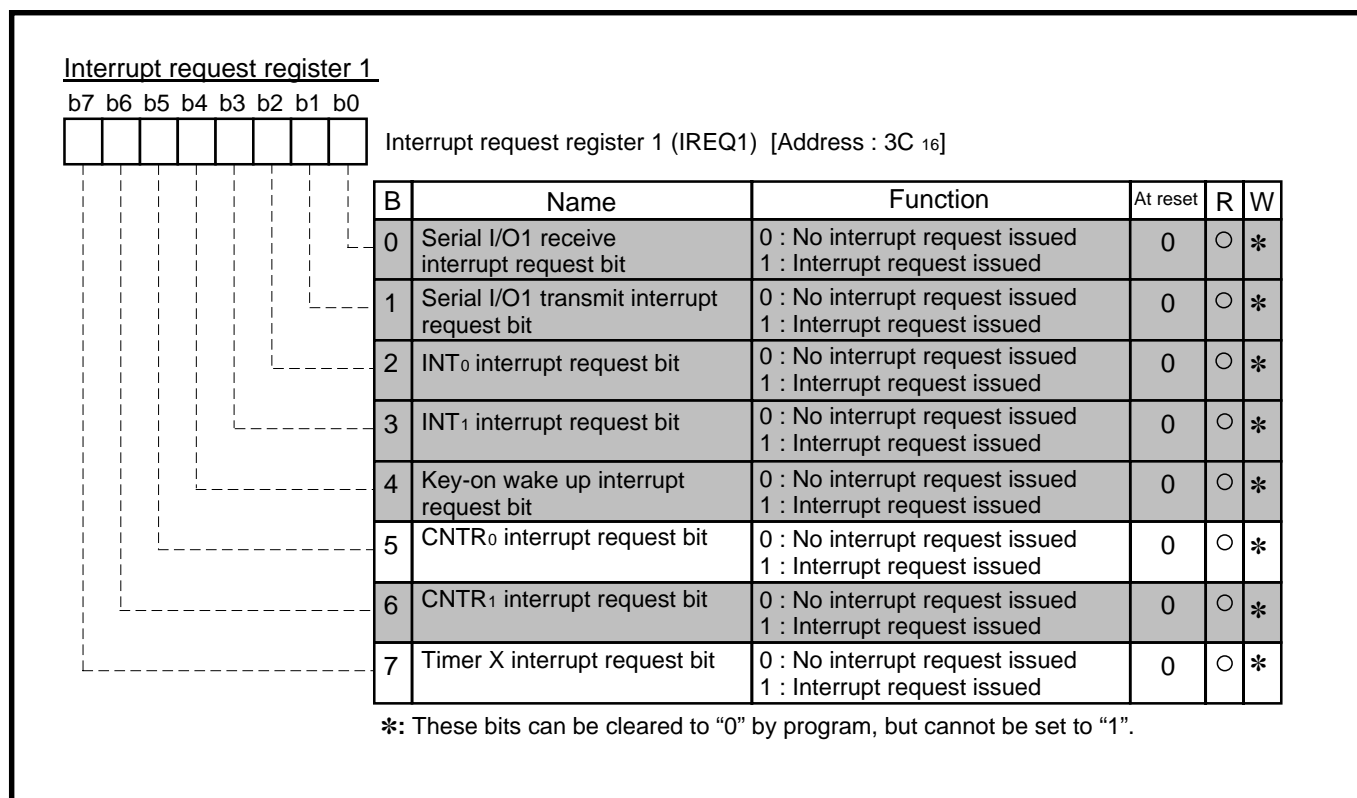


Fig. 2.4.8 Structure of Interrupt request register 1

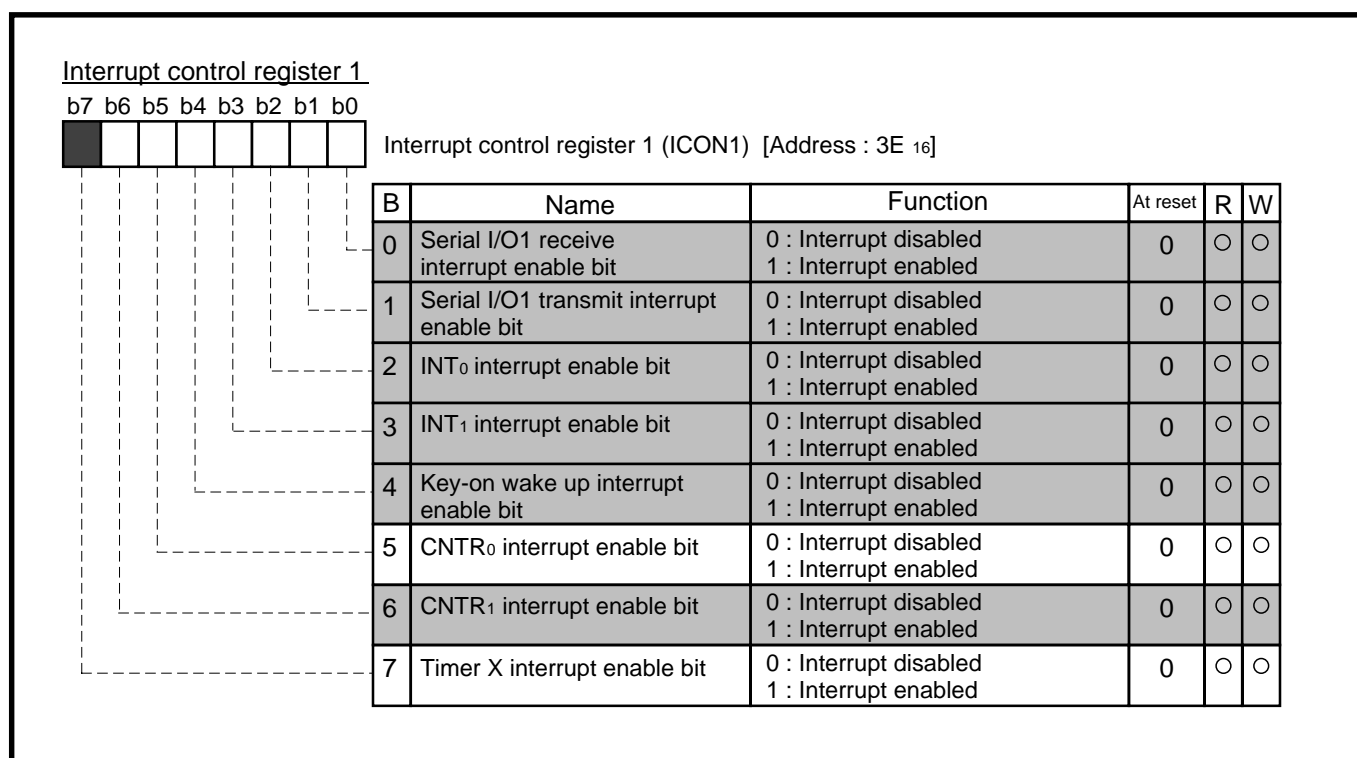


Fig. 2.4.9 Structure of Interrupt control register 1

2.4.3 Timer mode

(1) Operation description

Prescaler X counts the selected count source by the timer X count source selection bits. Each time the count clock is input, the contents of Prescaler X is decremented by 1. When the contents of Prescaler X reach "00₁₆", an underflow occurs at the next count clock, and the prescaler X latch is reloaded into Prescaler X and count continues. The division ratio of Prescaler X is 1/(n+1) provided that the value of Prescaler X is n.

The contents of Timer X is decremented by 1 each time the underflow signal of Prescaler X is input. When the contents of Timer X reach "00₁₆", an underflow occurs at the next count clock, and the timer X latch is reloaded into Timer X and count continues. The division ratio of Timer X is 1/(m+1) provided that the value of Timer X is m. Accordingly, the division ratio of Prescaler X and Timer X is provided as follows that the value of Prescaler X is n and the value of Timer X is m.

$$\text{Division ratio} = \frac{1}{(n+1) \times (m+1)}$$

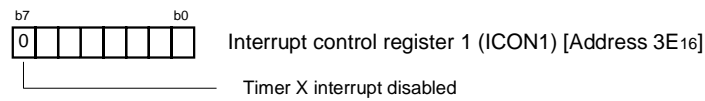
Timer X can stop counting by setting "1" to the timer X count stop bit.

Also, when Timer X underflows, the timer X interrupt request bit is set to "1".

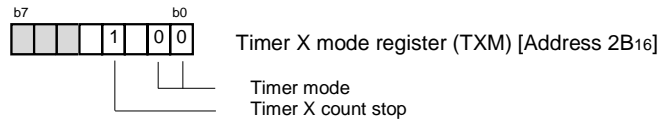
(2) Timer mode setting method

Figure 2.4.10 shows the setting method for timer mode of timer X.

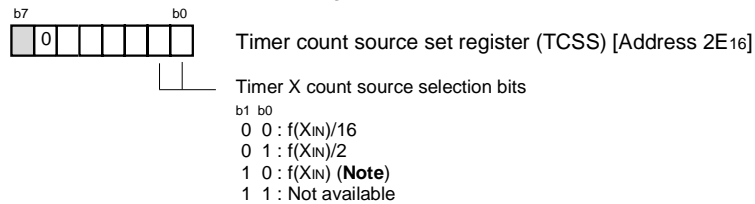
Process 1: Disable timer X interrupt.



Process 2: Set timer X mode register.



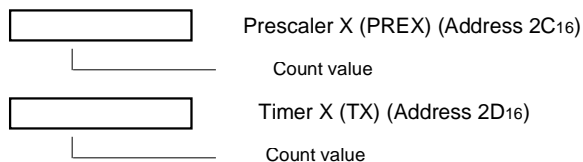
Process 3: Set timer count source set register.



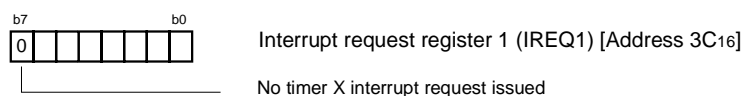
Note: $f(X_{IN})$ can be used only when a ceramic resonator or an on-chip oscillator is used. Do not use $f(X_{IN})$ at RC oscillation.

Process 4: Set the count value to timer X.

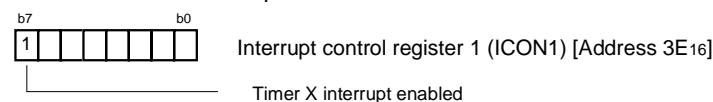
- Set the count value to prescaler X and timer X



Process 5: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer X interrupt request bit.



Process 6: When timer X interrupt is used, set "1" (interrupt enabled) to the timer X interrupt enable bit.



Process 7: Start counting of timer X.

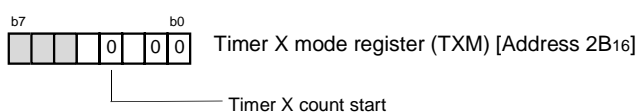


Fig. 2.4.10 Setting method for timer mode

(3) Application example of timer mode

Outline: The input clock is divided by the timer so that the clock is counted up every 250 ms intervals.

Specifications:

- The $f(X_{IN}) = 4.19 \text{ MHz}$ (2^{22} Hz) is divided by timer X.
- The clock is counted up in the timer X interrupt processing routine (timer X interrupt occurs every 250 ms).
- Operation clock: $f(X_{IN}) = 4.19 \text{ MHz}$, high-speed mode

Figure 2.4.11 shows the connection of timer and setting of division ratio and Figure 2.4.12 shows an example of control procedure.

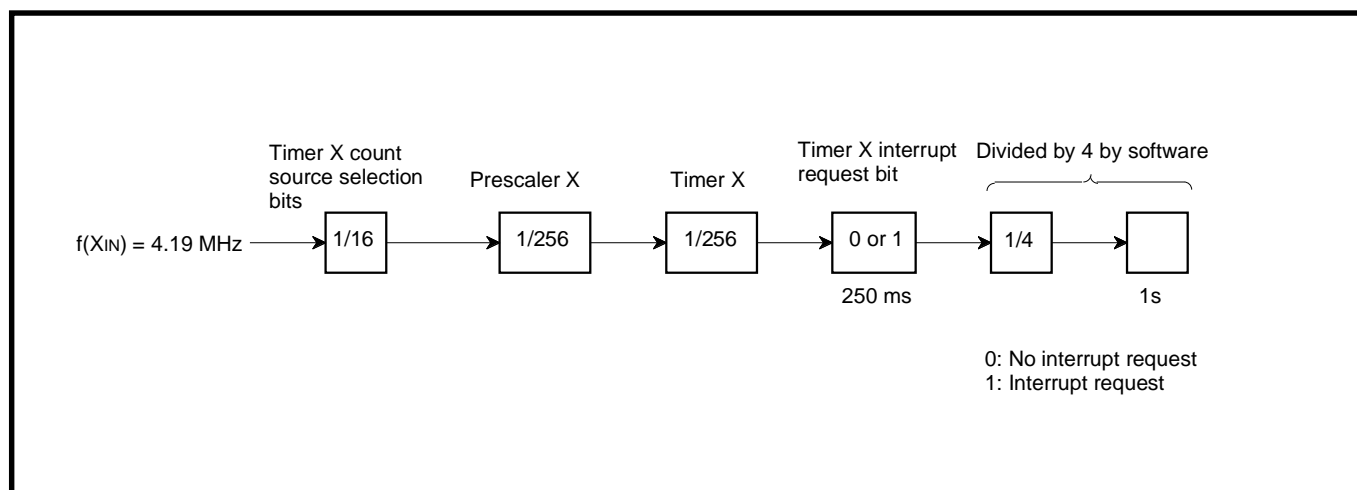


Fig. 2.4.11 Connection of timer and setting of division ratio

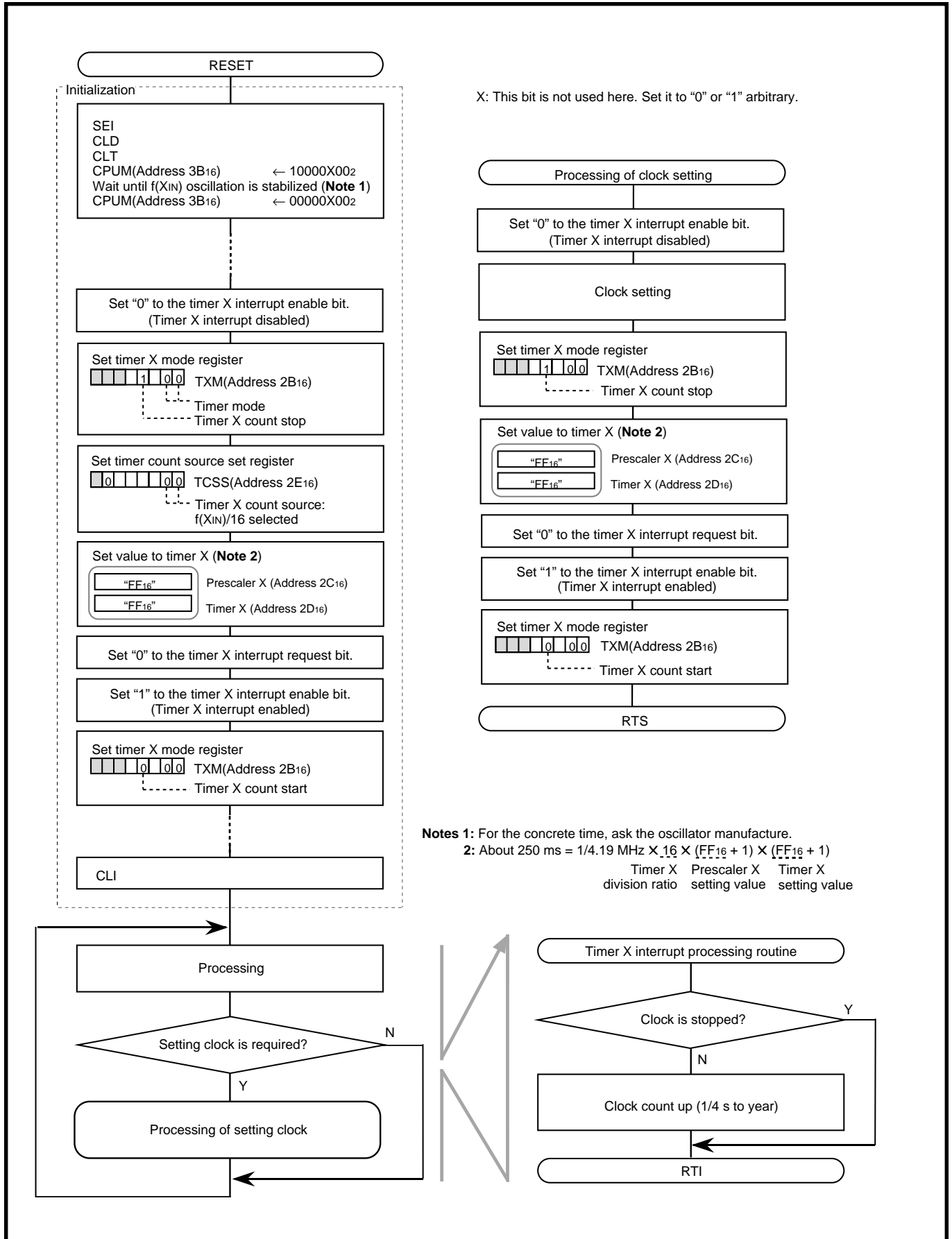


Fig. 2.4.12 Example of control procedure

2.4.4 Pulse output mode

(1) Operation description

In the pulse output mode, the waveform whose polarity is inverted each time timer X underflows is output from the P1₄/CNTR₀ pin.

The output level of CNTR₀ pin can be selected by the CNTR₀ active edge switch bit. When the CNTR₀ active edge switch bit is “0”, the output of CNTR₀ pin is started at “H” level. When this bit is “1”, the output is started at “L” level.

Also, the inverted waveform of pulse output from CNTR₀ pin can be output from TX_{OUT} pin by setting “1” to the P0₃/TX_{OUT} output valid bit.

When using a timer in this mode, set the port P1₄ and P0₃ direction registers to output mode.

Timer X can stop counting by setting “1” to the timer X count stop bit.

Also, when Timer X underflows, the timer X interrupt request bit is set to “1”.

(2) Pulse output mode setting method

Figure 2.4.13 and Figure 2.4.14 show the setting method for pulse output mode of timer X.

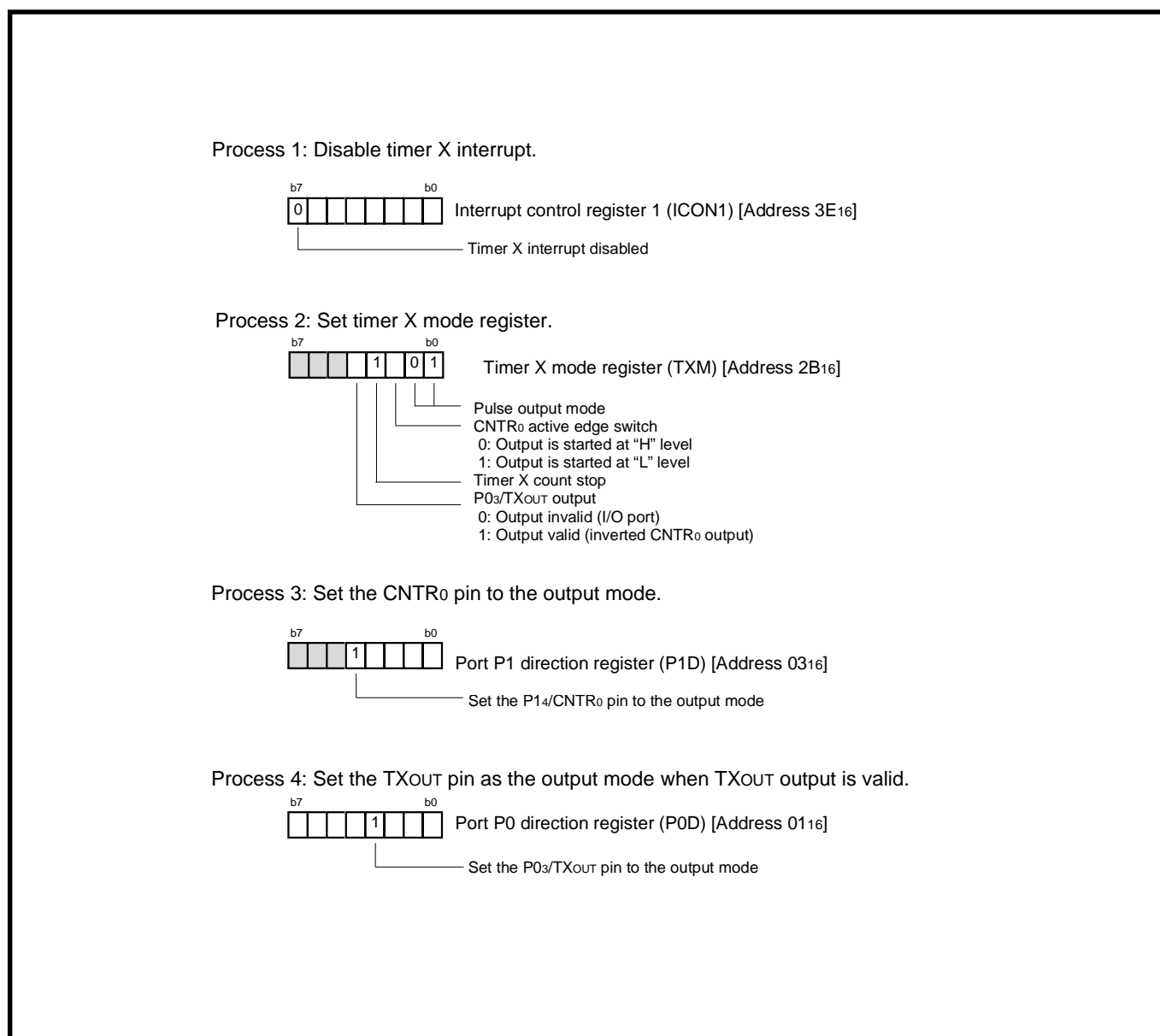
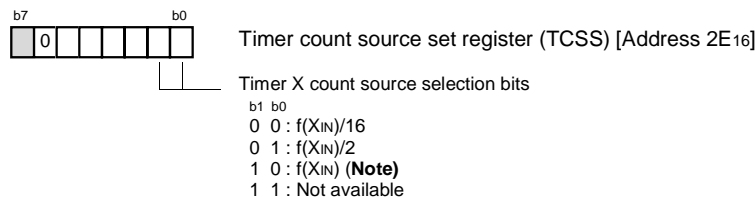


Fig. 2.4.13 Setting method for pulse output mode (1)

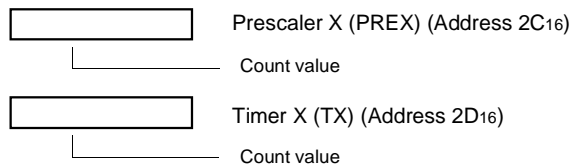
Process 5: Set timer count source set register.



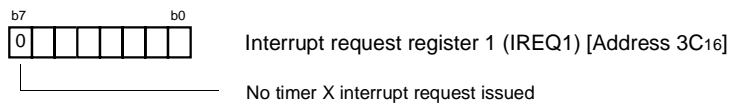
Note: $f(X_{IN})$ can be used only when a ceramic resonator or an on-chip oscillator is used.
Do not use $f(X_{IN})$ at RC oscillation.

Process 6: Set the count value to timer X.

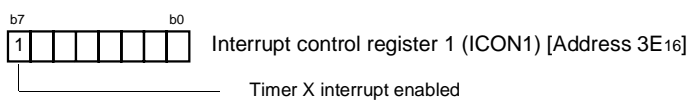
- Set the count value to prescaler X and timer X



Process 7: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer X interrupt request bit.



Process 8: When the interrupt is used, set "1" (interrupt enabled) to the timer X interrupt enable bit.



Process 9: Start counting of timer X.

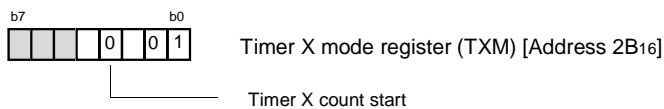


Fig. 2.4.14 Setting method for pulse output mode (2)

(3) Application example of pulse output mode

Outline: The pulse output mode of timer X is used for a piezoelectric buzzer output.

Specifications: The rectangular waveform which is clock $f(X_{IN}) = 4 \text{ MHz}$ divided up to 4 kHz is output from the P14/CNTR₀ pin.

The level of the P14/CNTR₀ pin is fixed to "H" while a piezoelectric buzzer output is stopped.

Operation clock: $f(X_{IN}) = 4 \text{ MHz}$, double-speed mode

Figure 2.4.15 shows an example of a peripheral circuit, Figure 2.4.16 shows the connection of timer and setting of the division ratio, and Figure 2.4.17 shows an example of control procedure.

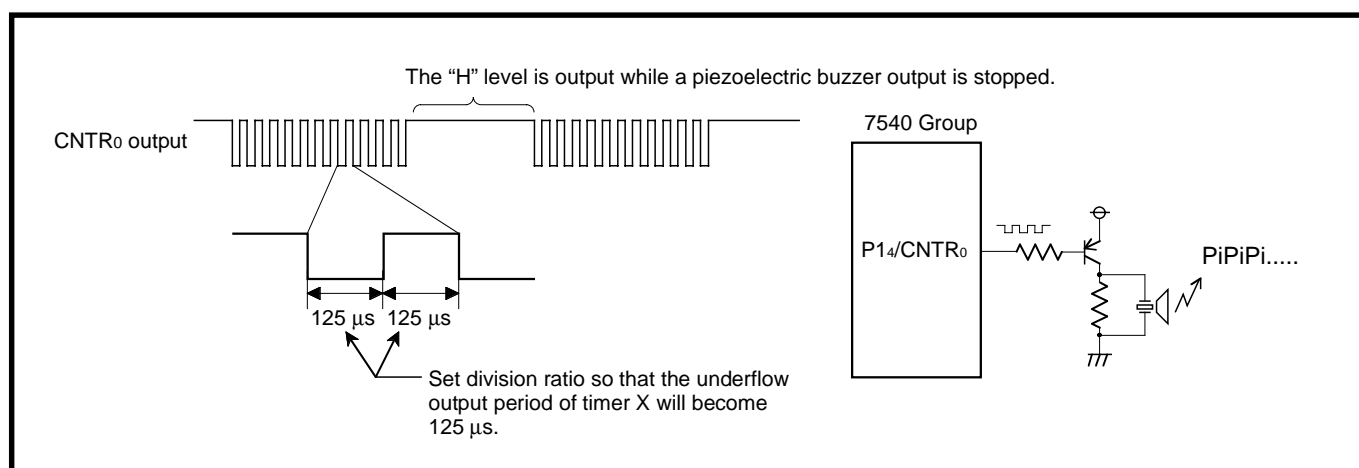


Fig. 2.4.15 Example of peripheral circuit

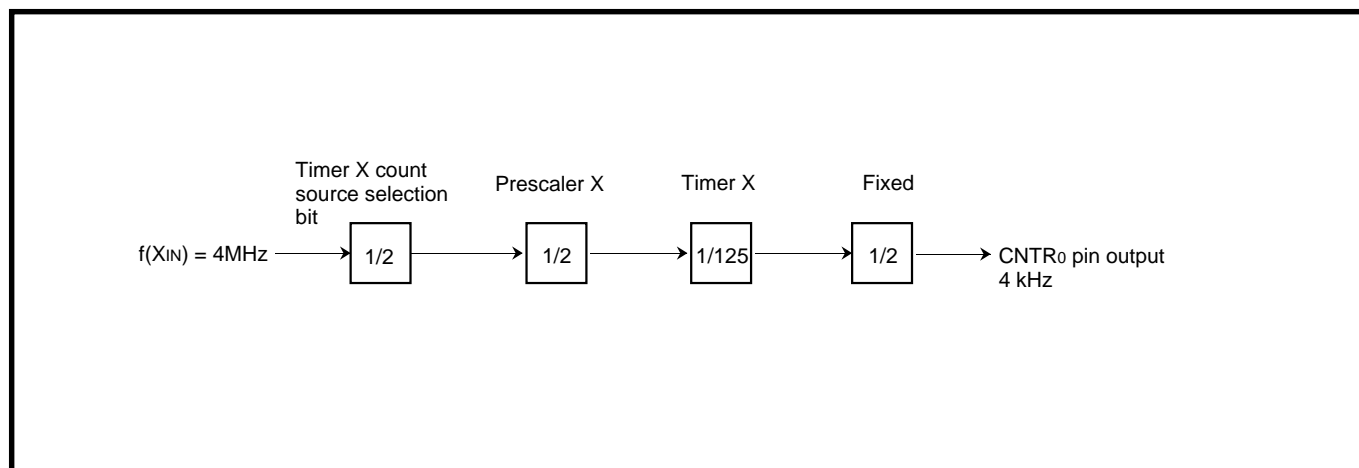


Fig. 2.4.16 Connection of timer and setting of division ratio

2.4.5 Event counter mode

(1) Operation description

The timer X counts signals input from the P14/CNTR₀ pin.

Except for this, the operation in event counter mode is the same as in timer mode.

The active edge of CNTR₀ pin input signal can be selected from rising or falling by the CNTR₀ active edge switch bit.

Timer X can stop counting by setting "1" to the timer X count stop bit.

Also, when Timer X underflows, the timer X interrupt request bit is set to "1".

(2) Event counter mode setting method

Figure 2.4.18 and Figure 2.4.19 show the setting method for event counter mode of timer X.

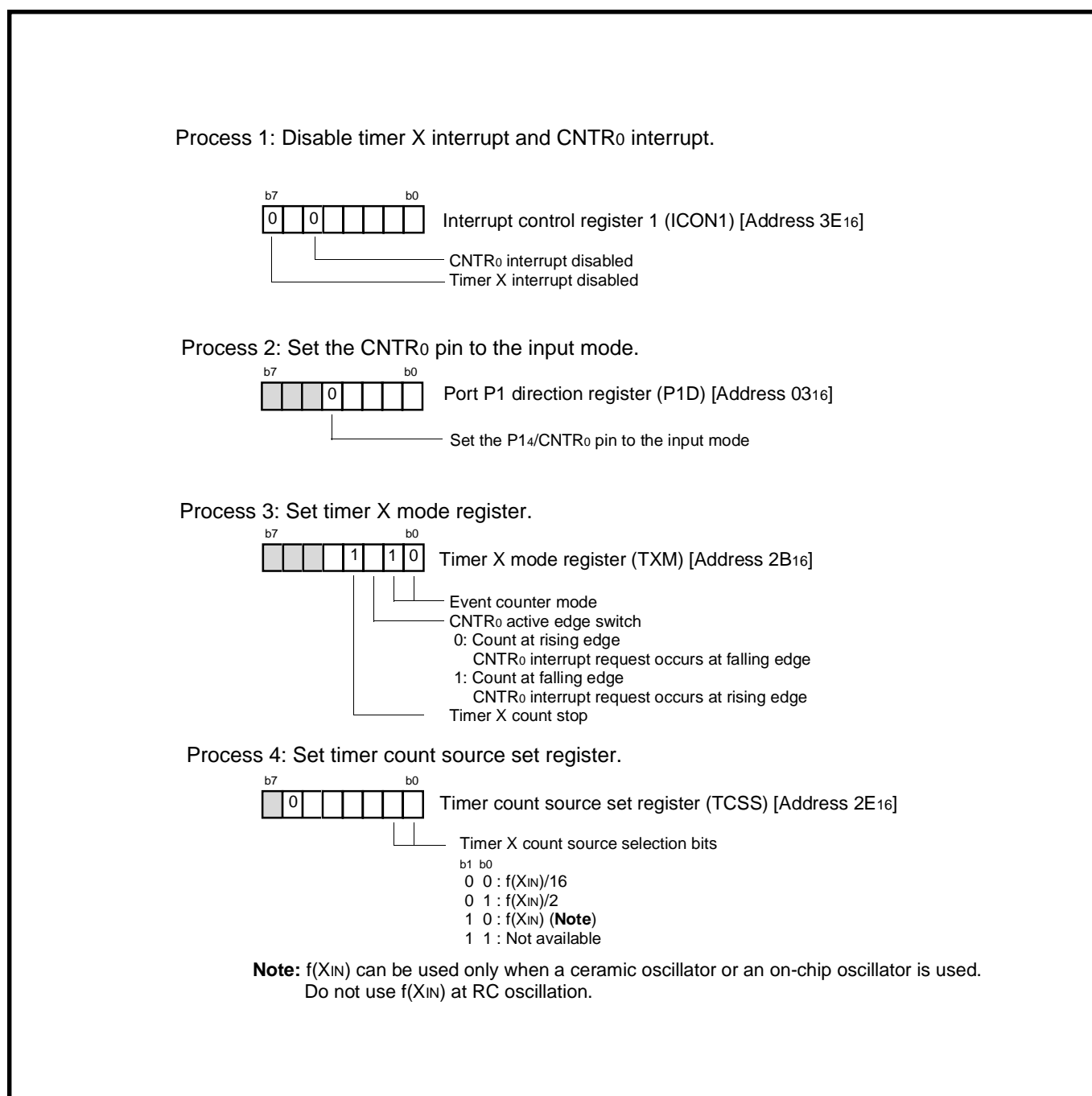
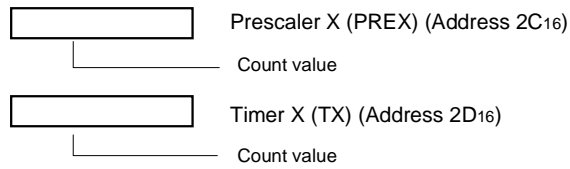


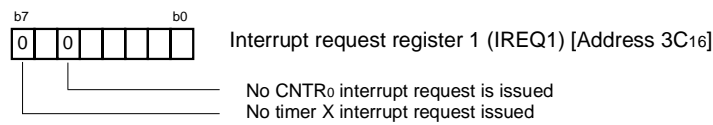
Fig. 2.4.18 Setting method for event counter mode (1)

Process 5: Set the count value to timer X.

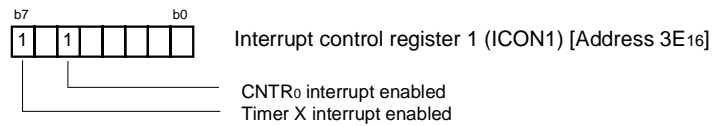
- Set the count value to prescaler X and timer X



Process 6: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer X interrupt request bit and CNTR₁ interrupt request bit.



Process 7: When the interrupt is used, set "1" (interrupt enabled) to the timer X interrupt enable bit.



Process 8: Start counting of timer X.

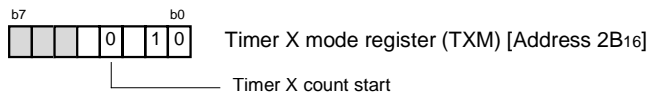


Fig. 2.4.19 Setting method for event counter mode (2)

(3) Application example of event counter mode

Outline: Pulses generated corresponding to the water flow rate are counted for a fixed period (100 ms), and the water flow rate during this period is calculated.

Specifications: Pulses generated corresponding to the water flow rate are input to the P14/CNTR₀ pin and counted using timer X.

The contents of timer X are read in the timer Y interrupt processing routine generated after 100 ms from the start of counting pulses, and the water flow rate during 100 ms is calculated.

Operation clock: $f(X_{IN}) = 8 \text{ MHz}$, high-speed mode

Figure 2.4.20 shows an example of peripheral circuit, Figure 2.4.21 shows the method of measuring water flow rate, and Figure 2.4.21 shows an example of control procedure.

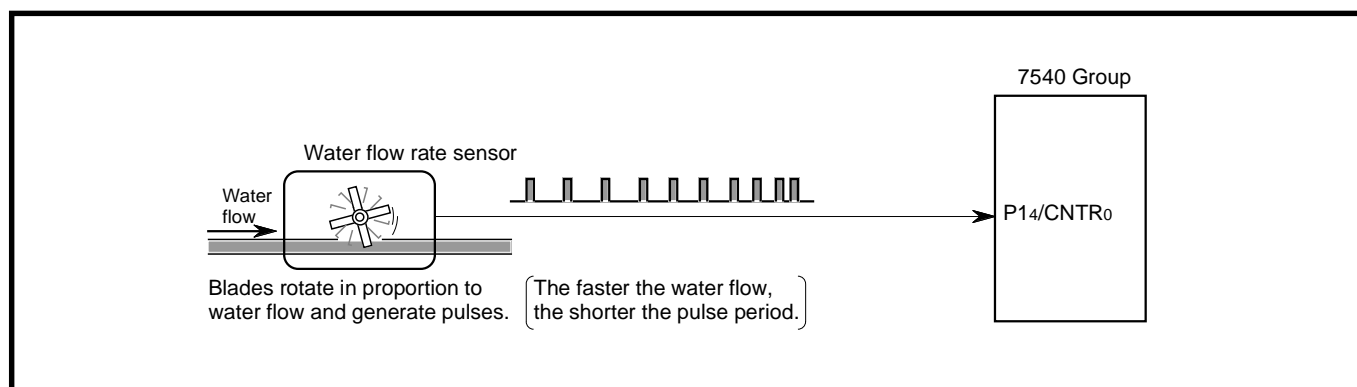


Fig. 2.4.20 Example of peripheral circuit

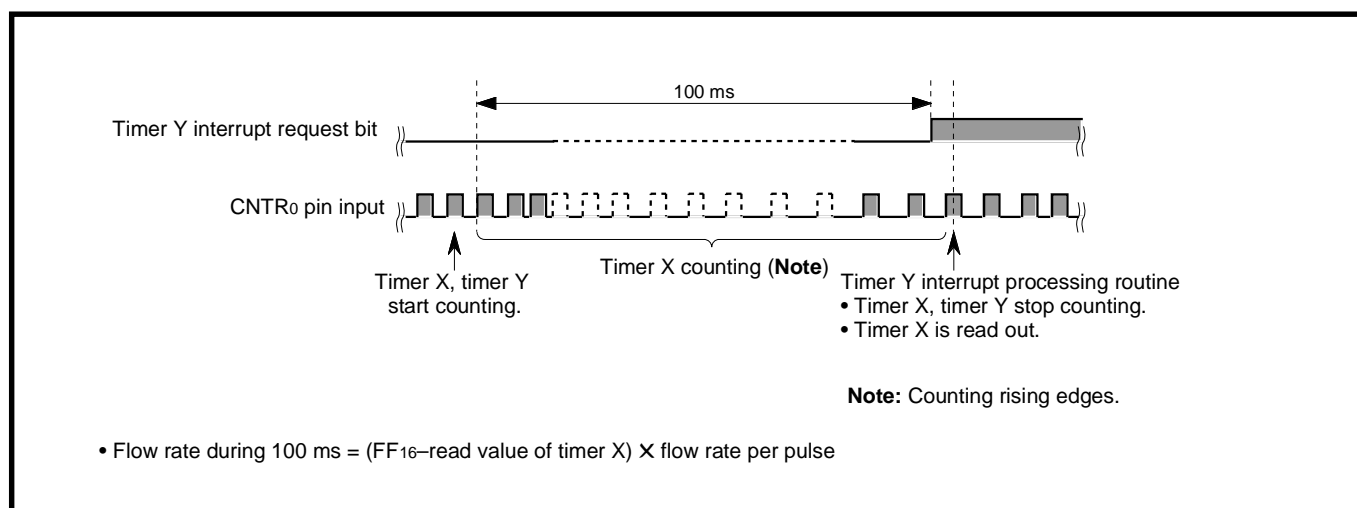
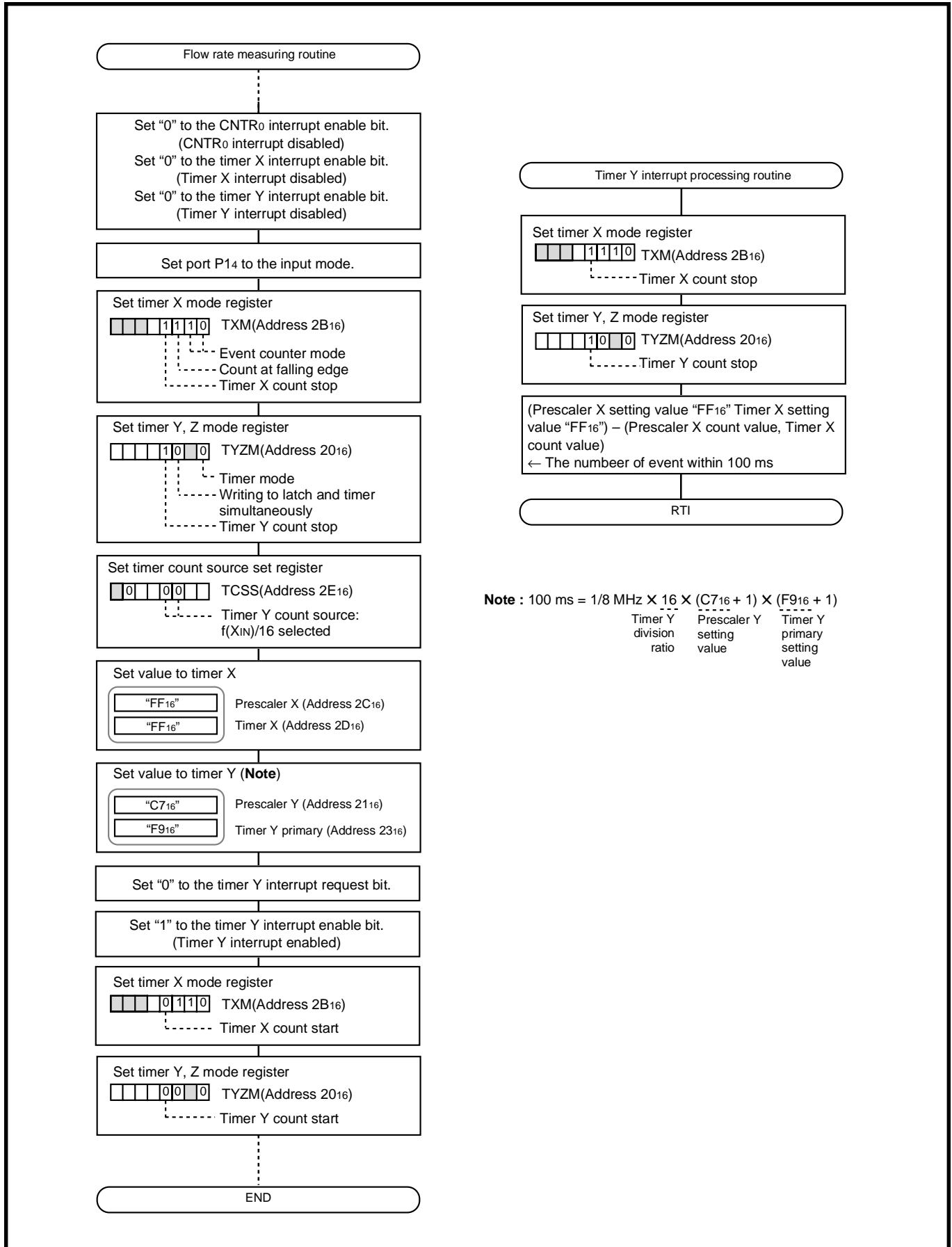


Fig. 2.4.21 Method of measuring water flow rate



Note : $100\text{ ms} = \frac{1}{8}\text{ MHz} \times 16 \times (C7_{16} + 1) \times (F9_{16} + 1)$

| | | |
|------------------------------|---------------------------------|--|
| Timer Y division ratio | Prescaler Y setting value | Timer Y primary setting value |
|------------------------------|---------------------------------|--|

Fig. 2.4.22 Example of control procedure

2.4.6 Pulse width measurement mode

(1) Operation description

In the pulse width measurement mode, the pulse width of the signal input to P14/CNTR₀ pin is measured.

The operation of Timer X can be controlled by the level of the signal input from the CNTR₀ pin. When the CNTR₀ active edge switch bit is "0", the signal selected by the timer X count source selection bit is counted while the input signal level of CNTR₀ pin is "H". The count is stopped while the pin is "L". Also,

when the CNTR₀ active edge switch bit is "1", the signal selected by the timer X count source selection bit is counted while the input signal level of CNTR₀ pin is "L". The count is stopped while the pin is "H".

Timer X can stop counting by setting "1" to the timer X count stop bit.

Also, when Timer X underflows, the timer X interrupt request bit is set to "1".

(2) Pulse width HL continuously measurement mode setting method

Figure 2.4.23 and Figure 2.4.24 show the setting method for pulse width measurement mode of timer X.

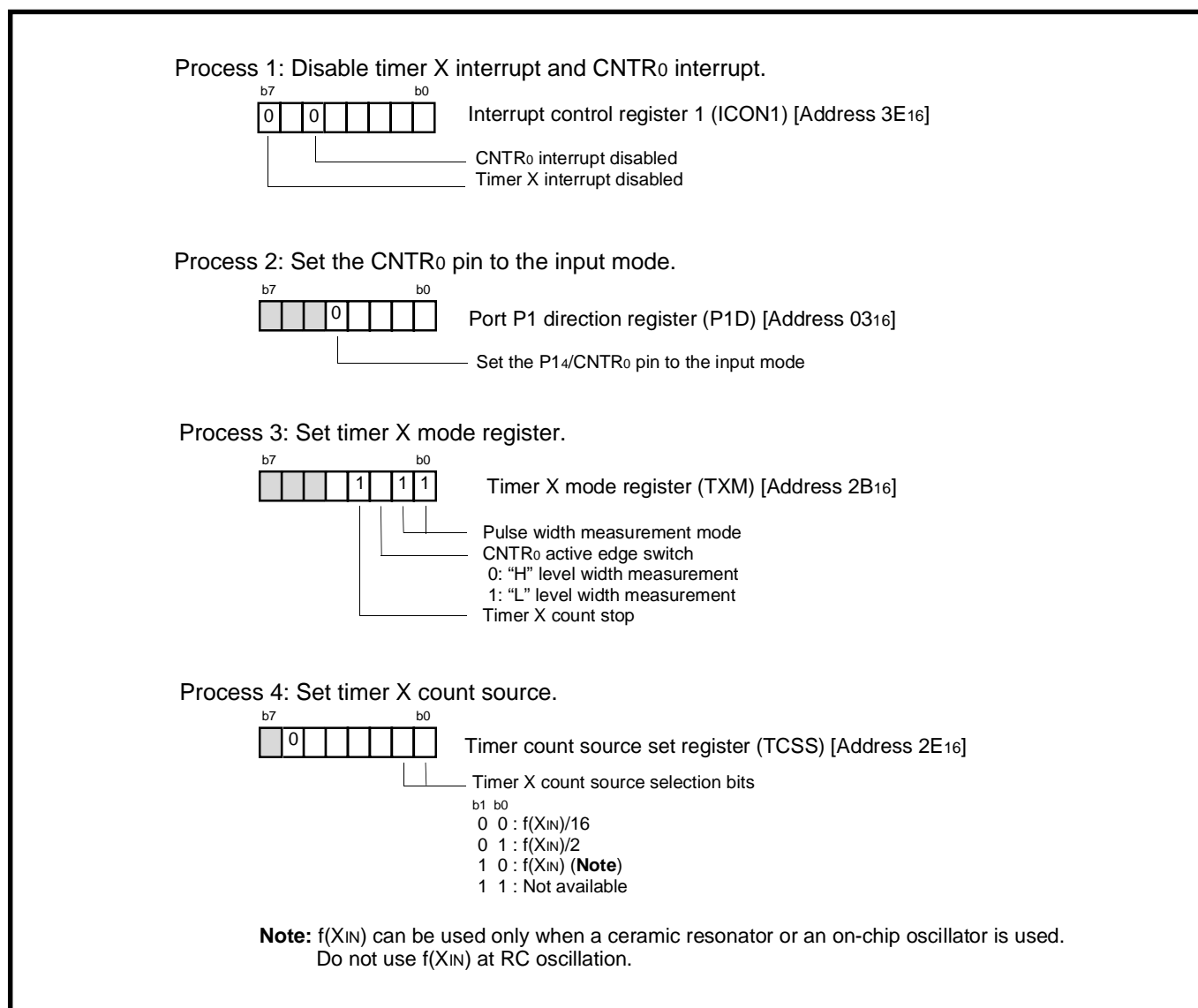
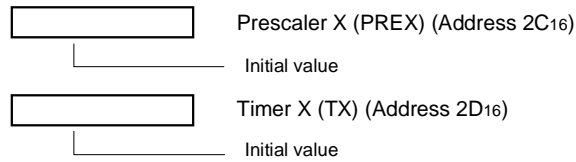


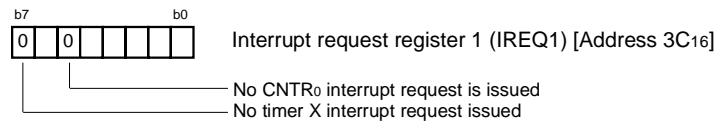
Fig. 2.4.23 Setting method for pulse width measurement mode (1)

Process 5: Set the count value to timer X.

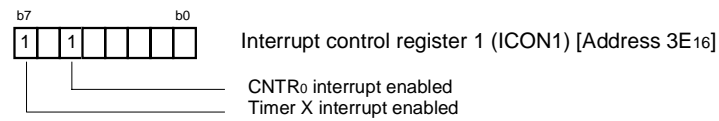
- Set the initial value to prescaler X and timer X



Process 6: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer X interrupt request bit and CNTR₀ interrupt request bit.



Process 7: When the interrupt is used, set "1" (interrupt enabled) to the timer X interrupt enable bit.



Process 8: Start counting of timer X.

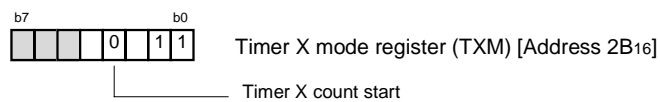


Fig. 2.4.24 Setting method for pulse width measurement mode (2)

(3) Application example of pulse width measurement mode

Outline: “H” level width of pulse input to P14/CNTR₀ pin is counted.

Specifications: The “H” level width of a FG pulse input to the P14/CNTR₀ pin is counted. An underflow is detected by the timer X interrupt. The completion of “H” level of input pulse is detected by the CNTR₀ interrupt.

Operation clock: $f(X_{IN}) = 4.19$ MHz, high-speed mode

Example: When $f(X_{IN}) = 4.19$ MHz, the count source becomes $3.8 \mu\text{s}$ divided by 16. Measurement can be made up to 250 ms in the range of “FFF₁₆” to “0000₁₆”.

Figure 2.4.25 shows a connection of the timer and setting of the division ratio. Figure 2.4.26 shows an example of control procedure.

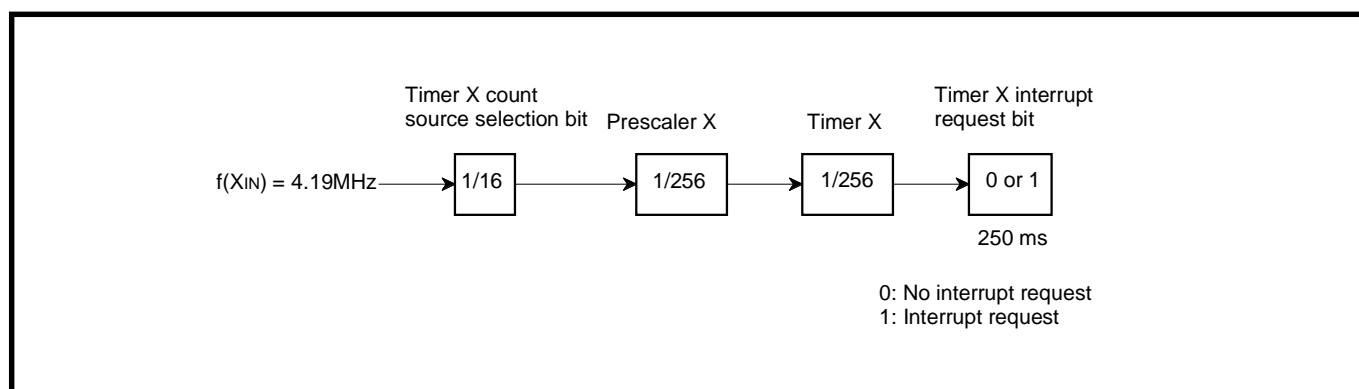


Fig. 2.4.25 Connection of timer and setting of division ratio

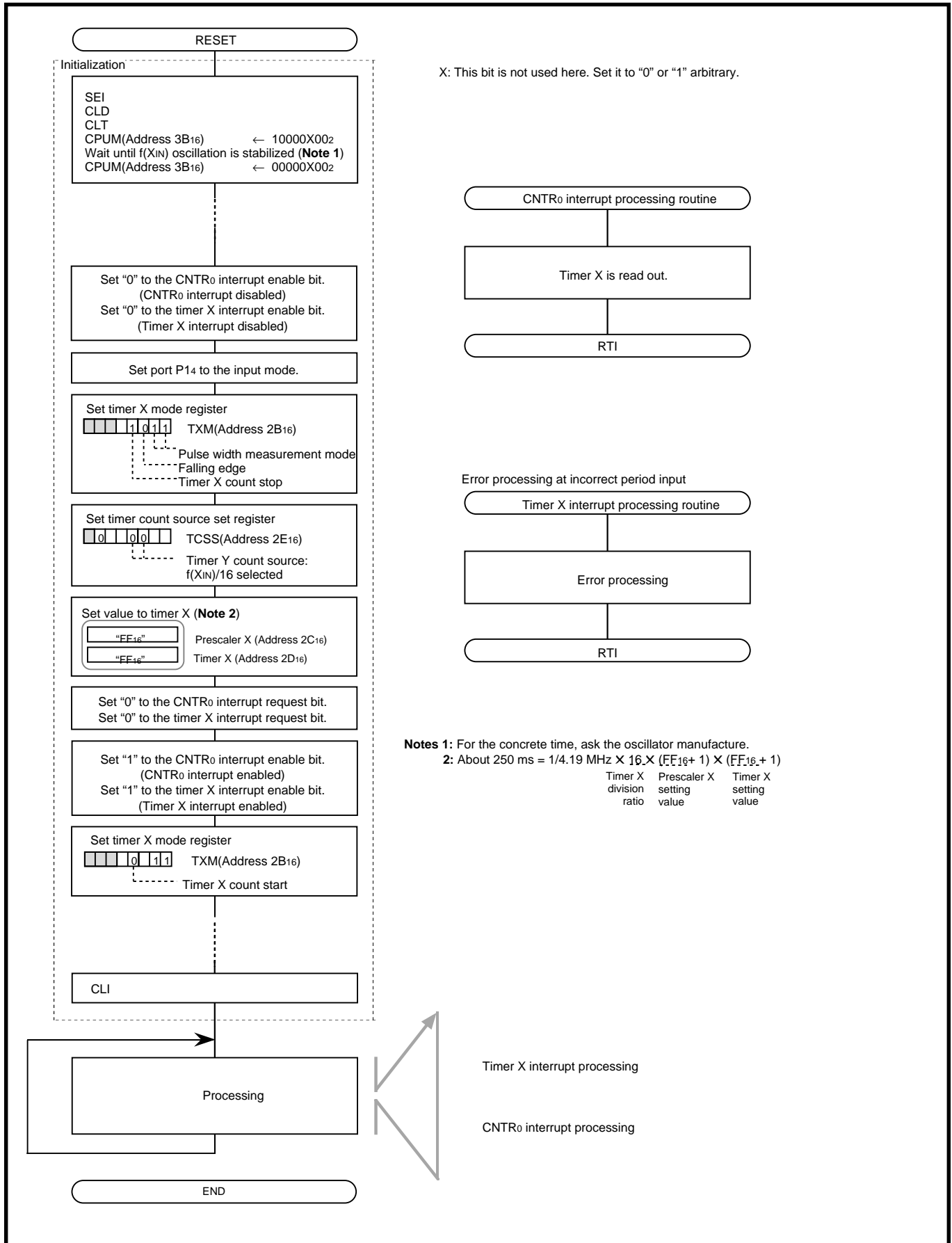


Fig. 2.4.26 Example of control procedure

2.4.7 Notes on timer X

Notes on using each mode of timer X are described below.

(1) Count source

- ① $f(X_{IN})$ can be used only when a ceramic oscillator or an on-chip oscillator is used.
Do not use $f(X_{IN})$ at RC oscillation.

(2) Pulse output mode

- ① In order to use CNTR₀ pin, set “1” to bit 4 of the port P1 direction register (output mode).
- ② In order to use TX_{OUT} pin, set “1” to bit 3 of the port P0 direction register (output mode).
- ③ CNTR₀ interrupt active edge depends on the CNTR₀ active edge switch bit. When this bit is “0”, the CNTR₀ interrupt request bit is set to “1” at the falling edge of CNTR₀ pin input signal. When this bit is “1”, the CNTR₀ interrupt request bit is set to “1” at the rising edge of CNTR₀ pin input signal.

(3) Pulse width measurement mode

- ① In order to use CNTR₀ pin, set “1” to bit 4 of the port P1 direction register (output mode).
- ② CNTR₀ interrupt active edge depends on the CNTR₀ active edge switch bit. When this bit is “0”, the CNTR₀ interrupt request bit is set to “1” at the falling edge of CNTR₀ pin input signal. When this bit is “1”, the CNTR₀ interrupt request bit is set to “1” at the rising edge of CNTR₀ pin input signal.

2.5 Timer Y and timer Z

This paragraph explains the registers setting method and the notes relevant to the timer Y and timer Z.

2.5.1 Memory map

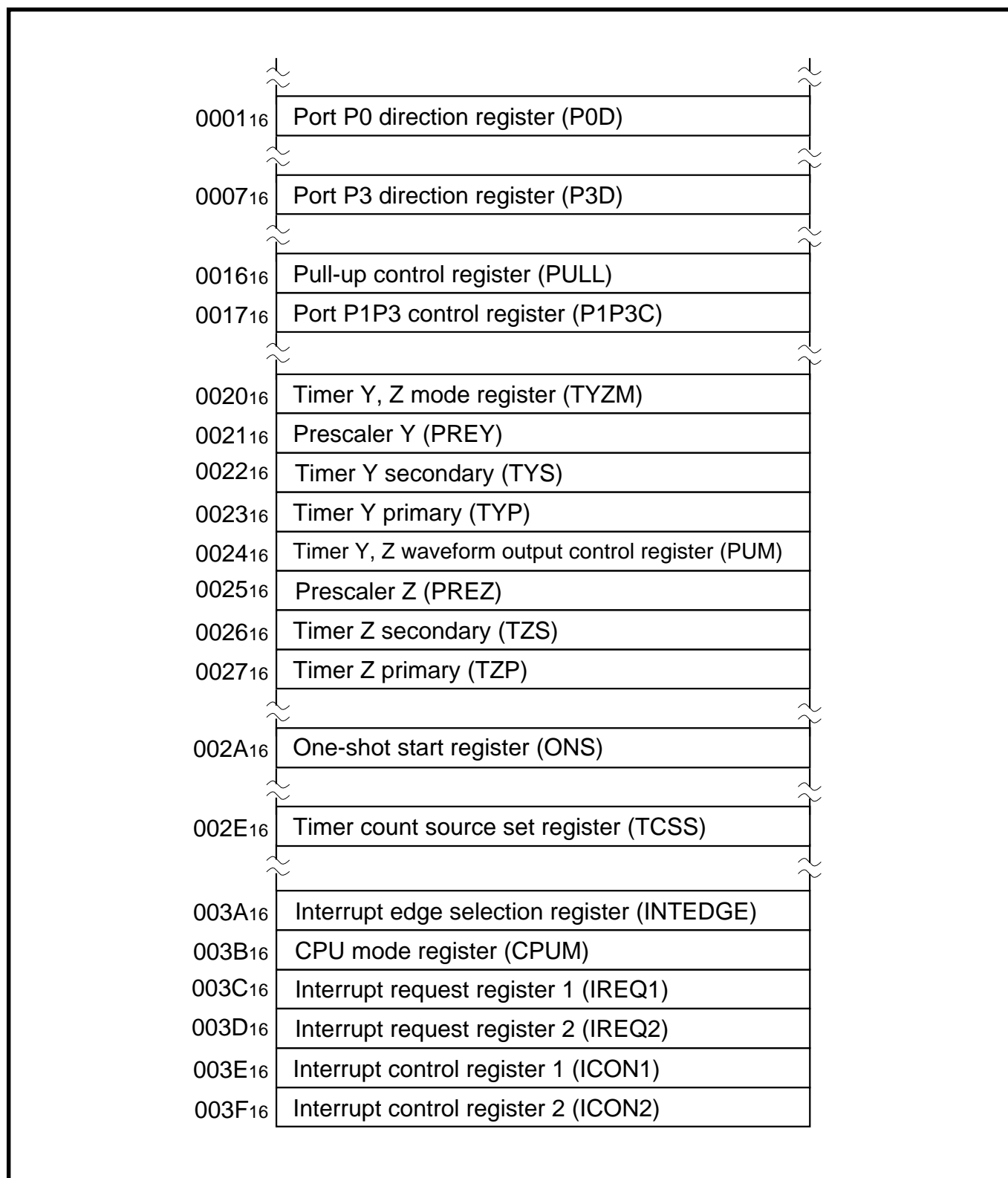


Fig. 2.5.1 Memory map of registers relevant to timer Y and timer Z

2.5.2 Relevant registers

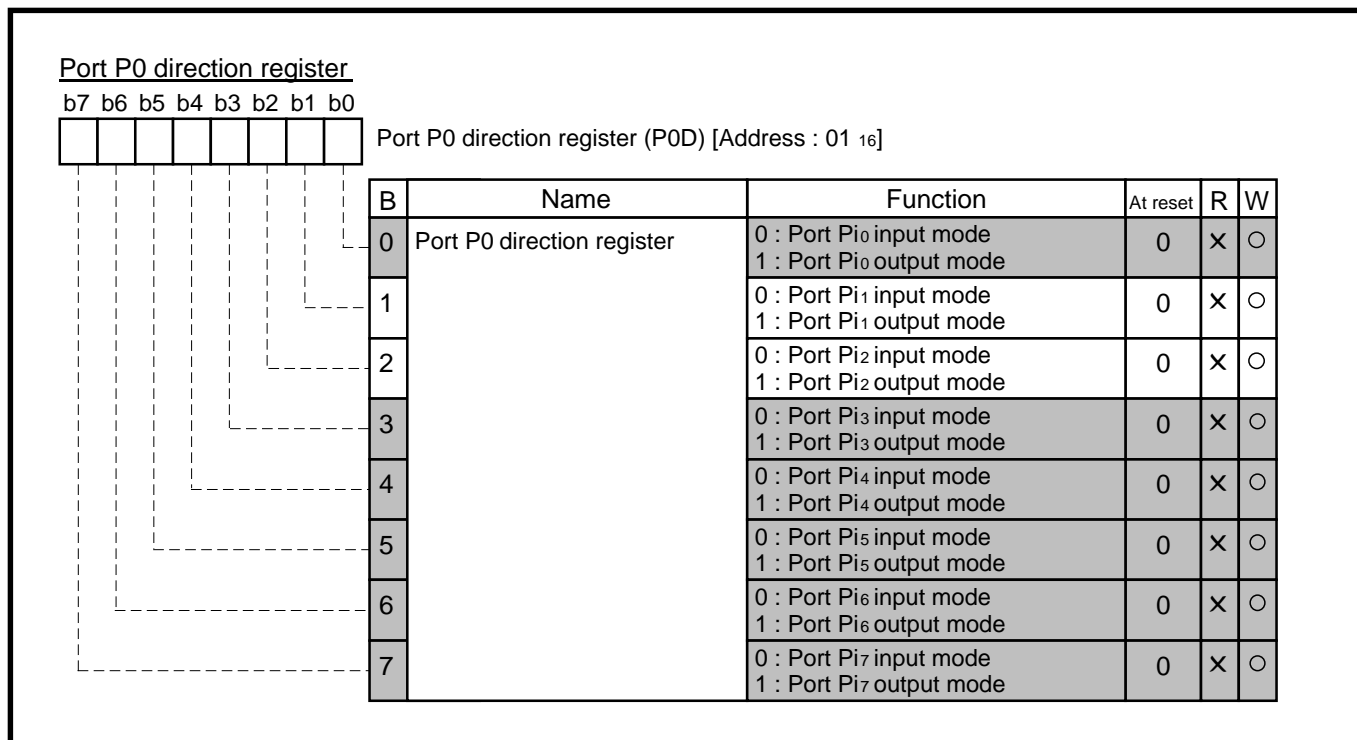


Fig. 2.5.2 Structure of Port P0 direction register

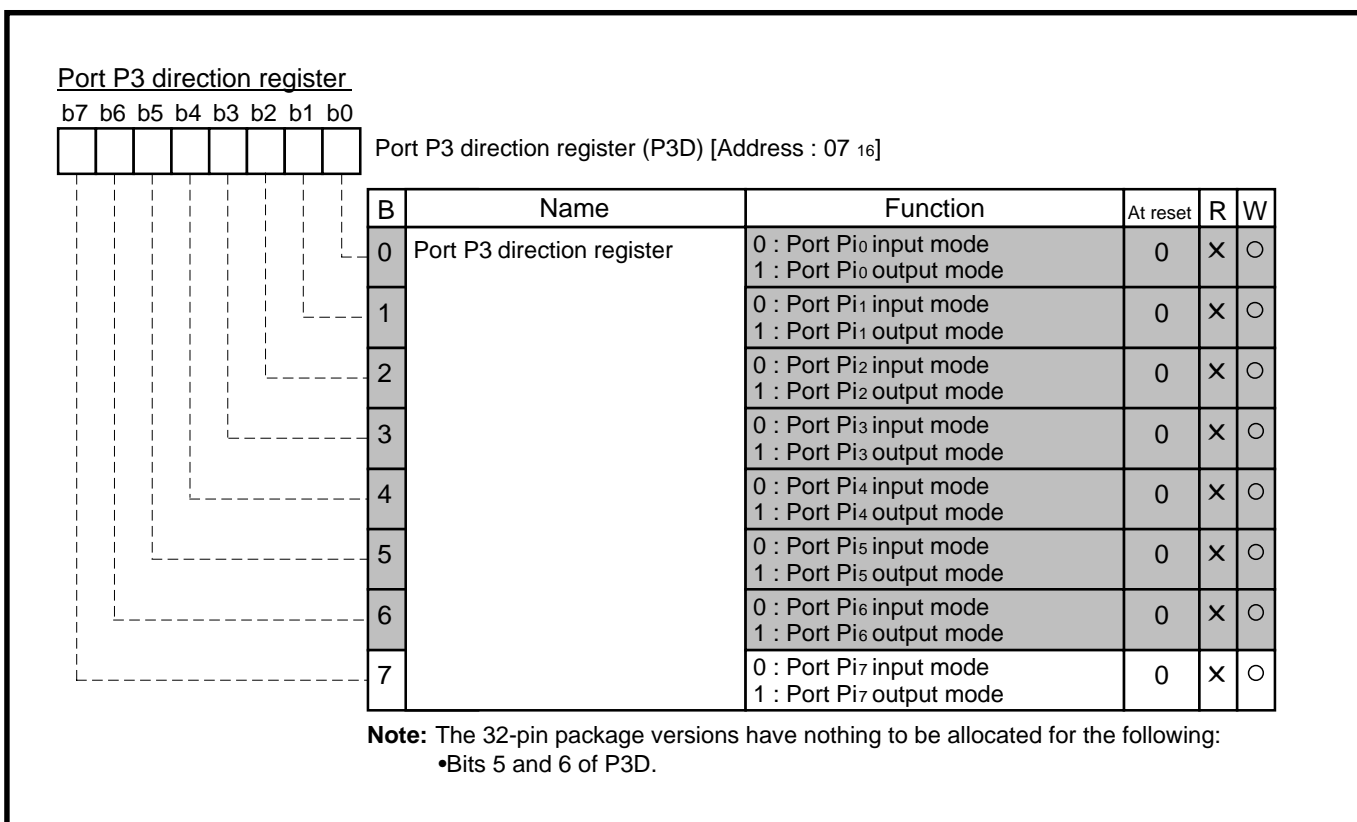


Fig. 2.5.3 Structure of Port P3 direction register

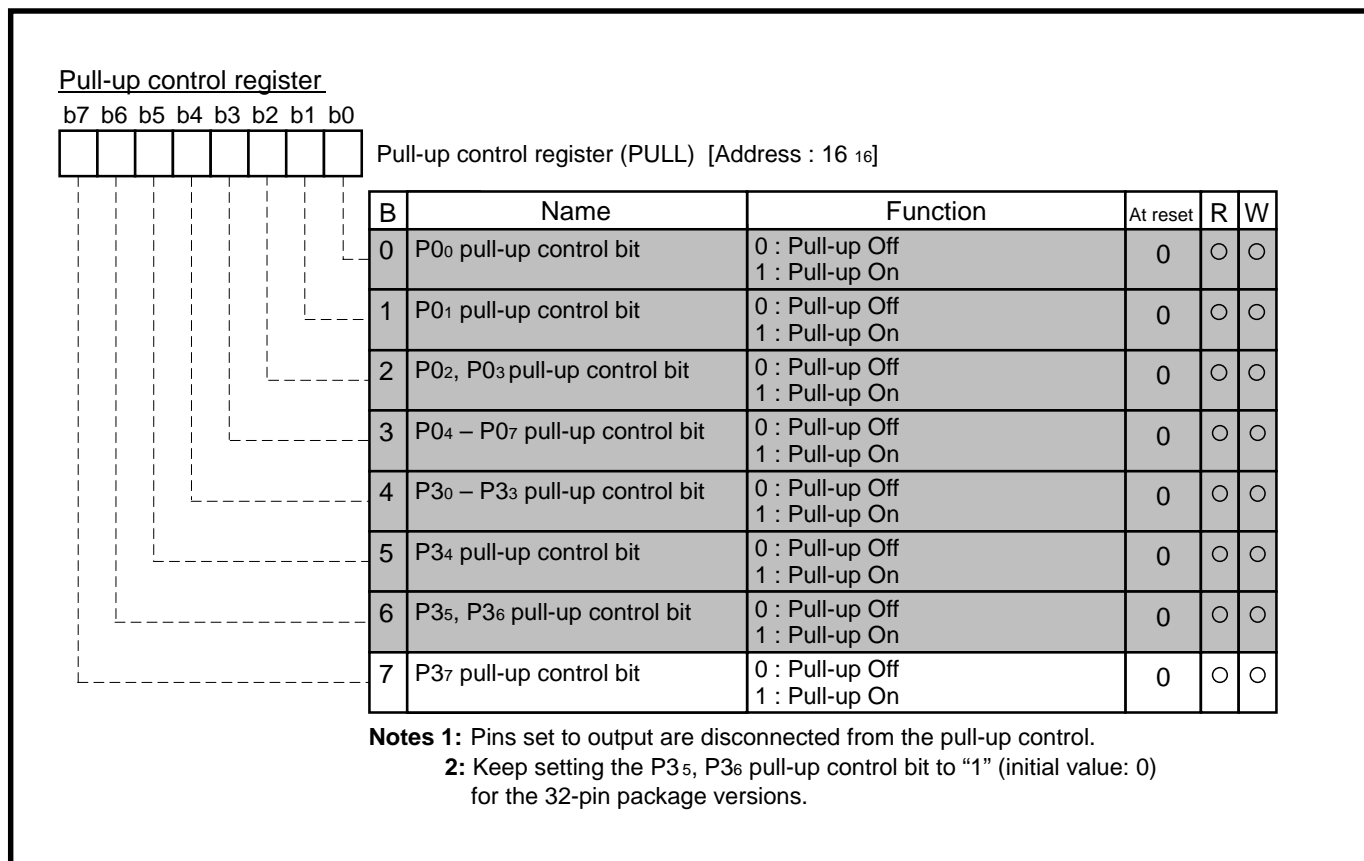


Fig. 2.5.4 Structure of Pull-up control register

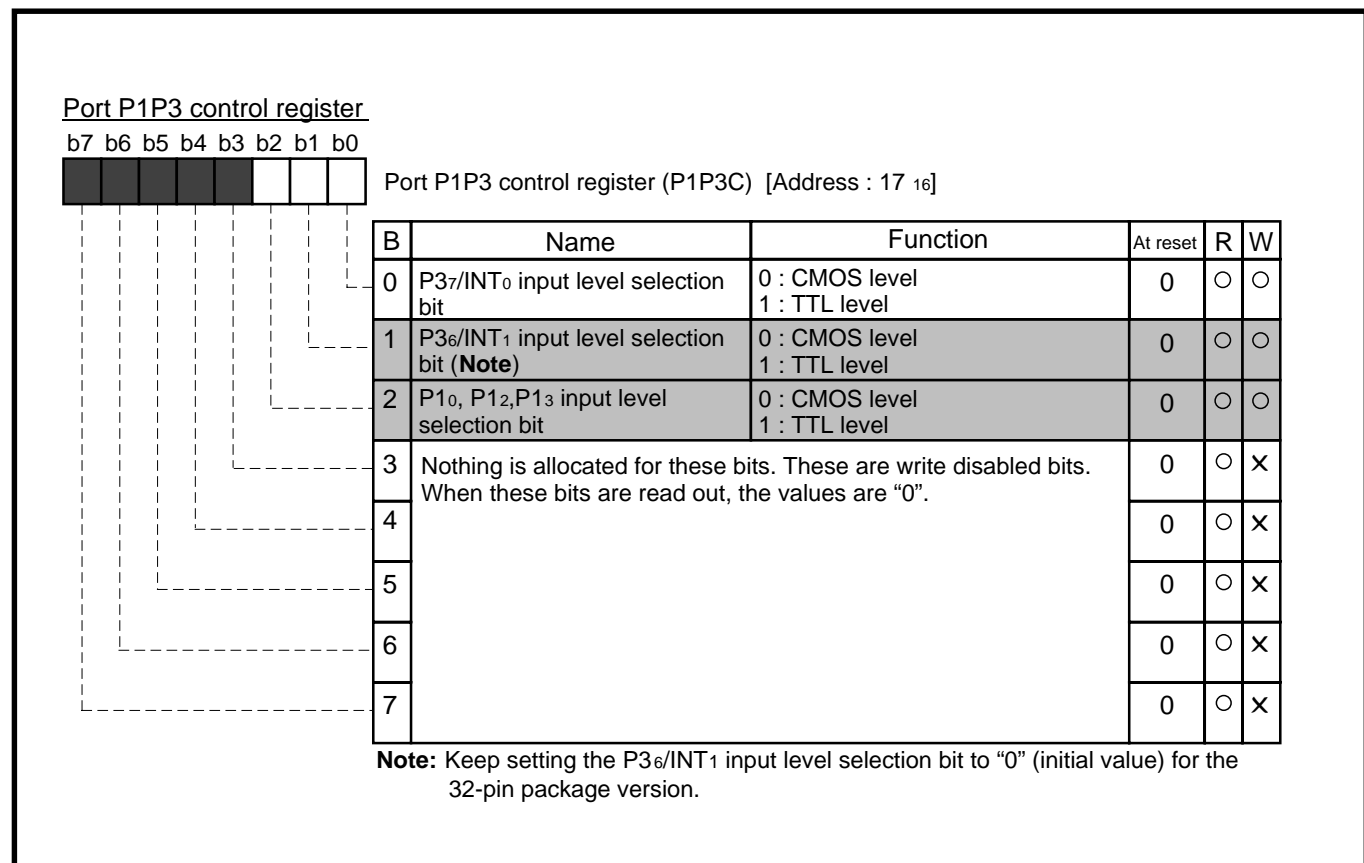


Fig. 2.5.5 Structure of Port P1P3 control register

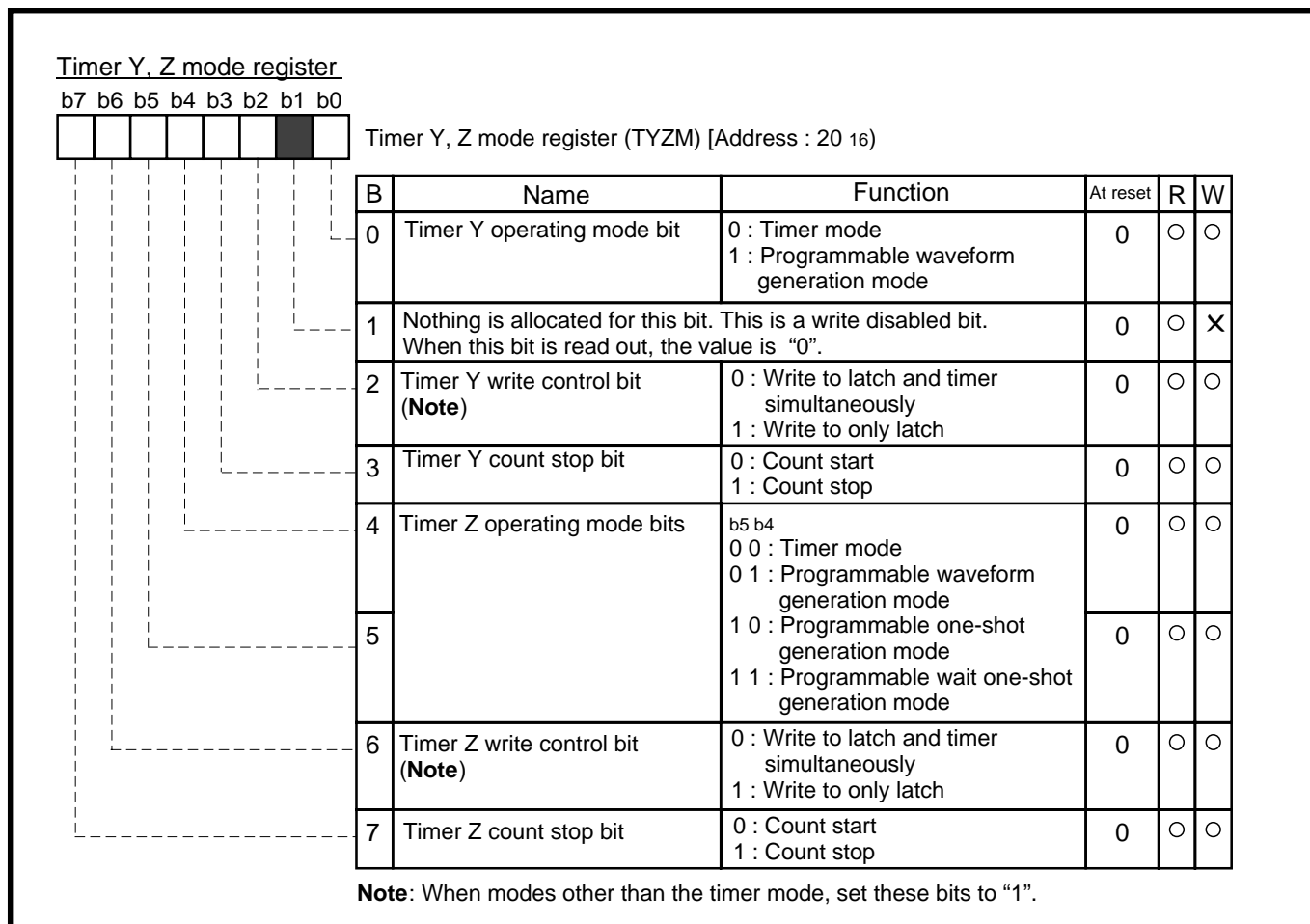


Fig. 2.5.6 Structure of Timer Y, Z mode register

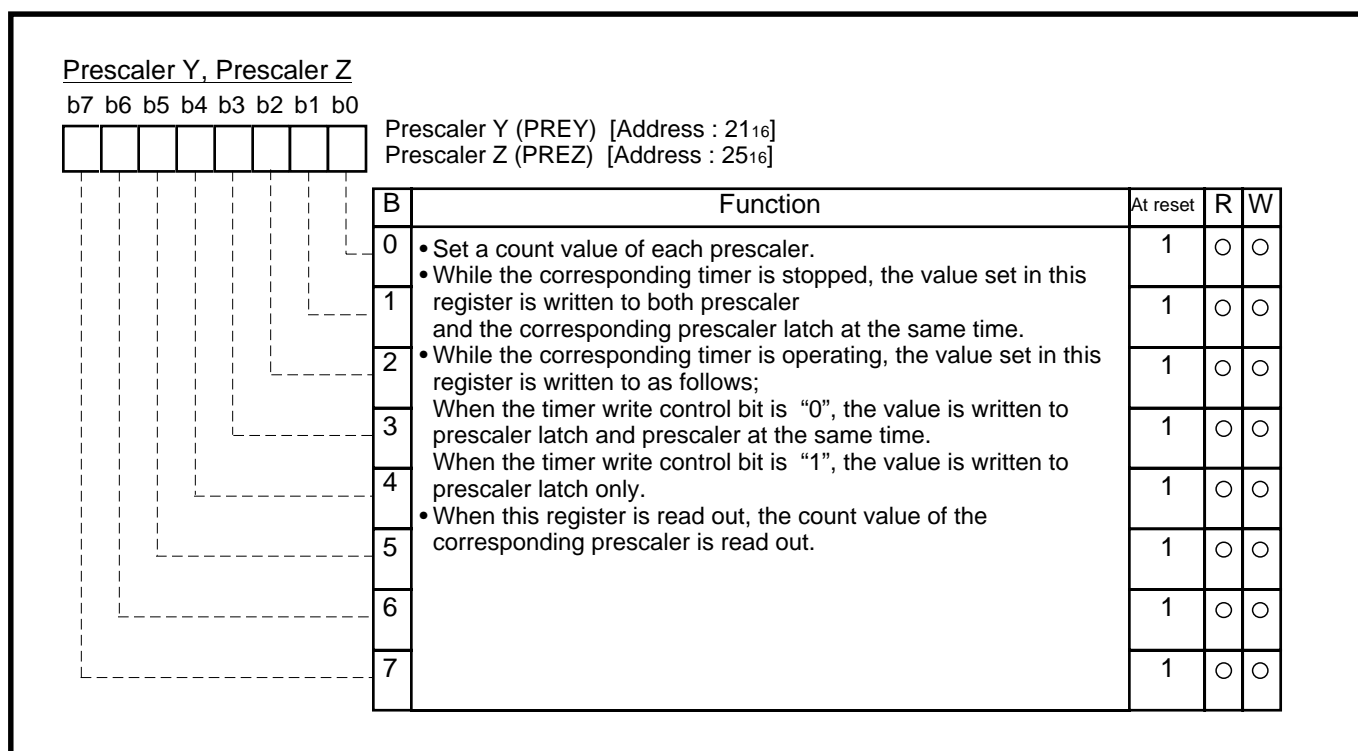


Fig. 2.5.7 Structure of Prescaler Y, Prescaler Z

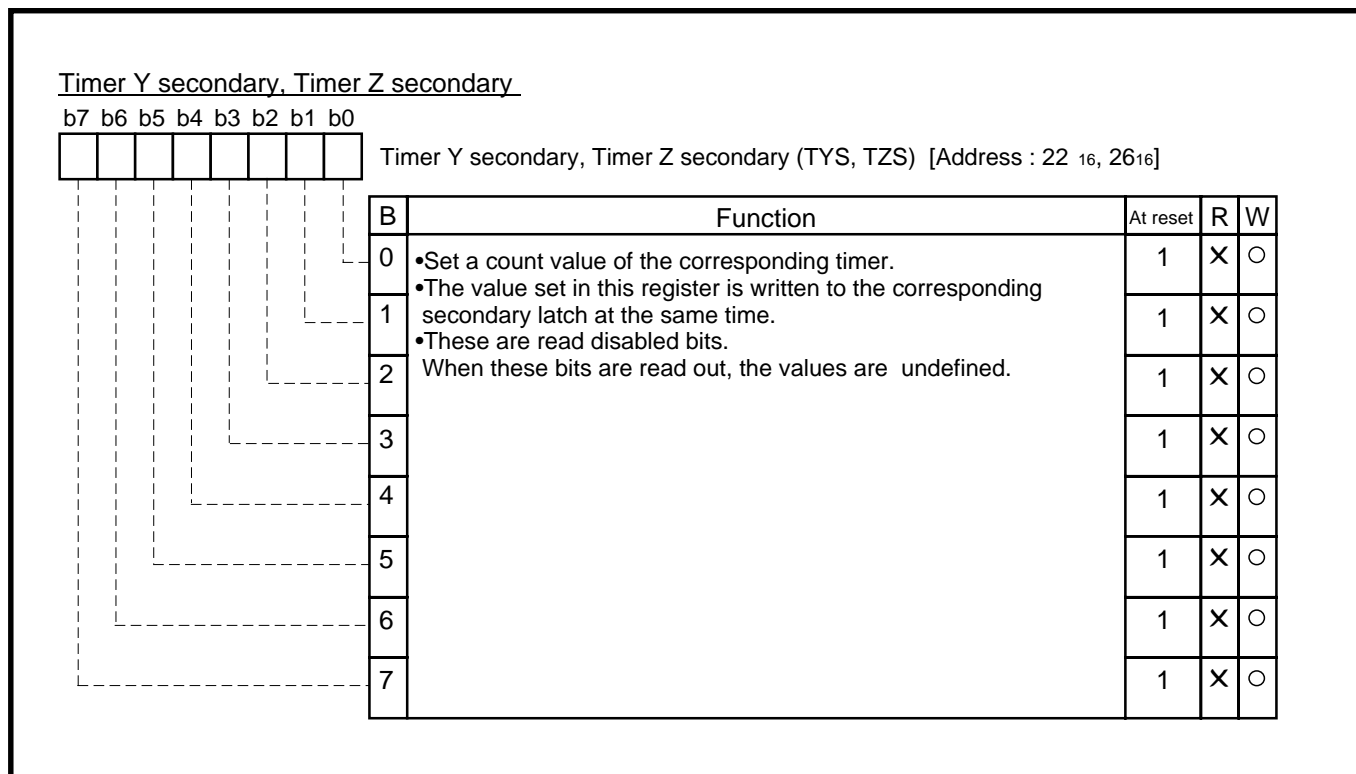


Fig. 2.5.8 Structure of Timer Y secondary, Timer Z secondary

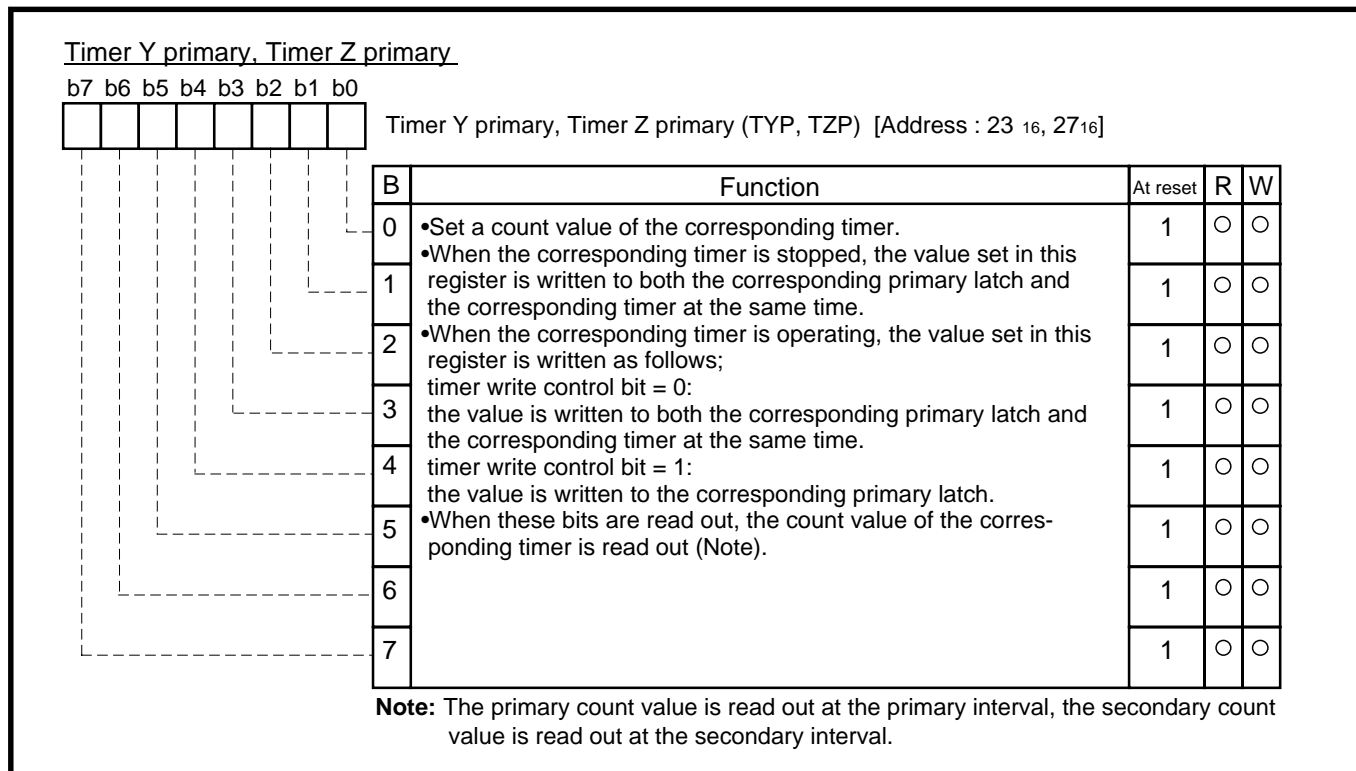


Fig. 2.5.9 Structure of Timer Y primary, Timer Z primary

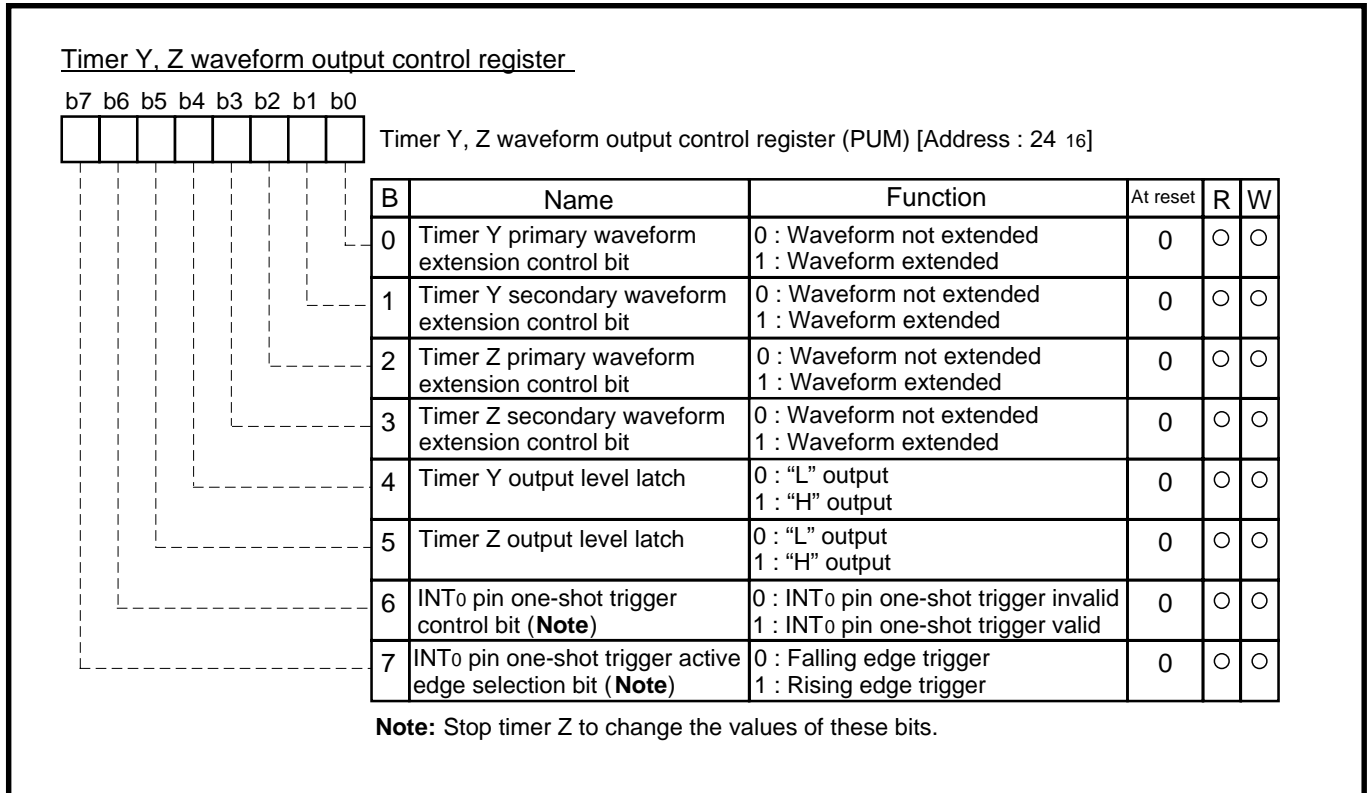


Fig. 2.5.10 Structure of Timer Y, Z waveform output control register

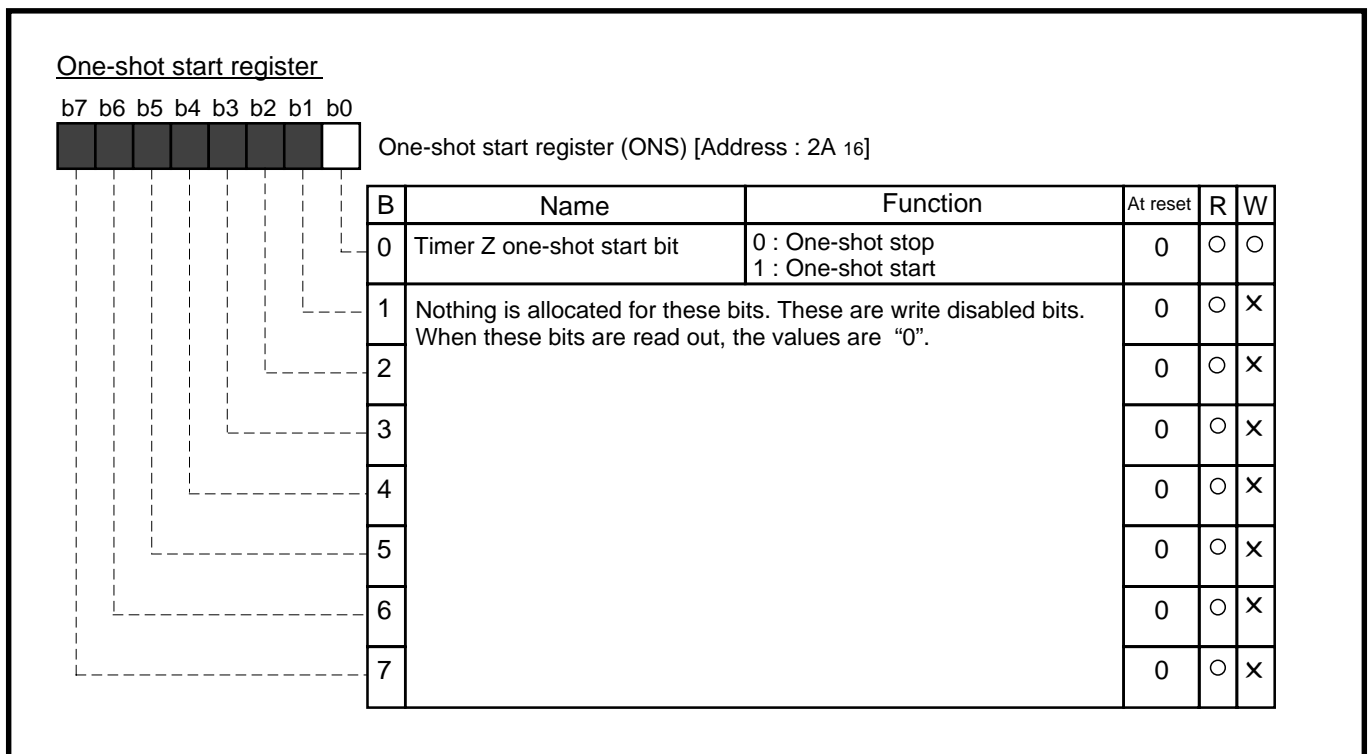


Fig. 2.5.11 Structure of One-shot start register

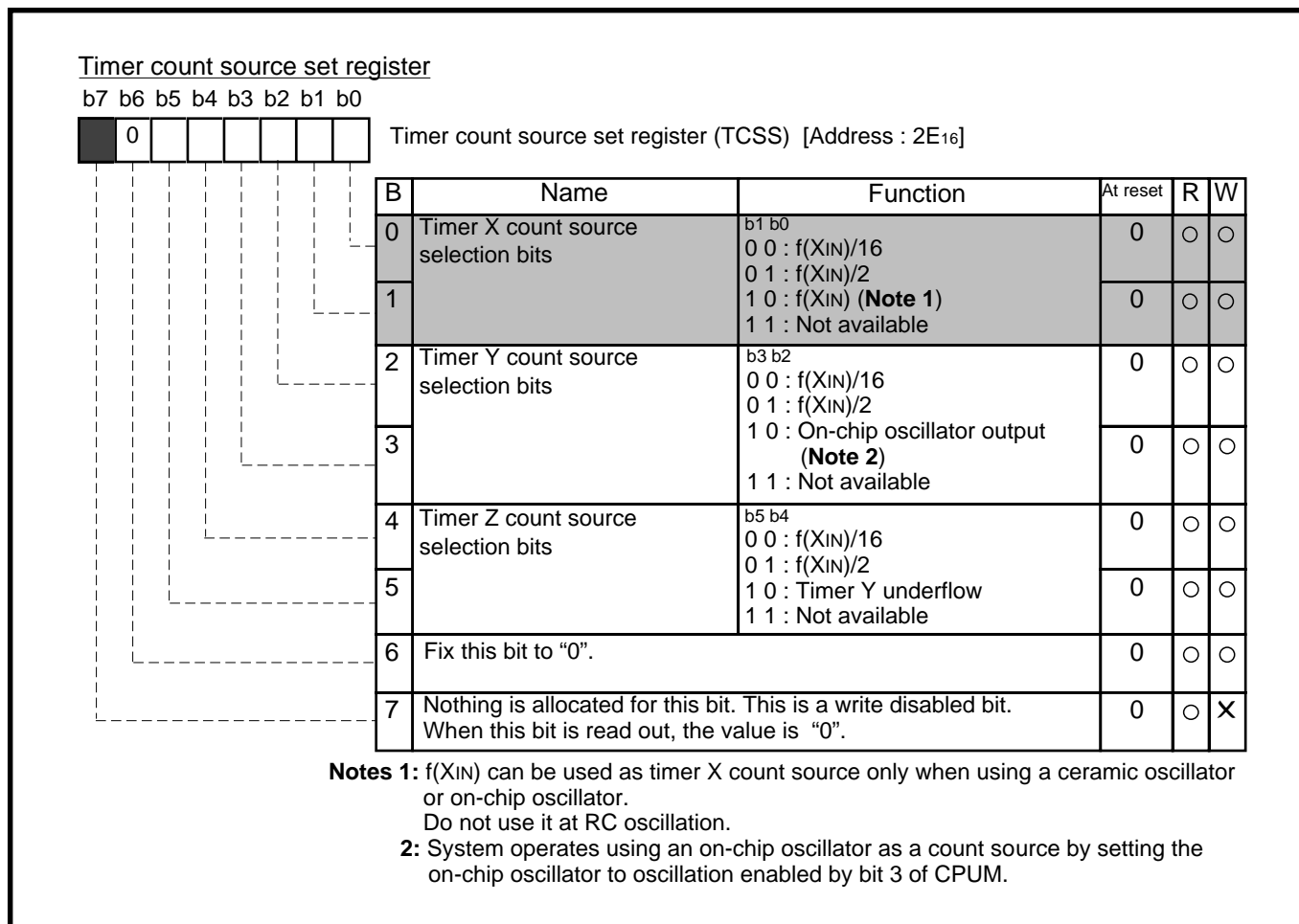


Fig. 2.5.12 Structure of Timer count source set register

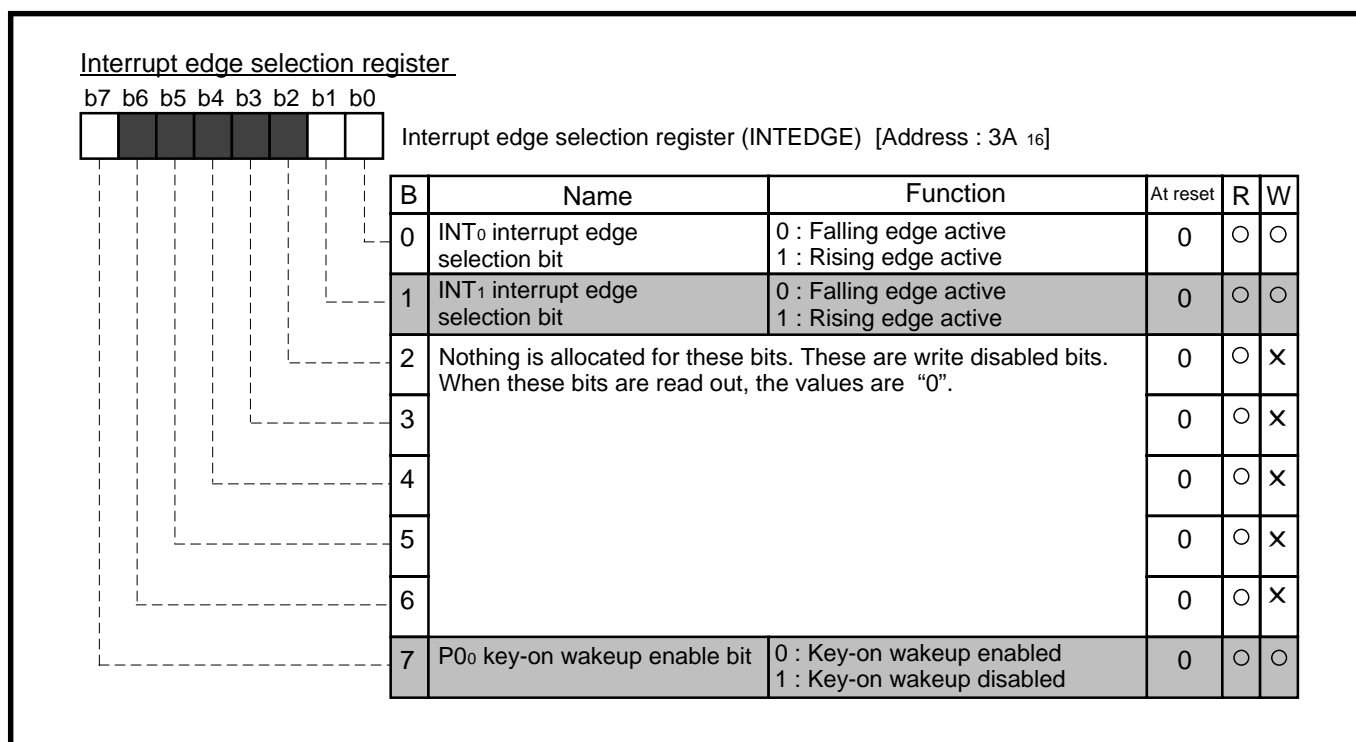


Fig. 2.5.13 Structure of Interrupt edge selection register

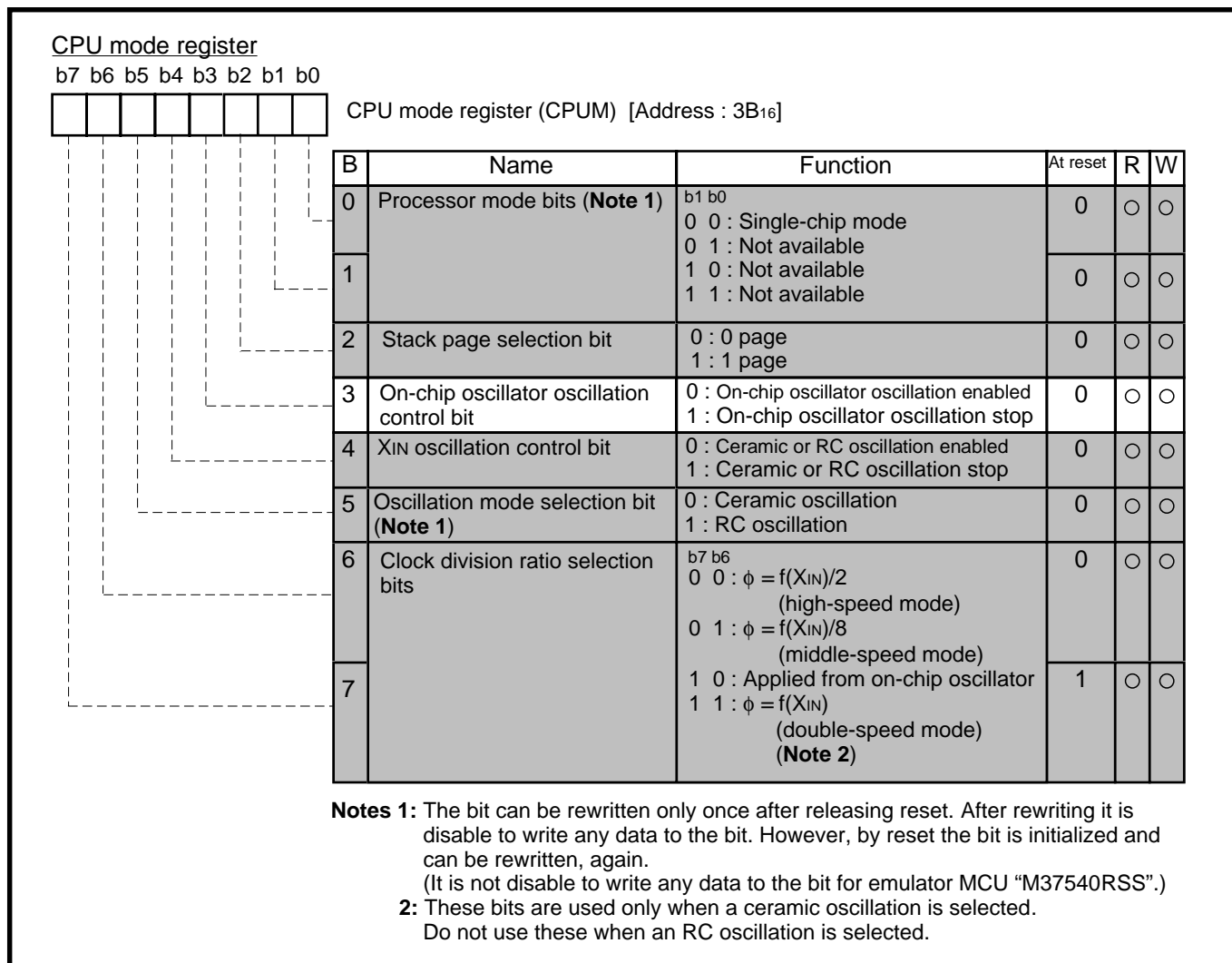


Fig. 2.5.14 Structure of CPU mode register

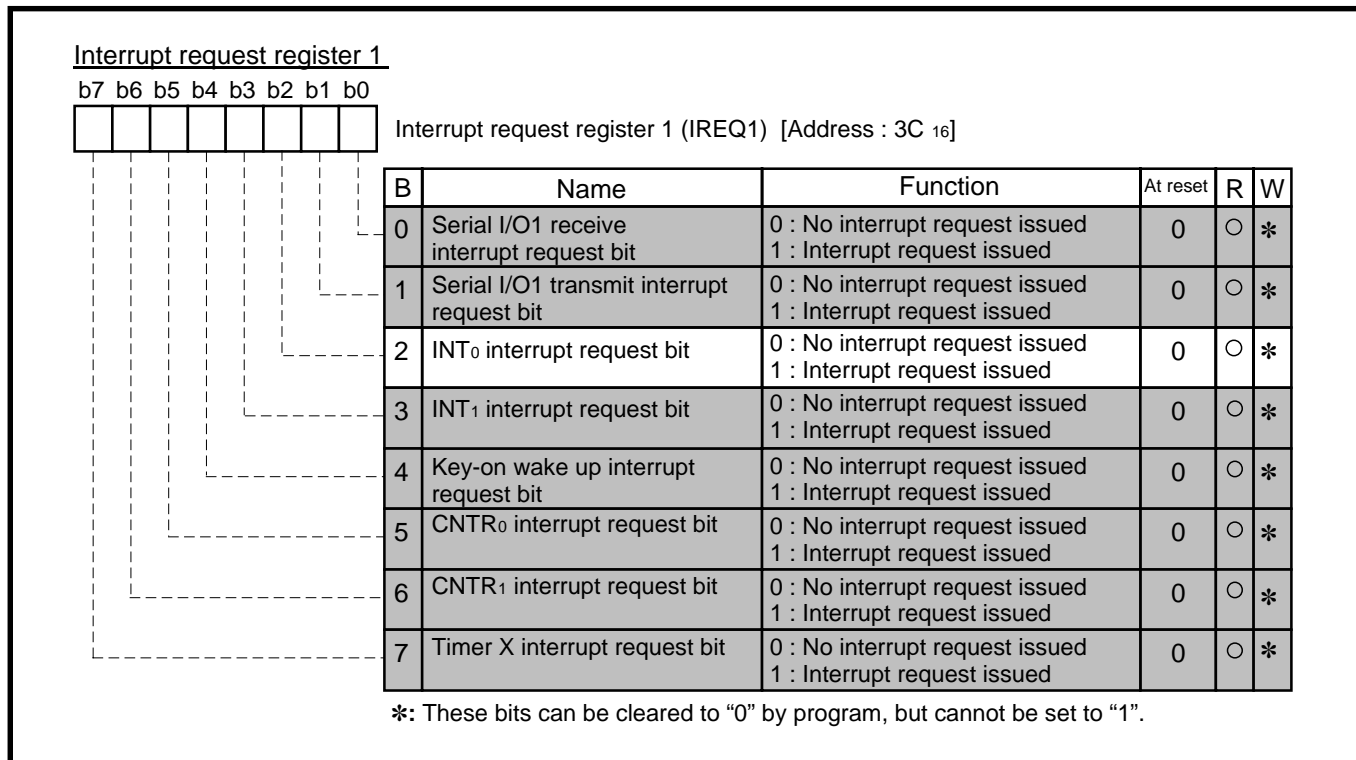


Fig. 2.5.15 Structure of Interrupt request register 1

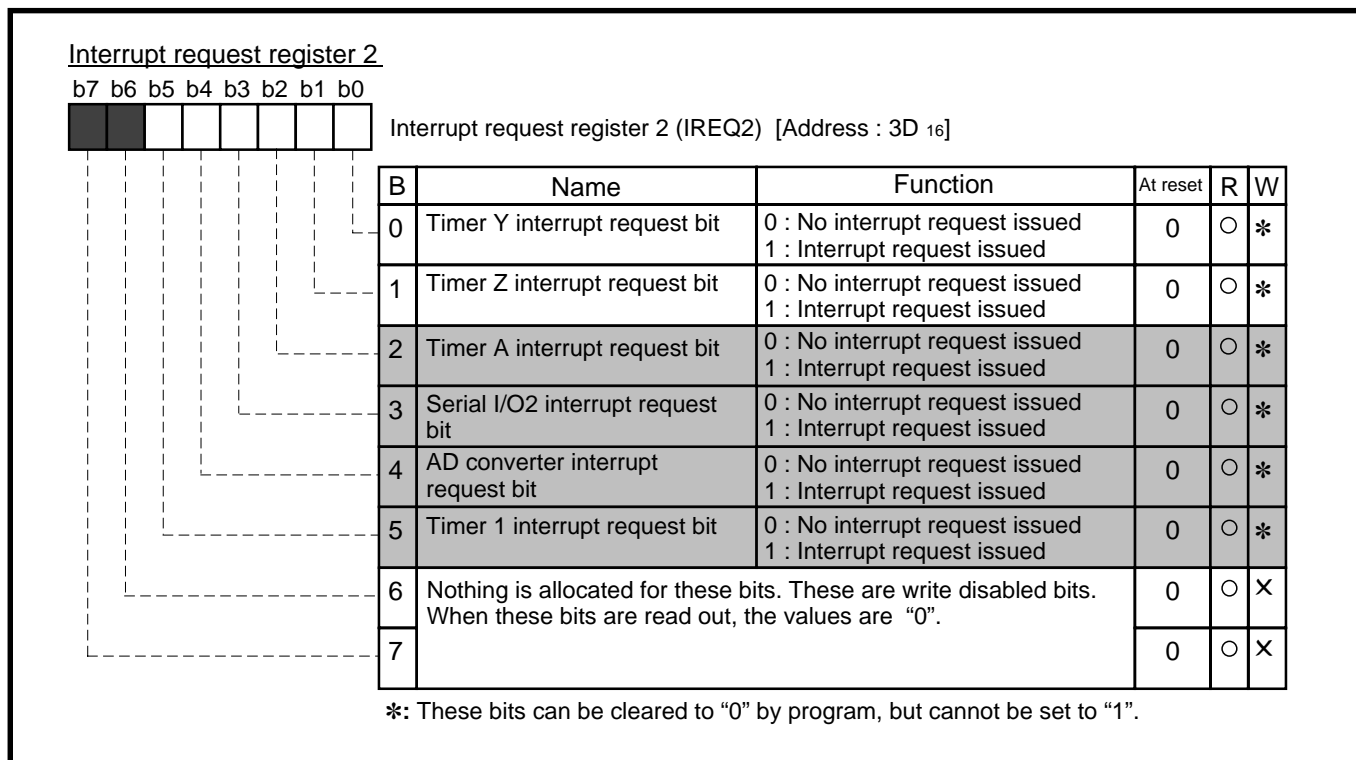


Fig. 2.5.16 Structure of Interrupt request register 2

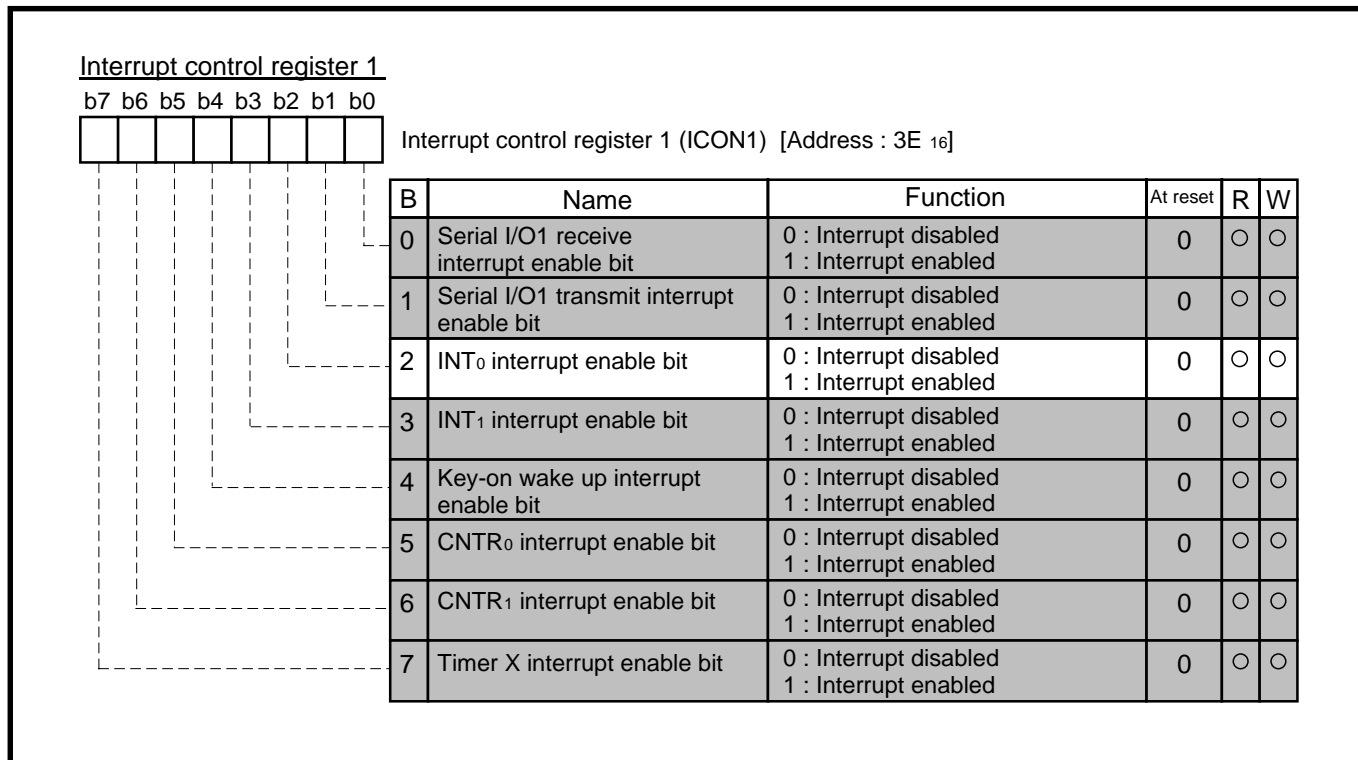


Fig. 2.5.17 Structure of Interrupt control register 1

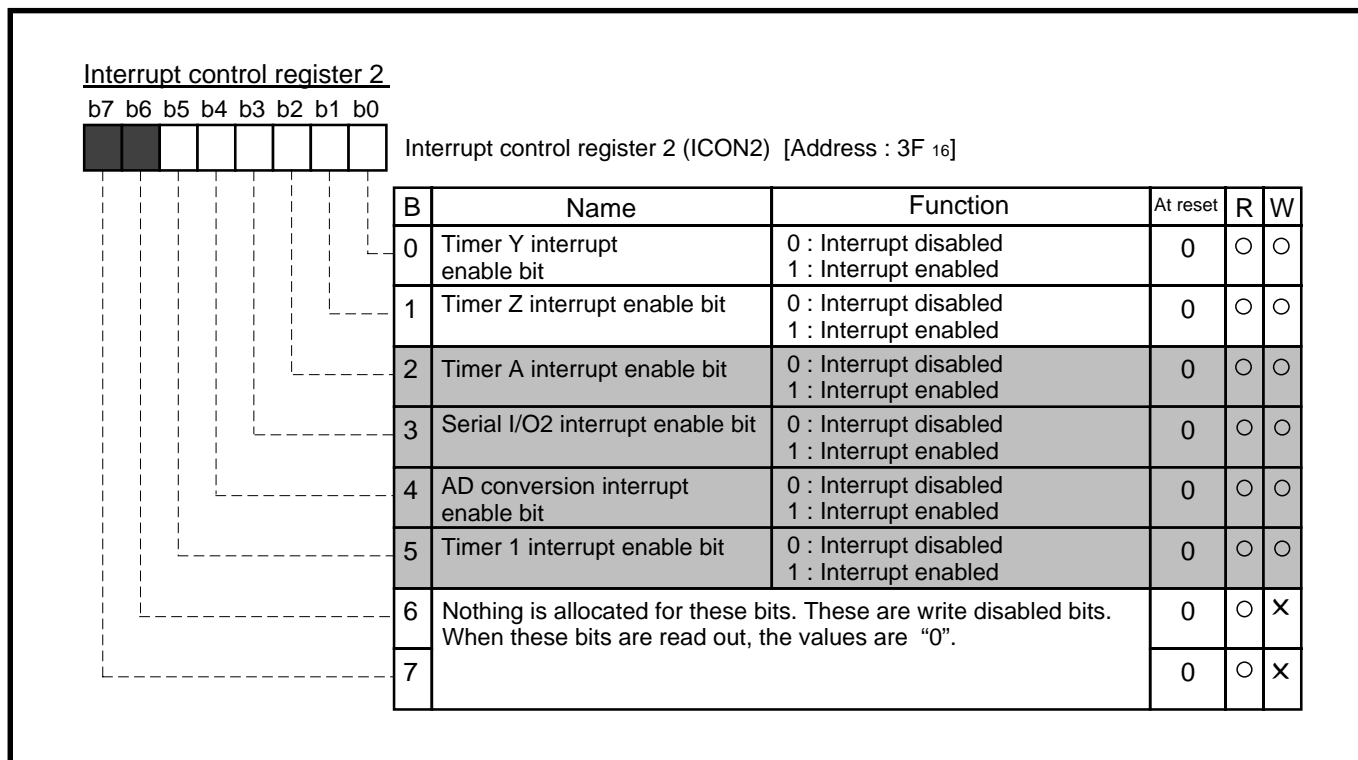


Fig. 2.5.18 Structure of Interrupt control register 2

2.5.3 Timer mode (timer Y and timer Z)

The basic operation of Timer Y and Timer Z are the same. In this section, Timer Y is explained.

(1) Operation description

Prescaler Y counts the count source selected by the timer Y count source selection bits. Each time the count clock is input, the contents of Prescaler Y is decremented by 1.

When the contents of Prescaler Y reach "00₁₆", an underflow occurs at the next count clock, and the prescaler Y latch is reloaded into Prescaler Y and count continues. The division ratio of Prescaler Y is 1/(n+1) provided that the value of Prescaler Y is n.

The contents of Timer Y is decremented by 1 each time the underflow signal of Prescaler Y is input. When the contents of Timer Y reach "00₁₆", an underflow occurs at the next count clock, and the timer Y primary latch is reloaded into Timer Y and count continues.

(In the timer mode, the contents of timer Y primary latch is counted. Timer Y secondary latch is not used in this mode.)

The division ratio of Timer Y is 1/(m+1) provided that the value of Timer Y is m. Accordingly, the division ratio of Prescaler Y and Timer Y is provided as follows that the value of Prescaler Y is n and the value of Timer Y is m.

$$\text{Division ratio} = \frac{1}{(n+1) \times (m+1)}$$

In the timer mode, writing to "latch only" or "latches and Prescaler Y and timer Y primary" can be selected by the setting value of the timer Y write control bit.

Timer Y can stop counting by setting "1" to the timer Y count stop bit.

Also, when timer Y underflows, the timer Y interrupt request bit is set to "1".

Timer Y reloads the value of latch when counting is stopped by the timer count stop bit.

(When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

(2) Timer mode setting method

Figure 2.5.19 shows the setting method for timer mode of Timer Y.

When Timer Z is used, registers are set by the same method.

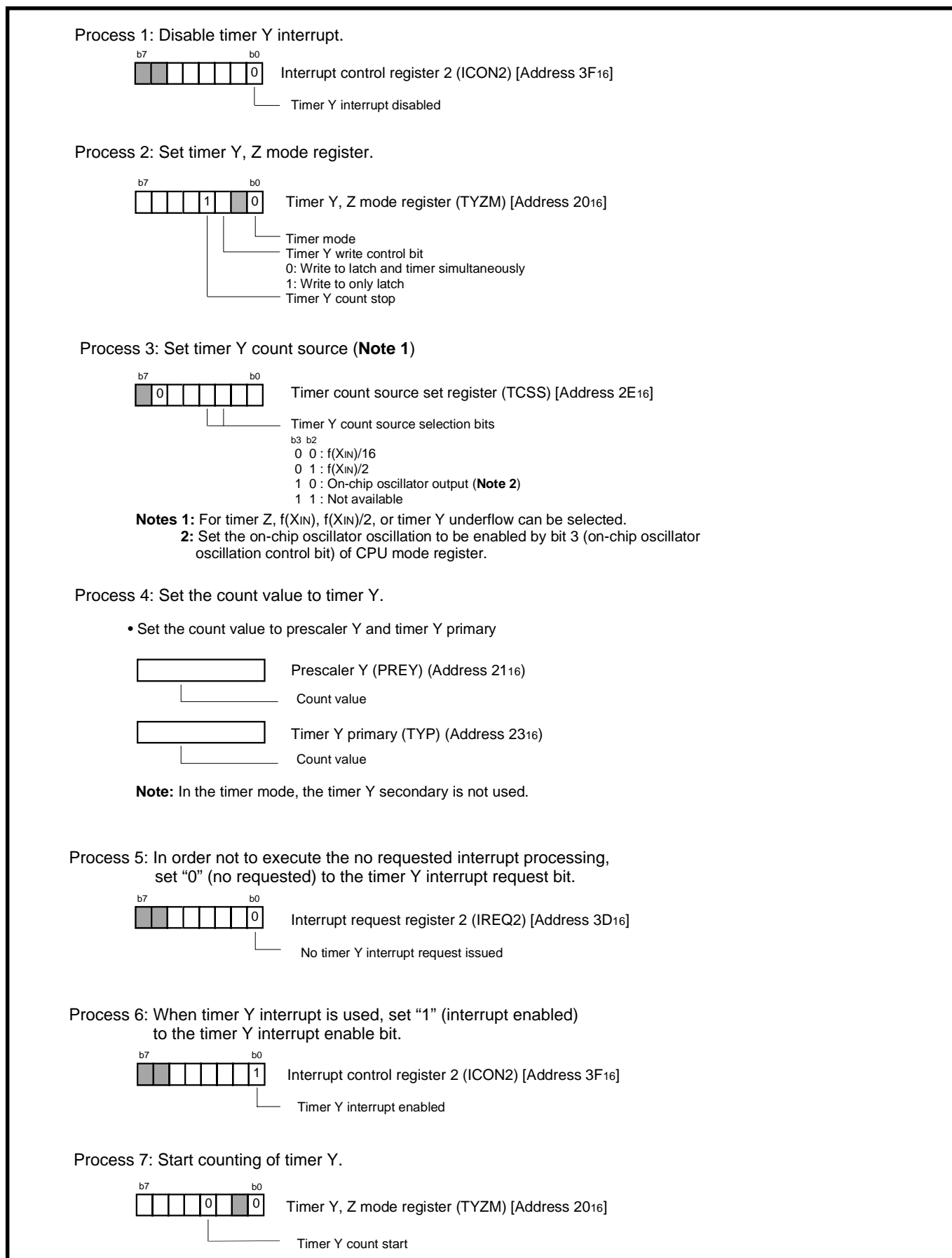


Fig. 2.5.19 Setting method for timer mode

(3) Application example of timer mode

Outline: Pulses generated corresponding to the water flow rate are counted for a fixed period (100 ms), and the water flow rate during this period is calculated.

Specifications: Pulses generated corresponding to the water flow rate are input to the P14/CNTR₁ pin and counted using timer X.

The contents of timer X are read in the timer Y interrupt processing routine generated after 100 ms from the start of counting pulses, and the water flow rate during 100 ms is calculated.

Operation clock: $f(X_{IN}) = 8 \text{ MHz}$, high-speed mode

Figure 2.5.20 shows an example of peripheral circuit, Figure 2.5.21 shows the method of measuring water flow rate, and Figure 2.5.21 shows an example of control procedure.

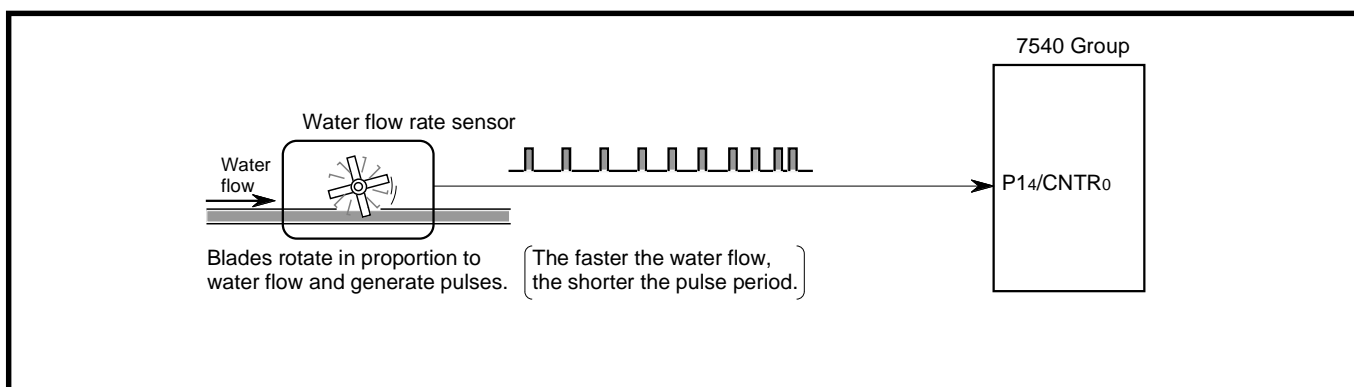


Fig. 2.5.20 Example of peripheral circuit

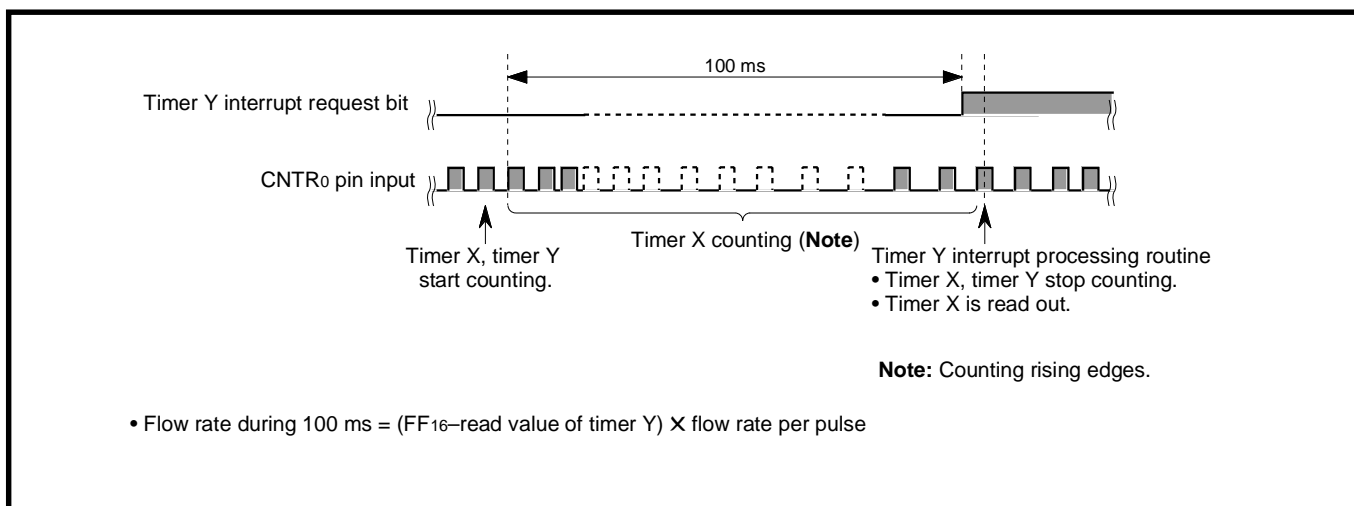


Fig. 2.5.21 Method of measuring water flow rate

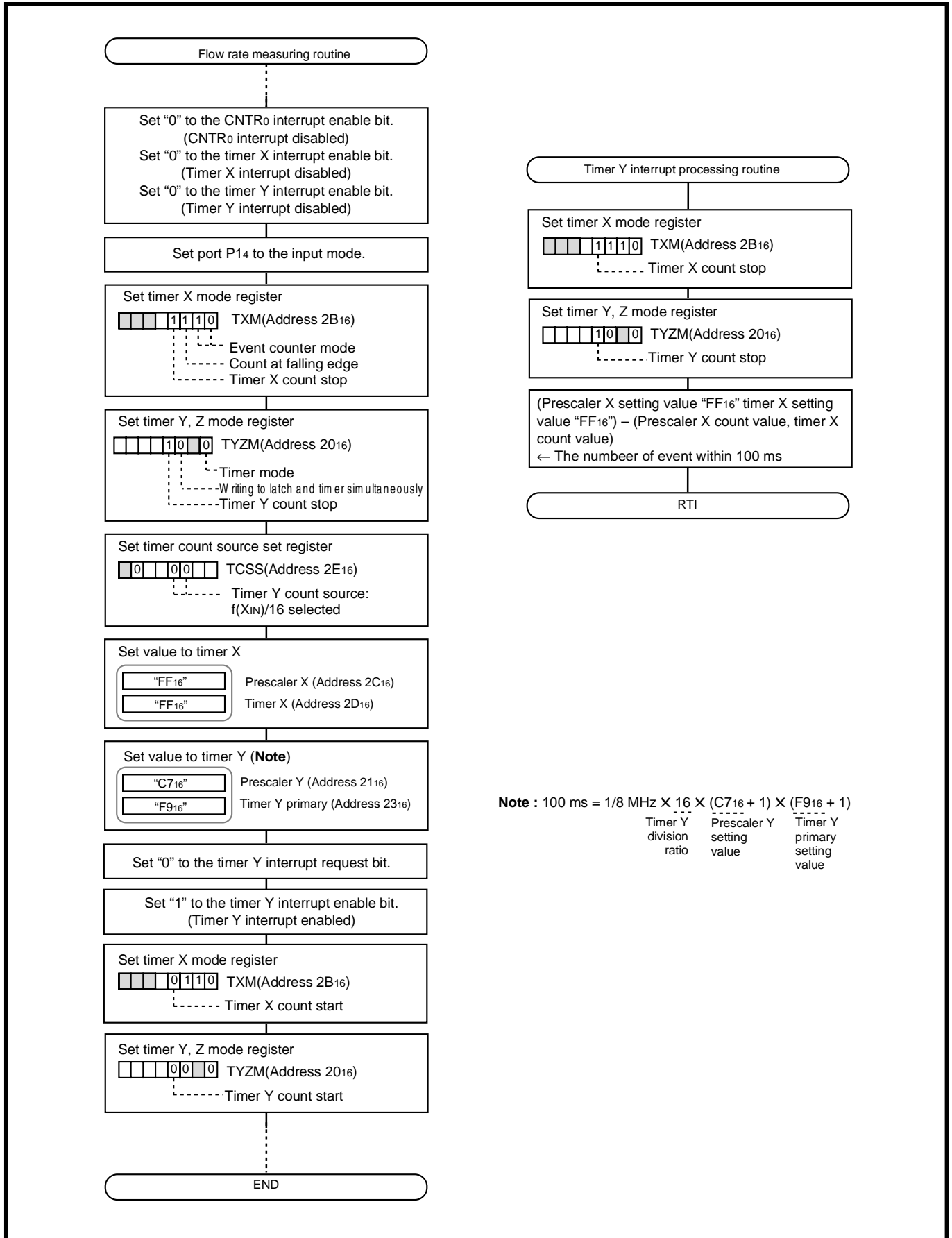


Fig. 2.5.22 Example of control procedure

2.5.4 Programmable waveform generation mode (timer Y and timer Z)

The basic operation of Timer Y and Timer Z are the same. In this section, Timer Y is explained.

(1) Operation description

In the programmable waveform generation mode, timer counts the setting value of timer Y primary (TYP) and the setting value of timer Y secondary (TYS) alternately, the waveform whose polarity is inverted each time Timer Y underflows is output from P0₁/TY_{OUT} pin.

When using this mode, be sure to set "1" to the timer Y write control bit to select "write to latch only". Also, set the port P0₁ direction registers to output mode.

The active edge of output waveform is set by the timer Y output level latch. When "0" is set to the timer Y output level latch, "H" interval by the setting value of TYP or "L" interval by the setting value of TYS is output alternately. When "1" is set to the timer Y output level latch, "L" interval by the setting value of TYP or "H" interval by the setting value of TYS is output alternately.

Also, in this mode, the primary interval and the secondary interval of the output waveform can be extended respectively for 0.5 cycle of timer count source clock by setting the timer Y primary waveform extension control bit (b2) and the timer Y secondary waveform extension control bit (b3) of PUM to "1". As a result, the waveforms of more accurate resolution can be output.

When b2 and b3 of PUM are used, the frequency and duty of the output waveform are as follows;

$$\text{Waveform frequency: FYOUT} = \frac{2 \times (\text{TMYCL})}{(2 \times (\text{TYP}+1)+\text{EXPYP})+(2 \times (\text{TYS}+1)+\text{EXPYS})}$$

$$\text{Duty: DYOUT} = \frac{2 \times (\text{TYP}+1)+\text{EXPYP}}{(2 \times (\text{TYP}+1)+\text{EXPYP})+(2 \times (\text{TYS}+1)+\text{EXPYS})}$$

TMYCL: Timer Y count source (frequency)

TYP: Timer Y primary

TYS: Timer Y secondary

EXPYP (1 bit): Timer Y primary waveform extension control bit

EXPYS (1 bit): Timer Y secondary waveform extension control bit

In the programmable waveform generation mode, when values of the TYP, TYS, EXPYP and EXPYS are changed, the output waveform is changed at the beginning (timer Y primary waveform interval) of waveform period.

When the count values are changed, set values to the TYS, EXPYP and EXPYS first. After then, set the value to TYP. The values are set all at once at the beginning of the next waveform period when the value is set to TYP. (When writing at timer stop is executed, writing to TYP at last is required.)

Timer Y can stop counting by setting "1" to the timer Y count stop bit.

Also, when timer Y underflows, the timer Y interrupt request bit is set to "1".

Timer Y reloads the value of latch when counting is stopped by the timer Y count stop bit. (When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

- Notes 1:** In the programmable waveform generation mode, values of TYS, EXPYP, and EXPYS are valid by writing to TYP because the setting to them is executed all at once by writing to TYP. Even when changing TYP is not required, write the same value again.
- 2:** In the programmable waveform generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TYP and the timing of timer underflow during the secondary interval simultaneously.
An example of a measurement is shown below.
ex.) The underflow by the primary and the underflow by secondary are stored by polling etc. using timer Y interrupt.
Writing is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.
(Depending on a primary and a secondary setting values, and primary write timing, it may be impossible.)
- 3:** The waveform extension function by the timer Y waveform extension control bits can be used only when "00₁₆" is set to Prescaler Y.
When the value other than "00₁₆" is set to Prescaler Y, be sure to set "0" to EXPYP and EXPYS.
The waveform extension function by the timer Z waveform extension control bits can be used only when "00₁₆" is set to Prescaler Z. When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
- 4:** When using this mode, be sure to set "1" to the timer Y write control bit to select "write to latch only".
- 5:** When TYS is read out, the undefined value is read out. However, while timer Y counts the setting value of TYS, the count value during the secondary interval can be obtained by reading the timer Y primary.
- 6:** In order to use TY_{OUT} pin, set "1" to bit 1 of the port P0 direction register (output mode).

Figure 2.5.23 shows the timing diagram of the programmable waveform generation mode.

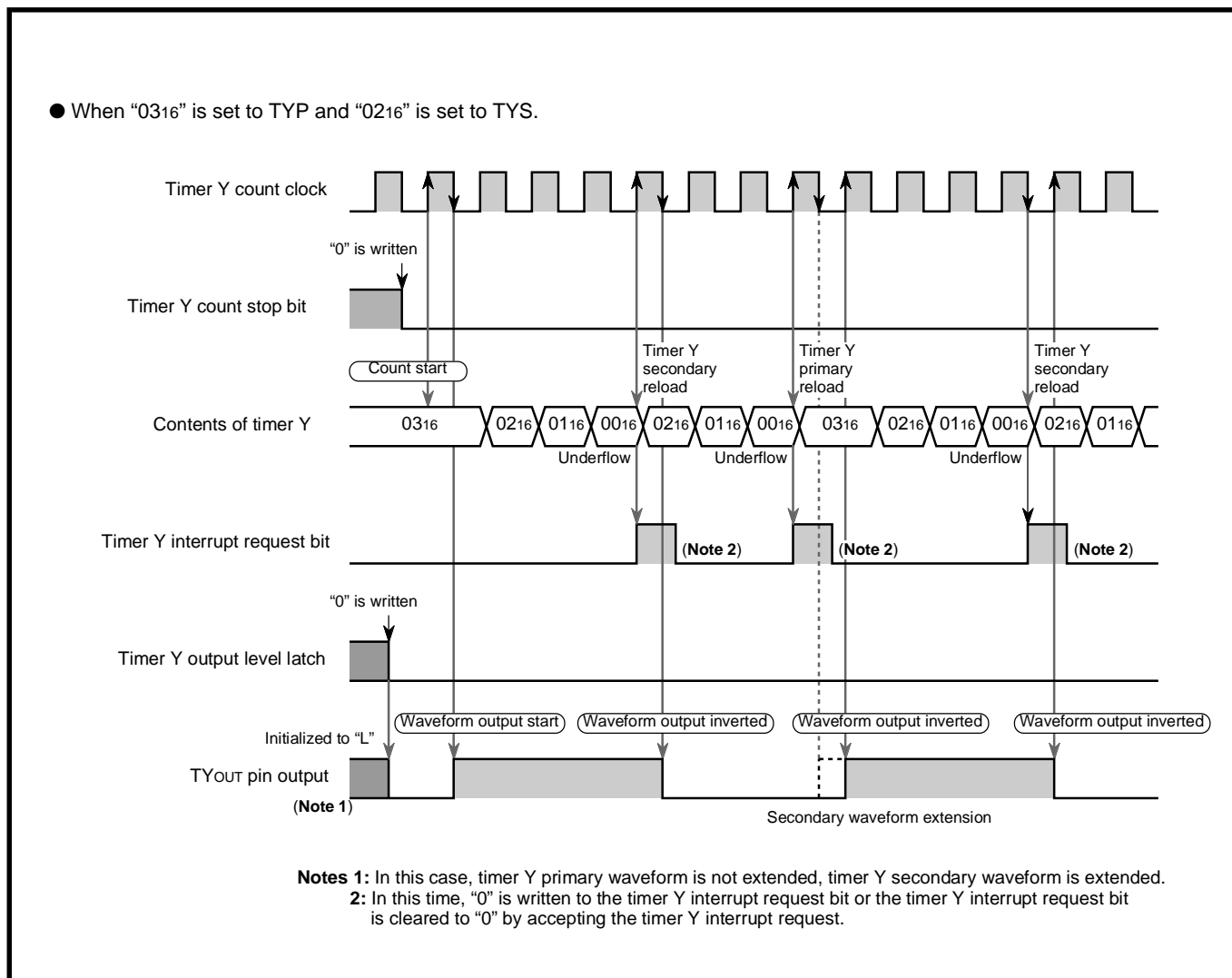


Fig. 2.5.23 Timing diagram of programmable waveform generation mode

(2) Programmable waveform generation mode setting method

Figure 2.5.24 and Figure 2.5.25 show the setting method for programmable waveform generation mode of timer Y.

When timer Z is used, registers are set by the same method.

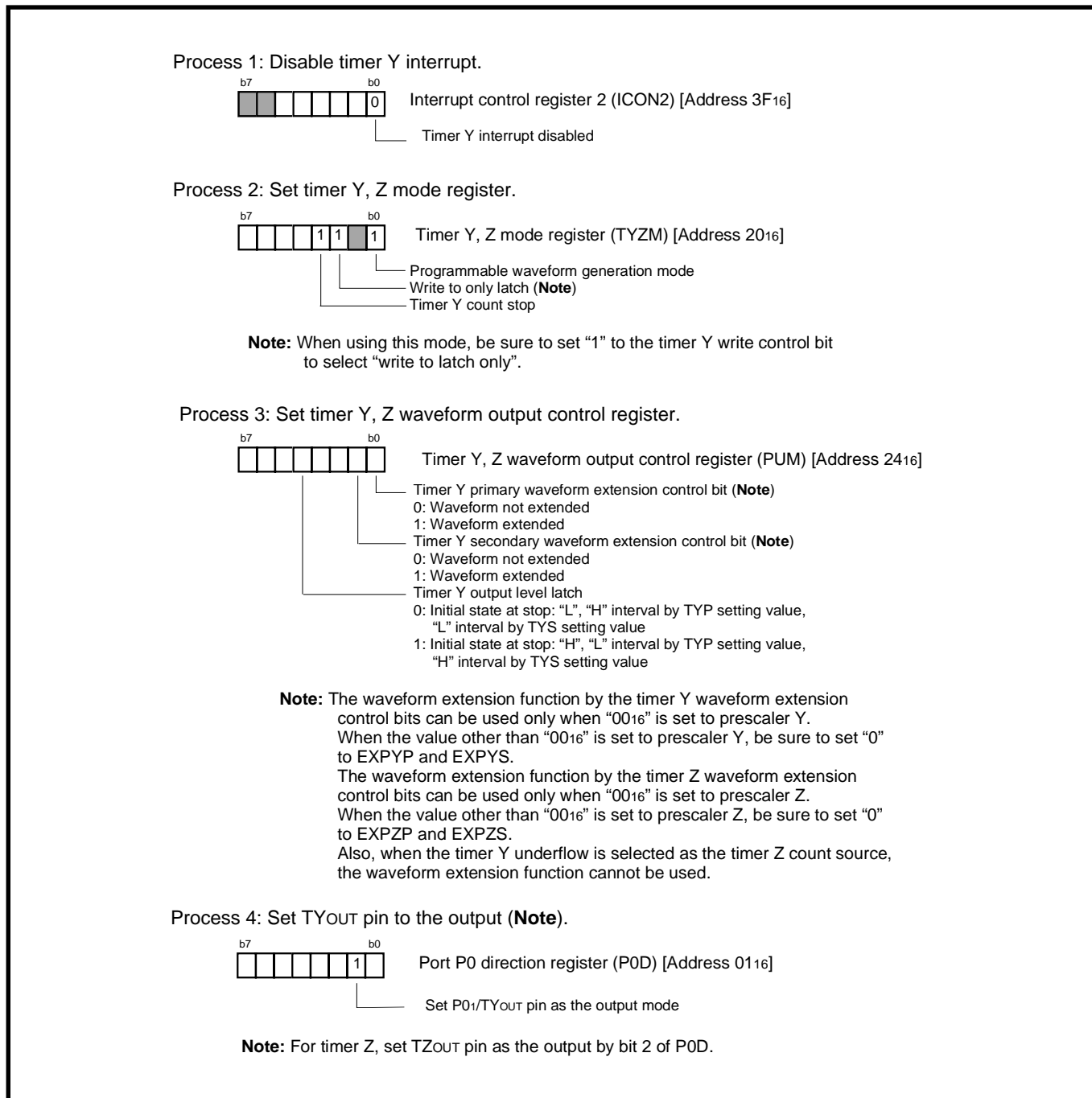
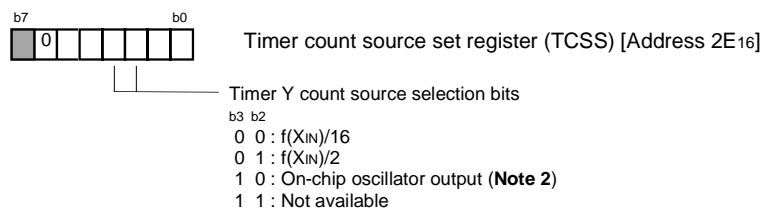


Fig. 2.5.24 Setting method for programmable waveform generation mode (1)

Process 5: Set timer Y count source (**Note 1**).

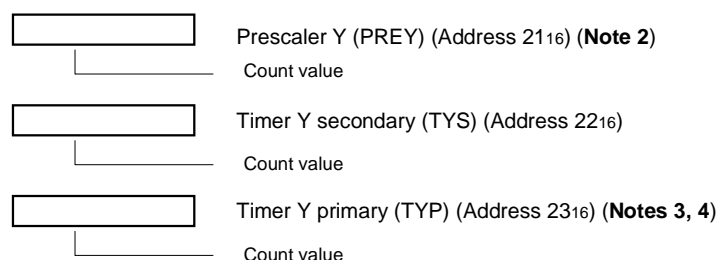


Notes 1: For Timer Z, $f(X_{IN})/16$, $f(X_{IN})/2$, or timer Y underflow can be selected. However, when the timer Z waveform expansion function is used, do not select the timer Y underflow for the timer Z count source.

2: Set the on-chip oscillator oscillation to be enabled by bit 3 (on-chip oscillator oscillation control bit) of CPU mode register.

Process 6: Set the count value to timer Y (**Note 1**).

- Set the count value to prescaler Y, timer Y secondary and timer Y primary



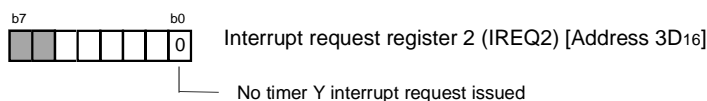
Notes 1: In the programmable waveform generation mode, values of TYS, EXPYP, and EXPYS are valid by writing to TYP. Even when changing TYP is not required, write the same value again.

2: When the timer Y waveform extension function is used, be sure to set "0016" to prescaler Y.

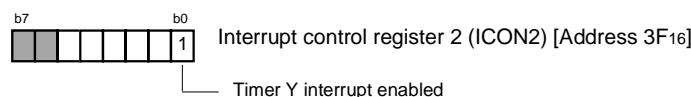
3: In the programmable waveform generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TYP and the timing of timer Y underflow during the secondary interval simultaneously.

4: Count values of the primary interval and secondary interval can be checked by reading the TYP (TYS is undefined at read).

Process 7: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer Y interrupt request bit.



Process 8: When Timer Y interrupt is used, set "1" (interrupt enabled) to the timer Y interrupt enable bit.



Process 9: Start counting of timer Y.

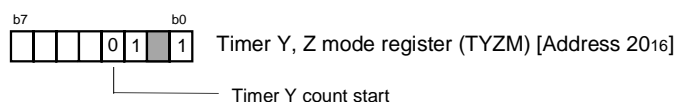


Fig. 2.5.25 Setting method for programmable waveform generation mode (2)

(3) Application example of programmable waveform generation mode

Outline: The waveform extension function is used and the waveform output is executed.

Specifications: The "H" width generated by TYP and the "L" width generated by TYS are output. Set each waveform extension function to be valid, and set the duty ratio to be 2:1. The frequency is 40 kHz.

Operation clock: $f(X_{IN}) = 8 \text{ MHz}$, high-speed mode

Figure 2.5.26 shows an example of waveform output and Figure 2.5.27 shows an example of control procedure.

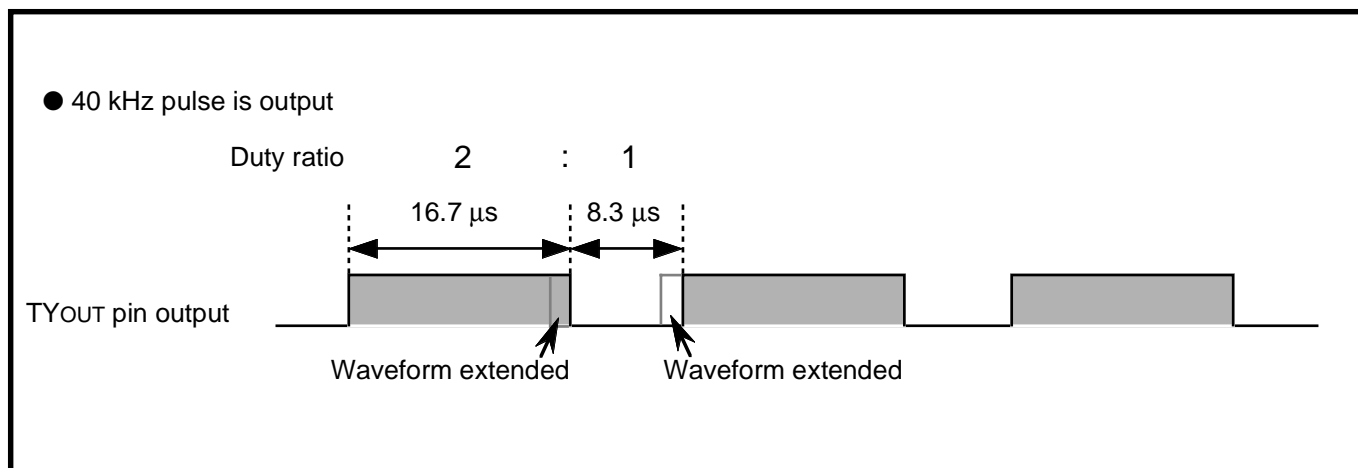


Fig. 2.5.26 Example of waveform output

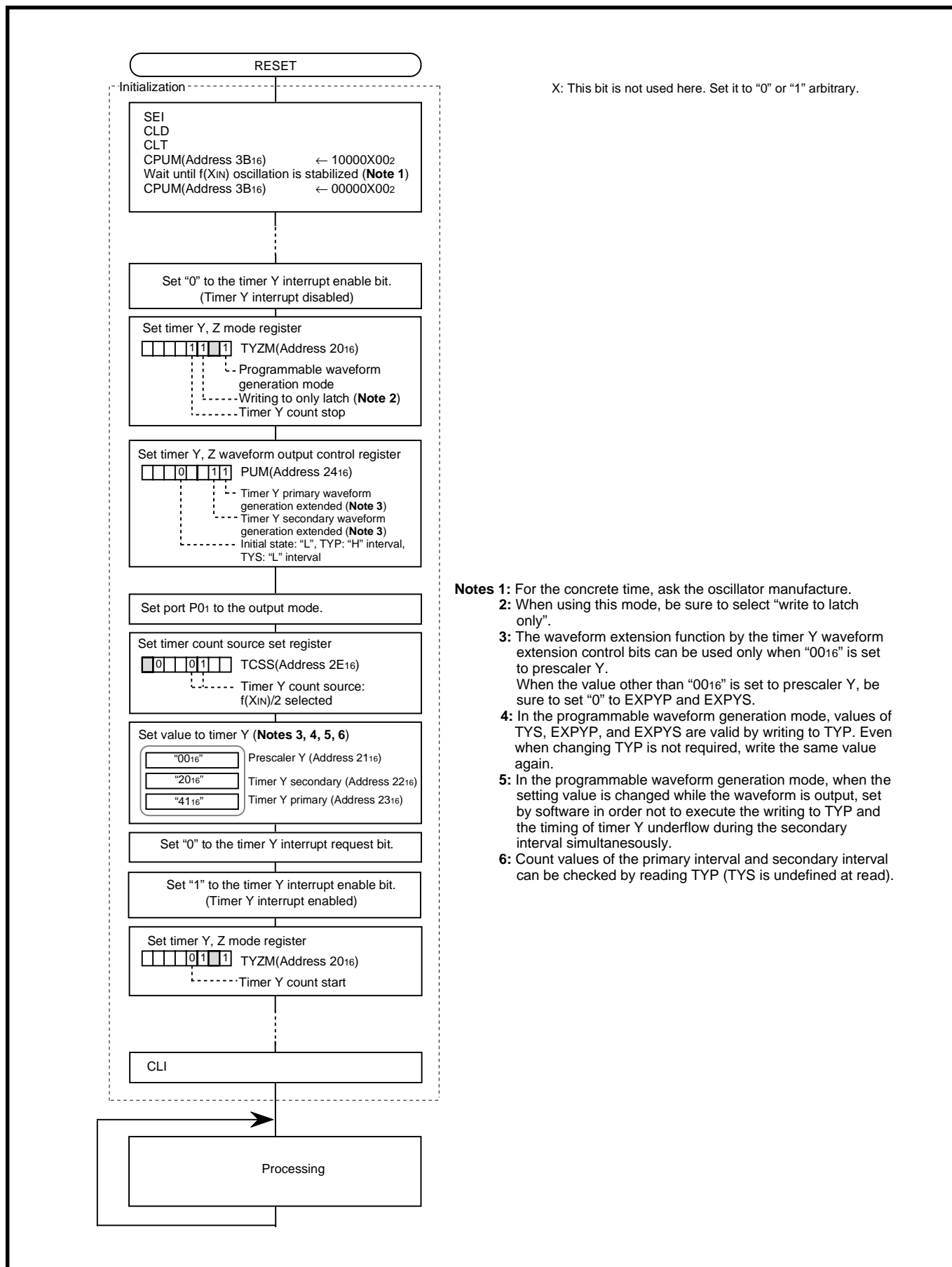


Fig. 2.5.27 Example of control procedure

2.5.5 Programmable one-shot generation mode (timer Z)

(1) Operation description

In the programmable one-shot generation mode, the one-shot pulse by the setting value of timer Z primary can be output from P0₂/TZ_{OUT} pin by software or external trigger to the P3₇/INT₀ pin. When using this mode, be sure to set “1” to the timer Z write control bit to select “write to latch only”. Also, set the port P0₂ direction registers to output mode. In this mode, the timer Z secondary (TZS) is not used.

The active edge of output waveform is set by the timer Z output level latch. When “0” is set to the timer Z output level latch, “H” pulse during the interval of the timer Z primary (TZP) setting value is output. When “1” is set to the timer Z output level latch, “L” pulse during the interval of the TZP setting value is output.

Also, in this mode, the interval of the one-shot pulse output can be extended for 0.5 cycle of timer count source clock by setting the timer Z primary waveform extension control bit (EXPZP) to “1”.

As a result, the waveforms of more accurate resolution can be output.

During the one-shot pulse output interval, the one-shot pulse output can be stopped forcibly by writing “0” to the timer Z one-shot start bit.

In the programmable one-shot generation mode, when the count values are changed, set value to the EXPZP first. After then, set the value to TZP. The values are set all at once at the beginning of the next one-shot pulse when the value is set to TZP. (Even when writing at timer stop is executed, writing to TZP at last is required.)

Timer Z can stop counting by setting “1” to the timer Z count stop bit.

Also, when timer Z underflows, the timer Z interrupt request bit is set to “1”.

Timer Z reloads the value of latch when counting is stopped by the timer Z count stop bit.

(When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

Notes 1: In the programmable one-shot generation mode, the value of EXPZP becomes valid by writing to TZP. Even when changing TZP is not required, write the same value again.

2: In the programmable one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow simultaneously.

An example of a measurement is shown below.

ex.) The underflow of timer is stored by polling etc. using timer Z interrupt.

Writing to primary is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.

(Depending on a primary setting value, primary write timing, software and timing of external trigger to INT₀ pin, it may be impossible.)

3: The waveform extension function by the timer Z waveform extension control bits can be used only when “00₁₆” is set to Prescaler Z.

When the value other than “00₁₆” is set to Prescaler Z, be sure to set “0” to EXPZP. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.

4: When using this mode, be sure to set “1” to the timer Z write control bit to select “write to latch only”.

5: In order to use TZ_{OUT} pin, set “1” to bit 2 of the port P0 direction register (output mode).

6: Stop Timer Z to change the INT₀ pin one-shot trigger control bit and INT₀ pin one-shot trigger active edge selection bit.

Figure 2.5.28 shows the timing diagram of the programmable one-shot generation mode.

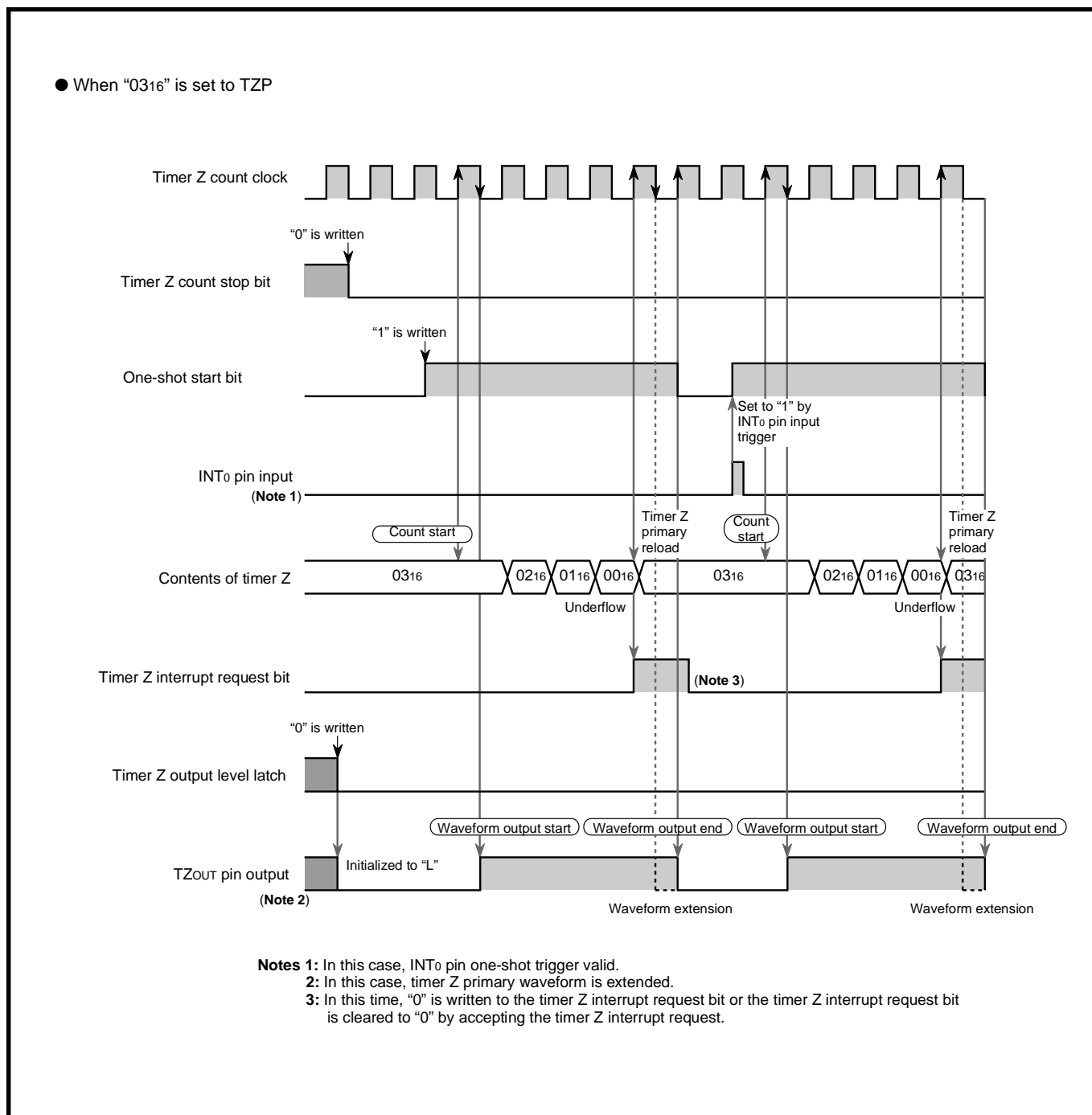


Fig. 2.5.28 Timing diagram of programmable one-shot generation mode

(2) Event counter mode setting method

Figure 2.5.29 to Figure 2.5.31 show the setting method for programmable one-shot generation mode of timer Z.

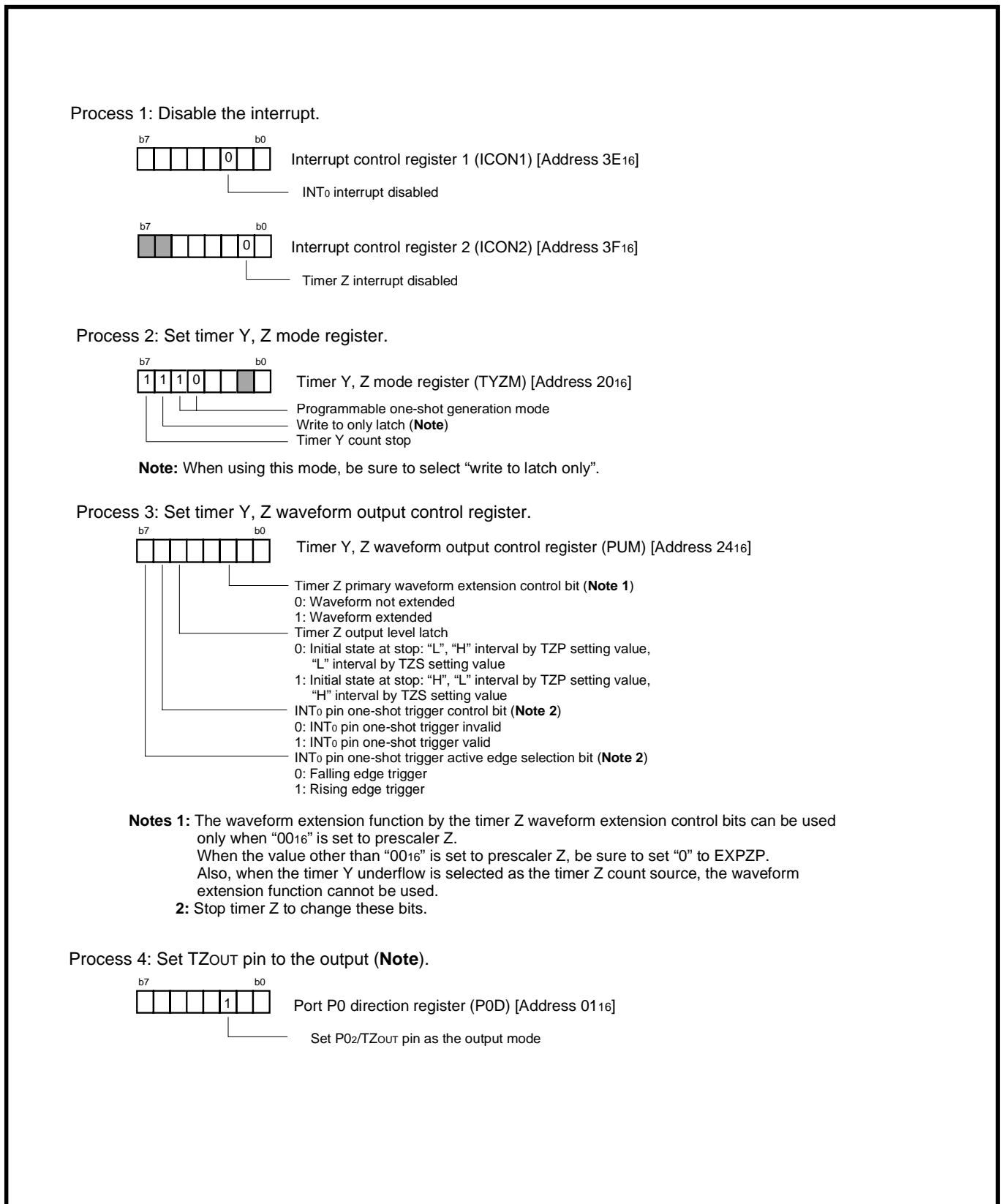
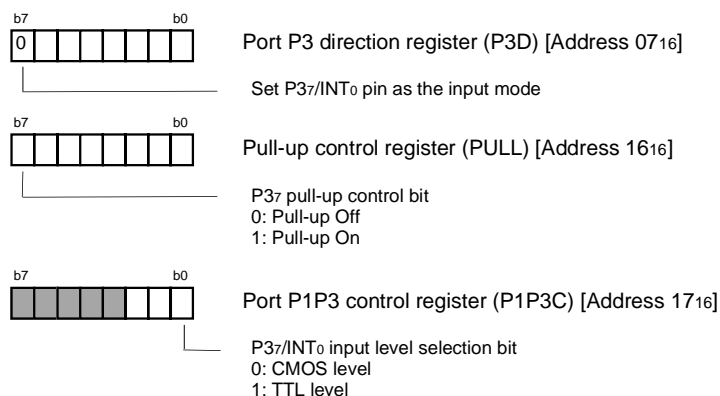


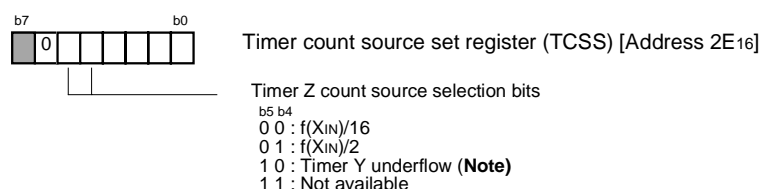
Fig. 2.5.29 Setting method for programmable one-shot generation mode (1)

Process 5: When the trigger by INT0 pin input is selected:

Set port P3 direction register, pull-up control register and port P1P3 control register



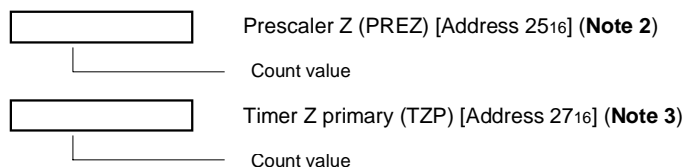
Process 6: Set the timer Z count source.



Note: When the timer Z waveform extension function is used, do not select the timer Y underflow as the timer Z count source.

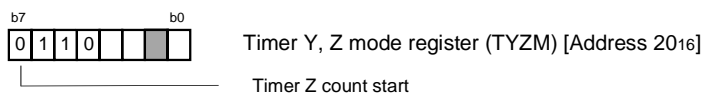
Process 7: Set the one-shot pulse width (**Note 1**).

- Set the count value to prescaler Z and timer Z primary



- Notes 1:** In the programmable one-shot generation mode, TZS is not used. When the count setting value is changed, value of EXPZP is valid by writing to TZP. Even when changing TZP is not required, write the same value again.
- 2:** When the timer Z waveform extension function is used, be sure to set "00₁₆" to prescaler Z.
- 3:** In the programmable one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer Z underflow simultaneously.

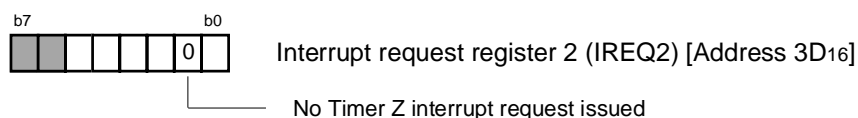
Process 8: Set the standby state to accept the one-shot start trigger (**Note**).



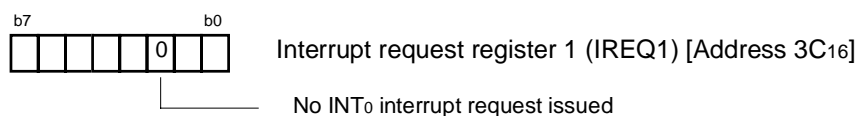
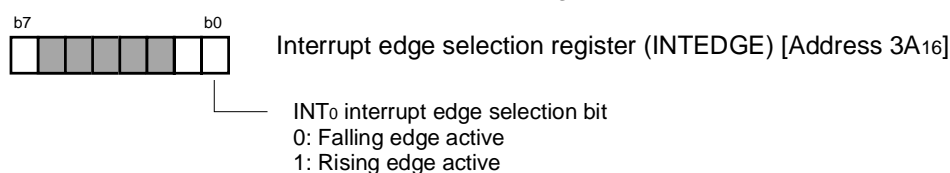
Note: When the INT0 pin one-shot trigger control bit of PUM is set to "valid", timer Z counting is started by the input of trigger to INT0 pin after this setting.

Fig. 2.5.30 Setting method for programmable one-shot generation mode (2)

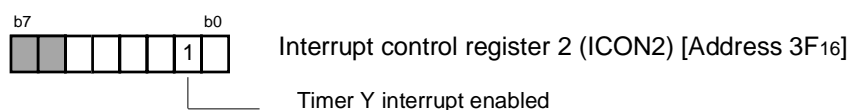
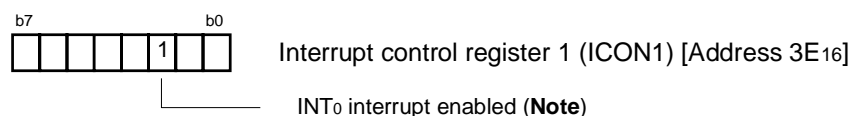
Process 9: In order not to execute the no requested interrupt processing, set "0" (no requested) to the timer Z interrupt request bit.



- When the INT₀ pin one-shot trigger control bit of PUM is set to "valid" and the INT₀ interrupt is used, set the following;

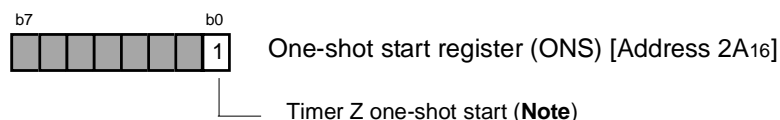


Process 10: When the interrupt is used, set "1" (interrupt enabled) to the corresponding interrupt enable bit.



Note: When the INT₀ pin one-shot trigger control bit is set to "valid", the INT₀ interrupt can be accepted after this setting.

Process 11: Start counting of timer Z.



- When the INT₀ pin one-shot trigger control bit of PUM is set to "valid", the timer Z count is started by input of trigger to the INT₀ pin.

Note: Pulse is output from TZOUT pin. After output, this bit is initialized to "0".

Fig. 2.5.31 Setting method for programmable one-shot generation mode (3)

(3) Application example of programmable one-shot generation mode

Outline: The phase control signal to the load is output by using the programmable one-shot generation mode of Timer Z.

Specifications: The phase control signal to the load is output from the P0₂/TZ_{OUT} pin using the programmable one-shot generation mode of timer Z.

- Count source: $f(X_{IN})/16$
- Rising edges of the signal input to the P3₇/INT₀ pin from the trigger detection circuit are detected.
- A triac is turned on at the "H" level.
The period of the feedback signal input from the load is measured, analyzed, and used to adjust the phase control signal.
Operation clock: $f(X_{IN}) = 8 \text{ MHz}$, high-speed mode

For the measurement of the period of the feedback signal, refer to the period measurement mode of the using timer.

Figure 2.5.32 shows an example of peripheral circuit, Figure 2.5.33 shows an example of an operation timing, and Figure 2.5.34 shows an example of a control procedure.

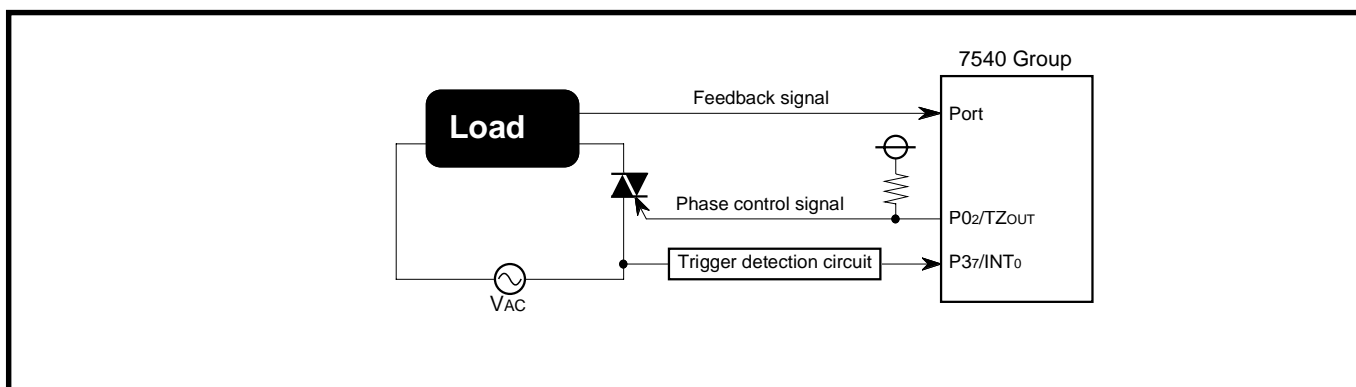


Fig. 2.5.32 Example of peripheral circuit

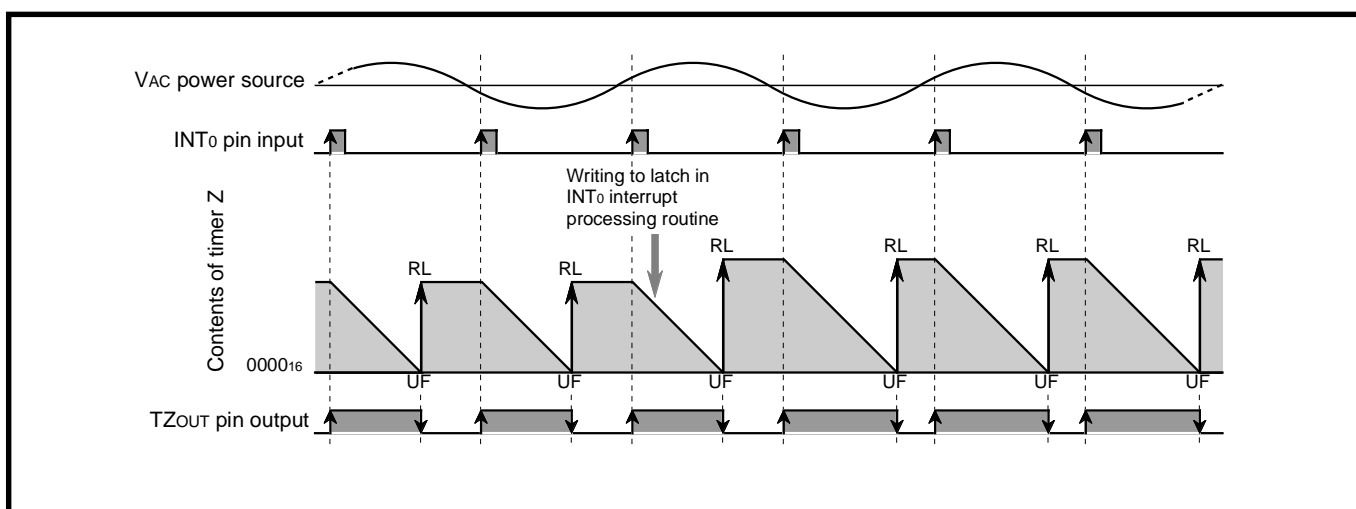


Fig. 2.5.33 Example of operation timing

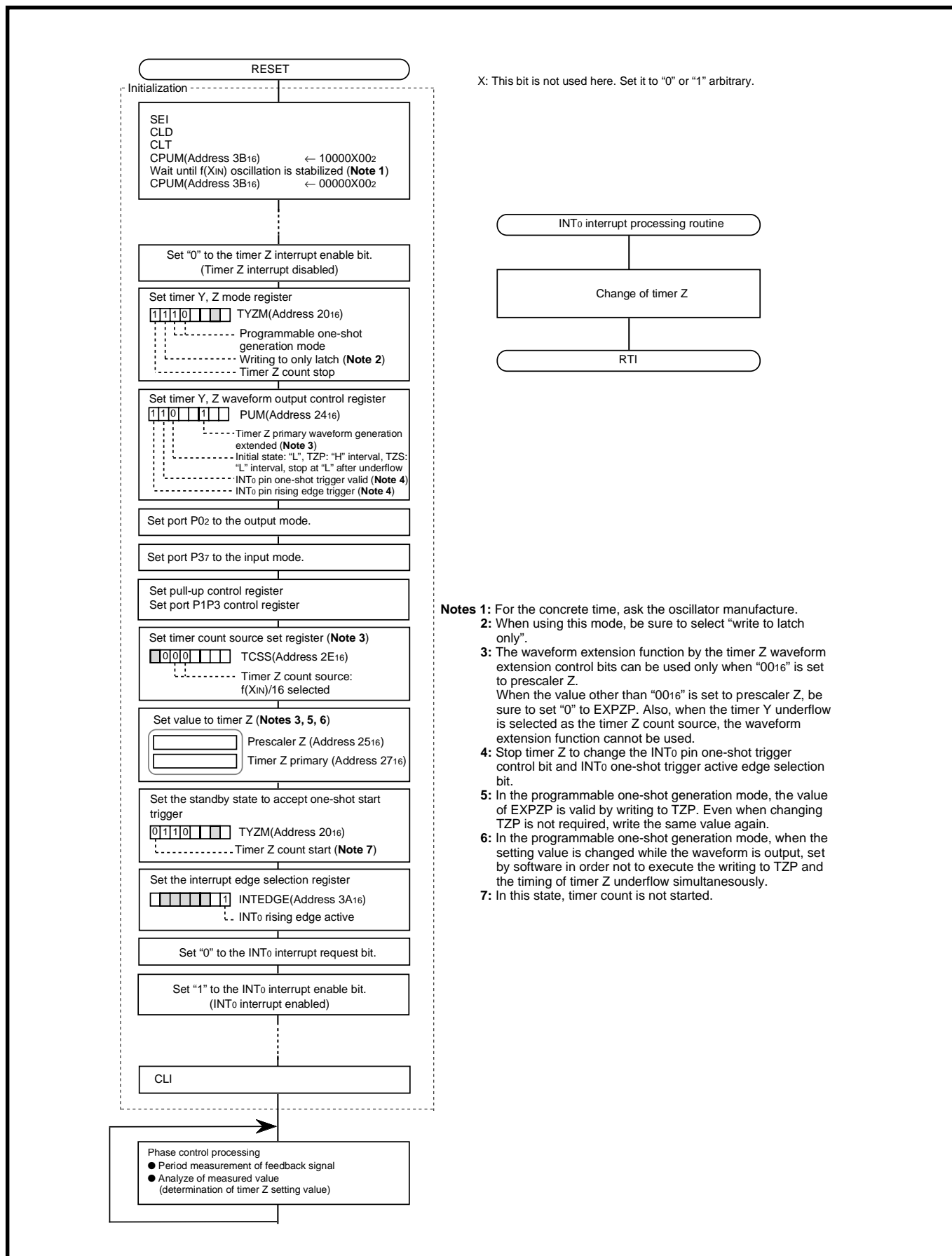


Fig. 2.5.34 Example of control procedure

2.5.6 Programmable wait one-shot generation mode (timer Z)

(1) Operation description

In the programmable wait one-shot generation mode, the one-shot pulse by the setting value of timer Z secondary (TZS) can be output from P0₂/TZ_{OUT} pin by software or external trigger to P3₇/INT₀ pin after the wait by the setting value of the timer Z primary (TZP). When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only". Also, set the port P0₂ direction registers to output mode.

The active edge of output waveform is set by the timer Z output level latch. When "0" is set to the timer Z output level latch, after the wait during the interval of the TZP setting value, "H" pulse during the interval of the TZS setting value is output. When "1" is set to the timer Z output level latch, after the wait during the interval of the TZP setting value, "L" pulse during the interval of the TZS setting value is output.

Also, in this mode, the intervals of the wait and the one-shot pulse output can be extended for 0.5 cycle of timer count source clock by setting the timer Z primary waveform extension control bit (EXPZP) and the timer Z secondary waveform extension control bit (EXPZS) to "1". As a result, the waveforms of more accurate resolution can be output.

In the programmable wait one-shot generation mode, the trigger by software or the external INT₀ pin can be accepted by writing "0" to the timer Z count stop bit after the count value is set. (At the time when "0" is written to the timer Z count stop bit, Timer Z stops.)

By writing "1" to the timer Z one-shot start bit, or by inputting the valid trigger to the INT₀ pin after the trigger to the INT₀ pin becomes valid by writing "1" to the INT₀ pin one-shot trigger control bit, Timer Z starts counting.

While Timer Z counts the TZP, the initial value of the TZ_{OUT} pin output is retained. When Timer Z underflows, the value of TZS is reloaded, at the same time, the output of TZ_{OUT} pin is inverted.

When Timer Z underflows, the output of TZ_{OUT} pin is inverted again and Timer Z stops. When also the trigger of INT₀ pin is accepted, the contents of the one-shot start bit is changed to "1" by hardware.

The falling or rising can be selected as the edge of the valid trigger of INT₀ pin by the INT₀ pin one-shot trigger edge selection bit.

During the wait interval and the one-shot pulse output interval, the one-shot pulse output can be stopped forcibly by writing "0" to the timer Z one-shot start bit.

In the programmable wait one-shot generation mode, when the count values are changed, set values to the TZS, EXPZP and EXPZS first. After then, set the value to TZP. The values are set all at once at the beginning of the next wait interval when the value is set to TZP. (When writing at timer stop is executed, writing to TZP at last is required.)

Timer Z can stop counting by setting "1" to the timer Z count stop bit.

Also, when timer Z underflows, the timer Z interrupt request bit is set to "1".

Timer Z reloads the value of latch when counting is stopped by the timer Z count stop bit.

(When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

- Notes 1:** In the programmable wait one-shot generation mode, values of TZS, EXPZP and EXPZS are valid by writing to TZP. Even when changing TZP is not required, write the same value again.
- 2:** In the programmable wait one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow during the secondary interval simultaneously.
An example of a measurement is shown below.
ex.) The underflow by the primary and the underflow by secondary are stored by polling etc. using timer Z interrupt.
Writing to primary is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.
(Depending on a primary setting value, primary write timing, software and timing of external trigger to INT₀ pin, it may be impossible.)
- 3:** The waveform extension function by the timer Z waveform extension control bits can be used only when "00₁₆" is set to Prescaler Z.
When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
- 4:** When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".
- 5:** When TZS is read out, the undefined value is read out. However, while Timer Z counts the setting value of TZS (during one-shot output), the count value during the secondary interval can be obtained by reading TZP.
- 6:** In order to use TZ_{OUT} pin, set "1" to bit 2 of the port P0 direction register (output mode).
- 7:** Stop Timer Z to change the INT₀ pin one-shot trigger control bit and INT₀ pin one-shot trigger active edge selection bit.

Figure 2.5.35 shows the timing diagram of the programmable wait one-shot generation mode.

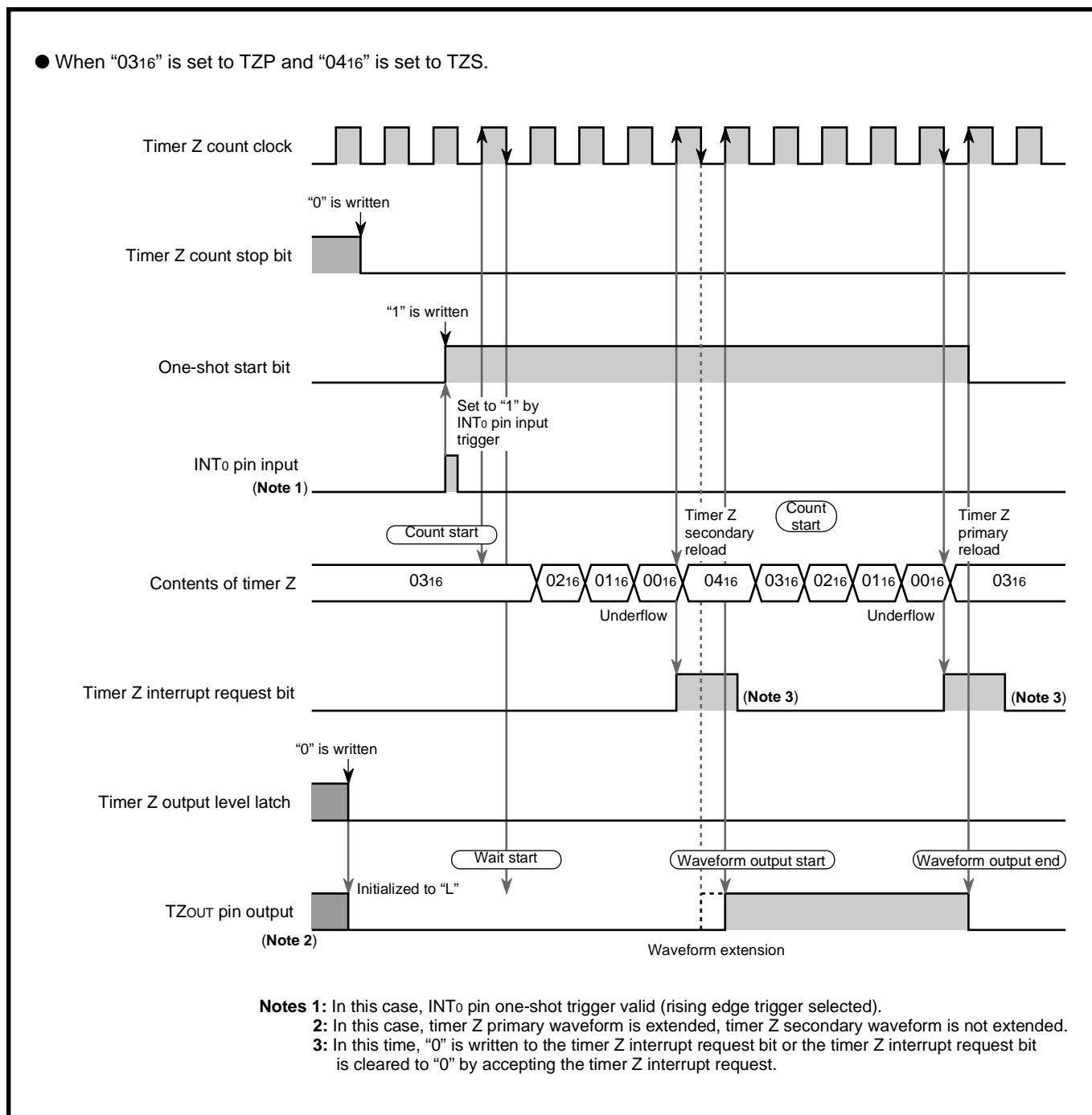


Fig. 2.5.35 Timing diagram of programmable wait one-shot generation mode

(2) Programmable wait one-shot generation mode setting method

Figure 2.5.36 to Figure 2.5.38 show the setting method for programmable wait one-shot generation mode of Timer Z.

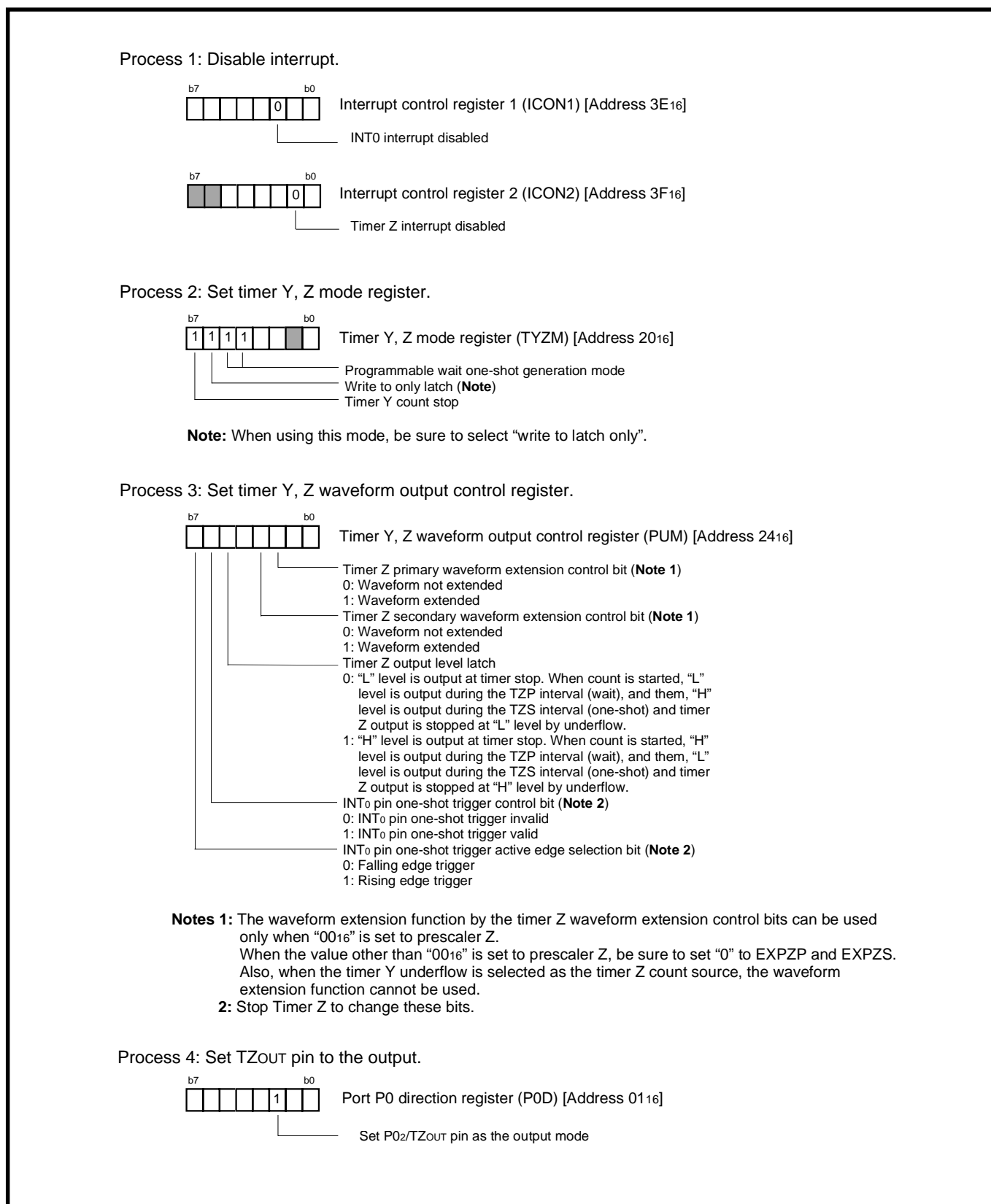
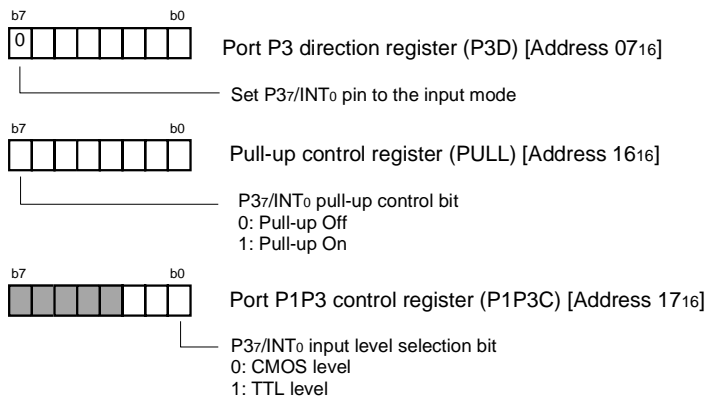
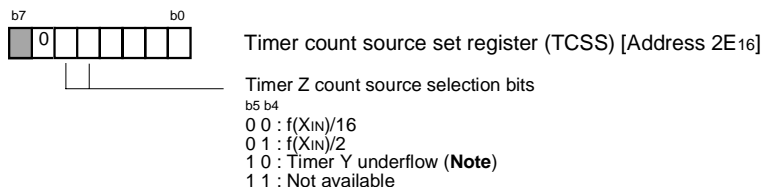


Fig. 2.5.36 Setting method for programmable wait one-shot generation mode (1)

Process 5: When the trigger by INT₀ pin input is selected:
Set port P3 direction register, pull-up control register and port P1P3 control register



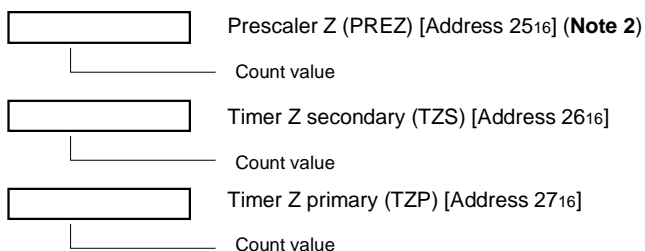
Process 6: Set the timer Z count source.



Note: When the timer Z waveform extension function is used, do not select the timer Y underflow for the timer Z count source.

Process 7: Set the wait interval, one-shot pulse width (**Note 1**).

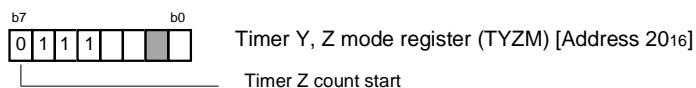
- Set the wait interval to the timer Z primary, and one-shot pulse width to the timer Z secondary.



- Notes 1:** In the programmable wait one-shot generation mode, values of TZS, EXPZP, and EXPZS are valid by writing to TZP. Even when changing TZP is not required, write the same value again.
- 2: When the timer Z waveform extension function is used, be sure to set "00₁₆" to prescaler Z.
 - 3: In the programmable wait one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer Z underflow during the secondary interval simultaneously.
 - 4: Count values of the primary interval (during wait) and secondary interval (during one-shot output) can be checked by reading TZP (TZS is undefined at read).

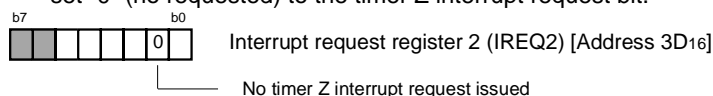
Fig. 2.5.37 Setting method for programmable wait one-shot generation mode (2)

Process 8: Set the standby state to accept the one-shot start trigger (**Note**).

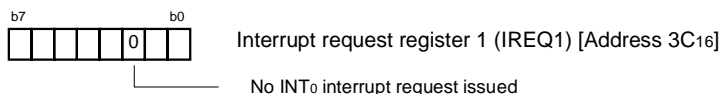
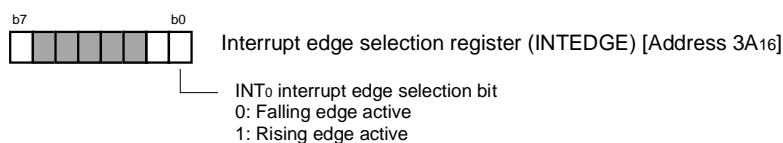


Note: When the INT₀ pin one-shot trigger control bit of PUM is set to “valid”, timer Z counting is started by the input of trigger to INT₀ pin after this setting.

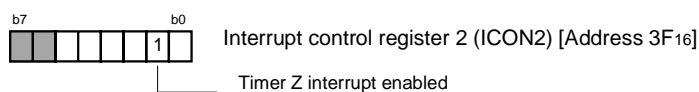
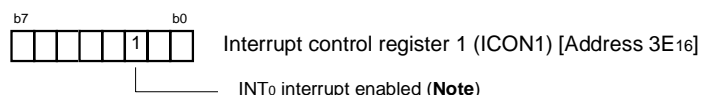
Process 9: In order not to execute the no requested interrupt processing, set “0” (no requested) to the timer Z interrupt request bit.



● When the INT₀ pin one-shot trigger control bit is set to “valid” and the INT₀ interrupt is used, set the following;

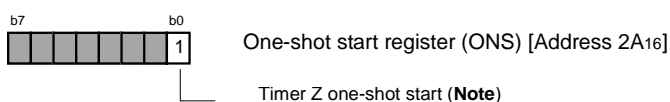


Process 10: When the interrupt is used, set “1” (interrupt enabled) to the corresponding interrupt enable bit.



Note: When the INT₀ pin one-shot trigger control bit is set to “valid”, the INT₀ interrupt can be accepted after this setting.

Process 11: Start counting of timer Z.



● When the INT₀ pin one-shot trigger control bit of PUM is set to “valid”, the timer Z count is started by input of trigger to the INT₀ pin.

Note: Pulse is output from TZOUT pin. After output, this bit is initialized to “0”.

Fig. 2.5.38 Setting method for programmable wait one-shot generation mode (3)

(3) Application example of programmable wait one-shot generation mode

Outline: The wait one-shot pulse synchronized with the PWM waveform output from the P0₁/TY_{OUT} pin is generated from Timer Z by using the programmable waveform generation mode of Timer Y.

Specifications: TY_{OUT} pin is connected to the P3₇/INT₀ pin. The wait one-shot pulse is output by the INT₀ pin input as trigger.

Operation clock: $f(X_{IN}) = 8 \text{ MHz}$, high-speed mode

As for the usage of Timer Y, refer to the above mentioned programmable waveform generation mode. Figure 2.5.39 shows an example of waveform generation and peripheral circuit. Figure 2.5.40 shows an example of control procedure.

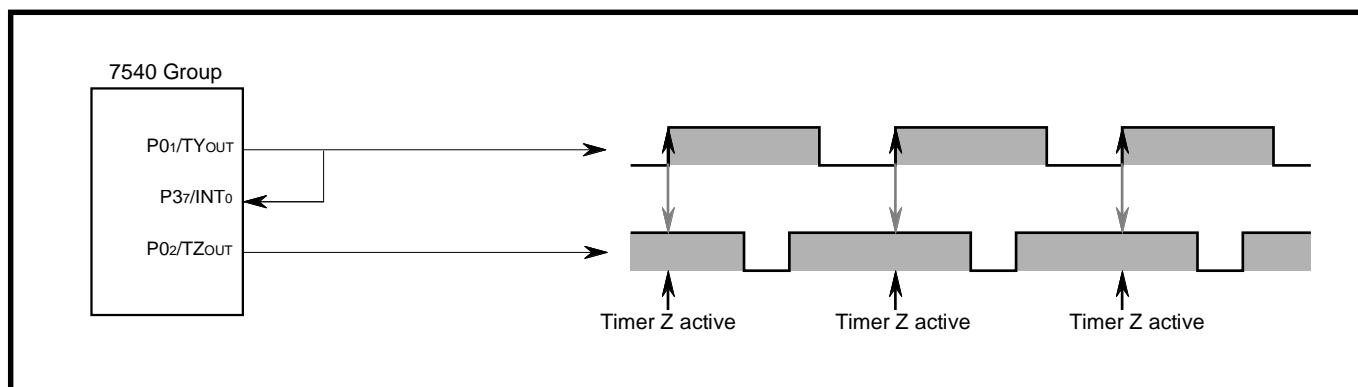
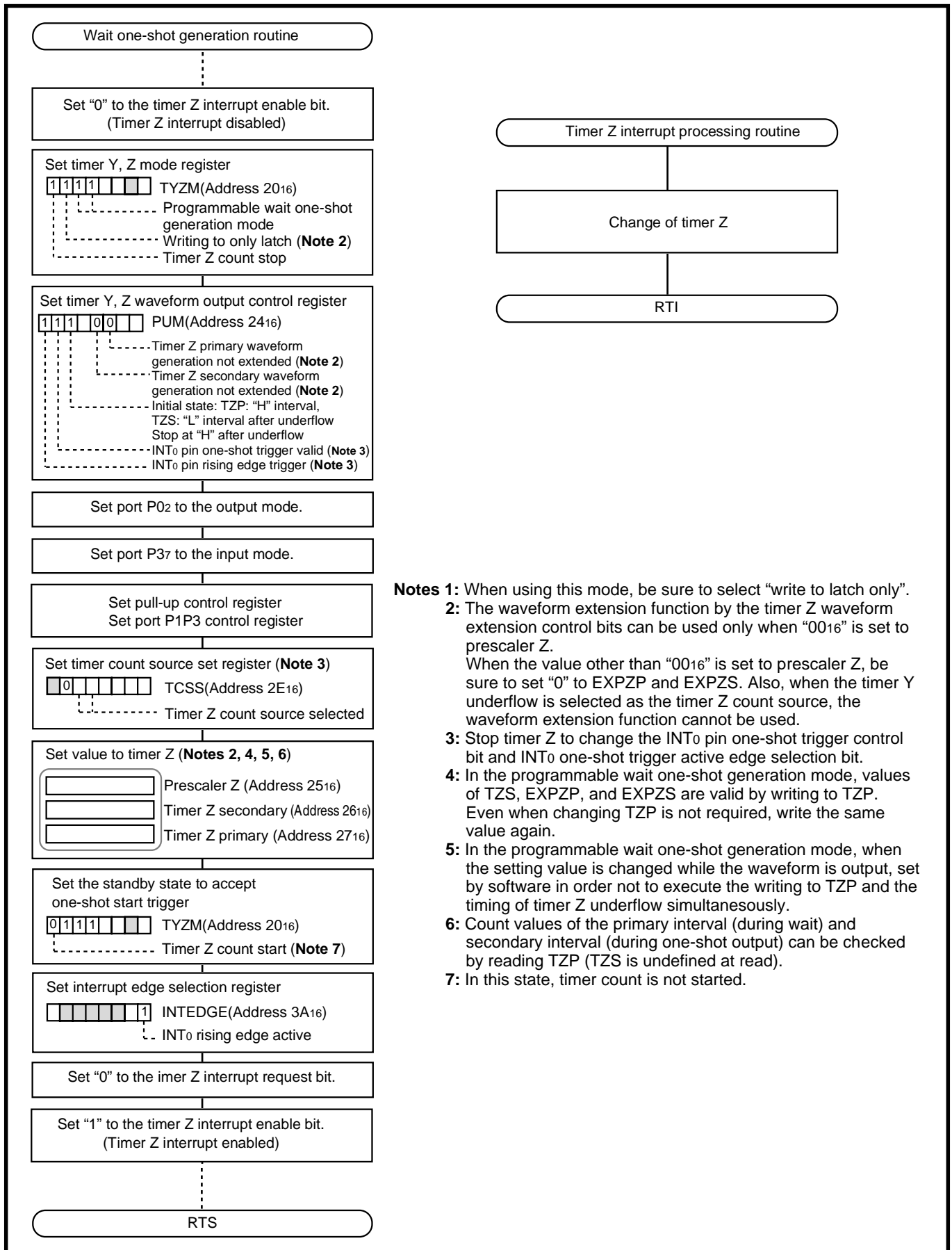


Fig. 2.5.39 Example of waveform generation and peripheral circuit



- Notes**
- 1: When using this mode, be sure to select "write to latch only".
 - 2: The waveform extension function by the timer Z waveform extension control bits can be used only when "00₁₆" is set to prescaler Z. When the value other than "00₁₆" is set to prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
 - 3: Stop timer Z to change the INT₀ pin one-shot trigger control bit and INT₀ one-shot trigger active edge selection bit.
 - 4: In the programmable wait one-shot generation mode, values of TZS, EXPZP, and EXPZS are valid by writing to TZP. Even when changing TZP is not required, write the same value again.
 - 5: In the programmable wait one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer Z underflow simultaneously.
 - 6: Count values of the primary interval (during wait) and secondary interval (during one-shot output) can be checked by reading TZP (TZS is undefined at read).
 - 7: In this state, timer count is not started.

Fig. 2.5.40 Example of control procedure

2.5.7 Notes on timer Y and timer Z

Notes on using each mode of Timer Y and Timer Z are described below.

(1) Timer mode (timer Y and timer Z)

- ① In the timer mode, TYP and TYS is not used.

(2) Programmable waveform generation mode (timer Y and timer Z)

- ① In the programmable waveform generation mode, values of TYS, EXPYP, and EXPYS are valid by writing to TYP because the setting to them is executed all at once by writing to TYP. Even when changing TYP is not required, write the same value again.
- ② In the programmable waveform generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TYP and the timing of timer underflow during the secondary interval simultaneously.
An example of a measurement is shown below.
ex.) The underflow by the primary and the underflow by secondary are stored by polling etc. using timer Y interrupt.
Writing to primary is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.
(Depending on a primary and a secondary setting values, and primary write timing, it may be impossible.)
- ③ The waveform extension function by the timer Y waveform extension control bits can be used only when "00₁₆" is set to Prescaler Y.
When the value other than "00₁₆" is set to Prescaler Y, be sure to set "0" to EXPYP and EXPYS. The waveform extension function by the timer Z waveform extension control bits can be used only when "00₁₆" is set to Prescaler Z. When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
- ④ When using this mode, be sure to set "1" to the timer Y write control bit to select "write to latch only".
- ⑤ When TYS is read out, the undefined value is read out. However, while timer Y counts the setting value of TYS, the count value during the secondary interval can be obtained by reading the timer Y primary.
- ⑥ In order to use TY_{OUT} pin, set "1" to bit 1 of the port P0 direction register (output mode).

(3) Programmable one-shot generation mode (timer Z)

- ① In the programmable one-shot generation mode, the value of EXPZP becomes valid by writing to TZP. Even when changing TZP is not required, write the same value again.
- ② In the programmable one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow simultaneously.

- ③ The waveform extension function by the timer Z waveform extension control bits can be used only when "00₁₆" is set to Prescaler Z.
When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
An example of a measurement is shown below.
ex.) The underflow of timer is stored by polling etc. using timer Z interrupt.
Writing to primary is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.
(Depending on a primary setting value, primary write timing, software and timing of external trigger to INT₀ pin, it may be impossible.)
- ④ When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".
- ⑤ In order to use TZ_{OUT} pin, set "1" to bit 2 of the port P0 direction register (output mode).
- ⑥ Stop Timer Z to change the INT₀ pin one-shot trigger control bit and INT₀ pin one-shot trigger active edge selection bit.

(4) Programmable wait one-shot generation mode (timer Z)

- ① In the programmable wait one-shot generation mode, values of TZS, EXPZP and EXPZS are valid by writing to TZP. Even when changing TZP is not required, write the same value again.
An example of a measurement is shown below.
ex.) The underflow by the primary and the underflow by secondary are stored by polling etc. using timer Z interrupt.
Writing to primary is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.
(Depending on a primary setting value, primary write timing, software and timing of external trigger to INT₀ pin, it may be impossible.)
- ② In the programmable wait one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow during the secondary interval simultaneously.
- ③ The waveform extension function by the timer Z waveform extension control bit can be used only when "00₁₆" is set to Prescaler Z.
When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
- ④ When using this mode, be sure to set "1" to the timer Z write control bits to select "write to latch only".
- ⑤ When TZS is read out, the undefined value is read out. However, while Timer Z counts the setting value of TZS (during one-shot output), the count value during the secondary interval can be obtained by reading TZP.
- ⑥ In order to use TZ_{OUT} pin, set "1" to bit 2 of the port P0 direction register (output mode).
- ⑦ Stop Timer Z to change the INT₀ pin one-shot trigger control bit and INT₀ pin one-shot trigger active edge selection bit.

2.6 Serial I/O1

This paragraph explains the registers setting method and the notes relevant to the serial I/O.

2.6.1 Memory map

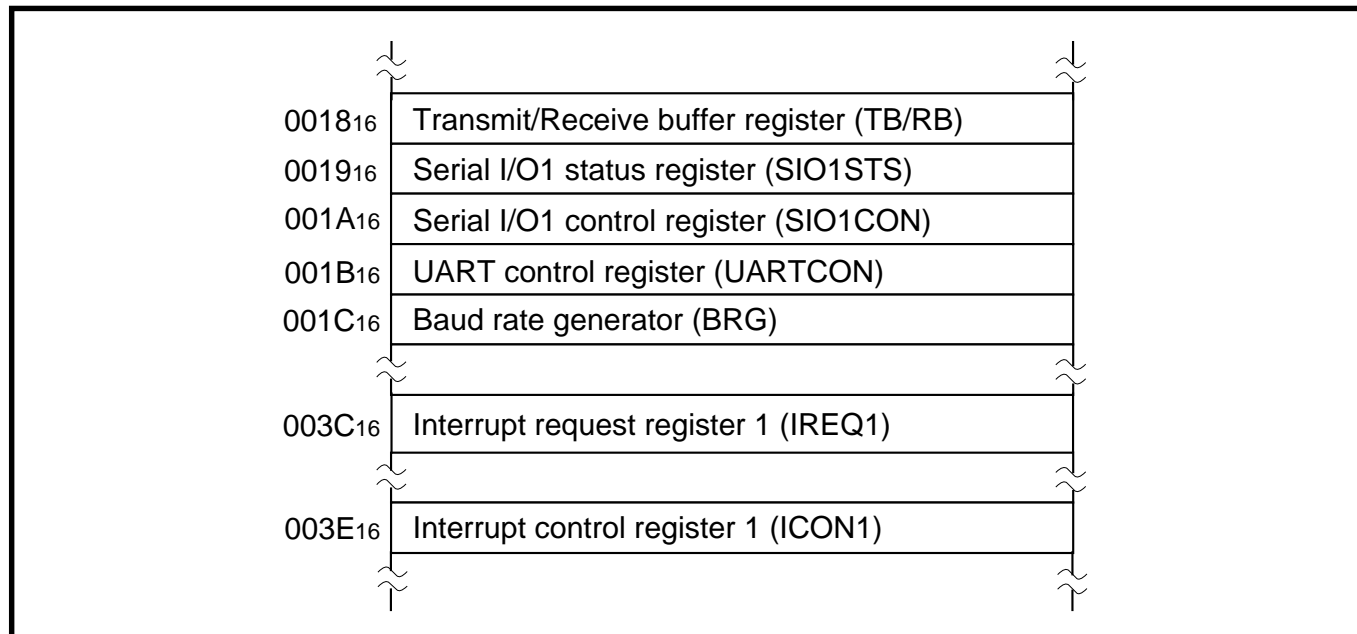


Fig. 2.6.1 Memory map of registers relevant to serial I/O

2.6.2 Relevant registers

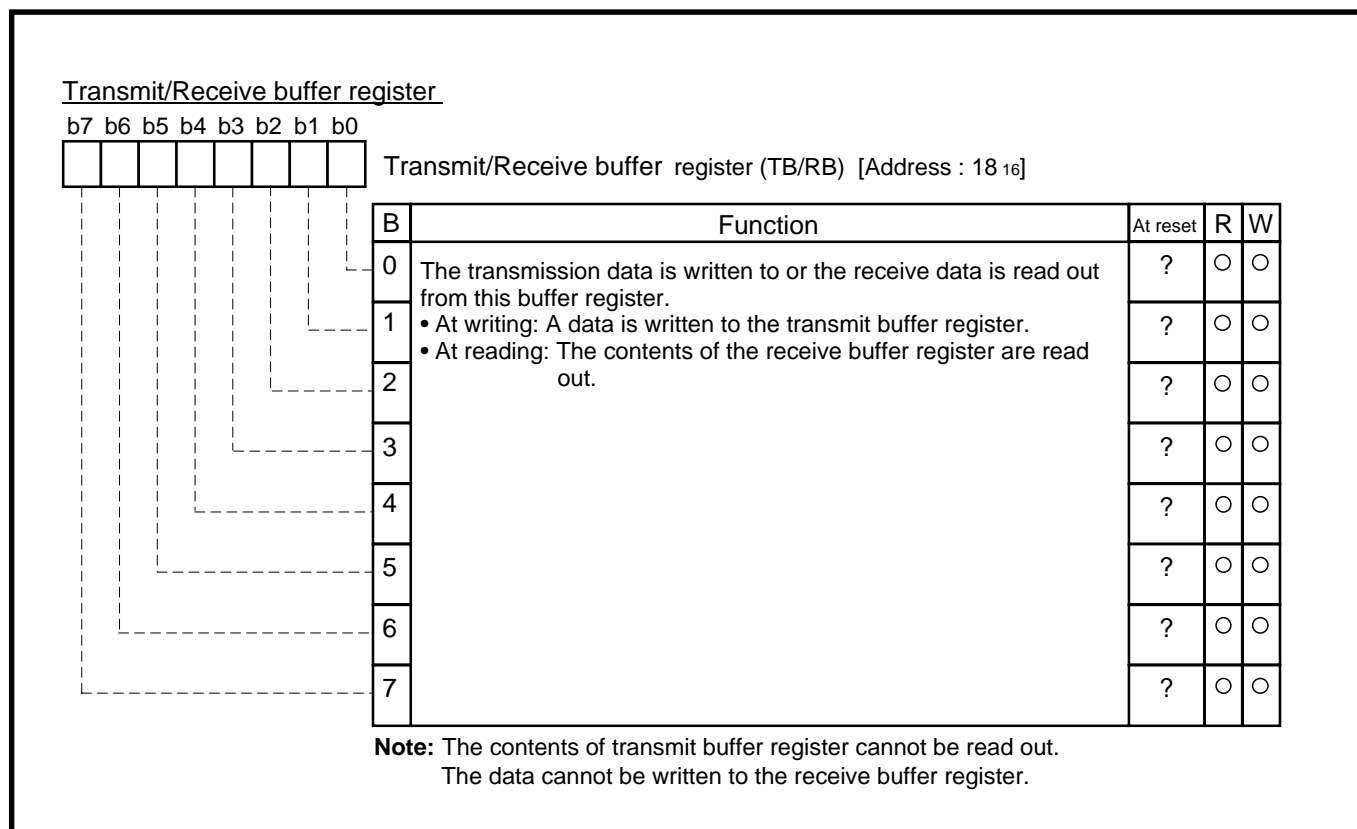


Fig. 2.6.2 Structure of Transmit/Receive buffer register

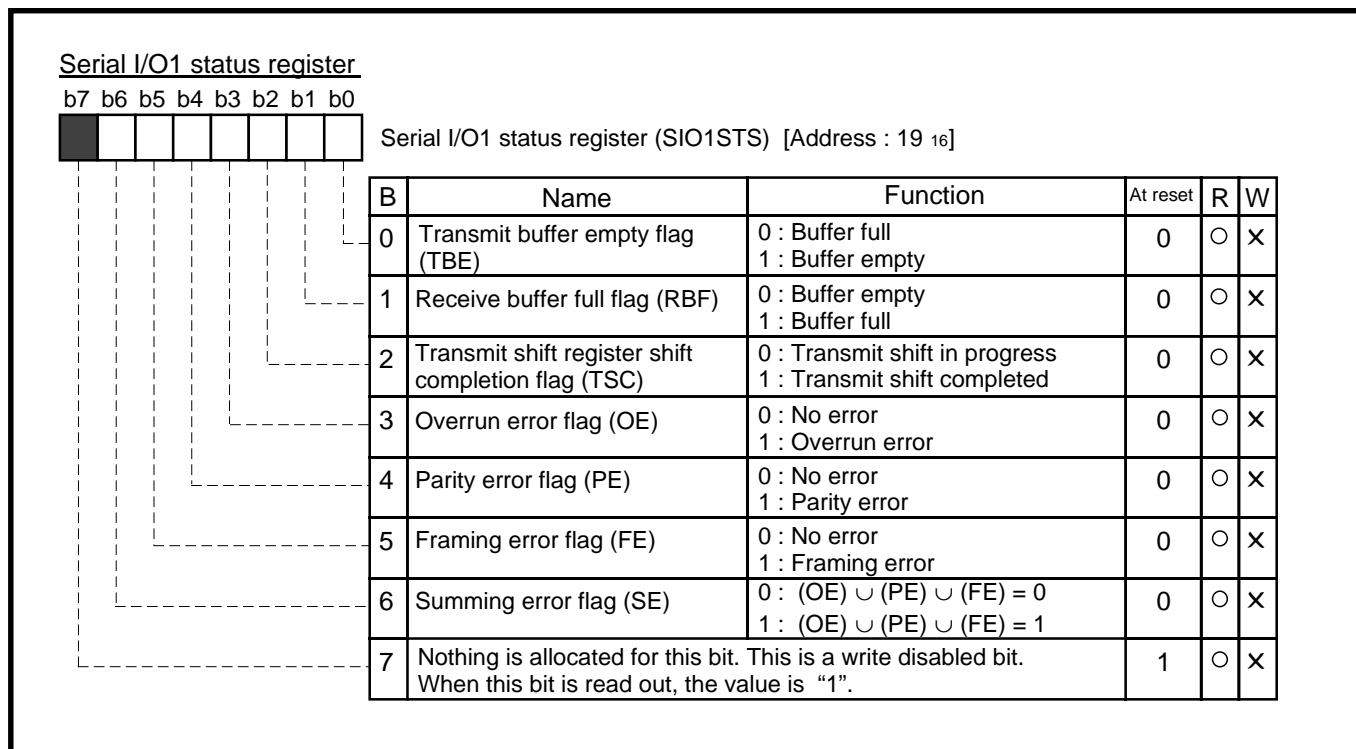


Fig. 2.6.3 Structure of Serial I/O1 status register

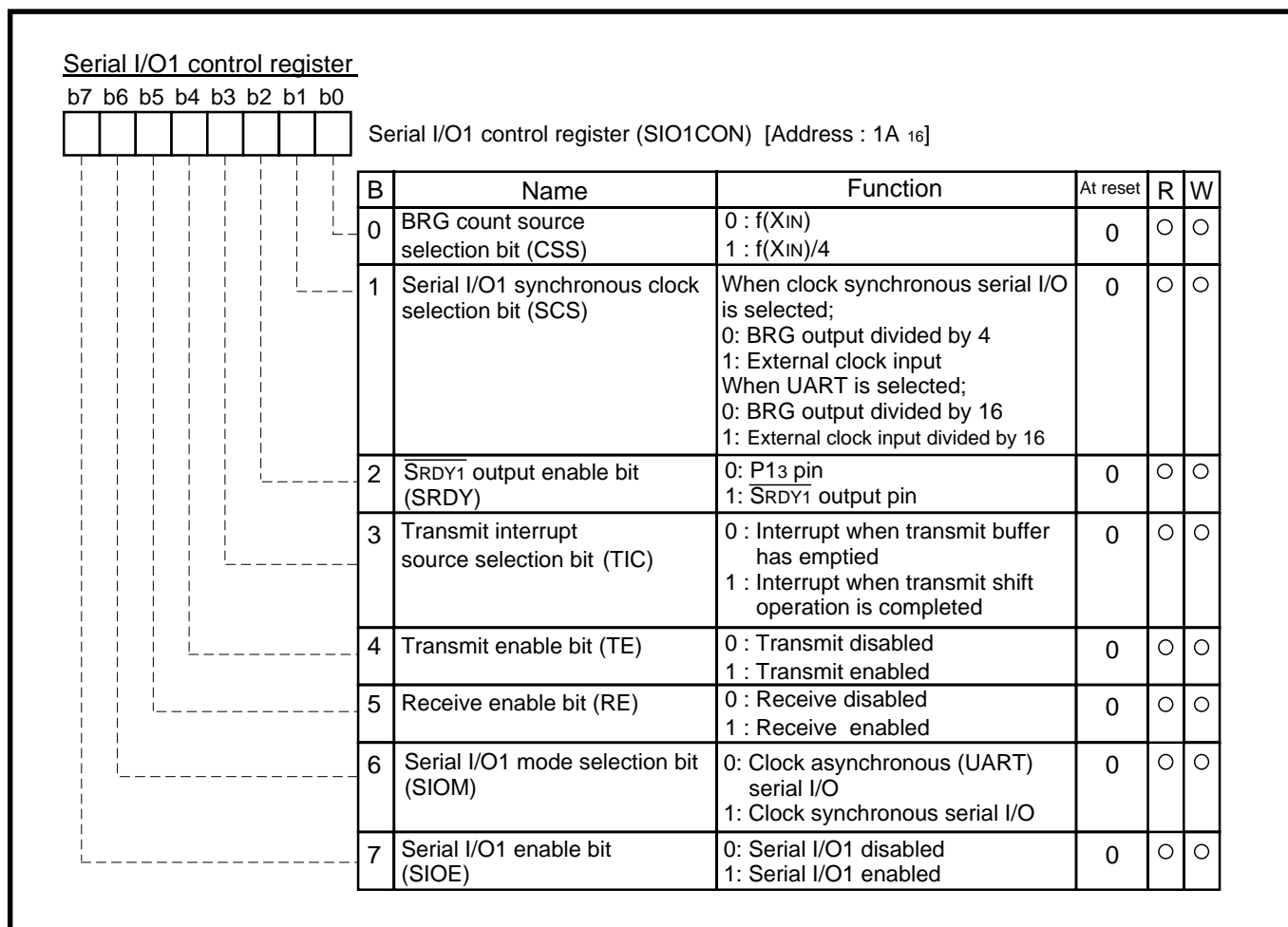


Fig. 2.6.4 Structure of Serial I/O1 control register

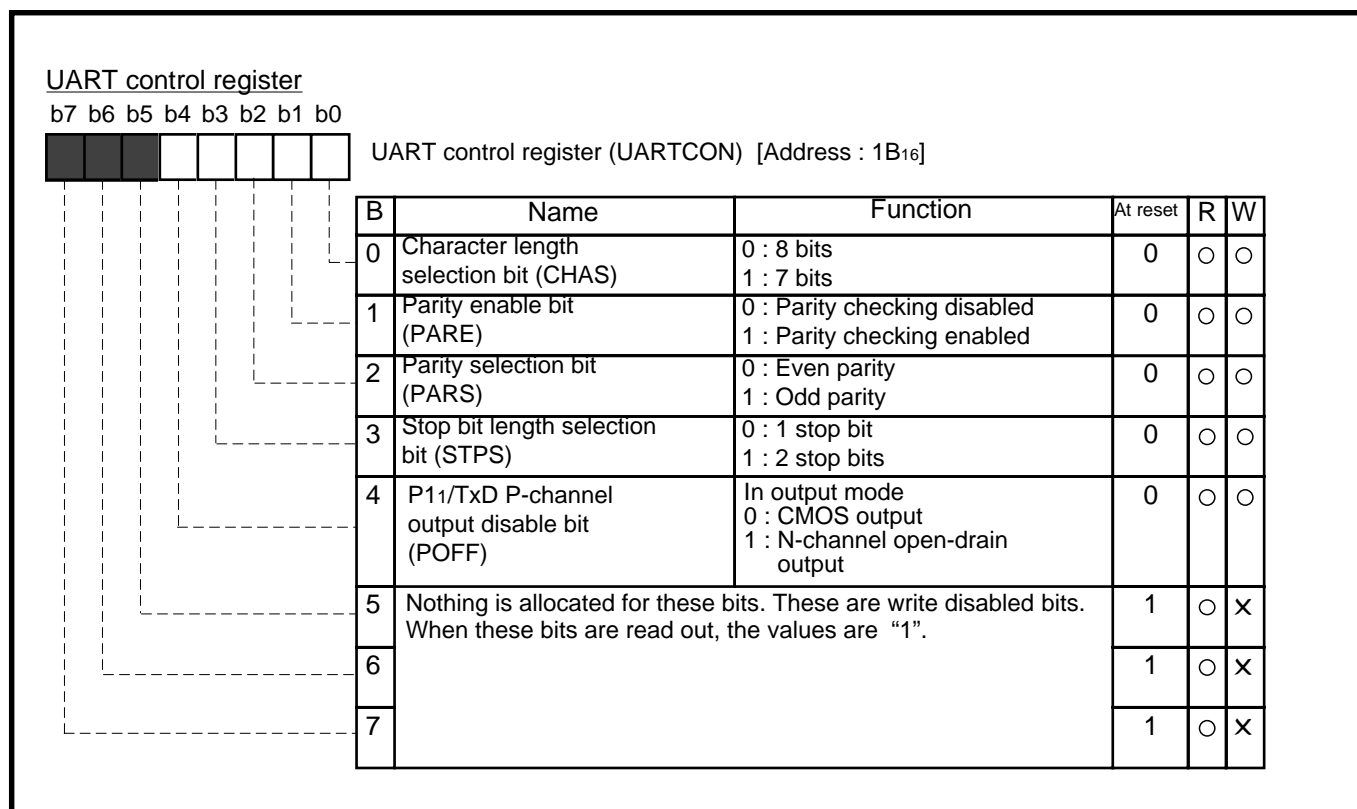


Fig. 2.6.5 Structure of UART control register

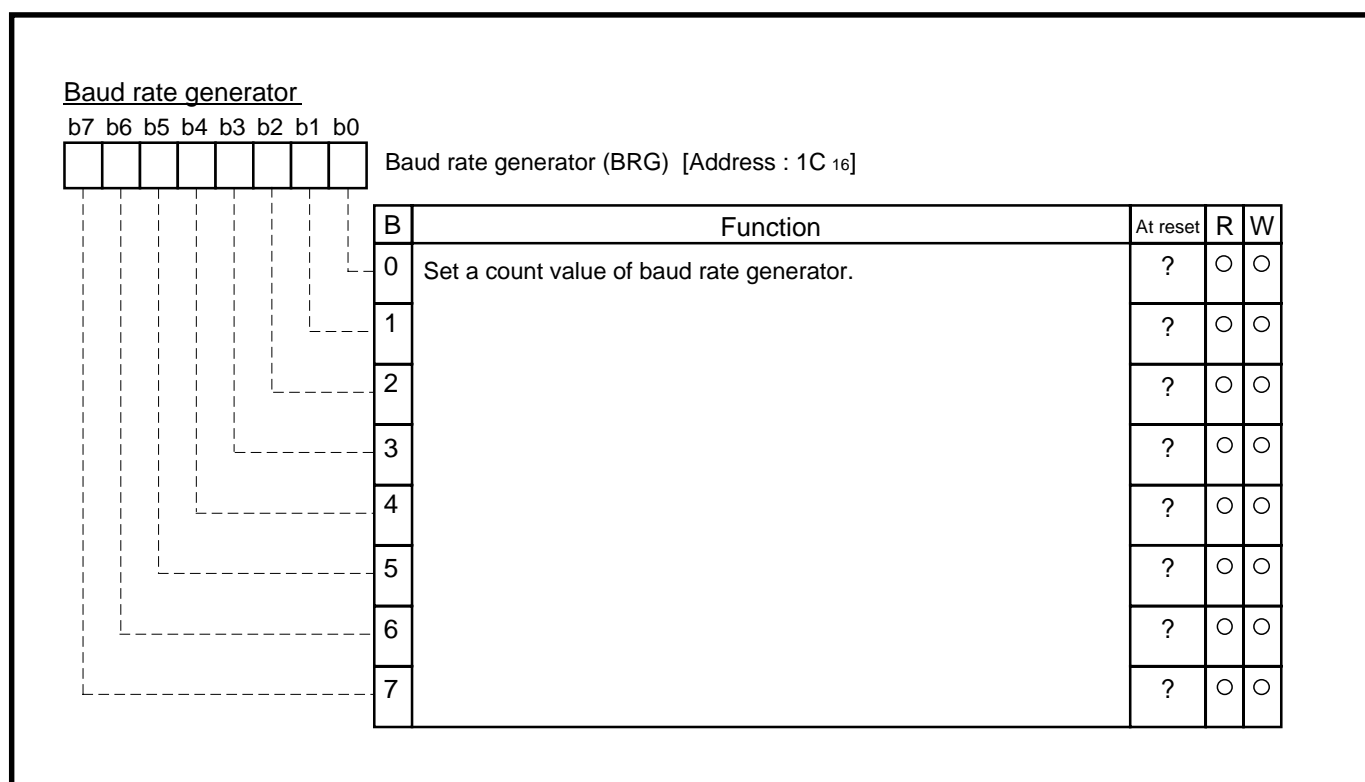


Fig. 2.6.6 Structure of Baud rate generator

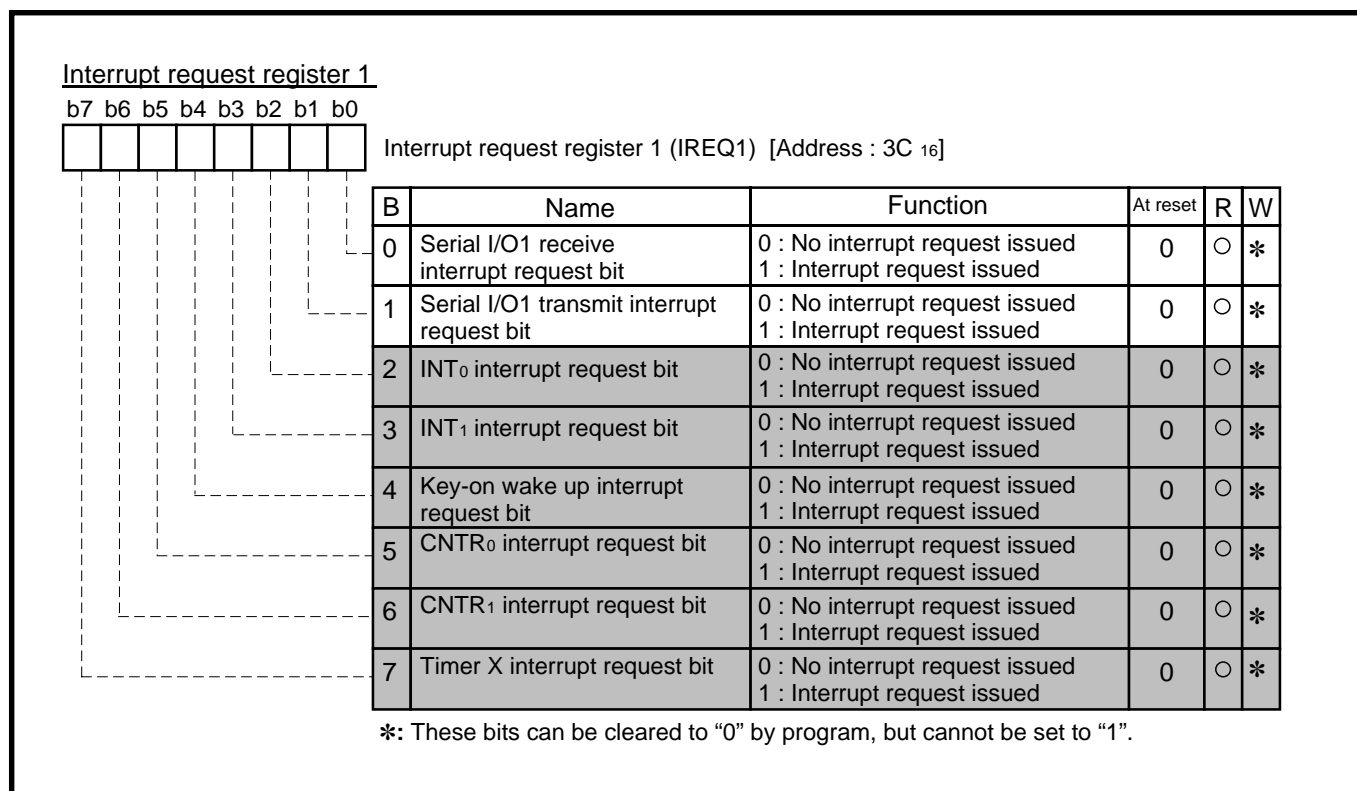


Fig. 2.6.7 Structure of Interrupt request register 1

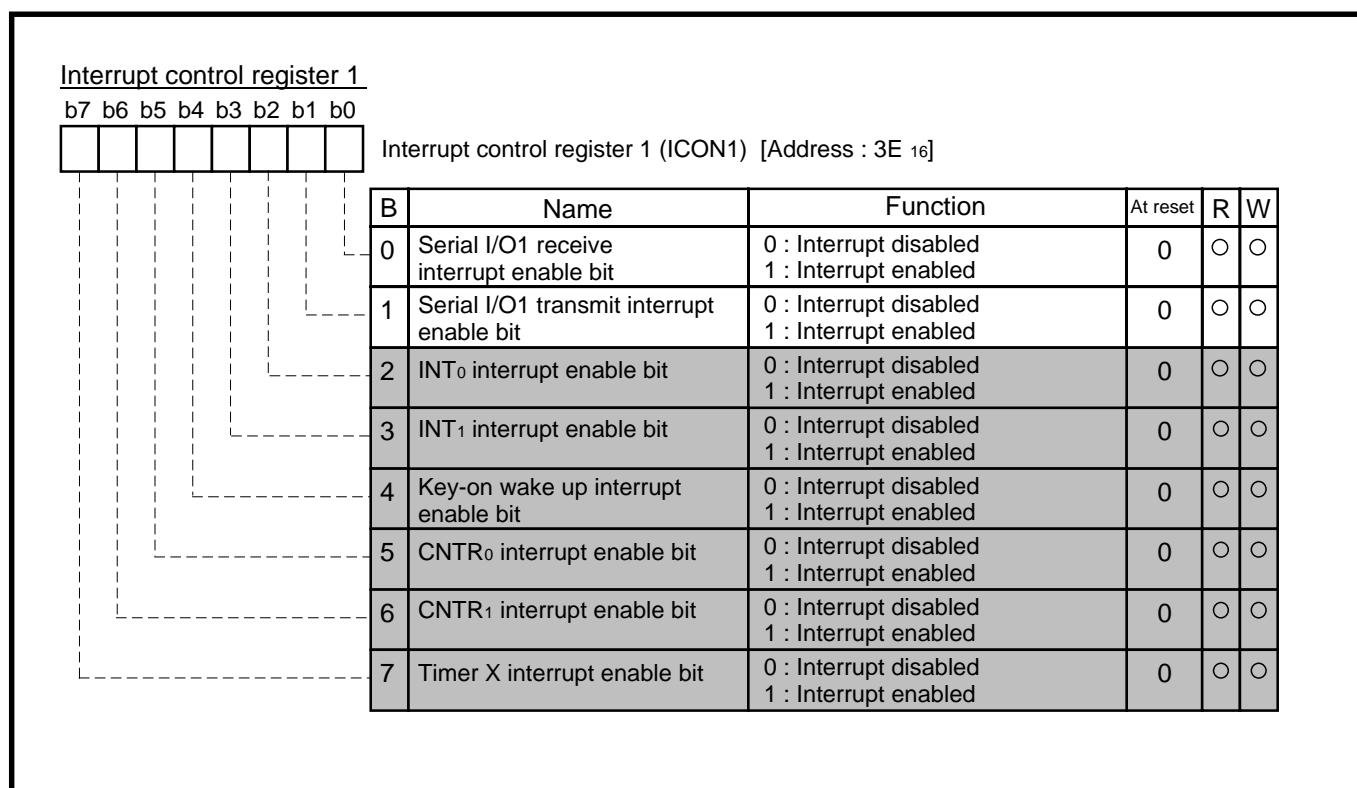


Fig. 2.6.8 Structure of Interrupt control register 1

2.6.3 Serial I/O1 transfer data format

Figure 2.6.9 shows the serial I/O1 transfer data format.

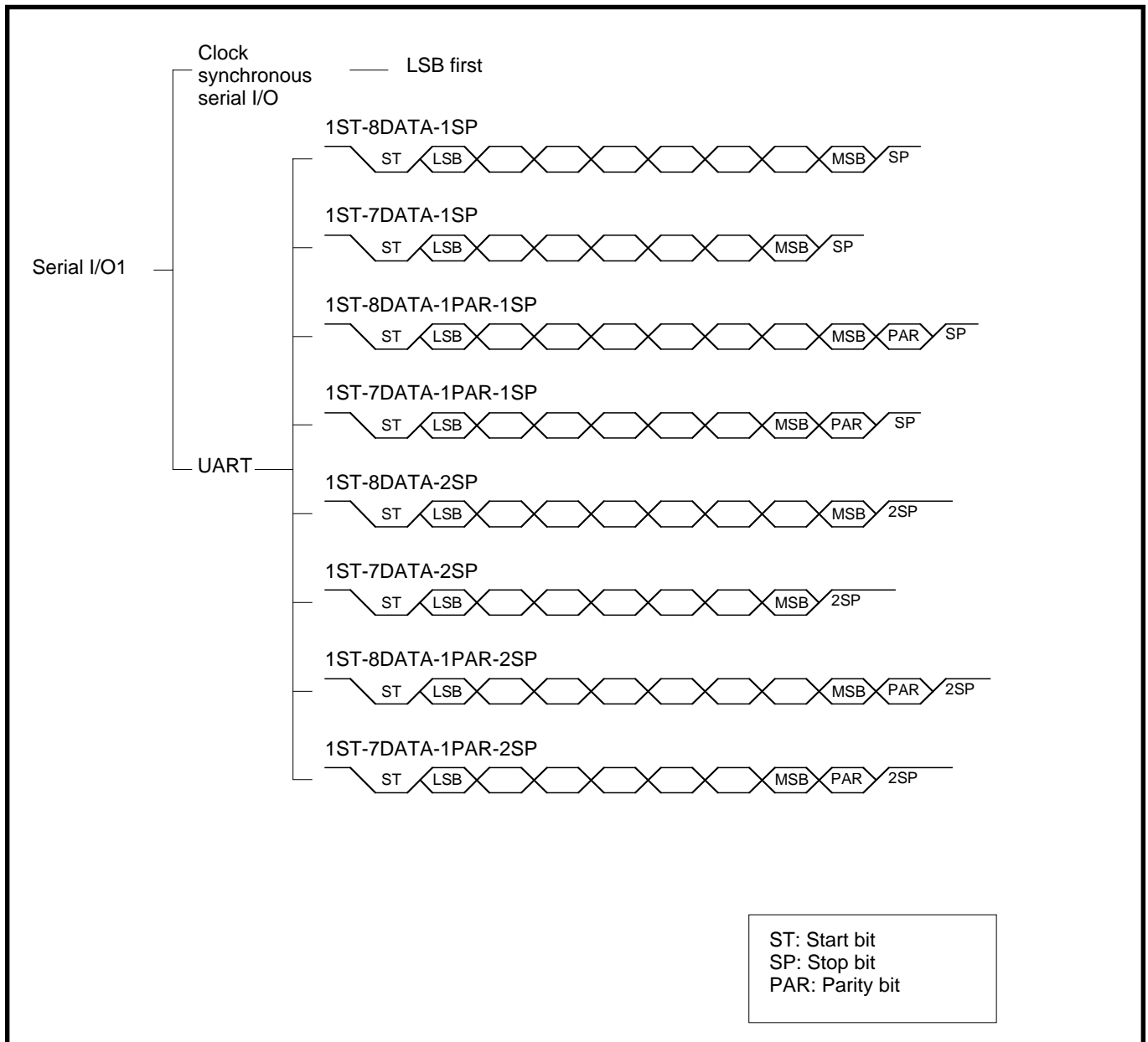


Fig. 2.6.9 Serial I/O1 transfer data format

2.6.4 Application example of clock synchronous serial I/O1

For clock synchronous serial I/O1, the transmitter and the receiver use the same clock. Synchronizing with this clock, the transmit operation of the transmitter and the receive operation of the receiver are executed at the same time. If an internal clock is used as the operation clock, transfer is started by a write signal to the TB/RB.

(1) Data transfer rate

The synchronous clock frequency is calculated by the following formula;

- When the internal clock is selected (when baud rate generator is used)

$$\text{Synchronous clock frequency [Hz]} = \frac{f(X_{IN})}{\text{Division ratio}^{*1} \times (\text{BRG setting value}^{*2} + 1) \times 4}$$

Division ratio^{*1} : "1" or "4" is selected (set by bit 0 of serial I/O1 control register)

BRG setting value^{*2} : 0 to 255 (00₁₆ to FF₁₆) is set

- When the external clock is selected

Synchronous clock frequency [Hz] = Clock input to S_{CLK1} pin

(2) Clock synchronous serial I/O setting method

Figure 2.6.10 and Figure 2.6.11 show the setting method for the clock synchronous serial I/O1.

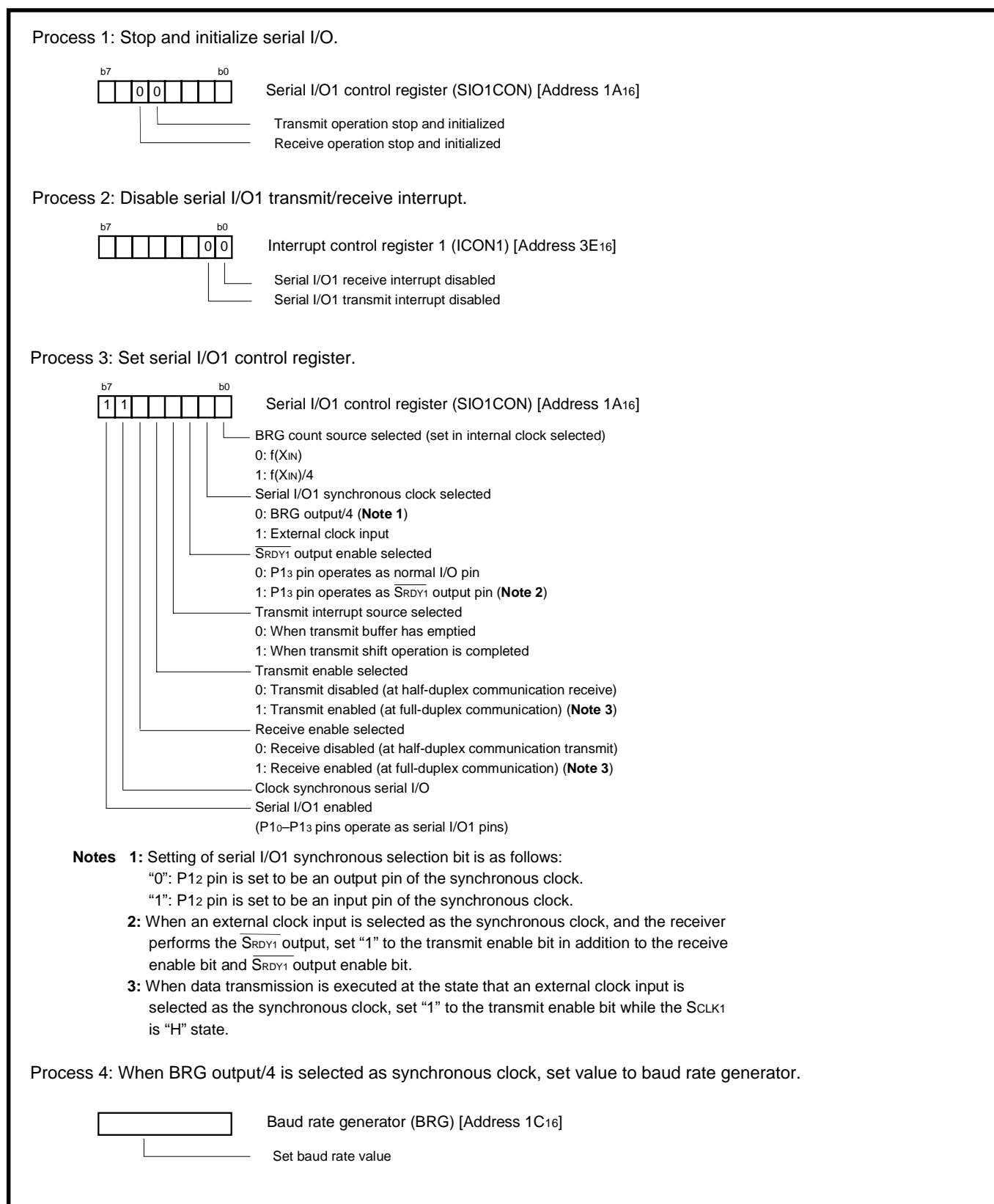
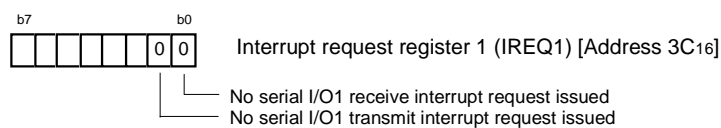
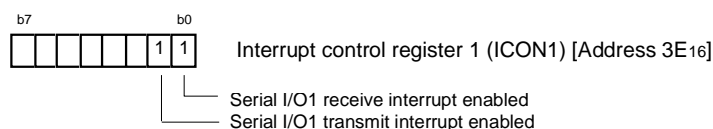


Fig. 2.6.10 Setting method for clock synchronous serial I/O1 (1)

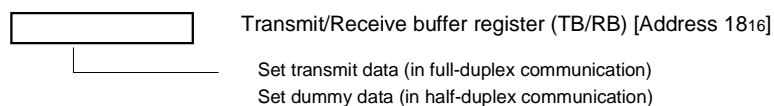
Process 5: In order not to execute the no requested interrupt processing, set "0" (no requested) to the serial I/O1 transmit/receive interrupt request bit.



Process 6: When the interrupt is used, set "1" (interrupt enabled) to the serial I/O transmit/receive interrupt enable bit.



Process 7: Transmit/Receive of serial data (**Notes 1, 2**).



Notes 1: When data transmission is executed at the state that an external clock input is selected as the synchronous clock, set the transmit data while the SCLK is "H" state.

2: When inputting the $\overline{\text{SRDY}}_1$ signal, set used pins to to the input mode before transmitting data.

Fig. 2.6.11 Setting method for clock synchronous serial I/O1 (2)

(3) Communication using clock synchronous serial I/O1 (transmit/receive)

Outline : 2-byte data is transmitted and received, using the clock synchronous serial I/O1. $\overline{\text{SRDY1}}$ signal is used for communication control.

- Specifications** :
- The serial I/O1 (clock synchronous serial I/O selected) is used.
 - Synchronous clock frequency : 125 kHz; $f(\text{X}_{\text{IN}}) = 4 \text{ MHz}$ divided by 32
 - The receiver outputs the $\overline{\text{SRDY1}}$ signal at 2 ms intervals which the timer generates, and 2-byte data is transferred from the transmitter to the receiver.

Figure 2.6.12 shows a connection diagram, Figure 2.6.13 shows a timing chart, Figure 2.6.14 shows the control procedure of transmitter, and Figure 2.6.15 shows an example of control procedure of receiver.

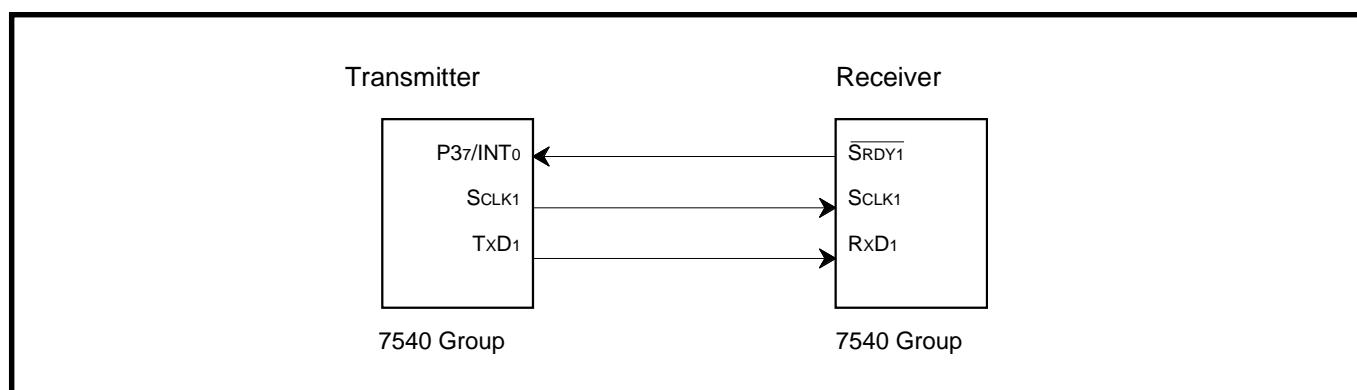


Fig. 2.6.12 Connection diagram

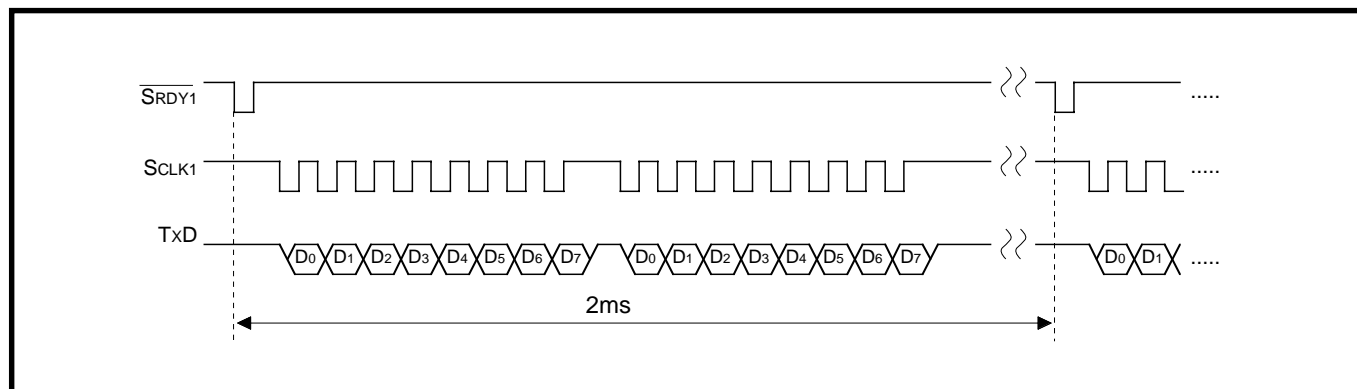


Fig. 2.6.13 Timing chart

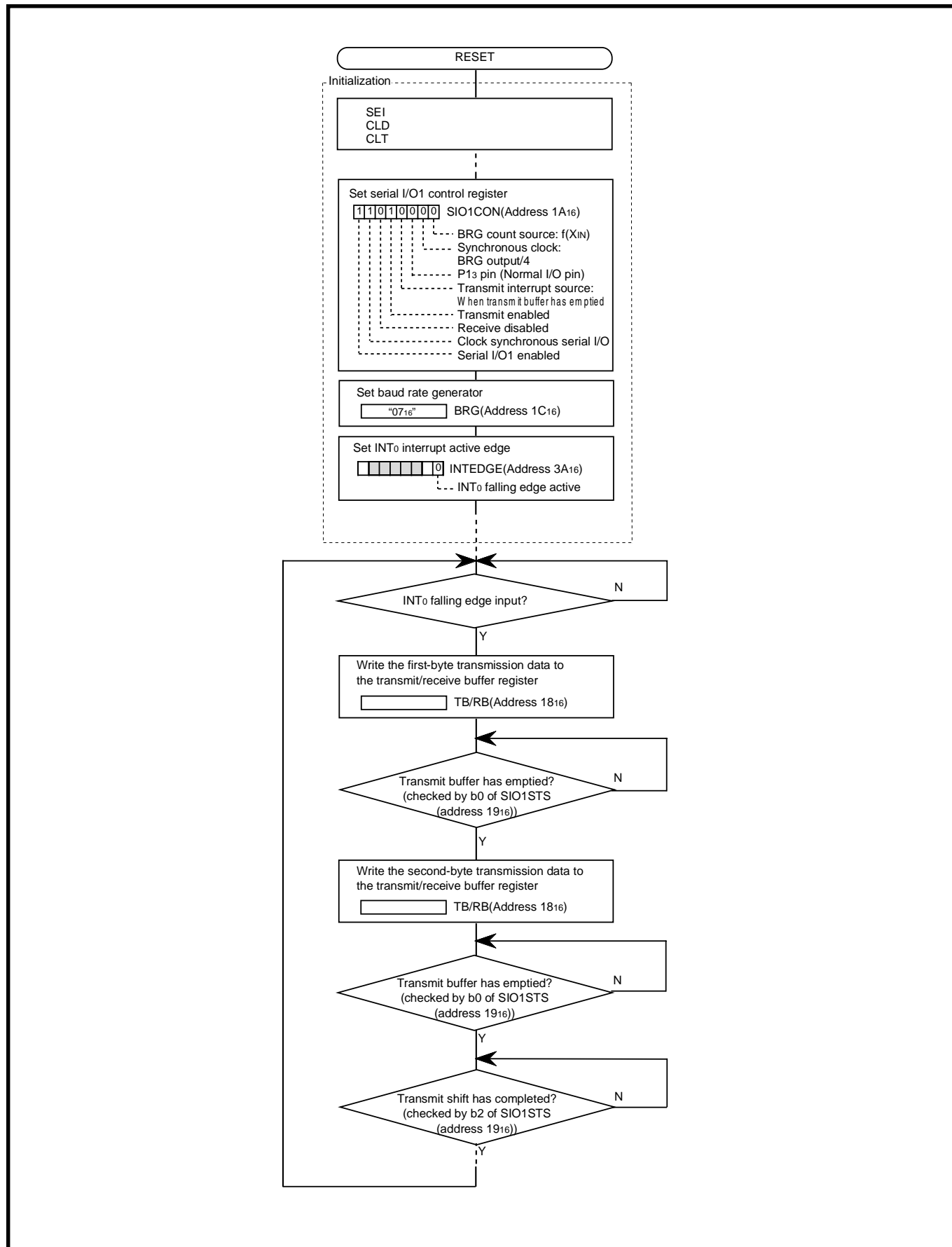


Fig. 2.6.14 Control procedure of transmitter

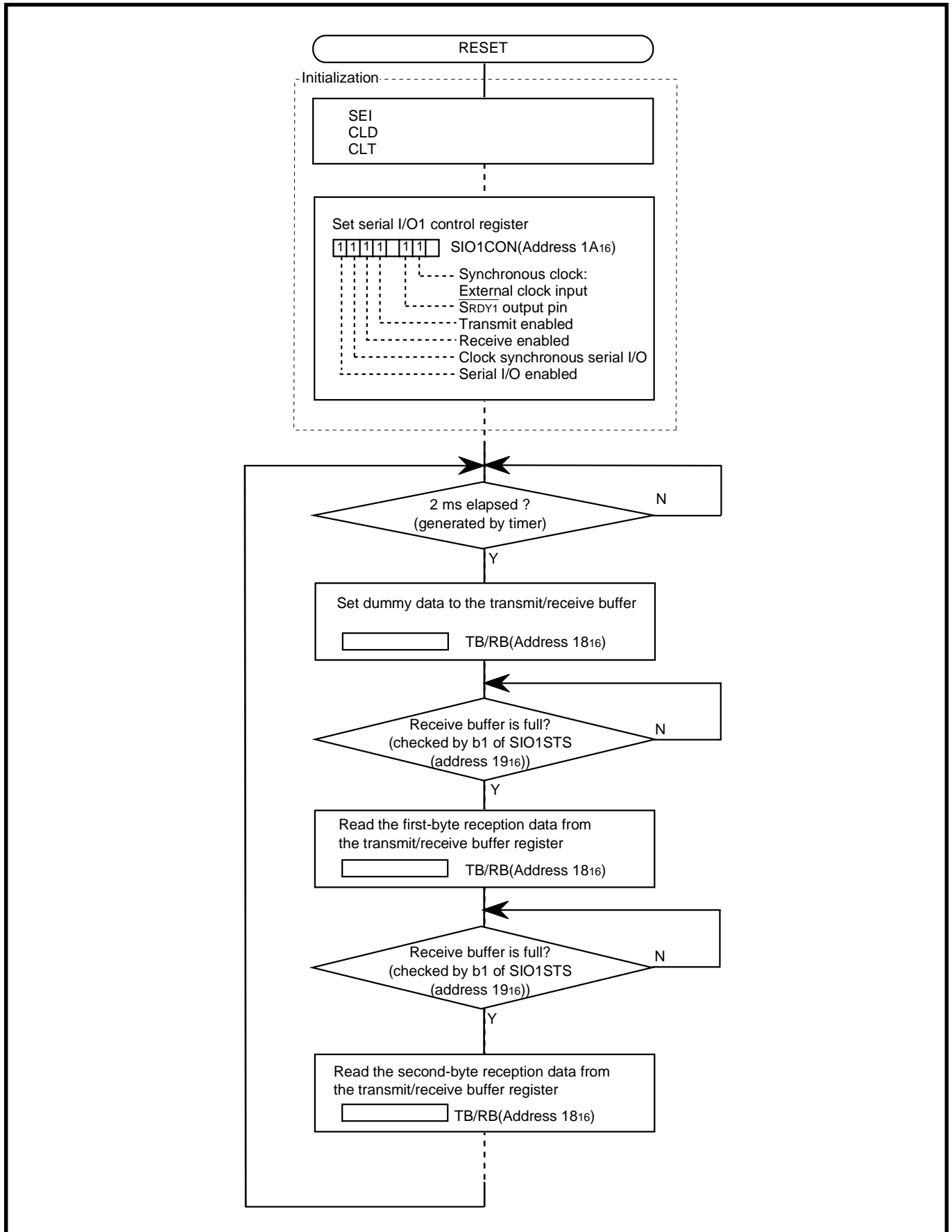


Fig. 2.6.15 Control procedure of receiver

2.6.5 Application example of clock asynchronous serial I/O1

For clock asynchronous serial I/O1 (UART), the transfer formats used by a transmitter and receiver must be identical.

In the 7540 Group, eight serial data transfer formats can be selected.

(1) Data transfer rate

The transfer bit rate is calculated by the following formula;

- When the internal clock is selected (when baud rate generator is used)

$$\text{Transfer bit rate [bps]} = \frac{f(X_{IN})}{\text{Division ratio}^{*1} \times (\text{BRG setting value}^{*2} + 1) \times 16}$$

Division ratio*1 : "1" or "4" is selected (set by bit 0 of serial I/O1 control register)

BRG setting value*2 : 0 to 255 (00₁₆ to FF₁₆) is set

- When the external clock is selected

$$\text{Transfer bit rate [bps]} = \text{Clock input to } S_{CLK1} \text{ pin}/16$$

Table 2.6.1 shows the setting example of baud rate generator and transfer bit rate values.

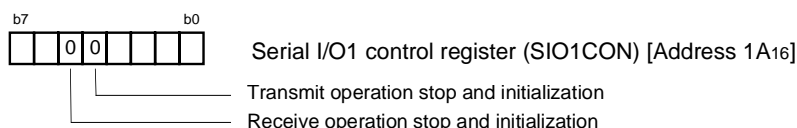
Table 2.6.1 Setting example of baud rate generator (BRG) and transfer bit rate values

| BRG count source | BRG set value | Transfer bit rate (bps) | |
|-------------------------|-------------------------|-------------------------------------|--------------------------------|
| | | At f(X _{IN}) = 4.9152 MHz | At f(X _{IN}) = 8 MHz |
| f(X _{IN}) / 4 | 255 (FF ₁₆) | 300 | 488.28125 |
| f(X _{IN}) / 4 | 127 (7F ₁₆) | 600 | 976.5625 |
| f(X _{IN}) / 4 | 63 (3F ₁₆) | 1200 | 1953.125 |
| f(X _{IN}) / 4 | 31 (1F ₁₆) | 2400 | 3906.25 |
| f(X _{IN}) / 4 | 15 (0F ₁₆) | 4800 | 7812.5 |
| f(X _{IN}) / 4 | 7 (07 ₁₆) | 9600 | 15625 |
| f(X _{IN}) / 4 | 3 (03 ₁₆) | 19200 | 31250 |
| f(X _{IN}) / 4 | 1 (01 ₁₆) | 38400 | 62500 |
| f(X _{IN}) | 3 (03 ₁₆) | 76800 | 125000 |
| f(X _{IN}) | 1 (01 ₁₆) | 153600 | 250000 |
| f(X _{IN}) | 0 (00 ₁₆) | 307200 | 500000 |

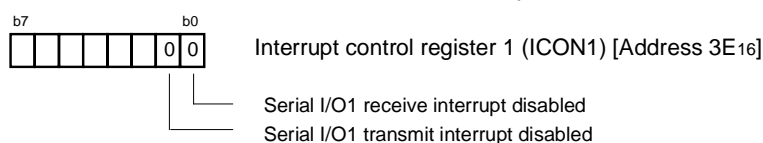
(2) UART setting method

Figure 2.6.16 and Figure 2.6.17 show the setting method for UART of serial I/O1.

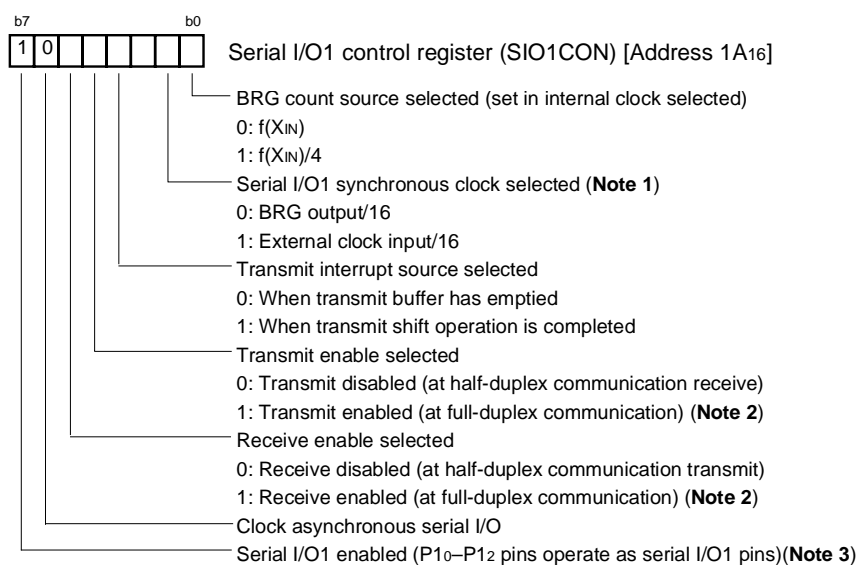
Process 1: Stop and initialize serial I/O.



Process 2: Disable serial I/O1 transmit/receive interrupt.



Process 3: Set serial I/O1 control register.



Note 1: Setting of serial I/O1 synchronous clock selection bit is as follows;

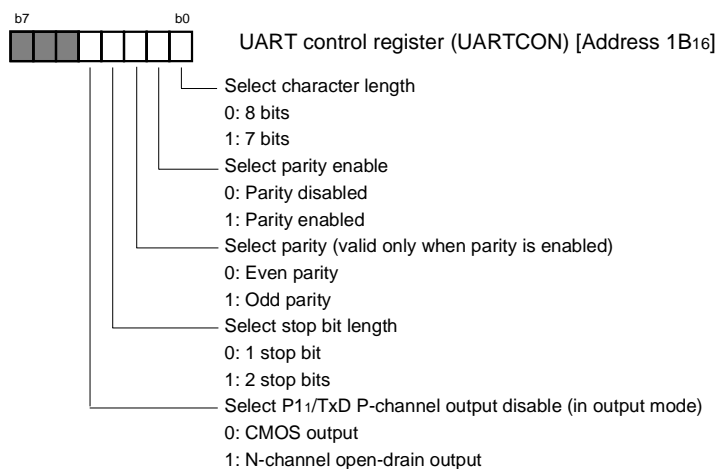
- “0”: P12 pin can be used as a normal I/O pin
- “1”: P12 pin is used as an input pin for an external clock.

2: When data transmission is executed at the state that an external clock input is selected as the synchronous clock, set “1” to the transmit enable bit while the SCLK1 is “H” state.

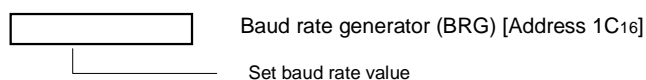
3: When clock asynchronous (UART) serial I/O is selected, P13 pin can be used as a normal I/O pin.

Fig. 2.6.16 Setting method for UART of serial I/O1 (1)

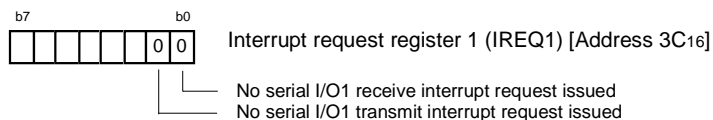
Process 4: Set UART control register.



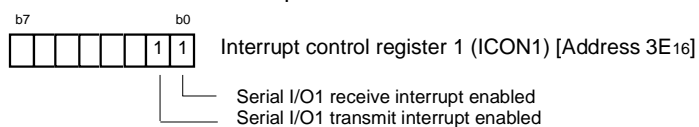
Process 5: When BRG output/16 is selected as synchronous clock, set value to baud rate generator.



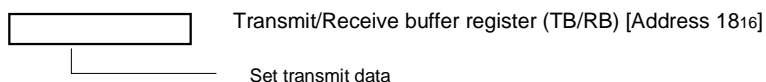
Process 6: In order not to execute the no requested interrupt processing, set "0" (no requested) to the serial I/O1 transmit/receive interrupt request bit.



Process 7: When the interrupt is used, set "1" (interrupt enabled) to the serial I/O1 transmit/receive interrupt enable bit.



Process 8: When transmitting, start serial data transmission (**Note**).



Note: When data transmission is executed at the state that an external clock input is selected as the synchronous clock, set the transmit data while the SCLK1 is "H" state.

Fig. 2.6.17 Setting method for UART of serial I/O1 (2)

(3) Communication using UART of serial I/O (transmit/receive)

Outline : 2-byte data is transmitted and received, using UART. Port P0₀ is used for communication control.

Specifications : •The Serial I/O1 (UART selected) is used.

- Transfer bit rate : 9600 bps ($f(X_{IN}) = 4.9152 \text{ MHz divided by } 512$)
 - Communication control using port P0₀ (output level of port P0₀ is controlled by software)
- 2-byte data is transferred from the transmitter to the receiver at 10 ms intervals which the timer generates.

Figure 2.6.18 shows a connection diagram, Figure 2.6.19 shows a timing chart, Figure 2.6.20 shows the control procedure of transmitter, and Figure 2.6.21 shows an example of control procedure of receiver.

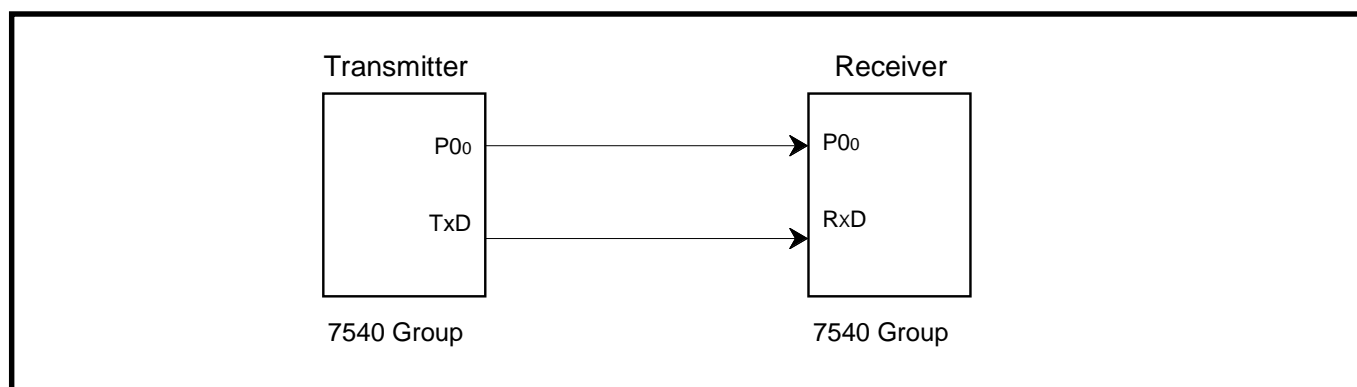


Fig. 2.6.18 Connection diagram

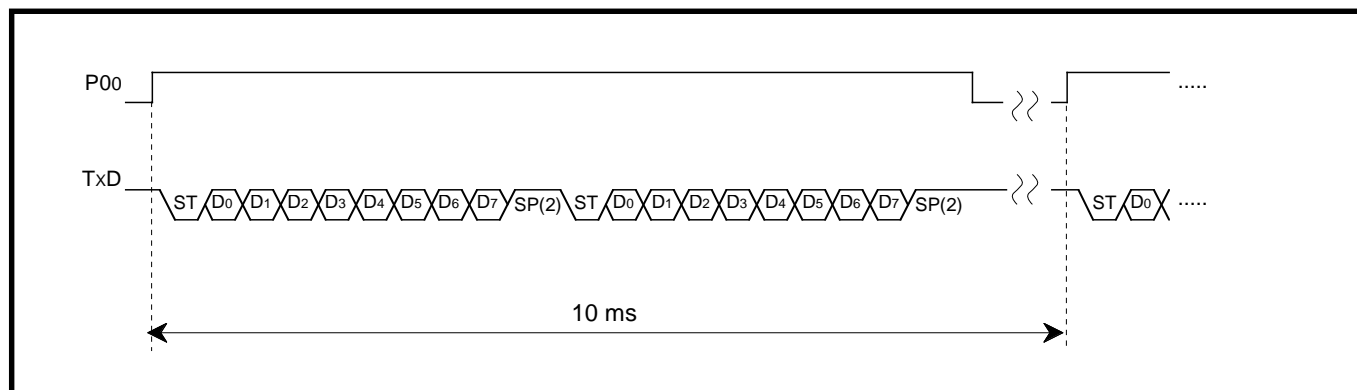


Fig. 2.6.19 Timing chart

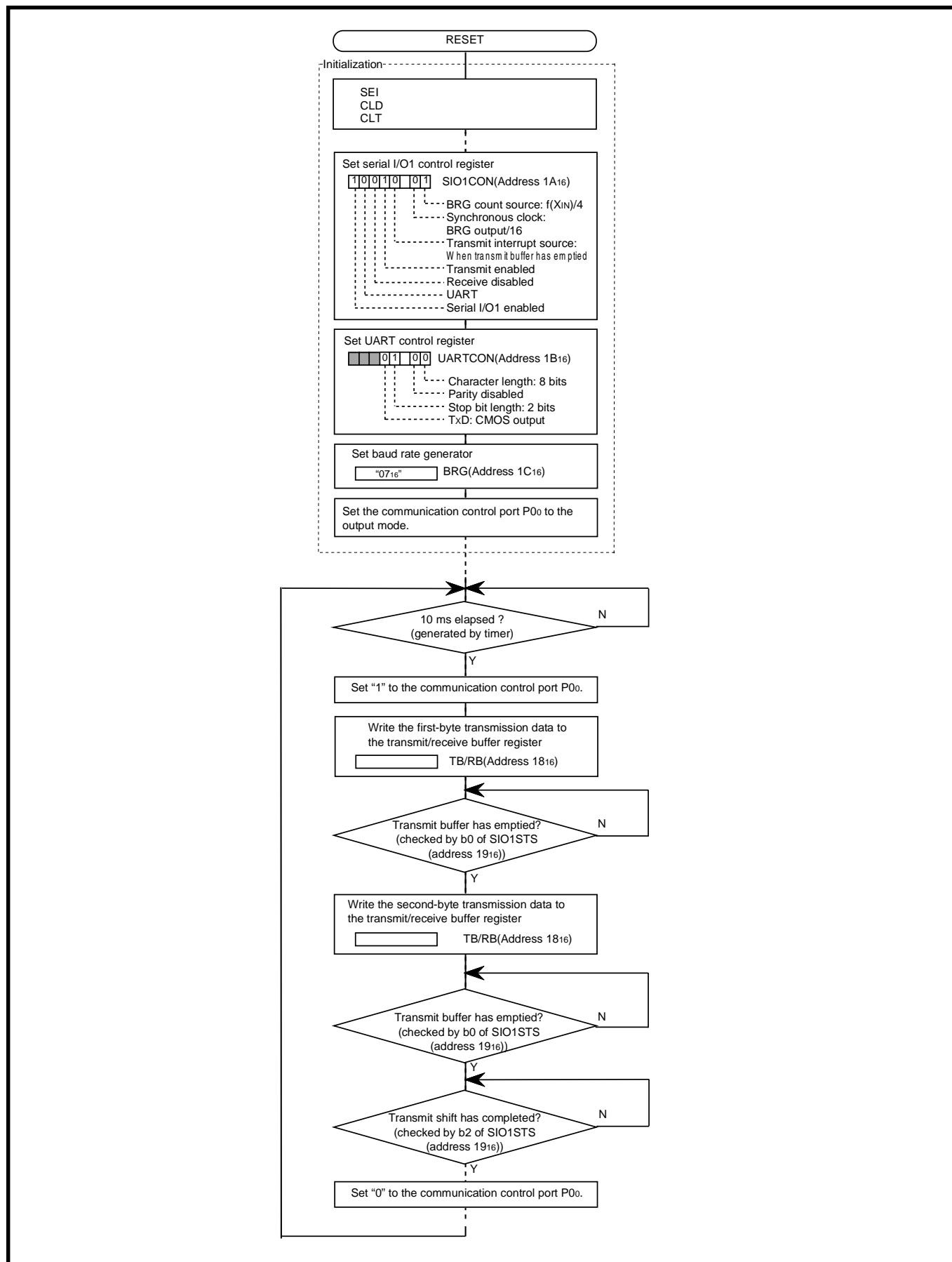


Fig. 2.6.20 Control procedure of transmitter

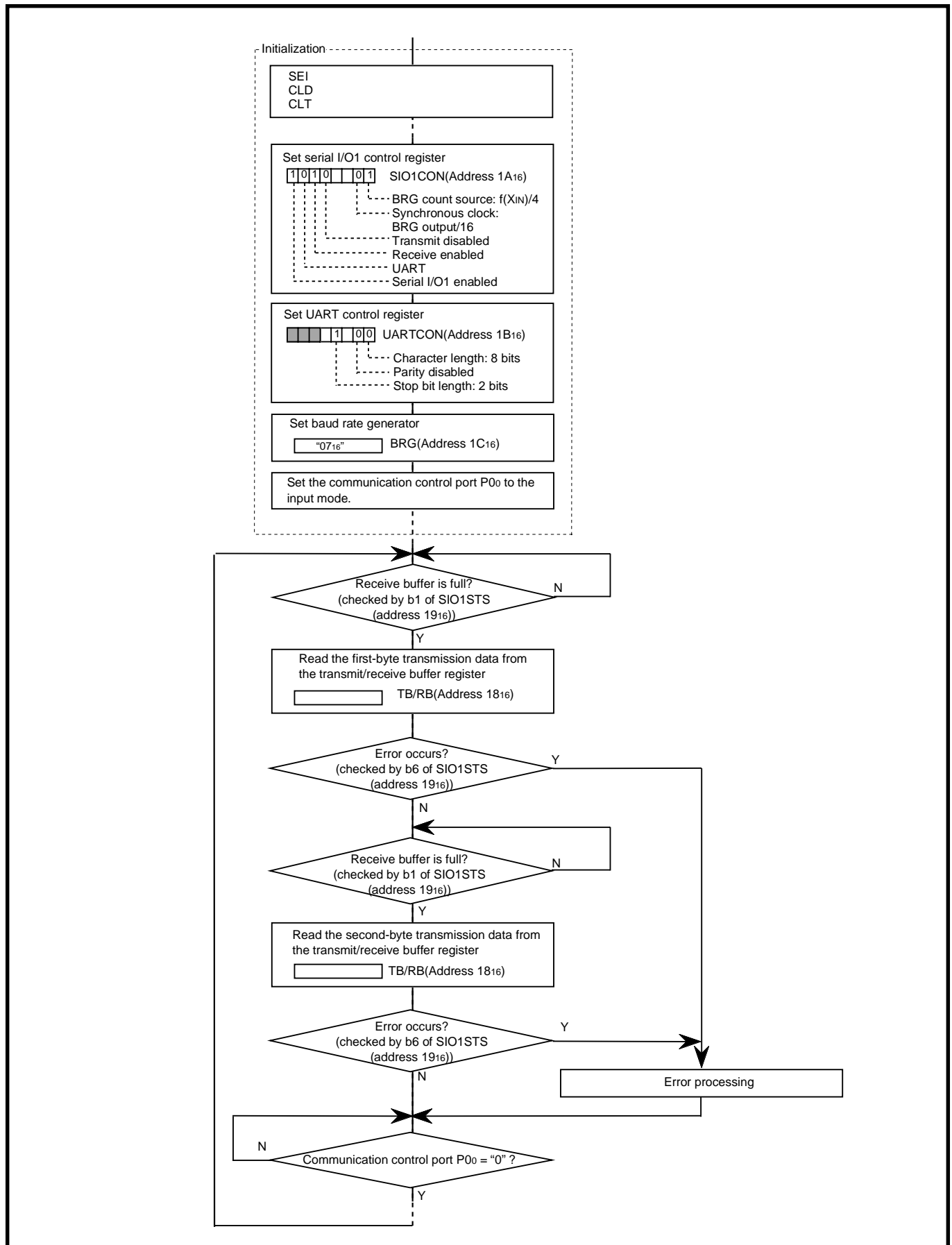


Fig. 2.6.21 Control procedure of receiver

2.6.6 Notes on Serial I/O1

Notes on using serial I/O1 are described below.

(1) Notes when selecting clock synchronous serial I/O

- ① When the clock synchronous serial I/O1 is used, serial I/O2 cannot be used.
- ② When the transmit operation is stopped, clear the serial I/O1 enable bit and the transmit enable bit to "0" (serial I/O1 and transmit disabled).

● Reason

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O1 enable bit is cleared to "0" (serial I/O1 disabled), the internal transmission is running (in this case, since pins TxD₁, RxD₁, S_{CLK1}, and $\overline{\text{SRDY1}}$ function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O1 enable bit is set to "1" at this time, the data during internally shifting is output to the TxD₁ pin and an operation failure occurs.

- ③ When the receive operation is stopped, clear the receive enable bit to "0" (receive disabled), or clear the serial I/O1 enable bit to "0" (serial I/O1 disabled).
- ④ When the transmit/receive operation is stopped, clear both the transmit enable bit and receive enable bit to "0" (transmit and receive disabled) simultaneously. (any one of data transmission and reception cannot be stopped.)

● Reason

In the clock synchronous serial I/O mode, the same clock is used for transmission and reception. If any one of transmission and reception is disabled, a bit error occurs because transmission and reception cannot be synchronized.

In this mode, the clock circuit of the transmission circuit also operates for data reception. Accordingly, the transmission circuit does not stop by clearing only the transmit enable bit to "0" (transmit disabled). Also, the transmission circuit cannot be initialized even if the serial I/O1 enable bit is cleared to "0" (serial I/O1 disabled) (same as ②).

- ⑤ When signals are output from the $\overline{\text{SRDY1}}$ pin on the reception side by using an external clock, set all of the receive enable bit, the $\overline{\text{SRDY1}}$ output enable bit, and the transmit enable bit to "1".
- ⑥ When the S_{RDY1} signal input is used, set the using pin to the input mode before data is written to the transmit/receive buffer register.
- ⑦ Setup of a serial I/O1 synchronous clock selection bit when a clock synchronous serial I/O is selected;
 - "0" : P₁₂ pin turns into an output pin of a synchronous clock.
 - "1" : P₁₂ pin turns into an input pin of a synchronous clock.
 Setup of a $\overline{\text{SRDY1}}$ output enable bit ($\overline{\text{SRDY1}}$) when a clock synchronous serial I/O1 is selected;
 - "0" : P₁₃ pin can be used as a normal I/O pin.
 - "1" : P₁₃ pin turns into a $\overline{\text{SRDY1}}$ output pin.

(2) Notes when selecting UART

- ① When the clock asynchronous serial I/O1 (UART) is used, serial I/O2 can be used only when BRG output divided by 16 is selected as the synchronous clock.
- ② When the transmit operation is stopped, clear the transmit enable bit to "0" (transmit disabled).

● Reason

Same as (1) ②.

- ③ When the receive operation is stopped, clear the receive enable bit to "0" (receive disabled).
- ④ When the transmit/receive operation is stopped, clear the transmit enable bit to "0" (transmit disabled) and receive enable bit to "0" (receive disabled).
- ⑤ Setup of a serial I/O1 synchronous clock selection bit when a clock asynchronous (UART) serial I/O is selected;
 - "0": P1₂ pin can be used as a normal I/O pin.
 - "1": P1₂ pin turns into an input pin of an external clock.
 When clock asynchronous (UART) type serial I/O is selected, it is P1₃ pin. It can be used as a normal I/O pin.

(3) Notes common to clock synchronous serial I/O and UART

- ① Set the serial I/O control register again after the transmission and the reception circuits are reset by clearing both the transmit enable bit and the receive enable bit to "0."
- ② The transmit shift completion flag changes from "1" to "0" with a delay of 0.5 to 1.5 shift clocks. When data transmission is controlled with referring to the flag after writing the data to the transmit buffer register, note the delay.

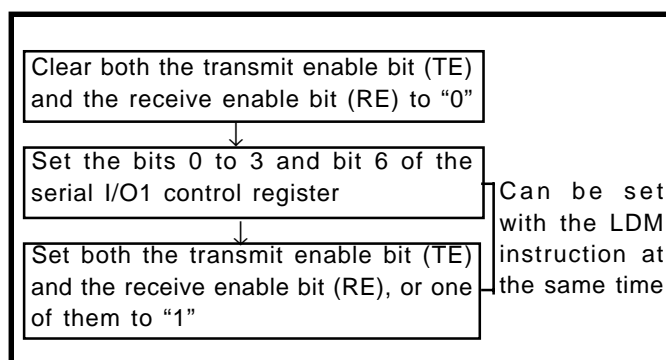


Fig. 2.6.22 Sequence of setting serial I/O1 control register again

- ③ When data transmission is executed at the state that an external clock input is selected as the synchronous clock, set "1" to the transmit enable bit while the S_{CLK1} is "H" state. Also, write to the transmit buffer register while the S_{CLK1} is "H" state.
- ④ When the transmit interrupt is used, set as the following sequence.
 - ❶ Serial I/O1 transmit interrupt enable bit is set to "0" (disabled).
 - ❷ Serial I/O1 transmit enable bit is set to "1".
 - ❸ Serial I/O1 transmit interrupt request bit is set to "0".
 - ❹ Serial I/O1 transmit interrupt enable bit is set to "1" (enabled).

● Reason

When the transmit enable bit is set to "1", the transmit buffer empty flag and transmit shift completion flag are set to "1".

Accordingly, even if the timing when any of the above flags is set to "1" is selected for the transmit interrupt source, interrupt request occurs and the transmit interrupt request bit is set.

- ⑤ Write to the baud rate generator (BRG) while the transmit/receive operation is stopped.

2.7 Serial I/O2

This paragraph explains the registers setting method and the notes relevant to the serial I/O.

2.7.1 Memory map

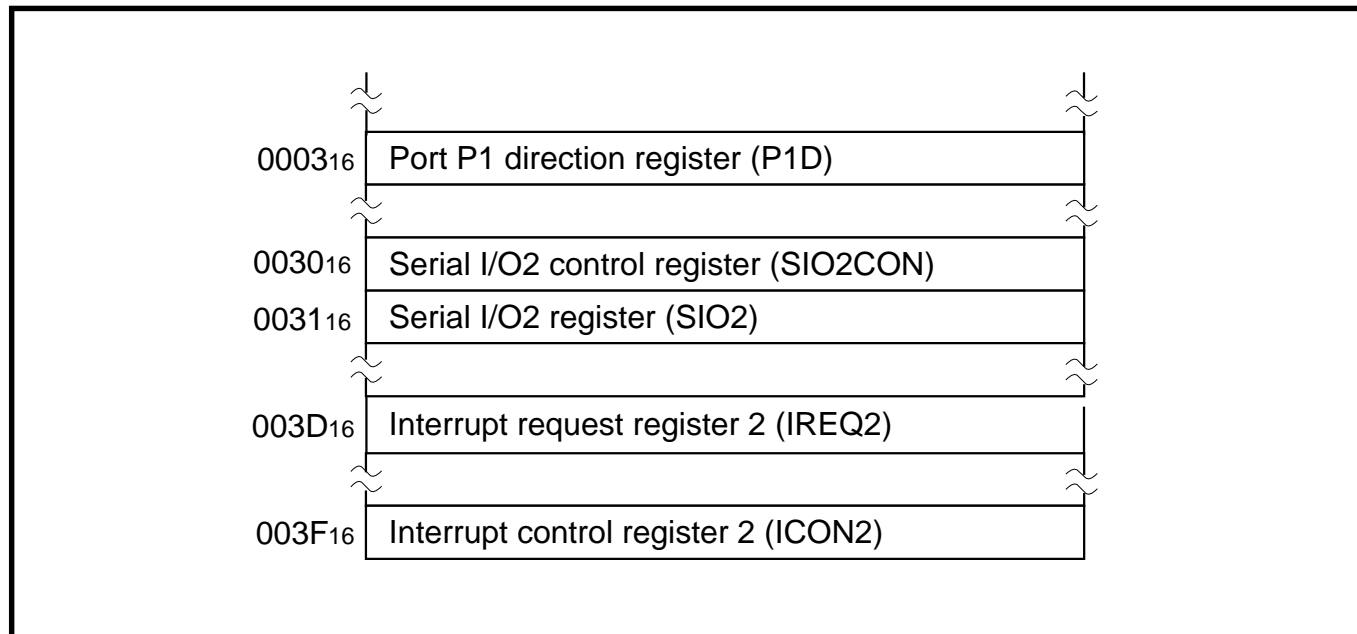


Fig. 2.7.1 Memory map of registers relevant to serial I/O2

2.7.2 Relevant registers

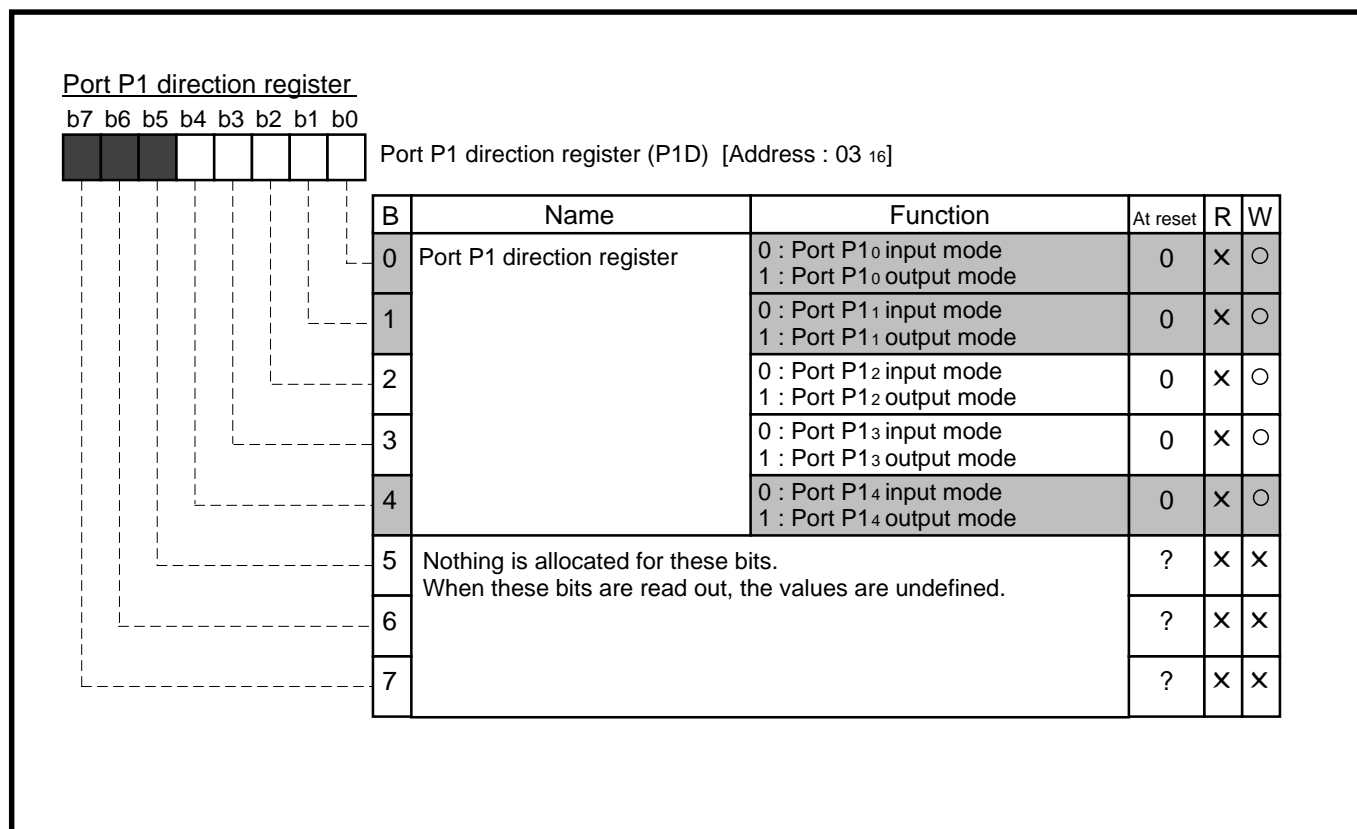


Fig. 2.7.2 Structure of Port P1 direction register

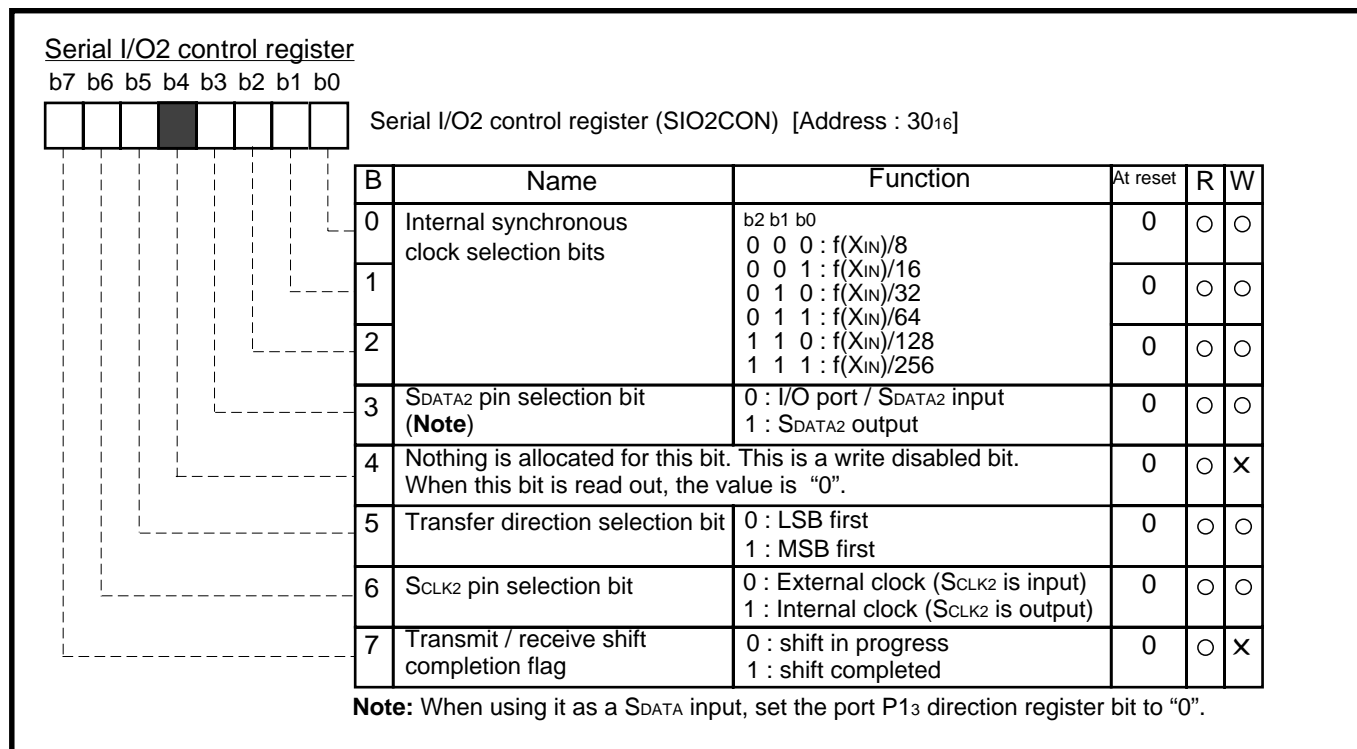


Fig. 2.7.3 Structure of Serial I/O2 control register

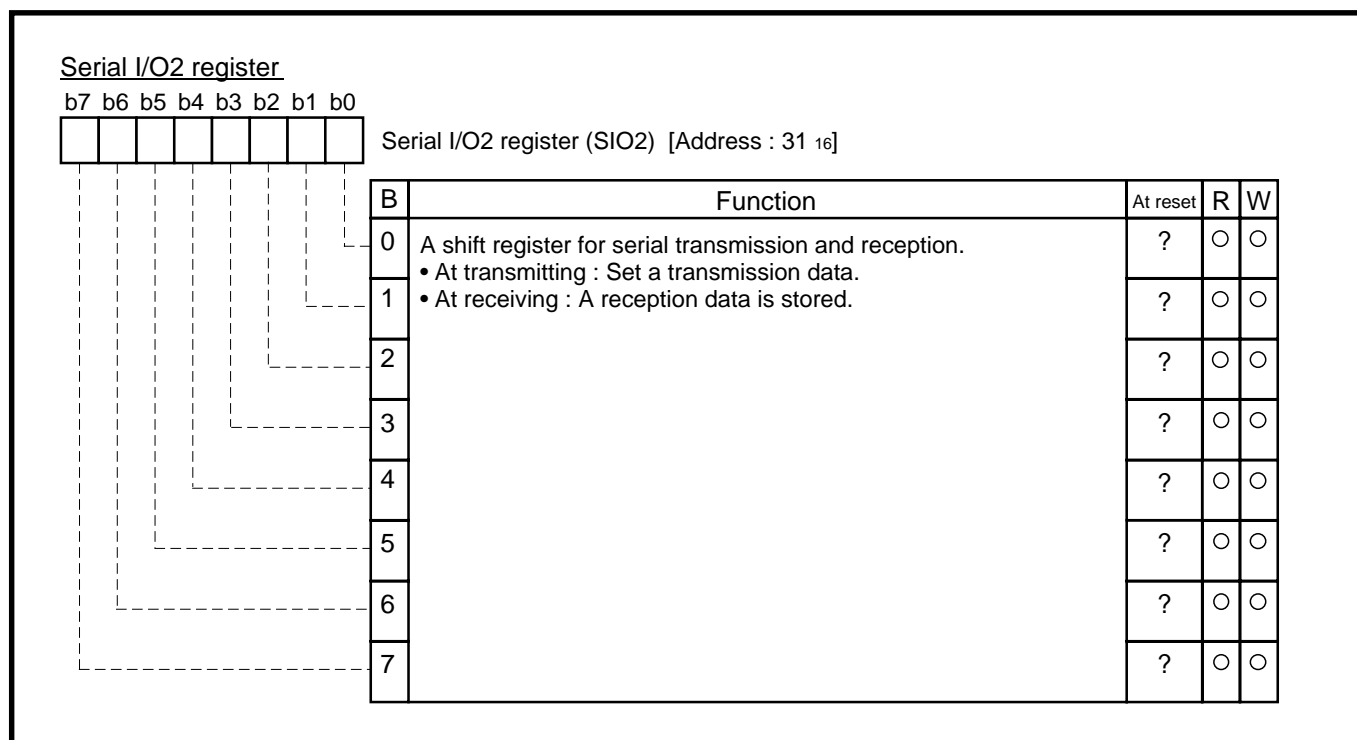


Fig. 2.7.4 Structure of Serial I/O2 register

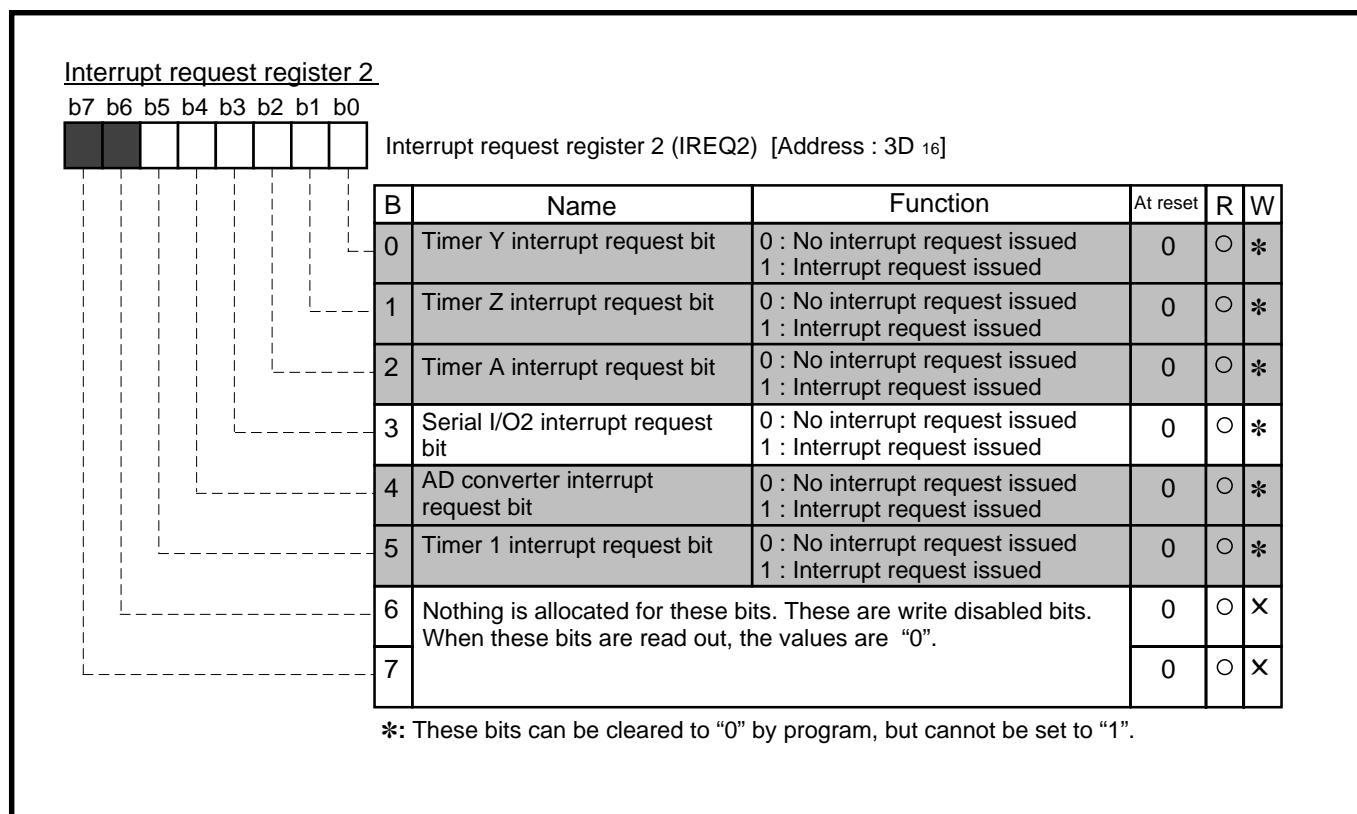


Fig. 2.7.5 Structure of Interrupt request register 2

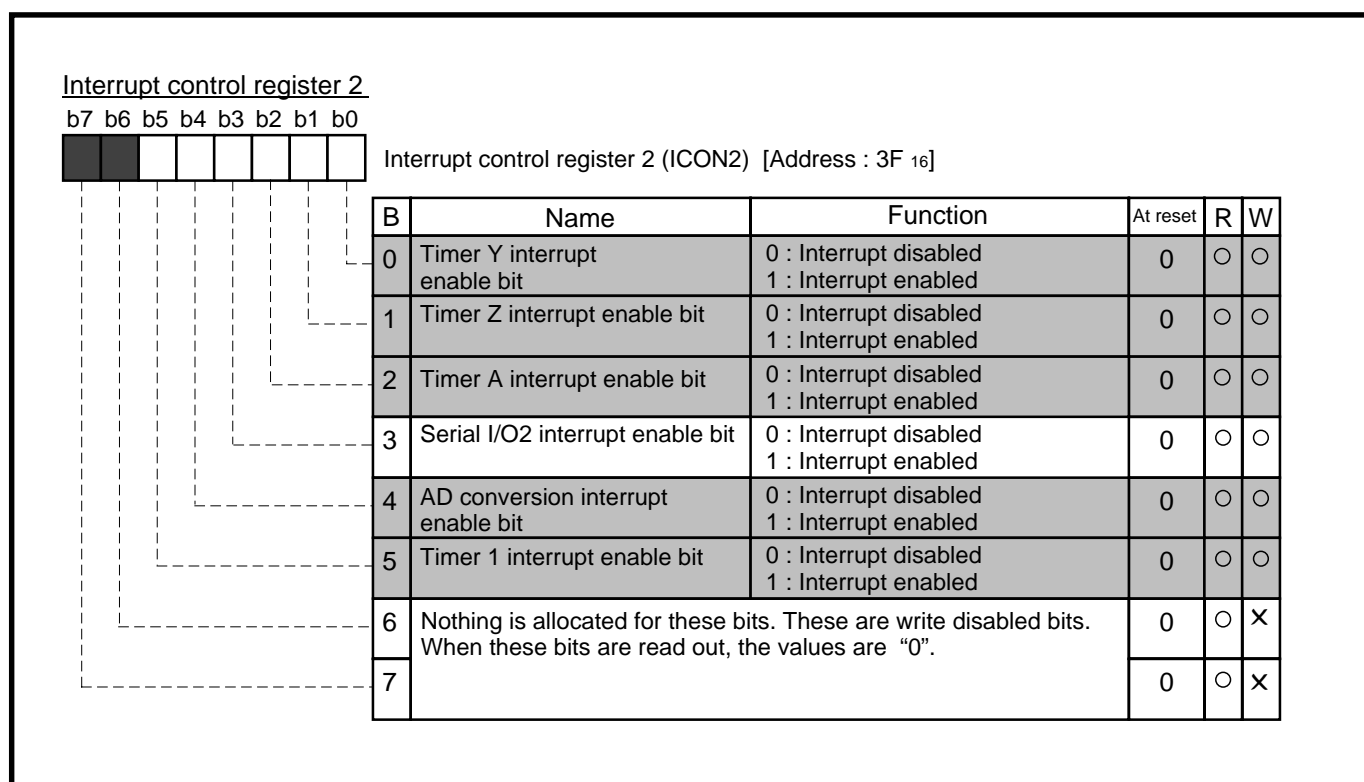


Fig. 2.7.6 Structure of Interrupt control register 2

2.7.3 Application example of serial I/O2

(1) Serial I/O2 setting method

Figure 2.7.7 and Figure 2.7.8 show the setting method for the serial I/O2.

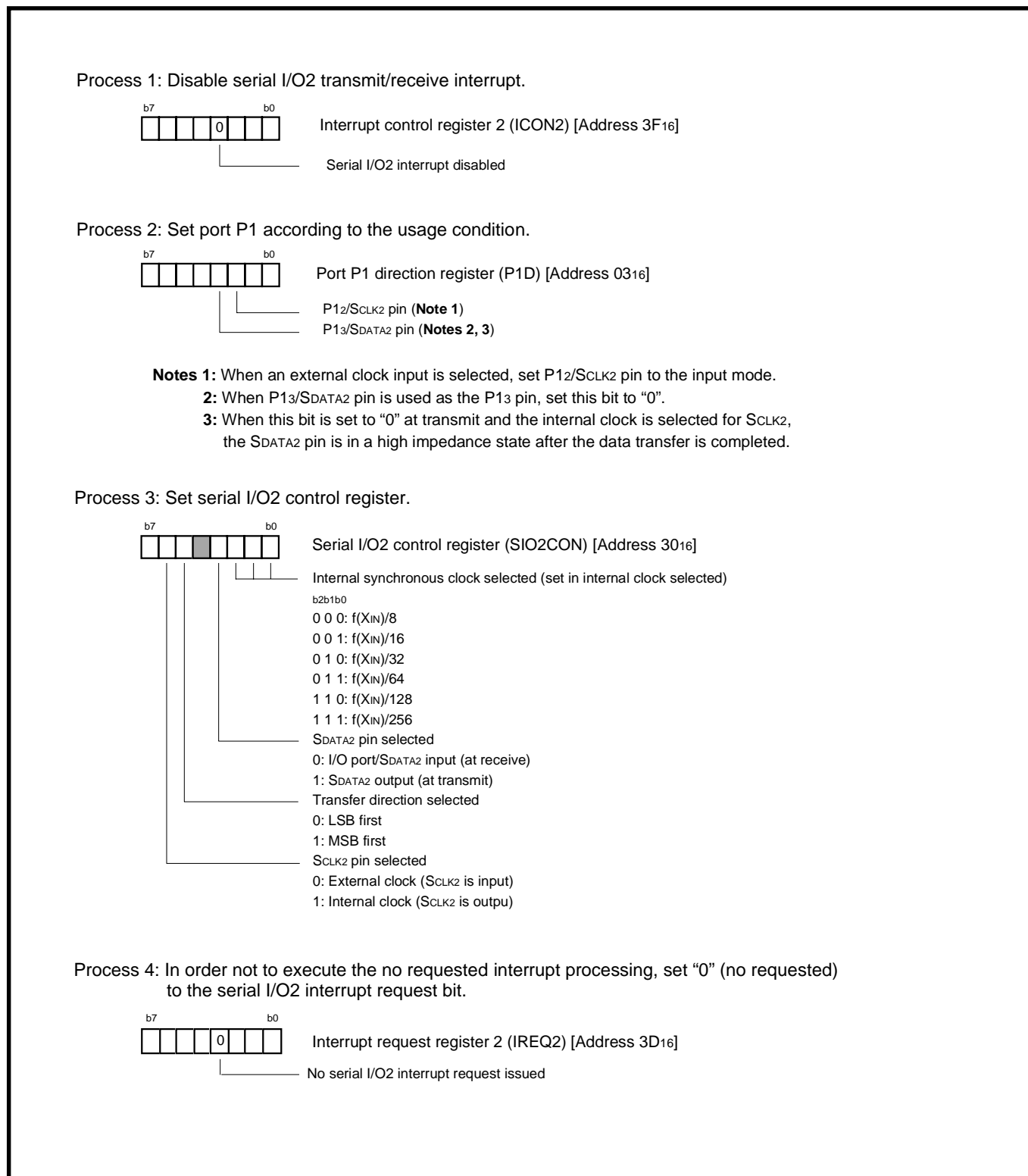


Fig. 2.7.7 Setting method for serial I/O2

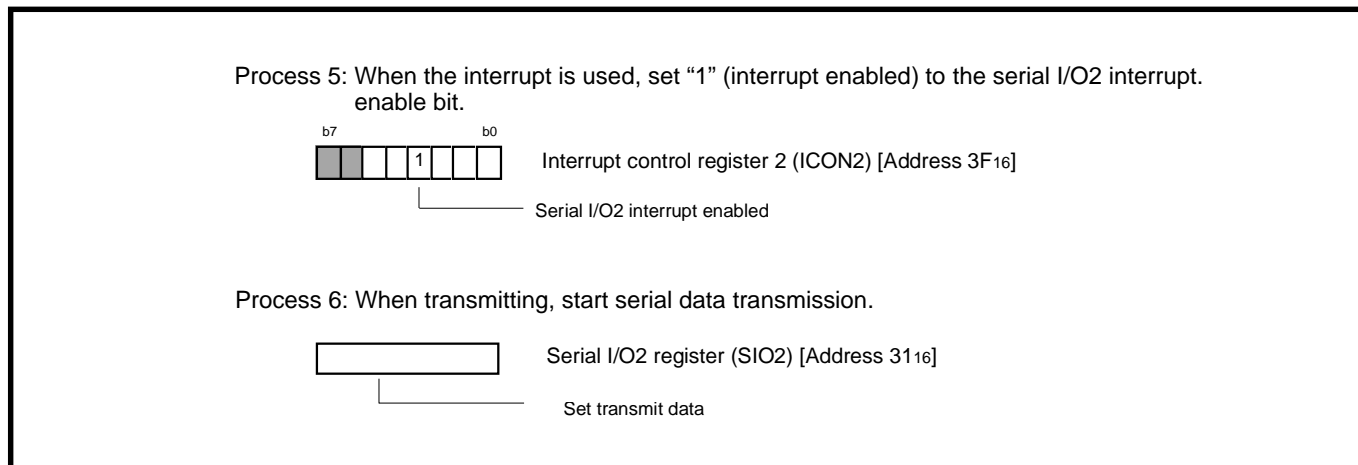


Fig. 2.7.8 Setting method for serial I/O2

(2) Communication using serial I/O2 (transmit/receive)

Outline: 2-byte data is transmitted and received, using the serial I/O2. Port P0₀ is used for communication control and outputs the quasi- $\overline{\text{SRDY}}$ signal.

- Specifications:**
- The serial I/O2, clock synchronous serial I/O, is used.
 - Synchronous clock frequency : 125 kHz; $f(X_{\text{IN}}) = 8 \text{ MHz}$ divided by 64
 - Transfer direction : LSB first
 - The receiver outputs the quasi- $\overline{\text{SRDY}}$ signal at 2 ms intervals which the timer generates, and 2-byte data is transferred from the transmitter to the receiver.

Figure 2.7.9 shows a connection diagram, Figure 2.7.10 shows a timing chart, Figure 2.7.11 shows the control procedure of transmitter, and Figure 2.7.12 shows an example of control procedure of receiver.

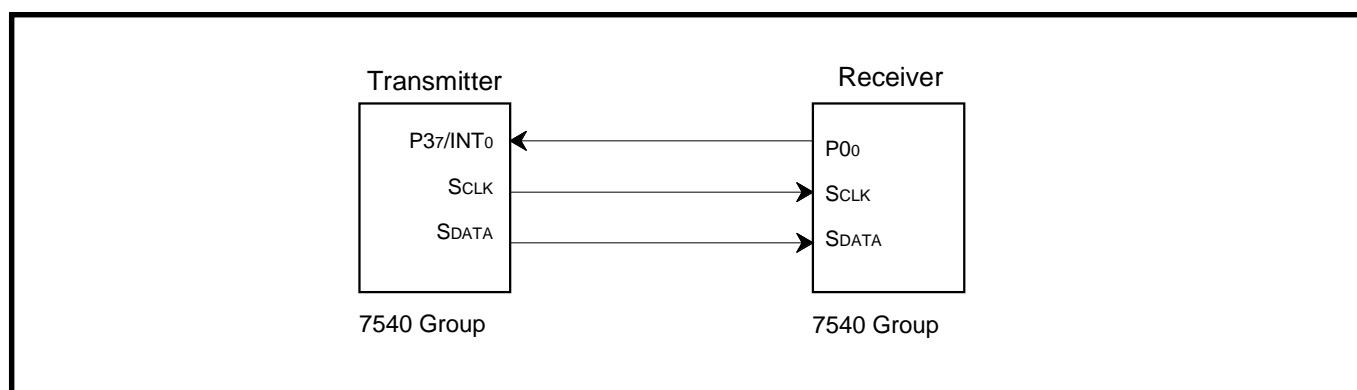


Fig. 2.7.9 Connection diagram

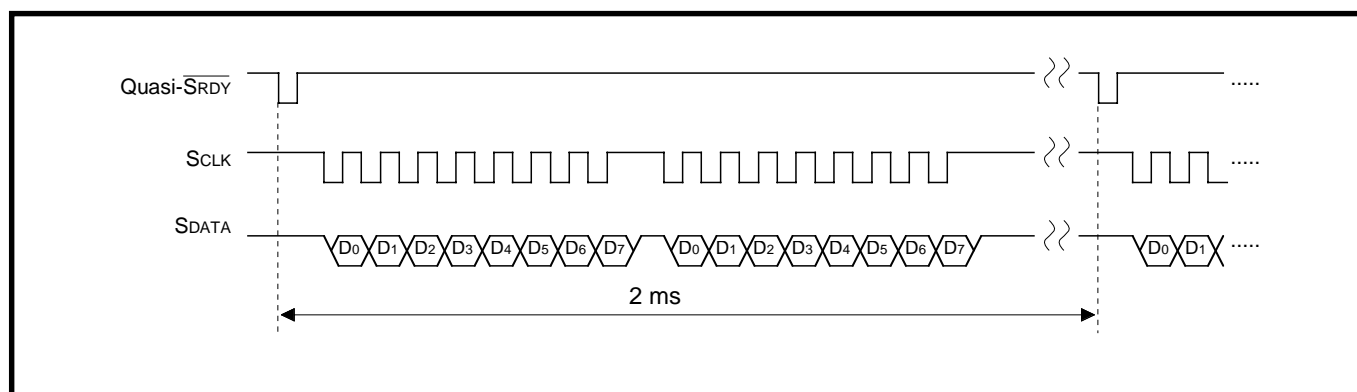


Fig. 2.7.10 Timing chart

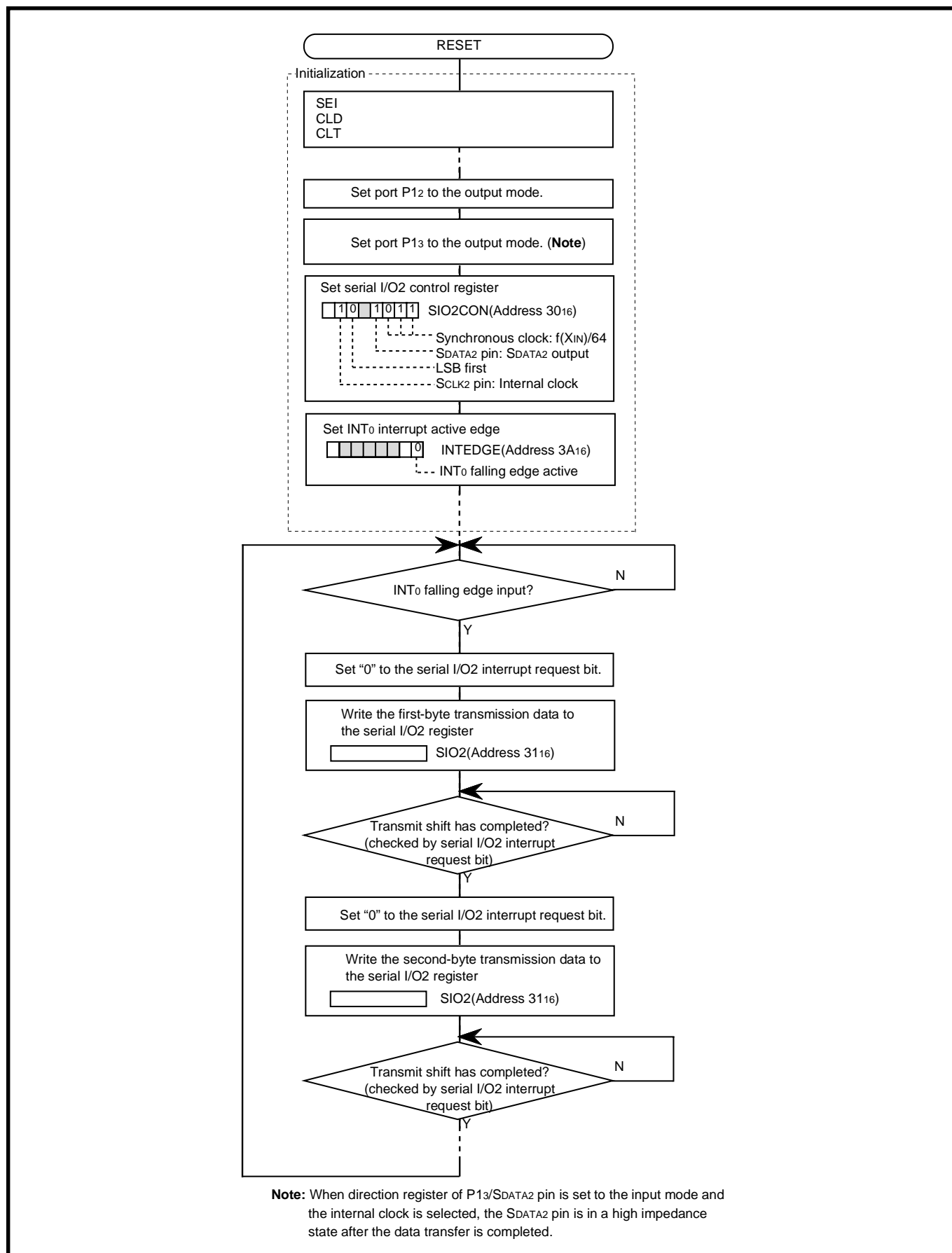


Fig. 2.7.11 Control procedure of transmission side

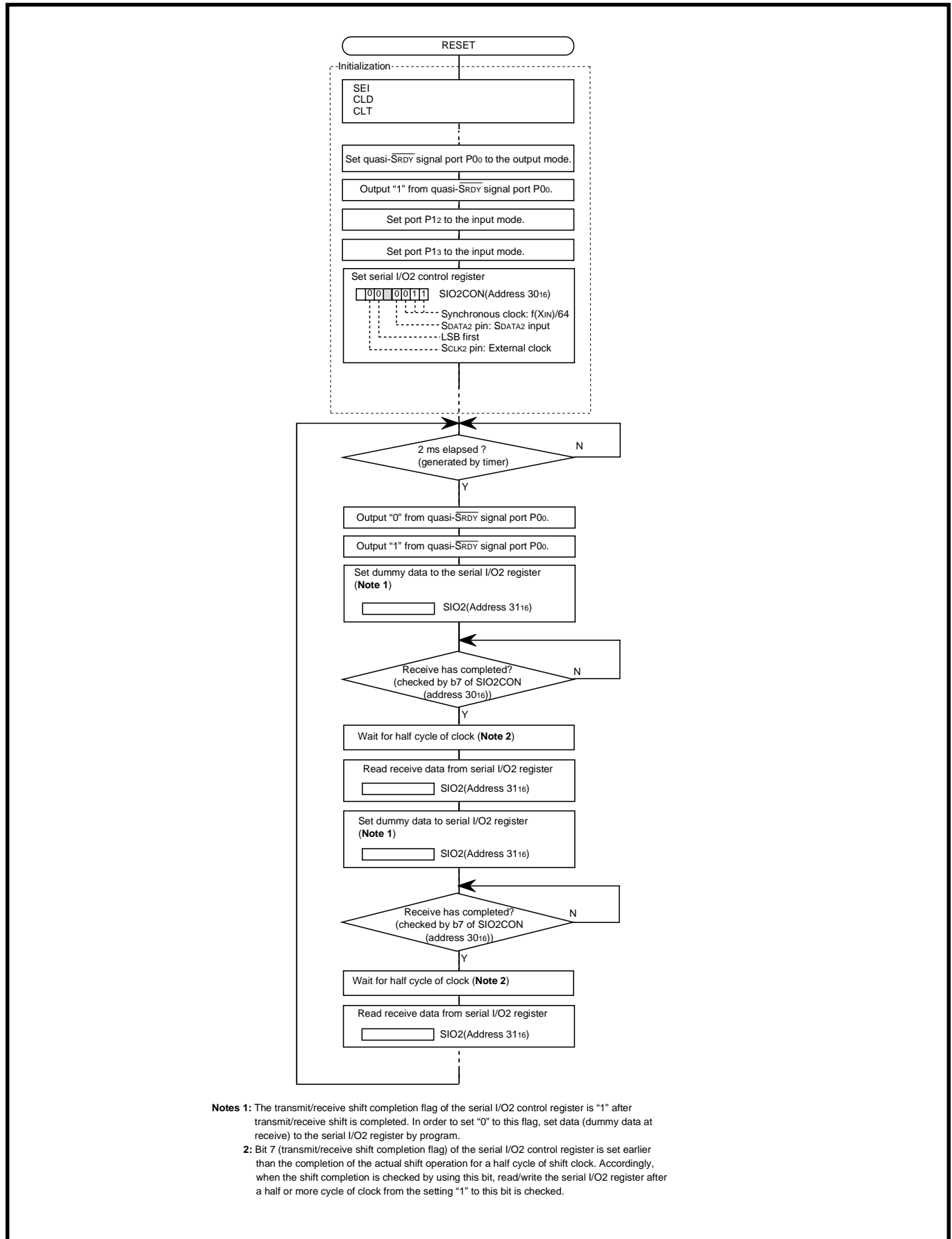


Fig. 2.7.12 Control procedure of reception side

2.7.4 Notes on serial I/O2

Notes on using serial I/O2 are described below.

(1) Note on serial I/O1

Serial I/O2 can be used only when serial I/O1 is not used or serial I/O1 is used as UART and the BRG output divided by 16 is selected as the synchronous clock.

(2) Note on S_{CLK2} pin

When an external clock is selected, set "0" to bit 2 of the port P1 direction register (input mode).

(3) Note on S_{DATA2} pin

When P1₃/S_{RDY1}/S_{DATA2} pin is used as the S_{DATA} input, set "0" to bit 3 of the port P1 direction register (input mode).

When the internal clock is selected as the transfer and P1₃/S_{DATA2} pin is set to the input mode, the S_{DATA2} pin is in a high-impedance state after the data transfer is completed.

(4) Notes on serial I/O2 transmit/receive shift completion flag

- ① The transmit/receive shift completion flag of the serial I/O2 control register is "1" after transmit/receive shift is completed. In order to set "0" to this flag, set data (dummy data at receive) to the serial I/O2 register by program.
- ② Bit 7 (transmit/receive shift completion flag) of the serial I/O2 control register is set earlier than the completion of the actual shift operation for a half cycle of shift clock. Accordingly, when the shift completion is checked by using this bit, read/write the serial I/O2 register after a half or more cycle of clock from the setting "1" to this bit is checked.

2.8 A/D converter

This paragraph explains the registers setting method and the notes relevant to the A/D converter.

2.8.1 Memory map

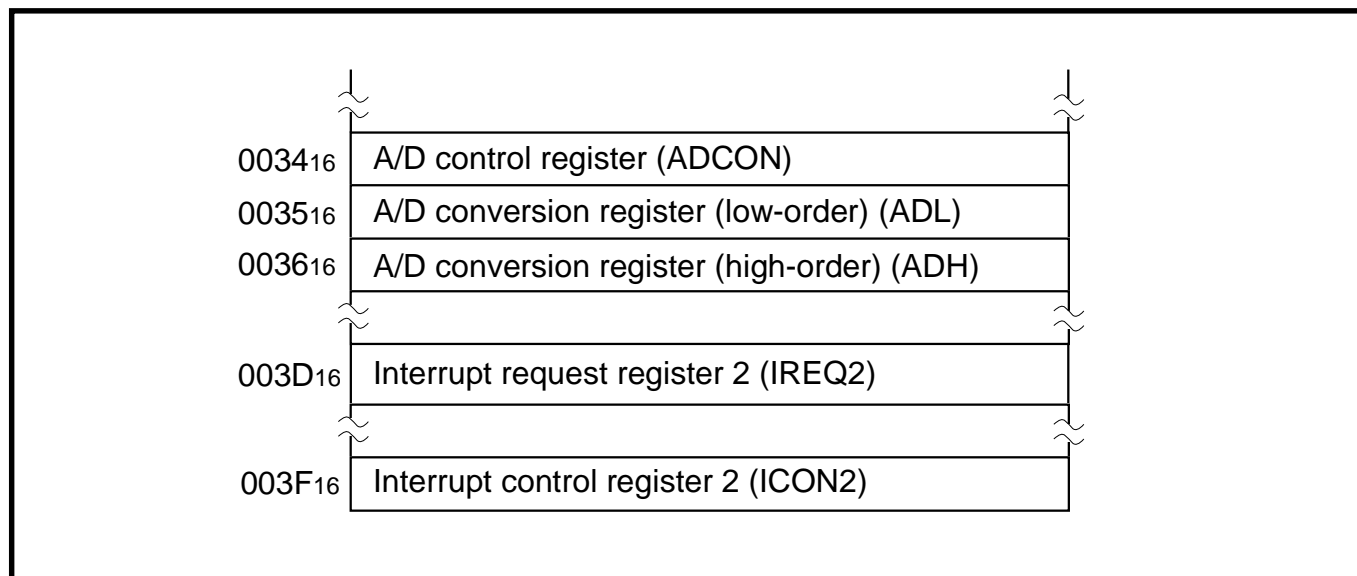


Fig. 2.8.1 Memory map of registers relevant to A/D converter

2.8.2 Relevant registers

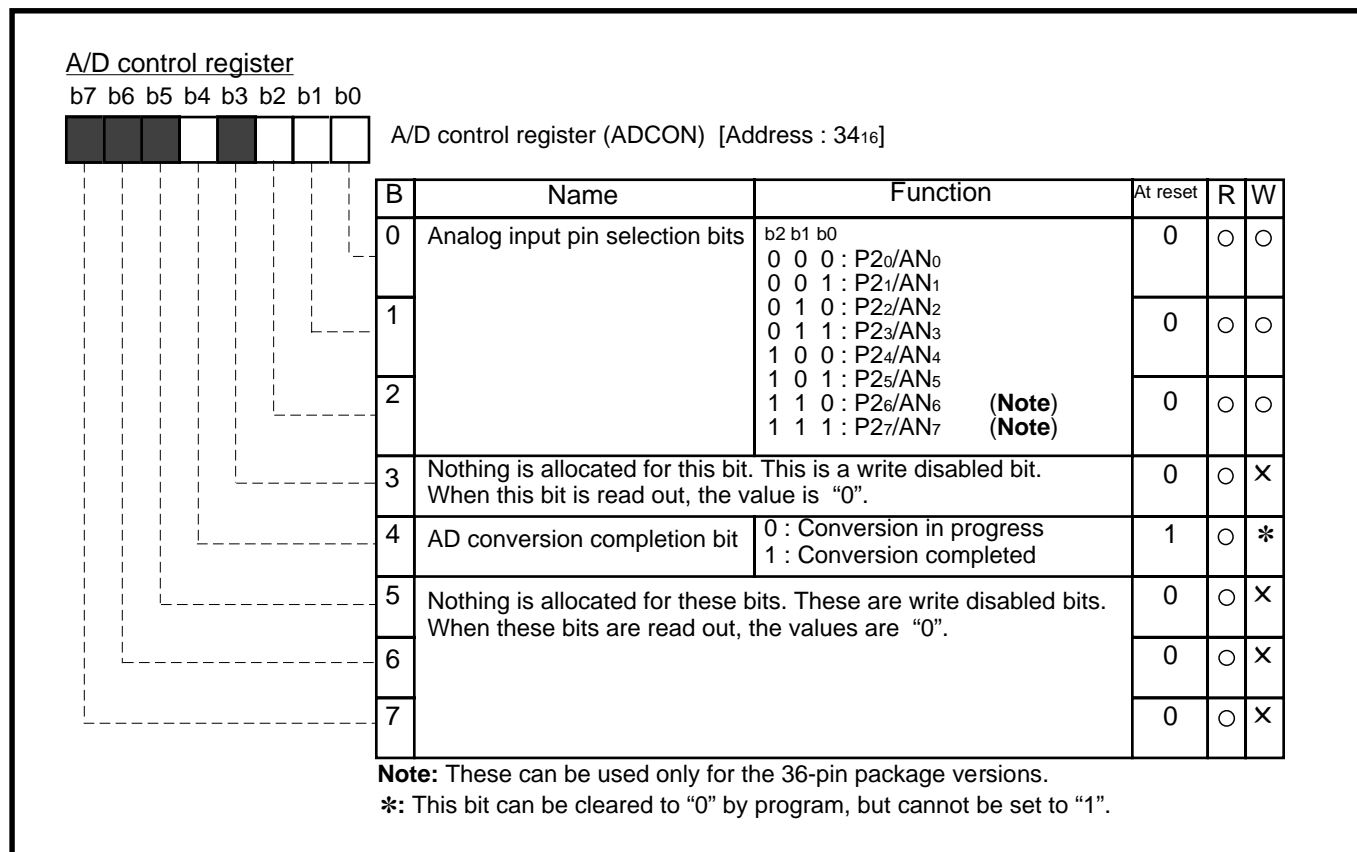


Fig. 2.8.2 Structure of A/D control register

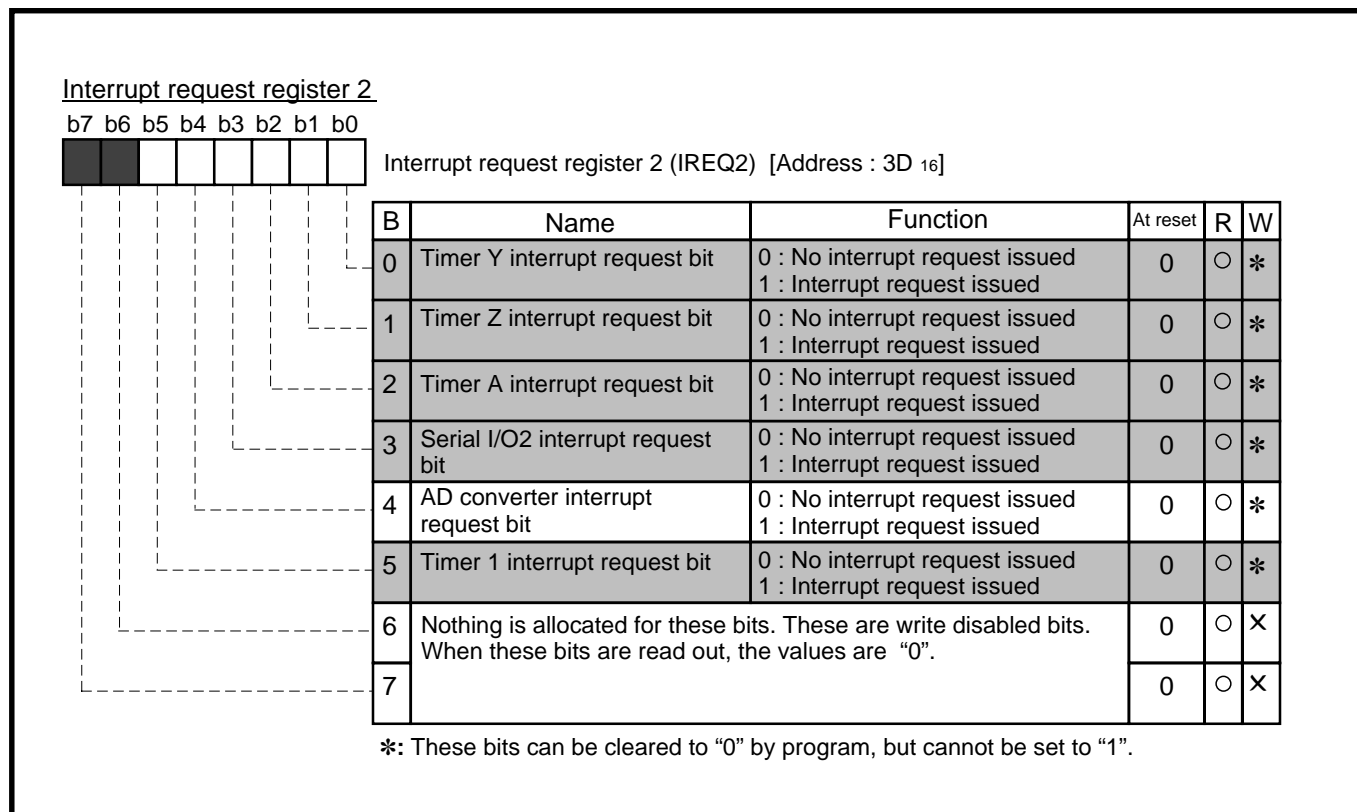


Fig. 2.8.5 Structure of Interrupt request register 2

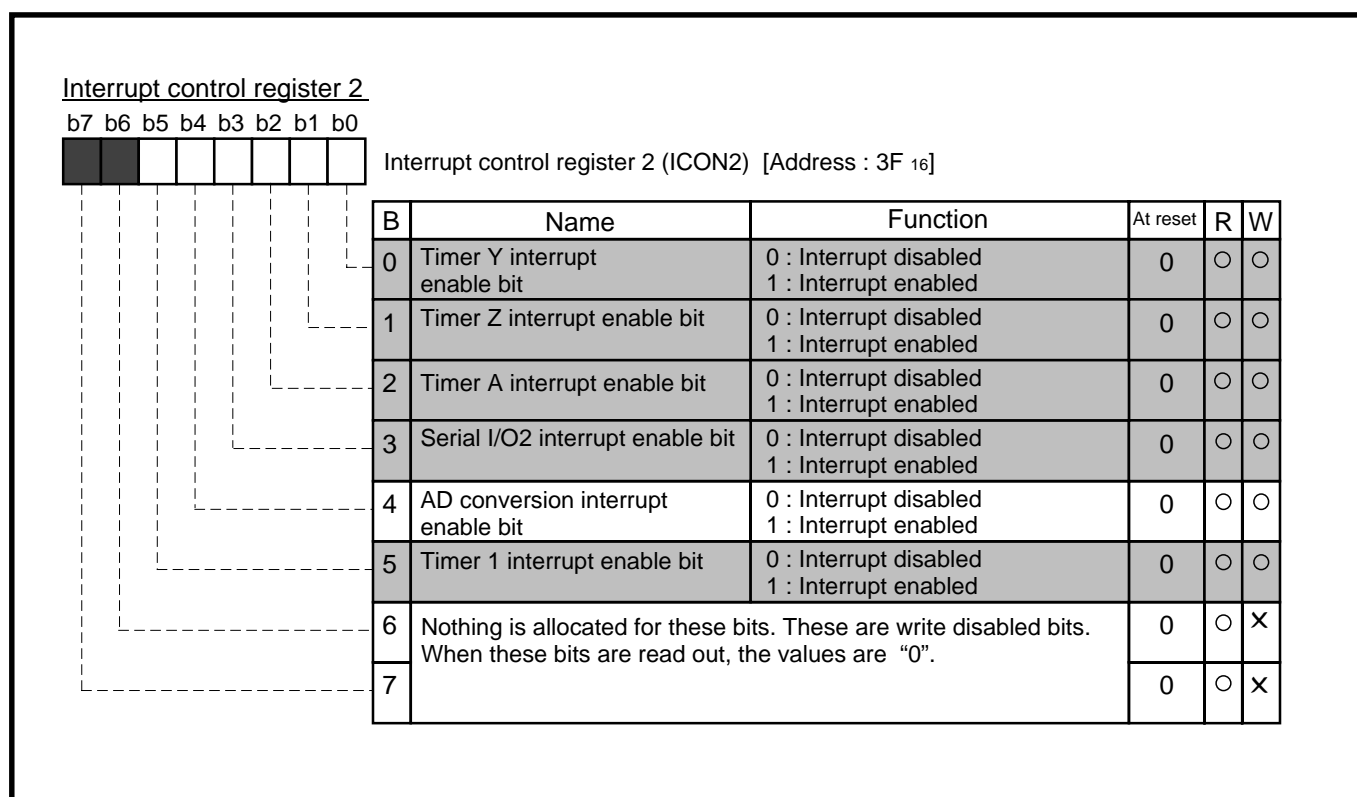


Fig. 2.8.6 Structure of Interrupt control register 2

2.8.3 A/D converter application examples

(1) Setting of A/D converter

Figure 2.8.7 shows the relevant registers setting.

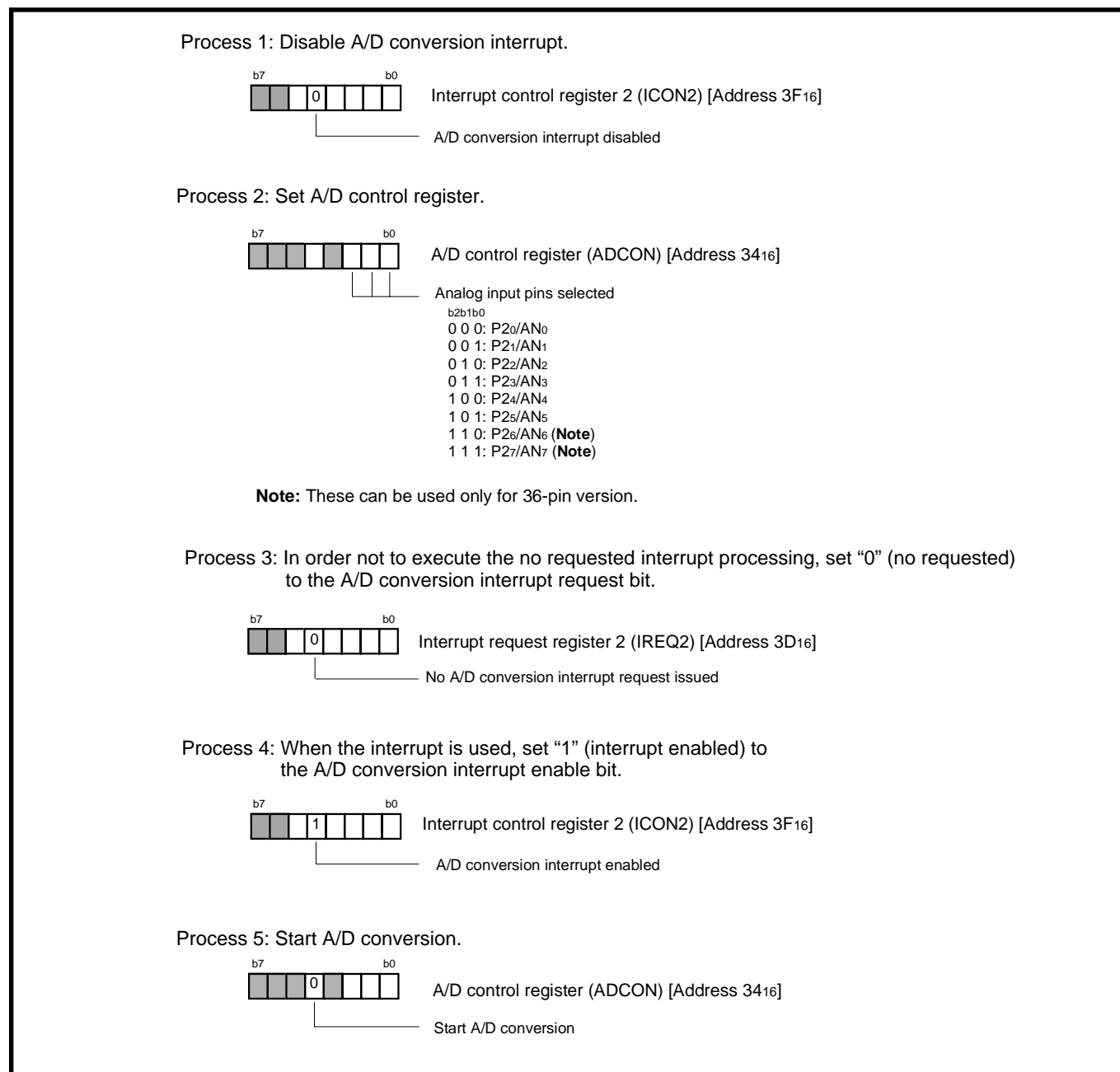


Fig. 2.8.7 Relevant registers setting

(2) Control procedure

Outline : The analog input voltage input from a sensor is converted to digital values.

Specifications : •The analog input voltage input from a sensor is converted to digital values.

•P20/AN0 pin is used as an analog input pin.

Figure 2.8.8 shows a connection diagram, and Figure 2.8.9 shows an example of control procedure.

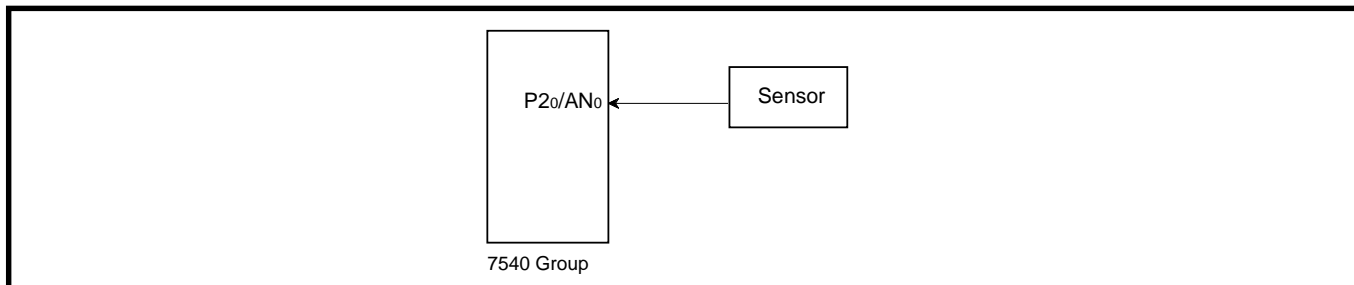


Fig. 2.8.8 Connection diagram

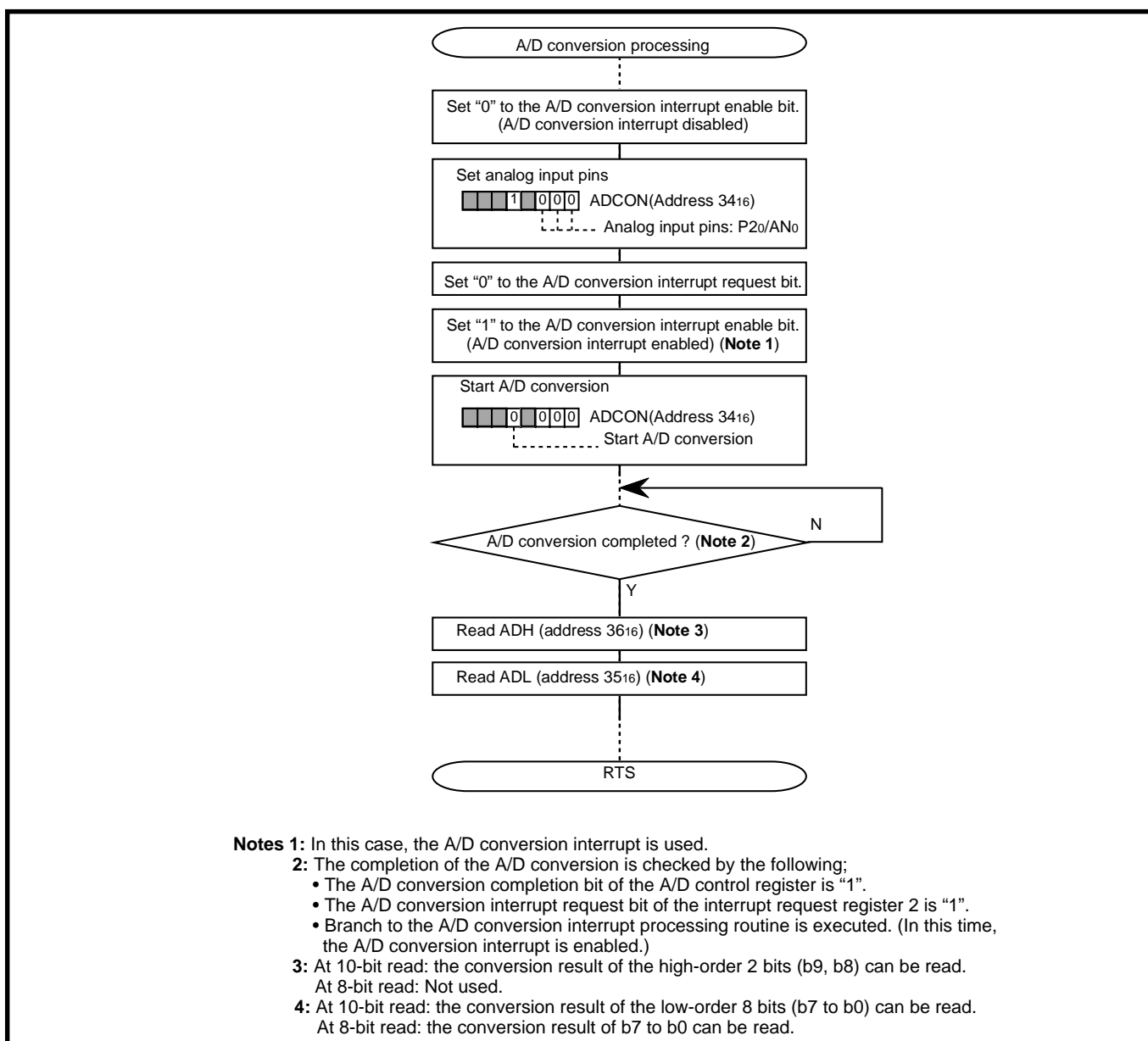


Fig. 2.8.9 Control procedure

2.8.4 Notes on A/D converter

Notes on A/D converter are described below.

(1) Analog input pin

Figure 2.8.10 shows the internal equivalent circuit of an analog input. In order to execute the A/D conversion correctly, to complete the charge to an internal capacitor within the specified time is required. The maximum output impedance of the analog input source required to complete the charge to a capacitor within the specified time is as follows;

About 35 k Ω (at $f(X_{IN}) = 8$ MHz)

When the maximum output impedance exceeds the above value, equip an analog input pin with an external capacitor of 0.01 μ F to 1 μ F between an analog input pin and V_{SS} .

Further, be sure to verify the operation of application products on the user side.

● Reason

An analog input pin includes the capacitor for analog voltage comparison. Accordingly, when signals from signal source with high impedance are input to an analog input pin, charge and discharge noise generates. This may cause the A/D conversion/comparison precision to be worse.

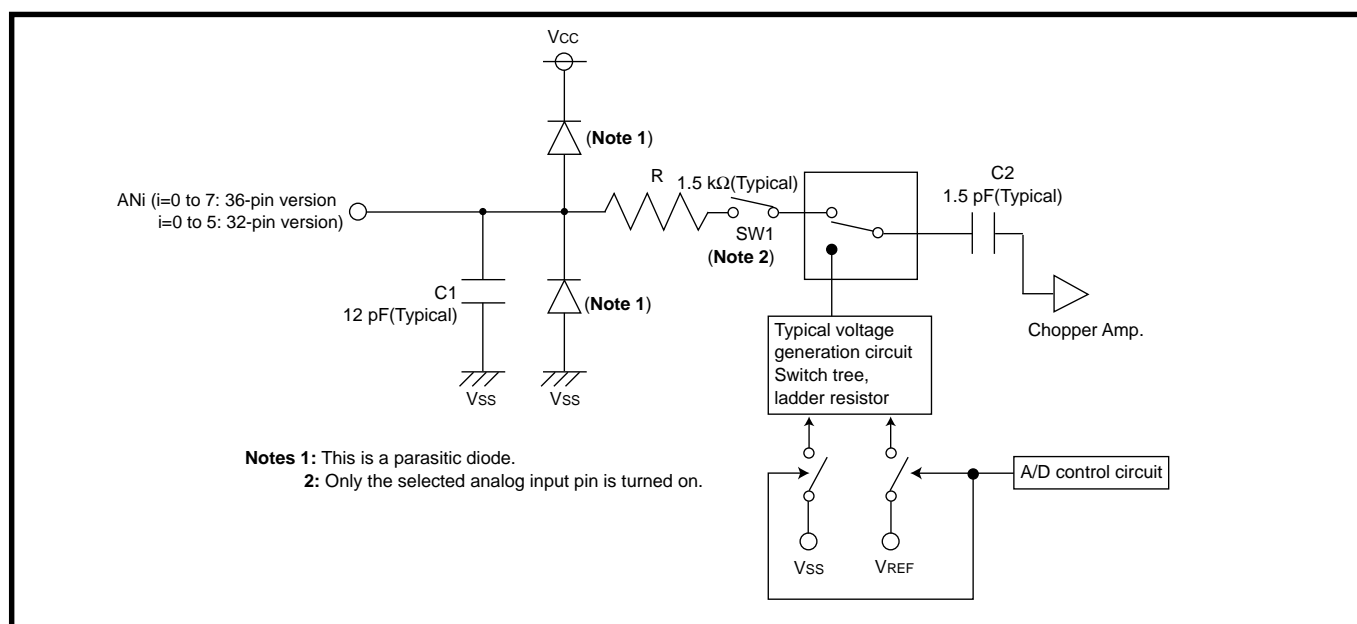


Fig. 2.8.10 Connection diagram

(2) Clock frequency during A/D conversion

The comparator consists of a capacity coupling, and a charge of the capacity will be lost if the clock frequency is too low. Thus, make sure the following during an A/D conversion.

- $f(X_{IN})$ is 500 kHz or more
- Do not execute the **STP** instruction

(3) Note on A/D converter

As for AD translation accuracy, on the following operating conditions, accuracy may become low.

- (1) Since the analog circuit inside a microcomputer becomes sensitive to noise when V_{REF} voltage is set up lower than V_{CC} voltage, accuracy may become low rather than the case where V_{REF} voltage and V_{CC} voltage are set up to the same value.
- (2) When V_{REF} voltage is lower than [3.0 V], the accuracy at the low temperature may become extremely low compared with that at room temperature. When the system would be used at low temperature, the use at $V_{REF}=3.0$ V or more is recommended.

2.9 Oscillation control

This paragraph explains the registers setting method and the notes relevant to the oscillation control.

2.9.1 Memory map

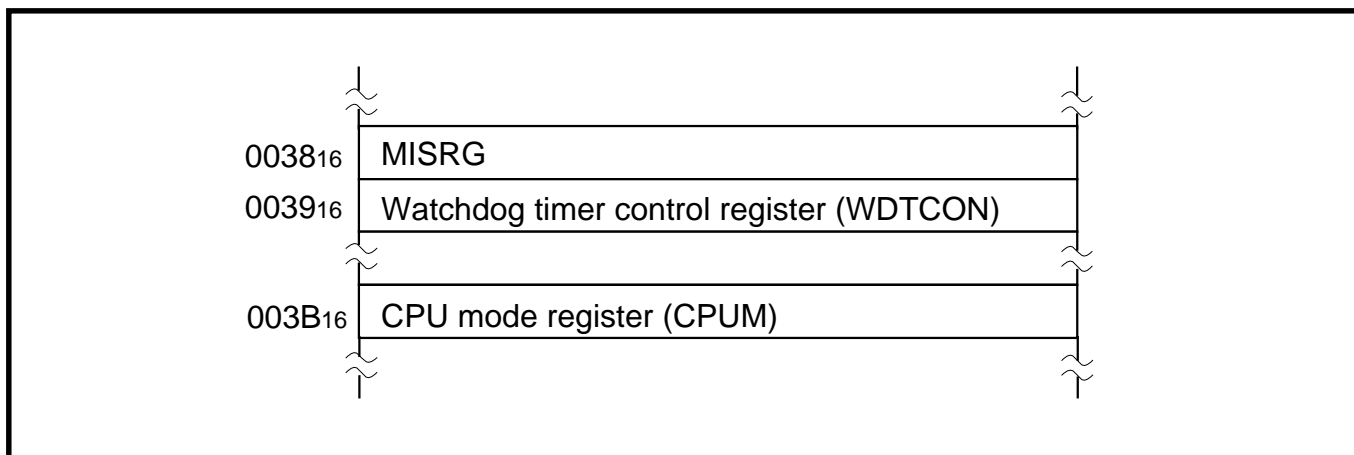


Fig. 2.9.1 Memory map of registers relevant to oscillation control

2.9.2 Relevant registers

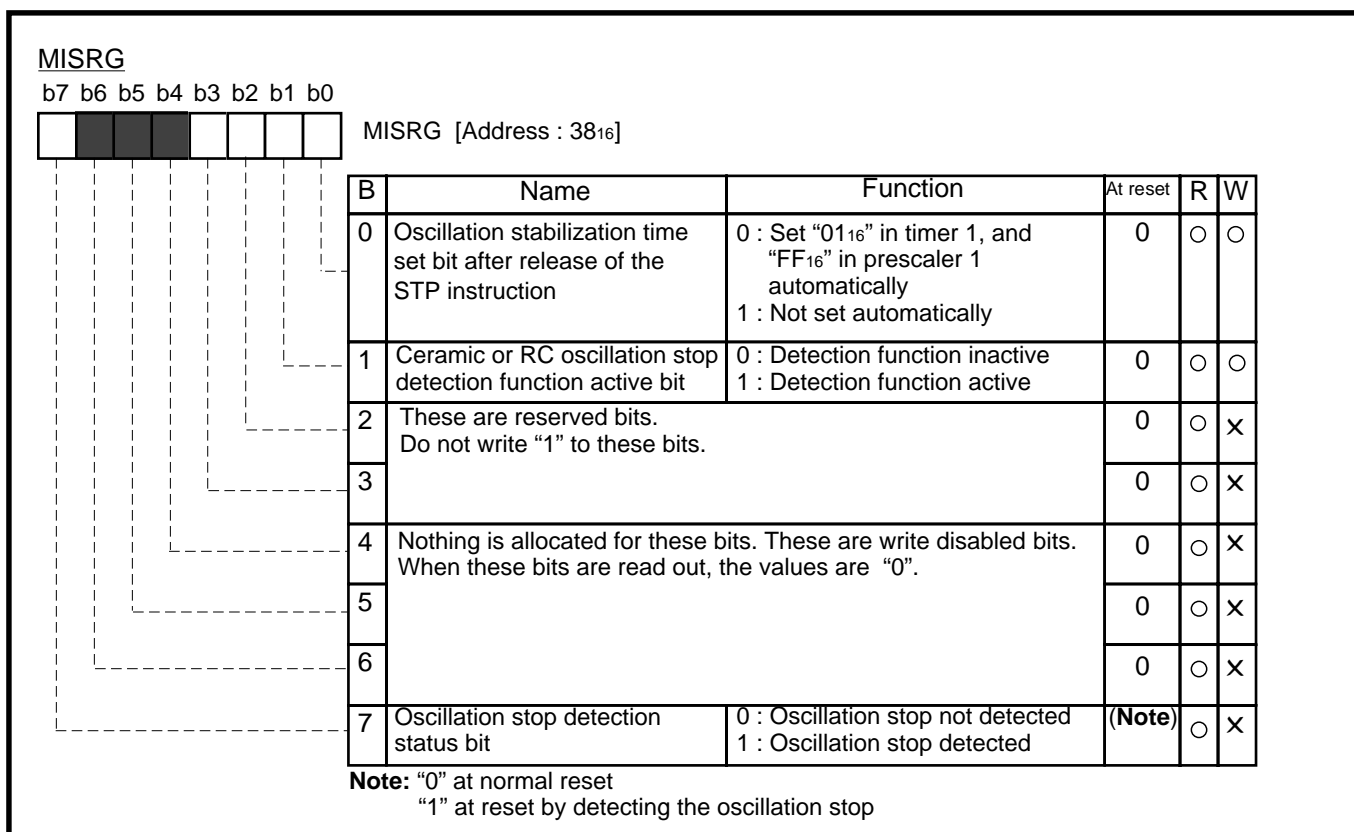


Fig. 2.9.2 Structure of MISRG

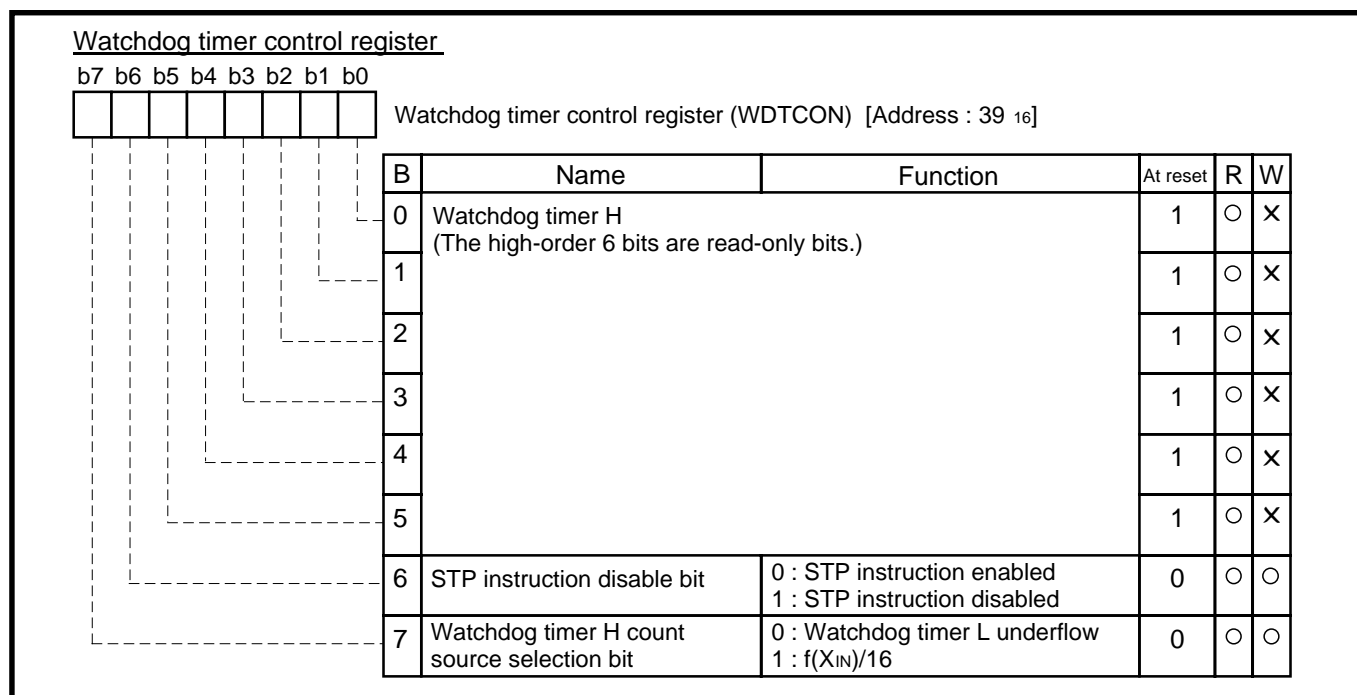


Fig. 2.9.3 Structure of Watchdog timer control register

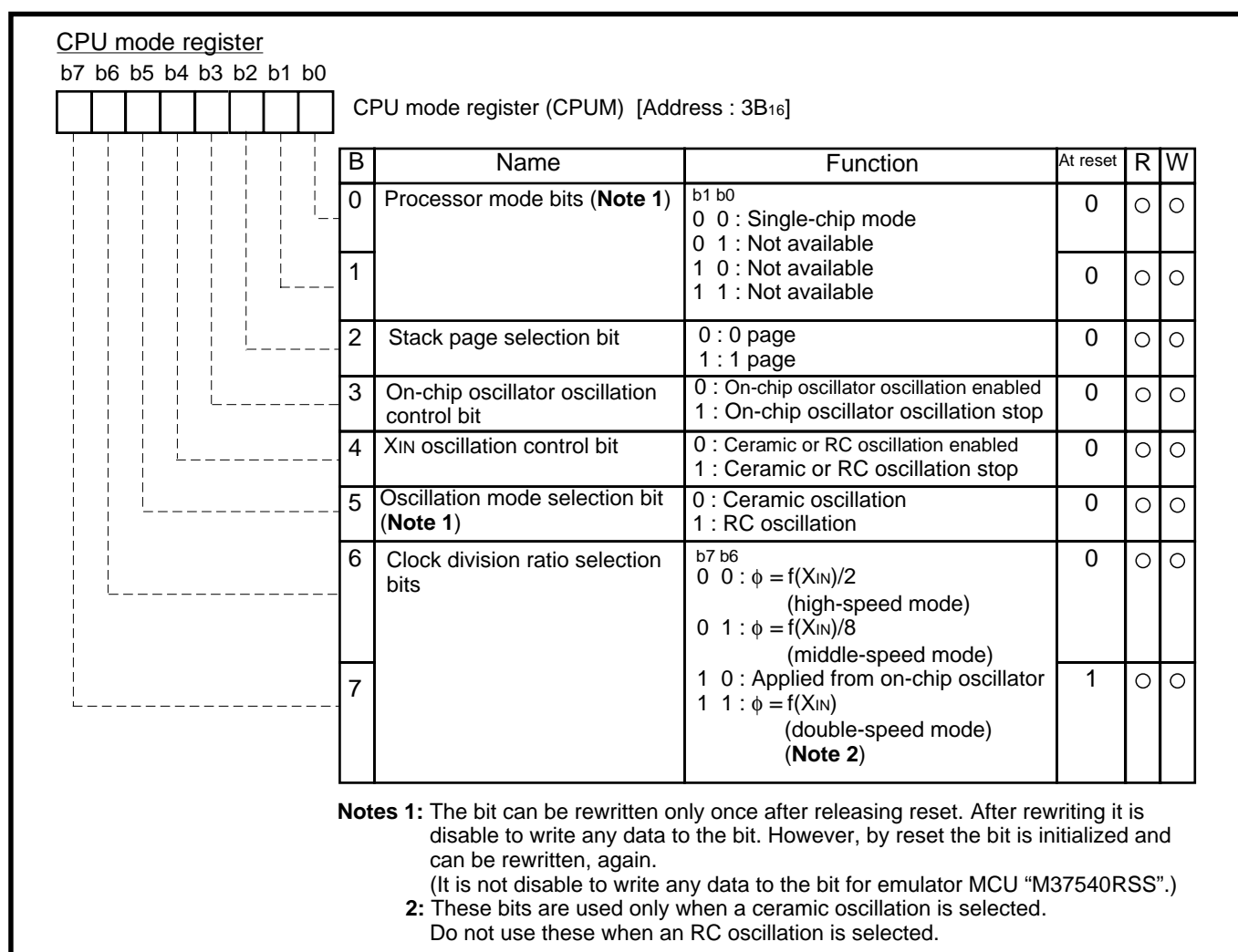


Fig. 2.9.4 Structure of CPU mode register

2.9.3 Application example of on-chip oscillator

The on-chip oscillator is the oscillation circuit which is equipped with the 7540 Group. External circuits can be eliminated by using this oscillator as the operation clock or by using this oscillator with a ceramic or RC oscillation circuit. When this oscillator is used as the operation clock, all peripheral functions can be used. In this section, the setting method and application example are explained.

Note: The 7540 Group starts operation by the on-chip oscillator.

(1) Setting method

Figure 2.9.5 shows the setting method when the on-chip oscillator is used as the operation clock.

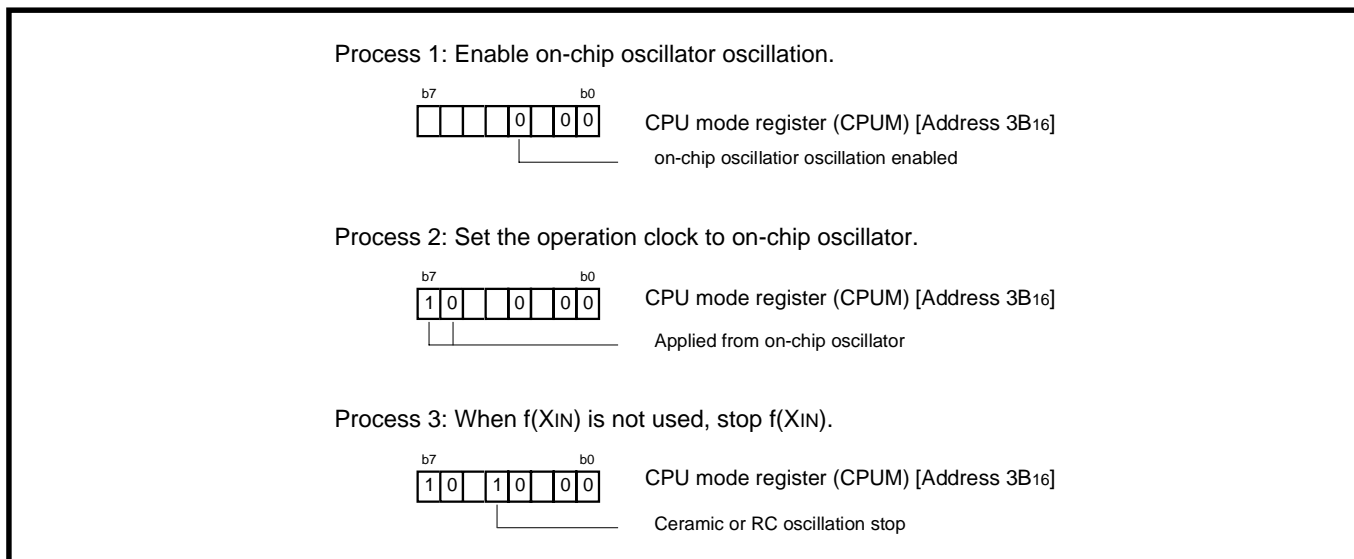


Fig. 2.9.5 Setting method when the on-chip oscillator is used as the operation clock

(2) Example of control procedure

Outline: The frequency of the on-chip oscillator is measured, and an error by the power source voltage or temperature is confirmed.

Specifications:

- The $f(X_{IN}) = 4$ MHz is divided by timer Z and 10 ms is detected. The on-chip oscillator is divided by timer Y.
- The count value of timer Y is read out in the timer Z interrupt processing routine which occurs every 10 ms, and an error from $f(X_{IN})$ is confirmed.

Figure 2.9.6 shows an example of control procedure.

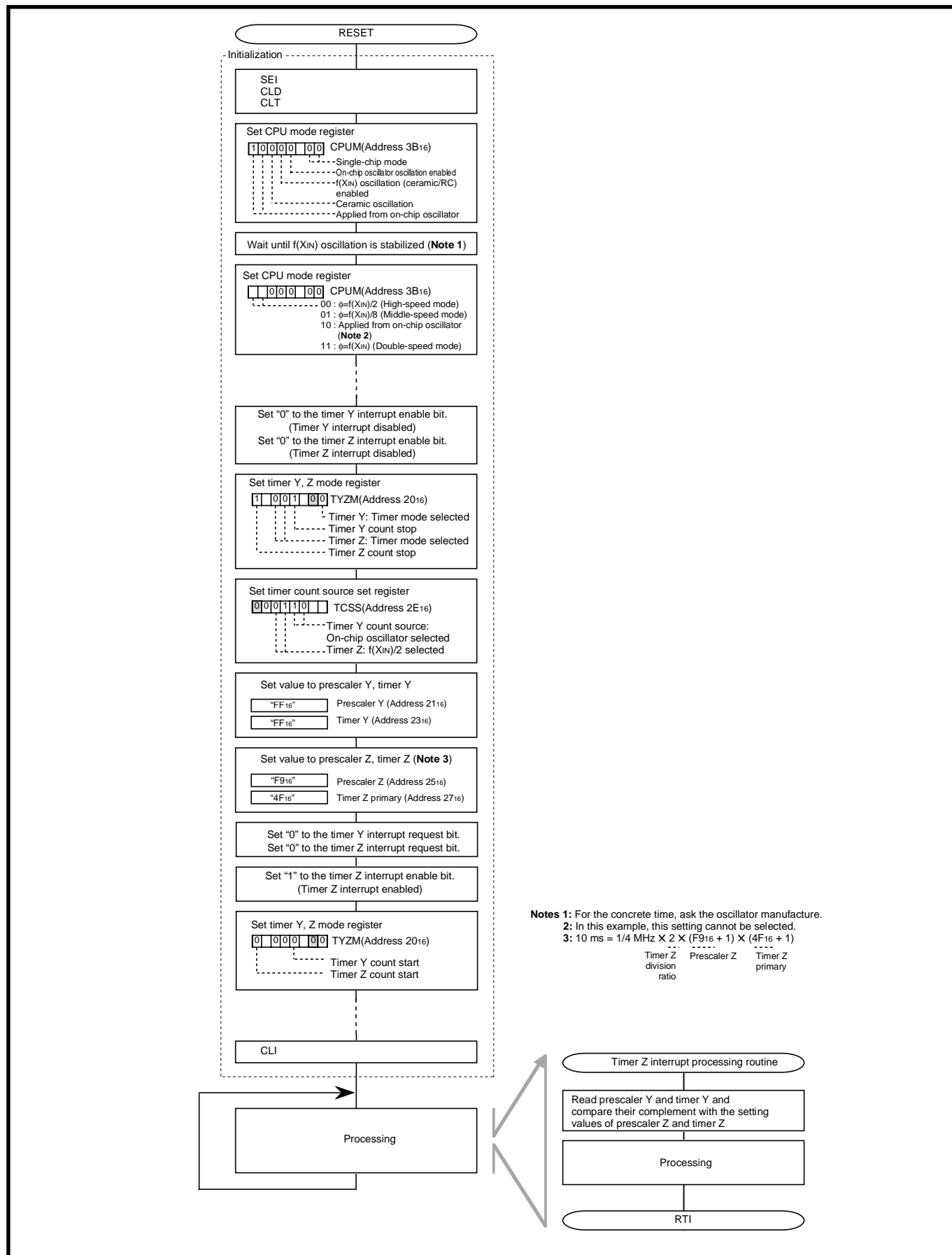


Fig. 2.9.6 Control procedure

2.9.4 Oscillation stop detection circuit

The oscillation stop detection circuit can be used to detect the stop by some failure or disconnection of an external ceramic oscillation circuit.

In this section, the setting method and application example.

(1) Operation description

When the stop of an external oscillation circuit is detected by the oscillation stop detection circuit, the oscillation stop detection status bit of MISRG is set to "1" and the internal reset occurs.

The 7540 Group starts operation by the on-chip oscillator after system is released from reset. Accordingly, error of the external oscillation circuit can be detected by checking the oscillation stop detection status bit after system starts operation.

Notes 1: When the stop mode is used, set the oscillation stop detection function to "invalid".

2: When $f(X_{IN})$ oscillation is stopped, set the oscillation stop detection function to "invalid".

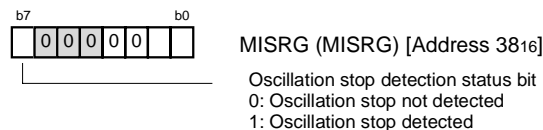
(2) Setting method

Figure 2.9.7 shows the initial setting method oscillation stop detection circuit.

Figure 2.9.8 shows the setting method for the oscillation stop detection circuit in the main processing.

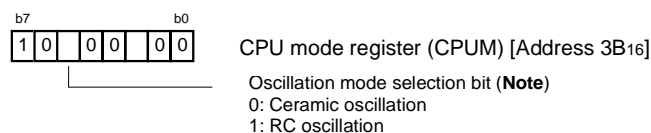
* Execute the following set at the beginning of program after system is released from reset.

Process 1: Check that reset by oscillation stop detection is executed by referring the oscillation stop detection status bit.



- Oscillation stop is detected
Some error occurs in the oscillation circuit.
Do not switch the operation clock and execute the processing when some error occurs.
- Oscillation stop is not detected
Execute the Process 2.

Process 2: Select oscillation mode.



Note: The bit can be rewritten only once after releasing reset. After rewriting it is disable to write any data to the bit. However, by reset the bit is initialized and can be rewritten, again. (It is not disable to write any data to the bit for emulator MCU "M37540RSS").

Process 3: Wait oscillation stabilizing (**Note**).

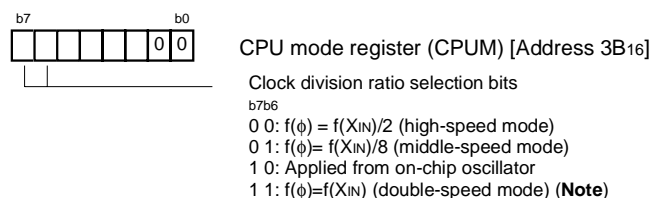
Note: This process can be eliminated when the RC oscillation is selected.
For the oscillation stabilizing time, ask the oscillator manufacture.

Process 4: Set the ceramic or RC oscillation stop detection function active bit.



Note: When some error occurs in the oscillation circuit, system is released from reset after setting of Process 4 is executed.

Process 5: Select clock division ratio.



Note: These bits are used only when a ceramic oscillation is selected.
Do not use these when an RC oscillation is selected.

Fig. 2.9.7 Initial setting method for the oscillation stop detection circuit

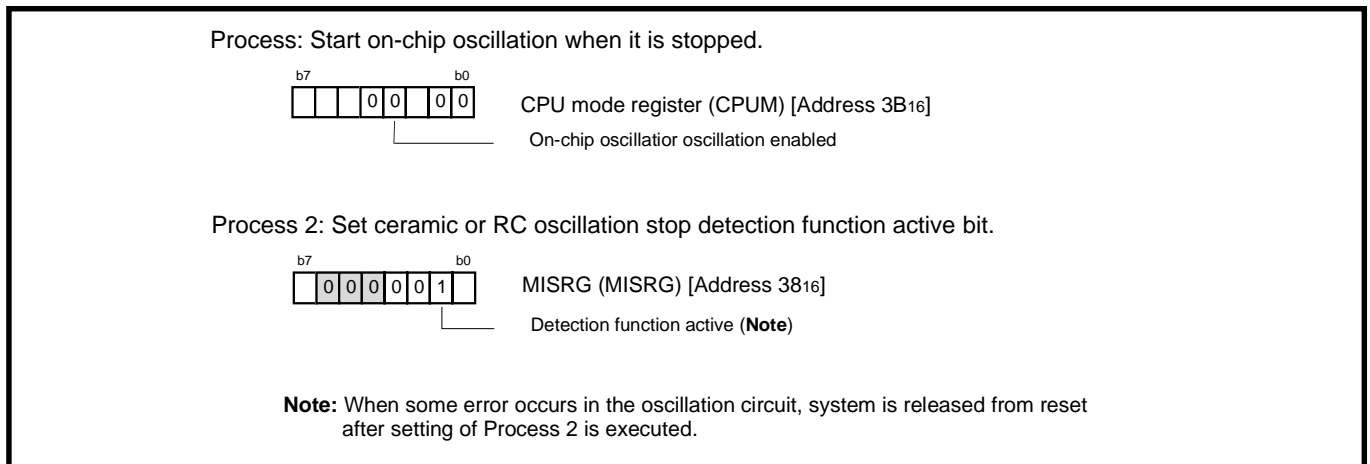


Fig. 2.9.8 Setting method for the oscillation stop detection circuit in main processing

2.9.5 State transition

In the 7540 Group, the operation clock is selected from the following 4 types.

- $f(X_{IN})/2$ (high-speed mode)
- $f(X_{IN})/8$ (middle-speed mode)
- On-chip oscillator
- $f(X_{IN})$ (double-speed mode) (**Note 1**)

Note 1: $f(X_{IN})$ can be used only at the ceramic oscillation. Do not use $f(X_{IN})$ at RC oscillation.

Also, in the 7540 Group, the function to stop CPU operation by software and to keep CPU wait in the following 2-type low power dissipation.

- Stop mode with the **STP** instruction (**Notes 2, 3, 4, 5, 6, 7**)
- Wait mode with the **WIT** instruction (**Note 8**)

Notes 2: When the stop mode is used, set the oscillation stop detection function to “invalid”.

3: When the stop mode is used, set “0” (**STP** instruction enabled) the **STP** instruction disable bit of the watchdog timer control register.

4: Timer 1 can be used to set the oscillation stabilizing time after release of the **STP** instruction. The oscillation stabilizing time after release of **STP** instruction can be selected from “set automatically”/ “not set automatically” by the oscillation stabilizing time set bit after release of the **STP** instruction of MISRG. When “0” is set to this bit, “01₁₆” is set to timer 1 and “FF₁₆” is set to prescaler 1 automatically. When “1” is set to this bit, nothing is set to timer 1 and prescaler 1. Therefore, set the wait time according to the oscillation stabilizing time of the oscillation. Also, when timer 1 is used, set values again to timer 1 and prescaler 1 after system is returned from the stop mode.

5: The **STP** instruction cannot be used during CPU is operating by the on-chip oscillator.

6: When the stop mode is used, stop the on-chip oscillator oscillation.

7: Do not execute the **STP** instruction during the A/D conversion.

8: When the wait mode is used, stop the clock except the operation clock source.

Figure 2.9.9 shows the state transition.

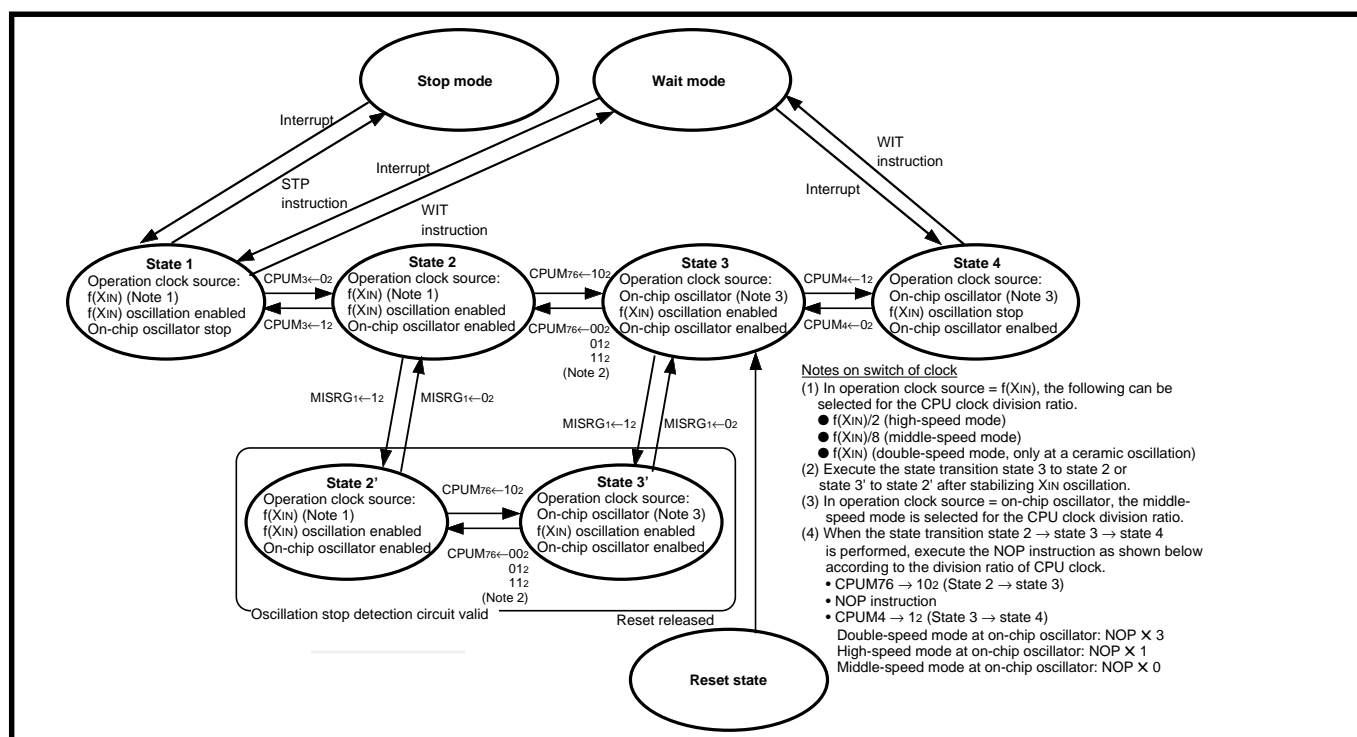


Fig. 2.9.9 State transition

(1) Example of control procedure

Outline: The on-chip oscillator is used, and the intermittent operation for the low-power dissipation can be realized.

Specifications: A mode is selected from the following modes 1 to 4 according to the usage condition. The return from mode 1 is executed by the timer A interrupt request which occurs every 0.5 s.

Mode 1: Wait mode by the on-chip oscillator oscillation

Operation clock source: On-chip oscillator

CPU stop, ceramic oscillation stop, on-chip oscillator oscillation

Mode 2: Middle-speed mode by the on-chip oscillator oscillation

Operation clock source: On-chip oscillator

CPU operation, ceramic oscillation stop, on-chip oscillator oscillation

Mode 3: Middle-speed mode by the ceramic oscillation

Operation clock source: Ceramic oscillation

CPU operation, ceramic oscillation, on-chip oscillator oscillation

Mode 4: Double-speed mode by the ceramic oscillation

Operation clock source: Ceramic oscillation

CPU operation, ceramic oscillation, on-chip oscillator oscillation

Figure 2.9.10 shows an example of mode transition and Figure 2.9.11 shows an example of control procedure.

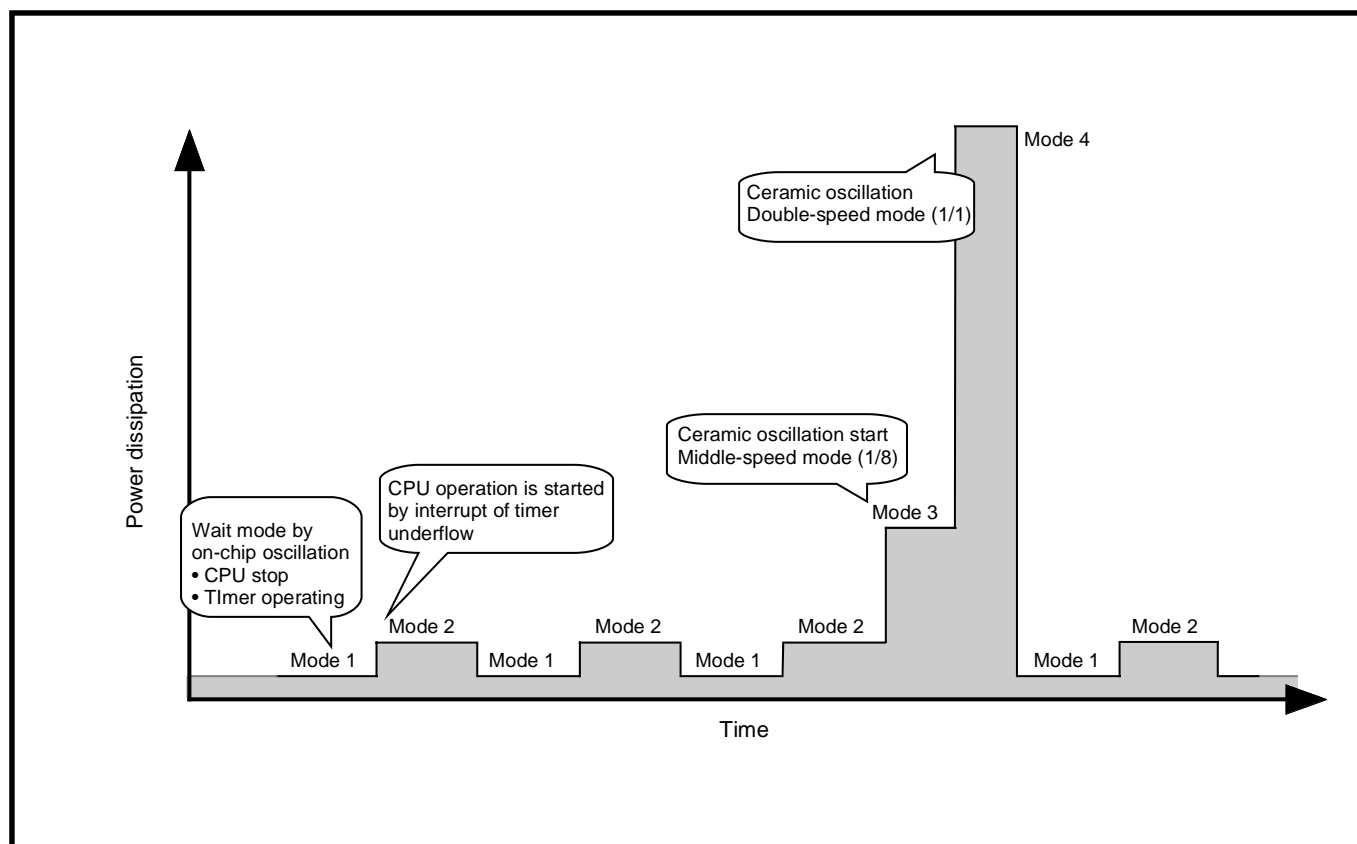


Fig. 2.9.10 Example of mode transition

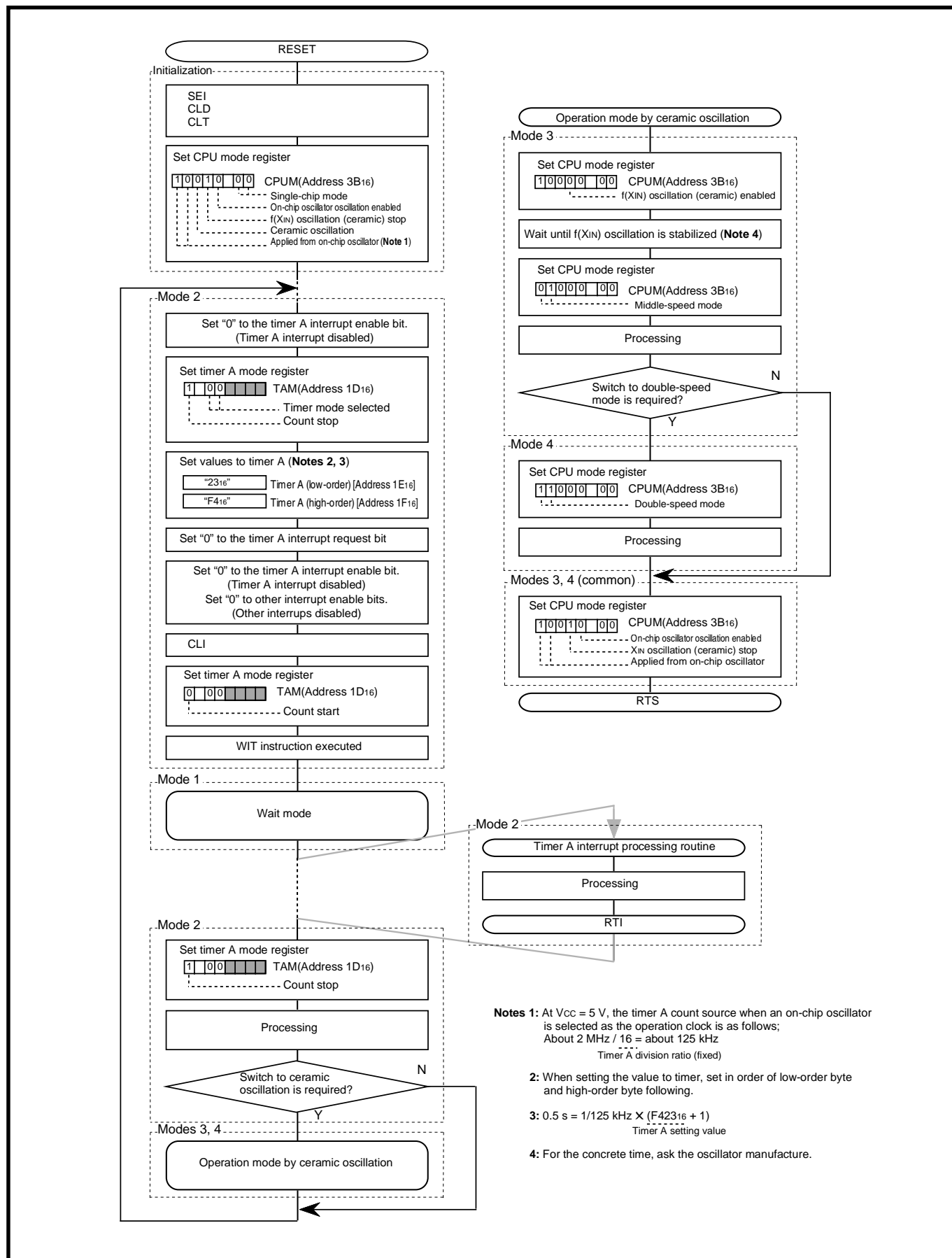


Fig. 2.9.11 Control procedure

2.9.6 Notes on oscillation stop detection circuit

Notes on using oscillation stop detection circuit are described below.

(1) Note on on-chip oscillator

- ① The 7540 Group starts operation by the on-chip oscillator.
- ② On-chip oscillator operation
The clock frequency of the on-chip oscillator depends on the supply voltage and the operation temperature range.
Be careful that variable frequencies when designing application products.

(2) Notes on oscillation circuit stop detection circuit

- ① When the stop mode is used, set the oscillation stop detection function to “invalid”.
- ② When $f(X_{IN})$ oscillation is stopped, set the oscillation stop detection function to “invalid”.
- ③ The oscillation stop detection circuit is not included in the emulator MCU “M37540RSS”.

(3) Notes on stop mode

- ① When the stop mode is used, set the oscillation stop detection function to “invalid”.
- ② When the stop mode is used, set “0” (**STP** instruction enabled) to the **STP** instruction disable bit of the watchdog timer control register.
- ③ Timer 1 can be used to set the oscillation stabilizing time after release of the **STP** instruction. The oscillation stabilizing time after release of **STP** instruction can be selected from “set automatically”/ “not set automatically” by the oscillation stabilizing time set bit after release of the **STP** instruction of MISRG. When “0” is set to this bit, “01₁₆” is set to timer 1 and “FF₁₆” is set to prescaler 1 automatically. When “1” is set to this bit, nothing is set to timer 1 and prescaler 1. Therefore, set the wait time according to the oscillation stabilizing time of the oscillation. Also, when timer 1 is used, set values again to timer 1 and prescaler 1 after system is returned from the stop mode.
- ④ The **STP** instruction cannot be used during CPU is operating by the on-chip oscillator.
- ⑤ When the stop mode is used, stop the on-chip oscillator oscillation.
- ⑥ Do not execute the **STP** instruction during the A/D conversion.

(4) Note on wait mode

- ① When the wait mode is used, stop the clock except the operation clock source.

(5) Notes on state transition

- ① When the operation clock source is $f(X_{IN})$, the CPU clock division ratio can be selected from the following;
 - $f(X_{IN})/2$ (high-speed mode)
 - $f(X_{IN})/8$ (middle-speed mode)
 - $f(X_{IN})$ (double-speed mode)The double-speed mode can be used only at ceramic oscillation.
Do not use the mode at RC oscillation.
- ② Stabilize the $f(X_{IN})$ oscillation to change the operation clock source from the on-chip oscillator to $f(X_{IN})$.

- ③ When the on-chip oscillation is used as the operation clock, the CPU clock division ratio is the middle-speed mode.
- ④ When the state transition state 2→state 3→state 4 is performed, execute the NOP instruction as shown below according to the division ratio of CPU clock.
- CPUM₇₆→10₂ (State 2→state 3)
 - NOP instruction
 - CPUM₄→1₂ (State 3→state 4)
- Double-speed mode at on-chip oscillator: NOPX3
High-speed mode at on-chip oscillator: NOPX1
Middle-speed mode at on-chip oscillator: NOPX0

CHAPTER 3

APPENDIX

- 3.1 Electrical characteristics**
- 3.2 Typical characteristics**
- 3.3 Notes on use**
- 3.4 Countermeasures against noise**
- 3.5 List of registers**
- 3.6 Package outline**
- 3.7 List of instruction code**
- 3.8 Machine instructions**
- 3.9 SFR memory map**
- 3.10 Pin configurations**
- 3.11 Differences between 7540 Group and 7531 Group**

3.1 Electrical characteristics

3.1.1 7540 Group (General purpose)

Applied to: M37540M2-XXXFP/SP/GP, M37540M4-XXXFP/SP/GP, M37540E2FP/SP/GP, M37540E8FP/SP/GP

(1) Absolute Maximum Ratings (General purpose)

Table 3.1.1 Absolute maximum ratings

| Symbol | Parameter | Conditions | Ratings | Unit |
|------------------|--|--|-------------------------------|------|
| V _{CC} | Power source voltage | All voltages are based on V _{SS} . Output transistors are cut off. | -0.3 to 6.5 (Note 1) | V |
| V _I | Input voltage P00–P07, P10–P14, P20–P27, P30–P37, VREF | | -0.3 to V _{CC} + 0.3 | V |
| V _I | Input voltage $\overline{\text{RESET}}$, X _{IN} | | -0.3 to V _{CC} + 0.3 | V |
| V _I | Input voltage CNV _{SS} (Note 2) | | -0.3 to 13 | V |
| V _O | Output voltage P00–P07, P10–P14, P20–P27, P30–P37, X _{OUT} | | -0.3 to V _{CC} + 0.3 | V |
| P _d | Power dissipation | T _a = 25°C | 300 (Note 3) | mW |
| T _{opr} | Operating temperature | | -20 to 85 | °C |
| T _{stg} | Storage temperature | | -40 to 125 | °C |

Notes 1: This is the rating value for the Mask ROM version.

The rating value for the One Time PROM version is -0.3 to 7.0 V.

2: It is a rating only for the One Time PROM version. Connect to V_{SS} for the mask ROM version.

3: 200 mW for the 32P6U package product.

(2) Recommended Operating Conditions (General purpose)

Table 3.1.2 Recommended operating conditions (1)
(V_{CC} = 2.2 to 5.5 V, T_a = -20 to 85 °C, unless otherwise noted)

| Symbol | Parameter | Limits | | | Unit | |
|------------------------|--|--|--|---------------------|------|-----|
| | | Min. | Typ. | Max. | | |
| V _{CC} | Power source voltage (ceramic) | f(X _{IN}) = 8 MHz (High-, Middle-speed mode) | 4.0 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 4 MHz (High-, Middle-speed mode) | 2.4 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 2 MHz (High-, Middle-speed mode) | 2.2 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 6 MHz (Double-speed mode) | 4.5 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 4 MHz (Double-speed mode) | 4.0 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 2 MHz (Double-speed mode) | 2.4 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 1 MHz (Double-speed mode) | 2.2 | 5.0 | 5.5 | V |
| | | Power source voltage (RC) | f(X _{IN}) = 4 MHz (High-, Middle-speed mode) | 4.0 | 5.0 | 5.5 |
| | f(X _{IN}) = 2 MHz (High-, Middle-speed mode) | | 2.4 | 5.0 | 5.5 | V |
| | f(X _{IN}) = 1 MHz (High-, Middle-speed mode) | | 2.2 | 5.0 | 5.5 | V |
| V _{SS} | Power source voltage | | 0 | | V | |
| V _{REF} | Analog reference voltage | 2.0 | | V _{CC} | V | |
| V _{IH} | "H" input voltage P00–P07, P10–P14, P20–P27, P30–P37 | 0.8V _{CC} | | V _{CC} | V | |
| V _{IH} | "H" input voltage (TTL input level selected) P10, P12, P13, P36, P37 (Note 1) | 2.0 | | V _{CC} | V | |
| V _{IH} | "H" input voltage RESET, X _{IN} | 0.8V _{CC} | | V _{CC} | V | |
| V _{IL} | "L" input voltage P00–P07, P10–P14, P20–P27, P30–P37 | 0 | | 0.3V _{CC} | V | |
| V _{IL} | "L" input voltage (TTL input level selected) P10, P12, P13, P36, P37 (Note 1) | 0 | | 0.8 | V | |
| V _{IL} | "L" input voltage RESET, CNV _{SS} | 0 | | 0.2V _{CC} | V | |
| V _{IL} | "L" input voltage X _{IN} | 0 | | 0.16V _{CC} | V | |
| ΣI _{OH(peak)} | "H" total peak output current (Note 2) P00–P07, P10–P14, P20–P27, P30–P37 | | | -80 | mA | |
| ΣI _{OL(peak)} | "L" total peak output current (Note 2) P00–P07, P10–P14, P20–P27, P37 | | | 80 | mA | |
| ΣI _{OL(peak)} | "L" total peak output current (Note 2) P30–P36 | | | 60 | mA | |
| ΣI _{OH(avg)} | "H" total average output current (Note 2) P00–P07, P10–P14, P20–P27, P30–P37 | | | -40 | mA | |
| ΣI _{OL(avg)} | "L" total average output current (Note 2) P00–P07, P10–P14, P20–P27, P37 | | | 40 | mA | |
| ΣI _{OL(avg)} | "L" total average output current (Note 2) P30–P36 | | | 30 | mA | |

Note 1: V_{CC} = 4.0 to 5.5V

2: The total output current is the sum of all the currents flowing through all the applicable ports. The total average current is an average value measured over 100 ms. The total peak current is the peak value of all the currents.

Table 3.1.3 Recommended operating conditions (2)
(V_{CC} = 2.2 to 5.5 V, T_a = -20 to 85 °C, unless otherwise noted)

| Symbol | Parameter | | Limits | | | Unit |
|-----------------------|---|--|--------|------|------|------|
| | | | Min. | Typ. | Max. | |
| I _{OH(peak)} | "H" peak output current (Note 1) | P00-P07, P10-P14, P20-P27, P30-P37 | | | -10 | mA |
| I _{OL(peak)} | "L" peak output current (Note 1) | P00-P07, P10-P14, P20-P27, P37 | | | 10 | mA |
| I _{OL(peak)} | "L" peak output current (Note 1) | P30-P36 | | | 30 | mA |
| I _{OH(avg)} | "H" average output current (Note 2) | P00-P07, P10-P14, P20-P27, P30-P37 | | | -5 | mA |
| I _{OL(avg)} | "L" average output current (Note 2) | P00-P07, P10-P14, P20-P27, P37 | | | 5 | mA |
| I _{OL(avg)} | "L" average output current (Note 2) | P30-P36 | | | 15 | mA |
| f(XIN) | Internal clock oscillation frequency (Note 3) at ceramic oscillation or external clock input | V _{CC} = 4.5 to 5.5 V Double-speed mode | | | 6 | MHz |
| | | V _{CC} = 4.0 to 5.5 V Double-speed mode | | | 4 | MHz |
| | | V _{CC} = 2.4 to 5.5 V Double-speed mode | | | 2 | MHz |
| | Internal clock oscillation frequency (Note 3) at ceramic oscillation or external clock input | V _{CC} = 2.2 to 5.5 V Double-speed mode | | | 1 | MHz |
| | | V _{CC} = 4.0 to 5.5 V High-, Middle-speed mode | | | 8 | MHz |
| | | V _{CC} = 2.4 to 5.5 V High-, Middle-speed mode | | | 4 | MHz |
| | Internal clock oscillation frequency (Note 3) at RC oscillation | V _{CC} = 2.2 to 5.5 V High-, Middle-speed mode | | | 2 | MHz |
| | | V _{CC} = 4.0 to 5.5 V High-, Middle-speed mode | | | 4 | MHz |
| | | V _{CC} = 2.4 to 5.5 V High-, Middle-speed mode | | | 2 | MHz |
| | Internal clock oscillation frequency (Note 3) at RC oscillation | V _{CC} = 2.2 to 5.5 V High-, Middle-speed mode | | | 1 | MHz |

Notes 1: The peak output current is the peak current flowing in each port.

2: The average output current I_{OL} (avg), I_{OH} (avg) in an average value measured over 100 ms.

3: When the oscillation frequency has a duty cycle of 50 %.

(3) Electrical Characteristics (General purpose)**Table 3.1.4 Electrical characteristics (1)** **$V_{CC} = 2.2$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Test conditions | Limits | | | Unit |
|---------|---|--|---------|------|-------|------|
| | | | Min. | Typ. | Max. | |
| VOH | "H" output voltage P00–P07, P10–P14, P20–P27, P30–P37 (Note 1) | IOH = –5 mA VCC = 4.0 to 5.5 V | VCC–1.5 | | | V |
| | | IOH = –1.0 mA VCC = 2.2 to 5.5 V | VCC–1.0 | | | V |
| VOL | "L" output voltage P00–P07, P10–P14, P20–P27, P37 | IOL = 5 mA VCC = 4.0 to 5.5 V | | | 1.5 | V |
| | | IOL = 1.5 mA VCC = 4.0 to 5.5 V | | | 0.3 | V |
| | | IOL = 1.0 mA VCC = 2.2 to 5.5 V | | | 1.0 | V |
| VOL | "L" output voltage P30–P36 | IOL = 15 mA VCC = 4.0 to 5.5 V | | | 2.0 | V |
| | | IOL = 1.5 mA VCC = 4.0 to 5.5 V | | | 0.3 | V |
| | | IOL = 10 mA VCC = 2.2 to 5.5 V | | | 1.0 | V |
| VT+–VT– | Hysteresis CNTR0, CNTR1, INT0, INT1 (Note 2) P00–P07 (Note 3) | | | 0.4 | | V |
| VT+–VT– | Hysteresis RXD, SCLK1, SCLK2, SDATA2 (Note 2) | | | 0.5 | | V |
| VT+–VT– | Hysteresis RESET | | | 0.5 | | V |
| IiH | "H" input current P00–P07, P10–P14, P20–P27, P30–P37 | VI = VCC (Pin floating. Pull up transistors "off") | | | 5.0 | μA |
| IiH | "H" input current RESET | VI = VCC | | | 5.0 | μA |
| IiH | "H" input current XIN | VI = VCC | | 4.0 | | μA |
| IiL | "L" input current P00–P07, P10–P14, P20–P27, P30–P37 | VI = VSS (Pin floating. Pull up transistors "off") | | | –5.0 | μA |
| IiL | "L" input current RESET, CNVSS | VI = VSS | | | –5.0 | μA |
| IiL | "L" input current XIN | VI = VSS | | –4.0 | | μA |
| IiL | "L" input current P00–P07, P30–P37 | VI = VSS (Pull up transistors "on") | | –0.2 | –0.5 | mA |
| VRAM | RAM hold voltage | When clock stopped | 2.0 | | 5.5 | V |
| ROSC | On-chip oscillator oscillation frequency | VCC = 5.0 V, Ta = 25 °C | 1000 | 2000 | 3000 | kHz |
| DOSC | Oscillation stop detection circuit detection frequency | VCC = 5.0 V, Ta = 25 °C | 62.5 | 125 | 187.5 | kHz |

Notes 1: P11 is measured when the P11/TxD1 P-channel output disable bit of the UART control register (bit 4 of address 001B16) is "0".

2: RXD1, SCLK1, SCLK2, SDATA2, INT0, and INT1 have hysteresises only when bits 0 to 2 of the port P1P3 control register are set to "0" (CMOS level).

3: It is available only when operating key-on wake up.

Table 3.1.5 Electrical characteristics (2)
(V_{CC} = 2.2 to 5.5 V, V_{SS} = 0 V, Ta = -20 to 85 °C, unless otherwise noted)

| Symbol | Parameter | Test conditions | | Limits | | | Unit | | |
|--------|----------------------|-----------------------|--|--|--|------------|------|-----|-----|
| | | | | Min. | Typ. | Max. | | | |
| ICC | Power source current | One Time PROM version | High-speed mode, f(X _{IN}) = 8 MHz Output transistors "off" | | | 5.0 | 8.0 | mA | |
| | | | High-speed mode, f(X _{IN}) = 2 MHz, V _{CC} = 2.2 V Output transistors "off" | | | 0.5 | 1.5 | mA | |
| | | | Double-speed mode, f(X _{IN}) = 6 MHz Output transistors "off" | | | 6.0 | 10.0 | mA | |
| | | | Middle-speed mode, f(X _{IN}) = 8 MHz Output transistors "off" | | | 2.0 | 5.0 | mA | |
| | | | On-chip oscillator operation mode, V _{CC} = 5 V Output transistors "off" | | | 350 | 1000 | μA | |
| | | | f(X _{IN}) = 8 MHz (in WIT state), functions except timer 1 disabled, Output transistors "off" | | | 1.6 | 3.2 | mA | |
| | | | f(X _{IN}) = 2 MHz, V _{CC} = 2.2 V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | | 0.2 | | mA | |
| | | | On-chip oscillator operation mode, V _{CC} = 5V Output transistors "off" | | | 150 | 450 | μA | |
| | | | Increment when A/D conversion is executed f(X _{IN}) = 8 MHz, V _{CC} = 5 V | | | 0.5 | | mA | |
| | | | All oscillation stopped (in STP state) | | Ta = 25 °C | 0.1 | 1.0 | μA | |
| | | | | | Ta = 85 °C | | 10 | μA | |
| | | | Mask ROM version | | High-speed mode, f(X _{IN}) = 8 MHz Output transistors "off" | | | 3.5 | 6.5 |
| | | | | High-speed mode, f(X _{IN}) = 2 MHz, V _{CC} = 2.2 V Output transistors "off" | | | 0.4 | 1.2 | mA |
| | | | | Double-speed mode, f(X _{IN}) = 6 MHz Output transistors "off" | | | 4.5 | 8.0 | mA |
| | | | | Middle-speed mode, f(X _{IN}) = 8 MHz Output transistors "off" | | | 2.0 | 5.0 | mA |
| | | | | On-chip oscillator operation mode, V _{CC} = 5 V Output transistors "off" | | | 300 | 900 | μA |
| | | | | f(X _{IN}) = 8 MHz (in WIT state), functions except timer 1 disabled, Output transistors "off" | | | 1.6 | 3.2 | mA |
| | | | | f(X _{IN}) = 2 MHz, V _{CC} = 2.2 V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | | 0.2 | | mA |
| | | | | On-chip oscillator operation mode, V _{CC} = 5V Output transistors "off" | | | 150 | 450 | μA |
| | | | | Increment when A/D conversion is executed f(X _{IN}) = 8 MHz, V _{CC} = 5 V | | | 0.5 | | mA |
| | | | | All oscillation stopped (in STP state) | | Ta = 25 °C | 0.1 | 1.0 | μA |
| | | | | | | Ta = 85 °C | | 10 | μA |

(4) A/D Converter Characteristics (General purpose)**Table 3.1.6 A/D Converter characteristics****(V_{CC} = 2.7 to 5.5 V, V_{SS} = 0 V, T_a = -20 to 85 °C, unless otherwise noted)**

| | Symbol | Parameter | Test conditions | Limits | | | Unit |
|-----------------------|--------------------------------------|--------------------------------------|--|--------|------|------|---------|
| | | | | Min. | Typ. | Max. | |
| One Time PROM version | — | Resolution | | | | 10 | Bits |
| | — | Linearity error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±3 | LSB |
| | — | Differential nonlinear error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±0.9 | LSB |
| | VOT | Zero transition voltage | V _{CC} = V _{REF} = 5.12 V | 0 | 5 | 20 | mV |
| | | | V _{CC} = V _{REF} = 3.072 V | 0 | 3 | 15 | mV |
| | VFST | Full scale transition voltage | V _{CC} = V _{REF} = 5.12 V | 5105 | 5115 | 5125 | mV |
| | | | V _{CC} = V _{REF} = 3.072 V | 3060 | 3069 | 3075 | mV |
| | tCONV | Conversion time | | | | 122 | tc(XIN) |
| | RLADDER | Ladder resistor | | | 55 | | kΩ |
| IVREF | Reference power source input current | V _{REF} = 5.0 V | 50 | 150 | 200 | μA | |
| | | V _{REF} = 3.0 V | 50 | 70 | 120 | | |
| II(AD) | A/D port input current | | | | 5.0 | μA | |
| Mask ROM version | — | Resolution | | | | 10 | Bits |
| | — | Linearity error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±3 | LSB |
| | — | Differential nonlinear error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±1.5 | LSB |
| | VOT | Zero transition voltage | V _{CC} = V _{REF} = 5.12 V | 0 | 15 | 35 | mV |
| | | | V _{CC} = V _{REF} = 3.072 V | 0 | 9 | 21 | mV |
| | VFST | Full scale transition voltage | V _{CC} = V _{REF} = 5.12 V | 5105 | 5125 | 5150 | mV |
| | | | V _{CC} = V _{REF} = 3.072 V | 3060 | 3075 | 3090 | mV |
| | tCONV | Conversion time | | | | 122 | tc(XIN) |
| | RLADDER | Ladder resistor | | | 55 | | kΩ |
| | IVREF | Reference power source input current | V _{REF} = 5.0 V | 50 | 150 | 200 | μA |
| | | | V _{REF} = 3.0 V | 50 | 70 | 120 | |
| II(AD) | A/D port input current | | | | 5.0 | μA | |

(5) Timing Requirements (General purpose)**Table 3.1.7 Timing requirements (1)****(V_{CC} = 4.0 to 5.5 V, V_{SS} = 0 V, Ta = -20 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|--------------------------------|--|--------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _w (RESET) | Reset input "L" pulse width | 2 | | | μs |
| t _c (XIN) | External clock input cycle time | 125 | | | ns |
| t _{WH} (XIN) | External clock input "H" pulse width | 50 | | | ns |
| t _{WL} (XIN) | External clock input "L" pulse width | 50 | | | ns |
| t _c (CNTR0) | CNTR0 input cycle time | 200 | | | ns |
| t _{WH} (CNTR0) | CNTR0, INT0, INT1, input "H" pulse width | 80 | | | ns |
| t _{WL} (CNTR0) | CNTR0, INT0, INT1, input "L" pulse width | 80 | | | ns |
| t _c (CNTR1) | CNTR1 input cycle time | 2000 | | | ns |
| t _{WH} (CNTR1) | CNTR1 input "H" pulse width | 800 | | | ns |
| t _{WL} (CNTR1) | CNTR1 input "L" pulse width | 800 | | | ns |
| t _c (SCLK1) | Serial I/O1 clock input cycle time (Note) | 800 | | | ns |
| t _{WH} (SCLK1) | Serial I/O1 clock input "H" pulse width (Note) | 370 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock input "L" pulse width (Note) | 370 | | | ns |
| t _{su} (RxD1-SCLK1) | Serial I/O1 input set up time | 220 | | | ns |
| t _h (SCLK1-RxD1) | Serial I/O1 input hold time | 100 | | | ns |
| t _c (SCLK2) | Serial I/O2 clock input cycle time | 1000 | | | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock input "H" pulse width | 400 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock input "L" pulse width | 400 | | | ns |
| t _{su} (SDATA2-SCLK2) | Serial I/O2 input set up time | 200 | | | ns |
| t _h (SCLK2-SDATA2) | Serial I/O2 input hold time | 200 | | | ns |

Note: In this time, bit 6 of the serial I/O1 control register (address 001A16) is set to "1" (clock synchronous serial I/O1 is selected).

When bit 6 of the serial I/O1 control register is "0" (clock asynchronous serial I/O1 is selected), the rating values are divided by 4.

Table 3.1.8 Timing requirements (2)**(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -20 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|--------------------------------|--|--------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _w (RESET) | Reset input "L" pulse width | 2 | | | μs |
| t _c (XIN) | External clock input cycle time | 250 | | | ns |
| t _{WH} (XIN) | External clock input "H" pulse width | 100 | | | ns |
| t _{WL} (XIN) | External clock input "L" pulse width | 100 | | | ns |
| t _c (CNTR0) | CNTR0 input cycle time | 500 | | | ns |
| t _{WH} (CNTR0) | CNTR0, INT0, INT1, input "H" pulse width | 230 | | | ns |
| t _{WL} (CNTR0) | CNTR0, INT0, INT1, input "L" pulse width | 230 | | | ns |
| t _c (CNTR1) | CNTR1 input cycle time | 4000 | | | ns |
| t _{WH} (CNTR1) | CNTR1 input "H" pulse width | 1600 | | | ns |
| t _{WL} (CNTR1) | CNTR1 input "L" pulse width | 1600 | | | ns |
| t _c (SCLK1) | Serial I/O1 clock input cycle time (Note) | 2000 | | | ns |
| t _{WH} (SCLK1) | Serial I/O1 clock input "H" pulse width (Note) | 950 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock input "L" pulse width (Note) | 950 | | | ns |
| t _{su} (RxD1-SCLK1) | Serial I/O1 input set up time | 400 | | | ns |
| t _h (SCLK1-RxD1) | Serial I/O1 input hold time | 200 | | | ns |
| t _c (SCLK2) | Serial I/O2 clock input cycle time | 2000 | | | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock input "H" pulse width | 950 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock input "L" pulse width | 950 | | | ns |
| t _{su} (SDATA2-SCLK2) | Serial I/O2 input set up time | 400 | | | ns |
| t _h (SCLK2-SDATA2) | Serial I/O2 input hold time | 400 | | | ns |

Note: In this time, bit 6 of the serial I/O1 control register (address 001A16) is set to "1" (clock synchronous serial I/O1 is selected).

When bit 6 of the serial I/O1 control register is "0" (clock asynchronous serial I/O1 is selected), the rating values are divided by 4.

Table 3.1.9 Timing requirements (3)
(V_{CC} = 2.2 to 5.5 V, V_{SS} = 0 V, T_a = -20 to 85 °C, unless otherwise noted)

| Symbol | Parameter | Limits | | | Unit |
|--------------------------------|--|--------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _w (RESET) | Reset input "L" pulse width | 2 | | | μs |
| t _c (XIN) | External clock input cycle time | 500 | | | ns |
| t _{WH} (XIN) | External clock input "H" pulse width | 200 | | | ns |
| t _{WL} (XIN) | External clock input "L" pulse width | 200 | | | ns |
| t _c (CNTR0) | CNTR0 input cycle time | 1000 | | | ns |
| t _{WH} (CNTR0) | CNTR0, INT0, INT1, input "H" pulse width | 460 | | | ns |
| t _{WL} (CNTR0) | CNTR0, INT0, INT1, input "L" pulse width | 460 | | | ns |
| t _c (CNTR1) | CNTR1 input cycle time | 8000 | | | ns |
| t _{WH} (CNTR1) | CNTR1 input "H" pulse width | 3200 | | | ns |
| t _{WL} (CNTR1) | CNTR1 input "L" pulse width | 3200 | | | ns |
| t _c (SCLK1) | Serial I/O1 clock input cycle time (Note) | 4000 | | | ns |
| t _{WH} (SCLK1) | Serial I/O1 clock input "H" pulse width (Note) | 1900 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock input "L" pulse width (Note) | 1900 | | | ns |
| t _{su} (RxD1-SCLK1) | Serial I/O1 input set up time | 800 | | | ns |
| t _h (SCLK1-RxD1) | Serial I/O1 input hold time | 400 | | | ns |
| t _c (SCLK2) | Serial I/O2 clock input cycle time | 4000 | | | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock input "H" pulse width | 1900 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock input "L" pulse width | 1900 | | | ns |
| t _{su} (SDATA2-SCLK2) | Serial I/O2 input set up time | 800 | | | ns |
| t _h (SCLK2-SDATA2) | Serial I/O2 input hold time | 800 | | | ns |

Note: In this time, bit 6 of the serial I/O1 control register (address 001A16) is set to "1" (clock synchronous serial I/O1 is selected).
When bit 6 of the serial I/O1 control register is "0" (clock asynchronous serial I/O1 is selected), the rating values are divided by 4.

(6) Switching Characteristics (General purpose)**Table 3.1.10 Switching characteristics (1)****(V_{CC} = 4.0 to 5.5 V, V_{SS} = 0 V, Ta = -20 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------------------|--|-----------------------------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _{WH} (SCLK1) | Serial I/O1 clock output "H" pulse width | t _c (SCLK1)/2-30 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock output "L" pulse width | t _c (SCLK1)/2-30 | | | ns |
| t _d (SCLK1-TxD1) | Serial I/O1 output delay time | | | 140 | ns |
| t _v (SCLK1-TxD1) | Serial I/O1 output valid time | -30 | | | ns |
| t _r (SCLK1) | Serial I/O1 clock output rising time | | | 30 | ns |
| t _f (SCLK1) | Serial I/O1 clock output falling time | | | 30 | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock output "H" pulse width | t _c (SCLK2)/2-30 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock output "L" pulse width | t _c (SCLK2)/2-30 | | | ns |
| t _d (SCLK2-SDATA2) | Serial I/O2 output delay time | | | 140 | ns |
| t _v (SCLK2-SDATA2) | Serial I/O2 output valid time | 0 | | | ns |
| t _r (SCLK2) | Serial I/O2 clock output rising time | | | 30 | ns |
| t _f (SCLK2) | Serial I/O2 clock output falling time | | | 30 | ns |
| t _r (CMOS) | CMOS output rising time (Note 1) | | 10 | 30 | ns |
| t _f (CMOS) | CMOS output falling time (Note 1) | | 10 | 30 | ns |

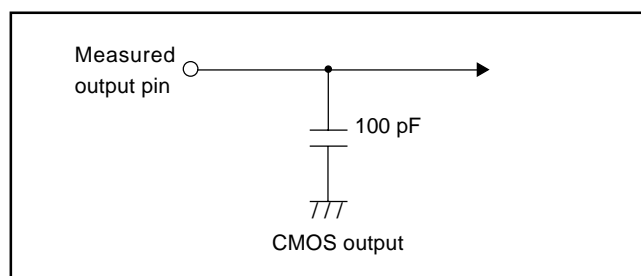
Note 1: Pin XOUT is excluded.**Table 3.1.11 Switching characteristics (2)****(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -20 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------------------|--|-----------------------------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _{WH} (SCLK1) | Serial I/O1 clock output "H" pulse width | t _c (SCLK1)/2-50 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock output "L" pulse width | t _c (SCLK1)/2-50 | | | ns |
| t _d (SCLK1-TxD1) | Serial I/O1 output delay time | | | 350 | ns |
| t _v (SCLK1-TxD1) | Serial I/O1 output valid time | -30 | | | ns |
| t _r (SCLK1) | Serial I/O1 clock output rising time | | | 50 | ns |
| t _f (SCLK1) | Serial I/O1 clock output falling time | | | 50 | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock output "H" pulse width | t _c (SCLK2)/2-50 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock output "L" pulse width | t _c (SCLK2)/2-50 | | | ns |
| t _d (SCLK2-SDATA2) | Serial I/O2 output delay time | | | 350 | ns |
| t _v (SCLK2-SDATA2) | Serial I/O2 output valid time | 0 | | | ns |
| t _r (SCLK2) | Serial I/O2 clock output rising time | | | 50 | ns |
| t _f (SCLK2) | Serial I/O2 clock output falling time | | | 50 | ns |
| t _r (CMOS) | CMOS output rising time (Note 1) | | 20 | 50 | ns |
| t _f (CMOS) | CMOS output falling time (Note 1) | | 20 | 50 | ns |

Note 1: Pin XOUT is excluded.

Table 3.1.12 Switching characteristics (3)**(V_{CC} = 2.2 to 5.5 V, V_{SS} = 0 V, Ta = -20 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------------------|--|-----------------------------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _{WH} (SCLK1) | Serial I/O1 clock output "H" pulse width | t _c (SCLK1)/2-70 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock output "L" pulse width | t _c (SCLK1)/2-70 | | | ns |
| t _d (SCLK1-TxD1) | Serial I/O1 output delay time | | | 450 | ns |
| t _v (SCLK1-TxD1) | Serial I/O1 output valid time | -30 | | | ns |
| t _r (SCLK1) | Serial I/O1 clock output rising time | | | 70 | ns |
| t _f (SCLK1) | Serial I/O1 clock output falling time | | | 70 | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock output "H" pulse width | t _c (SCLK2)/2-70 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock output "L" pulse width | t _c (SCLK2)/2-70 | | | ns |
| t _d (SCLK2-SDATA2) | Serial I/O2 output delay time | | | 450 | ns |
| t _v (SCLK2-SDATA2) | Serial I/O2 output valid time | 0 | | | ns |
| t _r (SCLK2) | Serial I/O2 clock output rising time | | | 70 | ns |
| t _f (SCLK2) | Serial I/O2 clock output falling time | | | 70 | ns |
| t _r (CMOS) | CMOS output rising time (Note 1) | | 25 | 70 | ns |
| t _f (CMOS) | CMOS output falling time (Note 1) | | 25 | 70 | ns |

Note 1: Pin XOUT is excluded.**Fig. 3.1.1 Switching characteristics measurement circuit diagram (General purpose)**

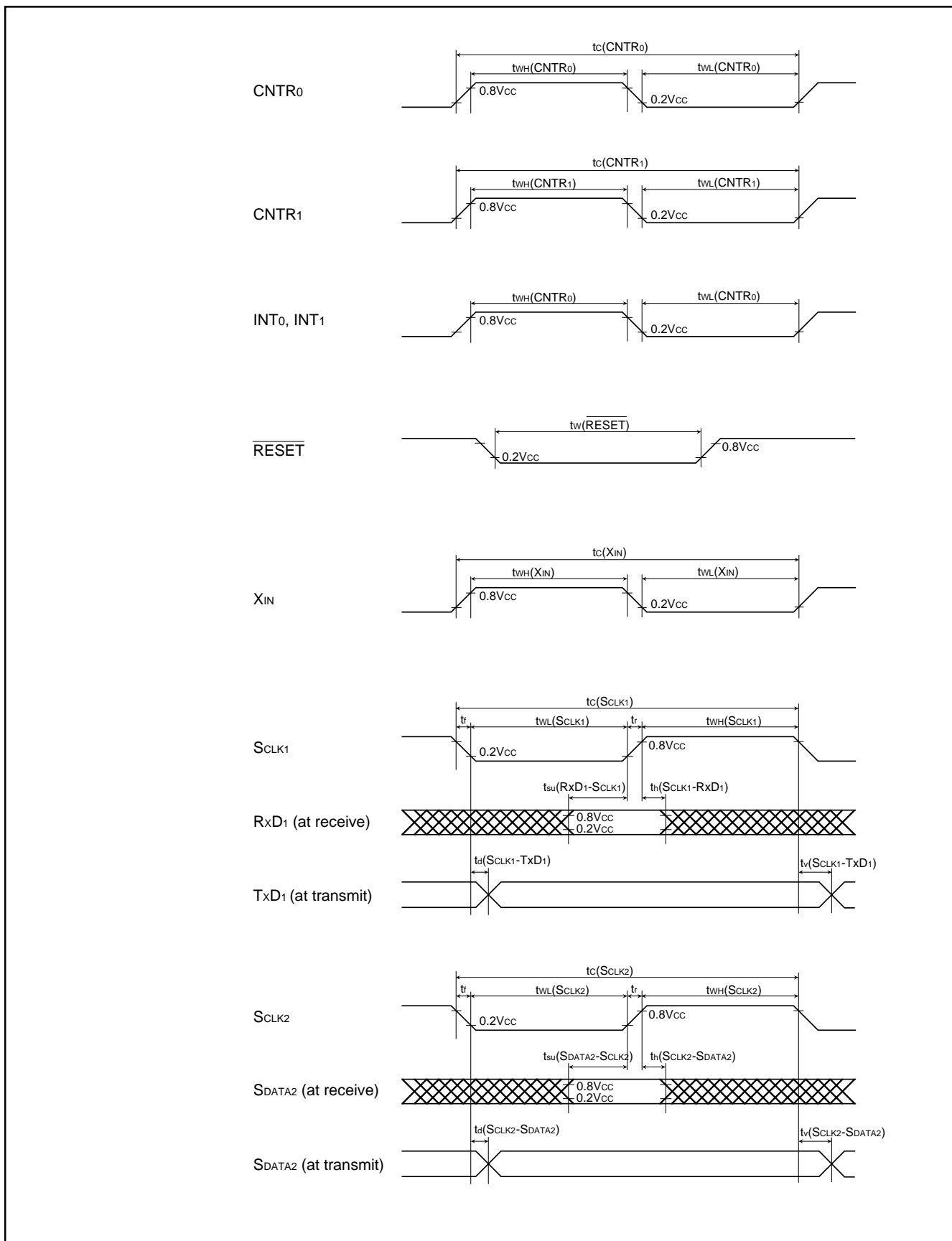


Fig. 3.1.2 Timing chart (General purpose)

3.1.2 7540Group (Extended operating temperature version)

Applied to: M37540M2T-XXXFP/GP, M37540M4T-XXXFP/GP, M37540E8T-XXXFP/GP

(2) Absolute Maximum Ratings (Extended operating temperature version)

Table 3.1.13 Absolute maximum ratings

| Symbol | Parameter | Conditions | Ratings | Unit |
|--------|--|---|-------------------------------|------|
| VCC | Power source voltage | All voltages are based on VSS. Output transistors are cut off. | -0.3 to 6.5 (Note 1) | V |
| Vi | Input voltage P00-P07, P10-P14, P20-P27, P30-P37, VREF | | -0.3 to VCC + 0.3 | V |
| Vi | Input voltage RESET, XIN, CNVSS | | -0.3 to VCC + 0.3 | V |
| Vo | Output voltage P00-P07, P10-P14, P20-P27, P30-P37, XOUT | | -0.3 to VCC + 0.3 | V |
| Pd | Power dissipation | Ta = 25°C | 300 (Note 2) | mW |
| Topr | Operating temperature | | -40 to 85 | °C |
| Tstg | Storage temperature | | -65 to 150 | °C |

Notes 1: This is the rating value for the Mask ROM version.

The rating value for the One Time PROM version is -0.3 to 7.0 V.

2: 200 mW for the 32P6U package product.

(2) Recommended Operating Conditions (Extended operating temperature version)

Table 3.1.14 Recommended operating conditions (1)

(V_{CC} = 2.4 to 5.5 V, T_a = -40 to 85 °C, unless otherwise noted)

| Symbol | Parameter | | Limits | | | Unit |
|---|--|---|--------------------|------|---------------------|------|
| | | | Min. | Typ. | Max. | |
| V _{CC} | Power source voltage (ceramic) | f(XIN) = 8 MHz (High-, Middle-speed mode) | 4.0 | 5.0 | 5.5 | V |
| | | f(XIN) = 4 MHz (High-, Middle-speed mode) | 2.4 | 5.0 | 5.5 | V |
| | | f(XIN) = 6 MHz (Double-speed mode) | 4.5 | 5.0 | 5.5 | V |
| | | f(XIN) = 4 MHz (Double-speed mode) | 4.0 | 5.0 | 5.5 | V |
| | | f(XIN) = 2 MHz (Double-speed mode) | 2.4 | 5.0 | 5.5 | V |
| | Power source voltage (RC) | f(XIN) = 4 MHz (High-, Middle-speed mode) | 4.0 | 5.0 | 5.5 | V |
| f(XIN) = 2 MHz (High-, Middle-speed mode) | | 2.4 | 5.0 | 5.5 | V | |
| V _{SS} | Power source voltage | | | 0 | | V |
| V _{REF} | Analog reference voltage | | 2.0 | | V _{CC} | V |
| V _{IH} | “H” input voltage P00–P07, P10–P14, P20–P27, P30–P37 | | 0.8V _{CC} | | V _{CC} | V |
| V _{IH} | “H” input voltage (TTL input level selected) P10, P12, P13, P36, P37 (Note 1) | | 2.0 | | V _{CC} | V |
| V _{IH} | “H” input voltage RESET, XIN | | 0.8V _{CC} | | V _{CC} | V |
| V _{IL} | “L” input voltage P00–P07, P10–P14, P20–P27, P30–P37 | | 0 | | 0.3V _{CC} | V |
| V _{IL} | “L” input voltage (TTL input level selected) P10, P12, P13, P36, P37 (Note 1) | | 0 | | 0.8 | V |
| V _{IL} | “L” input voltage RESET, CNV _{SS} | | 0 | | 0.2V _{CC} | V |
| V _{IL} | “L” input voltage XIN | | 0 | | 0.16V _{CC} | V |
| ΣIOH(peak) | “H” total peak output current (Note 2) P00–P07, P10–P14, P20–P27, P30–P37 | | | | -80 | mA |
| ΣIOL(peak) | “L” total peak output current (Note 2) P00–P07, P10–P14, P20–P27, P37 | | | | 80 | mA |
| ΣIOL(peak) | “L” total peak output current (Note 2) P30–P36 | | | | 60 | mA |
| ΣIOH(avg) | “H” total average output current (Note 2) P00–P07, P10–P14, P20–P27, P30–P37 | | | | -40 | mA |
| ΣIOL(avg) | “L” total average output current (Note 2) P00–P07, P10–P14, P20–P27, P37 | | | | 40 | mA |
| ΣIOL(avg) | “L” total average output current (Note 2) P30–P36 | | | | 30 | mA |

Note 1: V_{CC} = 4.0 to 5.5V**2:** The total output current is the sum of all the currents flowing through all the applicable ports. The total average current is an average value measured over 100 ms. The total peak current is the peak value of all the currents.

Table 3.1.15 Recommended operating conditions (2)
(V_{CC} = 2.4 to 5.5 V, T_a = -40 to 85 °C, unless otherwise noted)

| Symbol | Parameter | | Limits | | | Unit |
|-----------------------|---|--|--------|------|------|------|
| | | | Min. | Typ. | Max. | |
| I _{OH(peak)} | "H" peak output current (Note 1) | P00–P07, P10–P14, P20–P27, P30–P37 | | | -10 | mA |
| I _{OL(peak)} | "L" peak output current (Note 1) | P00–P07, P10–P14, P20–P27, P37 | | | 10 | mA |
| I _{OL(peak)} | "L" peak output current (Note 1) | P30–P36 | | | 30 | mA |
| I _{OH(avg)} | "H" average output current (Note 2) | P00–P07, P10–P14, P20–P27, P30–P37 | | | -5 | mA |
| I _{OL(avg)} | "L" average output current (Note 2) | P00–P07, P10–P14, P20–P27, P37 | | | 5 | mA |
| I _{OL(avg)} | "L" average output current (Note 2) | P30–P36 | | | 15 | mA |
| f(XIN) | Internal clock oscillation frequency (Note 3) at ceramic oscillation or external clock input | V _{CC} = 4.5 to 5.5 V Double-speed mode | | | 6 | MHz |
| | | V _{CC} = 4.0 to 5.5 V Double-speed mode | | | 4 | MHz |
| | Internal clock oscillation frequency (Note 3) at ceramic oscillation or external clock input | V _{CC} = 2.4 to 5.5 V Double-speed mode | | | 2 | MHz |
| | | V _{CC} = 4.0 to 5.5 V High-, Middle-speed mode | | | 8 | MHz |
| | Internal clock oscillation frequency (Note 3) at ceramic oscillation or external clock input | V _{CC} = 2.4 to 5.5 V High-, Middle-speed mode | | | 4 | MHz |
| | | V _{CC} = 4.0 to 5.5 V High-, Middle-speed mode | | | 4 | MHz |
| | Internal clock oscillation frequency (Note 3) at RC oscillation | V _{CC} = 4.0 to 5.5 V High-, Middle-speed mode | | | 4 | MHz |
| | | V _{CC} = 2.4 to 5.5 V High-, Middle-speed mode | | | 2 | MHz |

Notes 1: The peak output current is the peak current flowing in each port.

2: The average output current I_{OL} (avg), I_{OH} (avg) in an average value measured over 100 ms.

3: When the oscillation frequency has a duty cycle of 50 %.

(3) Electrical Characteristics (Extended operating temperature version)

Table 3.1.16 Electrical characteristics (1)

(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 85 °C, unless otherwise noted)

| Symbol | Parameter | Test conditions | Limits | | | Unit |
|---------|--|--|---------|------|-------|------|
| | | | Min. | Typ. | Max. | |
| VOH | "H" output voltage P00–P07, P10–P14, P20–P27, P30–P37 (Note 1) | IOH = -5 mA VCC = 4.0 to 5.5 V | VCC-1.5 | | | V |
| | | IOH = -1.0 mA VCC = 2.4 to 5.5 V | VCC-1.0 | | | V |
| VOL | "L" output voltage P00–P07, P10–P14, P20–P27, P37 | IOL = 5 mA VCC = 4.0 to 5.5 V | | | 1.5 | V |
| | | IOL = 1.5 mA VCC = 4.0 to 5.5 V | | | 0.3 | V |
| | | IOL = 1.0 mA VCC = 2.4 to 5.5 V | | | 1.0 | V |
| VOL | "L" output voltage P30–P36 | IOL = 15 mA VCC = 4.0 to 5.5 V | | | 2.0 | V |
| | | IOL = 1.5 mA VCC = 4.0 to 5.5 V | | | 0.3 | V |
| | | IOL = 10 mA VCC = 2.4 to 5.5 V | | | 1.0 | V |
| VT+–VT– | Hysteresis CNTR0, CNTR1, INT0, INT1(Note 2) P00–P07 (Note 3) | | | 0.4 | | V |
| VT+–VT– | Hysteresis RXD, SCLK1, SCLK2, SDATA2 (Note 2) | | | 0.5 | | V |
| VT+–VT– | Hysteresis RESET | | | 0.5 | | V |
| IiH | "H" input current P00–P07, P10–P14, P20–P27, P30–P37 | Vi = VCC (Pin floating. Pull up transistors "off") | | | 5.0 | μA |
| IiH | "H" input current RESET | Vi = VCC | | | 5.0 | μA |
| IiH | "H" input current XIN | Vi = VCC | | 4.0 | | μA |
| IiL | "L" input current P00–P07, P10–P14, P20–P27, P30–P37 | Vi = VSS (Pin floating. Pull up transistors "off") | | | -5.0 | μA |
| IiL | "L" input current RESET, CNVSS | Vi = VSS | | | -5.0 | μA |
| IiL | "L" input current XIN | Vi = VSS | | -4.0 | | μA |
| IiL | "L" input current P00–P07, P30–P37 | Vi = VSS (Pull up transistors "on") | | -0.2 | -0.5 | mA |
| VRAM | RAM hold voltage | When clock stopped | 2.0 | | 5.5 | V |
| ROSC | On-chip oscillator oscillation frequency | VCC = 5.0 V, Ta = 25 °C | 1000 | 2000 | 3000 | kHz |
| DOSC | Oscillation stop detection circuit detection frequency | VCC = 5.0 V, Ta = 25 °C | 62.5 | 125 | 187.5 | kHz |

Notes 1: P11 is measured when the P11/TXD1 P-channel output disable bit of the UART control register (bit 4 of address 001B16) is "0".

2: RXD1, SCLK1, SCLK2, SDATA2, INT0, and INT1 have hysteresises only when bits 0 to 2 of the port P1P3 control register are set to "0" (CMOS level).

3: It is available only when operating key-on wake up.

Table 3.1.17 Electrical characteristics (2)**(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 85 °C, unless otherwise noted)**

| Symbol | Test conditions | | Limits | | | Unit |
|---|-----------------------|--|------------|------|------|------|
| | | | Min. | Typ. | Max. | |
| ICC | One Time PROM version | High-speed mode, f(XIN) = 8 MHz Output transistors "off" | | 5.0 | 8.0 | mA |
| | | High-speed mode, f(XIN) = 2 MHz, VCC = 2.4 V Output transistors "off" | | 0.5 | 1.5 | mA |
| | | Double-speed mode, f(XIN) = 6 MHz, Output transistors "off" | | 6.0 | 10.0 | mA |
| | | Middle-speed mode, f(XIN) = 8 MHz, Output transistors "off" | | 2.0 | 5.0 | mA |
| | | On-chip oscillator operation mode, VCC = 5 V Output transistors "off" | | 350 | 1000 | μA |
| | | f(XIN) = 8 MHz (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 1.6 | 3.2 | mA |
| | | f(XIN) = 2 MHz, VCC = 2.4 V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 0.2 | | mA |
| | | On-chip oscillator operation mode, VCC = 5V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 150 | 450 | μA |
| | | Increment when A/D conversion is executed f(XIN) = 8 MHz, VCC = 5 V | | 0.5 | | mA |
| | | All oscillation stopped (in STP state) Output transistors "off" | Ta = 25 °C | 0.1 | 1.0 | μA |
| | | Ta = 85 °C | | 10 | μA | |
| | Mask ROM version | High-speed mode, f(XIN) = 8 MHz Output transistors "off" | | 3.5 | 6.5 | mA |
| | | High-speed mode, f(XIN) = 2 MHz, VCC = 2.4 V Output transistors "off" | | 0.4 | 1.2 | mA |
| | | Double-speed mode, f(XIN) = 6 MHz Output transistors "off" | | 4.5 | 8.0 | mA |
| | | Middle-speed mode, f(XIN) = 8 MHz Output transistors "off" | | 2.0 | 5.0 | mA |
| | | On-chip oscillator operation mode, VCC = 5 V Output transistors "off" | | 300 | 900 | μA |
| | | f(XIN) = 8 MHz (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 1.6 | 3.2 | mA |
| | | f(XIN) = 2 MHz, VCC = 2.4 V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 0.2 | | mA |
| | | On-chip oscillator operation mode, VCC = 5V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 150 | 450 | μA |
| | | Increment when A/D conversion is executed f(XIN) = 8 MHz, VCC = 5 V | | 0.5 | | mA |
| All oscillation stopped (in STP state) Output transistors "off" | | Ta = 25 °C | 0.1 | 1.0 | μA | |
| | Ta = 85 °C | | 10 | μA | | |

(4) A/D Converter Characteristics (Extended operating temperature version)

Table 3.1.18 A/D Converter characteristics

(V_{CC} = 2.7 to 5.5 V, V_{SS} = 0 V, T_a = -40 to 85 °C, unless otherwise noted)

| | Symbol | Parameter | Test conditions | Limits | | | Unit |
|-----------------------|--------------------------------------|-------------------------------|--|--------|------|------|---------|
| | | | | Min. | Typ. | Max. | |
| One Time PROM version | — | Resolution | | | | 10 | Bits |
| | — | Linearity error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±3 | LSB |
| | — | Differential nonlinear error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±0.9 | LSB |
| | VOT | Zero transition voltage | V _{CC} = V _{REF} = 5.12 V | 0 | 5 | 20 | mV |
| | | | V _{CC} = V _{REF} = 3.072 V | 0 | 3 | 15 | mV |
| | VFST | Full scale transition voltage | V _{CC} = V _{REF} = 5.12 V | 5105 | 5115 | 5125 | mV |
| | | | V _{CC} = V _{REF} = 3.072 V | 3060 | 3069 | 3075 | mV |
| | tCONV | Conversion time | | | | 122 | tc(XIN) |
| | RLADDER | Ladder resistor | | | 55 | | kΩ |
| Mask ROM version | — | Resolution | | | | 10 | Bits |
| | — | Linearity error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±3 | LSB |
| | — | Differential nonlinear error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±1.5 | LSB |
| | VOT | Zero transition voltage | V _{CC} = V _{REF} = 5.12 V | 0 | 15 | 35 | mV |
| | | | V _{CC} = V _{REF} = 3.072 V | 0 | 9 | 21 | mV |
| | VFST | Full scale transition voltage | V _{CC} = V _{REF} = 5.12 V | 5105 | 5125 | 5150 | mV |
| | | | V _{CC} = V _{REF} = 3.072 V | 3060 | 3075 | 3090 | mV |
| | tCONV | Conversion time | | | | 122 | tc(XIN) |
| | RLADDER | Ladder resistor | | | 55 | | kΩ |
| IVREF | Reference power source input current | V _{REF} = 5.0 V | 50 | 150 | 200 | μA | |
| | | V _{REF} = 3.0 V | 30 | 70 | 120 | μA | |
| II(AD) | A/D port input current | | | | 5.0 | μA | |

(5) Timing Requirements (Extended operating temperature version)**Table 3.1.19 Timing requirements (1)****(V_{CC} = 4.0 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|--------------------------------|--|--------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _w (RESET) | Reset input "L" pulse width | 2 | | | μs |
| t _c (XIN) | External clock input cycle time | 125 | | | ns |
| t _{WH} (XIN) | External clock input "H" pulse width | 50 | | | ns |
| t _{WL} (XIN) | External clock input "L" pulse width | 50 | | | ns |
| t _c (CNTR0) | CNTR0 input cycle time | 200 | | | ns |
| t _{WH} (CNTR0) | CNTR0, INT0, INT1, input "H" pulse width | 80 | | | ns |
| t _{WL} (CNTR0) | CNTR0, INT0, INT1, input "L" pulse width | 80 | | | ns |
| t _c (CNTR1) | CNTR1 input cycle time | 2000 | | | ns |
| t _{WH} (CNTR1) | CNTR1 input "H" pulse width | 800 | | | ns |
| t _{WL} (CNTR1) | CNTR1 input "L" pulse width | 800 | | | ns |
| t _c (SCLK1) | Serial I/O1 clock input cycle time (Note) | 800 | | | ns |
| t _{WH} (SCLK1) | Serial I/O1 clock input "H" pulse width (Note) | 370 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock input "L" pulse width (Note) | 370 | | | ns |
| t _{su} (RxD1-SCLK1) | Serial I/O1 input set up time | 220 | | | ns |
| t _h (SCLK1-RxD1) | Serial I/O1 input hold time | 100 | | | ns |
| t _c (SCLK2) | Serial I/O2 clock input cycle time | 1000 | | | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock input "H" pulse width | 400 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock input "L" pulse width | 400 | | | ns |
| t _{su} (SDATA2-SCLK2) | Serial I/O2 input set up time | 200 | | | ns |
| t _h (SCLK2-SDATA2) | Serial I/O2 input hold time | 200 | | | ns |

Note: In this time, bit 6 of the serial I/O1 control register (address 001A16) is set to "1" (clock synchronous serial I/O1 is selected).

When bit 6 of the serial I/O1 control register is "0" (clock asynchronous serial I/O1 is selected), the rating values are divided by 4.

Table 3.1.20 Timing requirements (2)**(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|--------------------------------|--|--------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _w (RESET) | Reset input "L" pulse width | 2 | | | μs |
| t _c (XIN) | External clock input cycle time | 250 | | | ns |
| t _{WH} (XIN) | External clock input "H" pulse width | 100 | | | ns |
| t _{WL} (XIN) | External clock input "L" pulse width | 100 | | | ns |
| t _c (CNTR0) | CNTR0 input cycle time | 500 | | | ns |
| t _{WH} (CNTR0) | CNTR0, INT0, INT1, input "H" pulse width | 230 | | | ns |
| t _{WL} (CNTR0) | CNTR0, INT0, INT1, input "L" pulse width | 230 | | | ns |
| t _c (CNTR1) | CNTR1 input cycle time | 4000 | | | ns |
| t _{WH} (CNTR1) | CNTR1 input "H" pulse width | 1600 | | | ns |
| t _{WL} (CNTR1) | CNTR1 input "L" pulse width | 1600 | | | ns |
| t _c (SCLK1) | Serial I/O1 clock input cycle time (Note) | 2000 | | | ns |
| t _{WH} (SCLK1) | Serial I/O1 clock input "H" pulse width (Note) | 950 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock input "L" pulse width (Note) | 950 | | | ns |
| t _{su} (RxD1-SCLK1) | Serial I/O1 input set up time | 400 | | | ns |
| t _h (SCLK1-RxD1) | Serial I/O1 input hold time | 200 | | | ns |
| t _c (SCLK2) | Serial I/O2 clock input cycle time | 2000 | | | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock input "H" pulse width | 950 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock input "L" pulse width | 950 | | | ns |
| t _{su} (SDATA2-SCLK2) | Serial I/O2 input set up time | 400 | | | ns |
| t _h (SCLK2-SDATA2) | Serial I/O2 input hold time | 400 | | | ns |

Note: In this time, bit 6 of the serial I/O1 control register (address 001A16) is set to "1" (clock synchronous serial I/O1 is selected).

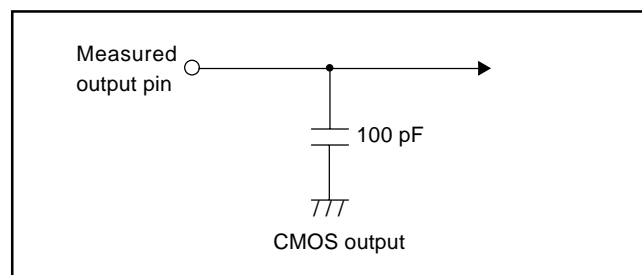
When bit 6 of the serial I/O1 control register is "0" (clock asynchronous serial I/O1 is selected), the rating values are divided by 4.

(6) Switching Characteristics (Extended operating temperature version)**Table 3.1.21 Switching characteristics (1)****(V_{CC} = 4.0 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------------------|--|-----------------------------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _{WH} (SCLK1) | Serial I/O1 clock output "H" pulse width | t _c (SCLK1)/2-30 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock output "L" pulse width | t _c (SCLK1)/2-30 | | | ns |
| t _d (SCLK1-TxD1) | Serial I/O1 output delay time | | | 140 | ns |
| t _v (SCLK1-TxD1) | Serial I/O1 output valid time | -30 | | | ns |
| t _r (SCLK1) | Serial I/O1 clock output rising time | | | 30 | ns |
| t _f (SCLK1) | Serial I/O1 clock output falling time | | | 30 | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock output "H" pulse width | t _c (SCLK2)/2-30 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock output "L" pulse width | t _c (SCLK2)/2-30 | | | ns |
| t _d (SCLK2-SDATA2) | Serial I/O2 output delay time | | | 140 | ns |
| t _v (SCLK2-SDATA2) | Serial I/O2 output valid time | 0 | | | ns |
| t _r (SCLK2) | Serial I/O2 clock output rising time | | | 30 | ns |
| t _f (SCLK2) | Serial I/O2 clock output falling time | | | 30 | ns |
| t _r (CMOS) | CMOS output rising time (Note 1) | | 10 | 30 | ns |
| t _f (CMOS) | CMOS output falling time (Note 1) | | 10 | 30 | ns |

Note 1: Pin XOUT is excluded.**Table 3.1.22 Switching characteristics (2)****(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 85 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------------------|--|-----------------------------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _{WH} (SCLK1) | Serial I/O1 clock output "H" pulse width | t _c (SCLK1)/2-50 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock output "L" pulse width | t _c (SCLK1)/2-50 | | | ns |
| t _d (SCLK1-TxD1) | Serial I/O1 output delay time | | | 350 | ns |
| t _v (SCLK1-TxD1) | Serial I/O1 output valid time | -30 | | | ns |
| t _r (SCLK1) | Serial I/O1 clock output rising time | | | 50 | ns |
| t _f (SCLK1) | Serial I/O1 clock output falling time | | | 50 | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock output "H" pulse width | t _c (SCLK2)/2-50 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock output "L" pulse width | t _c (SCLK2)/2-50 | | | ns |
| t _d (SCLK2-SDATA2) | Serial I/O2 output delay time | | | 350 | ns |
| t _v (SCLK2-SDATA2) | Serial I/O2 output valid time | 0 | | | ns |
| t _r (SCLK2) | Serial I/O2 clock output rising time | | | 50 | ns |
| t _f (SCLK2) | Serial I/O2 clock output falling time | | | 50 | ns |
| t _r (CMOS) | CMOS output rising time (Note 1) | | 20 | 50 | ns |
| t _f (CMOS) | CMOS output falling time (Note 1) | | 20 | 50 | ns |

Note 1: Pin XOUT is excluded.**Fig. 3.1.3 Switching characteristics measurement circuit diagram (Extended operating temperature)**

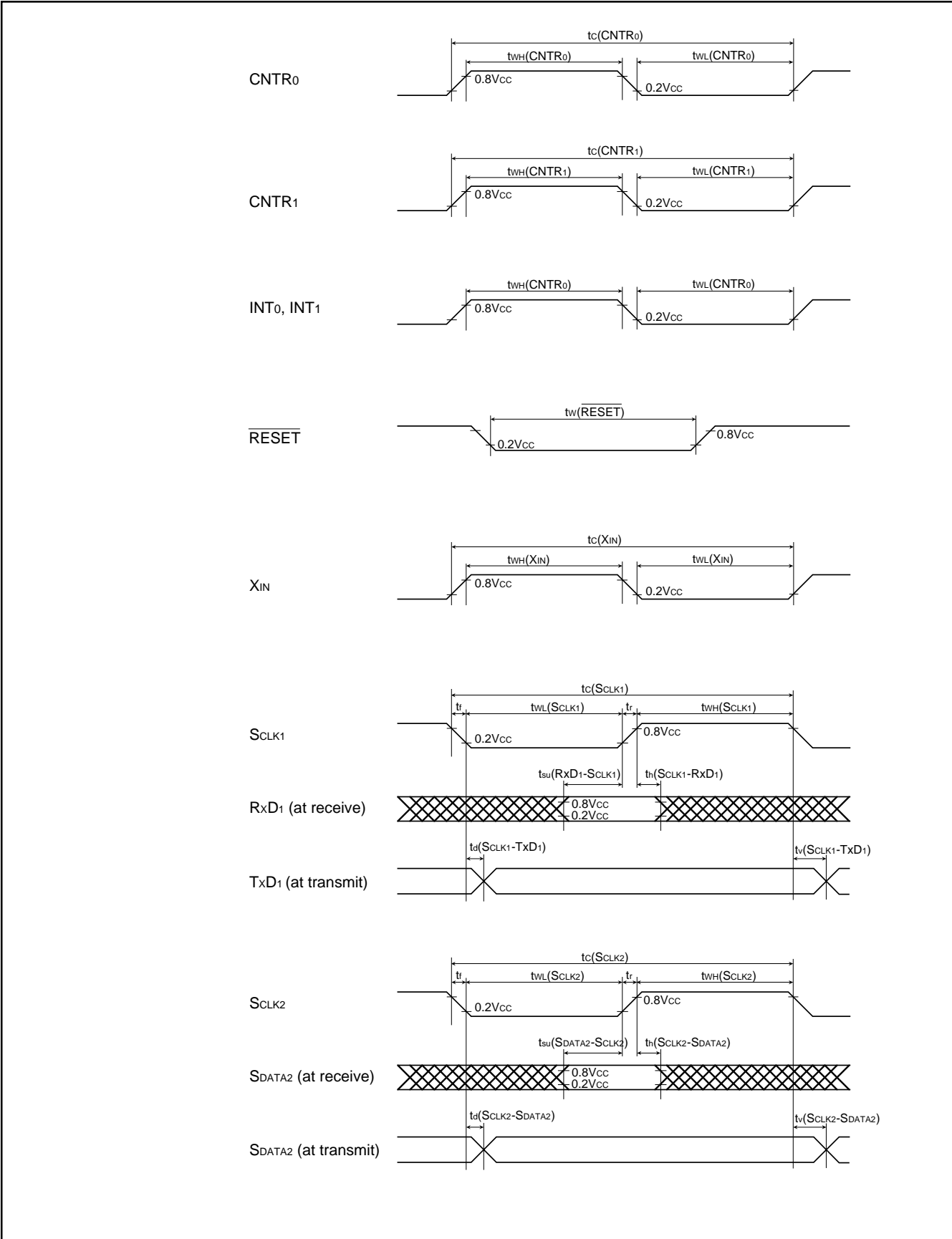


Fig. 3.1.4 Timing chart (Extended operating temperature version)

3.1.3 7540Group (Extended operating temperature 125 °C version)

Applied to: M37540M2V-XXXFP/GP, M37540M4V-XXXFP/GP, M37540E8V-XXXFP/GP

(1) Absolute Maximum Ratings (Extended operating temperature 125 °C version)

Table 3.1.23 Absolute maximum ratings

| Symbol | Parameter | Conditions | Ratings | Unit |
|--------|--|---|-------------------------------|------|
| VCC | Power source voltage | All voltages are based on VSS. Output transistors are cut off. | -0.3 to 6.5 (Note 1) | V |
| Vi | Input voltage P00-P07, P10-P14, P20-P27, P30-P37, VREF | | -0.3 to VCC + 0.3 | V |
| Vi | Input voltage RESET, XIN, CNVSS | | -0.3 to VCC + 0.3 | V |
| Vo | Output voltage P00-P07, P10-P14, P20-P27, P30-P37, XOUT | | -0.3 to VCC + 0.3 | V |
| Pd | Power dissipation | Ta = 25°C | 300 (Note 2) | mW |
| Topr | Operating temperature | | -40 to 125 (Note 3) | °C |
| Tstg | Storage temperature | | -65 to 150 | °C |

Notes 1: This is the rating value for the Mask ROM version.

The rating value for the One Time PROM version is -0.3 to 7.0 V.

2: 200 mW for the 32P6U package product.

3: In this version, the operating temperature range and total time are limited as follows;

55 °C to 85 °C: within total 6000 hours,

85 °C to 125 °C: within total 1000 hours.

(2) Recommended Operating Conditions (Extended operating temperature 125 °C version)

Table 3.1.24 Recommended operating conditions (1)

(V_{CC} = 2.4 to 5.5 V, T_a = -40 to 125 °C, unless otherwise noted)

| Symbol | Parameter | | Limits | | | Unit |
|------------------|--|--|--------------------|------|---------------------|------|
| | | | Min. | Typ. | Max. | |
| V _{CC} | Power source voltage (ceramic) | f(X _{IN}) = 8 MHz (High-, Middle-speed mode) | 4.0 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 4 MHz (High-, Middle-speed mode) | 2.4 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 4 MHz (Double-speed mode) | 4.0 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 2 MHz (Double-speed mode) | 2.4 | 5.0 | 5.5 | V |
| | Power source voltage (RC) | f(X _{IN}) = 4 MHz (High-, Middle-speed mode) | 4.0 | 5.0 | 5.5 | V |
| | | f(X _{IN}) = 2 MHz (High-, Middle-speed mode) | 2.4 | 5.0 | 5.5 | V |
| V _{SS} | Power source voltage | | | 0 | | V |
| V _{REF} | Analog reference voltage | | 2.0 | | V _{CC} | V |
| V _{IH} | "H" input voltage P00-P07, P10-P14, P20-P27, P30-P37 | | 0.8V _{CC} | | V _{CC} | V |
| V _{IH} | "H" input voltage (TTL input level selected) P10, P12, P13, P36, P37 (Note 1) | | 2.0 | | V _{CC} | V |
| V _{IH} | "H" input voltage RESET, X _{IN} | | 0.8V _{CC} | | V _{CC} | V |
| V _{IL} | "L" input voltage P00-P07, P10-P14, P20-P27, P30-P37 | | 0 | | 0.3V _{CC} | V |
| V _{IL} | "L" input voltage (TTL input level selected) P10, P12, P13, P36, P37 (Note 1) | | 0 | | 0.8 | V |
| V _{IL} | "L" input voltage RESET, CNV _{SS} | | 0 | | 0.2V _{CC} | V |
| V _{IL} | "L" input voltage X _{IN} | | 0 | | 0.16V _{CC} | V |
| ΣIOH(peak) | "H" total peak output current (Note 2) P00-P07, P10-P14, P20-P27, P30-P37 | | | | -80 | mA |
| ΣIOL(peak) | "L" total peak output current (Note 2) P00-P07, P10-P14, P20-P27, P37 | | | | 80 | mA |
| ΣIOL(peak) | "L" total peak output current (Note 2) P30-P36 | | | | 60 | mA |
| ΣIOH(avg) | "H" total average output current (Note 2) P00-P07, P10-P14, P20-P27, P30-P37 | | | | -40 | mA |
| ΣIOL(avg) | "L" total average output current (Note 2) P00-P07, P10-P14, P20-P27, P37 | | | | 40 | mA |
| ΣIOL(avg) | "L" total average output current (Note 2) P30-P36 | | | | 30 | mA |

Note 1: V_{CC} = 4.0 to 5.5V

2: The total output current is the sum of all the currents flowing through all the applicable ports. The total average current is an average value measured over 100 ms. The total peak current is the peak value of all the currents.

Table 3.1.25 Recommended operating conditions (2)**(V_{CC} = 2.4 to 5.5 V, T_a = -40 to 125 °C, unless otherwise noted)**

| Symbol | Parameter | | Limits | | | Unit |
|------------------------|---|--|--------|------|------|------|
| | | | Min. | Typ. | Max. | |
| I _{OH} (peak) | "H" peak output current (Note 1) | P00–P07, P10–P14, P20–P27, P30–P37 | | | -10 | mA |
| I _{OL} (peak) | "L" peak output current (Note 1) | P00–P07, P10–P14, P20–P27, P37 | | | 10 | mA |
| I _{OL} (peak) | "L" peak output current (Note 1) | P30–P36 | | | 30 | mA |
| I _{OH} (avg) | "H" average output current (Note 2) | P00–P07, P10–P14, P20–P27, P30–P37 | | | -5 | mA |
| I _{OL} (avg) | "L" average output current (Note 2) | P00–P07, P10–P14, P20–P27, P37 | | | 5 | mA |
| I _{OL} (avg) | "L" average output current (Note 2) | P30–P36 | | | 15 | mA |
| f(XIN) | Internal clock oscillation frequency (Note 3) at ceramic oscillation or external clock input | V _{CC} = 4.0 to 5.5 V Double-speed mode | | | 4 | MHz |
| | | V _{CC} = 2.4 to 5.5 V Double-speed mode | | | 2 | MHz |
| | Internal clock oscillation frequency (Note 3) at ceramic oscillation or external clock input | V _{CC} = 4.0 to 5.5 V High-, Middle-speed mode | | | 8 | MHz |
| | | V _{CC} = 2.4 to 5.5 V High-, Middle-speed mode | | | 4 | MHz |
| | Internal clock oscillation frequency (Note 3) at RC oscillation | V _{CC} = 4.0 to 5.5 V High-, Middle-speed mode | | | 4 | MHz |
| | | V _{CC} = 2.4 to 5.5 V High-, Middle-speed mode | | | 2 | MHz |

Notes 1: The peak output current is the peak current flowing in each port.**2:** The average output current I_{OL} (avg), I_{OH} (avg) in an average value measured over 100 ms.**3:** When the oscillation frequency has a duty cycle of 50 %.

(3) Electrical Characteristics (Extended operating temperature 125 °C version)**Table 3.1.26 Electrical characteristics (1)****(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 125 °C, unless otherwise noted)**

| Symbol | Parameter | Test conditions | Limits | | | Unit |
|---------|---|--|---------|------|-------|------|
| | | | Min. | Typ. | Max. | |
| VOH | "H" output voltage P00-P07, P10-P14, P20-P27, P30-P37 (Note 1) | IOH = -5 mA VCC = 4.0 to 5.5 V | VCC-1.5 | | | V |
| | | IOH = -1.0 mA VCC = 2.4 to 5.5 V | VCC-1.0 | | | V |
| VOL | "L" output voltage P00-P07, P10-P14, P20-P27, P37 | IOL = 5 mA VCC = 4.0 to 5.5 V | | | 1.5 | V |
| | | IOL = 1.5 mA VCC = 4.0 to 5.5 V | | | 0.3 | V |
| | | IOL = 1.0 mA VCC = 2.4 to 5.5 V | | | 1.0 | V |
| VOL | "L" output voltage P30-P36 | IOL = 15 mA VCC = 4.0 to 5.5 V | | | 2.0 | V |
| | | IOL = 1.5 mA VCC = 4.0 to 5.5 V | | | 0.3 | V |
| | | IOL = 10 mA VCC = 2.4 to 5.5 V | | | 1.0 | V |
| VT+–VT– | Hysteresis CNTR0, CNTR1, INT0, INT1 (Note 2) P00-P07 (Note 3) | | | 0.4 | | V |
| VT+–VT– | Hysteresis RXD, SCLK1, SCLK2, SDATA2 (Note 2) | | | 0.5 | | V |
| VT+–VT– | Hysteresis RESET | | | 0.5 | | V |
| IiH | "H" input current P00-P07, P10-P14, P20-P27, P30-P37 | Vi = VCC (Pin floating. Pull up transistors "off") | | | 5.0 | μA |
| IiH | "H" input current RESET | Vi = VCC | | | 5.0 | μA |
| IiH | "H" input current XIN | Vi = VCC | | 4.0 | | μA |
| IiL | "L" input current P00-P07, P10-P14, P20-P27, P30-P37 | Vi = VSS (Pin floating. Pull up transistors "off") | | | -5.0 | μA |
| IiL | "L" input current RESET, CNVSS | Vi = VSS | | | -5.0 | μA |
| IiL | "L" input current XIN | Vi = VSS | | -4.0 | | μA |
| IiL | "L" input current P00-P07, P30-P37 | Vi = VSS (Pull up transistors "on") | | -0.2 | -0.5 | mA |
| VRAM | RAM hold voltage | When clock stopped | 2.0 | | 5.5 | V |
| ROSC | On-chip oscillator oscillation frequency | VCC = 5.0 V, Ta = 25 °C | 1000 | 2000 | 3000 | kHz |
| DOSC | Oscillation stop detection circuit detection frequency | VCC = 5.0 V, Ta = 25 °C | 62.5 | 125 | 187.5 | kHz |

Notes 1: P11 is measured when the P11/TXD1 P-channel output disable bit of the UART control register (bit 4 of address 001B16) is "0".

2: RXD1, SCLK1, SCLK2, SDATA2, INT0, and INT1 have hysteresises only when bits 0 to 2 of the port P1P3 control register are set to "0" (CMOS level).

3: It is available only when operating key-on wake up.

Table 3.1.27 Electrical characteristics (2)**(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 125 °C, unless otherwise noted)**

| Symbol | Test conditions | | Limits | | | Unit |
|---|-----------------------|--|------------|------|------|------|
| | | | Min. | Typ. | Max. | |
| I _{CC} | One Time PROM version | High-speed mode, f(X _{IN}) = 8 MHz Output transistors "off" | | 5.0 | 8.0 | mA |
| | | High-speed mode, f(X _{IN}) = 2 MHz, V _{CC} = 2.4 V Output transistors "off" | | 0.5 | 1.5 | mA |
| | | Middle-speed mode, f(X _{IN}) = 8 MHz, Output transistors "off" | | 2.0 | 5.0 | mA |
| | | On-chip oscillator operation mode, V _{CC} = 5 V Output transistors "off" | | 350 | 1000 | μA |
| | | f(X _{IN}) = 8 MHz (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 1.6 | 3.2 | mA |
| | | f(X _{IN}) = 2 MHz, V _{CC} = 2.4 V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 0.2 | | mA |
| | | On-chip oscillator operation mode, V _{CC} = 5V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 150 | 450 | μA |
| | | Increment when A/D conversion is executed f(X _{IN}) = 8 MHz, V _{CC} = 5 V | | 0.5 | | mA |
| | | All oscillation stopped (in STP state) Output transistors "off" | Ta = 25 °C | 0.1 | 1.0 | μA |
| | | Ta = 125 °C | | 50 | μA | |
| | Mask ROM version | High-speed mode, f(X _{IN}) = 8 MHz Output transistors "off" | | 3.5 | 6.5 | mA |
| | | High-speed mode, f(X _{IN}) = 2 MHz, V _{CC} = 2.4 V Output transistors "off" | | 0.4 | 1.2 | mA |
| | | Middle-speed mode, f(X _{IN}) = 8 MHz, Output transistors "off" | | 2.0 | 5.0 | mA |
| | | On-chip oscillator operation mode, V _{CC} = 5 V Output transistors "off" | | 300 | 900 | μA |
| | | f(X _{IN}) = 8 MHz (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 1.6 | 3.2 | mA |
| | | f(X _{IN}) = 2 MHz, V _{CC} = 2.4 V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 0.2 | | mA |
| | | On-chip oscillator operation mode, V _{CC} = 5V (in WIT state), functions except timer 1 disabled, Output transistors "off" | | 150 | 450 | μA |
| | | Increment when A/D conversion is executed f(X _{IN}) = 8 MHz, V _{CC} = 5 V | | 0.5 | | mA |
| All oscillation stopped (in STP state) Output transistors "off" | | Ta = 25 °C | 0.1 | 1.0 | μA | |
| | Ta = 125 °C | | 50 | μA | | |

(4) A/D Converter Characteristics (Extended operating temperature 125 °C version)**Table 3.1.28 A/D Converter characteristics****(V_{CC} = 2.7 to 5.5 V, V_{SS} = 0 V, T_a = -40 to 125 °C, unless otherwise noted)**

| | Symbol | Parameter | Test conditions | Limits | | | Unit | |
|--|--------------------------------------|--------------------------------------|--|--|------|------|-----------------------------------|------|
| | | | | Min. | Typ. | Max. | | |
| One Time PROM version | — | Resolution | | | | 10 | Bits | |
| | — | Linearity error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±3 | LSB | |
| | — | Differential nonlinear error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±0.9 | LSB | |
| | VOT | Zero transition voltage | V _{CC} = V _{REF} = 5.12 V | 0 | 5 | 20 | mV | |
| | | | V _{CC} = V _{REF} = 3.072 V | 0 | 3 | 15 | mV | |
| | VFST | Full scale transition voltage | V _{CC} = V _{REF} = 5.12 V | 5105 | 5115 | 5125 | mV | |
| | | | V _{CC} = V _{REF} = 3.072 V | 3060 | 3069 | 3075 | mV | |
| | tCONV | Conversion time | | | | 122 | t _c (X _{IN}) | |
| | RLADDER | Ladder resistor | | | 55 | | kΩ | |
| Mask ROM version | IVREF | Reference power source input current | V _{REF} = 5.0 V | 50 | 150 | 200 | μA | |
| | | | V _{REF} = 3.0 V | 30 | 70 | 120 | | |
| | II(AD) | A/D port input current | | | | 7.0 | μA | |
| | Mask ROM version | — | Resolution | | | | 10 | Bits |
| | | — | Linearity error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±3 | LSB |
| | | — | Differential nonlinear error | V _{CC} = 2.7 to 5.5 V T _a = 25 °C | | | ±1.5 | LSB |
| | | VOT | Zero transition voltage | V _{CC} = V _{REF} = 5.12 V | 0 | 15 | 35 | mV |
| | | | | V _{CC} = V _{REF} = 3.072 V | 0 | 9 | 21 | mV |
| | | VFST | Full scale transition voltage | V _{CC} = V _{REF} = 5.12 V | 5105 | 5125 | 5150 | mV |
| V _{CC} = V _{REF} = 3.072 V | | | | 3060 | 3075 | 3090 | mV | |
| tCONV | | Conversion time | | | | 122 | t _c (X _{IN}) | |
| RLADDER | | Ladder resistor | | | 55 | | kΩ | |
| IVREF | Reference power source input current | V _{REF} = 5.0 V | 50 | 150 | 200 | μA | | |
| | | V _{REF} = 3.0 V | 30 | 70 | 120 | | | |
| II(AD) | A/D port input current | | | | 7.0 | μA | | |

(5) Timing Requirements (Extended operating temperature 125 °C version)**Table 3.1.29 Timing requirements (1)****(V_{CC} = 4.0 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 125 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------|--|--------|------|------|------|
| | | Min. | Typ. | Max. | |
| tw(RESET) | Reset input "L" pulse width | 2 | | | μs |
| tc(XIN) | External clock input cycle time | 125 | | | ns |
| tWH(XIN) | External clock input "H" pulse width | 50 | | | ns |
| tWL(XIN) | External clock input "L" pulse width | 50 | | | ns |
| tc(CNTR0) | CNTR0 input cycle time | 200 | | | ns |
| tWH(CNTR0) | CNTR0, INT0, INT1, input "H" pulse width | 80 | | | ns |
| tWL(CNTR0) | CNTR0, INT0, INT1, input "L" pulse width | 80 | | | ns |
| tc(CNTR1) | CNTR1 input cycle time | 2000 | | | ns |
| tWH(CNTR1) | CNTR1 input "H" pulse width | 800 | | | ns |
| tWL(CNTR1) | CNTR1 input "L" pulse width | 800 | | | ns |
| tc(SCLK1) | Serial I/O1 clock input cycle time (Note) | 800 | | | ns |
| tWH(SCLK1) | Serial I/O1 clock input "H" pulse width (Note) | 370 | | | ns |
| tWL(SCLK1) | Serial I/O1 clock input "L" pulse width (Note) | 370 | | | ns |
| tsu(RxD1-SCLK1) | Serial I/O1 input set up time | 220 | | | ns |
| th(SCLK1-RxD1) | Serial I/O1 input hold time | 100 | | | ns |
| tc(SCLK2) | Serial I/O2 clock input cycle time | 1000 | | | ns |
| tWH(SCLK2) | Serial I/O2 clock input "H" pulse width | 400 | | | ns |
| tWL(SCLK2) | Serial I/O2 clock input "L" pulse width | 400 | | | ns |
| tsu(SDATA2-SCLK2) | Serial I/O2 input set up time | 200 | | | ns |
| th(SCLK2-SDATA2) | Serial I/O2 input hold time | 200 | | | ns |

Note: In this time, bit 6 of the serial I/O1 control register (address 001A16) is set to "1" (clock synchronous serial I/O1 is selected).

When bit 6 of the serial I/O1 control register is "0" (clock asynchronous serial I/O1 is selected), the rating values are divided by 4.

Table 3.1.30 Timing requirements (2)**(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 125 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------|--|--------|------|------|------|
| | | Min. | Typ. | Max. | |
| tw(RESET) | Reset input "L" pulse width | 2 | | | μs |
| tc(XIN) | External clock input cycle time | 250 | | | ns |
| tWH(XIN) | External clock input "H" pulse width | 100 | | | ns |
| tWL(XIN) | External clock input "L" pulse width | 100 | | | ns |
| tc(CNTR0) | CNTR0 input cycle time | 500 | | | ns |
| tWH(CNTR0) | CNTR0, INT0, INT1, input "H" pulse width | 230 | | | ns |
| tWL(CNTR0) | CNTR0, INT0, INT1, input "L" pulse width | 230 | | | ns |
| tc(CNTR1) | CNTR1 input cycle time | 4000 | | | ns |
| tWH(CNTR1) | CNTR1 input "H" pulse width | 1600 | | | ns |
| tWL(CNTR1) | CNTR1 input "L" pulse width | 1600 | | | ns |
| tc(SCLK1) | Serial I/O1 clock input cycle time (Note) | 2000 | | | ns |
| tWH(SCLK1) | Serial I/O1 clock input "H" pulse width (Note) | 950 | | | ns |
| tWL(SCLK1) | Serial I/O1 clock input "L" pulse width (Note) | 950 | | | ns |
| tsu(RxD1-SCLK1) | Serial I/O1 input set up time | 400 | | | ns |
| th(SCLK1-RxD1) | Serial I/O1 input hold time | 200 | | | ns |
| tc(SCLK2) | Serial I/O2 clock input cycle time | 2000 | | | ns |
| tWH(SCLK2) | Serial I/O2 clock input "H" pulse width | 950 | | | ns |
| tWL(SCLK2) | Serial I/O2 clock input "L" pulse width | 950 | | | ns |
| tsu(SDATA2-SCLK2) | Serial I/O2 input set up time | 400 | | | ns |
| th(SCLK2-SDATA2) | Serial I/O2 input hold time | 400 | | | ns |

Note: In this time, bit 6 of the serial I/O1 control register (address 001A16) is set to "1" (clock synchronous serial I/O1 is selected).

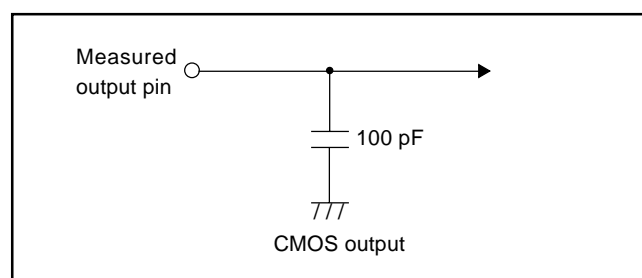
When bit 6 of the serial I/O1 control register is "0" (clock asynchronous serial I/O1 is selected), the rating values are divided by 4.

(6) Switching Characteristics (Extended operating temperature 125 °C version)**Table 3.1.30 Switching characteristics (1)****(V_{CC} = 4.0 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 125 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------------------|--|-----------------------------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _{WH} (SCLK1) | Serial I/O1 clock output "H" pulse width | t _c (SCLK1)/2-50 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock output "L" pulse width | t _c (SCLK1)/2-50 | | | ns |
| t _d (SCLK1-TxD1) | Serial I/O1 output delay time | | | 140 | ns |
| t _v (SCLK1-TxD1) | Serial I/O1 output valid time | -30 | | | ns |
| t _r (SCLK1) | Serial I/O1 clock output rising time | | | 30 | ns |
| t _f (SCLK1) | Serial I/O1 clock output falling time | | | 30 | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock output "H" pulse width | t _c (SCLK2)/2-50 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock output "L" pulse width | t _c (SCLK2)/2-50 | | | ns |
| t _d (SCLK2-SDATA2) | Serial I/O2 output delay time | | | 140 | ns |
| t _v (SCLK2-SDATA2) | Serial I/O2 output valid time | 0 | | | ns |
| t _r (SCLK2) | Serial I/O2 clock output rising time | | | 30 | ns |
| t _f (SCLK2) | Serial I/O2 clock output falling time | | | 30 | ns |
| t _r (CMOS) | CMOS output rising time (Note 1) | | 10 | 30 | ns |
| t _f (CMOS) | CMOS output falling time (Note 1) | | 10 | 30 | ns |

Note 1: Pin XOUT is excluded.**Table 3.1.31 Switching characteristics (2)****(V_{CC} = 2.4 to 5.5 V, V_{SS} = 0 V, Ta = -40 to 125 °C, unless otherwise noted)**

| Symbol | Parameter | Limits | | | Unit |
|-------------------------------|--|-----------------------------|------|------|------|
| | | Min. | Typ. | Max. | |
| t _{WH} (SCLK1) | Serial I/O1 clock output "H" pulse width | t _c (SCLK1)/2-80 | | | ns |
| t _{WL} (SCLK1) | Serial I/O1 clock output "L" pulse width | t _c (SCLK1)/2-80 | | | ns |
| t _d (SCLK1-TxD1) | Serial I/O1 output delay time | | | 350 | ns |
| t _v (SCLK1-TxD1) | Serial I/O1 output valid time | -30 | | | ns |
| t _r (SCLK1) | Serial I/O1 clock output rising time | | | 50 | ns |
| t _f (SCLK1) | Serial I/O1 clock output falling time | | | 50 | ns |
| t _{WH} (SCLK2) | Serial I/O2 clock output "H" pulse width | t _c (SCLK2)/2-80 | | | ns |
| t _{WL} (SCLK2) | Serial I/O2 clock output "L" pulse width | t _c (SCLK2)/2-80 | | | ns |
| t _d (SCLK2-SDATA2) | Serial I/O2 output delay time | | | 350 | ns |
| t _v (SCLK2-SDATA2) | Serial I/O2 output valid time | 0 | | | ns |
| t _r (SCLK2) | Serial I/O2 clock output rising time | | | 50 | ns |
| t _f (SCLK2) | Serial I/O2 clock output falling time | | | 50 | ns |
| t _r (CMOS) | CMOS output rising time (Note 1) | | 20 | 50 | ns |
| t _f (CMOS) | CMOS output falling time (Note 1) | | 20 | 50 | ns |

Note 1: Pin XOUT is excluded.**Fig. 3.1.5 Switching characteristics measurement circuit diagram (Extended operating temperature 125 °C version)**

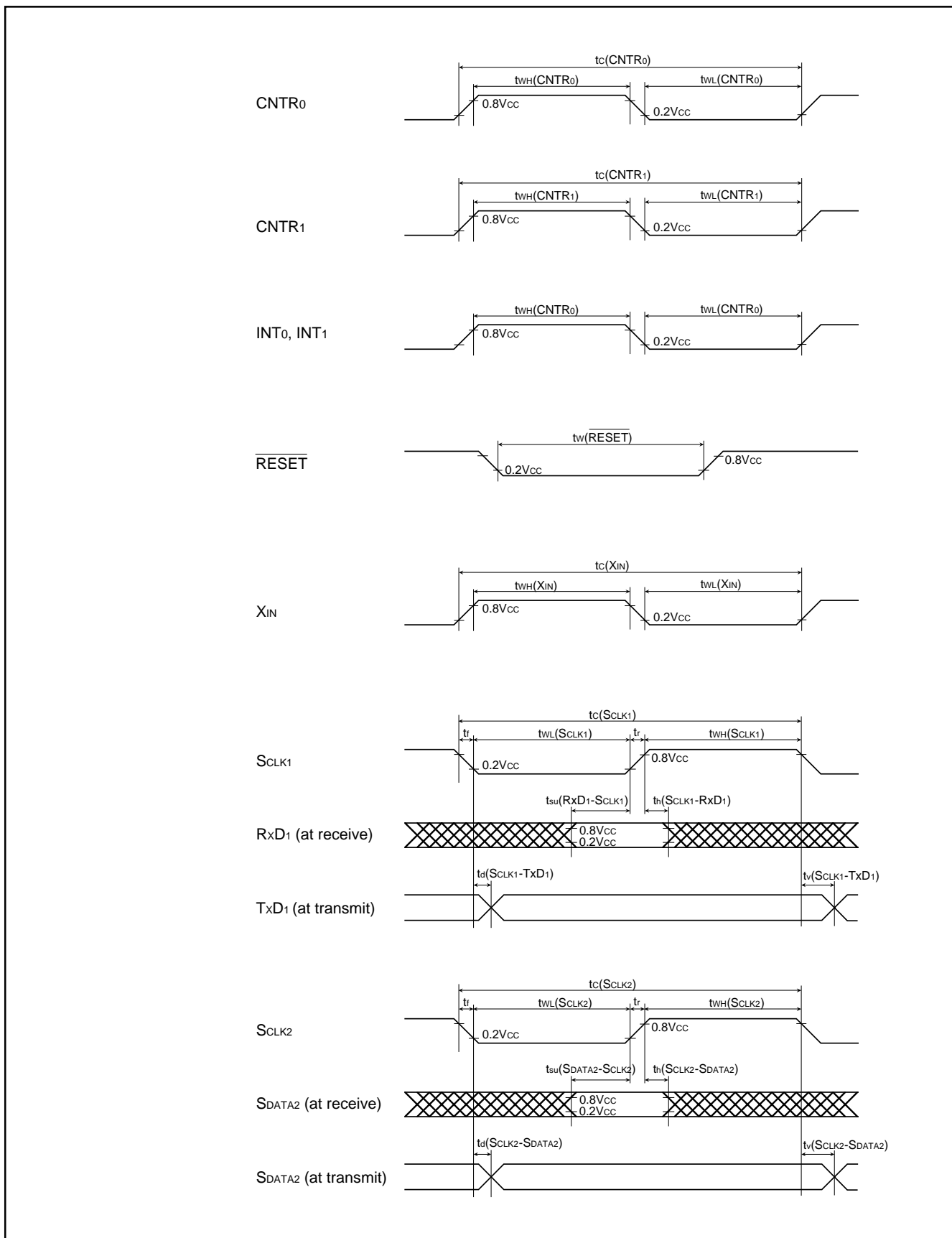


Fig. 3.1.6 Timing chart (Extended operating temperature 125 °C version)

3.2 Typical characteristics

Standard characteristics described below are just examples of the 7540 Group's characteristics and are not guaranteed. For rated values, refer to "3.1 Electrical characteristics".

3.2.1 Mask ROM version

(1) Power source current characteristic example (V_{CC} - I_{CC} characteristics)

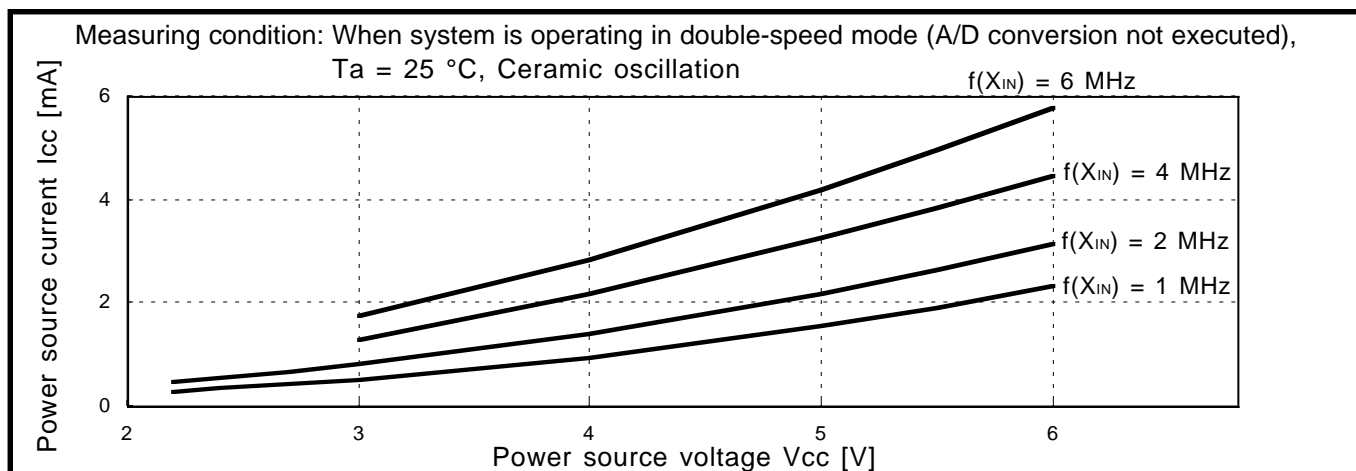


Fig. 3.2.1 V_{CC} - I_{CC} characteristics (in double-speed mode: Mask ROM version)

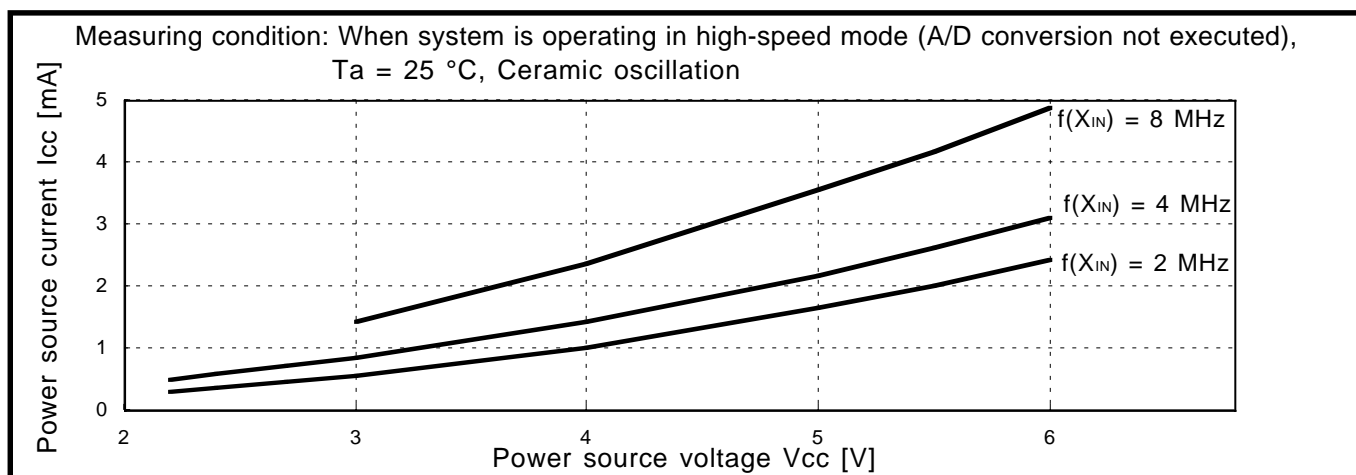


Fig. 3.2.2 V_{CC} - I_{CC} characteristics (in high-speed mode: Mask ROM version)

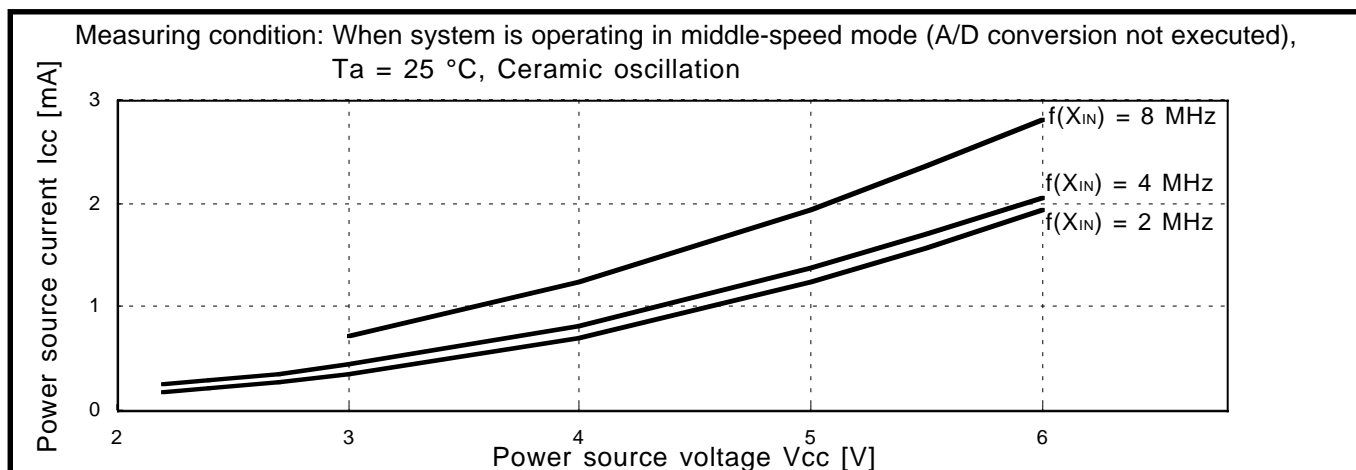


Fig. 3.2.3 V_{CC} - I_{CC} characteristics (in middle-speed mode: Mask ROM version)

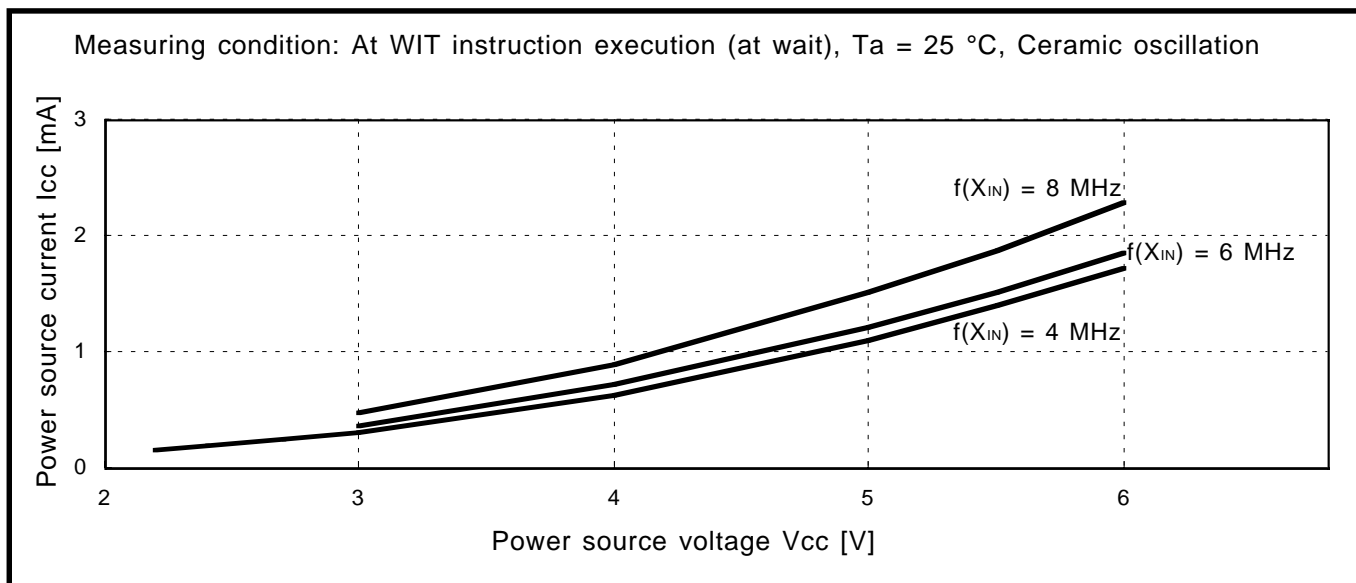


Fig. 3.2.4 V_{cc}-I_{cc} characteristics (at WIT instruction execution: Mask ROM version)

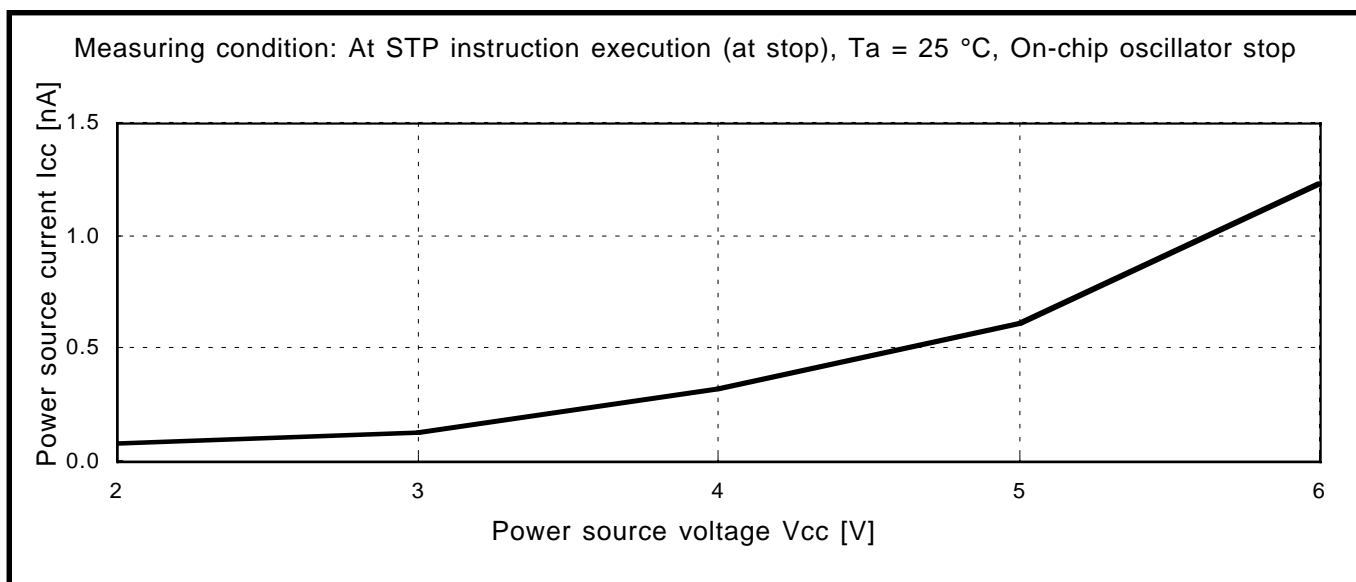


Fig. 3.2.5 V_{cc}-I_{cc} characteristics (at STP instruction execution: Mask ROM version)

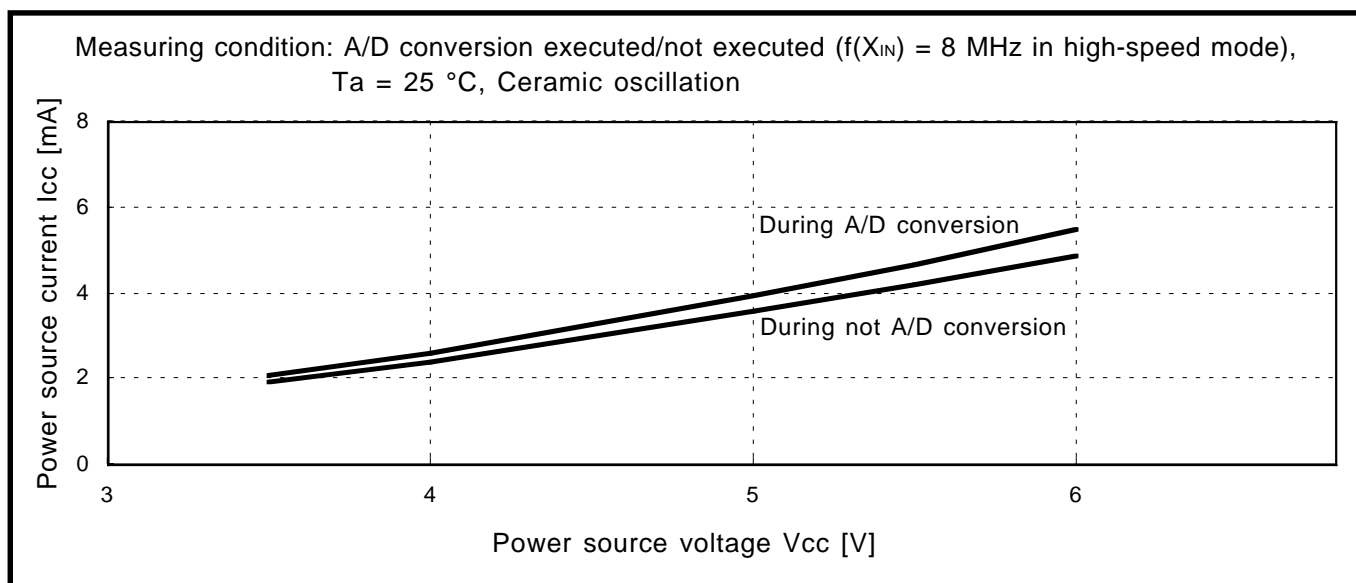


Fig. 3.2.6 V_{CC} - I_{CC} characteristics (addition when operating A/D conversion, $f(X_{IN}) = 8$ MHz in high-speed mode: Mask ROM version)

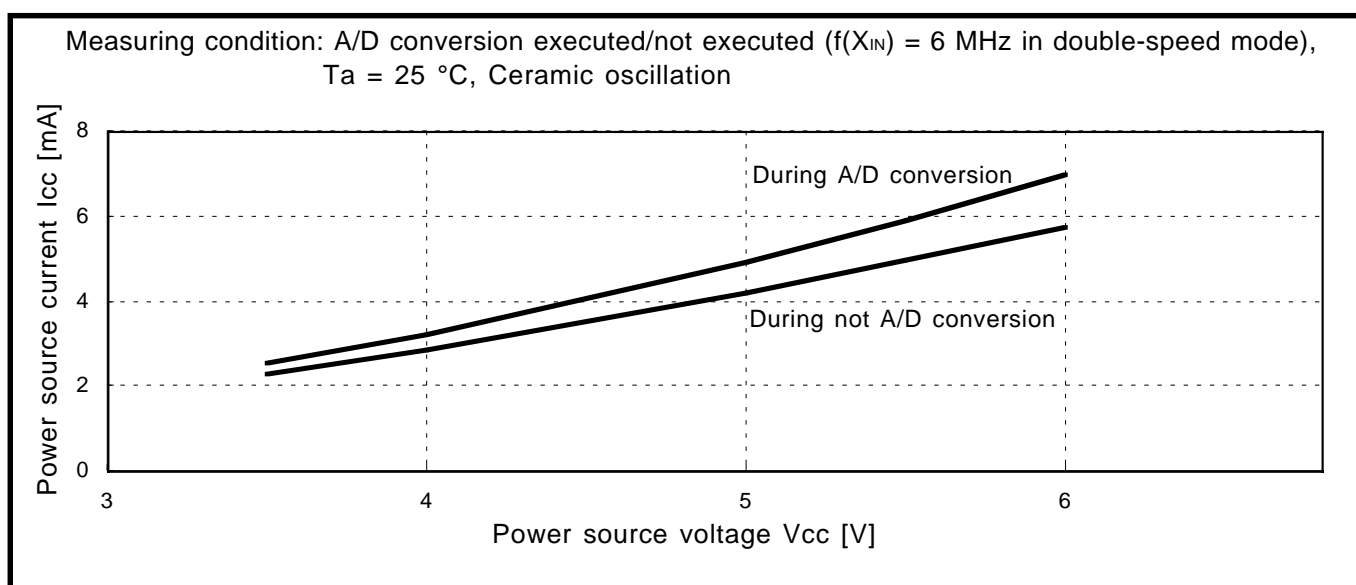


Fig. 3.2.7 V_{CC} - I_{CC} characteristics (addition when operating A/D conversion, $f(X_{IN}) = 6$ MHz in double-speed mode: Mask ROM version)

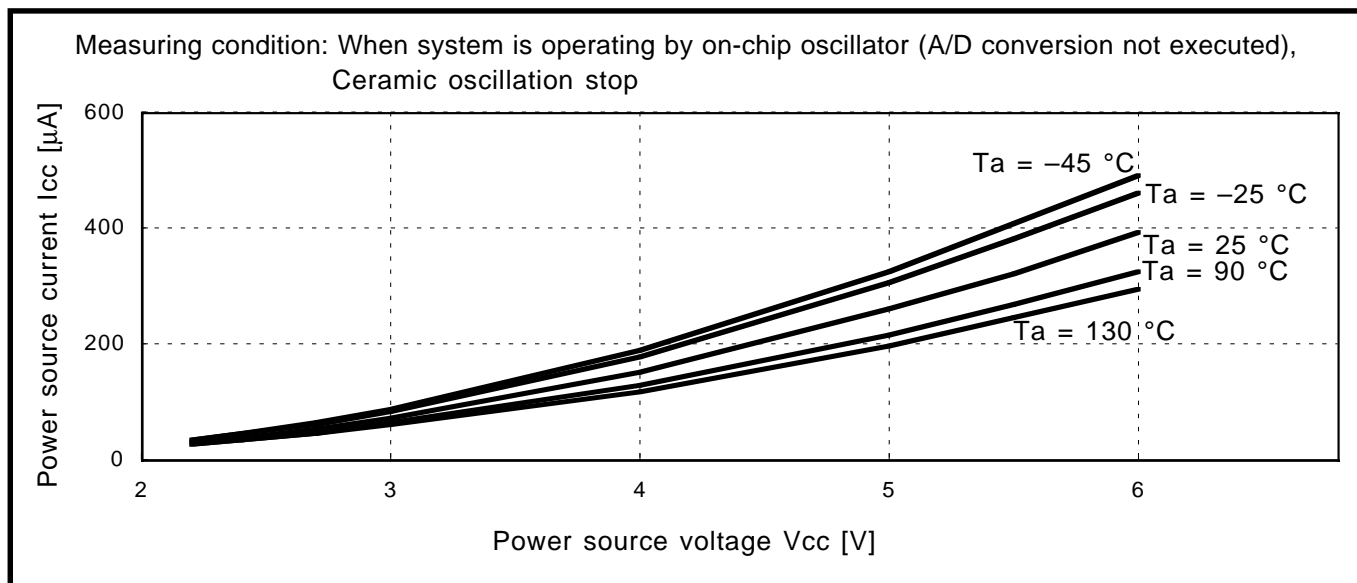


Fig. 3.2.8 V_{cc} - I_{cc} characteristics (When system is operating by on-chip oscillator, Ceramic oscillation stop: Mask ROM version)

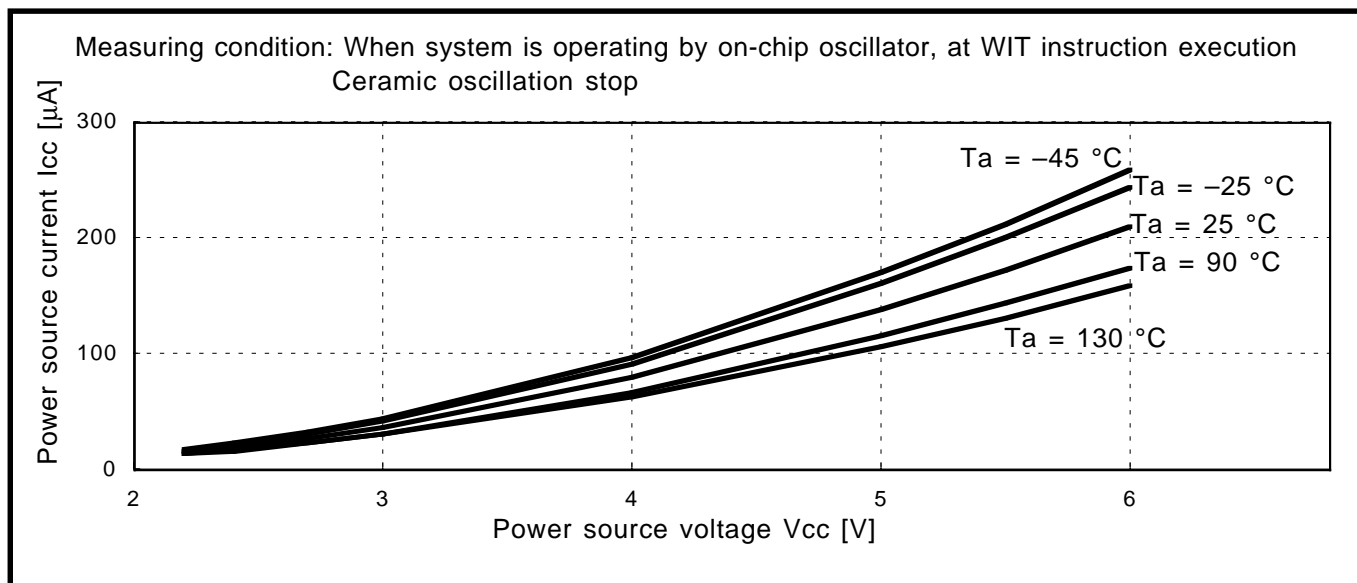


Fig. 3.2.9 V_{cc} - I_{cc} characteristics (When system is operating by on-chip oscillator, at WIT instruction execution, Ceramic oscillation stop: Mask ROM version)

(2) Power source current characteristic example ($f(X_{IN})$ - I_{CC} characteristics)

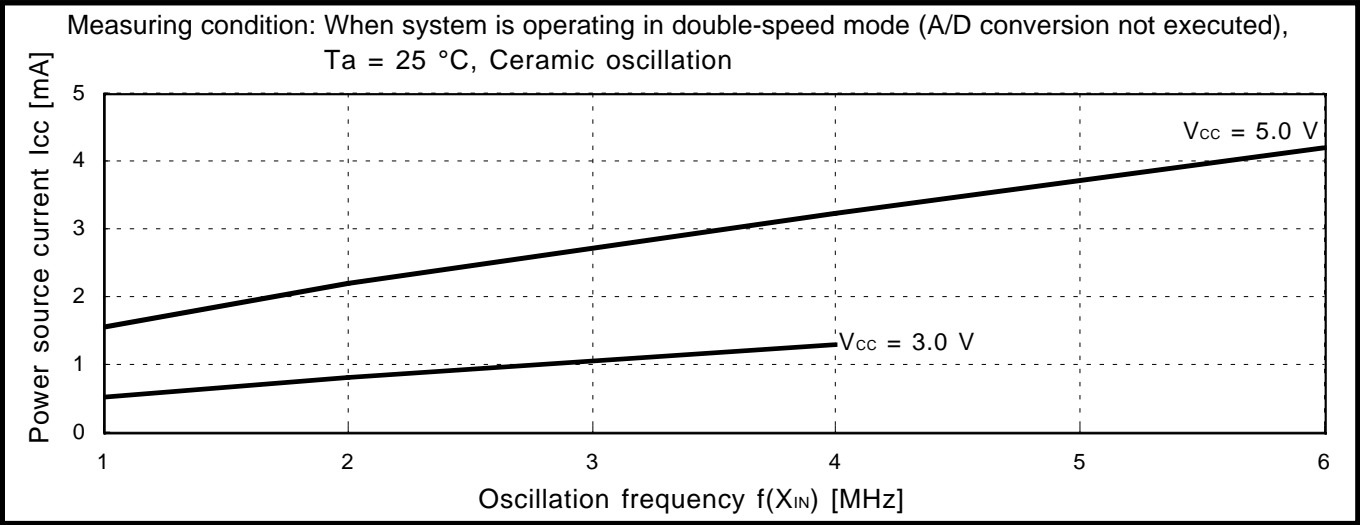


Fig. 3.2.10 $f(X_{IN})$ - I_{CC} characteristics (in double-speed mode: Mask ROM version)

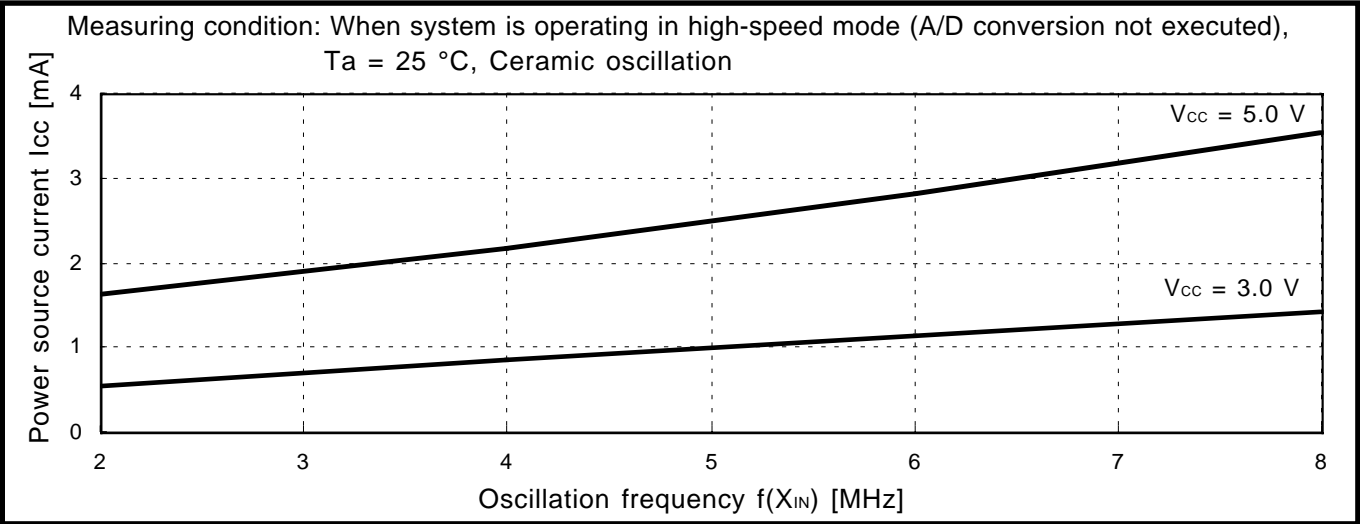


Fig. 3.2.11 $f(X_{IN})$ - I_{CC} characteristics (in high-speed mode: Mask ROM version)

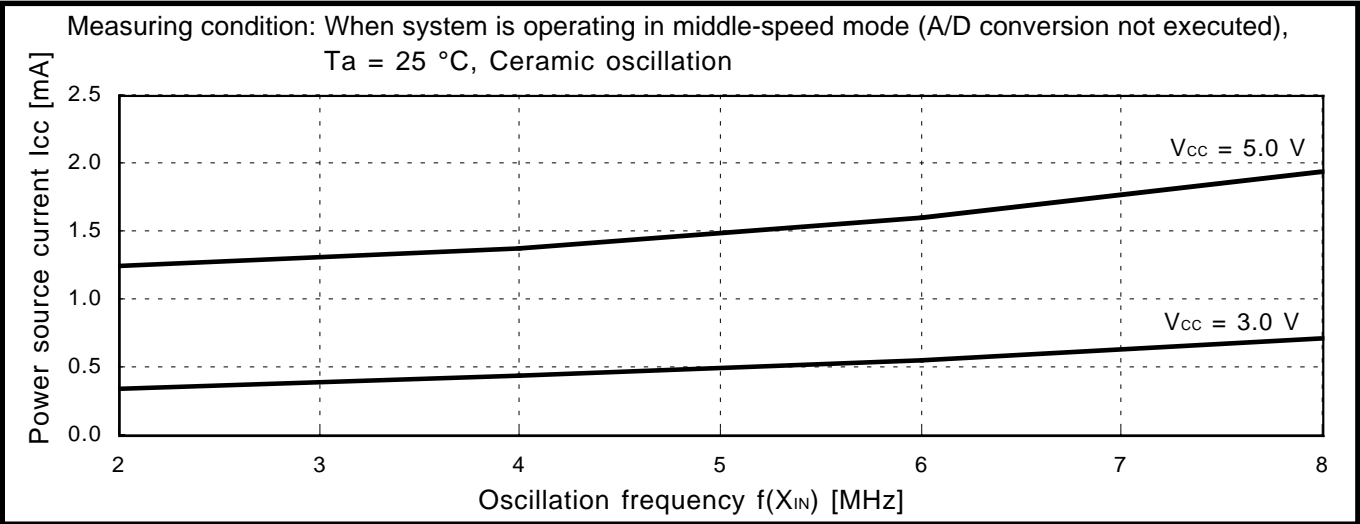


Fig. 3.2.12 $f(X_{IN})$ - I_{CC} characteristics (in middle-speed mode: Mask ROM version)

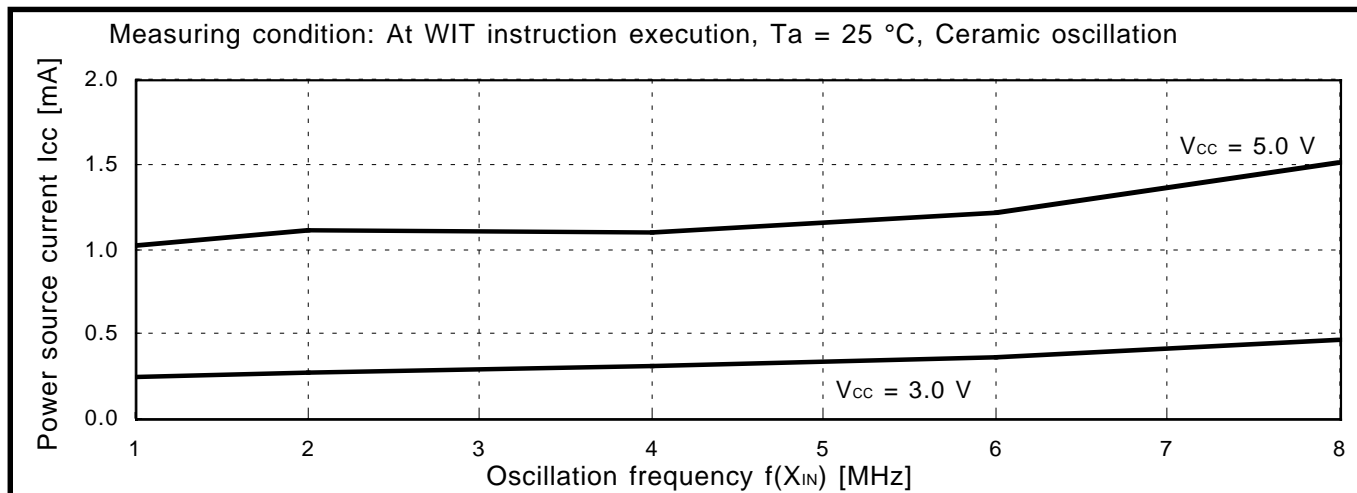


Fig. 3.2.13 $f(X_{IN})$ - I_{CC} characteristics (at WIT instruction execution: Mask ROM version)

(3) Power source current characteristic example (T_a - I_{CC} characteristics)

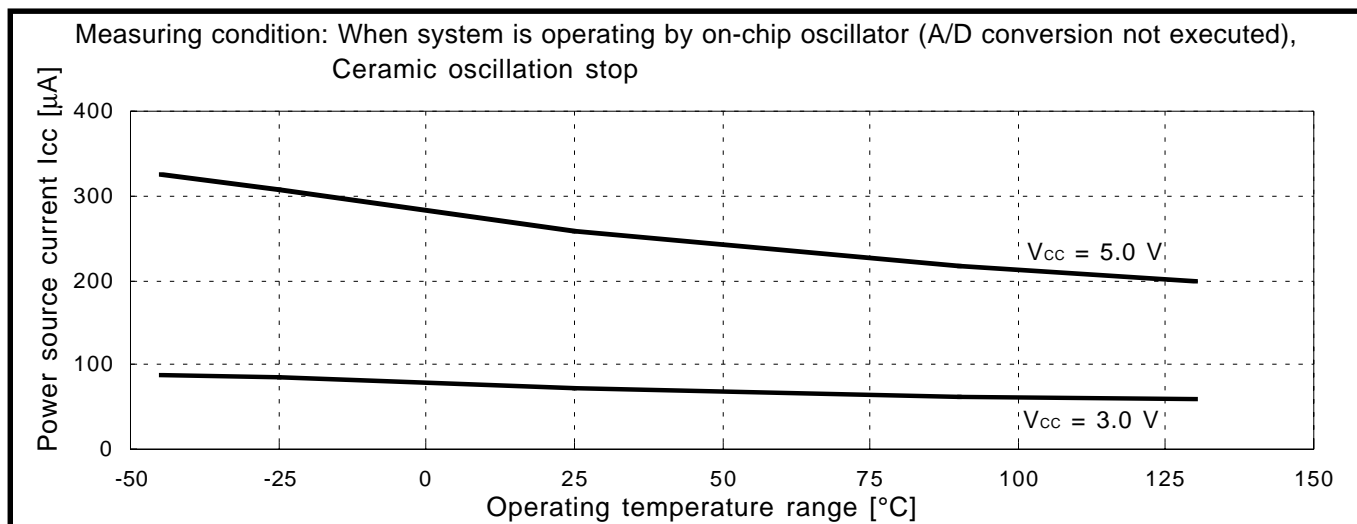


Fig. 3.2.14 T_a - I_{CC} characteristics (When system is operating by on-chip oscillator, Ceramic oscillation stop: Mask ROM version)

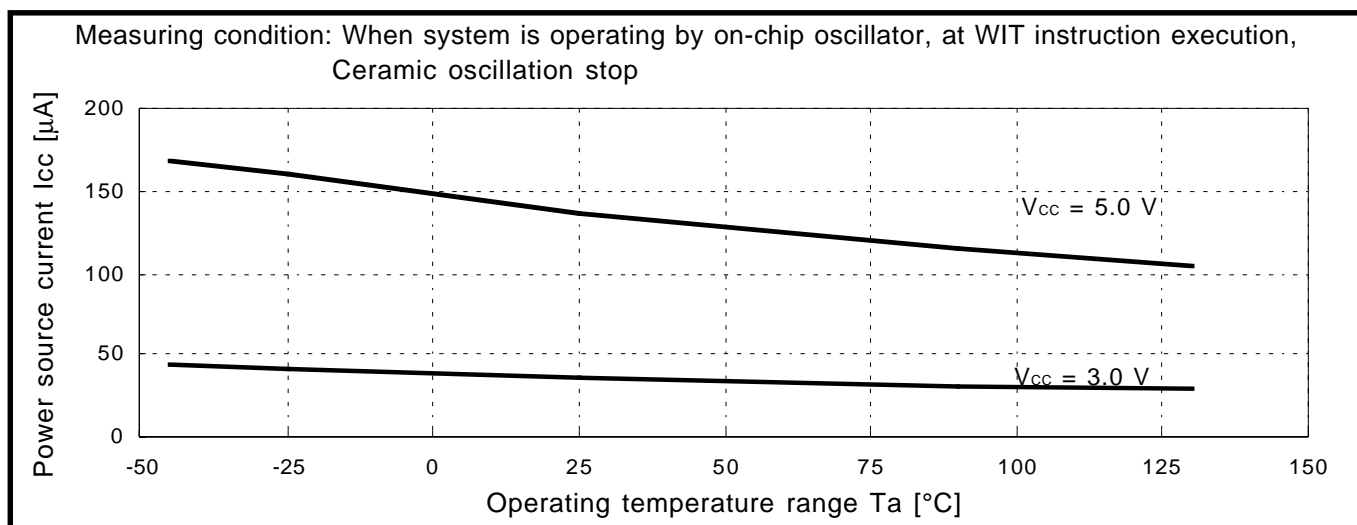


Fig. 3.2.15 T_a - I_{CC} characteristics (When system is operating by on-chip oscillator, at WIT instruction execution, Ceramic oscillation stop: Mask ROM version)

(4) Port typical characteristic example (V_{CC} - V_{IHL} characteristics)

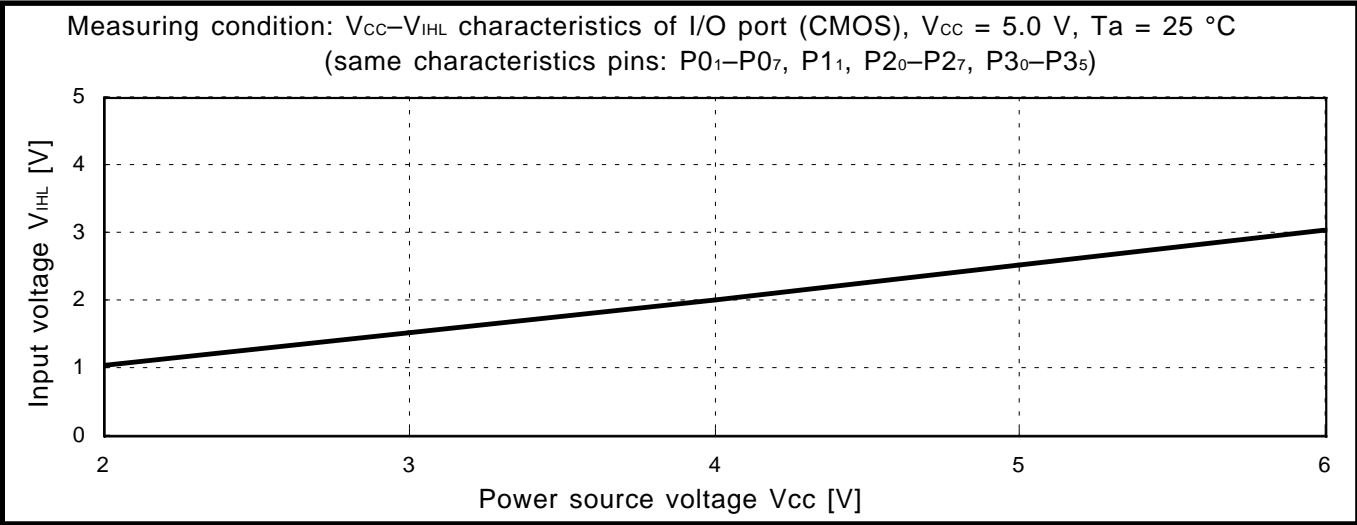


Fig. 3.2.16 V_{CC} - V_{IHL} characteristics (I/O port (CMOS): Mask ROM version)

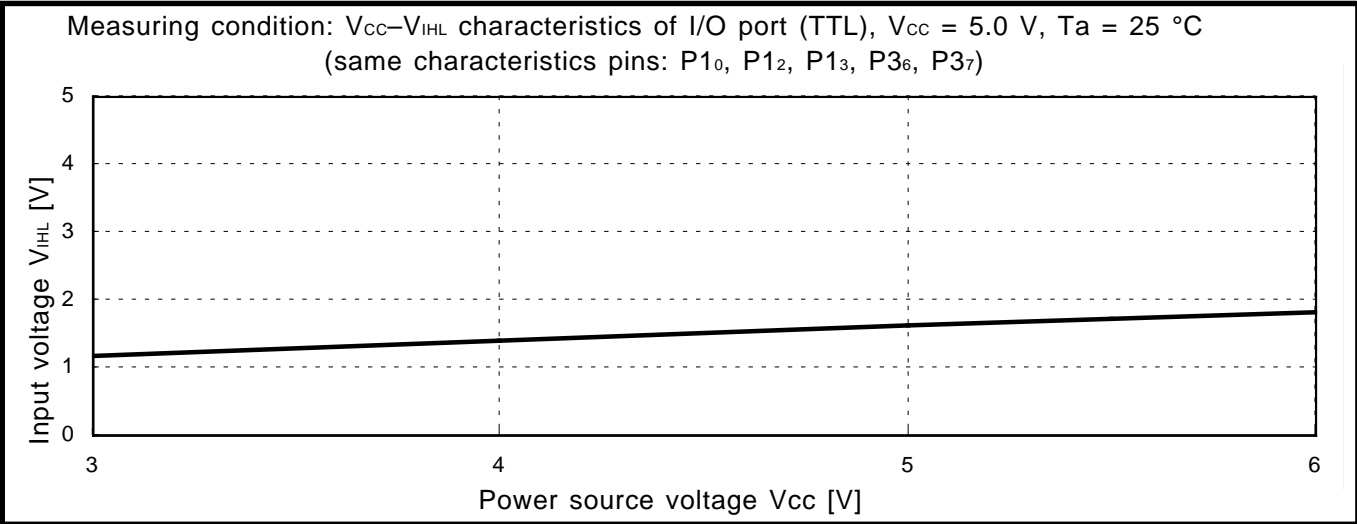


Fig. 3.2.17 V_{CC} - V_{IHL} characteristics (I/O port (TTL): Mask ROM version)

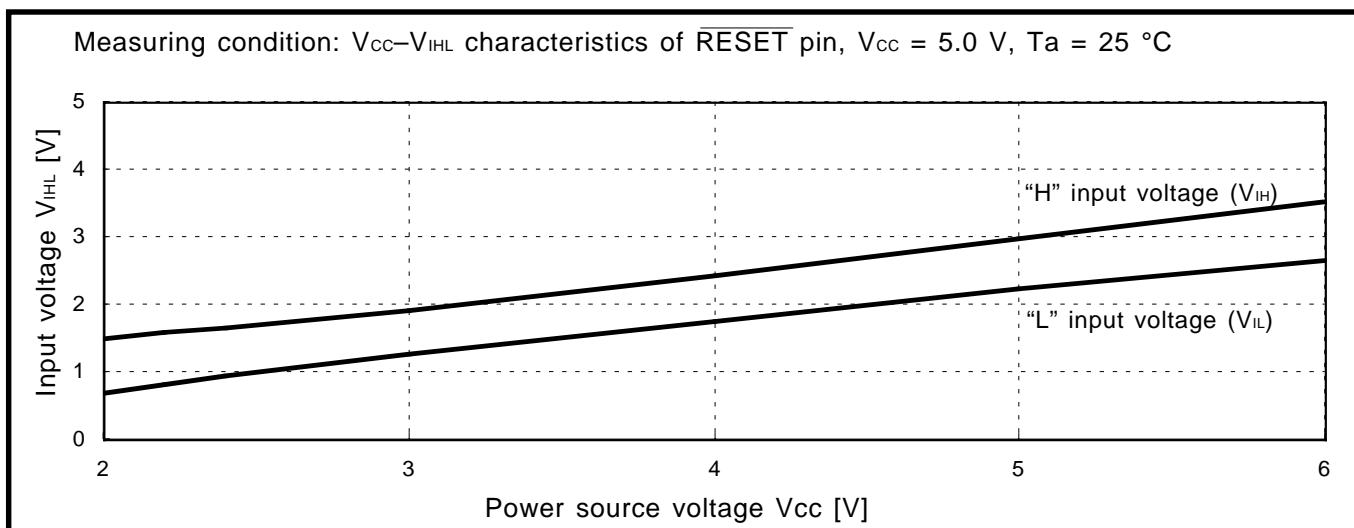


Fig. 3.2.18 V_{CC} - V_{IHL} characteristics ($\overline{\text{RESET}}$ pin: Mask ROM version)

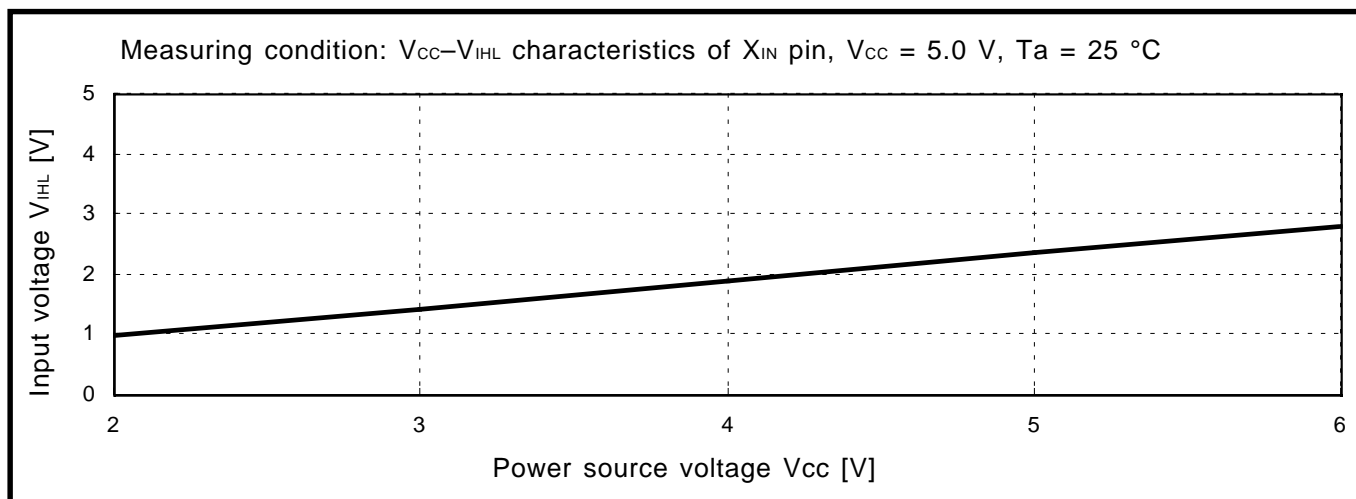


Fig. 3.2.19 V_{CC} - V_{IHL} characteristics (X_{IN} pin: Mask ROM version)

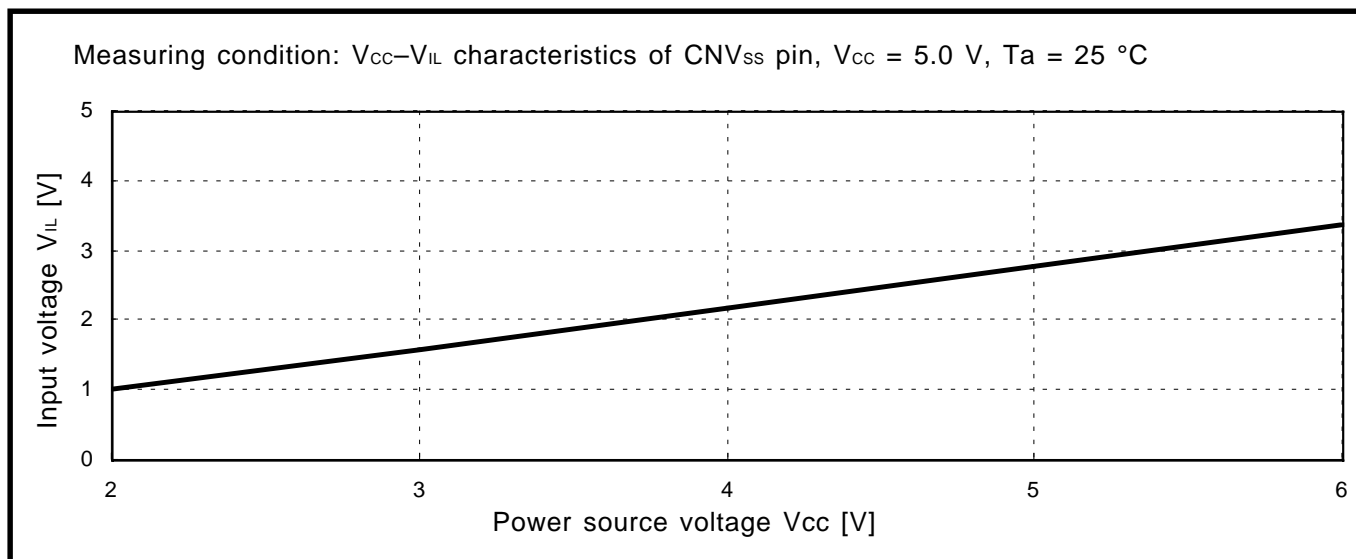


Fig. 3.2.20 V_{CC} - V_{IL} characteristics (CNV_{SS} pin: Mask ROM version)

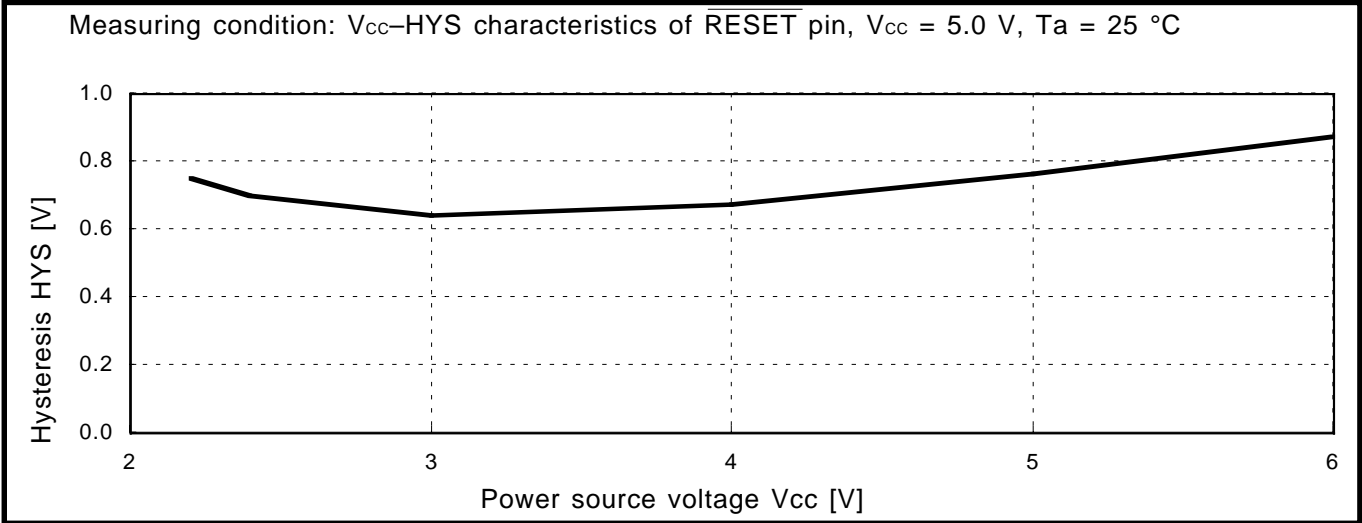


Fig. 3.2.21 V_{CC} -HYS characteristics (RESET pin: Mask ROM version)

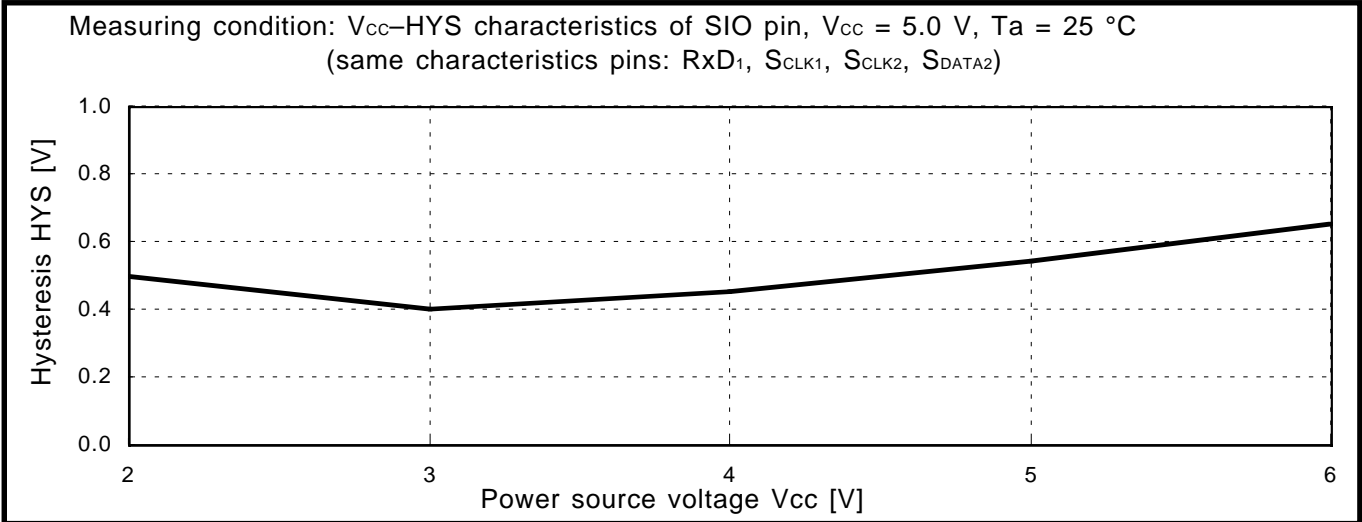


Fig. 3.2.22 V_{CC} -HYS characteristics (SIO pin: Mask ROM version)

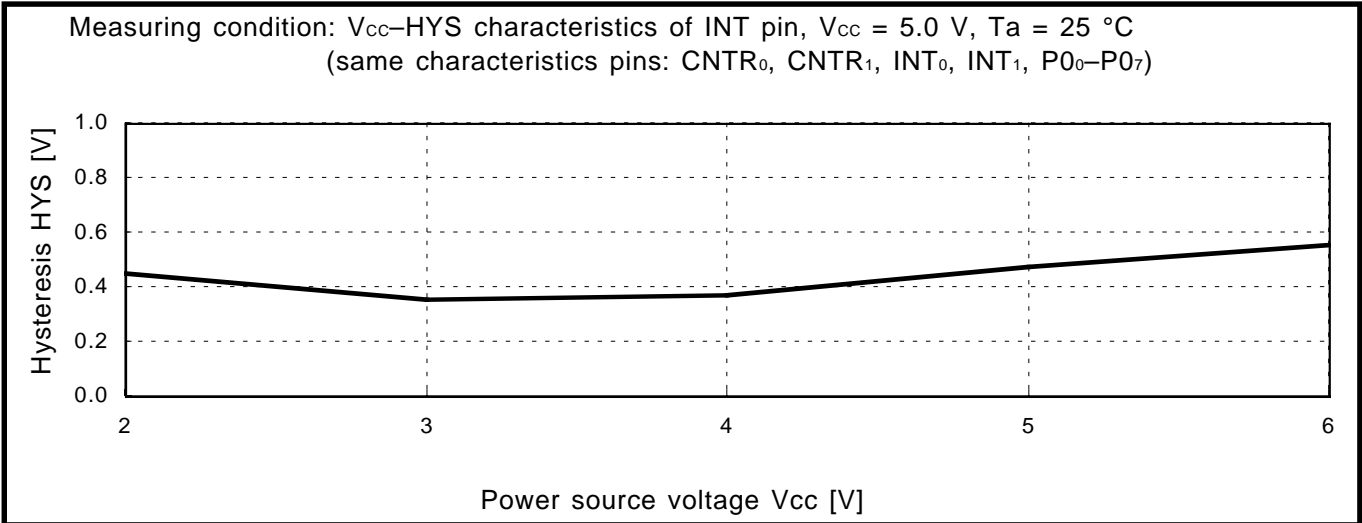
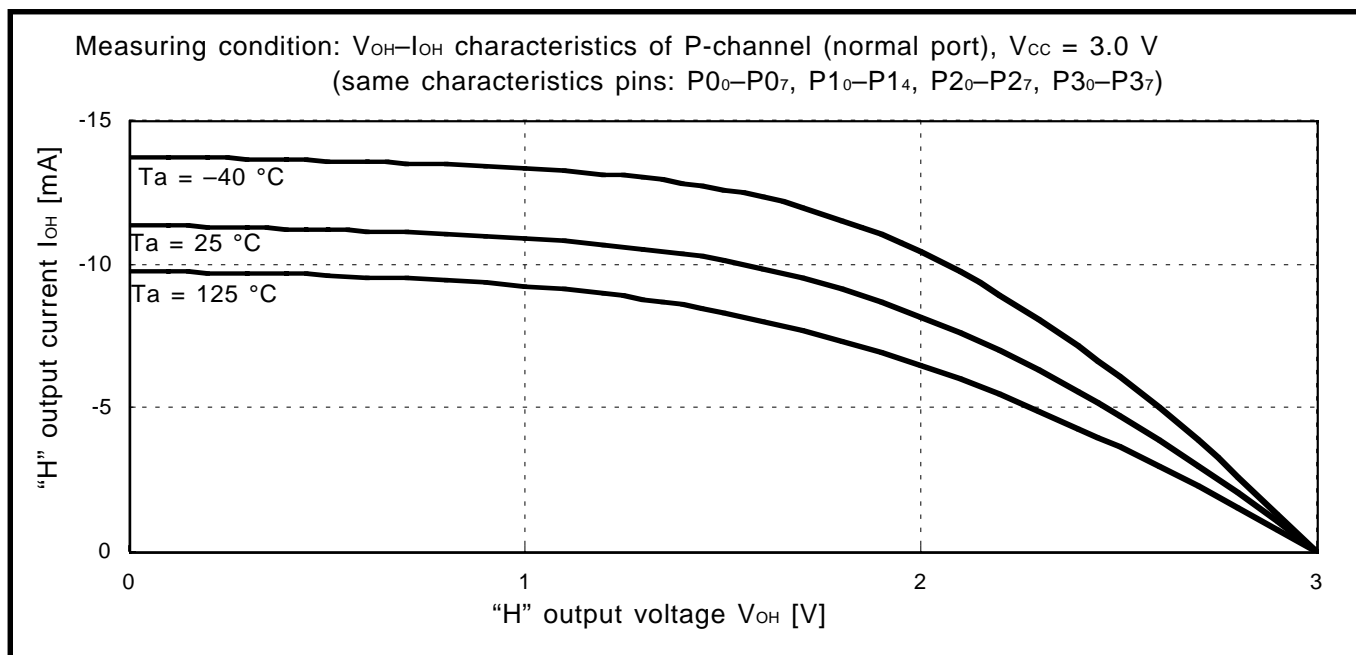
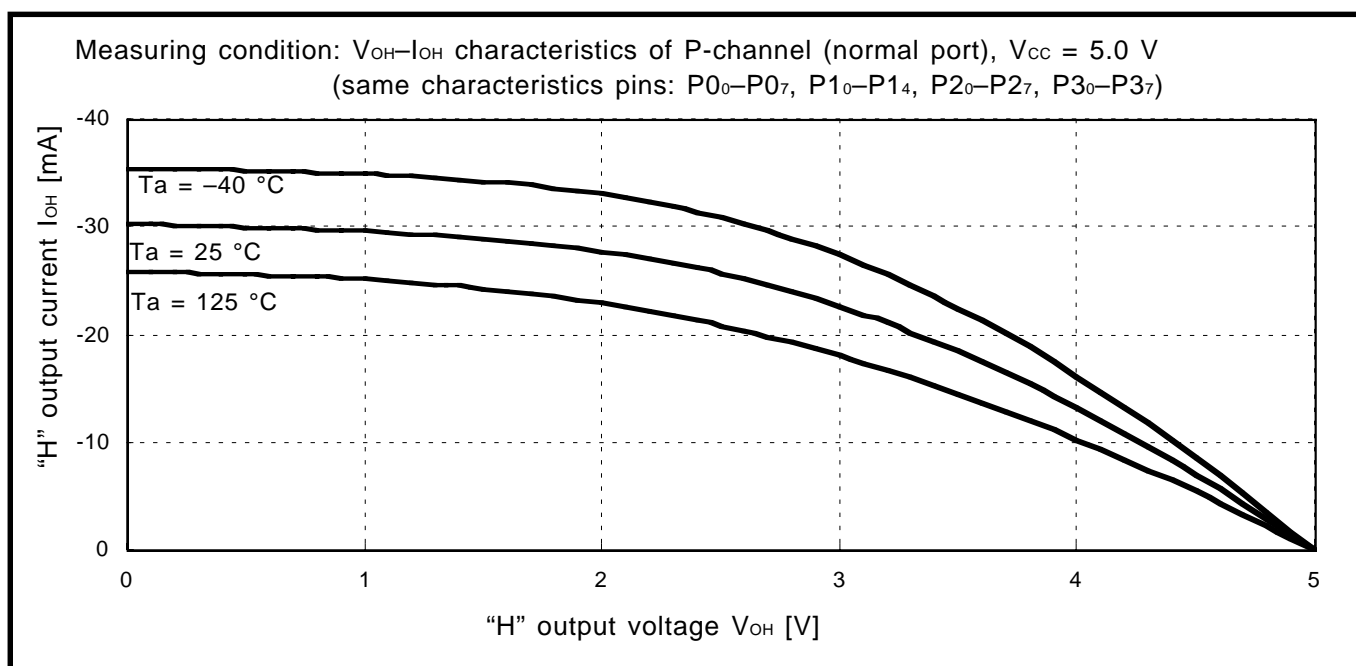


Fig. 3.2.23 V_{CC} -HYS characteristics (INT pin: Mask ROM version)

(5) Port typical characteristic example (V_{OH} - I_{OH} characteristics)**Fig. 3.2.24 V_{OH} - I_{OH} characteristics of P-channel ($V_{CC} = 3.0\text{ V}$, normal port: Mask ROM version)****Fig. 3.2.25 V_{OH} - I_{OH} characteristics of P-channel ($V_{CC} = 5.0\text{ V}$, normal port: Mask ROM version)**

(6) Port typical characteristic example (V_{OL} - I_{OL} characteristics)

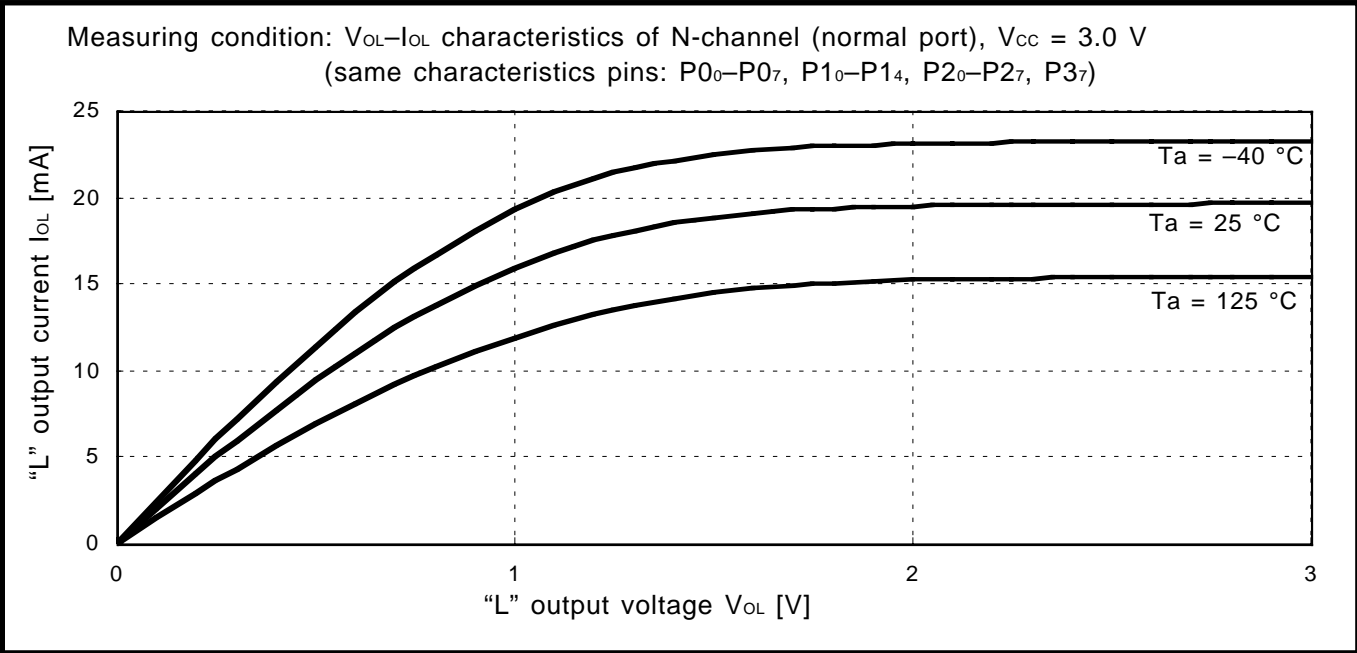


Fig. 3.2.26 V_{OL} - I_{OL} characteristics of N-channel ($V_{CC} = 3.0\text{ V}$, normal port: Mask ROM version)

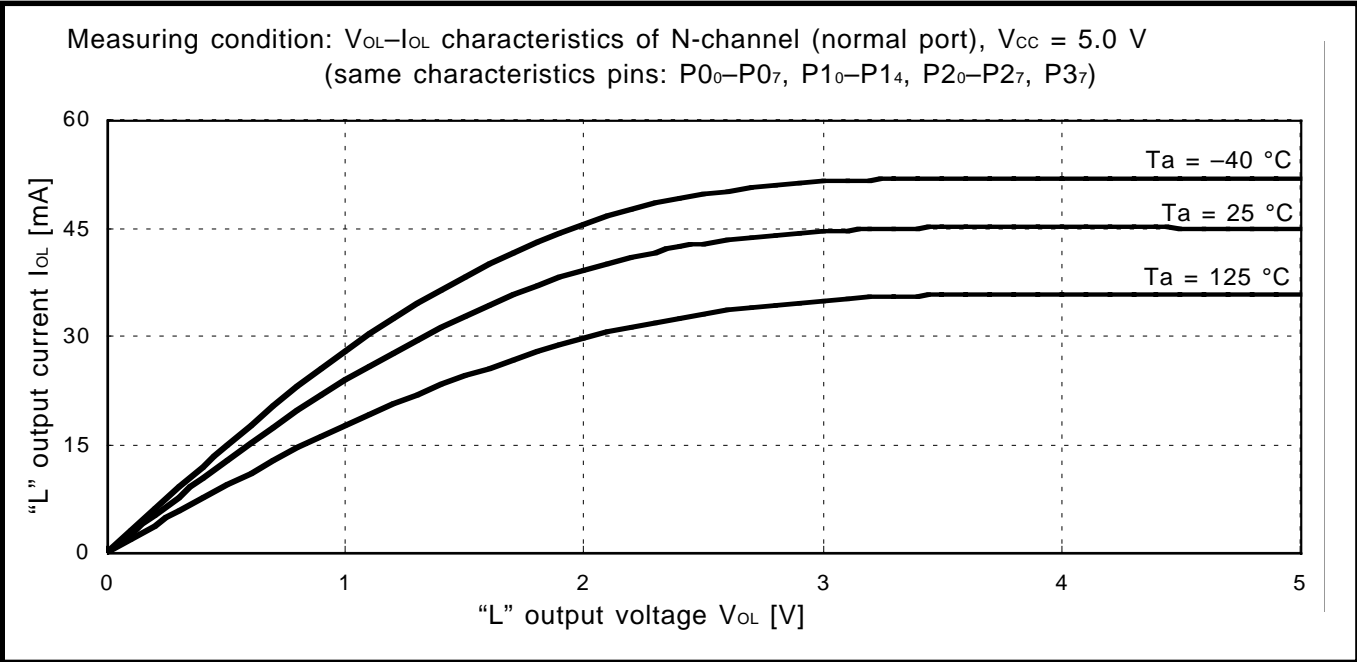


Fig. 3.2.27 V_{OL} - I_{OL} characteristics of N-channel ($V_{CC} = 5.0\text{ V}$, normal port: Mask ROM version)

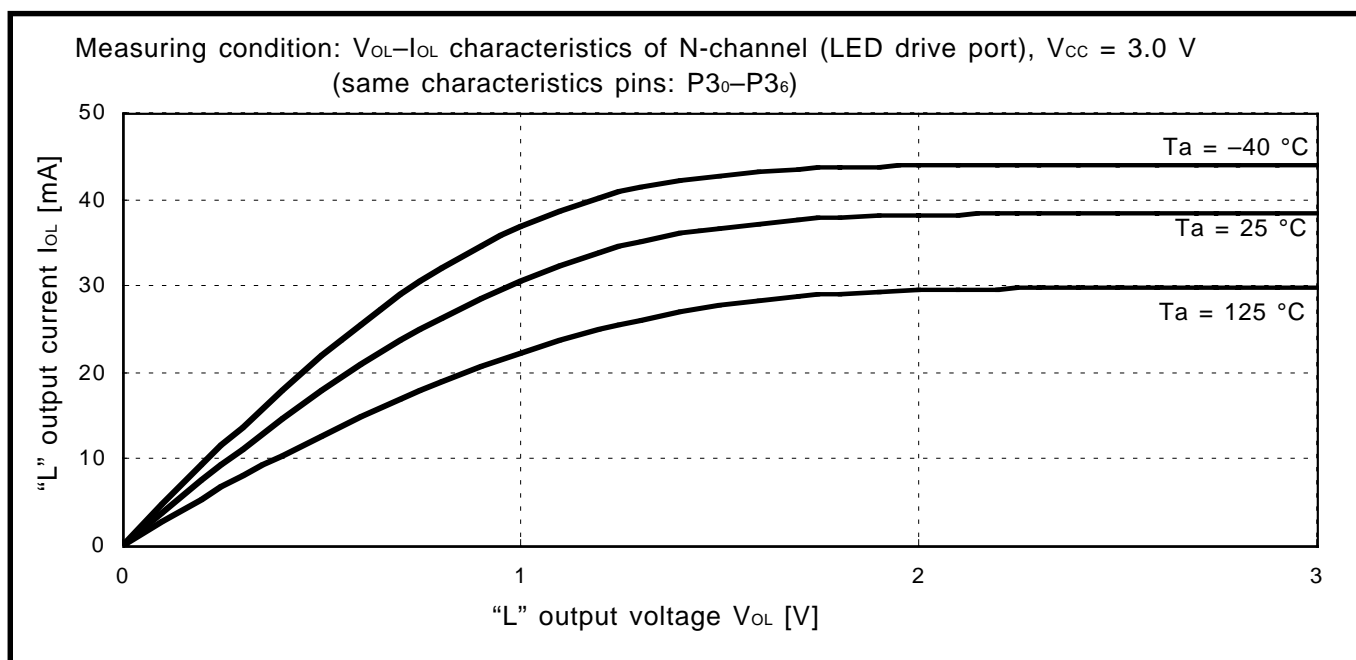


Fig. 3.2.28 V_{OL} - I_{OL} characteristics of N-channel ($V_{CC} = 3.0\text{ V}$, LED drive port: Mask ROM version)

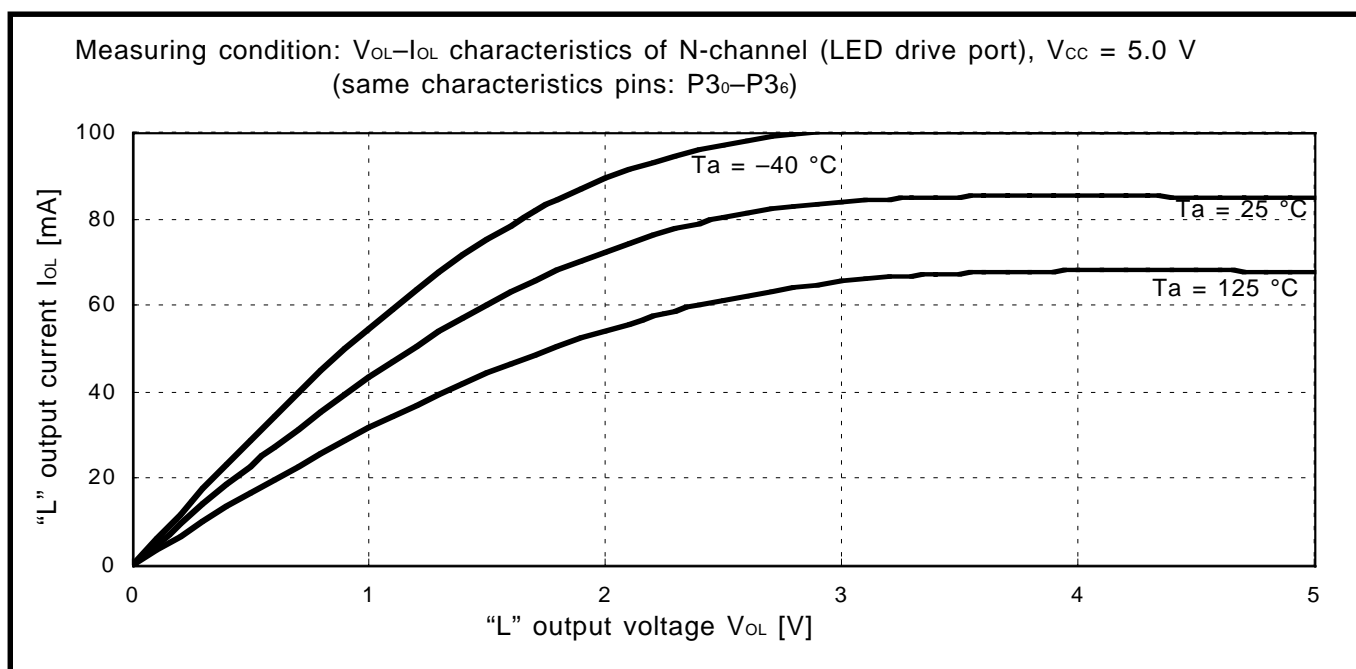


Fig. 3.2.29 V_{OL} - I_{OL} characteristics of N-channel ($V_{CC} = 5.0\text{ V}$, LED drive port: Mask ROM version)

(7) Port typical characteristic example (V_{CC} -IIL characteristics)

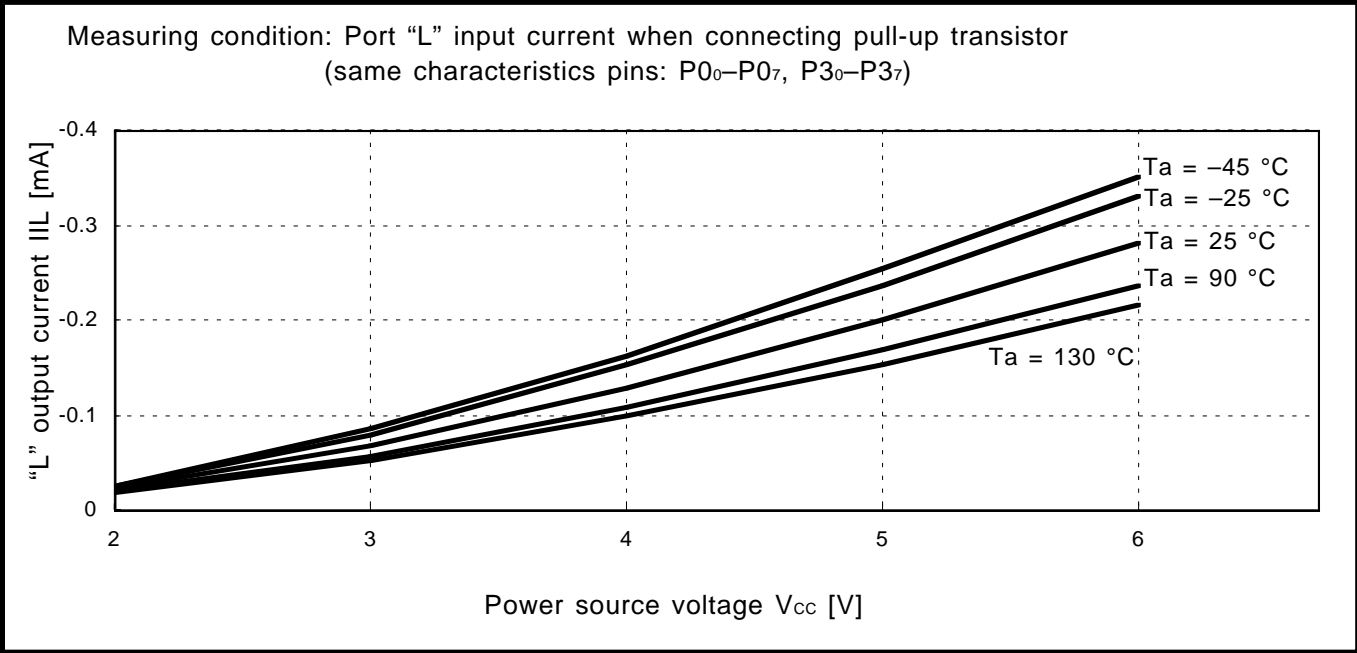


Fig. 3.2.30 V_{CC} -IIL characteristics (Port "L" input current when connecting pull-up transistor: Mask ROM version)

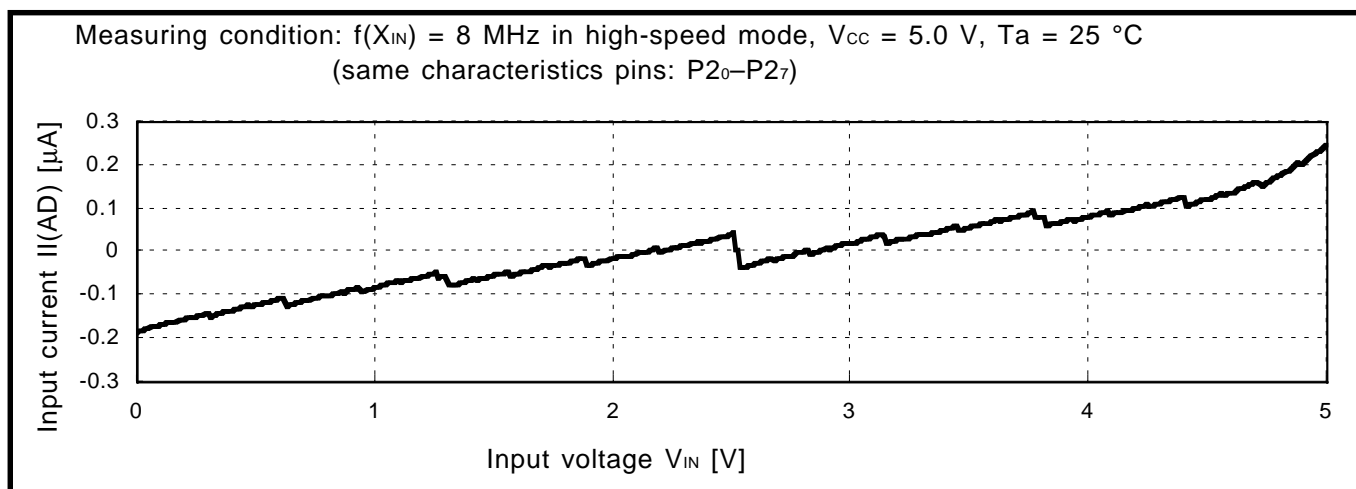
(8) Port typical characteristic example ($V_{IN-II(AD)}$ characteristics)

Fig. 3.2.31 $V_{IN-II(AD)}$ characteristics (A/D port input current during A/D conversion, $f(X_{IN}) = 8$ MHz in high-speed mode: Mask ROM version)

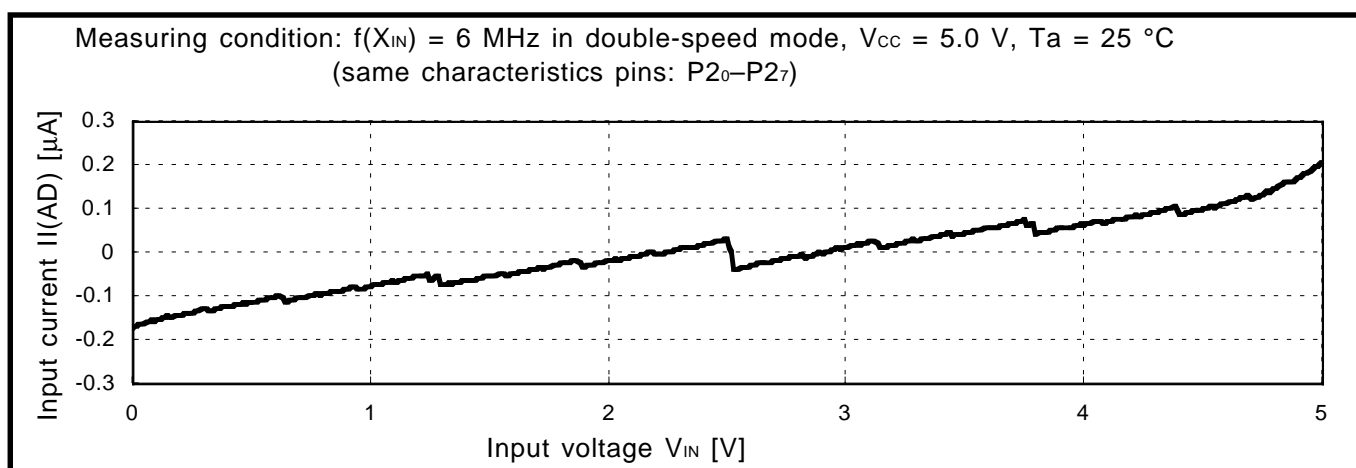


Fig. 3.2.32 $V_{IN-II(AD)}$ characteristics (A/D port input current during A/D conversion, $f(X_{IN}) = 6$ MHz in double-speed mode: Mask ROM version)

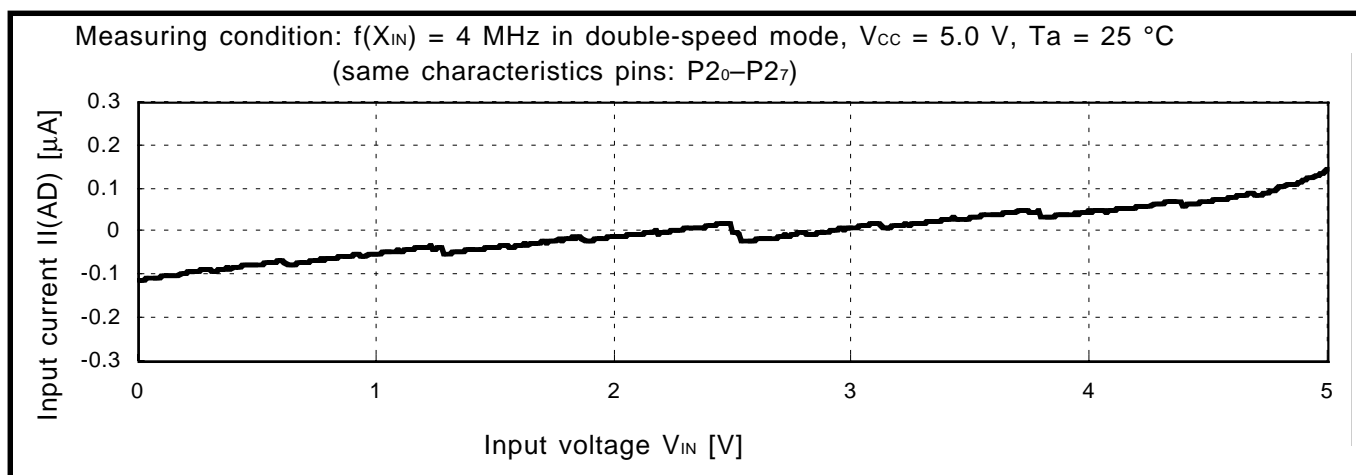


Fig. 3.2.33 $V_{IN-II(AD)}$ characteristics (A/D port input current during A/D conversion, $f(X_{IN}) = 4$ MHz in double-speed mode: Mask ROM version)

(9) On-chip oscillator frequency typical characteristic example

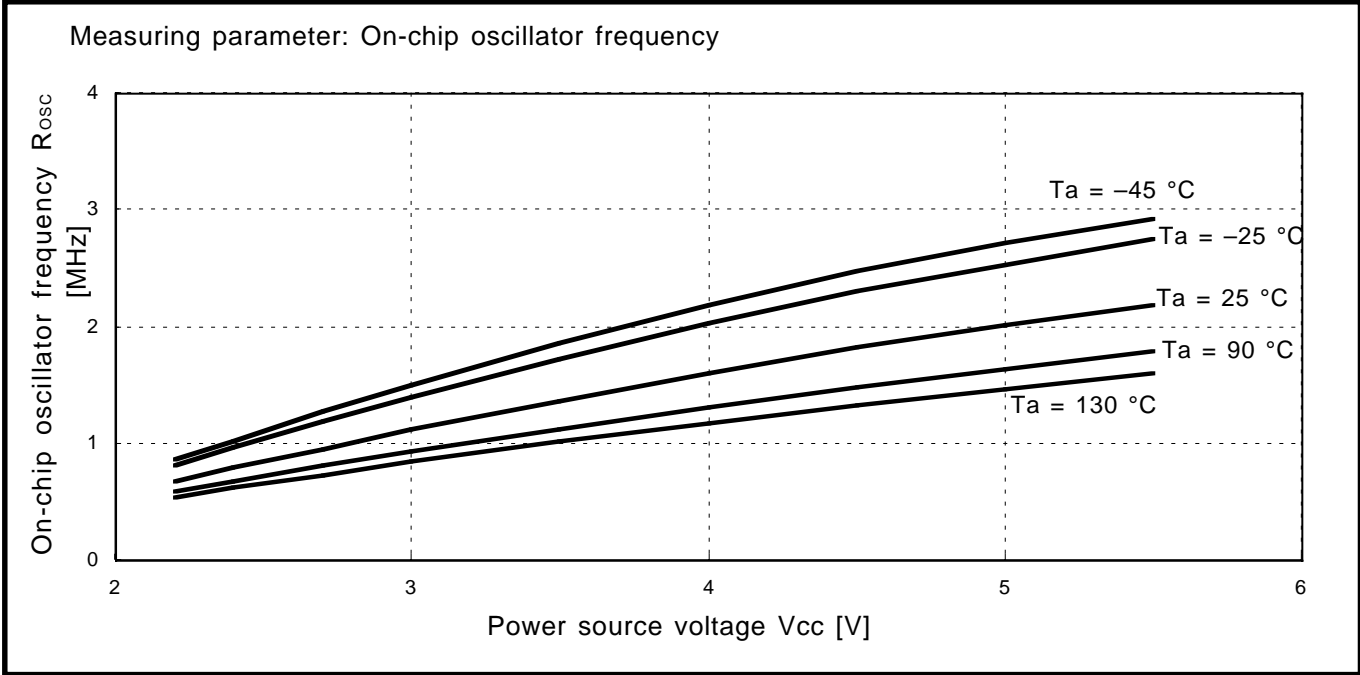


Fig. 3.2.34 V_{cc} - R_{osc} characteristics (on-chip oscillator frequency: Mask ROM version)

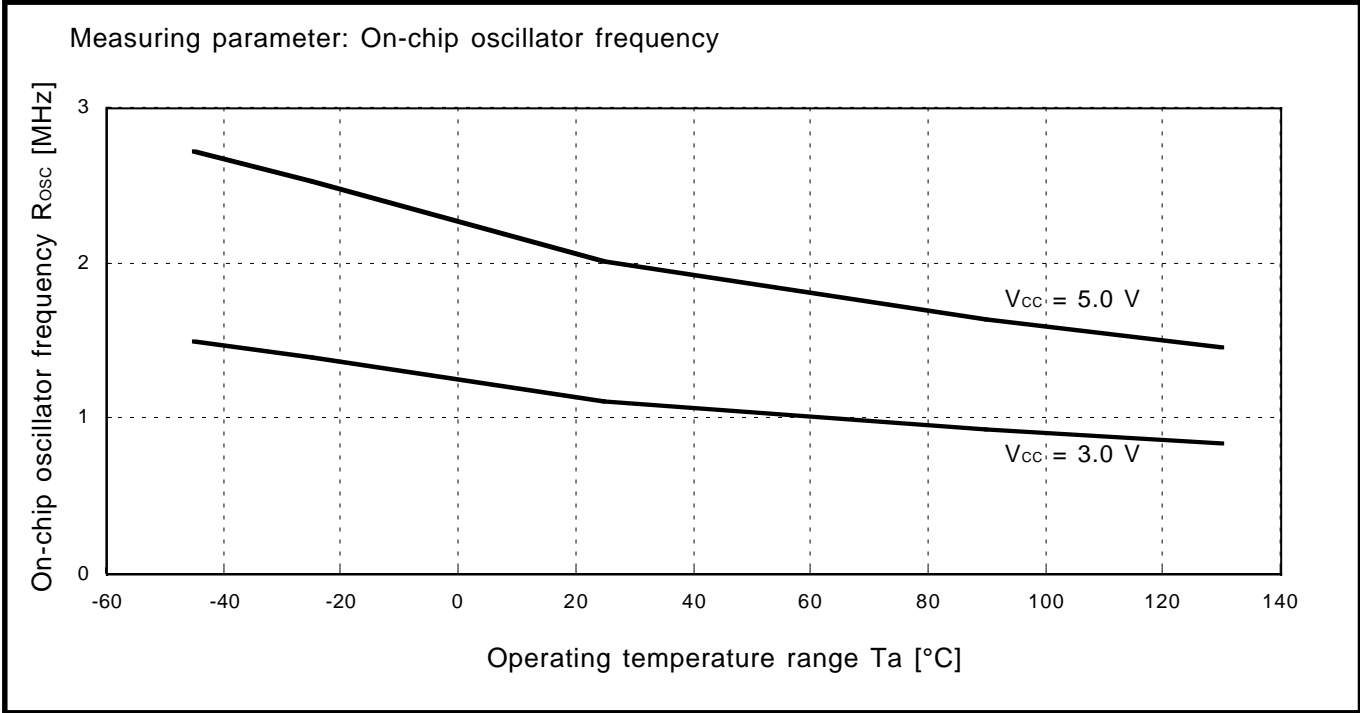
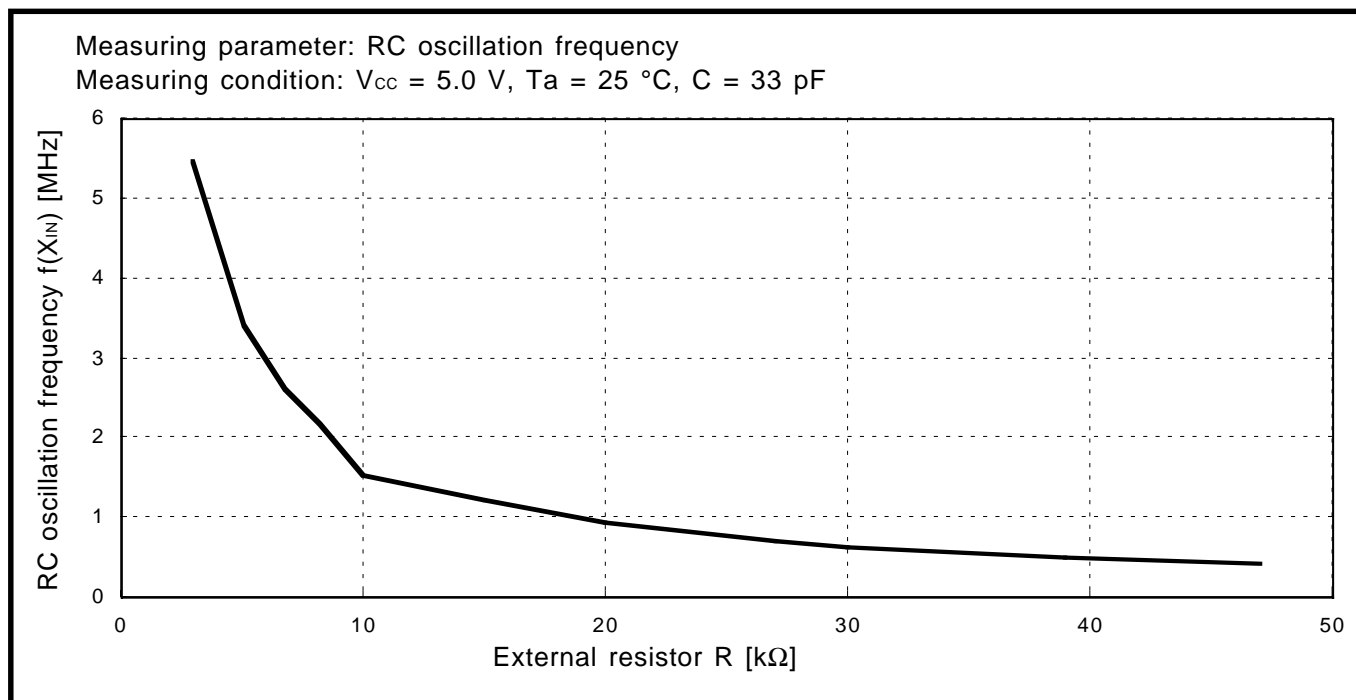
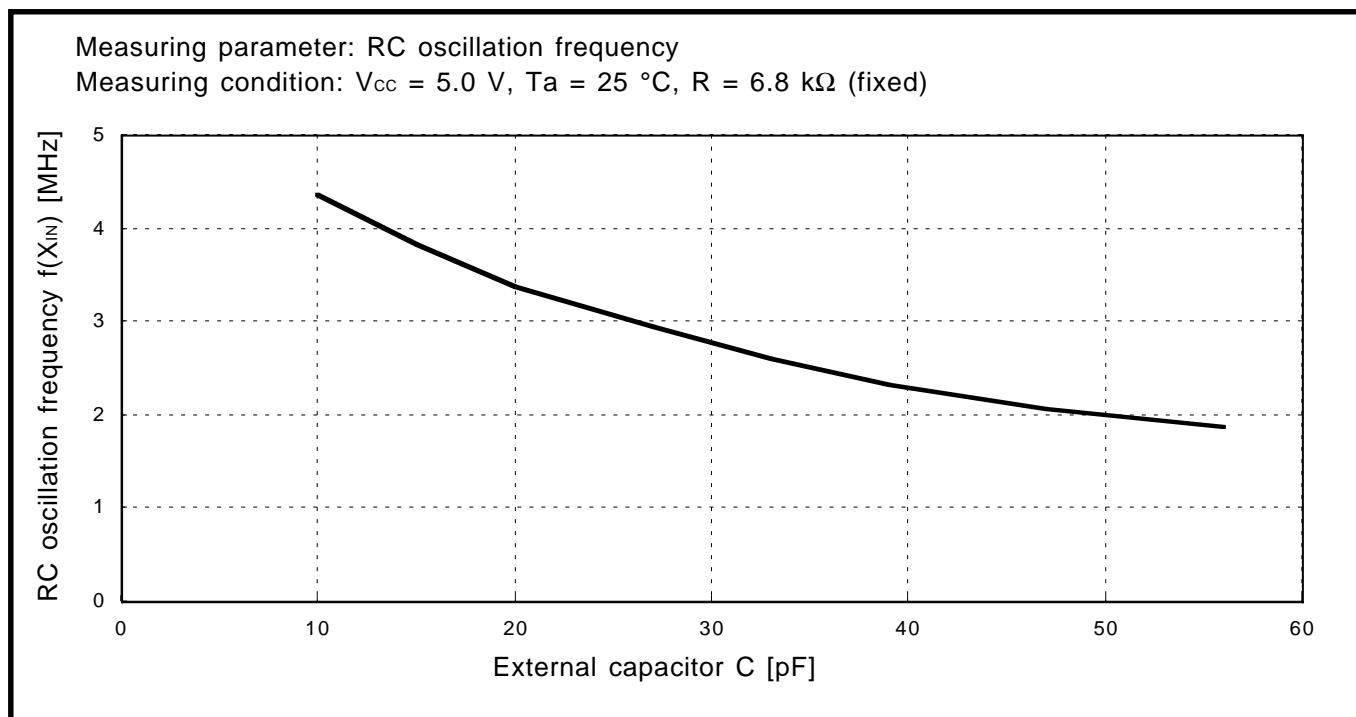


Fig. 3.2.35 T_a - R_{osc} characteristics (on-chip oscillator frequency: Mask ROM version)

(10) RC oscillation frequency typical characteristic example**Fig. 3.2.36 R- $f(X_{IN})$ characteristics (RC oscillation frequency: Mask ROM version)****Fig. 3.2.37 C- $f(X_{IN})$ characteristics (RC oscillation frequency: Mask ROM version)**

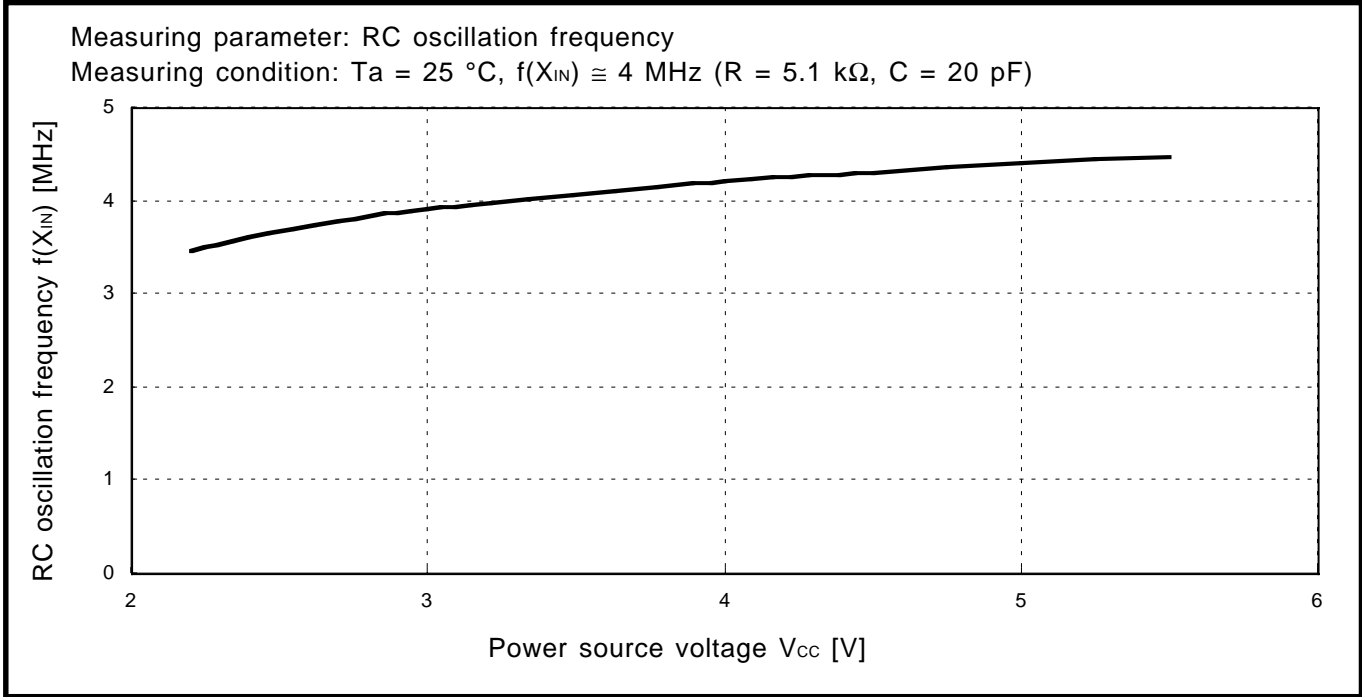


Fig. 3.2.38 V_{CC} - $f(X_{IN})$ characteristics (RC oscillation frequency: Mask ROM version)

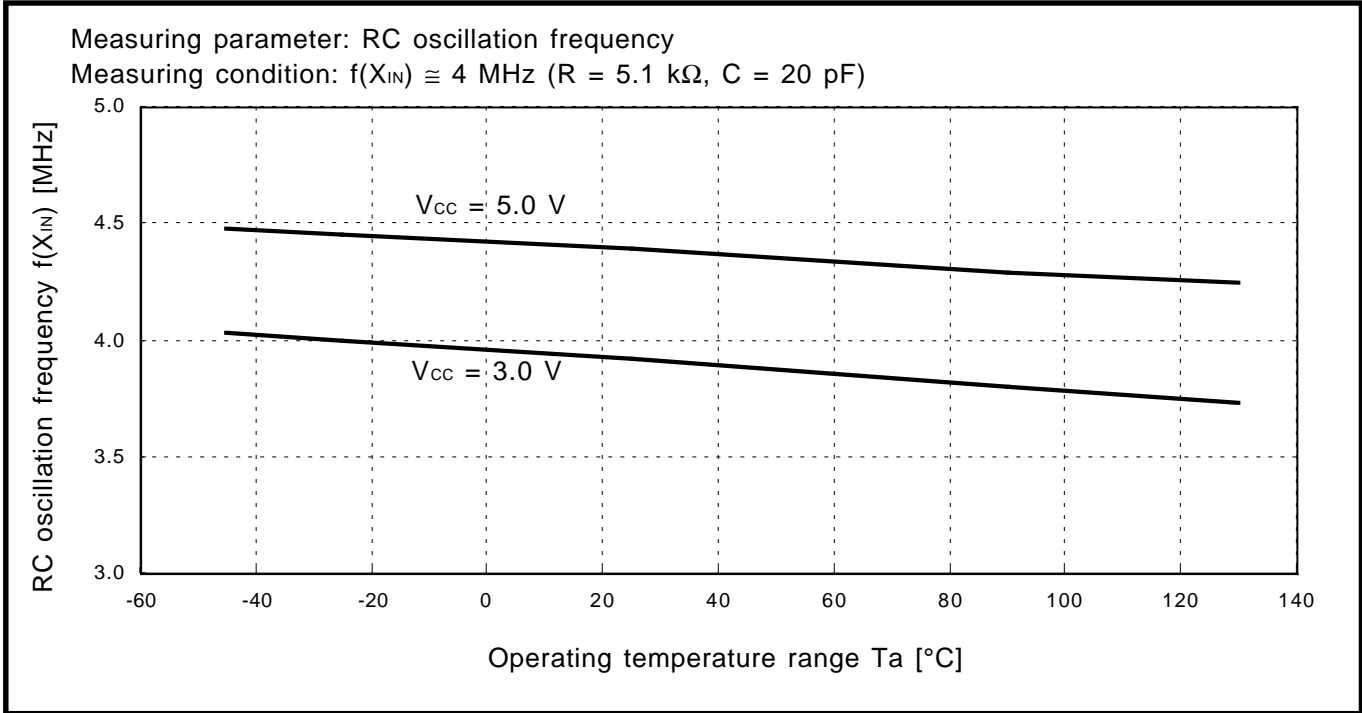


Fig. 3.2.39 T_a - $f(X_{IN})$ characteristics (RC oscillation frequency: Mask ROM version)

(11) A/D conversion typical characteristics example**① Definition of A/D conversion accuracy**

The A/D conversion accuracy is defined below (refer to Fig. 3.2.40).

●Relative accuracy

- Zero transition voltage (V_{OT})
This means an analog input voltage when the actual A/D conversion output data changes from “0” to “1.”
- Full-scale transition voltage (V_{FST})
This means an analog input voltage when the actual A/D conversion output data changes from “1023” to “1022.”
- Non-linearity error
This means a deviation from the line between V_{OT} and V_{FST} of a converted value between V_{OT} and V_{FST} .
- Differential non-linearity error
This means a deviation from the input potential difference required to change a converted value between V_{OT} and V_{FST} by 1 LSB of the 1 LSB at the relative accuracy.

●Absolute accuracy

This means a deviation from the ideal characteristics between 0 to V_{REF} of actual A/D conversion characteristics.

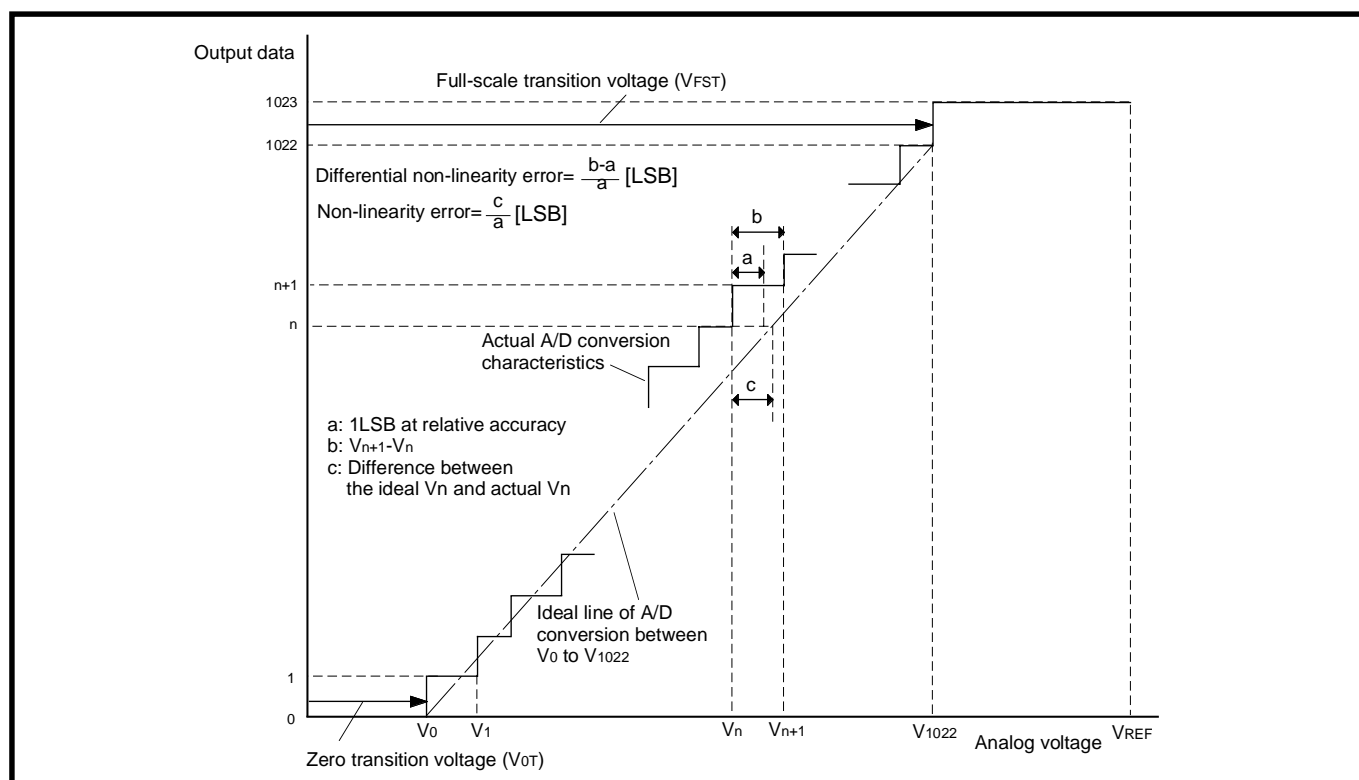


Fig. 3.2.40 Definition of A/D conversion accuracy

V_n : Analog input voltage when the output data changes from “ n ” to “ $n + 1$ ” ($n = 0$ to 1022)

- 1 LSB at relative accuracy $\rightarrow \frac{V_{FST} - V_{OT}}{1022}$ (V)
- 1 LSB at absolute accuracy $\rightarrow \frac{V_{REF}}{1024}$ (V)

② A/D conversion accuracy typical characteristics-1

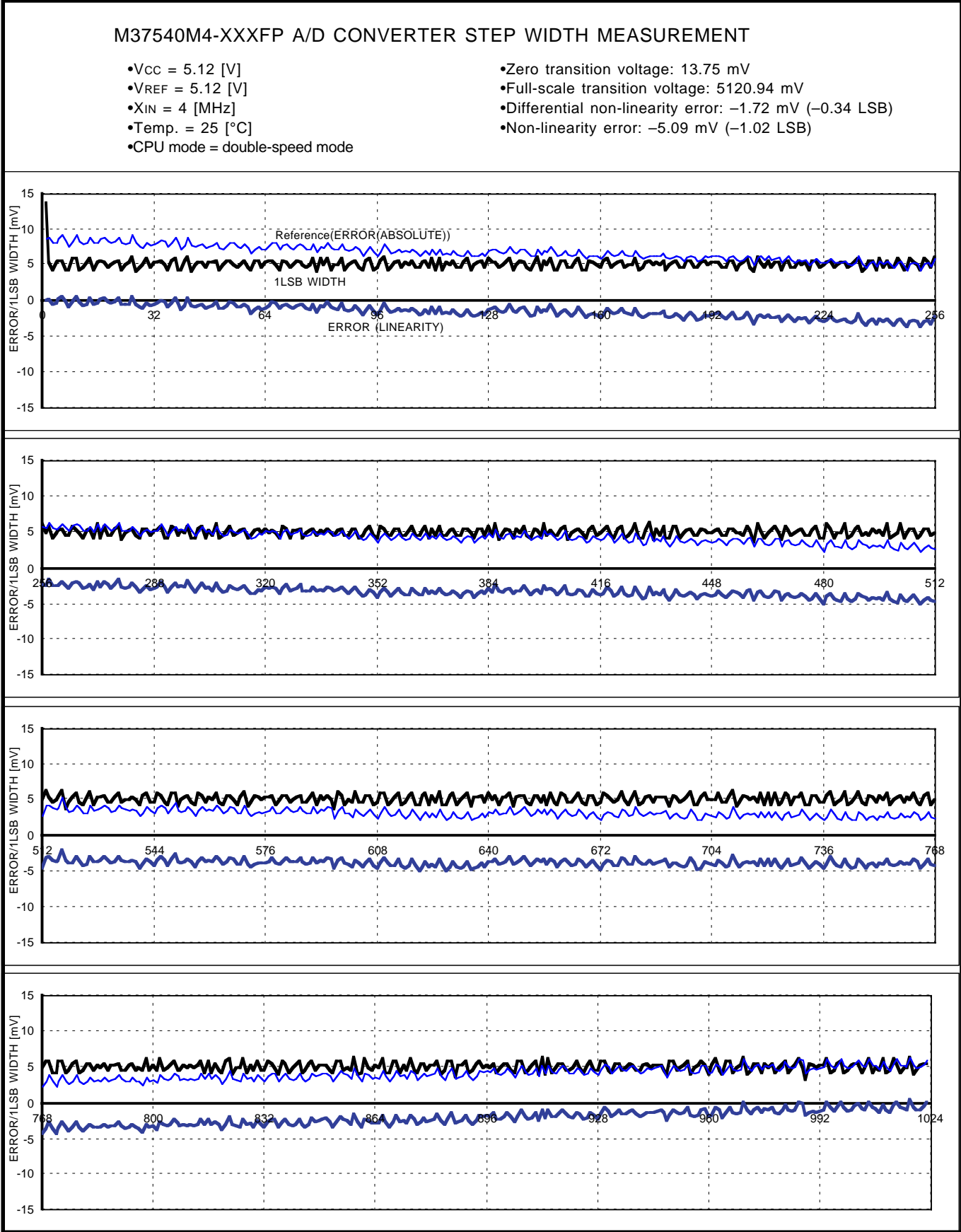


Fig. 3.2.41 A/D conversion accuracy typical characteristic example-1 (Mask ROM version)

③ A/D conversion accuracy typical characteristics-2

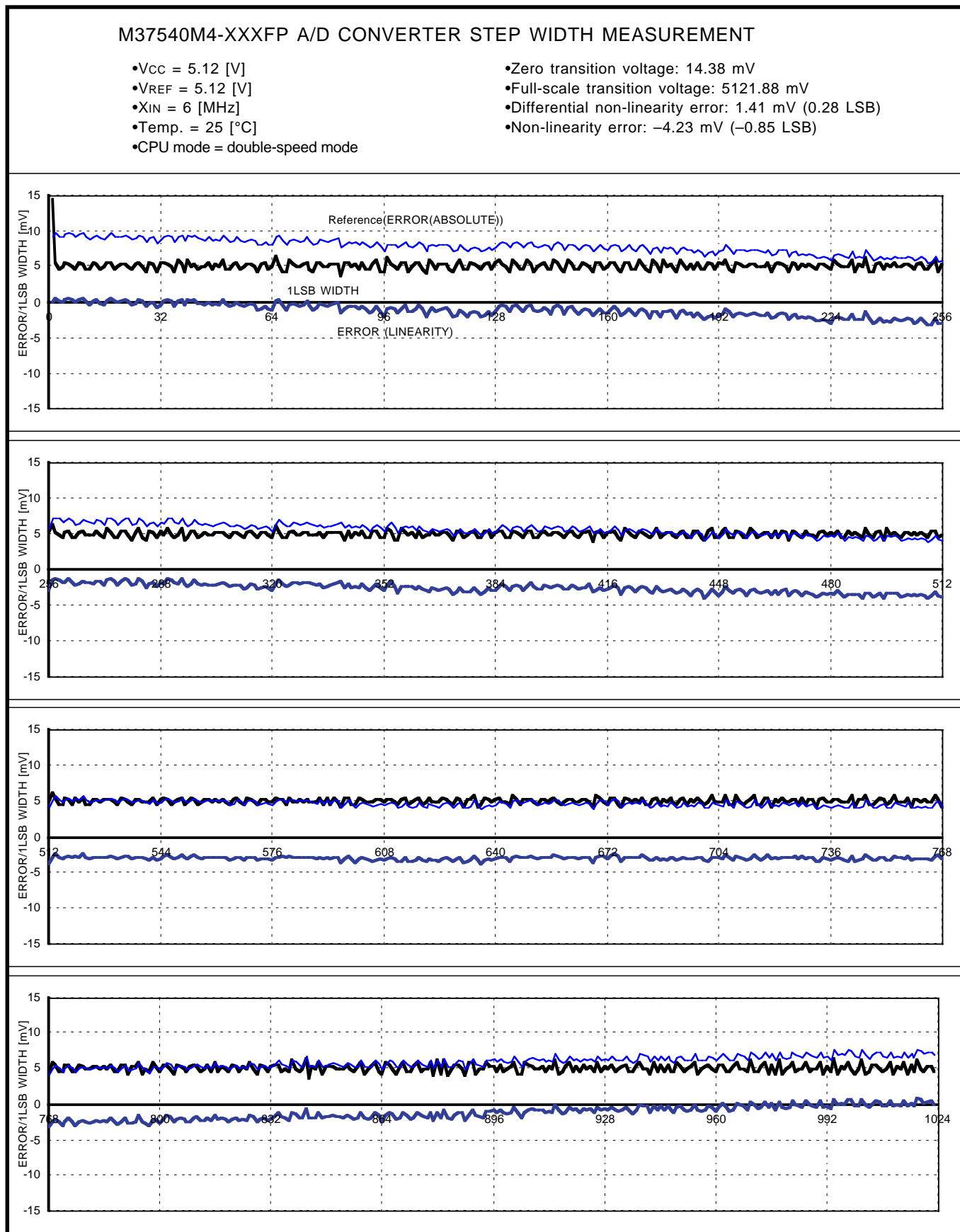


Fig. 3.2.42 A/D conversion accuracy typical characteristic example-2 (Mask ROM version)

④ A/D conversion accuracy typical characteristics-3

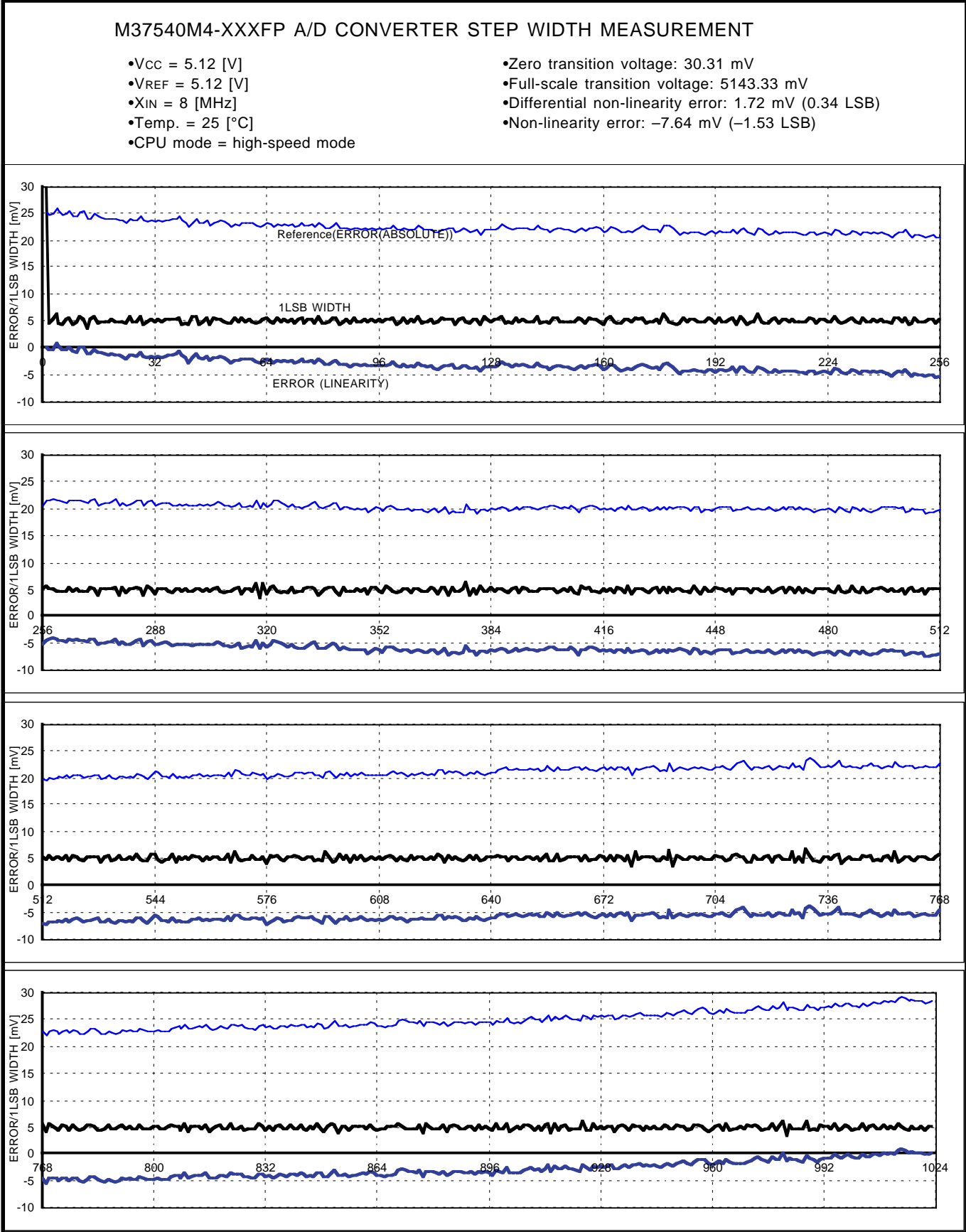
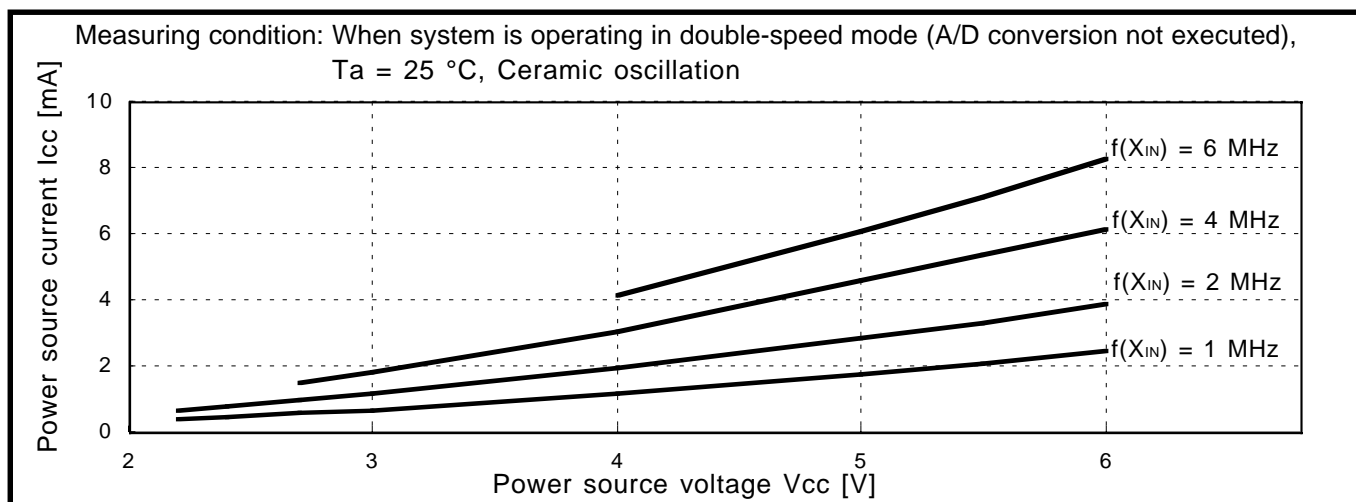
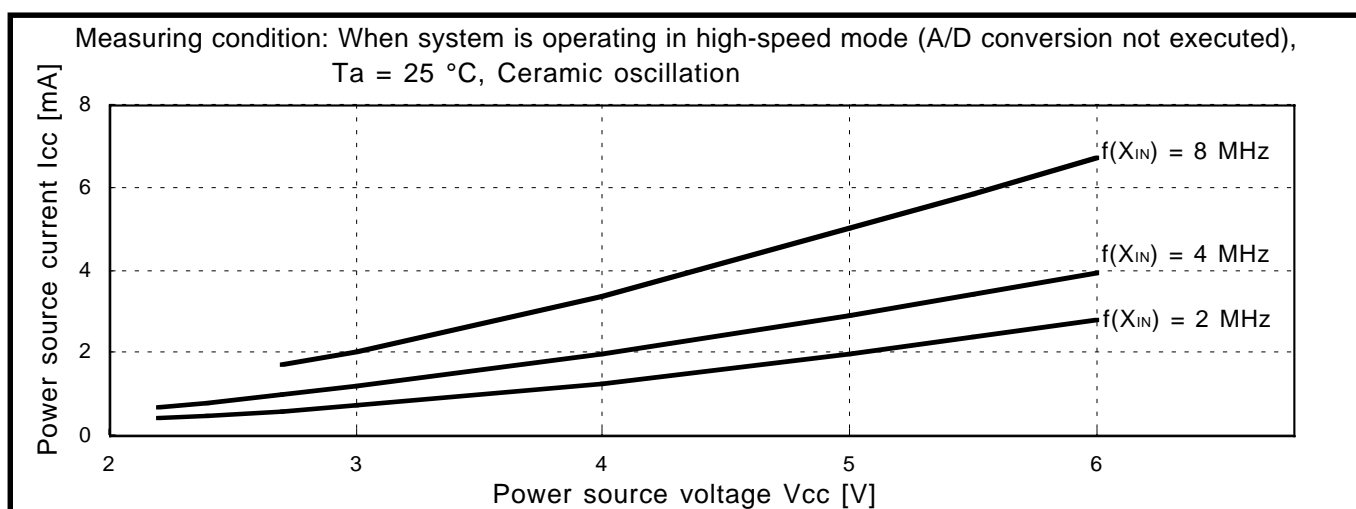
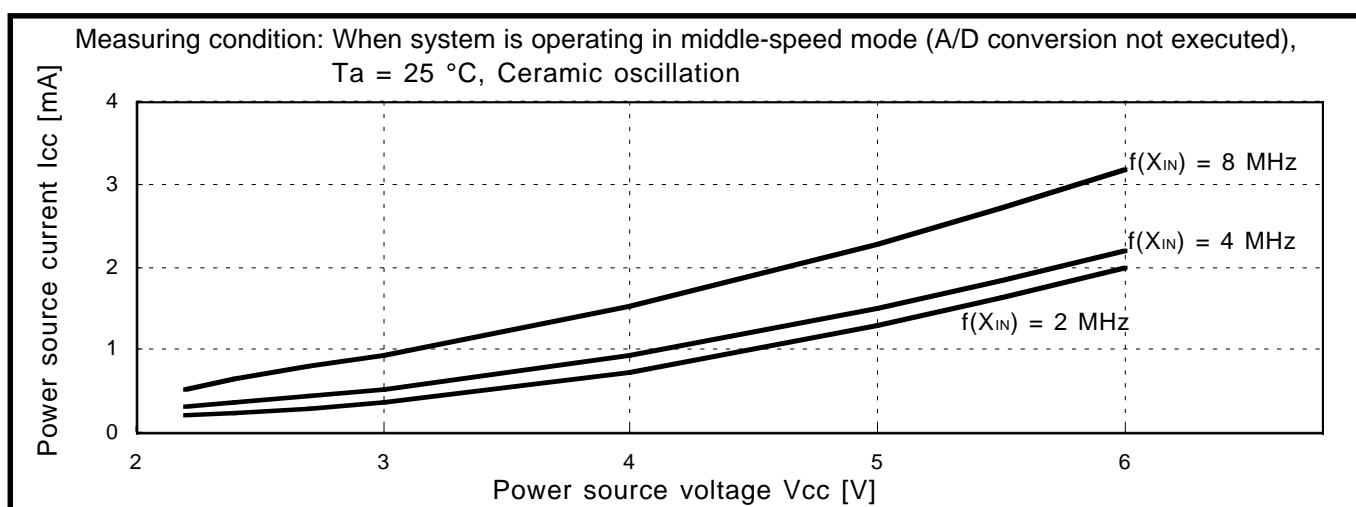


Fig. 3.2.43 A/D conversion accuracy typical characteristic example-3 (Mask ROM version)

3.2.2 One Time PROM version

(1) Power source current characteristic example (V_{CC} - I_{CC} characteristics)Fig. 3.2.44 V_{CC} - I_{CC} characteristics (in double-speed mode: One Time PROM version)Fig. 3.2.45 V_{CC} - I_{CC} characteristics (in high-speed mode: One Time PROM version)Fig. 3.2.46 V_{CC} - I_{CC} characteristics (in middle-speed mode: One Time PROM version)

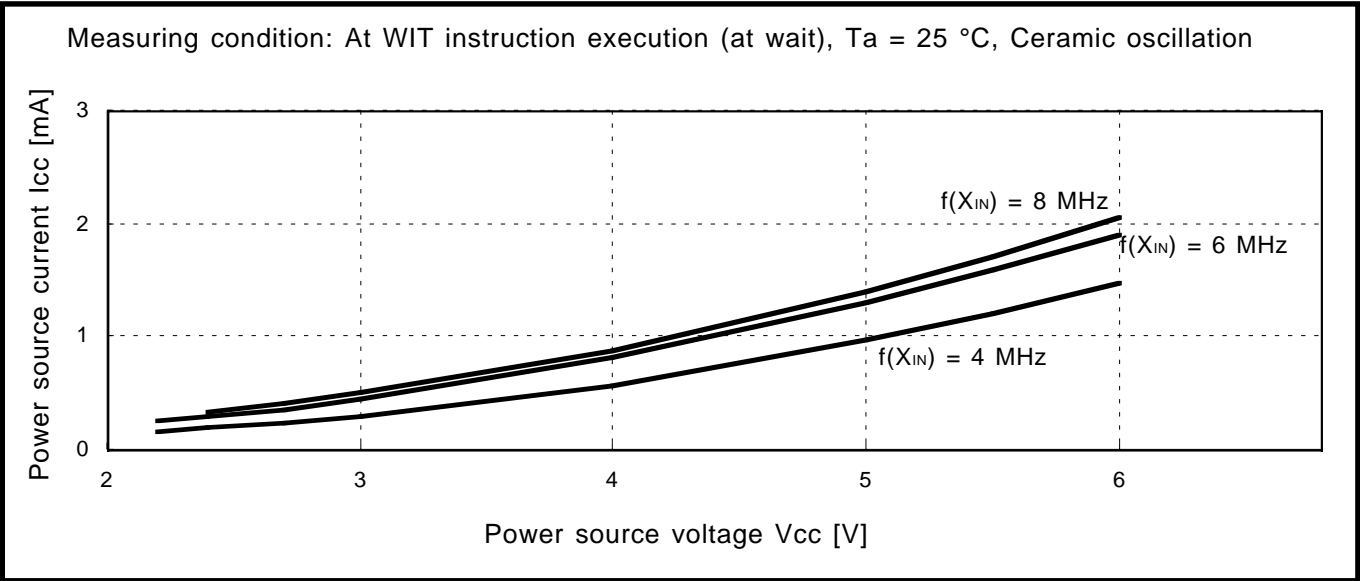


Fig. 3.2.47 V_{cc}-I_{cc} characteristics (at WIT instruction execution: One Time PROM version)

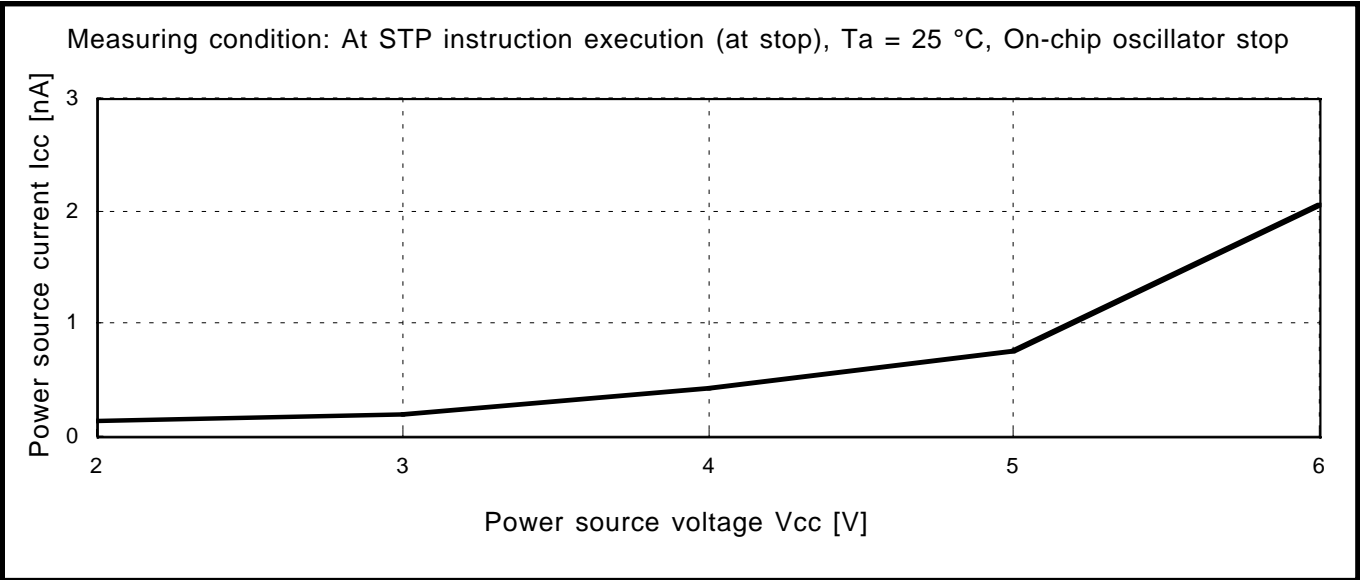


Fig. 3.2.48 V_{cc}-I_{cc} characteristics (at STP instruction execution: One Time PROM version)

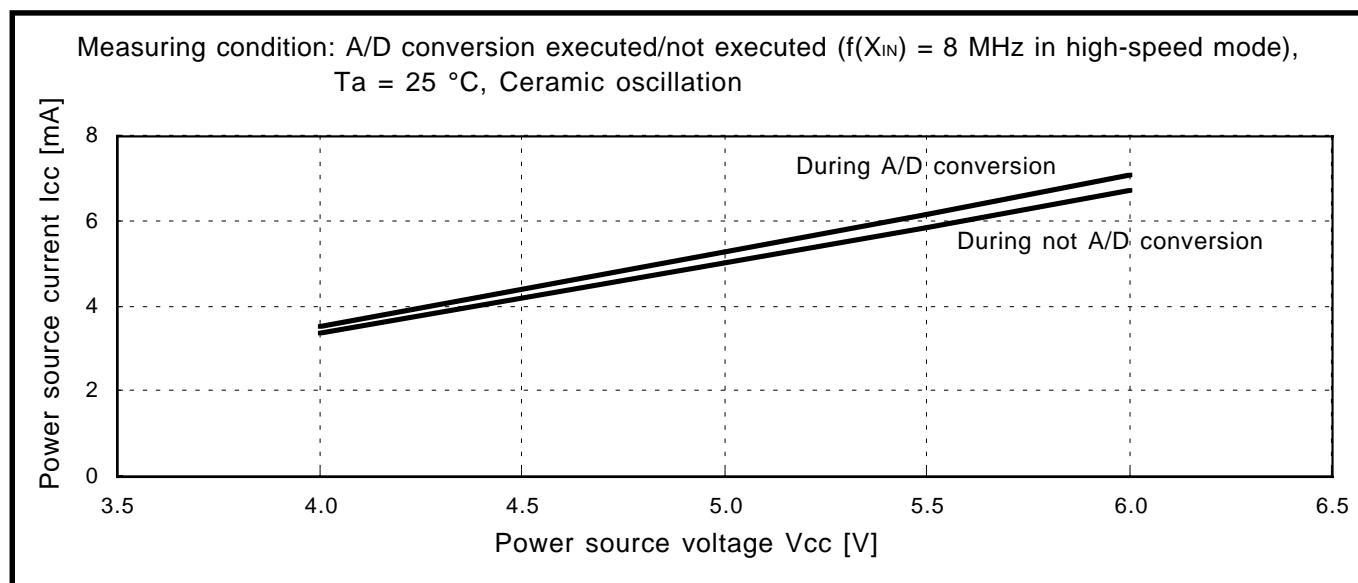


Fig. 3.2.49 V_{CC} - I_{CC} characteristics (addition when operating A/D conversion, $f(X_{IN}) = 8$ MHz in high-speed mode: One Time PROM version)

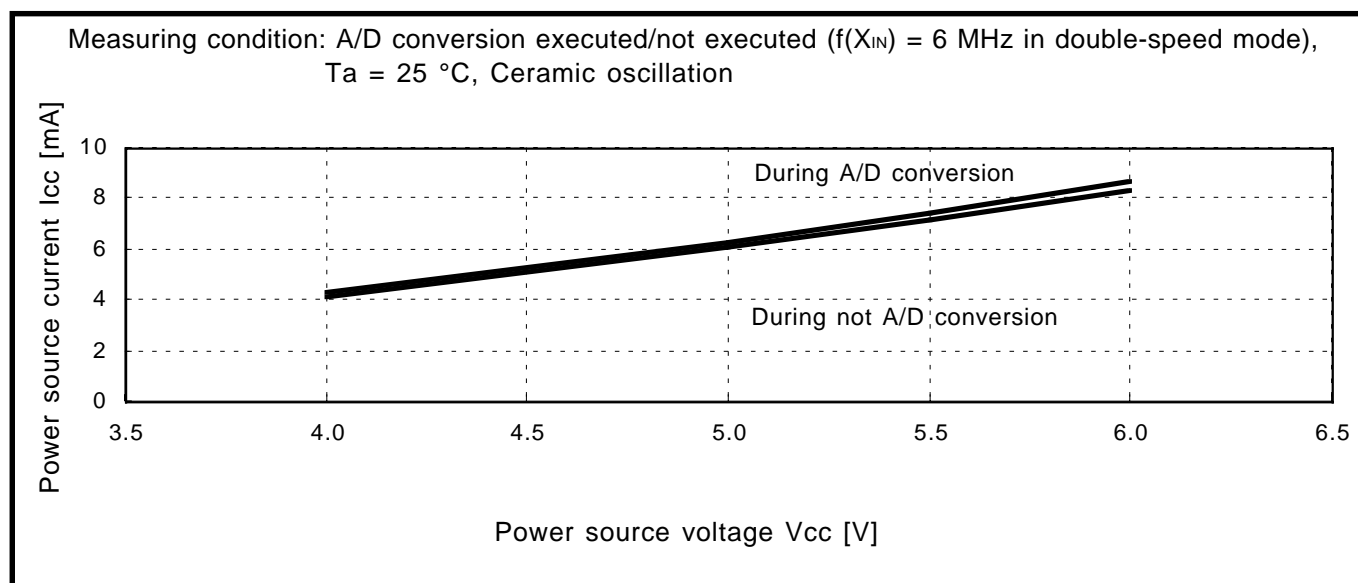


Fig. 3.2.50 V_{CC} - I_{CC} characteristics (addition when operating A/D conversion, $f(X_{IN}) = 6$ MHz in double-speed mode: One Time PROM version)

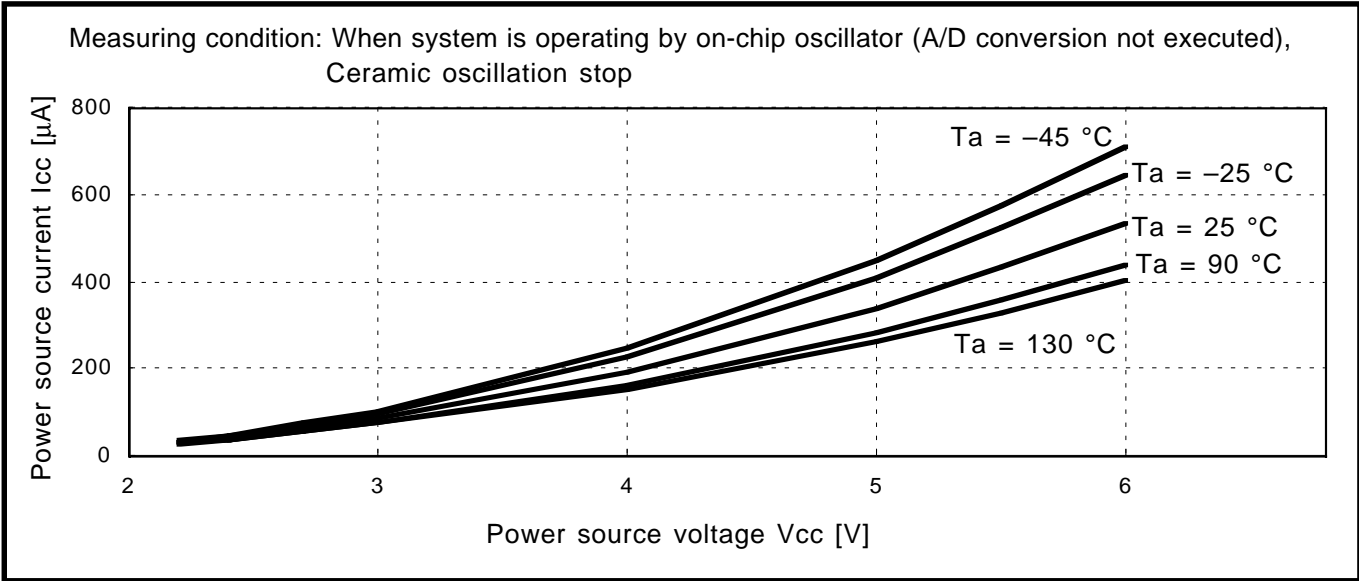


Fig. 3.2.51 V_{CC}-I_{CC} characteristics (When system is operating by on-chip oscillator, Ceramic oscillation stop: One Time PROM version)

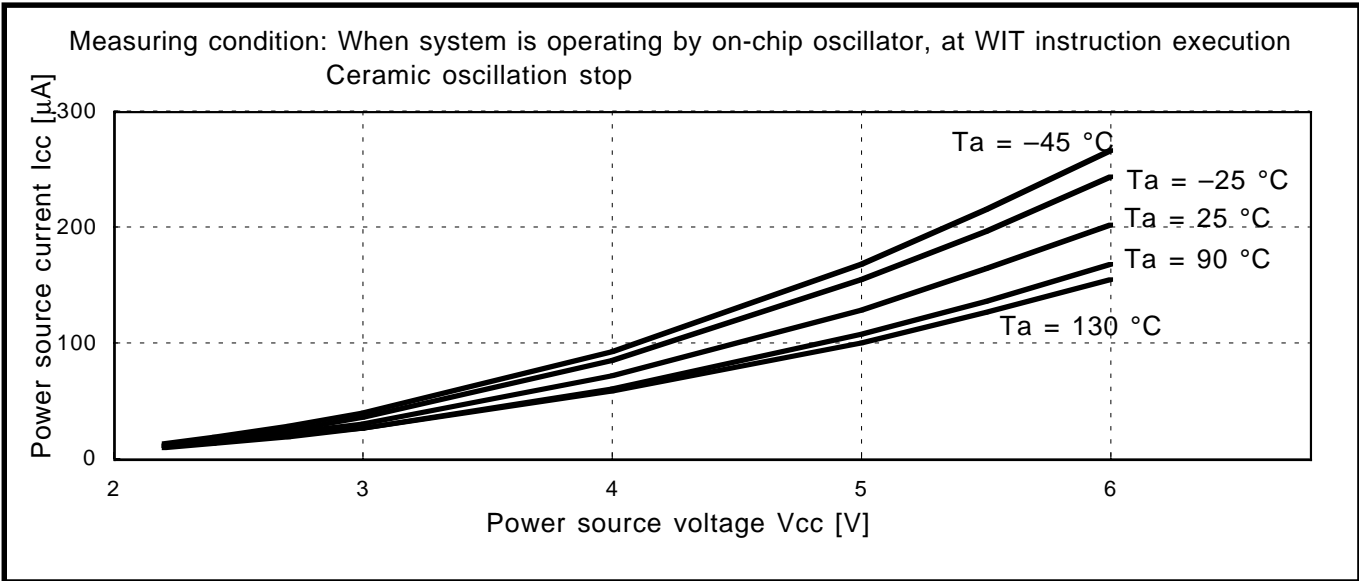


Fig. 3.2.52 V_{CC}-I_{CC} characteristics (When system is operating by on-chip oscillator, at WIT instruction execution, Ceramic oscillation stop: One Time PROM version)

(2) Power source current characteristic example ($f(X_{IN})$ - I_{CC} characteristics)

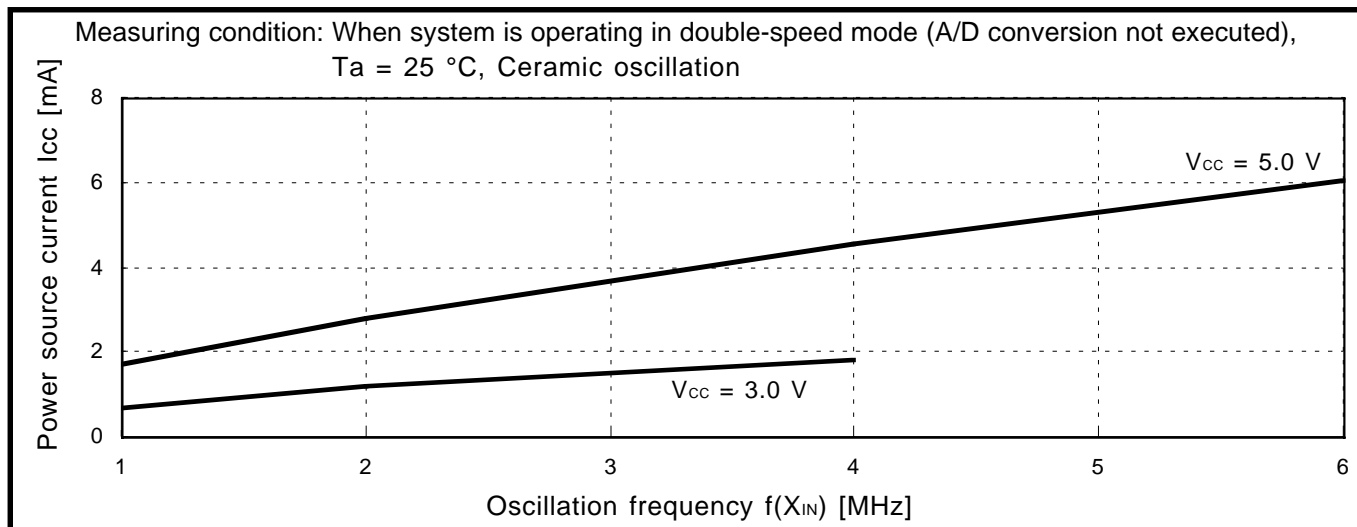


Fig. 3.2.53 $f(X_{IN})$ - I_{CC} characteristics (in double-speed mode: One Time PROM version)

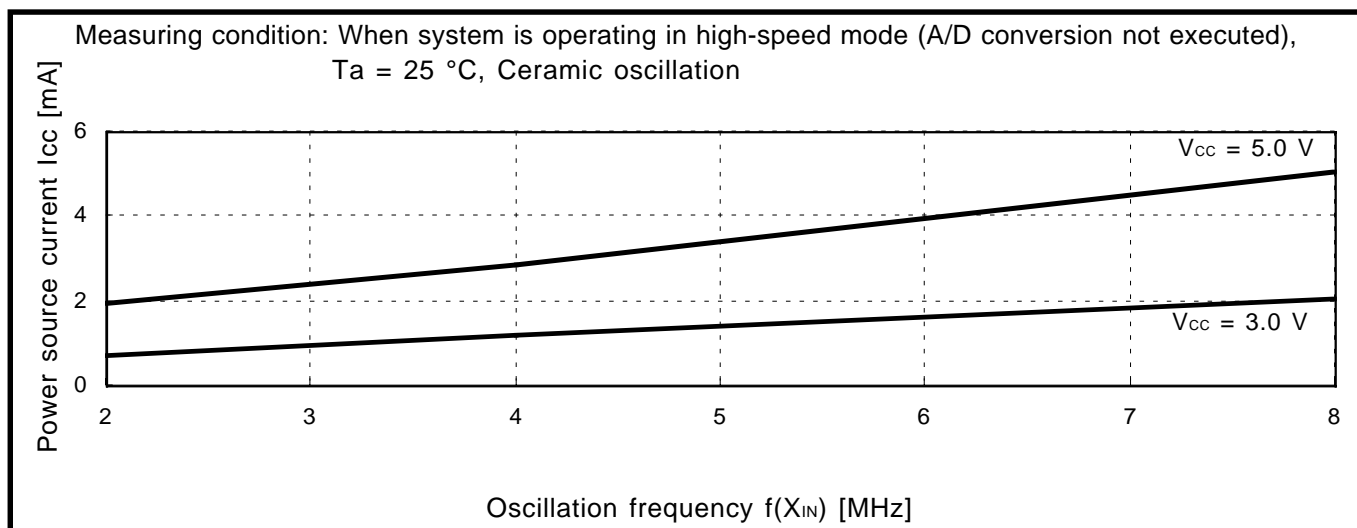


Fig. 3.2.54 $f(X_{IN})$ - I_{CC} characteristics (in high-speed mode: One Time PROM version)

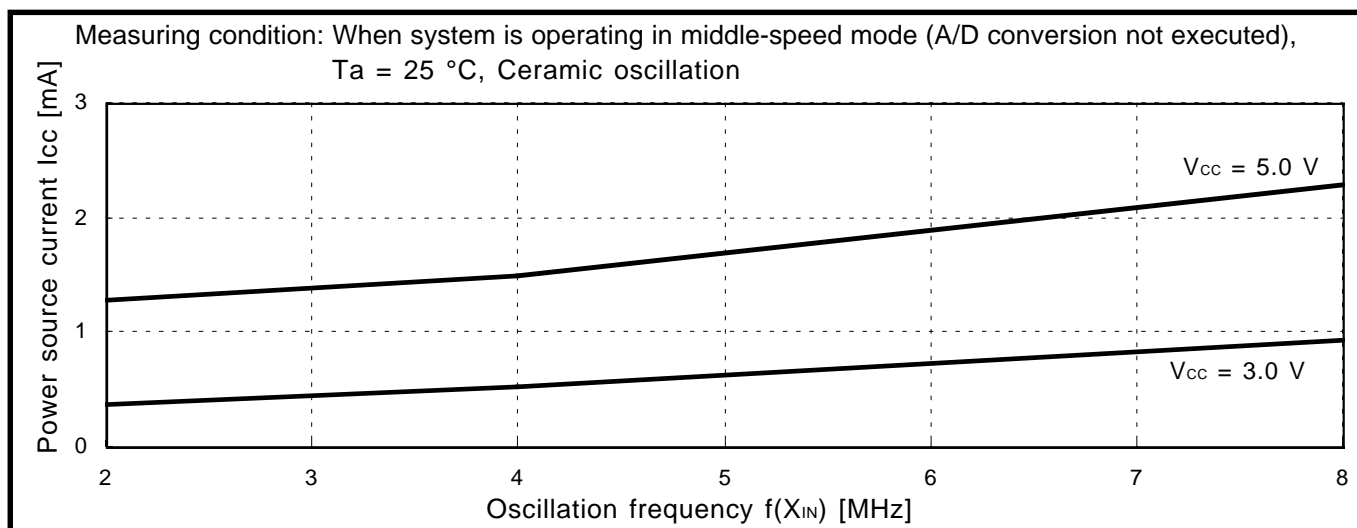


Fig. 3.2.55 $f(X_{IN})$ - I_{CC} characteristics (in middle-speed mode: One Time PROM version)

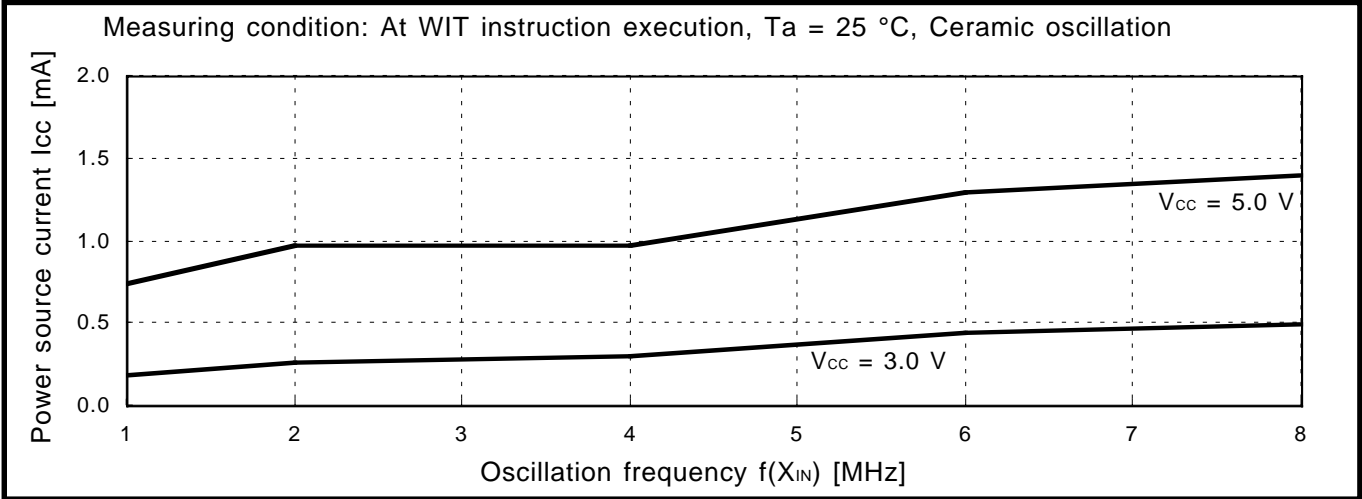


Fig. 3.2.56 f(X_{IN})-I_{CC} characteristics (at WIT instruction execution: One Time PROM version)

(3) Power source current characteristic example (Ta-I_{CC} characteristics)

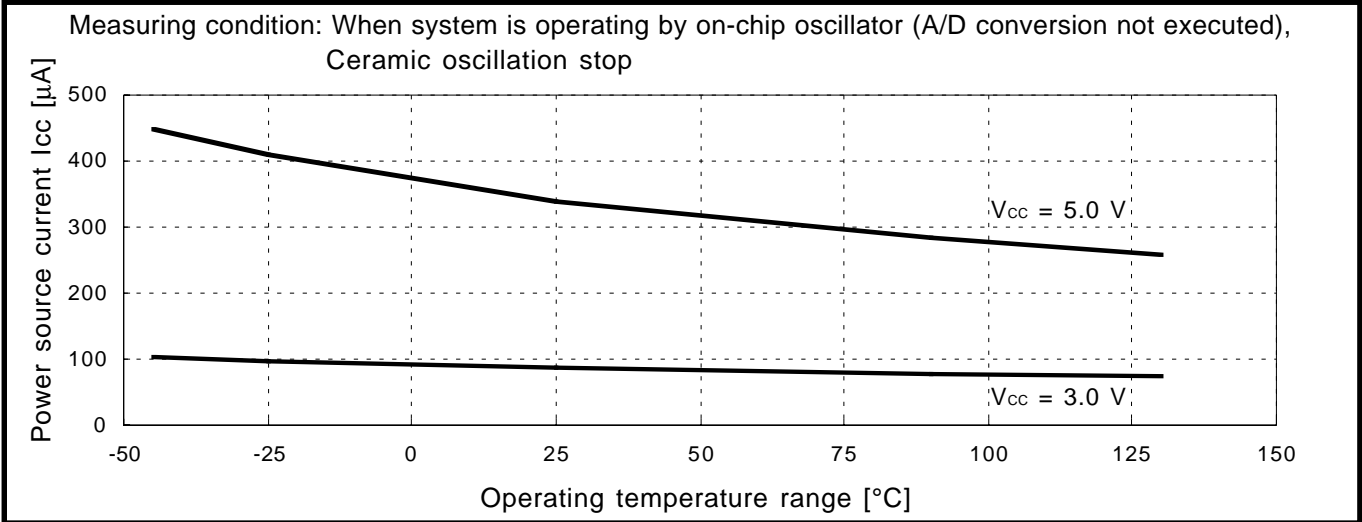


Fig. 3.2.57 Ta-I_{CC} characteristics (When system is operating by on-chip oscillator, Ceramic oscillation stop: One Time PROM version)

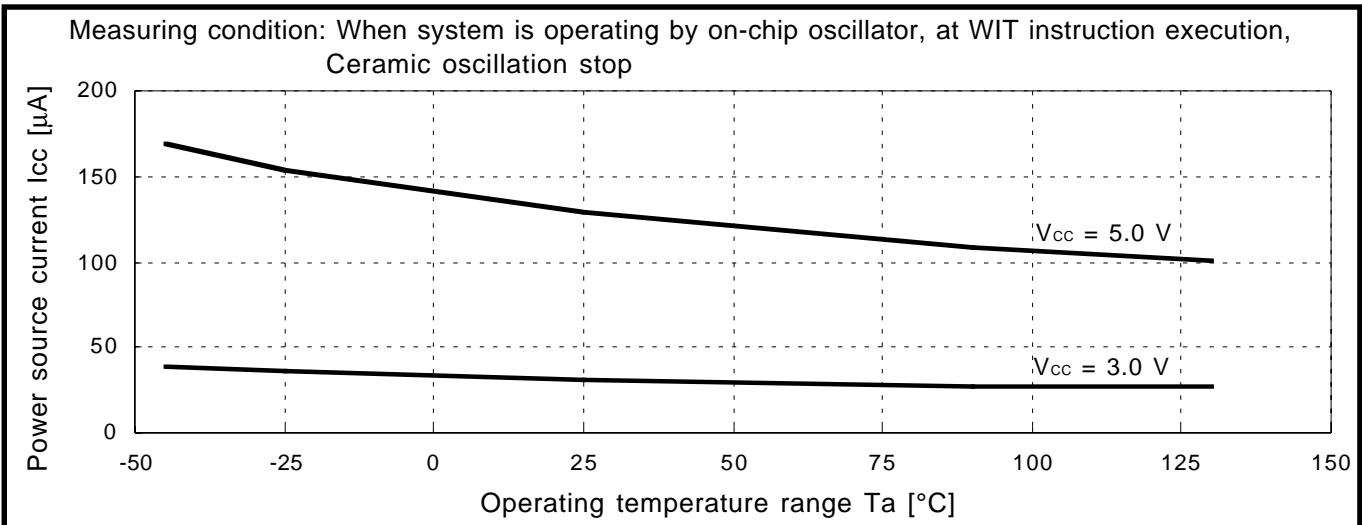
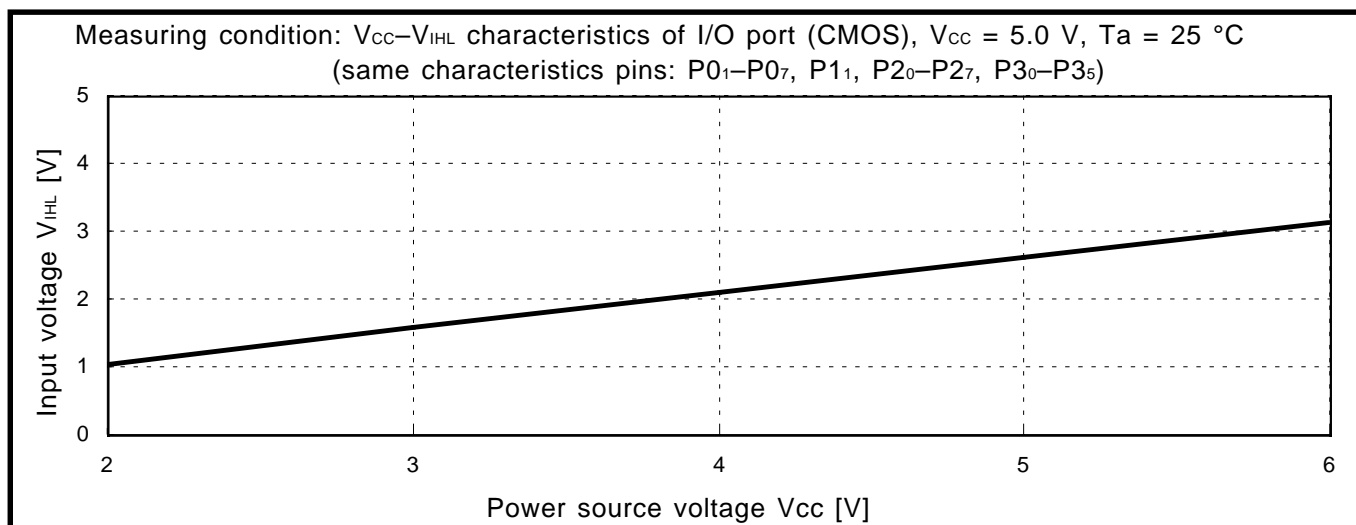
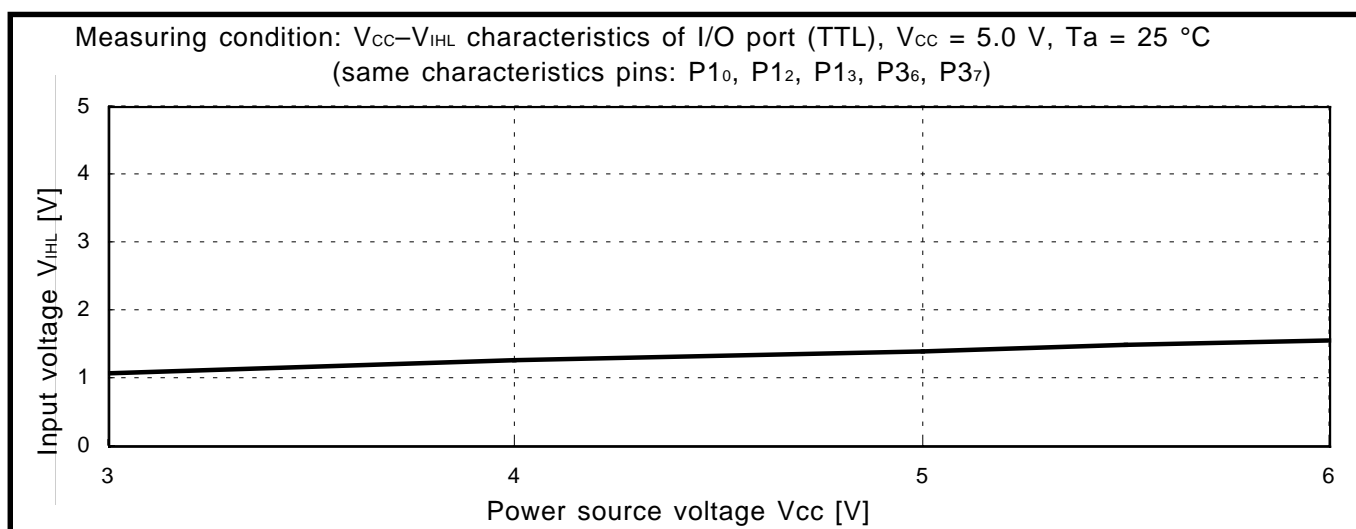


Fig. 3.2.58 Ta-I_{CC} characteristics (When system is operating by on-chip oscillator, at WIT instruction execution, Ceramic oscillation stop: One Time PROM version)

(4) Port typical characteristic example (V_{CC} - V_{IHL} characteristics)**Fig. 3.2.59 V_{CC} - V_{IHL} characteristics (I/O port (CMOS): One Time PROM version)****Fig. 3.2.60 V_{CC} - V_{IHL} characteristics (I/O port (TTL): One Time PROM version)**

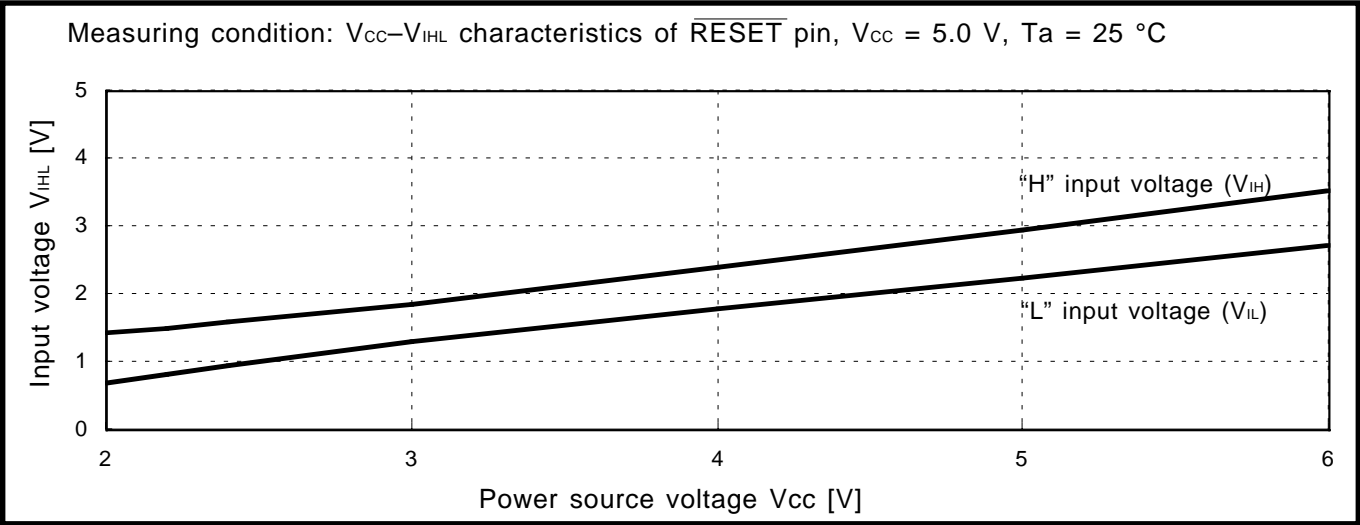


Fig. 3.2.61 V_{CC} - V_{IHL} characteristics ($\overline{\text{RESET}}$ pin: One Time PROM version)

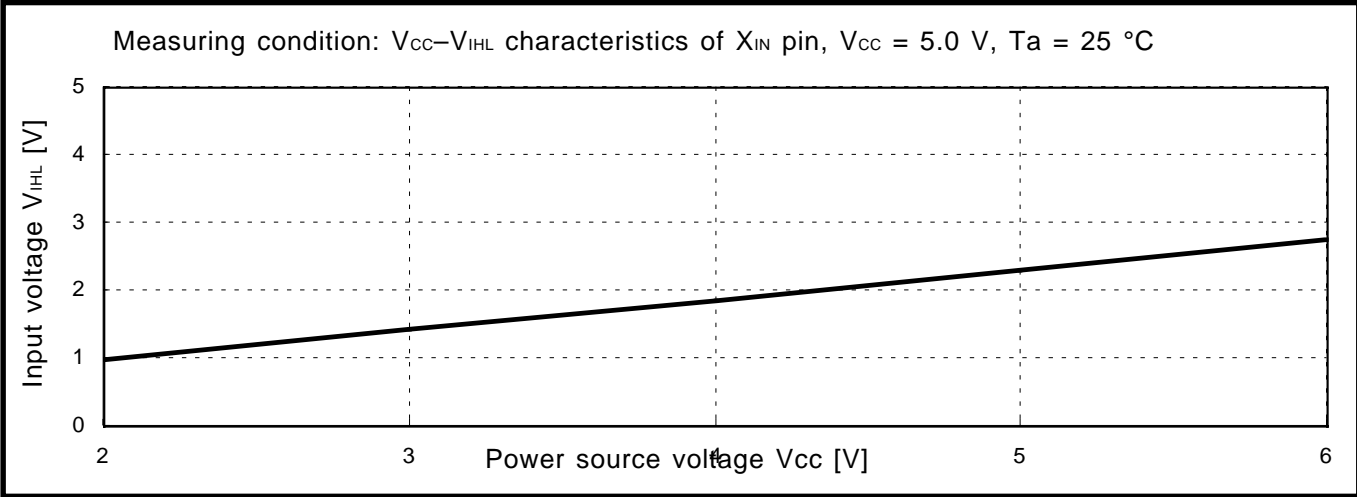


Fig. 3.2.62 V_{CC} - V_{IHL} characteristics (X_{IN} pin: One Time PROM version)

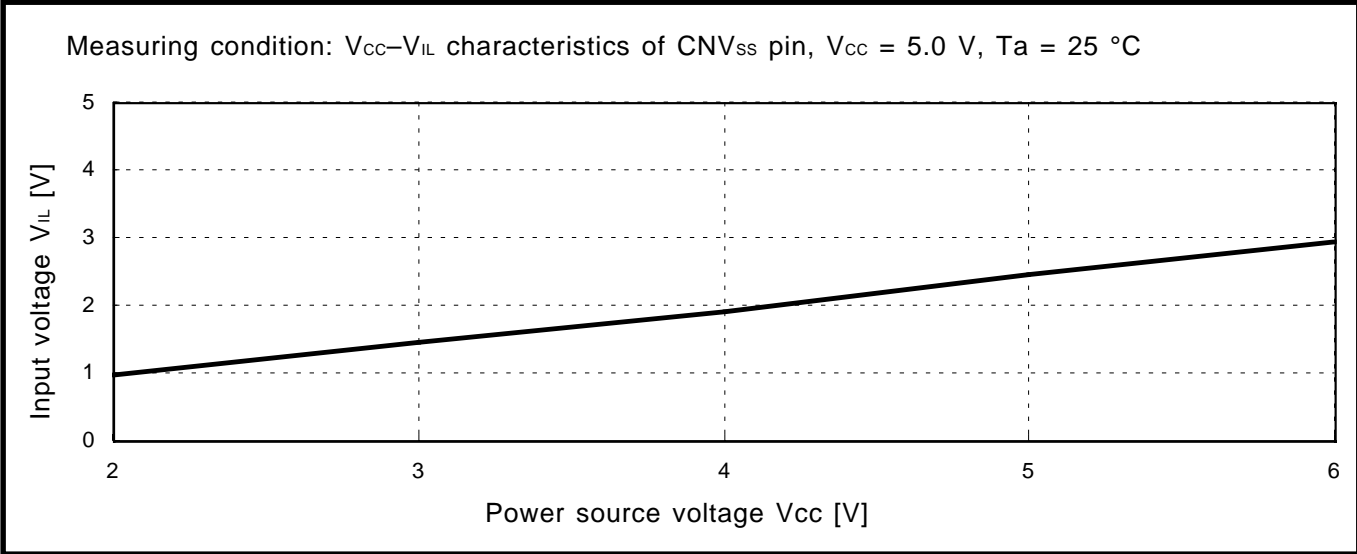


Fig. 3.2.63 V_{CC} - V_{IL} characteristics (CNV_{SS} pin: One Time PROM version)

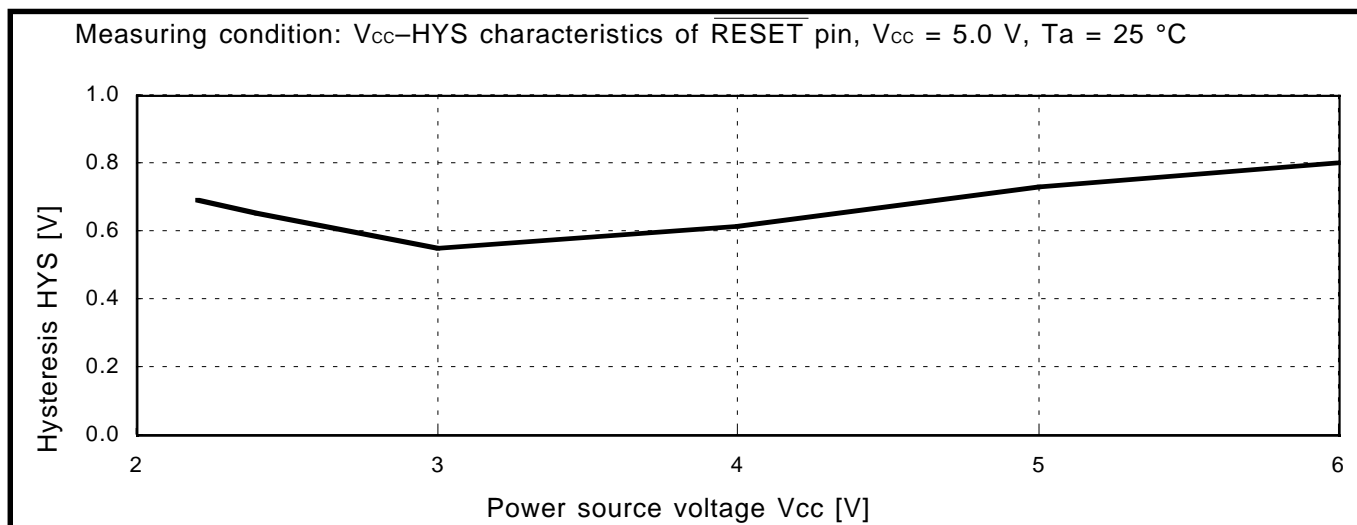


Fig. 3.2.64 V_{CC} -HYS characteristics (RESET pin: One Time PROM version)

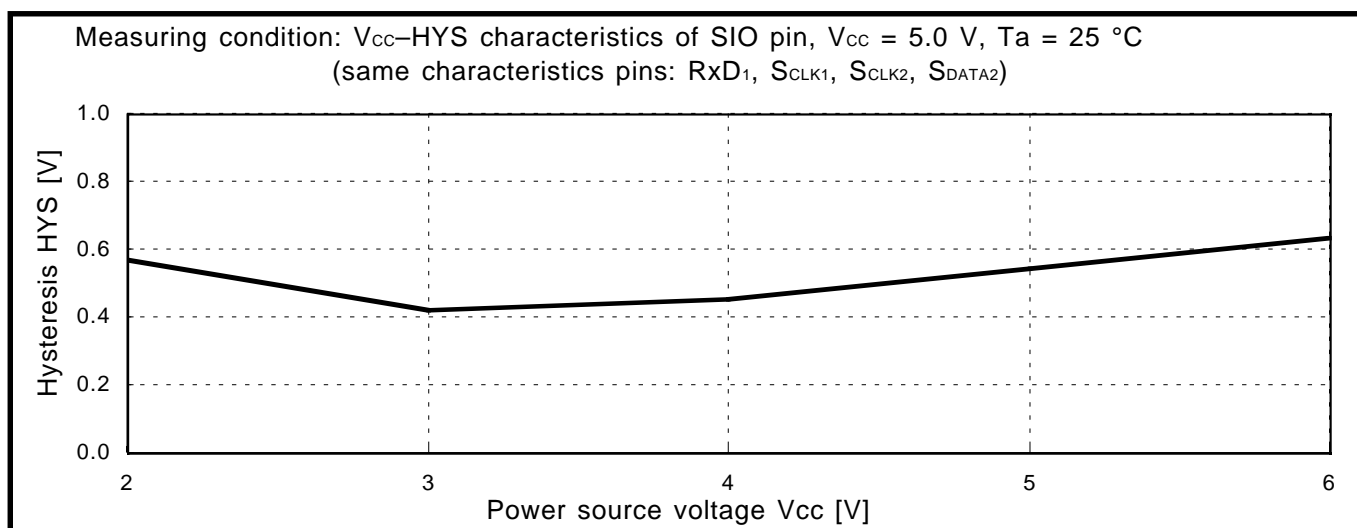


Fig. 3.2.65 V_{CC} -HYS characteristics (SIO pin: One Time PROM version)

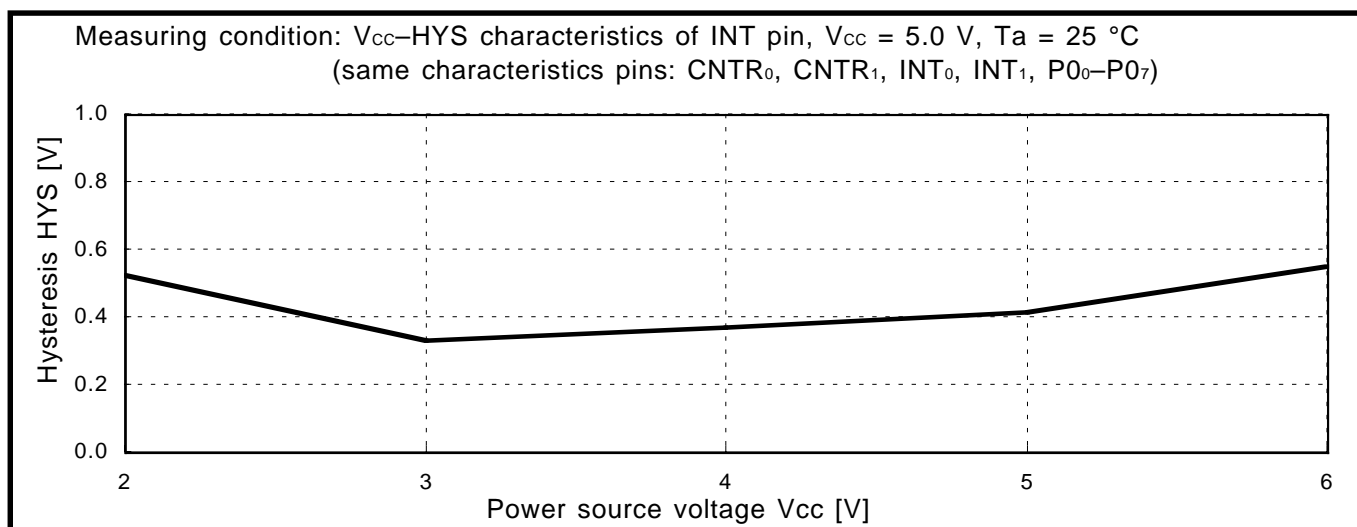


Fig. 3.2.66 V_{CC} -HYS characteristics (INT pin: One Time PROM version)

(5) Port typical characteristic example (V_{OH} - I_{OH} characteristics)

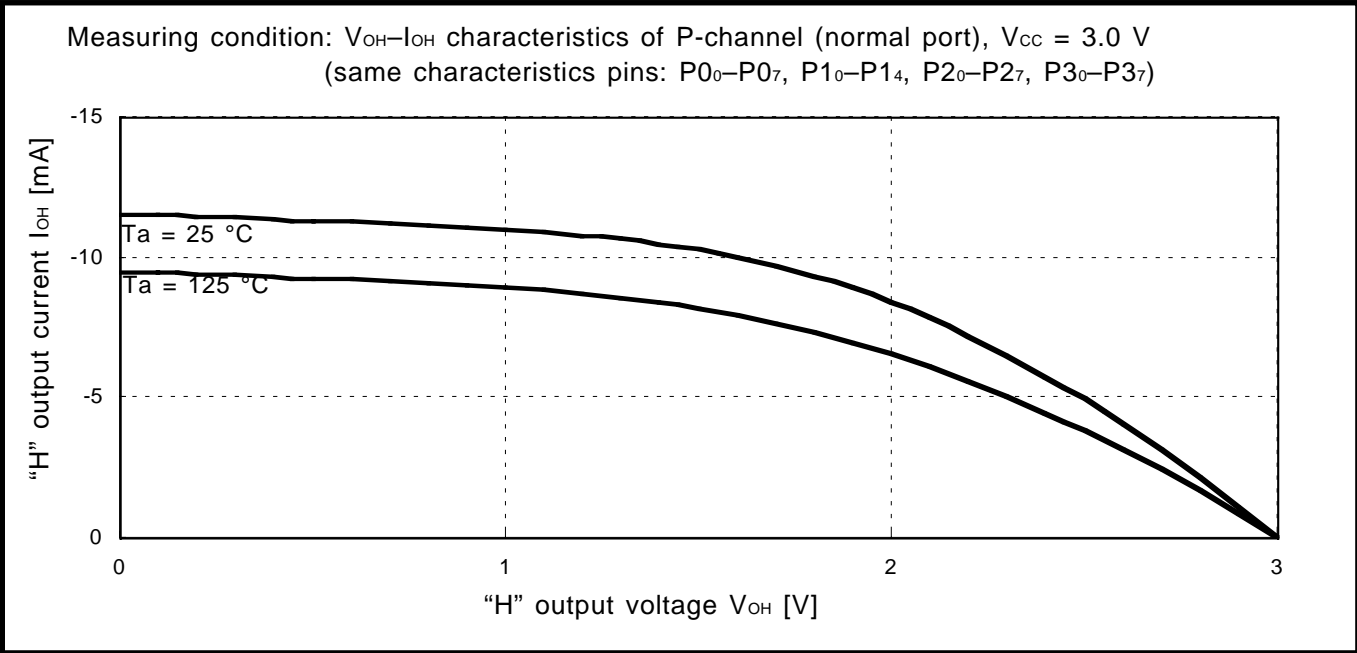


Fig. 3.2.67 V_{OH} - I_{OH} characteristics of P-channel ($V_{CC} = 3.0\text{ V}$, normal port: One Time PROM version)

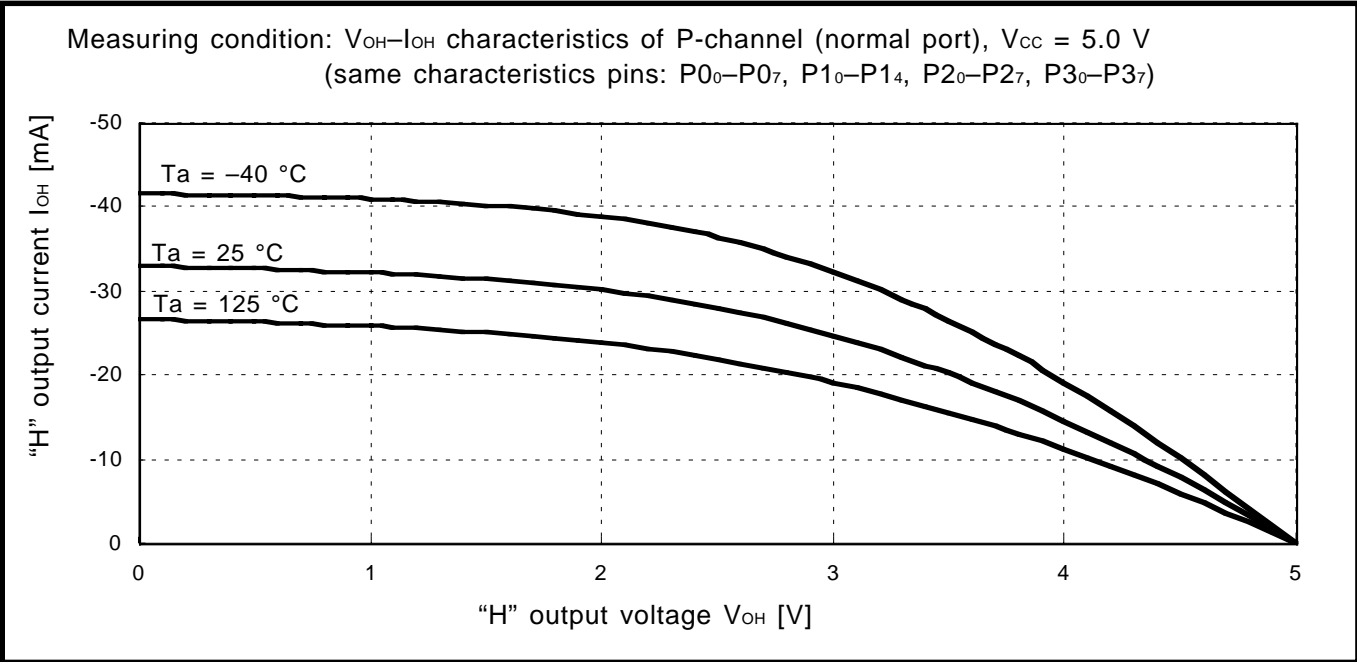
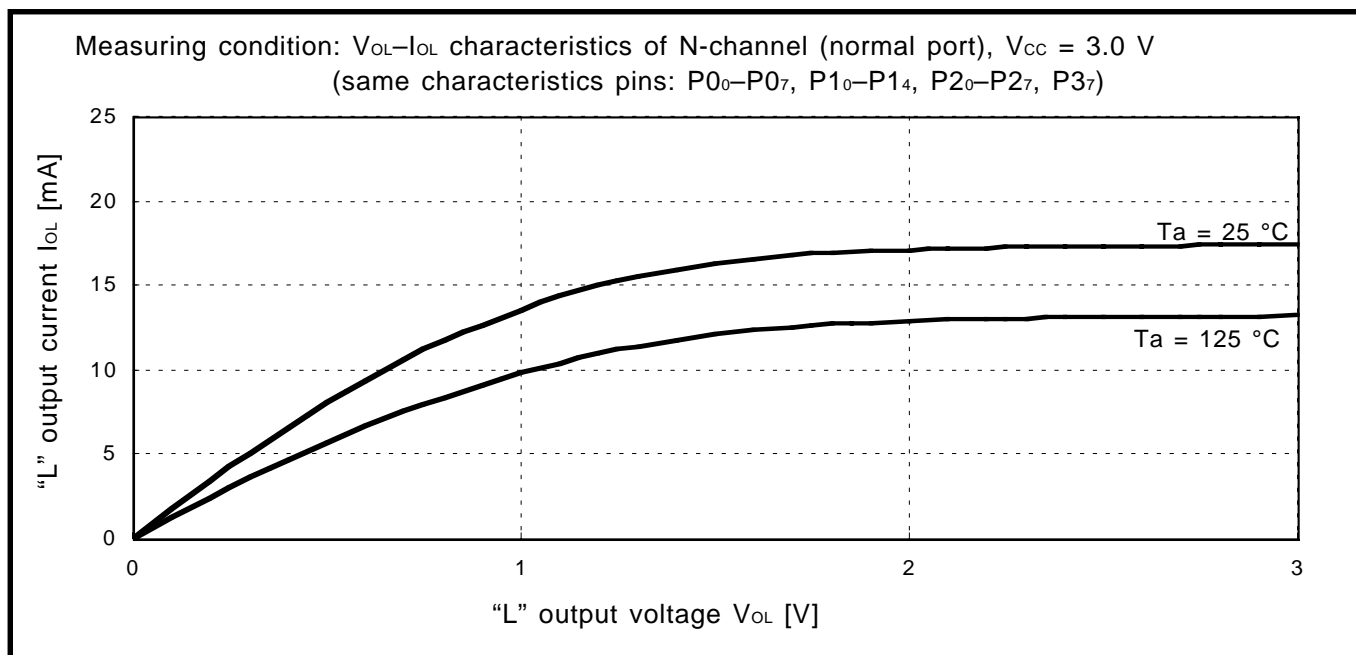
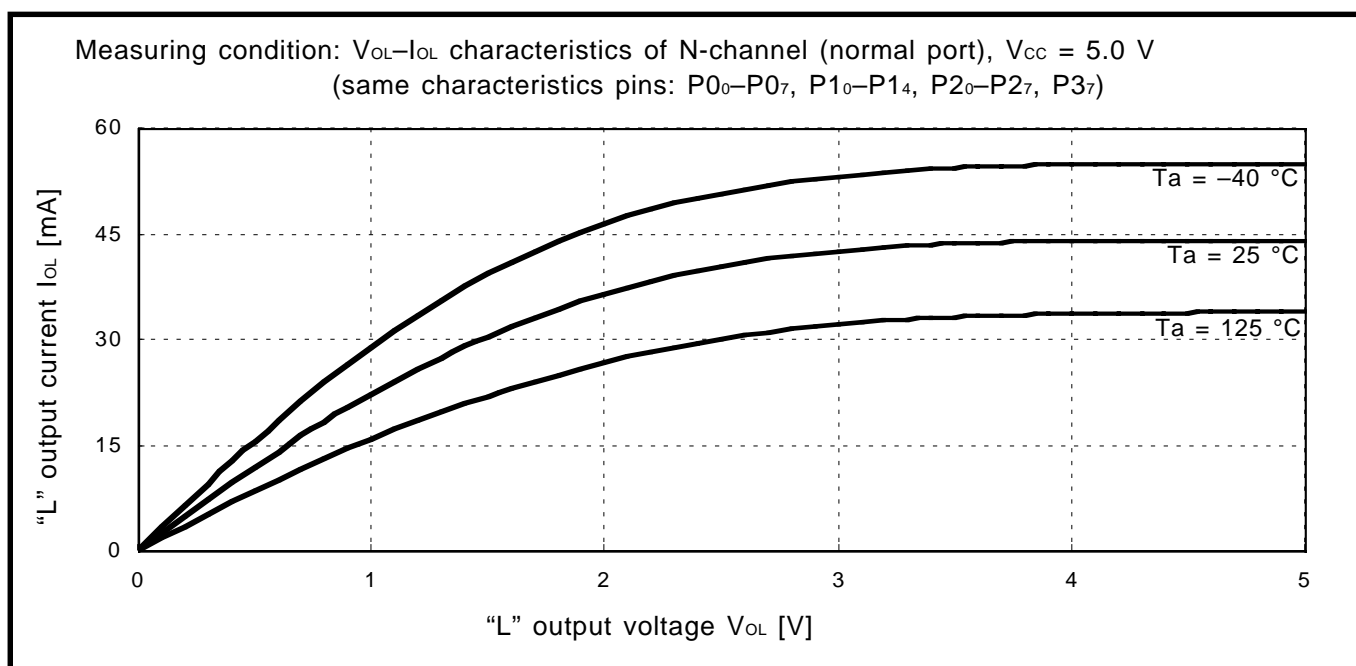


Fig. 3.2.68 V_{OH} - I_{OH} characteristics of P-channel ($V_{CC} = 5.0\text{ V}$, normal port: One Time PROM version)

(6) Port typical characteristic example (V_{OL} - I_{OL} characteristics)**Fig. 3.2.69 V_{OL} - I_{OL} characteristics of N-channel ($V_{CC} = 3.0$ V, normal port: One Time PROM version)****Fig. 3.2.70 V_{OL} - I_{OL} characteristics of N-channel ($V_{CC} = 5.0$ V, normal port: One Time PROM version)**

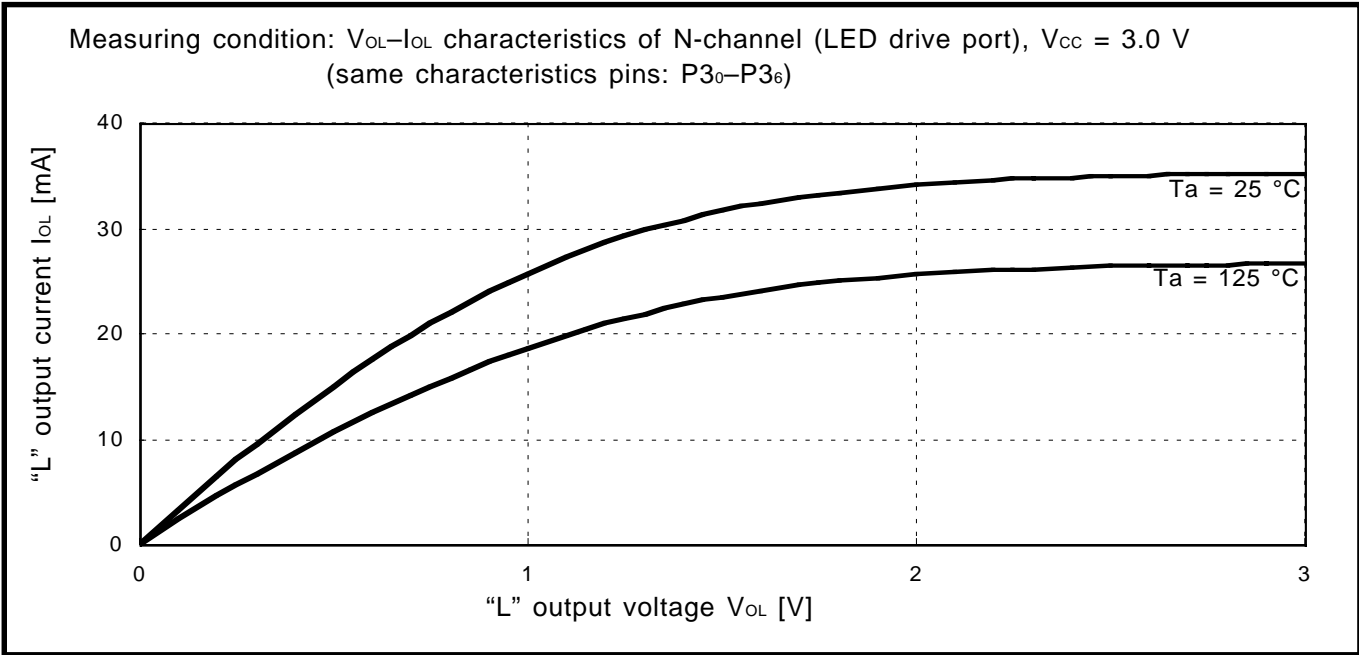


Fig. 3.2.71 V_{OL} - I_{OL} characteristics of N-channel ($V_{CC} = 3.0\text{ V}$, LED drive port: One Time PROM version)

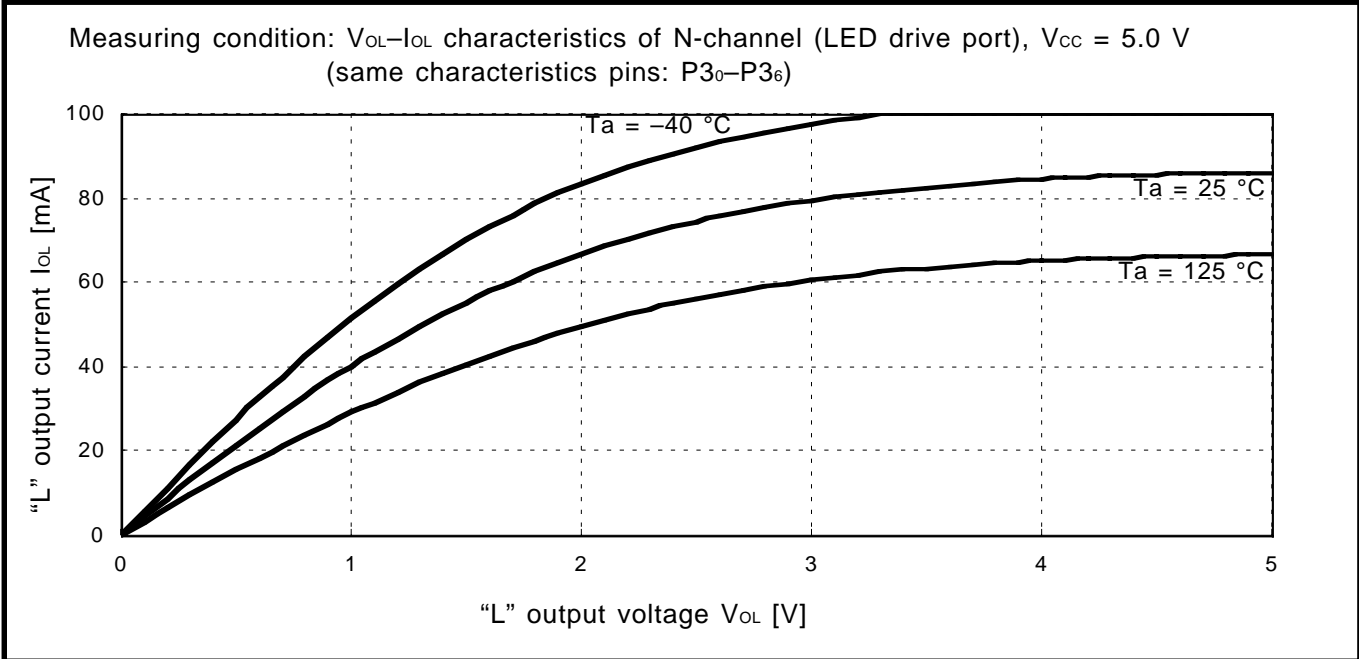


Fig. 3.2.72 V_{OL} - I_{OL} characteristics of N-channel ($V_{CC} = 5.0\text{ V}$, LED drive port: One Time PROM version)

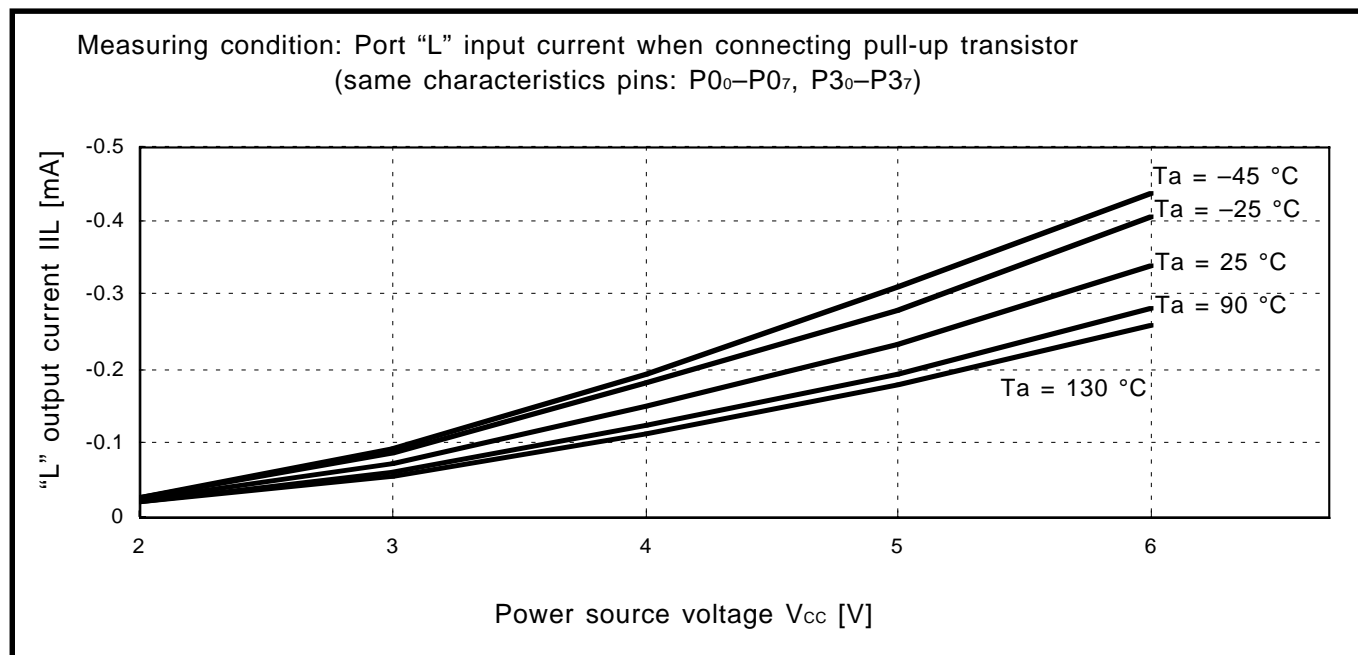
(7) Port typical characteristic example (V_{CC} -IIL characteristics)

Fig. 3.2.73 V_{CC} -IIL characteristics (Port "L" input current when connecting pull-up transistor: One Time PROM version)

(8) Port typical characteristic example ($V_{IN-II(AD)}$ characteristics)

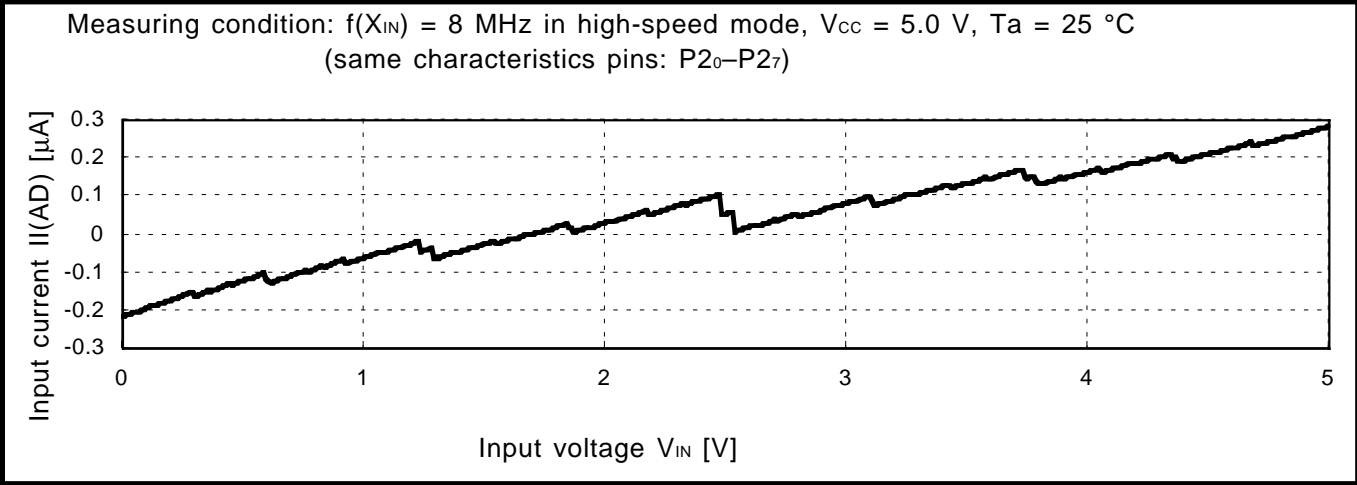


Fig. 3.2.74 $V_{IN-II(AD)}$ characteristics (A/D port input current during A/D conversion, $f(X_{IN}) = 8\text{ MHz}$ in high-speed mode: One Time PROM version)

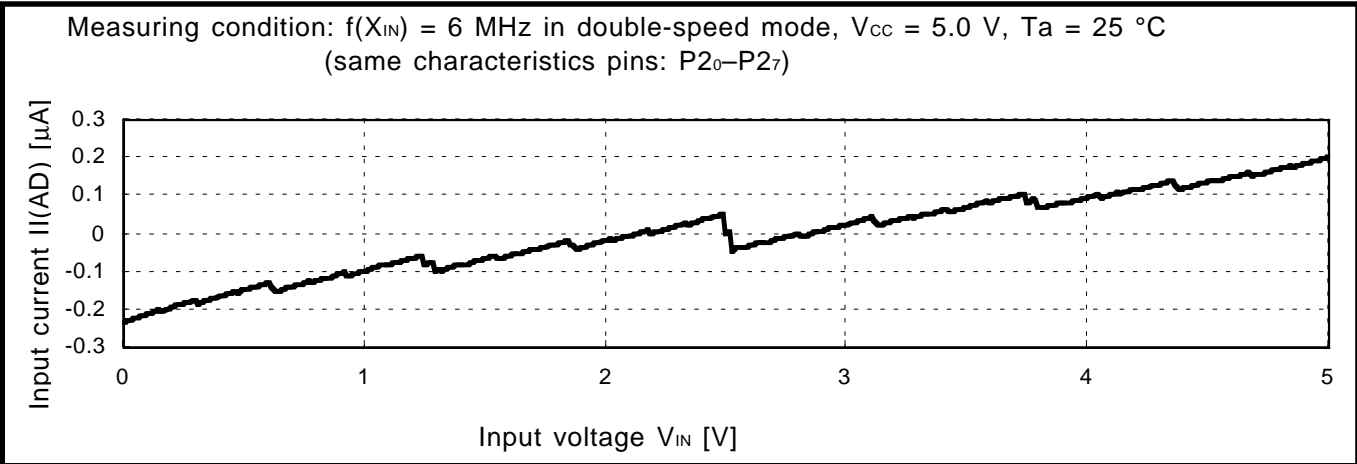


Fig. 3.2.75 $V_{IN-II(AD)}$ characteristics (A/D port input current during A/D conversion, $f(X_{IN}) = 6\text{ MHz}$ in double-speed mode: One Time PROM version)

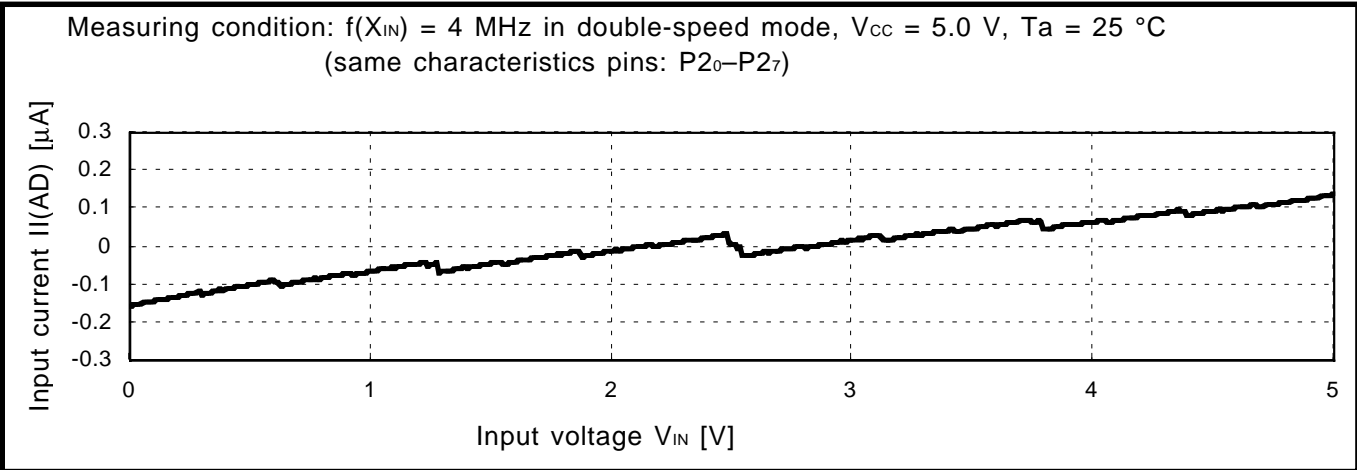


Fig. 3.2.76 $V_{IN-II(AD)}$ characteristics (A/D port input current during A/D conversion, $f(X_{IN}) = 4\text{ MHz}$ in double-speed mode: One Time PROM version)

(9) On-chip oscillator frequency typical characteristic example

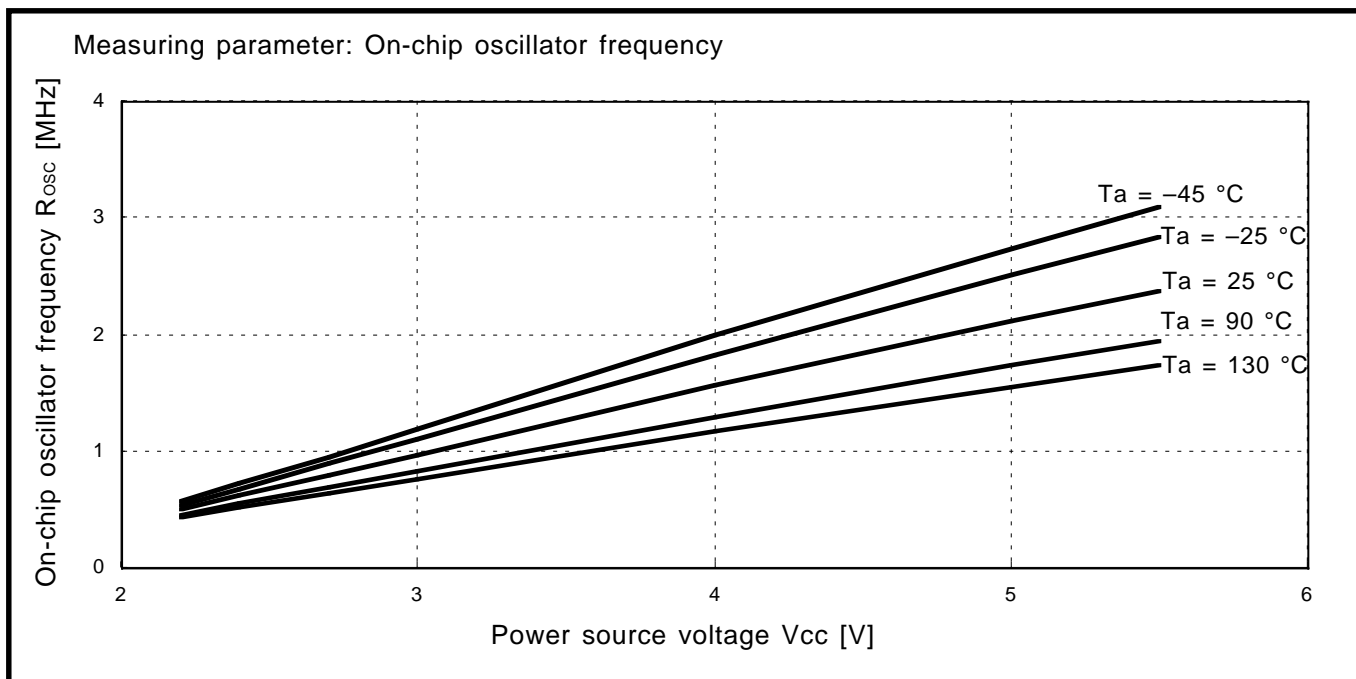


Fig. 3.2.77 V_{CC} - R_{osc} characteristics (on-chip oscillator frequency: One Time PROM version)

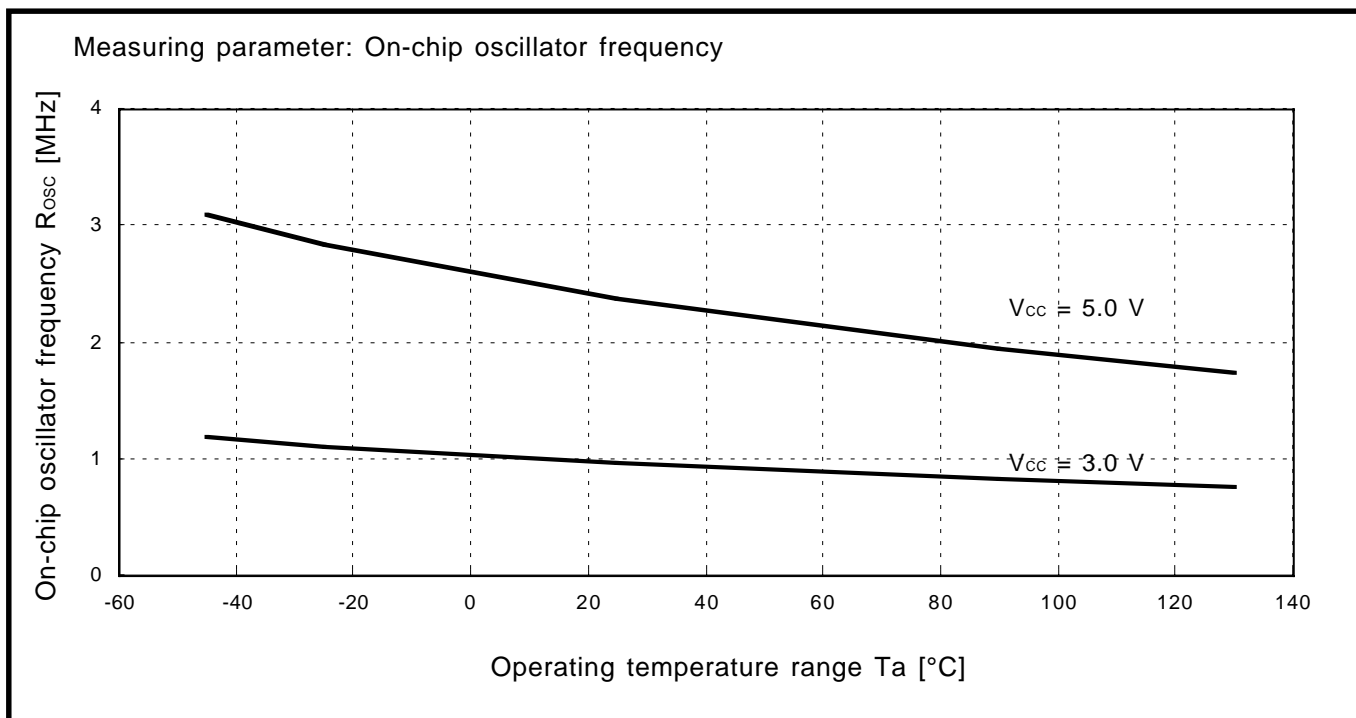


Fig. 3.2.78 T_a - R_{osc} characteristics (on-chip oscillator frequency: One Time PROM version)

(10) RC oscillation frequency typical characteristic example

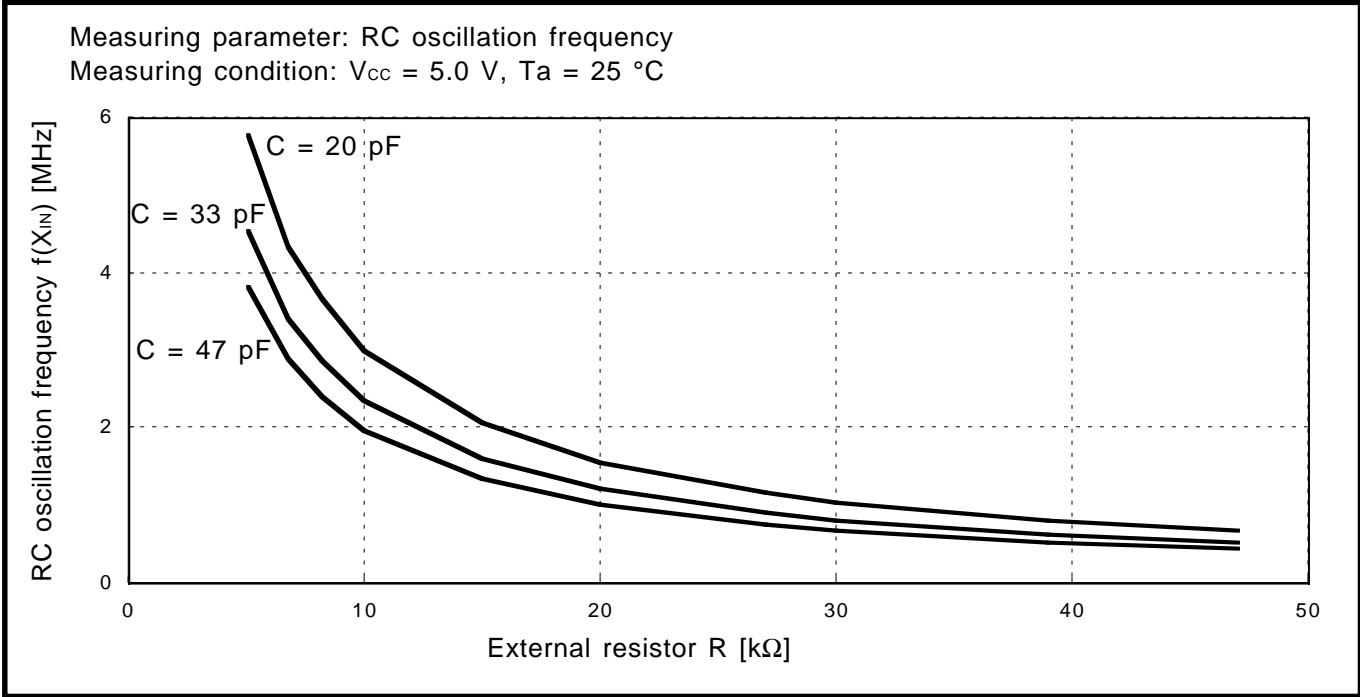


Fig. 3.2.79 R- $f(X_{IN})$ characteristics (RC oscillation frequency: One Time PROM version)

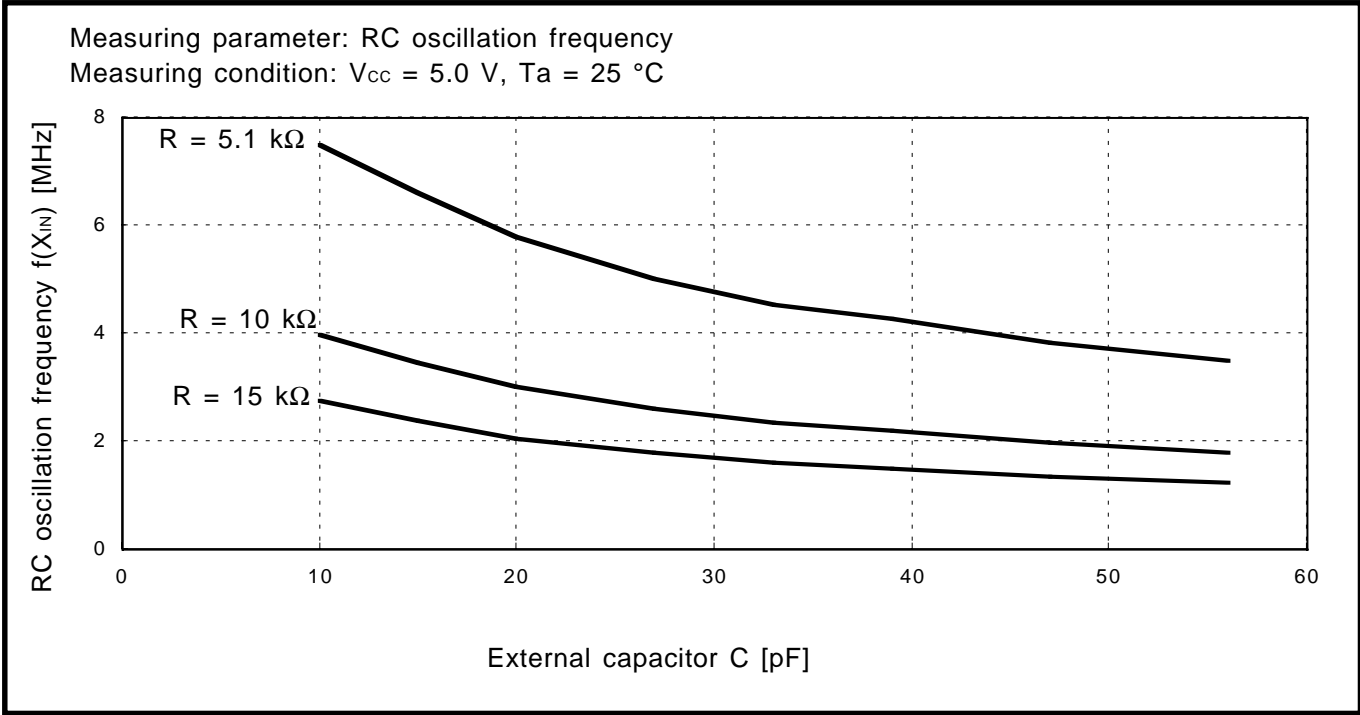


Fig. 3.2.80 C- $f(X_{IN})$ characteristics (RC oscillation frequency: One Time PROM version)

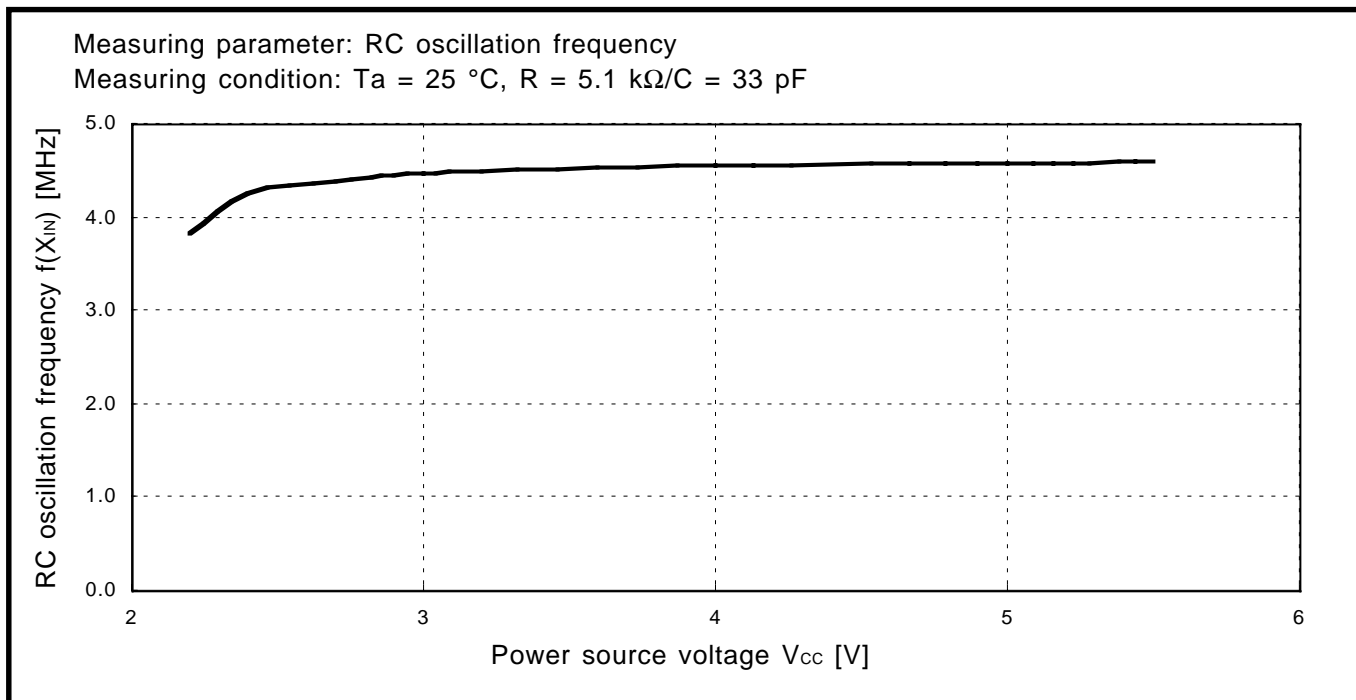


Fig. 3.2.81 V_{CC} - $f(X_{IN})$ characteristics (RC oscillation frequency: One Time PROM version)

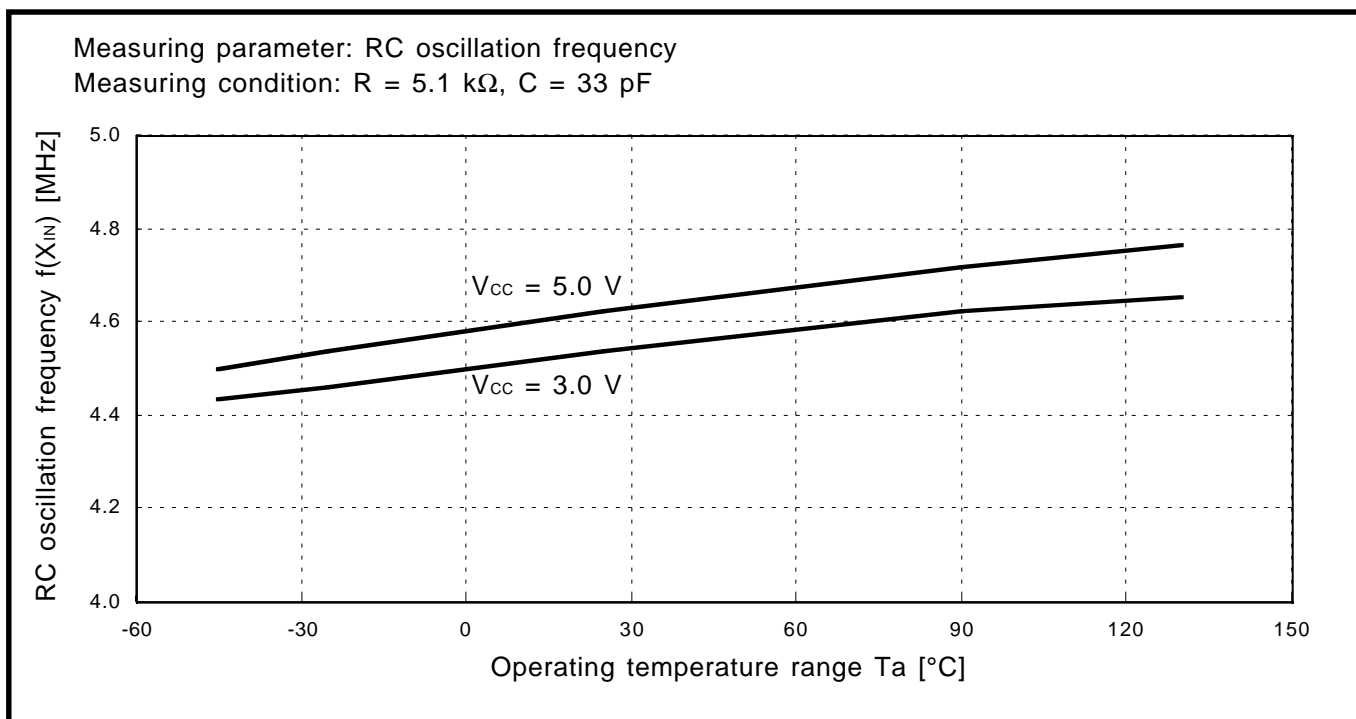


Fig. 3.2.82 T_a - $f(X_{IN})$ characteristics (RC oscillation frequency: One Time PROM version)

(11) A/D conversion typical characteristics example

① **Definition of A/D conversion accuracy**

The A/D conversion accuracy is defined below (refer to Fig. 3.2.83).

● **Relative accuracy**

- Zero transition voltage (V_{OT})
This means an analog input voltage when the actual A/D conversion output data changes from “0” to “1.”
- Full-scale transition voltage (V_{FST})
This means an analog input voltage when the actual A/D conversion output data changes from “1023” to “1022.”
- Non-linearity error
This means a deviation from the line between V_{OT} and V_{FST} of a converted value between V_{OT} and V_{FST} .
- Differential non-linearity error
This means a deviation from the input potential difference required to change a converted value between V_{OT} and V_{FST} by 1 LSB of the 1 LSB at the relative accuracy.

● **Absolute accuracy**

This means a deviation from the ideal characteristics between 0 to V_{REF} of actual A/D conversion characteristics.

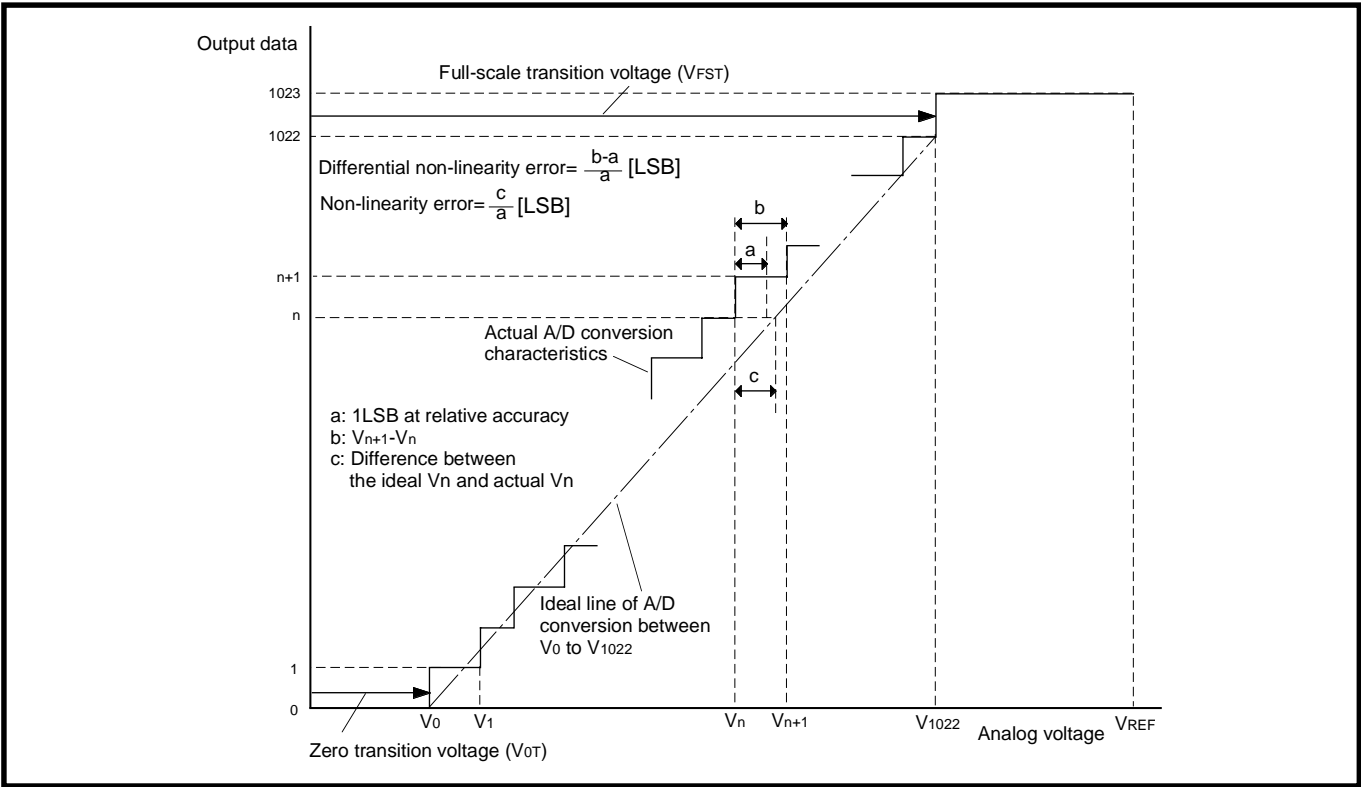


Fig. 3.2.83 Definition of A/D conversion accuracy

V_n : Analog input voltage when the output data changes from “n” to “n + 1” (n = 0 to 1022)

- 1 LSB at relative accuracy $\rightarrow \frac{V_{FST} - V_{OT}}{1022}$ (V)
- 1 LSB at absolute accuracy $\rightarrow \frac{V_{REF}}{1024}$ (V)

② A/D conversion accuracy typical characteristics-1

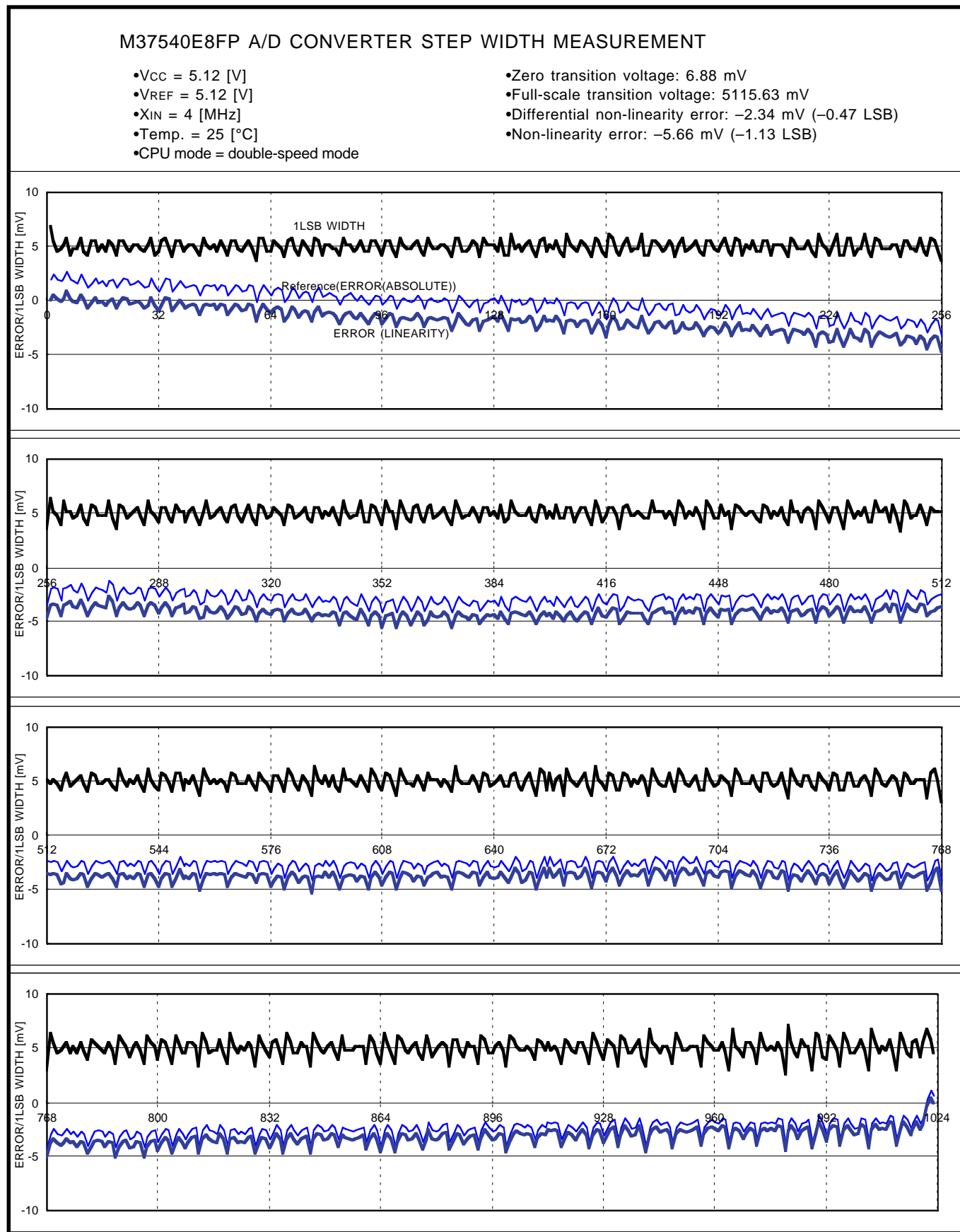


Fig. 3.2.84 A/D conversion accuracy typical characteristic example-1 (One Time PROM version)

③ A/D conversion accuracy typical characteristics-2

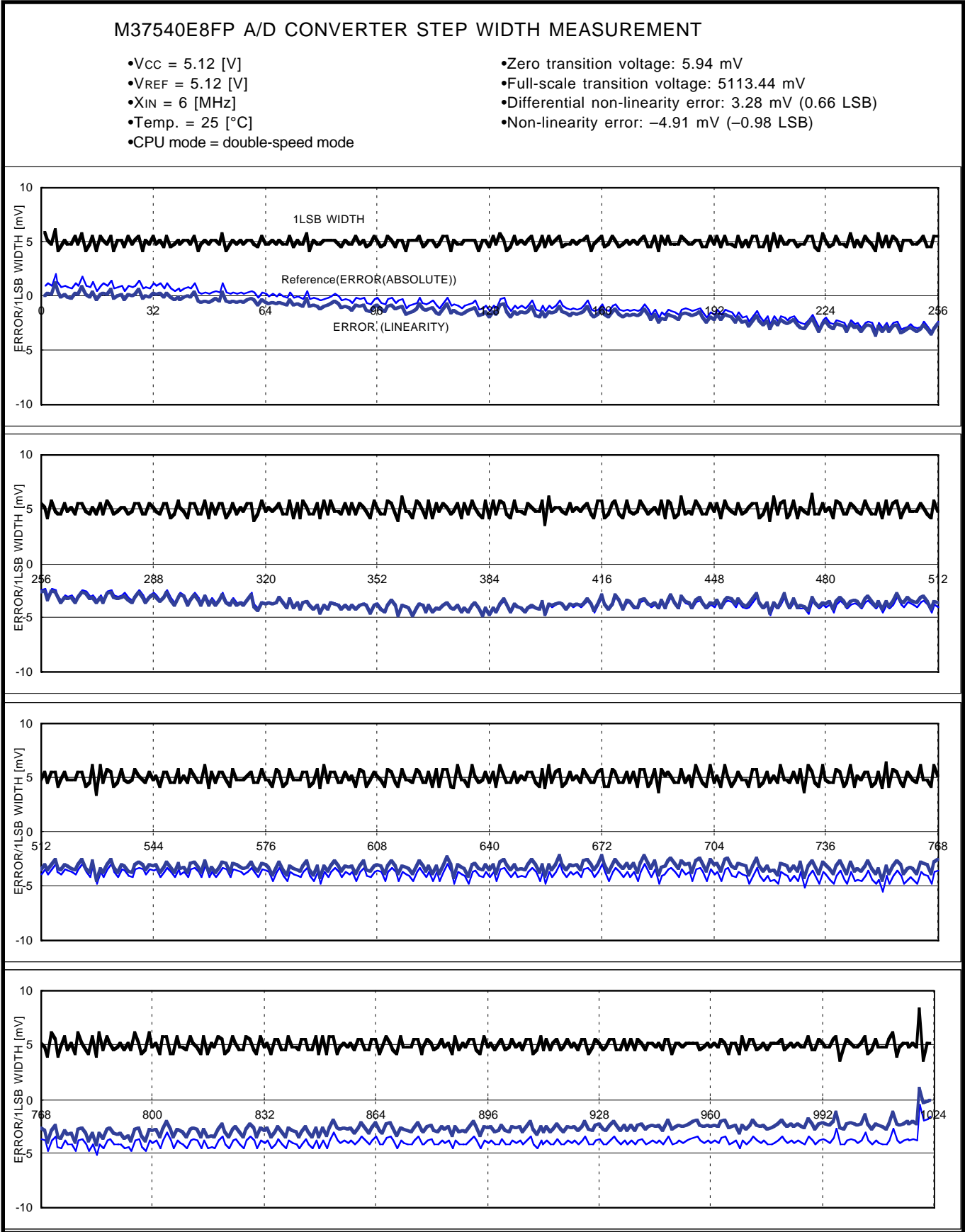


Fig. 3.2.85 A/D conversion accuracy typical characteristic example-2 (One Time PROM version)

④ A/D conversion accuracy typical characteristics-3

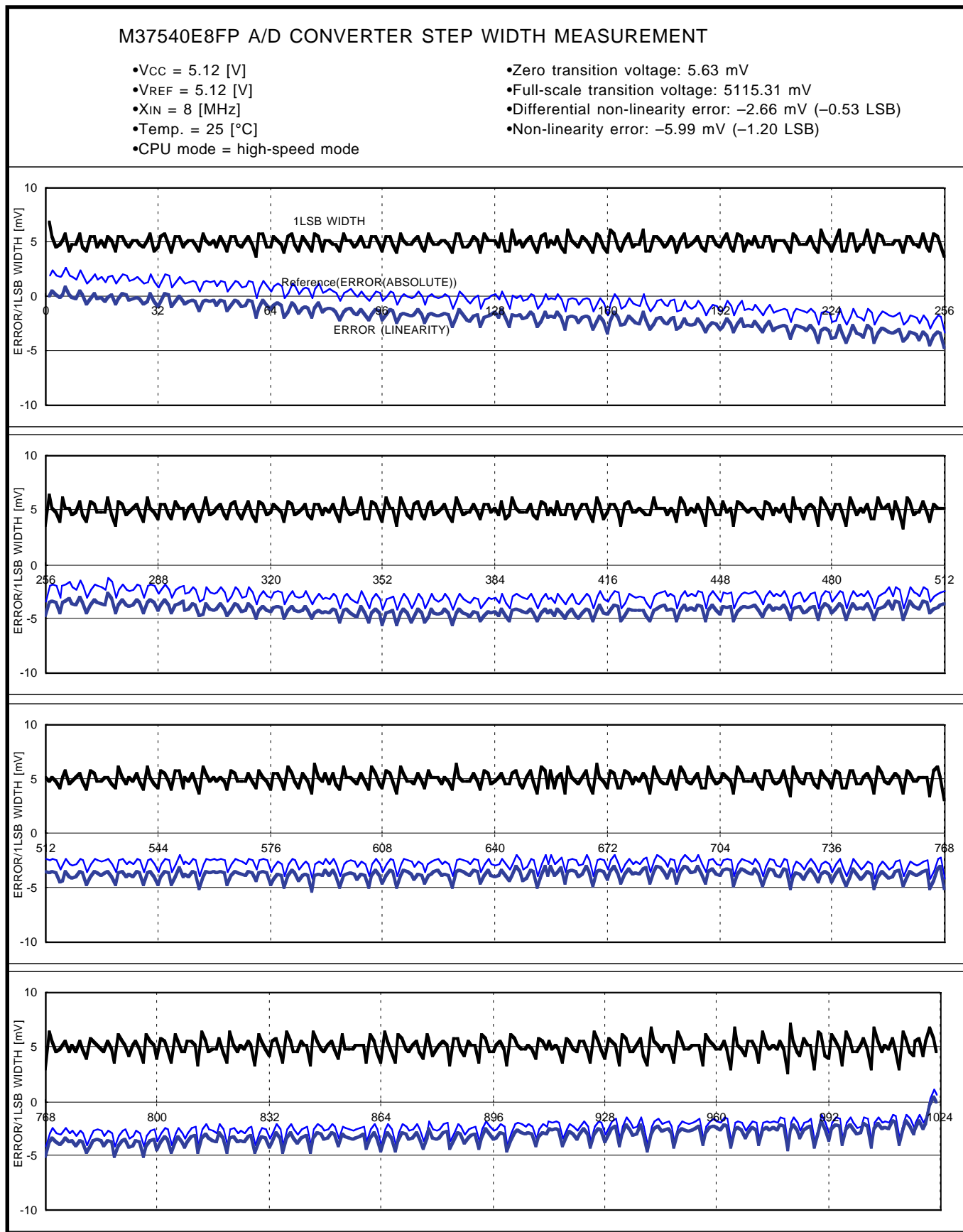


Fig. 3.2.86 A/D conversion accuracy typical characteristic example-3 (One Time PROM version)

3.3 Notes on use

3.3.1 Notes on input and output ports

Notes on using input and output ports are described below.

(1) Notes in stand-by state

In stand-by state*¹ for low-power dissipation, do not make input levels of an input port and an I/O port “undefined”.

Pull-up (connect the port to VCC) or pull-down (connect the port to VSS) these ports through a resistor.

When determining a resistance value, note the following points:

- External circuit
- Variation of output levels during the ordinary operation

When using a built-in pull-up resistor, note on varied current values:

- When setting as an input port : Fix its input level
- When setting as an output port : Prevent current from flowing out to external.

● Reason

The output transistor becomes the OFF state, which causes the ports to be the high-impedance state. Note that the level becomes “undefined” depending on external circuits.

Accordingly, the potential which is input to the input buffer in a microcomputer is unstable in the state that input levels of a input port and an I/O port are “undefined”. This may cause power source current.

*¹ stand-by state : the stop mode by executing the **STP** instruction
the wait mode by executing the **WIT** instruction

(2) Modifying output data with bit managing instruction

When the port latch of an I/O port is modified with the bit managing instruction*², the value of the unspecified bit may be changed.

● Reason

The bit managing instructions are read-modify-write form instructions for reading and writing data by a byte unit. Accordingly, when these instructions are executed on a bit of the port latch of an I/O port, the following is executed to all bits of the port latch.

- As for a bit which is set for an input port :
The pin state is read in the CPU, and is written to this bit after bit managing.
- As for a bit which is set for an output port :
The bit value of the port latch is read in the CPU, and is written to this bit after bit managing.

Note the following :

- Even when a port which is set as an output port is changed for an input port, its port latch holds the output data.
- As for a bit of the port latch which is set for an input port, its value may be changed even when not specified with a bit managing instruction in case where the pin state differs from its port latch contents.

*² bit managing instructions : **SEB**, and **CLB** instructions

(3) Usage for the 32-pin version

- ① Fix the P3₅, P3₆ pull-up control bit of the pull-up control register to “1”.
- ② Keep the P3₆/INT₁ input level selection bit of the port P1P3 control register “0” (initial state).

3.3.2 Termination of unused pins

(1) Terminate unused pins

① I/O ports :

- Set the I/O ports for the input mode and connect them to VCC or VSS through each resistor of 1 k Ω to 10 k Ω .
Ports that permit the selecting of a built-in pull-up resistor can also use this resistor. Set the I/O ports for the output mode and open them at "L" or "H".
- When opening them in the output mode, the input mode of the initial status remains until the mode of the ports is switched over to the output mode by the program after reset. Thus, the potential at these pins is undefined and the power source current may increase in the input mode. With regard to an effects on the system, thoroughly perform system evaluation on the user side.
- Since the direction register setup may be changed because of a program runaway or noise, set direction registers by program periodically to increase the reliability of program.

(2) Termination remarks

① Input ports and I/O ports :

Do not open in the input mode.

● Reason

- The power source current may increase depending on the first-stage circuit.
- An effect due to noise may be easily produced as compared with proper termination ② and ③ shown on the above.

② I/O ports :

When setting for the input mode, do not connect to VCC or VSS directly.

● Reason

If the direction register setup changes for the output mode because of a program runaway or noise, a short circuit may occur between a port and VCC (or VSS).

③ I/O ports :

When setting for the input mode, do not connect multiple ports in a lump to VCC or VSS through a resistor.

● Reason

If the direction register setup changes for the output mode because of a program runaway or noise, a short circuit may occur between ports.

- At the termination of unused pins, perform wiring at the shortest possible distance (20 mm or less) from microcomputer pins.

3.3.3 Notes on Timer

- When n (0 to 255) is written to a timer latch, the frequency division ratio is $1/(n+1)$.
- When a count source of timer X, timer Y or timer Z is switched, stop a count of timer X.

3.3.4 Notes on Timer A

Notes on using timer A are described below.

(1) Common to all modes

- ① When reading timer A (high-order) (TAH) and timer A (low-order) (TAL), the contents of timer A is read out. Read both registers in order of TAH and TAL following, certainly. TAH and TAL keep the values until they are read out. Also, do not write to them during read. In this case, unexpected operation may occur.
- ② When writing data to TAL and TAH even when timer A is operating or stopped, the data are set to timer A and timer A latch simultaneously. Write both registers in order of TAL and TAH following, certainly. Also, do not read them during write. In this case, unexpected operation may occur.

(2) Period measurement mode, event counter mode, and pulse width HL continuously measurement mode

- ① In order to use CNTR₁ pin, set "0" to bit 0 of the port P0 direction register (input mode).
- ② In order to use CNTR₁ pin, set "1" to bit 7 of the interrupt control register to disable the P0₀ key-on wakeup function.
- ③ CNTR₁ interrupt active edge depends on the CNTR₁ active edge switch bit. When this bit is "0", the CNTR₁ interrupt request bit is set to "1" at the falling edge of the CNTR₁ pin input signal. When this bit is "1", the CNTR₁ interrupt request bit is set to "1" at the rising edge of the CNTR₁ pin input signal. However, in the pulse width HL continuously measurement mode, CNTR₁ interrupt request is generated at both rising and falling edges of CNTR₁ pin input signal regardless of the setting of CNTR₁ active edge switch bit.

3.3.5 Notes on timer 1

Note on timer 1 is described below.

(1) Notes on set of the oscillation stabilizing time

Timer 1 can be used to set the oscillation stabilizing time after release of the **STP** instruction. The oscillation stabilizing time after release of STP instruction can be selected from "set automatically"/"not set automatically" by the oscillation stabilizing time set bit after release of the **STP** instruction of MISRG. When "0" is set to this bit, "01₁₆" is set to timer 1 and "FF₁₆" is set to prescaler 1 automatically. When "1" is set to this bit, nothing is set to timer 1 and prescaler 1. Therefore, set the wait time according to the oscillation stabilizing time of the oscillation. Also, when timer 1 is used, set values again to timer 1 and prescaler 1 after system is returned from the stop mode.

3.3.6 Notes on Timer X

Notes on using each mode of timer X are described below.

(1) Count source

- ① $f(X_{IN})$ can be used only when a ceramic oscillator or an on-chip oscillator is used.
Do not use $f(X_{IN})$ at RC oscillation.

(2) Pulse output mode

- ① In order to use CNTR₀ pin, set "1" to bit 4 of the port P1 direction register (output mode).
- ② In order to use TX_{OUT} pin, set "1" to bit 3 of the port P0 direction register (output mode).
- ③ CNTR₀ interrupt active edge depends on the CNTR₀ active edge switch bit. When this bit is "0", the CNTR₀ interrupt request bit is set to "1" at the falling edge of CNTR₀ pin input signal. When this bit is "1", the CNTR₀ interrupt request bit is set to "1" at the rising edge of CNTR₀ pin input signal.

(3) Pulse width measurement mode

- ① In order to use CNTR₀ pin, set "1" to bit 4 of the port P1 direction register (output mode).
- ② CNTR₀ interrupt active edge depends on the CNTR₀ active edge switch bit. When this bit is "0", the CNTR₀ interrupt request bit is set to "1" at the falling edge of CNTR₀ pin input signal. When this bit is "1", the CNTR₀ interrupt request bit is set to "1" at the rising edge of CNTR₀ pin input signal.

3.3.7 Notes on timer Y and timer Z

Notes on using each mode of Timer Y and Timer Z are described below.

(1) Timer mode (timer Y and timer Z)

- ① In the timer mode, TYP and TYS is not used.

(2) Programmable waveform generation mode (timer Y and timer Z)

- ① In the programmable waveform generation mode, values of TYS, EXPYP, and EXPYS are valid by writing to TYP because the setting to them is executed all at once by writing to TYP. Even when changing TYP is not required, write the same value again.
- ② In the programmable waveform generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TYP and the timing of timer underflow during the secondary interval simultaneously.
An example of a measurement is shown below.
ex.) The underflow by the primary and the underflow by secondary are stored by polling etc. using timer Y interrupt.
Writing to primary is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.
(Depending on a primary and a secondary setting values, and primary write timing, it may be impossible.)
- ③ The waveform extension function by the timer Y waveform extension control bits can be used only when "00₁₆" is set to Prescaler Y.
When the value other than "00₁₆" is set to Prescaler Y, be sure to set "0" to EXPYP and EXPYS. The waveform extension function by the timer Z waveform extension control bits can be used only when "00₁₆" is set to Prescaler Z. When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
- ④ When using this mode, be sure to set "1" to the timer Y write control bit to select "write to latch only".
- ⑤ When TYS is read out, the undefined value is read out. However, while timer Y counts the setting value of TYS, the count value during the secondary interval can be obtained by reading the timer Y primary.
- ⑥ In order to use TY_{OUT} pin, set "1" to bit 1 of the port P0 direction register (output mode).

(3) Programmable one-shot generation mode (timer Z)

- ① In the programmable one-shot generation mode, the value of EXPZP becomes valid by writing to TZP. Even when changing TZP is not required, write the same value again.
- ② In the programmable one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow simultaneously.

- ③ The waveform extension function by the timer Z waveform extension control bits can be used only when "00₁₆" is set to Prescaler Z.
When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
An example of a measurement is shown below.
ex.) The underflow of timer is stored by polling etc. using timer Z interrupt.
Writing to primary is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.
(Depending on a primary setting value, primary write timing, software and timing of external trigger to INT₀ pin, it may be impossible.)
- ④ When using this mode, be sure to set "1" to the timer Z write control bit to select "write to latch only".
- ⑤ In order to use TZ_{OUT} pin, set "1" to bit 2 of the port P0 direction register (output mode).
- ⑥ Stop Timer Z to change the INT₀ pin one-shot trigger control bit and INT₀ pin one-shot trigger active edge selection bit.

(4) Programmable wait one-shot generation mode (timer Z)

- ① In the programmable wait one-shot generation mode, values of TZS, EXPZP and EXPZS are valid by writing to TZP. Even when changing TZP is not required, write the same value again.
An example of a measurement is shown below.
ex.) The underflow by the primary and the underflow by secondary are stored by polling etc. using timer Z interrupt.
Writing is performed in by judging that there is no problem if the underflow by secondary is completed with reference to primary write operation before.
(Depending on a primary setting value, primary write timing, software and timing of external trigger to INT₀ pin, it may be impossible.)
- ② In the programmable wait one-shot generation mode, when the setting value is changed while the waveform is output, set by software in order not to execute the writing to TZP and the timing of timer underflow during the secondary interval simultaneously.
- ③ The waveform extension function by the timer Z waveform extension control bit can be used only when "00₁₆" is set to Prescaler Z.
When the value other than "00₁₆" is set to Prescaler Z, be sure to set "0" to EXPZP and EXPZS. Also, when the timer Y underflow is selected as the timer Z count source, the waveform extension function cannot be used.
- ④ When using this mode, be sure to set "1" to the timer Z write control bits to select "write to latch only".
- ⑤ When TZS is read out, the undefined value is read out. However, while Timer Z counts the setting value of TZS (during one-shot output), the count value during the secondary interval can be obtained by reading TZP.
- ⑥ In order to use TZ_{OUT} pin, set "1" to bit 2 of the port P0 direction register (output mode).
- ⑦ Stop Timer Z to change the INT₀ pin one-shot trigger control bit and INT₀ pin one-shot trigger active edge selection bit.

(5) Common to all modes (timer Y and timer Z)

Timer Y can stop counting by setting "1" to the timer Y count stop bit in any mode.

Also, when Timer Y underflows, the timer Y interrupt request bit is set to "1".

Timer Y reloads the value of latch when counting is stopped by the timer Y count stop bit. (When timer is read out while timer is stopped, the value of latch is read. The value of timer can be read out only while timer is operating.)

3.3.8 Notes on Serial I/O1

Notes on using serial I/O1 are described below.

(1) Notes when selecting clock synchronous serial I/O

- ① When the clock synchronous serial I/O1 is used, serial I/O2 cannot be used.
- ② When the transmit operation is stopped, clear the serial I/O1 enable bit and the transmit enable bit to "0" (serial I/O1 and transmit disabled).

● Reason

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O1 enable bit is cleared to "0" (serial I/O1 disabled), the internal transmission is running (in this case, since pins TxD₁, RxD₁, SCLK₁, and $\overline{\text{SRDY}}_1$ function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O1 enable bit is set to "1" at this time, the data during internally shifting is output to the TxD₁ pin and an operation failure occurs.

- ③ When the receive operation is stopped, clear the receive enable bit to "0" (receive disabled), or clear the serial I/O1 enable bit to "0" (serial I/O1 disabled).
- ④ When the transmit/receive operation is stopped, clear both the transmit enable bit and receive enable bit to "0" (transmit and receive disabled) simultaneously. (any one of data transmission and reception cannot be stopped.)

● Reason

In the clock synchronous serial I/O mode, the same clock is used for transmission and reception. If any one of transmission and reception is disabled, a bit error occurs because transmission and reception cannot be synchronized.

In this mode, the clock circuit of the transmission circuit also operates for data reception. Accordingly, the transmission circuit does not stop by clearing only the transmit enable bit to "0" (transmit disabled). Also, the transmission circuit cannot be initialized even if the serial I/O1 enable bit is cleared to "0" (serial I/O1 disabled) (same as ②).

- ⑤ When signals are output from the $\overline{\text{SRDY}}_1$ pin on the reception side by using an external clock, set all of the receive enable bit, the $\overline{\text{SRDY}}_1$ output enable bit, and the transmit enable bit to "1".
- ⑥ When the SRDY_1 signal input is used, set the using pin to the input mode before data is written to the transmit/receive buffer register.
- ⑦ Setup of a serial I/O1 synchronous clock selection bit when a clock synchronous serial I/O is selected;
 - "0" : P1₂ pin turns into an output pin of a synchronous clock.
 - "1" : P1₂ pin turns into an input pin of a synchronous clock.
 Setup of a $\overline{\text{SRDY}}_1$ output enable bit ($\overline{\text{SRDY}}_1$) when a clock synchronous serial I/O1 is selected;
 - "0" : P1₃ pin can be used as a normal I/O pin.
 - "1" : P1₃ pin turns into a SRDY_1 output pin.

(2) Notes when selecting UART

- ① When the clock asynchronous serial I/O1 (UART) is used, serial I/O2 can be used only when BRG output divided by 16 is selected as the synchronous clock.
- ② When the transmit operation is stopped, clear the transmit enable bit to "0" (transmit disabled).

● Reason

Same as (1) ②.

- ③ When the receive operation is stopped, clear the receive enable bit to "0" (receive disabled).
- ④ When the transmit/receive operation is stopped, clear the transmit enable bit to "0" (transmit disabled) and receive enable bit to "0" (receive disabled).
- ⑤ Setup of a serial I/O1 synchronous clock selection bit when a clock asynchronous (UART) serial I/O is selected;
 - "0": P1₂ pin can be used as a normal I/O pin.
 - "1": P1₂ pin turns into an input pin of an external clock.
 When clock asynchronous (UART) type serial I/O is selected, it is P1₃ pin. It can be used as a normal I/O pin.

(3) Notes common to clock synchronous serial I/O and UART

- ① Set the serial I/O control register again after the transmission and the reception circuits are reset by clearing both the transmit enable bit and the receive enable bit to "0."
- ② The transmit shift completion flag changes from "1" to "0" with a delay of 0.5 to 1.5 shift clocks. When data transmission is controlled with referring to the flag after writing the data to the transmit buffer register, note the delay.

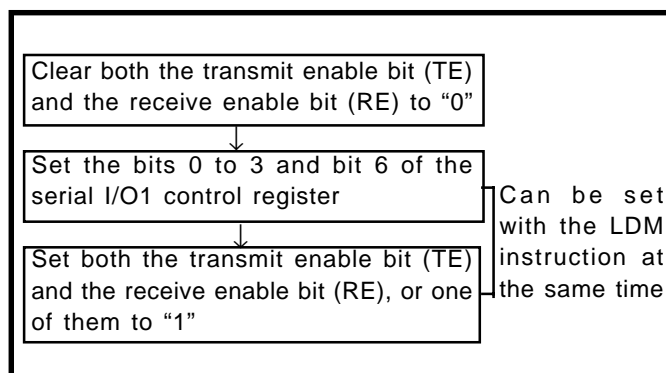


Fig. 3.3.1 Sequence of setting serial I/O1 control register again

- ③ When data transmission is executed at the state that an external clock input is selected as the synchronous clock, set "1" to the transmit enable bit while the S_{CLK1} is "H" state. Also, write to the transmit buffer register while the S_{CLK1} is "H" state.
- ④ When the transmit interrupt is used, set as the following sequence.
 - ① Serial I/O1 transmit interrupt enable bit is set to "0" (disabled).
 - ② Serial I/O1 transmit enable bit is set to "1".
 - ③ Serial I/O1 transmit interrupt request bit is set to "0".
 - ④ Serial I/O1 transmit interrupt enable bit is set to "1" (enabled).

● Reason

When the transmit enable bit is set to "1", the transmit buffer empty flag and transmit shift completion flag are set to "1".

Accordingly, even if the timing when any of the above flags is set to "1" is selected for the transmit interrupt source, interrupt request occurs and the transmit interrupt request bit is set.

- ⑤ Write to the baud rate generator (BRG) while the transmit/receive operation is stopped.

3.3.9 Notes on serial I/O2

Notes on using serial I/O2 are described below.

(1) Note on serial I/O1

Serial I/O2 can be used only when serial I/O1 is not used or serial I/O1 is used as UART and the BRG output divided by 16 is selected as the synchronous clock.

(2) Note on S_{CLK2} pin

When an external clock is selected, set "0" to bit 2 of the port P1 direction register (input mode).

(3) Note on S_{DATA2} pin

When P1₃/S_{RDY1}/S_{DATA2} pin is used as the S_{DATA} input, set "0" to bit 3 of the port P1 direction register (input mode).

When the internal clock is selected as the transfer and P1₃/S_{DATA2} pin is set to the input mode, the S_{DATA2} pin is in a high-impedance state after the data transfer is completed.

(4) Notes on serial I/O2 transmit/receive shift completion flag

- ① The transmit/receive shift completion flag of the serial I/O2 control register is "1" after transmit/receive shift is completed. In order to set "0" to this flag, set data (dummy data at receive) to the serial I/O2 register by program.
- ② Bit 7 (transmit/receive shift completion flag) of the serial I/O2 control register is set earlier than the completion of the actual shift operation for a half cycle of shift clock. Accordingly, when the shift completion is checked by using this bit, read/write the serial I/O2 register after a half or more cycle of clock from the setting "1" to this bit is checked.

3.3.10 Notes on A/D converter

Notes on A/D converter are described below.

(1) Analog input pin

Figure 3.3.2 shows the internal equivalent circuit of an analog input. In order to execute the A/D conversion correctly, to complete the charge to an internal capacitor within the specified time is required. The maximum output impedance of the analog input source required to complete the charge to a capacitor within the specified time is as follows;

About 35 k Ω (at $f(X_{IN}) = 8$ MHz)

When the maximum output impedance exceeds the above value, equip an analog input pin with an external capacitor of 0.01 μ F to 1 μ F between an analog input pin and V_{SS}.

Further, be sure to verify the operation of application products on the user side.

● Reason

An analog input pin includes the capacitor for analog voltage comparison. Accordingly, when signals from signal source with high impedance are input to an analog input pin, charge and discharge noise generates. This may cause the A/D conversion/comparison precision to be worse.

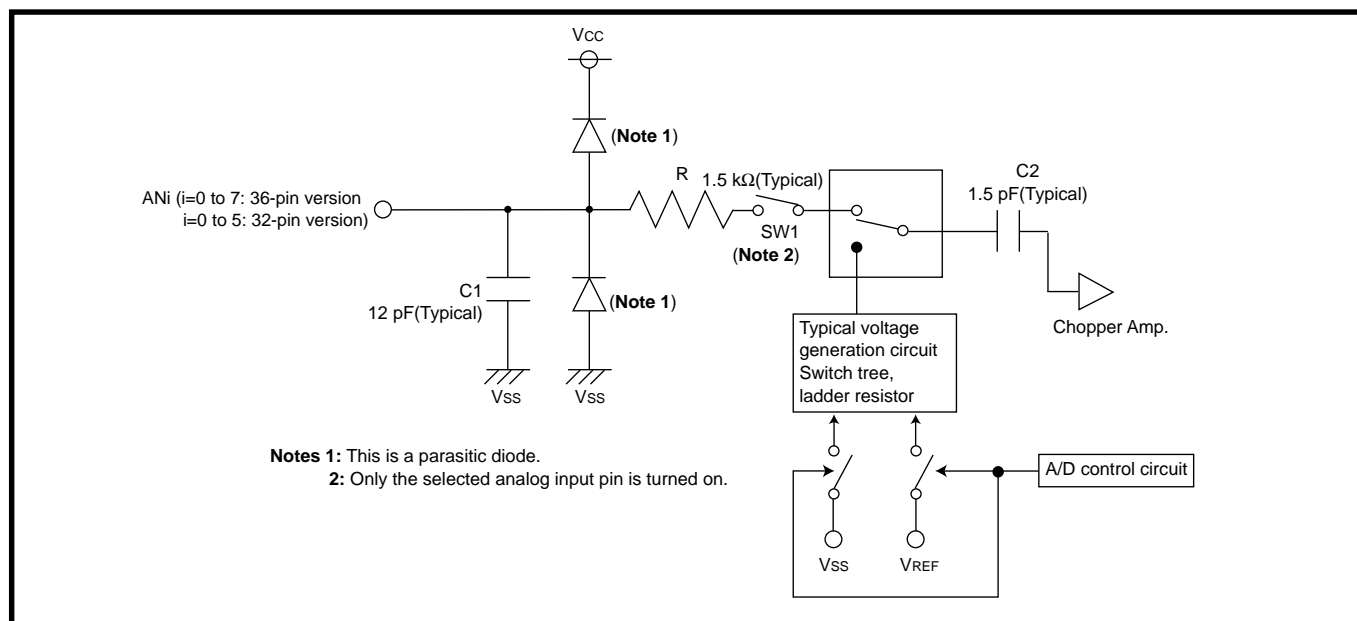


Fig. 3.3.2 Connection diagram

(2) Clock frequency during A/D conversion

The comparator consists of a capacity coupling, and a charge of the capacity will be lost if the clock frequency is too low. Thus, make sure the following during an A/D conversion.

- $f(X_{IN})$ is 500 kHz or more
- Do not execute the **STP** instruction

(3) Note on A/D converter

As for AD translation accuracy, on the following operating conditions, accuracy may become low.

- (1) Since the analog circuit inside a microcomputer becomes sensitive to noise when VREF voltage is set up lower than Vcc voltage, accuracy may become low rather than the case where VREF voltage and Vcc voltage are set up to the same value.
- (2) When VREF voltage is lower than [3.0 V], the accuracy at the low temperature may become extremely low compared with that at room temperature. When the system would be used at low temperature, the use at VREF=3.0 V or more is recommended.

3.3.11 Notes on oscillation stop detection circuit

Notes on using oscillation stop detection circuit are described below.

(1) Note on on-chip oscillator

- ① The 7540 Group starts operation by the on-chip oscillator.
- ② On-chip oscillator operation
The clock frequency of the on-chip oscillator depends on the supply voltage and the operation temperature range.
Be careful that variable frequencies when designing application products.

(2) Notes on oscillation circuit stop detection circuit

- ① When the stop mode is used, set the oscillation stop detection function to "invalid".
- ② When $f(X_{IN})$ oscillation is stopped, set the oscillation stop detection function to "invalid".
- ③ The oscillation stop detection circuit is not included in the emulator MCU "M37540RSS".

(3) Notes on stop mode

- ① When the stop mode is used, set the oscillation stop detection function to "invalid".
- ② When the stop mode is used, set "0" (**STP** instruction enabled) to the **STP** instruction disable bit of the watchdog timer control register.
- ③ Timer 1 can be used to set the oscillation stabilizing time after release of the **STP** instruction. The oscillation stabilizing time after release of **STP** instruction can be selected from "set automatically"/"not set automatically" by the oscillation stabilizing time set bit after release of the **STP** instruction of MISRG. When "0" is set to this bit, "01₁₆" is set to timer 1 and "FF₁₆" is set to prescaler 1 automatically. When "1" is set to this bit, nothing is set to timer 1 and prescaler 1. Therefore, set the wait time according to the oscillation stabilizing time of the oscillation. Also, when timer 1 is used, set values again to timer 1 and prescaler 1 after system is returned from the stop mode.
- ④ The **STP** instruction cannot be used during CPU is operating by the on-chip oscillator.
- ⑤ When the stop mode is used, stop the on-chip oscillator oscillation.
- ⑥ Do not execute the **STP** instruction during the A/D conversion.

(4) Note on wait mode

- ① When the wait mode is used, stop the clock except the operation clock source.

(5) Notes on state transition

- ① When the operation clock source is $f(X_{IN})$, the CPU clock division ratio can be selected from the following;
 - $f(X_{IN})/2$ (high-speed mode)
 - $f(X_{IN})/8$ (middle-speed mode)
 - $f(X_{IN})$ (double-speed mode)
 The double-speed mode can be used only at ceramic oscillation.
Do not use the mode at RC oscillation.
- ② Stabilize the $f(X_{IN})$ oscillation to change the operation clock source from the on-chip oscillator to $f(X_{IN})$.

- ③ When the on-chip oscillation is used as the operation clock, the CPU clock division ratio is the middle-speed mode.
- ④ When the state transition state 2→state 3→state 4 is performed, execute the NOP instruction as shown below according to the division ratio of CPU clock.
- CPUM₇₆→10₂ (State 2→state 3)
 - NOP instruction
 - CPUM₄→1₂ (State 3→state 4)
- Double-speed mode at on-chip oscillator: NOPX3
 High-speed mode at on-chip oscillator: NOPX1
 Middle-speed mode at on-chip oscillator: NOPX0

(6) Switch of ceramic and RC oscillations

After releasing reset the operation starts by starting an on-chip oscillator. Then, a ceramic oscillation or an RC oscillation is selected by setting bit 5 of the CPU mode register.

(7) Double-speed mode

When a ceramic oscillation is selected, a double-speed mode can be used. Do not use it when an RC oscillation is selected.

(8) Clock division ratio, X_{IN} oscillation control, on-chip oscillator control

The state transition shown in Figure 3.3.3 can be performed by setting the clock division ratio selection bits (bits 7 and 6), X_{IN} oscillation control bit (bit 4), on-chip oscillator oscillation control bit (bit 3) of CPU mode register. Be careful of notes on use in Figure 3.3.3.

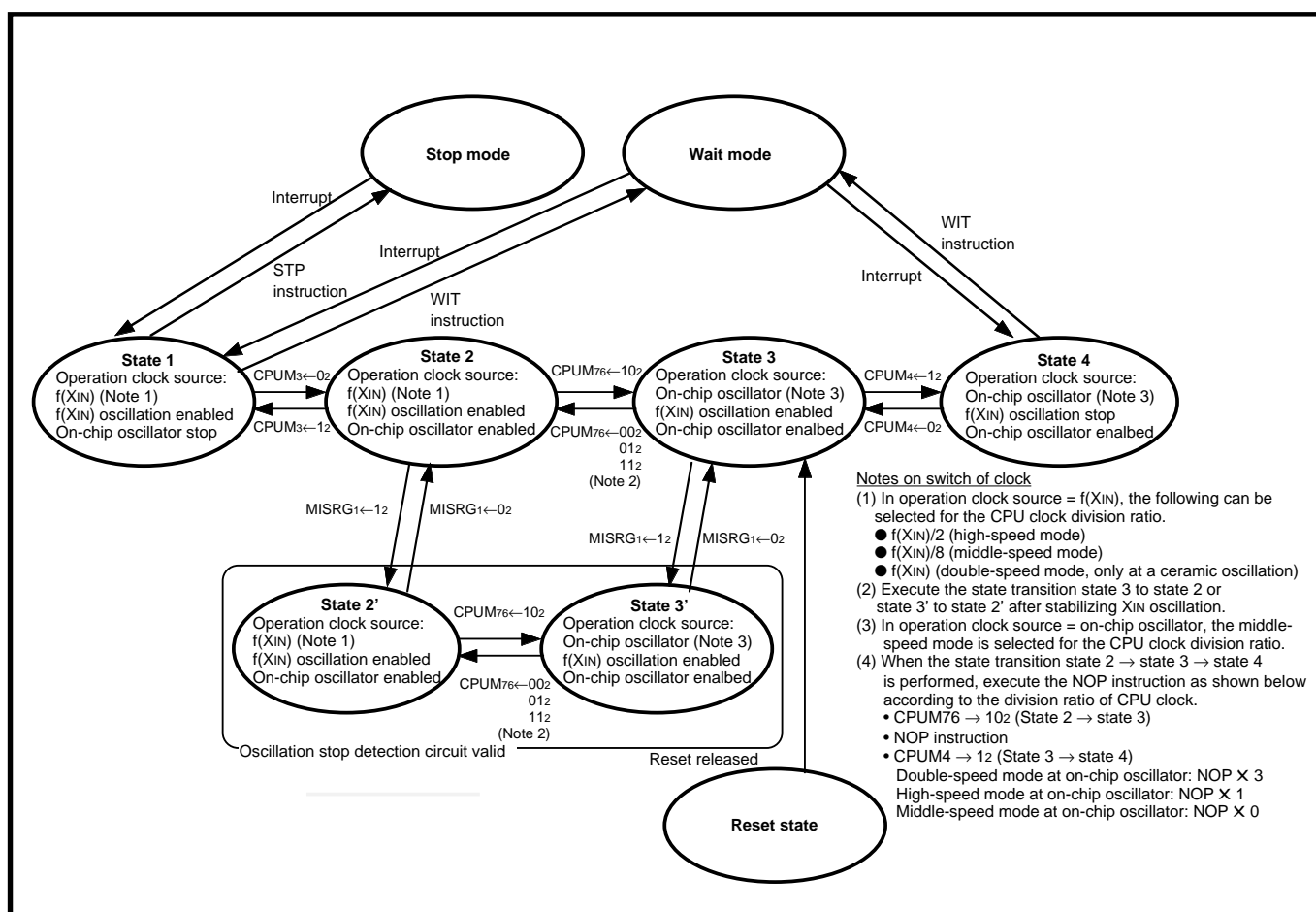


Fig. 3.3.3 State transition

3.3.12 Notes on CPU mode register

(1) Switching method of CPU mode register after releasing reset

Switch the CPU mode register (CPUM) at the head of program after releasing reset in the following method.

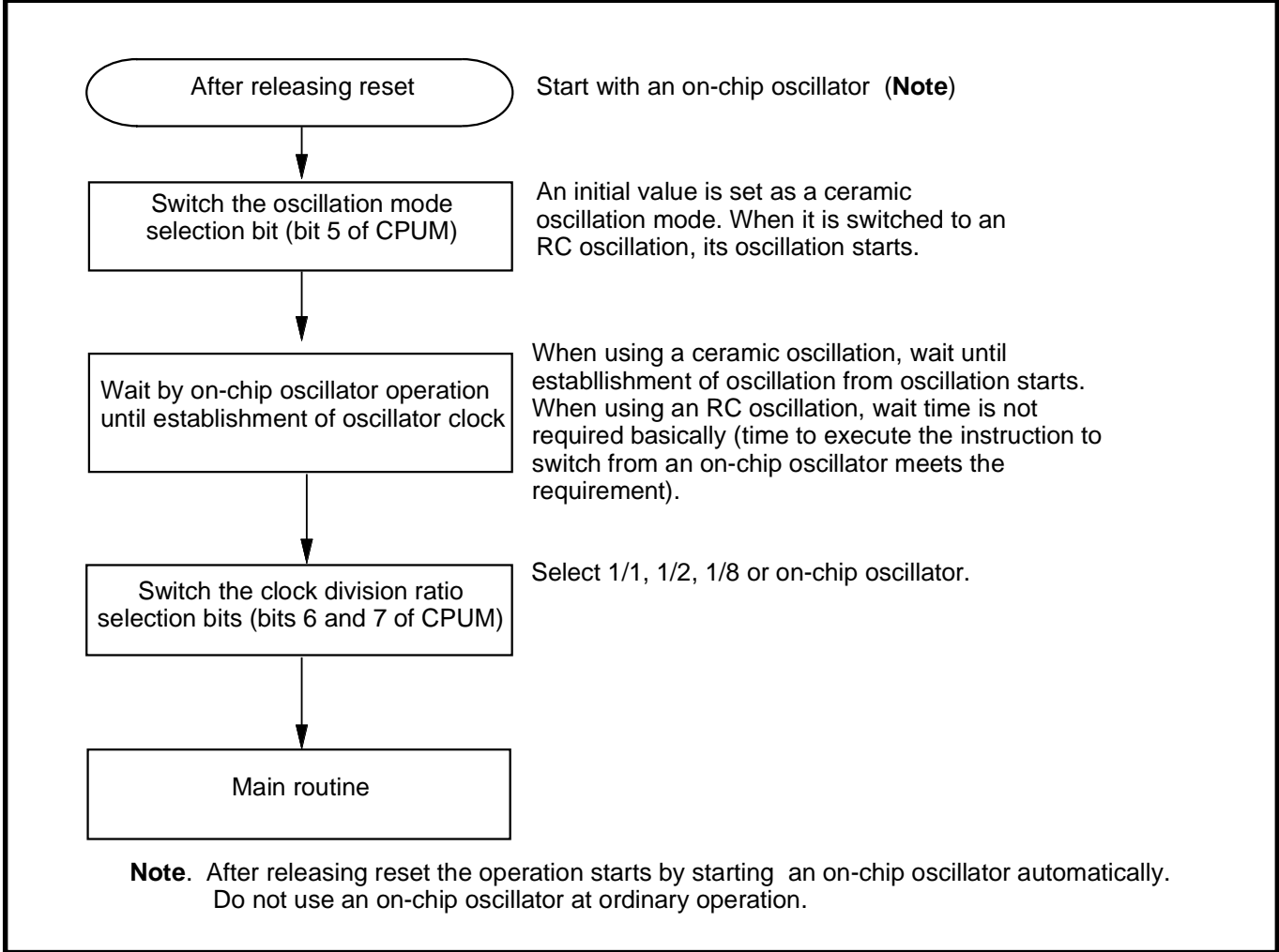


Fig. 3.3.4 Switching method of CPU mode register

(2) CPU mode register

Bits 5, 1 and 0 of CPU mode register are used to select oscillation mode and to control operation modes of the microcomputer. In order to prevent the dead-lock by error-writing (ex. program run-away), these bits can be rewritten only once after releasing reset. After rewriting it is disable to write any data to the bit. (The emulator MCU "M37540RSS" is excluded.)

Also, when the read-modify-write instructions (SEB, CLB) are executed to bits 2 to 4, 6 and 7, bits 5, 1 and 0 are locked.

3.3.13 Notes on interrupts

(1) Switching external interrupt detection edge

For the products able to switch the external interrupt detection edge, switch it as the following sequence.

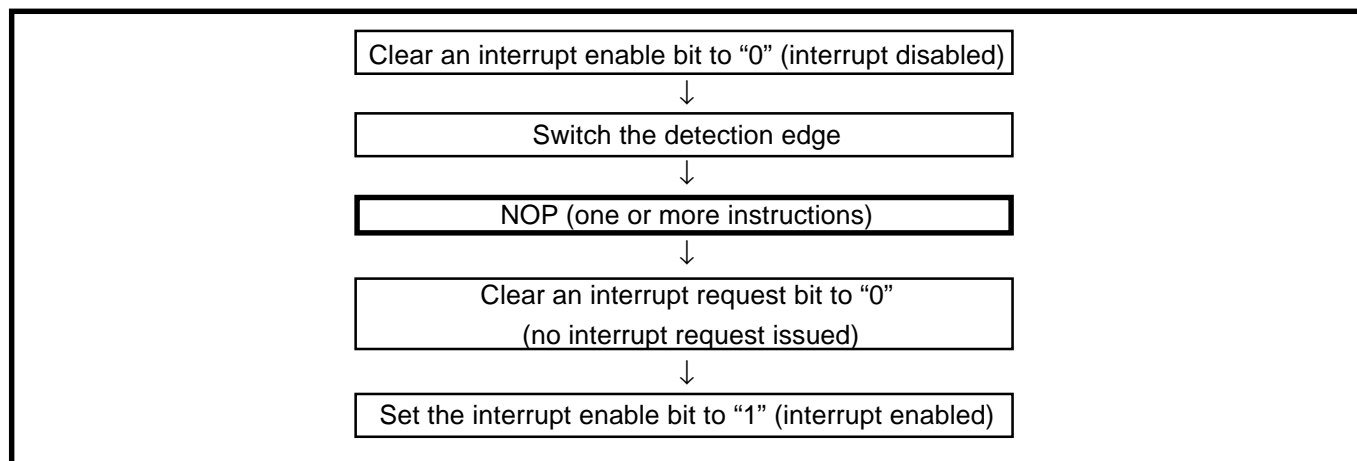


Fig. 3.3.5 Sequence of switch the detection edge

- Reason

The interrupt circuit recognizes the switching of the detection edge as the change of external input signals. This may cause an unnecessary interrupt.

(2) Check of interrupt request bit

When executing the **BBC** or **BBS** instruction to an interrupt request bit of an interrupt request register immediately after this bit is set to "0" by using a data transfer instruction, execute one or more instructions before executing the **BBC** or **BBS** instruction.

- Reason

If the **BBC** or **BBS** instruction is executed immediately after an interrupt request bit of an interrupt request register is cleared to "0", the value of the interrupt request bit before being cleared to "0" is read.

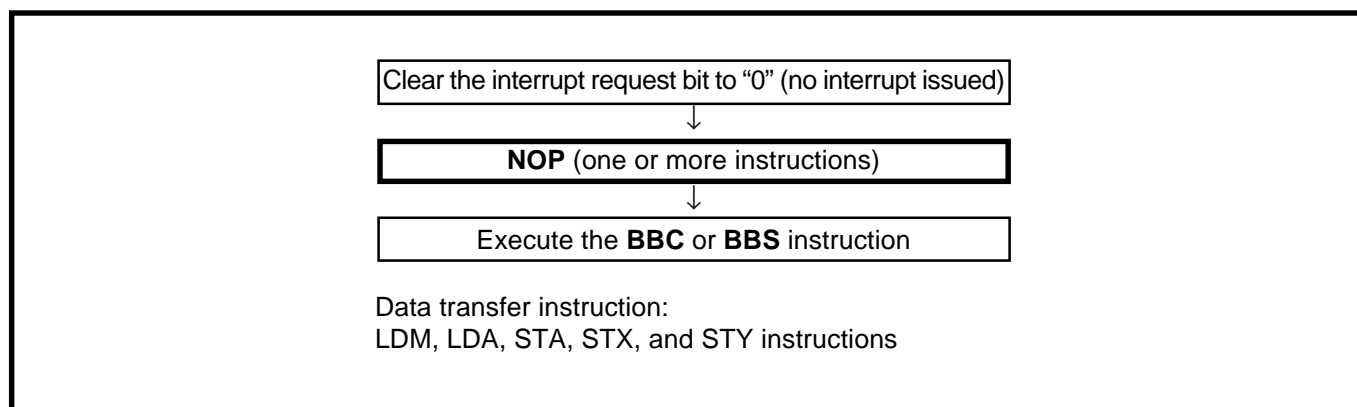


Fig. 3.3.6 Sequence of check of interrupt request bit

(3) Structure of interrupt control register 2

Fix the bit 7 of the interrupt control register 1 to "0". Figure 3.3.7 shows the structure of the interrupt control register 2.

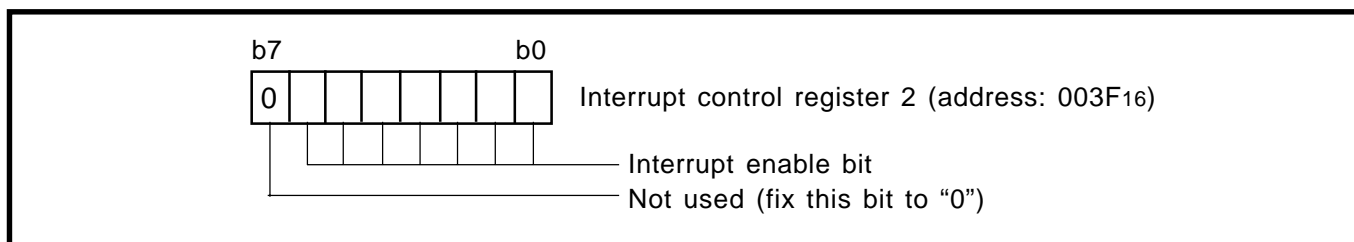


Fig. 3.3.7 Structure of interrupt control register 2

(4) Interrupt

When setting the followings, the interrupt request bit may be set to "1".

- When switching external interrupt active edge

Related register: Interrupt edge selection register (address 003A₁₆)

Timer X mode register (address 002B₁₆)

Timer A mode register (address 001D₁₆)

When not requiring the interrupt occurrence synchronized with these setting, take the following sequence.

- ① Set the corresponding interrupt enable bit to "0" (disabled).
- ② Set the interrupt edge select bit (active edge switch bit).
- ③ Set the corresponding interrupt request bit to "0" after 1 or more instructions have been executed.
- ④ Set the corresponding interrupt enable bit to "1" (enabled).

3.3.14 Notes on $\overline{\text{RESET}}$ pin**(1) Connecting capacitor**

In case where the $\overline{\text{RESET}}$ signal rise time is long, connect a ceramic capacitor or others across the $\overline{\text{RESET}}$ pin and the Vss pin. And use a 1000 pF or more capacitor for high frequency use. When connecting the capacitor, note the following :

- Make the length of the wiring which is connected to a capacitor as short as possible.
- Be sure to verify the operation of application products on the user side.

● Reason

If the several nanosecond or several ten nanosecond impulse noise enters the $\overline{\text{RESET}}$ pin, it may cause a microcomputer failure.

3.3.15 Notes on programming

(1) Processor status register

① Initializing of processor status register

Flags which affect program execution must be initialized after a reset.

In particular, it is essential to initialize the T and D flags because they have an important effect on calculations.

● Reason

After a reset, the contents of the processor status register (PS) are undefined except for the I flag which is "1".

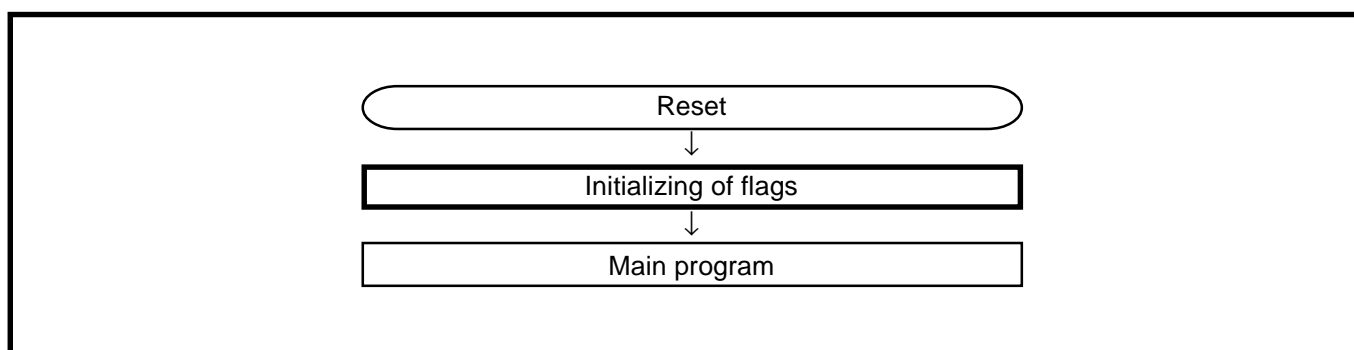


Fig. 3.3.8 Initialization of processor status register

② How to reference the processor status register

To reference the contents of the processor status register (PS), execute the **PHP** instruction once then read the contents of (S+1). If necessary, execute the **PLP** instruction to return the PS to its original status.

A **NOP** instruction should be executed after every **PLP** instruction.

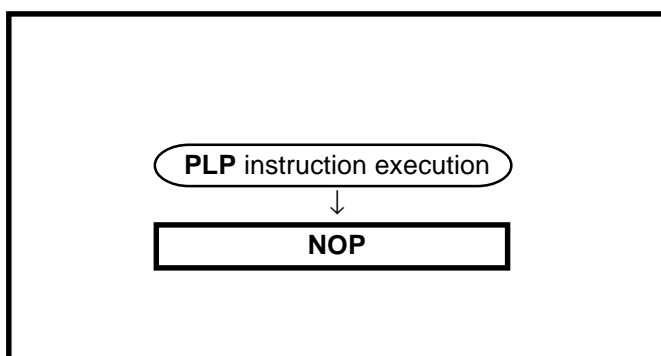


Fig. 3.3.9 Sequence of PLP instruction execution

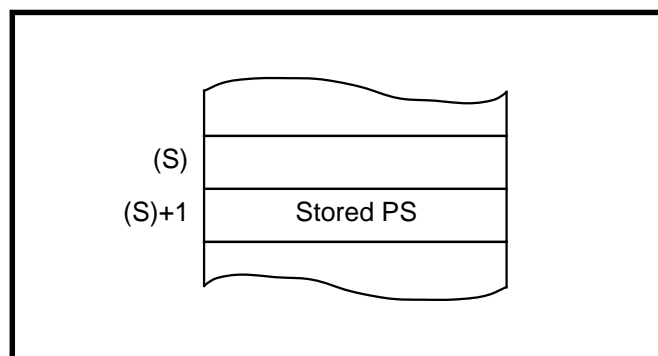


Fig. 3.3.10 Stack memory contents after PHP instruction execution

(2) Decimal calculations

① Execution of decimal calculations

The **ADC** and **SBC** are the only instructions which will yield proper decimal notation, set the decimal mode flag (D) to “1” with the **SED** instruction. After executing the **ADC** or **SBC** instruction, execute another instruction before executing the **SEC**, **CLC**, or **CLD** instruction.

② Notes on status flag in decimal mode

When decimal mode is selected, the values of three of the flags in the status register (the N, V, and Z flags) are invalid after a **ADC** or **SBC** instruction is executed.

The carry flag (C) is set to “1” if a carry is generated as a result of the calculation, or is cleared to “0” if a borrow is generated. To determine whether a calculation has generated a carry, the C flag must be initialized to “0” before each calculation. To check for a borrow, the C flag must be initialized to “1” before each calculation.

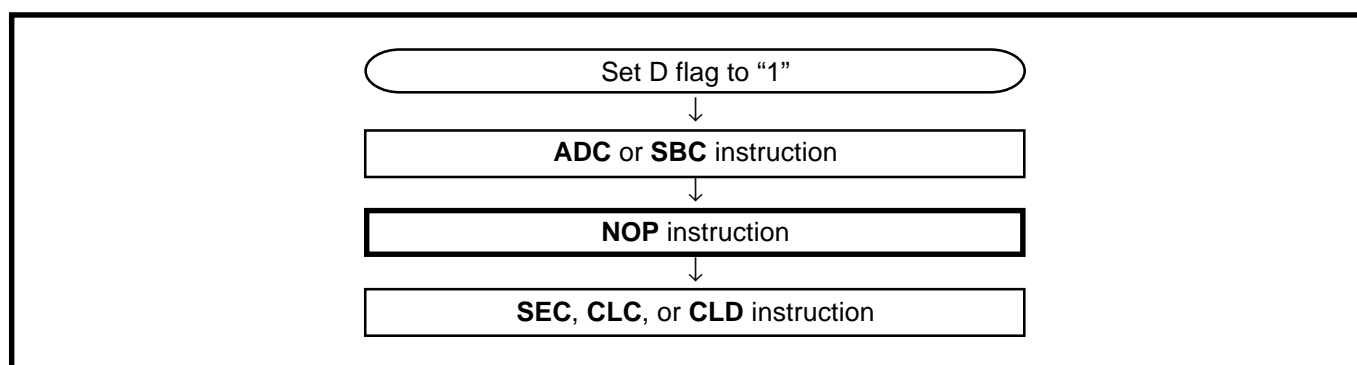


Fig. 3.3.11 Status flag at decimal calculations

(3) JMP instruction

When using the **JMP** instruction in indirect addressing mode, do not specify the last address on a page as an indirect address.

(4) Interrupts

The contents of the interrupt request bit do not change even if the **BBC** or **BBS** instruction is executed immediately after they are changed by program because this instruction is executed for the previous contents. For executing the instruction for the changed contents, execute one instruction before executing the **BBC** or **BBS** instruction.

(5) Ports

- The values of the port direction registers cannot be read.

That is, it is impossible to use the **LDA** instruction, memory operation instruction when the T flag is “1”, addressing mode using direction register values as qualifiers, and bit test instructions such as **BBC** and **BBS**.

It is also impossible to use bit operation instructions such as **CLB** and **SEB** and read/modify/write instructions of direction registers for calculations such as **ROR**.

For setting direction registers, use the **LDM** instruction, **STA** instruction, etc.

(6) A/D Conversion

Do not execute the **STP** instruction during A/D conversion.

(7) Instruction Execution Timing

The instruction execution time can be obtained by multiplying the frequency of the internal clock f by the number of cycles mentioned in the machine-language instruction table.

The frequency of the internal clock f is the same as that of the X_{IN} in double-speed mode, twice the X_{IN} cycle in high-speed mode and 8 times the X_{IN} cycle in middle-speed mode.

(8) CPU Mode Register

The oscillation mode selection bit and processor mode bits can be rewritten only once after releasing reset. However, after rewriting it is disable to write any value to the bit. (Emulator MCU is excluded.)

When a ceramic oscillation is selected, a double-speed mode of the clock division ratio selection bits can be used. Do not use it when an RC oscillation is selected.

3.3.16 Programming and test of built-in PROM version

As for in the One Time PROM version (shipped in blank), its built-in PROM can be read or programmed with a general-purpose PROM programmer using a special programming adapter.

The programming test and screening for PROM of the One Time PROM version (shipped in blank) are not performed in the assembly process and the following processes. To ensure reliability after programming, performing programming and test according to the Figure 3.3.12 before actual use are recommended.

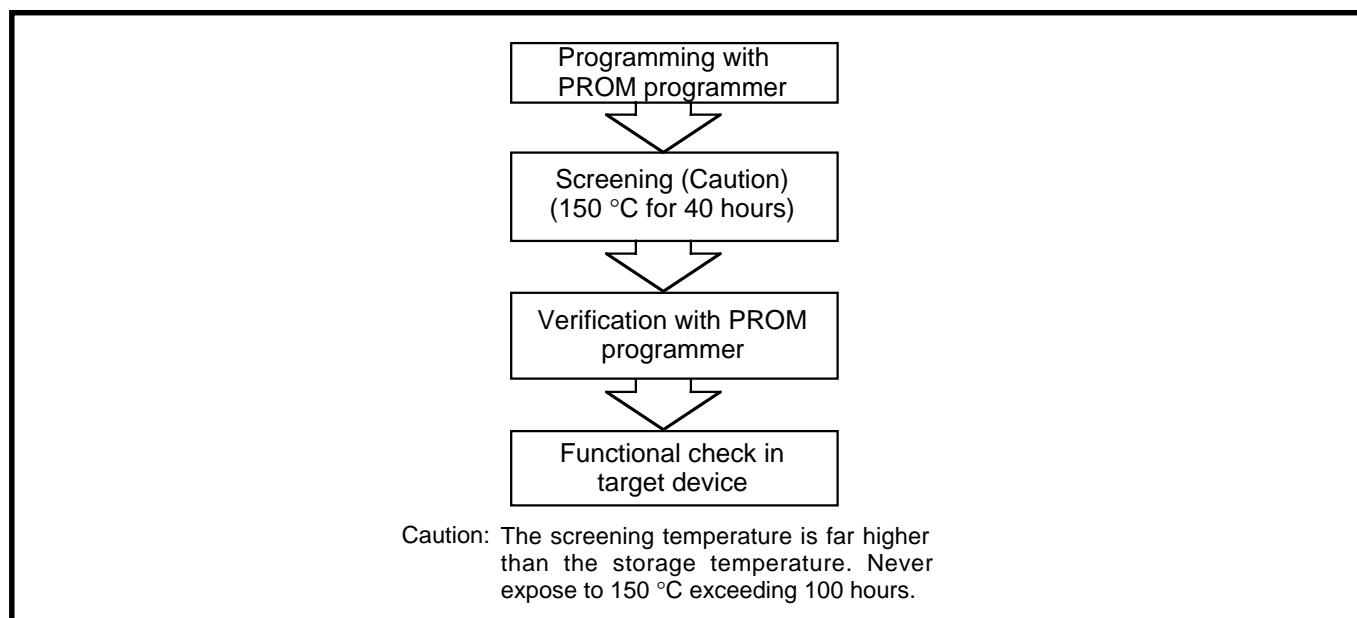


Fig. 3.3.12 Programming and testing of One Time PROM version

(1) One Time PROM Version

The CNVss pin is connected to the internal memory circuit block by a low-ohmic resistance, since it has the multiplexed function to be a programmable power source pin (V_{PP} pin) as well.

To improve the noise reduction, connect a track between CNVss pin and Vss pin with 1 to 10 k Ω resistance.

The mask ROM version track of CNVss pin has no operational interference even if it is connected via a resistor.

3.3.17 Handling of Power Source Pin

In order to avoid a latch-up occurrence, connect a capacitor suitable for high frequencies as bypass capacitor between power source pin (V_{CC} pin) and GND pin (V_{SS} pin). Besides, connect the capacitor to as close as possible. For bypass capacitor which should not be located too far from the pins to be connected, a ceramic capacitor of 0.01 μF to 0.1 μF is recommended.

3.3.18 Notes on built-in PROM version

(1) Programming adapter

Use a special programming adapter shown in Table 3.3.1 and a general-purpose PROM programmer when reading from or programming to the built-in PROM in the built-in PROM version.

Table 3.3.1 Programming adapters

| Part Number | Programming adapter |
|---|---------------------|
| M37540E8GP (One Time PROM version shipped in blank) | PCA7435GPG03 |
| M37540E8SP (One Time PROM version shipped in blank) | PCA7435SPG02 |
| M37540E8FP (One Time PROM version shipped in blank) | PCA7435FPG02 |

(2) Programming/reading

In PROM mode, operation is the same as that of the M5M27C101AK, but programming conditions of PROM programmer are not set automatically because there are no internal device ID codes. Accurately set the following conditions for data programming /reading. Take care not to apply 21 V to VPP pin (is also used as the CNVss pin), or the product may be permanently damaged.

- Programming voltage: 12.5 V
- Setting of PROM programmer switch: refer to Table 3.3.2.

Table 3.3.2 PROM programmer address setting

| Part Number | PROM programmer start address | PROM programmer end address |
|-------------|---|---|
| M37540E8GP | Address 08080 ₁₆ (Note) | Address 0FFFD ₁₆ (Note) |
| M37540E8SP | | |
| M37540E8FP | | |

Note: Addresses 8080₁₆ to FFFD₁₆ in the built-in PROM corresponds to addresses 08080₁₆ to 0FFFD₁₆ in the PROM programmer.

3.3.19 Note on Power Source Voltage

When the power source voltage value of a microcomputer is less than the value which is indicated as the recommended operating conditions, the microcomputer does not operate normally and may perform unstable operation.

In a system where the power source voltage drops slowly when the power source voltage drops or the power supply is turned off, reset a microcomputer when the supply voltage is less than the recommended operating conditions and design a system not to cause errors to the system by this unstable operation.

3.3.20 Electric Characteristic Differences Among Mask ROM and One Time PROM Version MCUs

There are differences in electric characteristics, operation margin, noise immunity, and noise radiation among mask ROM and One Time PROM version MCUs due to the differences in the manufacturing processes.

When manufacturing an application system with One Time PROM version and then switching to use of the mask ROM version, perform sufficient evaluations for the commercial samples of the mask ROM version.

3.4 Countermeasures against noise

3.4.1 Shortest wiring length

(1) Package

Select the smallest possible package to make the total wiring length short.

● Reason

The wiring length depends on a microcomputer package. Use of a small package, for example QFP and not DIP, makes the total wiring length short to reduce influence of noise.

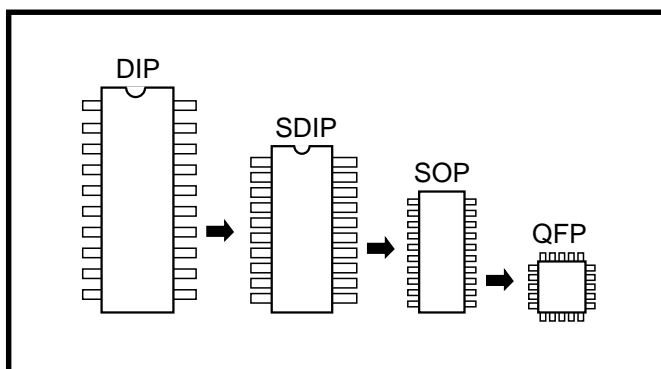


Fig. 3.4.1 Selection of packages

(2) Wiring for $\overline{\text{RESET}}$ pin

Make the length of wiring which is connected to the $\overline{\text{RESET}}$ pin as short as possible. Especially, connect a capacitor across the $\overline{\text{RESET}}$ pin and the V_{SS} pin with the shortest possible wiring (within 20mm).

● Reason

The width of a pulse input into the $\overline{\text{RESET}}$ pin is determined by the timing necessary conditions. If noise having a shorter pulse width than the standard is input to the $\overline{\text{RESET}}$ pin, the reset is released before the internal state of the microcomputer is completely initialized. This may cause a program runaway.

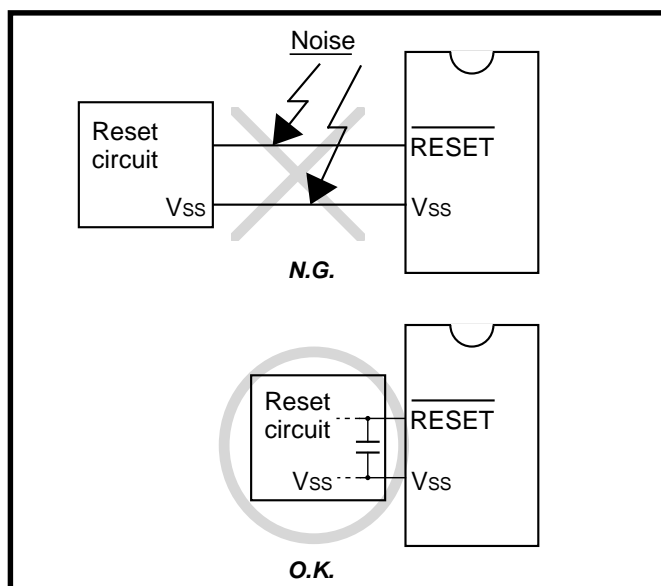


Fig. 3.4.2 Wiring for the $\overline{\text{RESET}}$ pin

(3) Wiring for clock input/output pins

- Make the length of wiring which is connected to clock I/O pins as short as possible.
- Make the length of wiring (within 20mm) across the grounding lead of a capacitor which is connected to an oscillator and the Vss pin of a microcomputer as short as possible.
- Separate the Vss pattern only for oscillation from other Vss patterns.

● Reason

If noise enters clock I/O pins, clock waveforms may be deformed. This may cause a program failure or program runaway. Also, if a potential difference is caused by the noise between the Vss level of a microcomputer and the Vss level of an oscillator, the correct clock will not be input in the microcomputer.

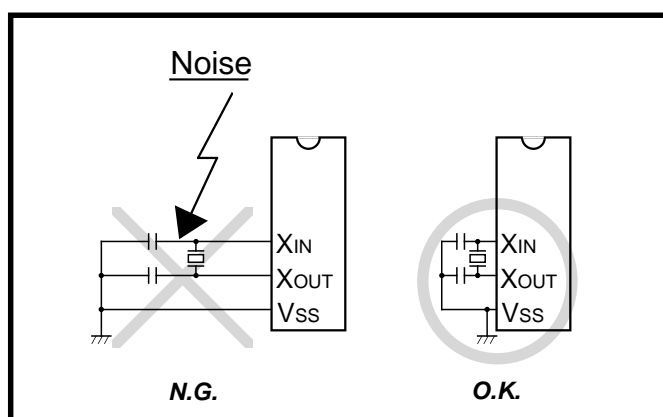


Fig. 3.4.3 Wiring for clock I/O pins

(4) Wiring to CNVss pin

Connect the CNVss pin to the Vss pin with the shortest possible wiring.

● Reason

The processor mode of a microcomputer is influenced by a potential at the CNVss pin. If a potential difference is caused by the noise between pins CNVss and Vss, the processor mode may become unstable. This may cause a microcomputer malfunction or a program runaway.

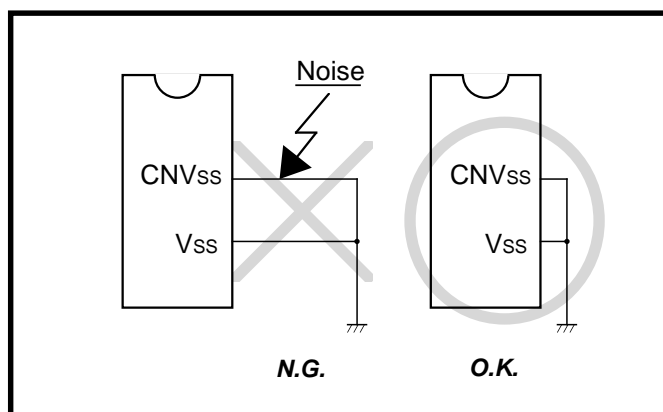


Fig. 3.4.4 Wiring for CNVss pin

(5) Wiring to VPP pin of One Time PROM version

Connect an approximately 5 k Ω resistor to the VPP pin the shortest possible in series and also to the VSS pin. When not connecting the resistor, make the length of wiring between the VPP pin and the VSS pin the shortest possible.

Note: Even when a circuit which included an approximately 5 k Ω resistor is used in the Mask ROM version, the microcomputer operates correctly.

● Reason

The VPP pin of the One Time PROM is the power source input pin for the built-in PROM. When programming in the built-in PROM, the impedance of the VPP pin is low to allow the electric current for writing flow into the PROM. Because of this, noise can enter easily. If noise enters the VPP pin, abnormal instruction codes or data are read from the built-in PROM, which may cause a program runaway.

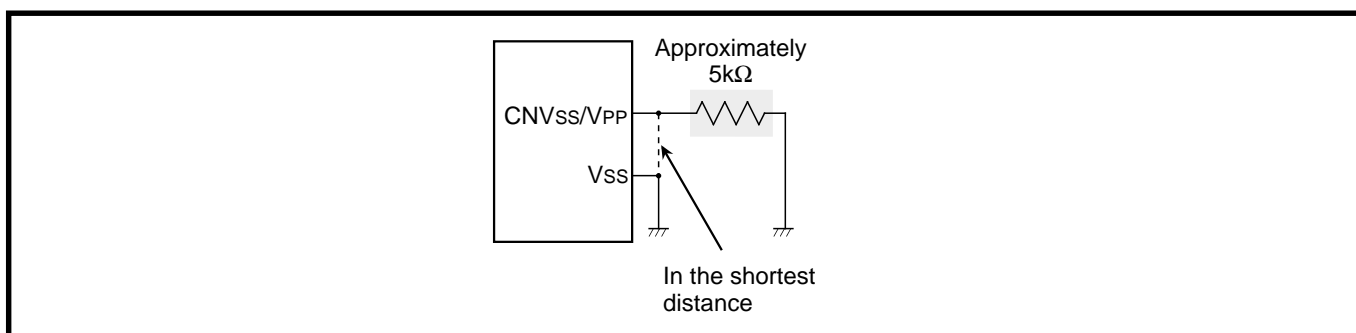


Fig. 3.4.5 Wiring for the VPP pin of the One Time PROM

3.4.2 Connection of bypass capacitor across Vss line and Vcc line

Connect an approximately 0.1 μ F bypass capacitor across the VSS line and the VCC line as follows:

- Connect a bypass capacitor across the VSS pin and the VCC pin at equal length.
- Connect a bypass capacitor across the VSS pin and the VCC pin with the shortest possible wiring.
- Use lines with a larger diameter than other signal lines for VSS line and VCC line.
- Connect the power source wiring via a bypass capacitor to the VSS pin and the VCC pin.

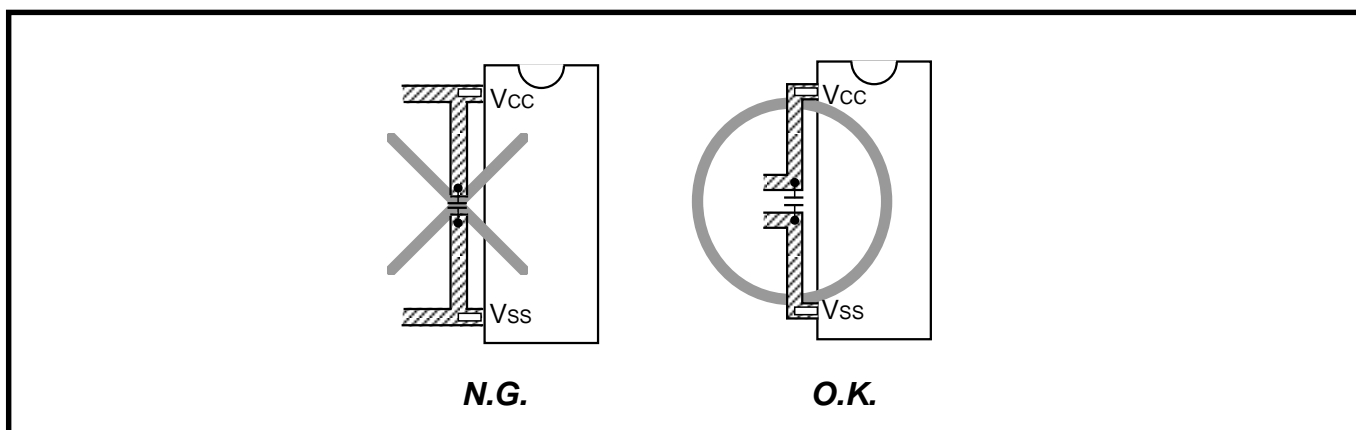


Fig. 3.4.6 Bypass capacitor across the Vss line and the Vcc line

3.4.3 Wiring to analog input pins

- Connect an approximately $100\ \Omega$ to $1\ \text{k}\Omega$ resistor to an analog signal line which is connected to an analog input pin in series. Besides, connect the resistor to the microcomputer as close as possible.
- Connect an approximately $1000\ \text{pF}$ capacitor across the Vss pin and the analog input pin. Besides, connect the capacitor to the Vss pin as close as possible. Also, connect the capacitor across the analog input pin and the Vss pin at equal length.

● Reason

Signals which is input in an analog input pin (such as an A/D converter/comparator input pin) are usually output signals from sensor. The sensor which detects a change of event is installed far from the printed circuit board with a microcomputer, the wiring to an analog input pin is longer necessarily. This long wiring functions as an antenna which feeds noise into the microcomputer, which causes noise to an analog input pin.

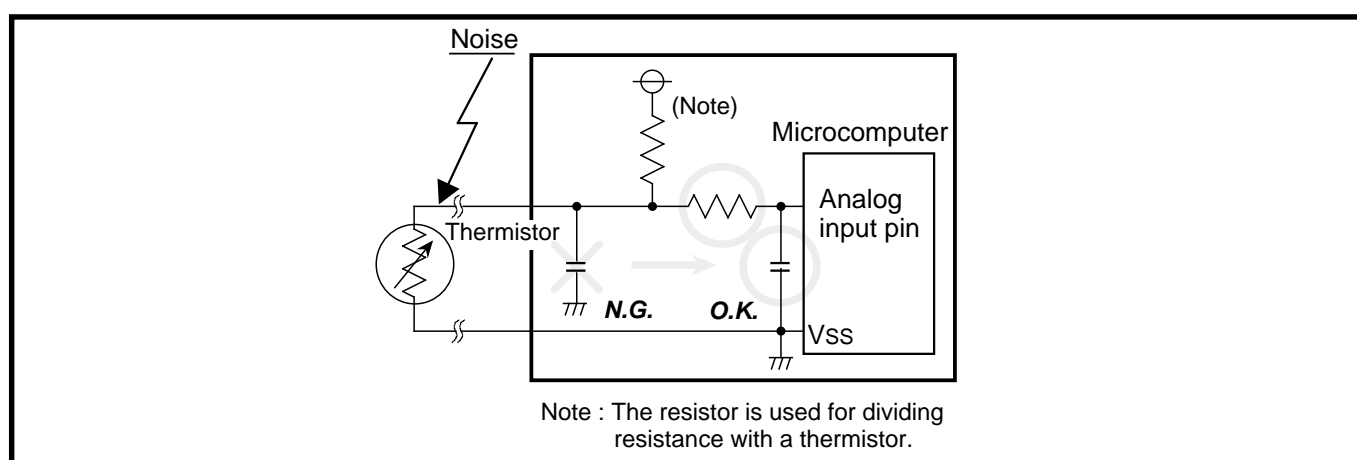


Fig. 3.4.7 Analog signal line and a resistor and a capacitor

3.4.4 Oscillator concerns

Take care to prevent an oscillator that generates clocks for a microcomputer operation from being affected by other signals.

(1) Keeping oscillator away from large current signal lines

Install a microcomputer (and especially an oscillator) as far as possible from signal lines where a current larger than the tolerance of current value flows.

● Reason

In the system using a microcomputer, there are signal lines for controlling motors, LEDs, and thermal heads or others. When a large current flows through those signal lines, strong noise occurs because of mutual inductance.

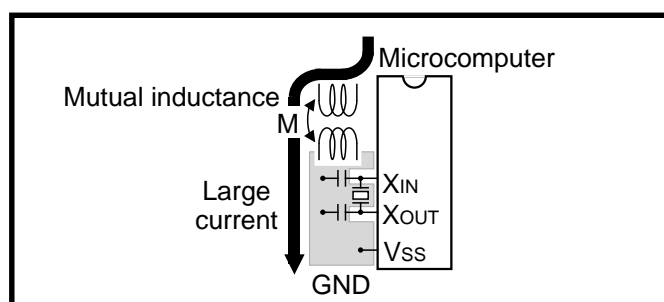


Fig. 3.4.8 Wiring for a large current signal line

(2) Installing oscillator away from signal lines where potential levels change frequently

Install an oscillator and a connecting pattern of an oscillator away from signal lines where potential levels change frequently. Also, do not cross such signal lines over the clock lines or the signal lines which are sensitive to noise.

● Reason

Signal lines where potential levels change frequently (such as the CNTR pin signal line) may affect other lines at signal rising edge or falling edge. If such lines cross over a clock line, clock waveforms may be deformed, which causes a microcomputer failure or a program runaway.

3) Oscillator protection using Vss pattern

As for a two-sided printed circuit board, print a Vss pattern on the underside (soldering side) of the position (on the component side) where an oscillator is mounted.

Connect the Vss pattern to the microcomputer Vss pin with the shortest possible wiring. Besides, separate this Vss pattern from other Vss patterns.

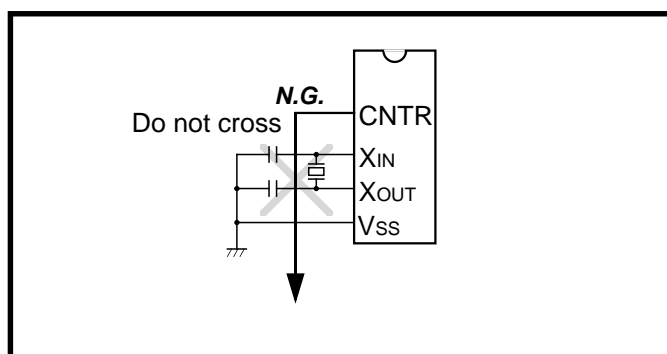


Fig. 3.4.9 Wiring of signal lines where potential levels change frequently

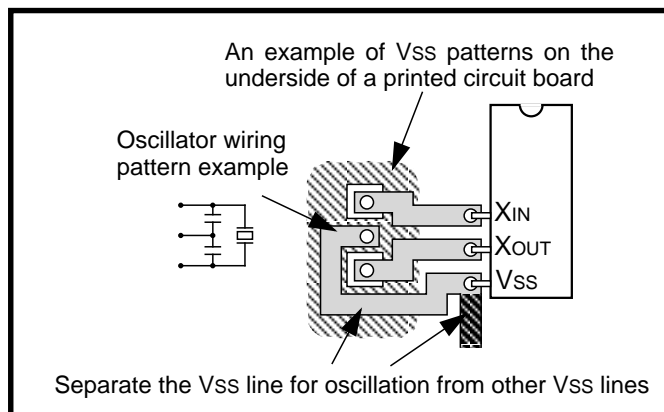


Fig. 3.4.10 Vss pattern on the underside of an oscillator

3.4.5 Setup for I/O ports

Setup I/O ports using hardware and software as follows:

<Hardware>

- Connect a resistor of 100 Ω or more to an I/O port in series.

<Software>

- As for an input port, read data several times by a program for checking whether input levels are equal or not.
- As for an output port, since the output data may reverse because of noise, rewrite data to its port latch at fixed periods.
- Rewrite data to direction registers and pull-up control registers at fixed periods.

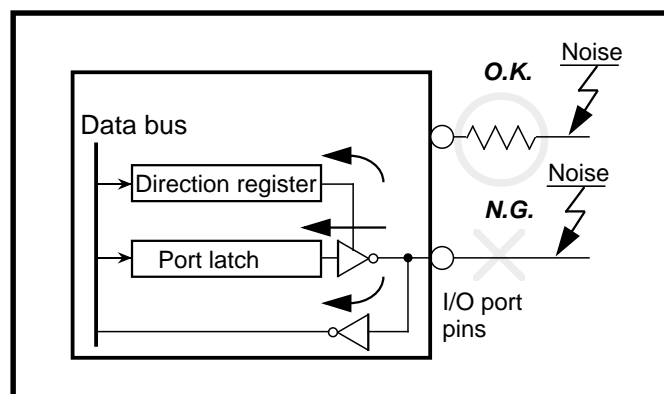


Fig. 3.4.11 Setup for I/O ports

Note: When a direction register is set for input port again at fixed periods, a several-nanosecond short pulse may be output from this port. If this is undesirable, connect a capacitor to this port to remove the noise pulse.

3.4.6 Providing of watchdog timer function by software

If a microcomputer runs away because of noise or others, it can be detected by a software watchdog timer and the microcomputer can be reset to normal operation. This is equal to or more effective than program runaway detection by a hardware watchdog timer. The following shows an example of a watchdog timer provided by software.

In the following example, to reset a microcomputer to normal operation, the main routine detects errors of the interrupt processing routine and the interrupt processing routine detects errors of the main routine. This example assumes that interrupt processing is repeated multiple times in a single main routine processing.

<The main routine>

- Assigns a single byte of RAM to a software watchdog timer (SWDT) and writes the initial value N in the SWDT once at each execution of the main routine. The initial value N should satisfy the following condition:
 $N+1 \geq$ (Counts of interrupt processing executed in each main routine)
 As the main routine execution cycle may change because of an interrupt processing or others, the initial value N should have a margin.
- Watches the operation of the interrupt processing routine by comparing the SWDT contents with counts of interrupt processing after the initial value N has been set.
- Detects that the interrupt processing routine has failed and determines to branch to the program initialization routine for recovery processing in the following case:
 If the SWDT contents do not change after interrupt processing.

<The interrupt processing routine>

- Decrements the SWDT contents by 1 at each interrupt processing.
- Determines that the main routine operates normally when the SWDT contents are reset to the initial value N at almost fixed cycles (at the fixed interrupt processing count).
- Detects that the main routine has failed and determines to branch to the program initialization routine for recovery processing in the following case:
 If the SWDT contents are not initialized to the initial value N but continued to decrement and if they reach 0 or less.

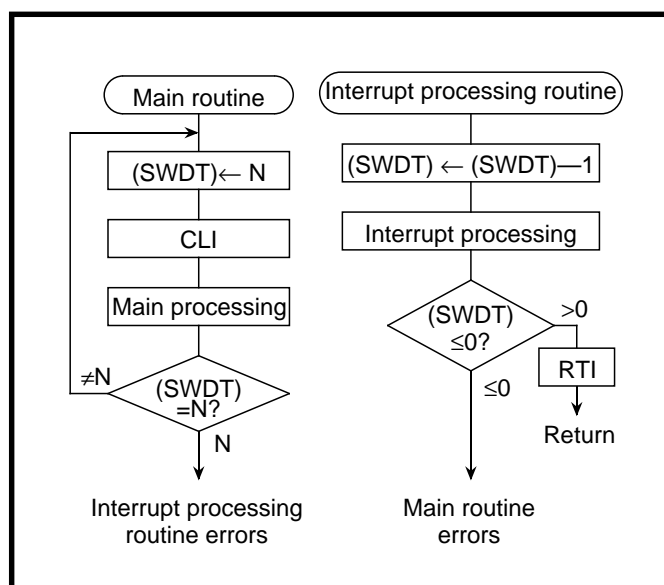


Fig. 3.4.12 Watchdog timer by software

3.5 List of registers

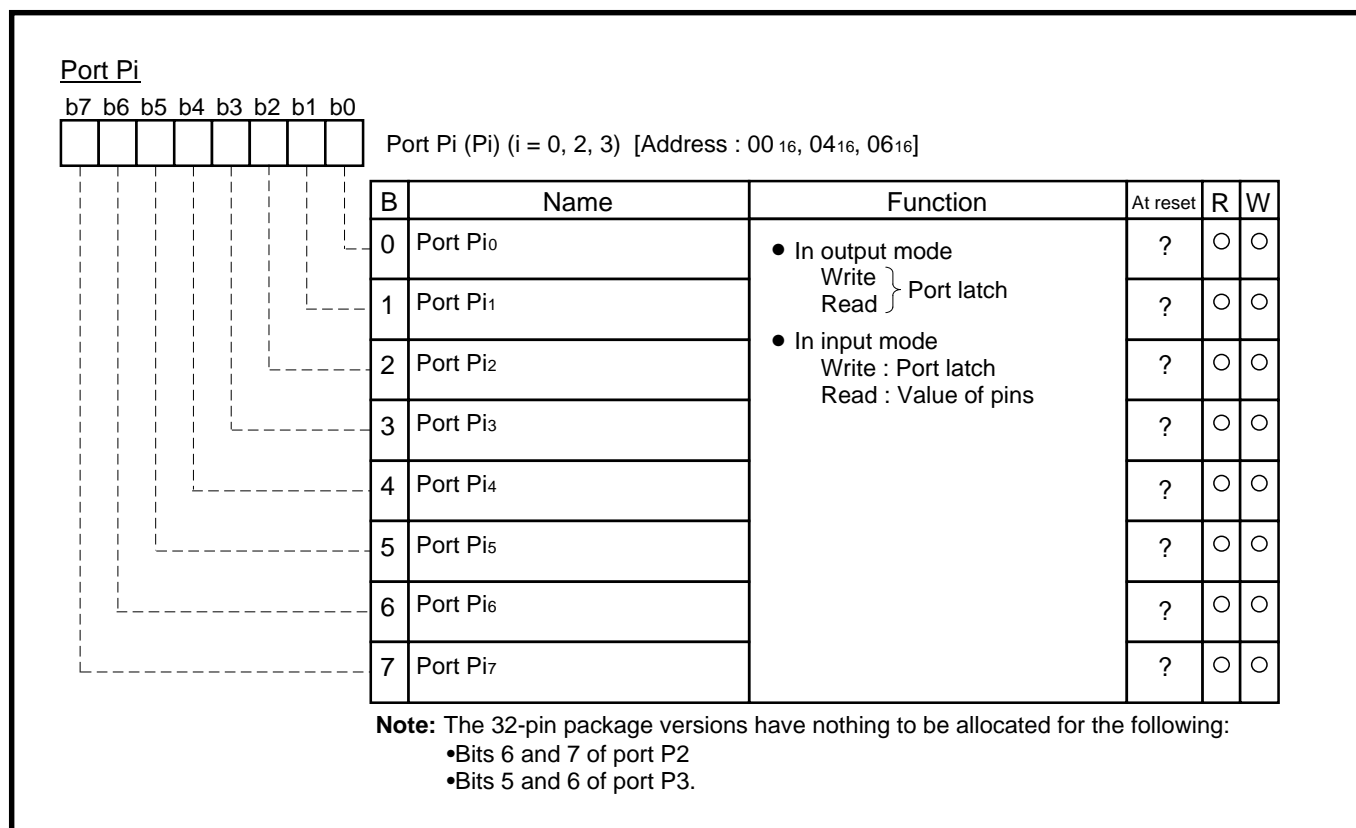


Fig. 3.5.1 Structure of Port Pi (i = 0, 2, 3)

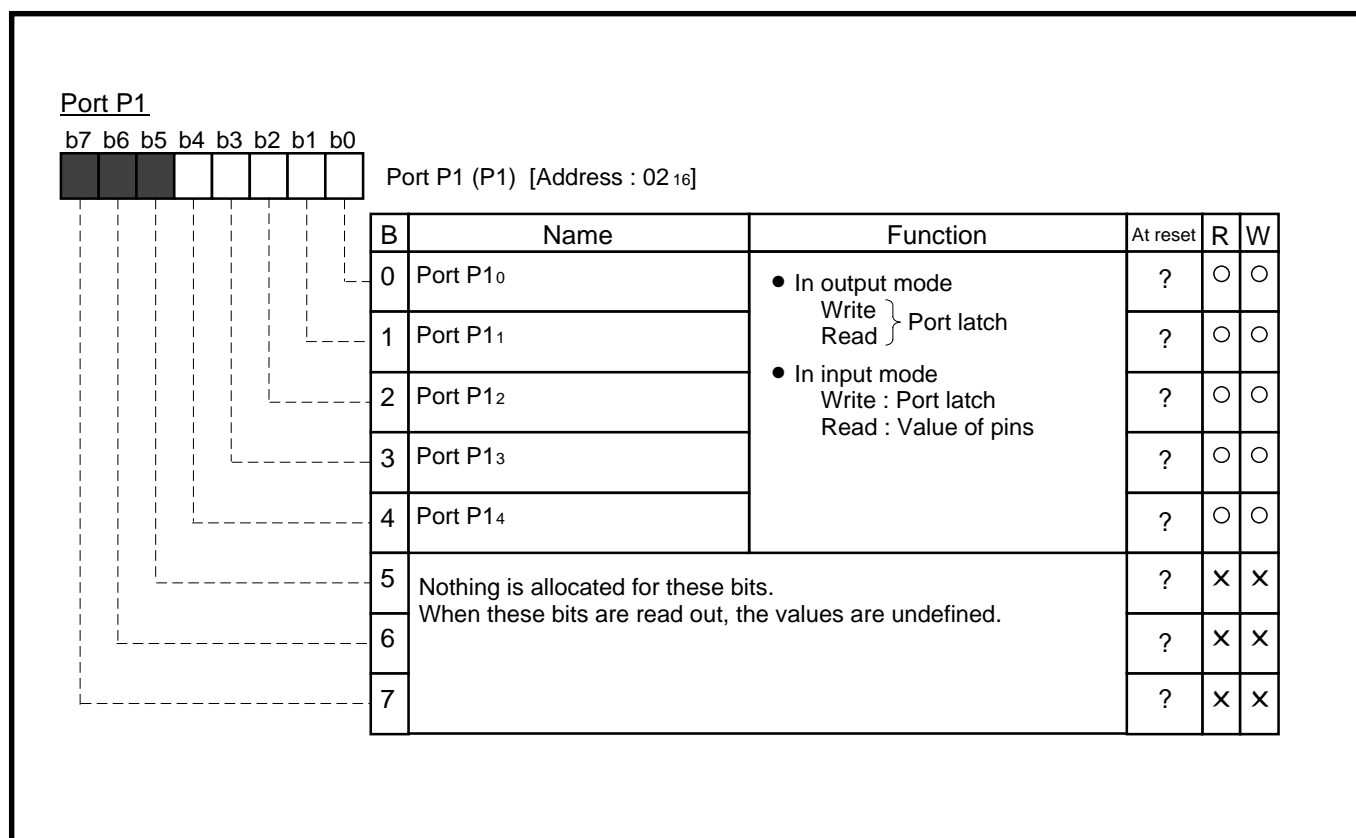


Fig. 3.5.2 Structure of Port P1

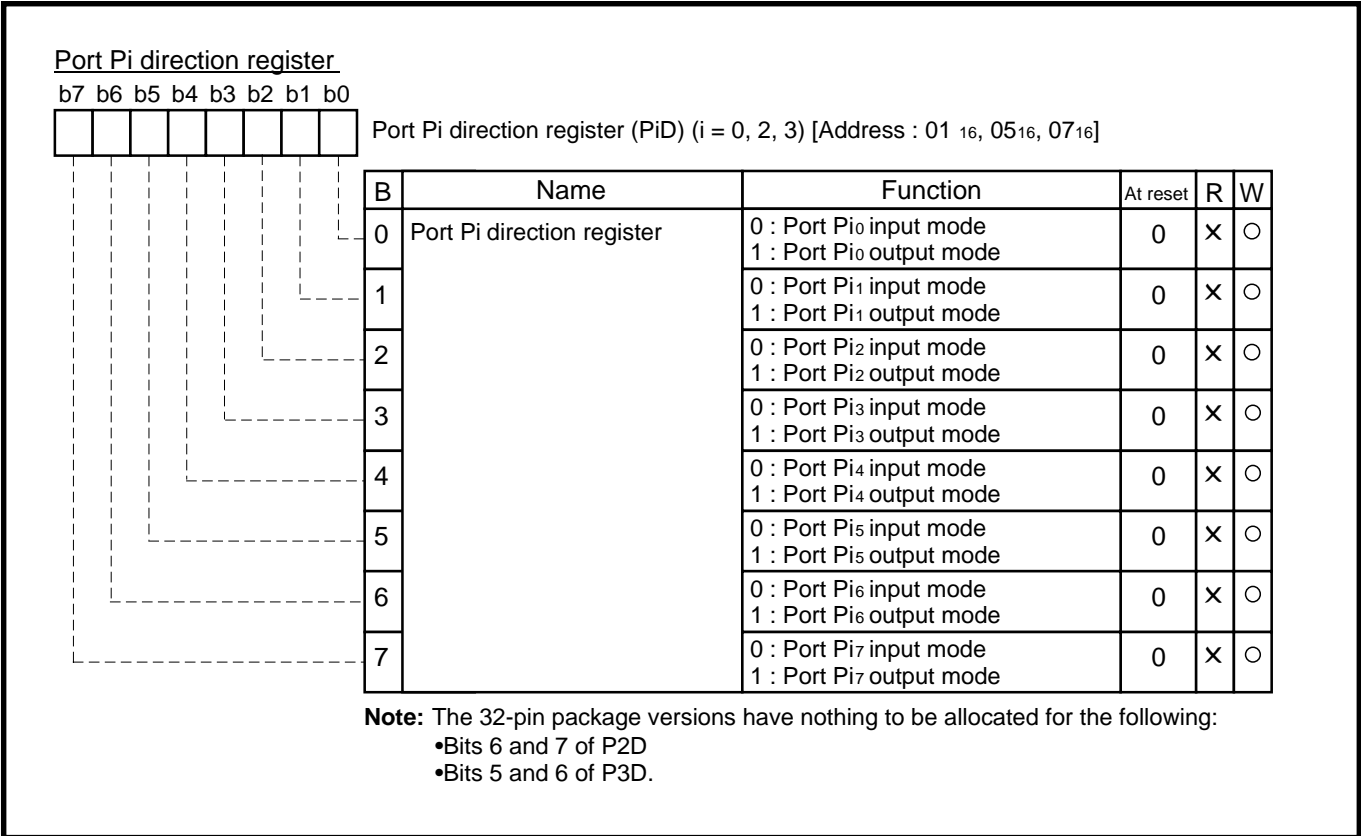


Fig. 3.5.3 Structure of Port Pi direction register (i = 0, 2, 3)

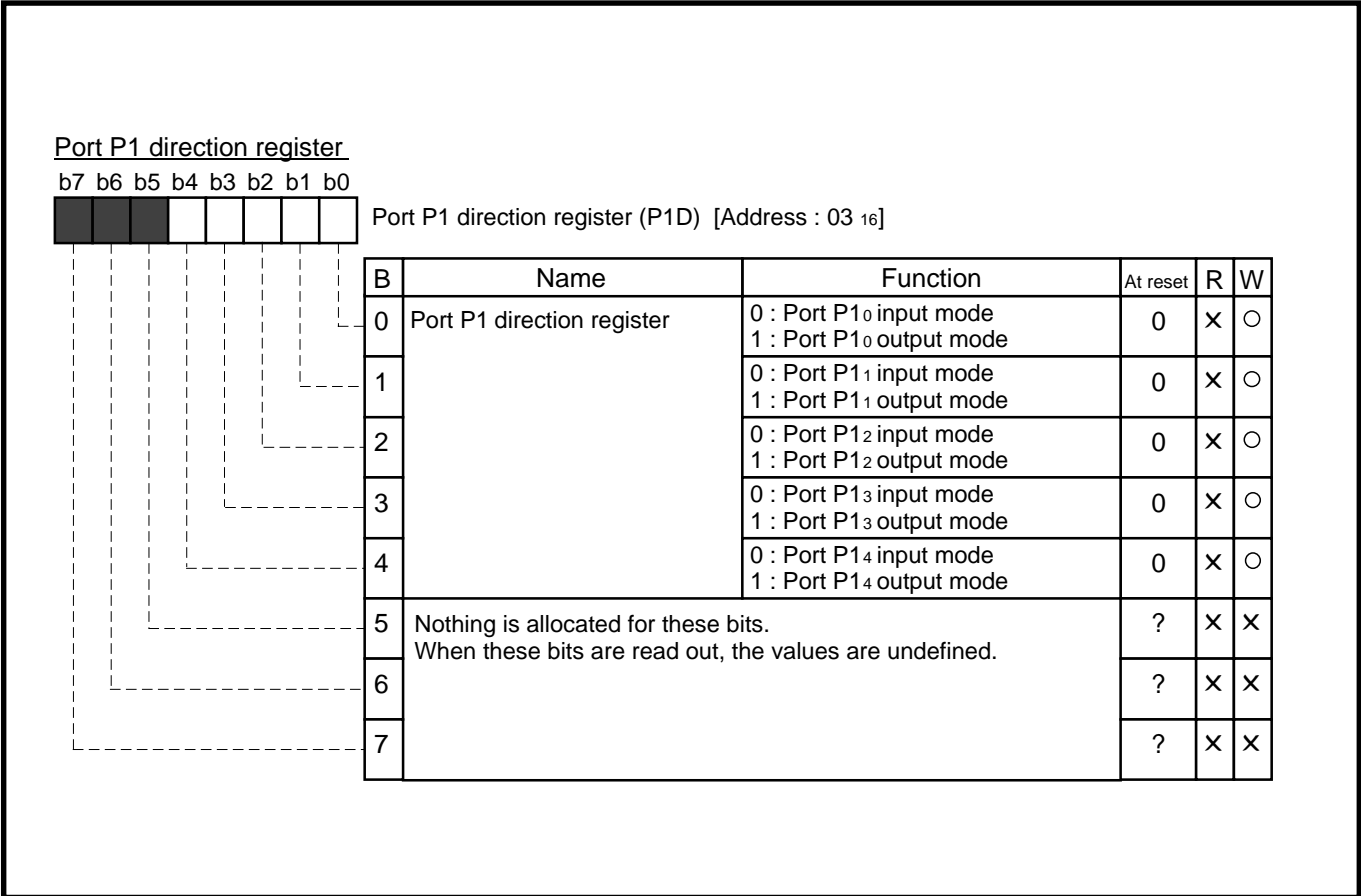


Fig. 3.5.4 Structure of Port P1 direction register

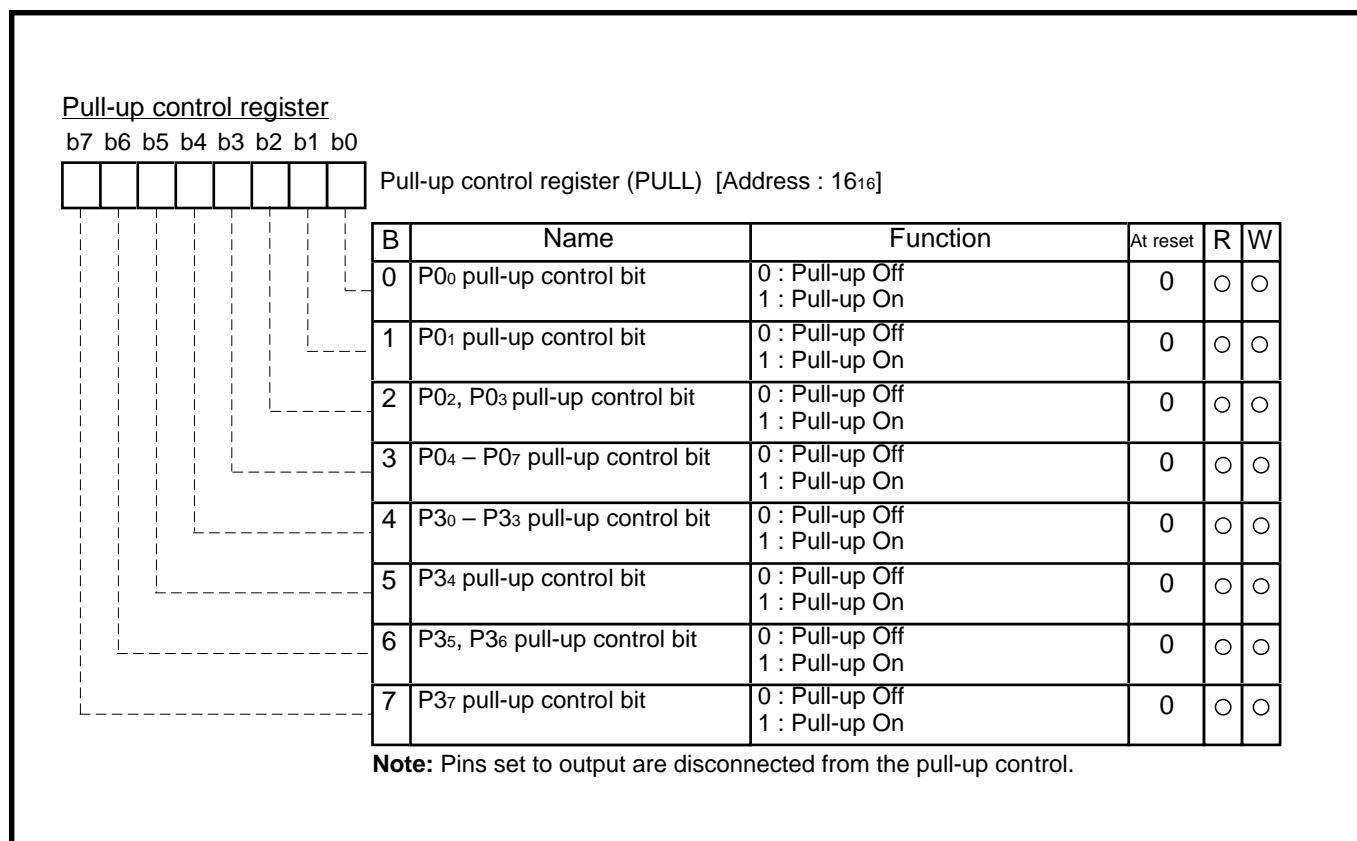


Fig. 3.5.5 Structure of Pull-up control register

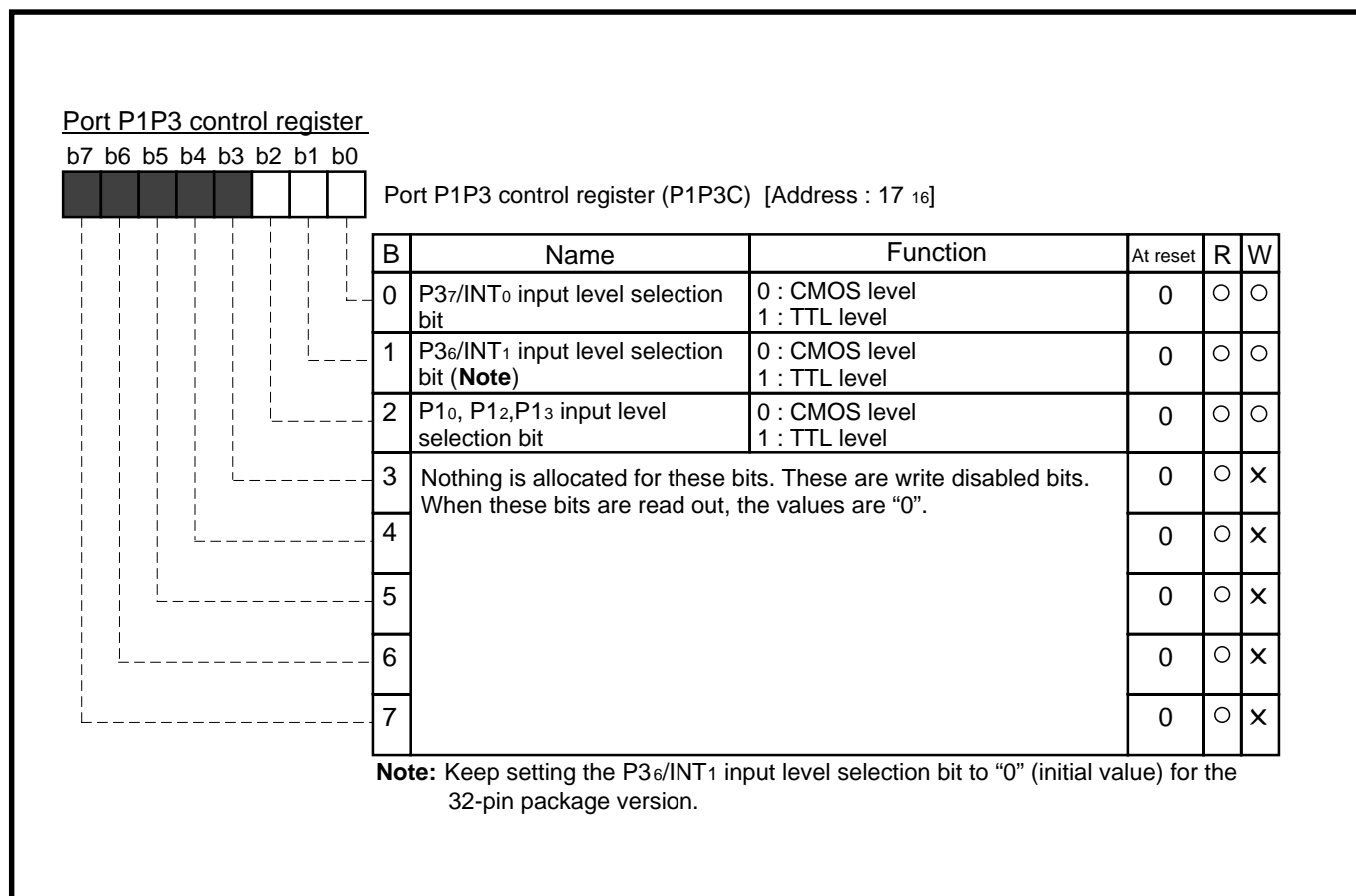


Fig. 3.5.6 Structure of Port P1P3 control register

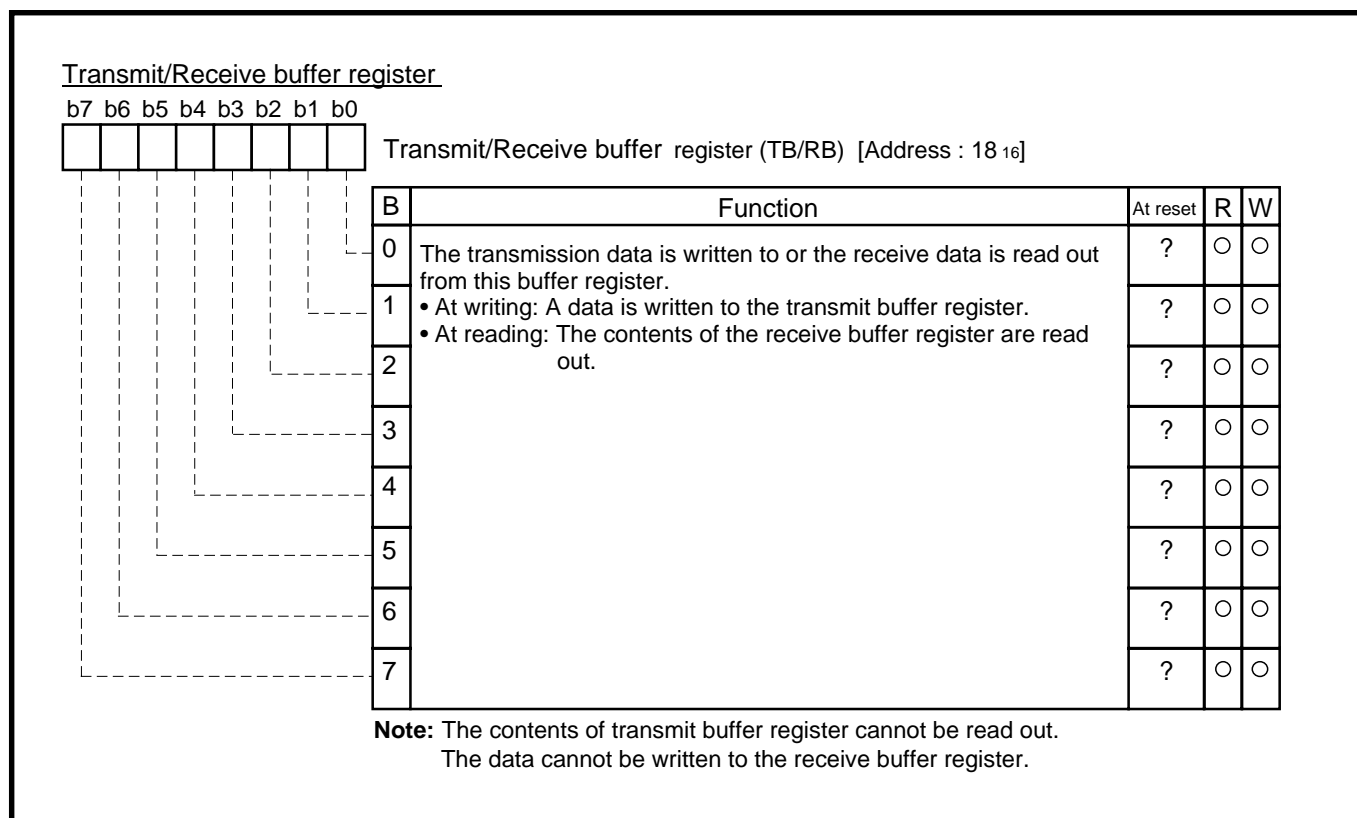


Fig. 3.5.7 Structure of Transmit/Receive buffer register

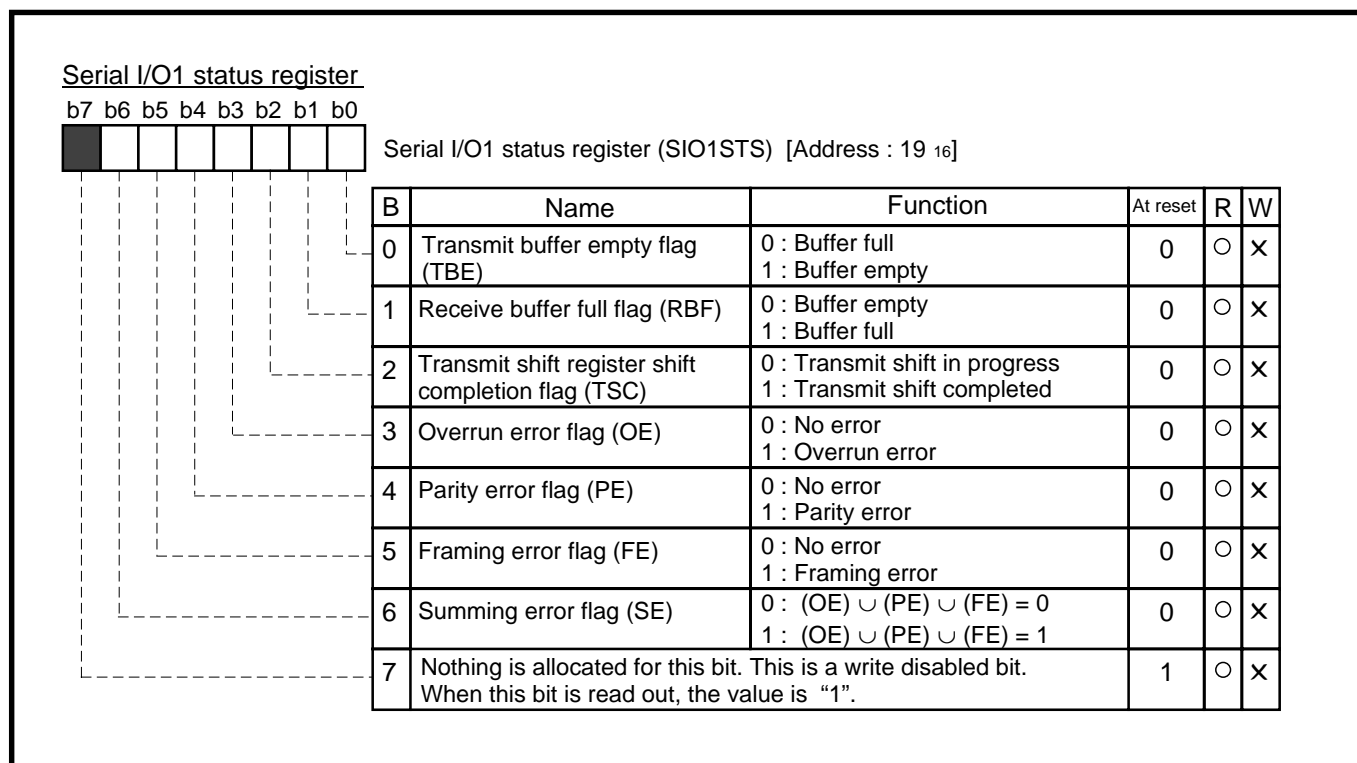


Fig. 3.5.8 Structure of Serial I/O1 status register

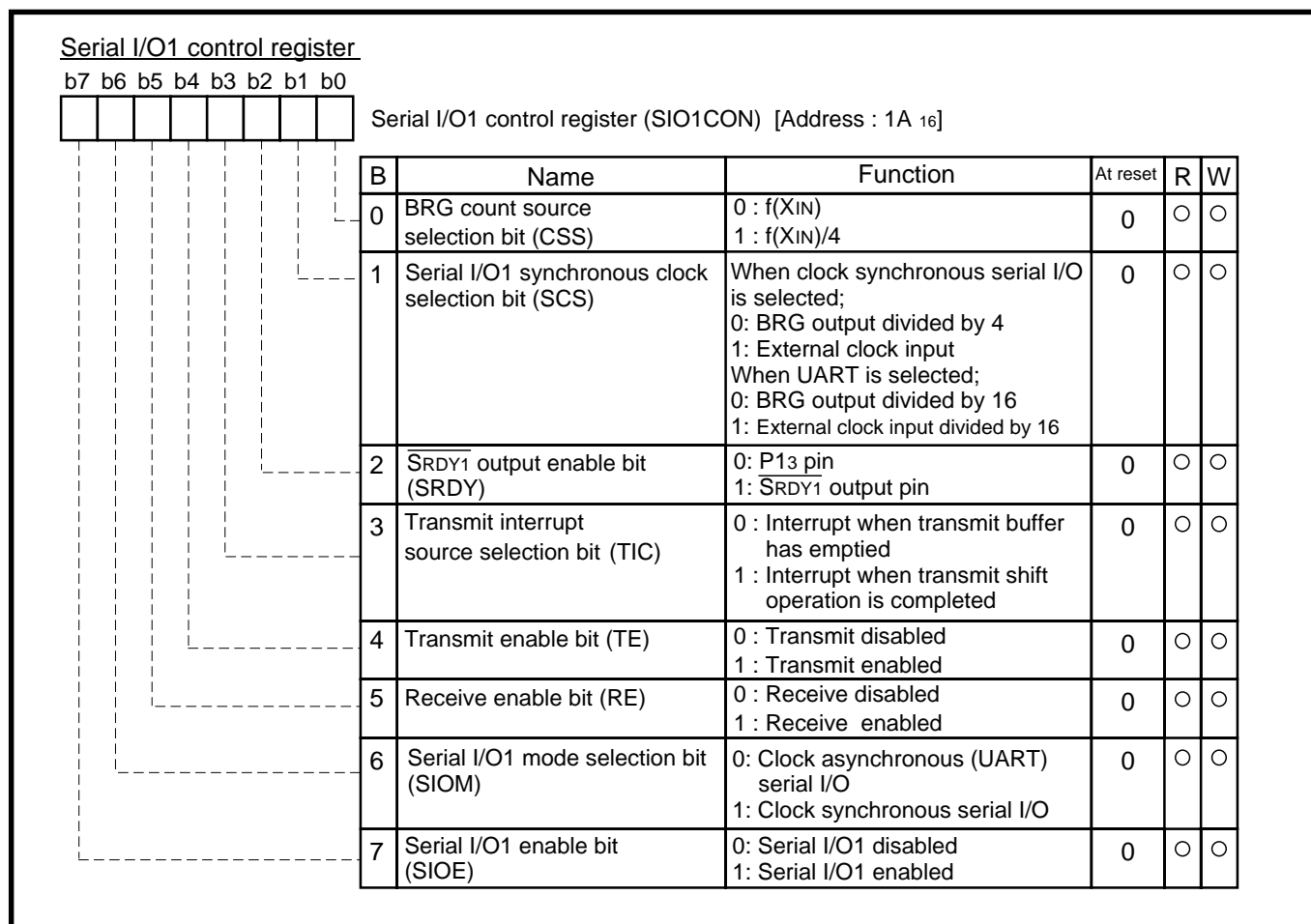


Fig. 3.5.9 Structure of Serial I/O1 control register

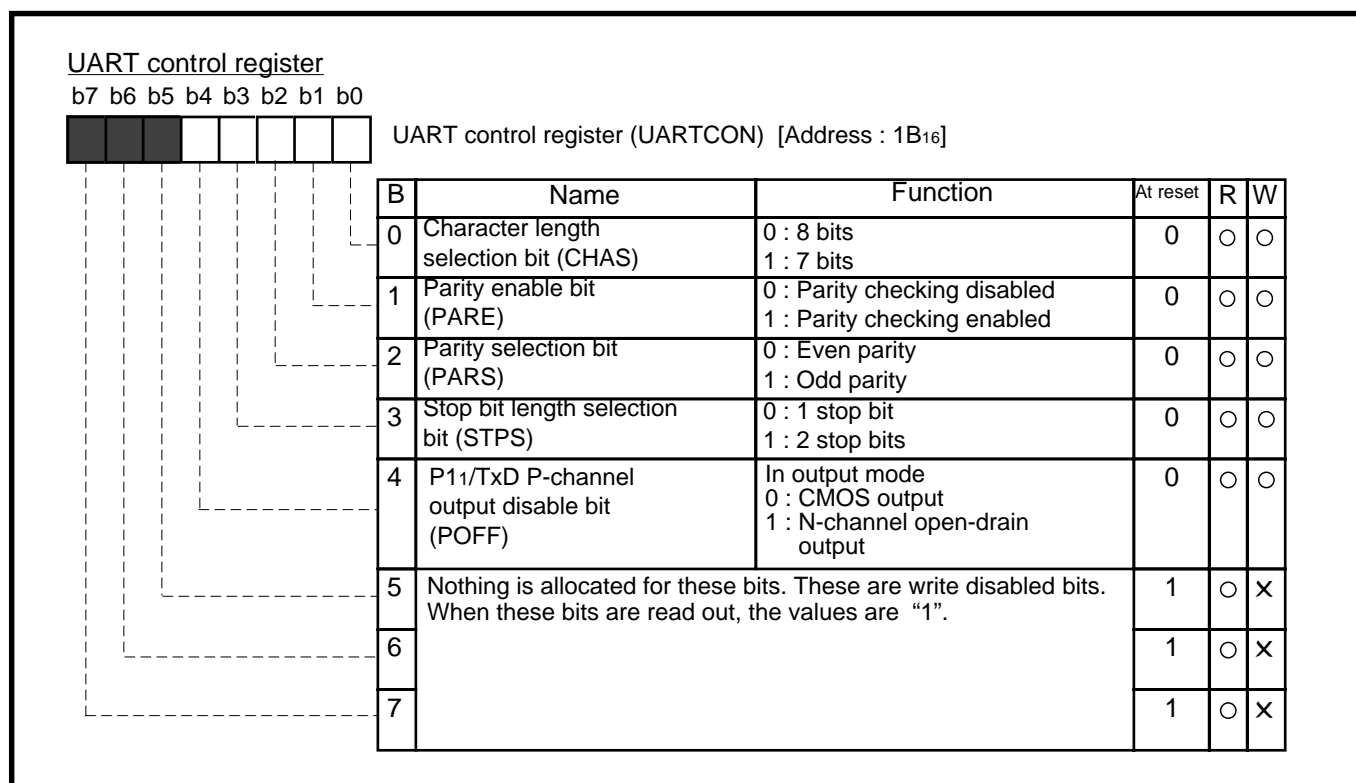


Fig. 3.5.10 Structure of UART control register

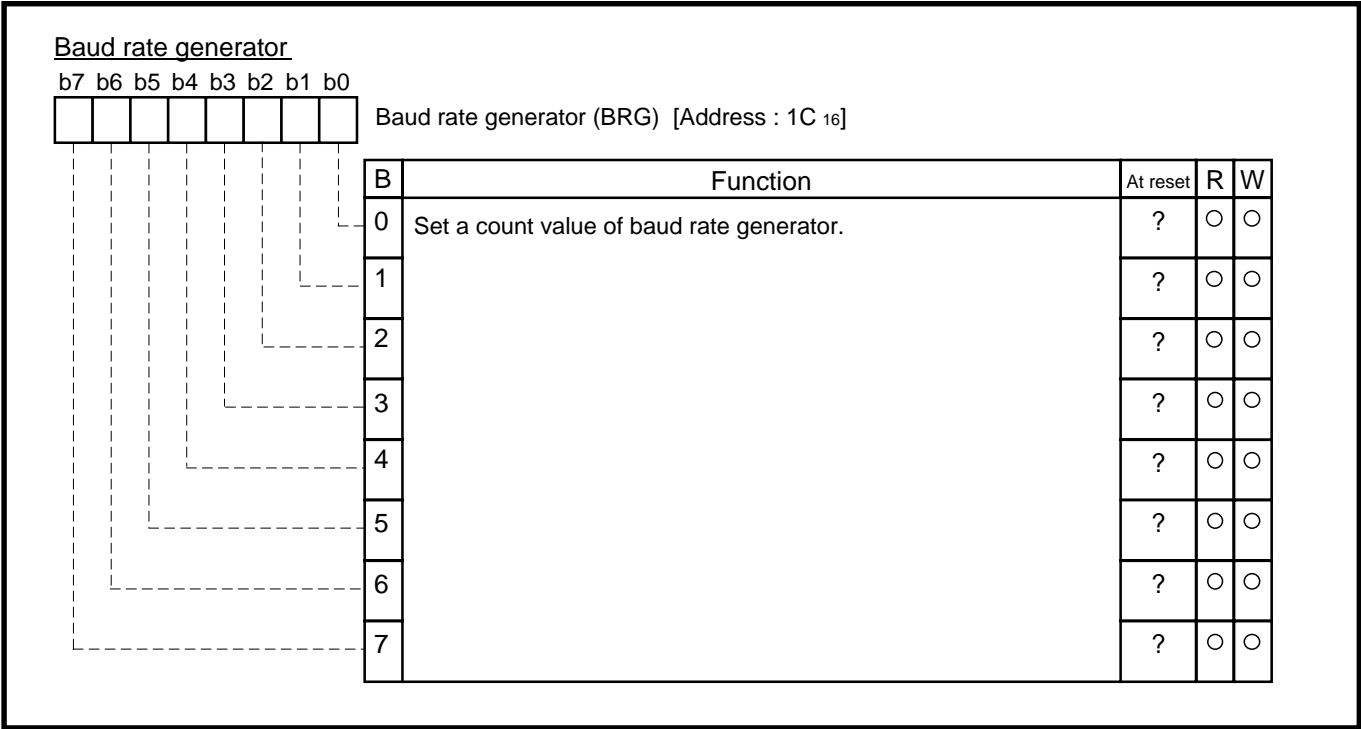


Fig. 3.5.11 Structure of Baud rate generator

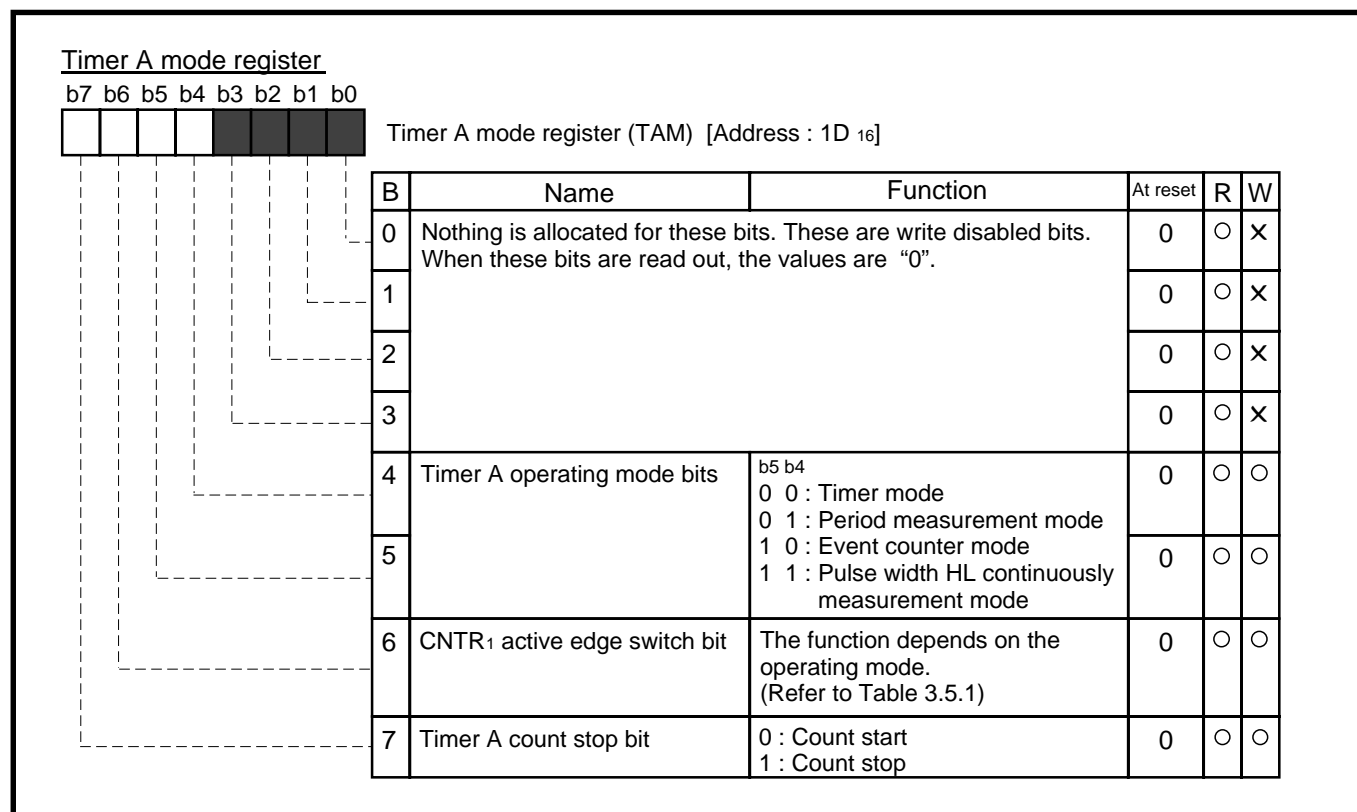


Fig. 3.5.12 Structure of Timer A mode register

Table 3.5.1 CNTR₁ active edge switch bit function

| Timer A operating modes | CNTR ₁ active edge switch bit | |
|--|--|---|
| Timer mode | "0" | CNTR ₁ interrupt request occurrence: Falling edge ; No influence to timer A count |
| | "1" | CNTR ₁ interrupt request occurrence: Rising edge ; No influence to timer A count |
| Period measurement mode | "0" | Pulse output start: Falling edge period measurement CNTR ₁ interrupt request occurrence: Falling edge |
| | "1" | Pulse output start: Rising edge period measurement CNTR ₁ interrupt request occurrence: Rising edge |
| Event counter mode | "0" | Timer A: Rising edge count CNTR ₁ interrupt request occurrence: Falling edge |
| | "1" | Timer A: Falling edge count CNTR ₁ interrupt request occurrence: Rising edge |
| Pulse width HL continuously measurement mode | "0" | CNTR ₁ interrupt request occurrence: Falling edge and rising edge ; No influence to timer A count |
| | "1" | CNTR ₁ interrupt request occurrence: Rising edge and falling edge ; No influence to timer A count |

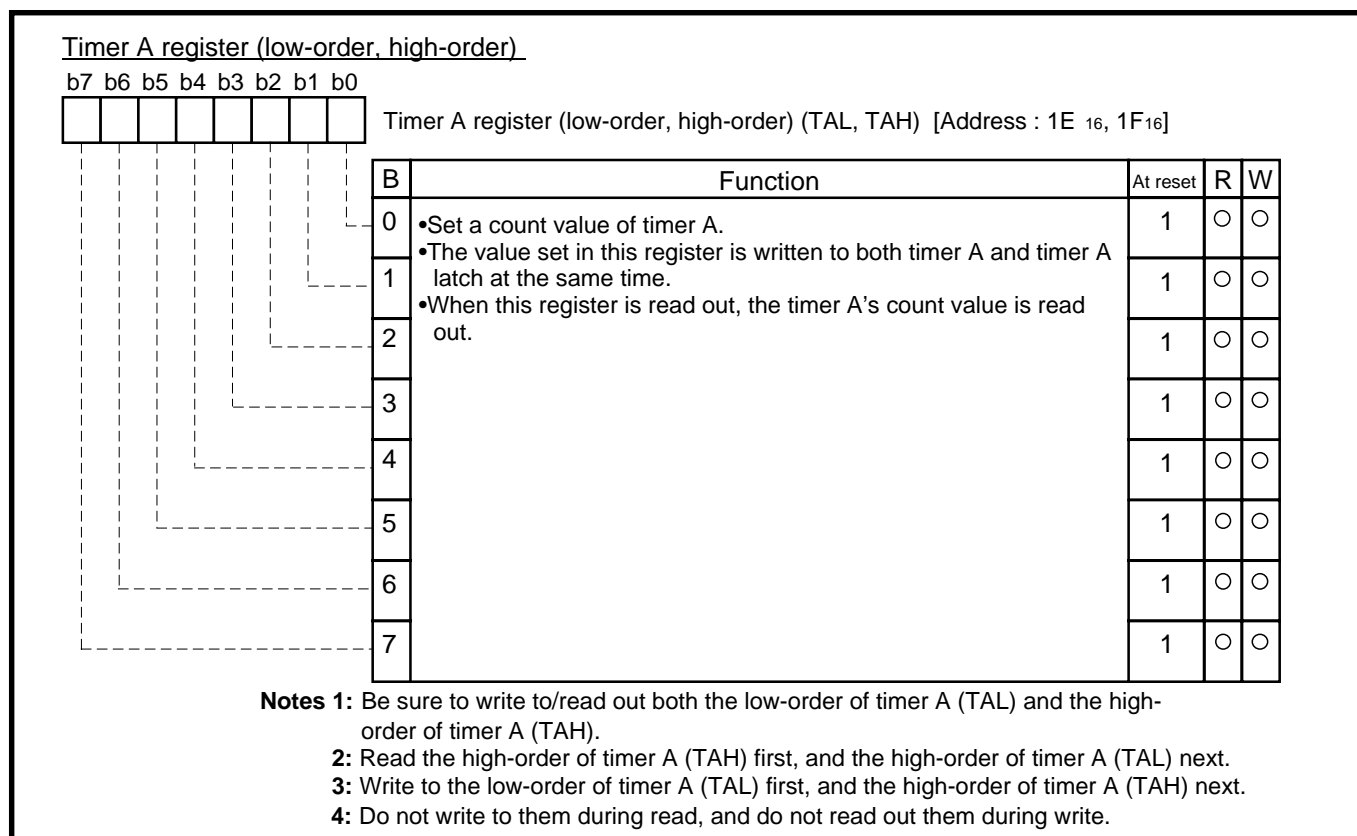


Fig. 3.5.13 Structure of Timer A register

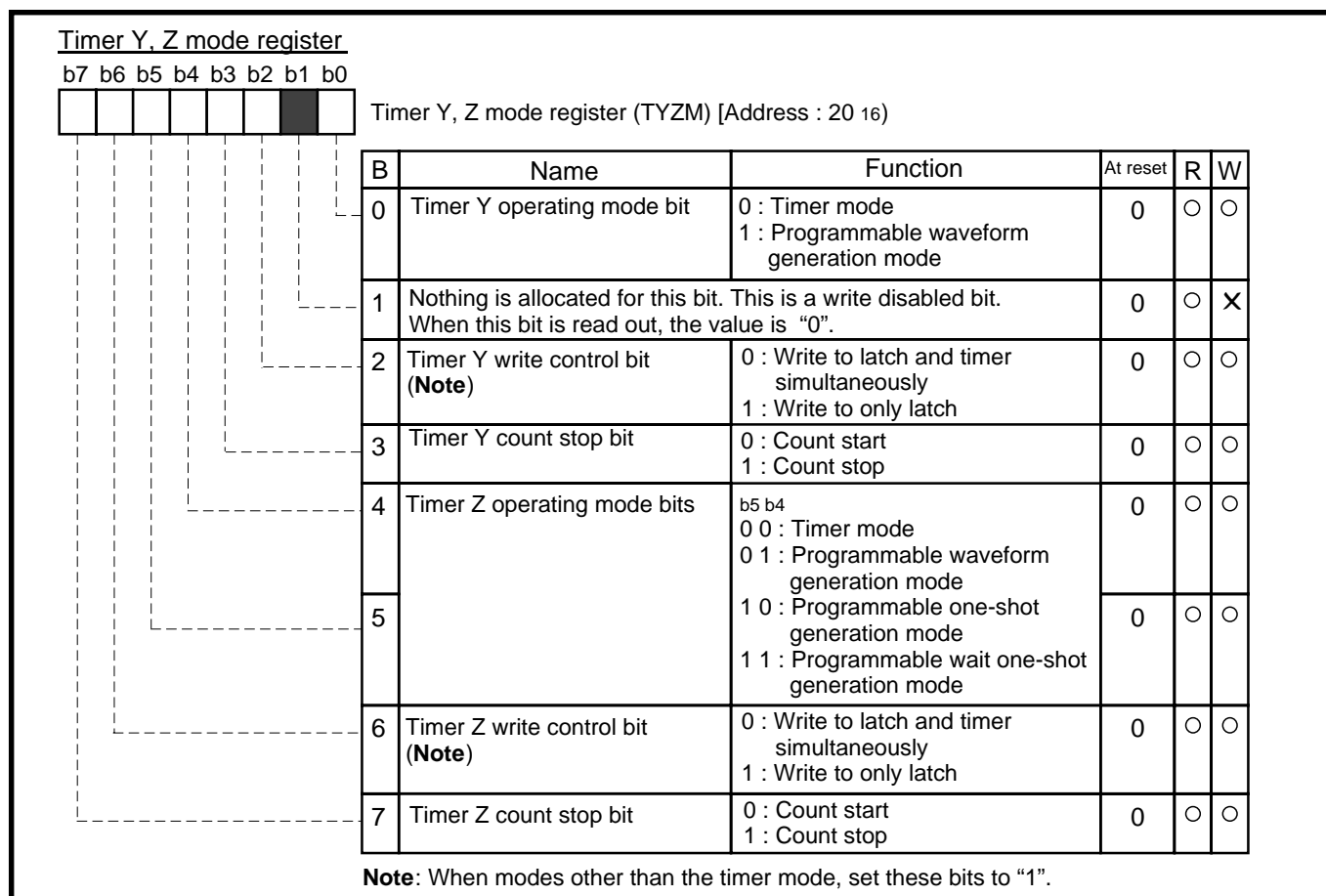


Fig. 3.5.14 Structure of Timer Y, Z mode register

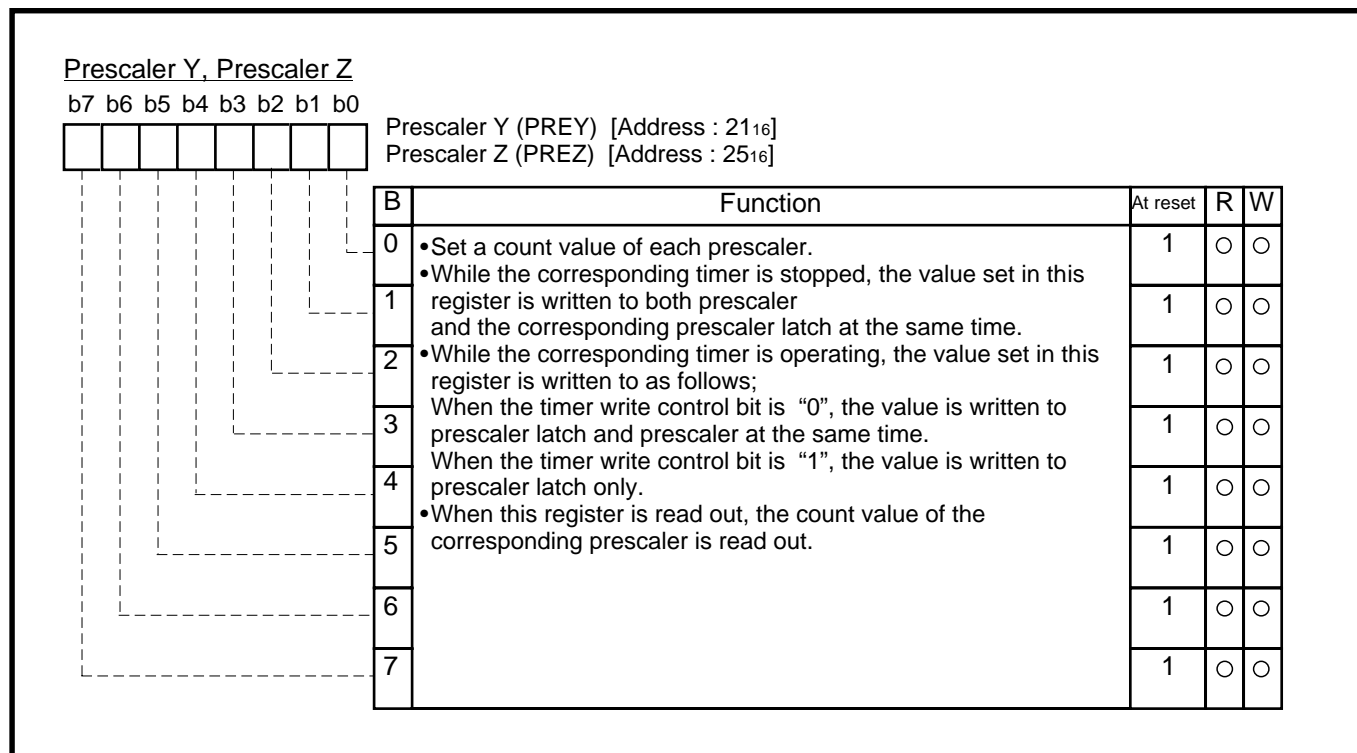


Fig. 3.5.15 Structure of Prescaler Y, Prescaler Z

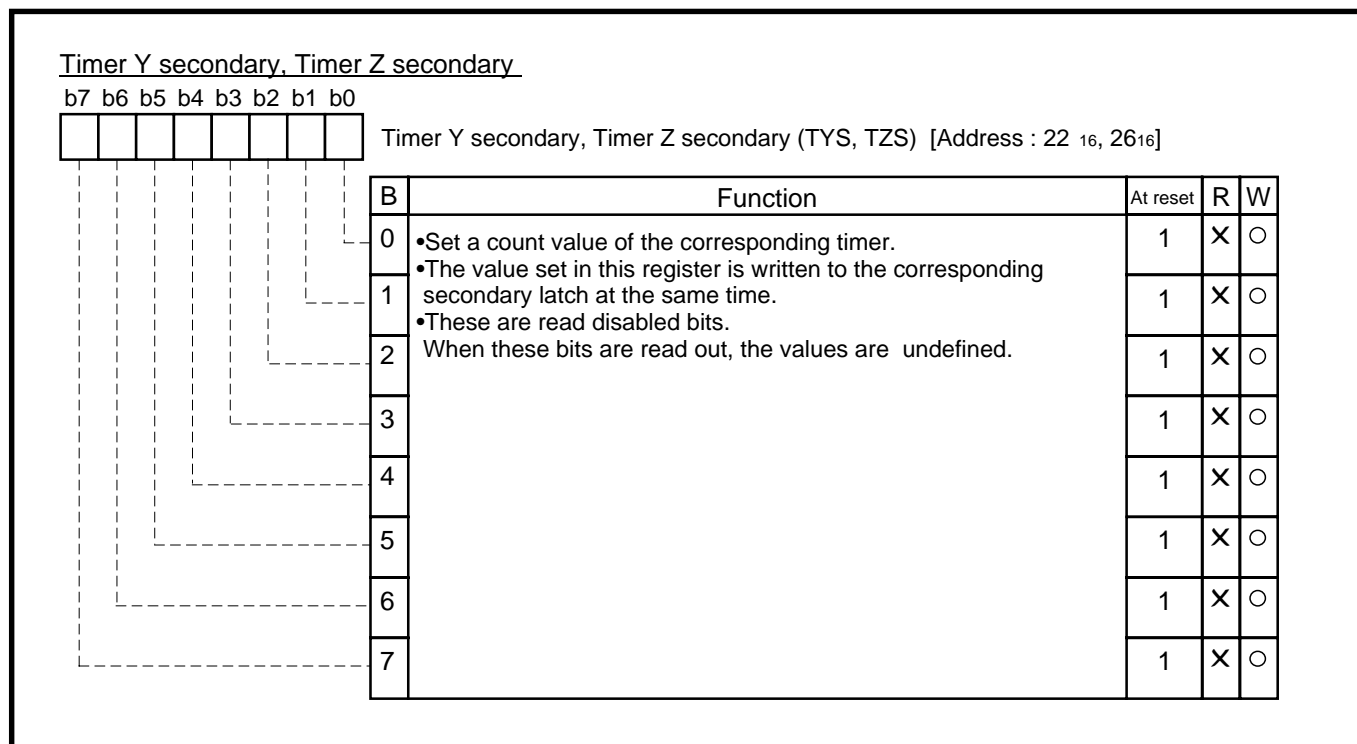


Fig. 3.5.16 Structure of Timer Y secondary, Timer Z secondary

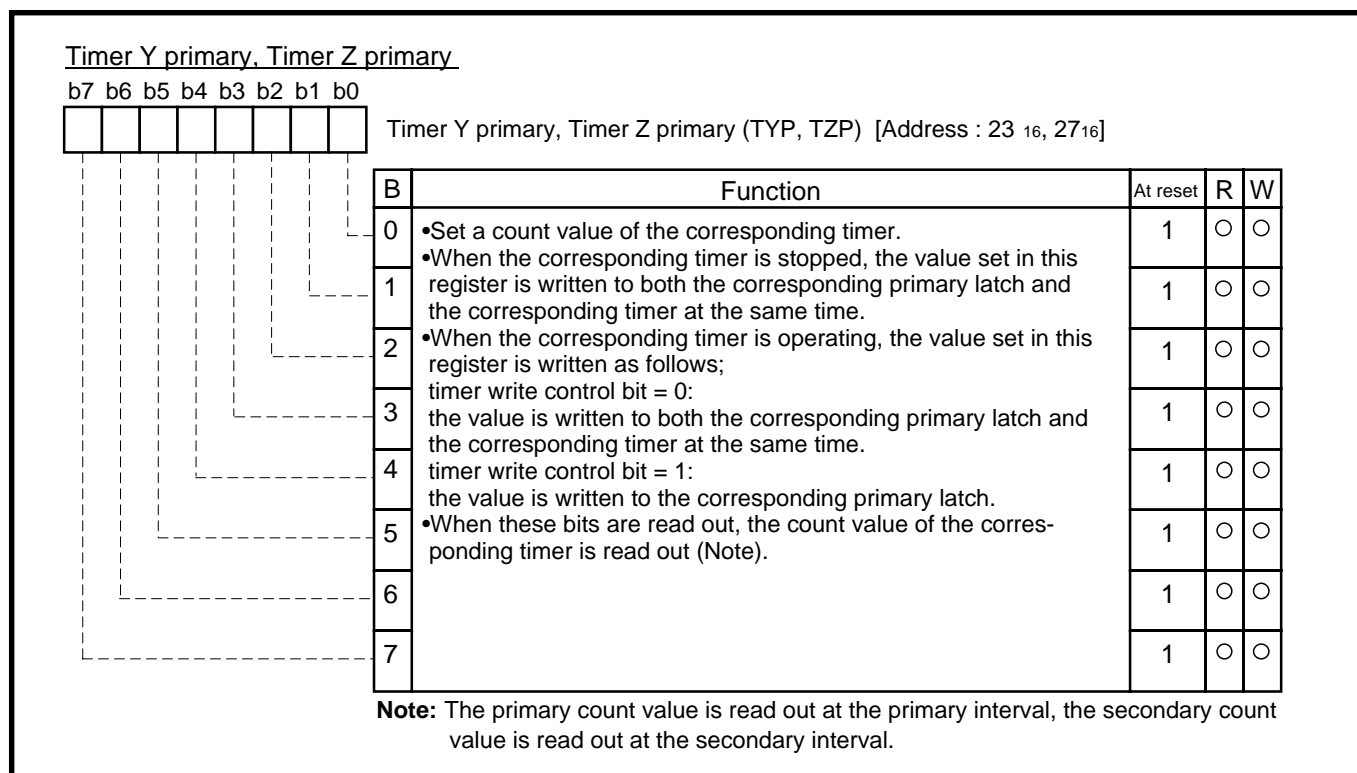


Fig. 3.5.17 Structure of Timer Y primary, Timer Z primary

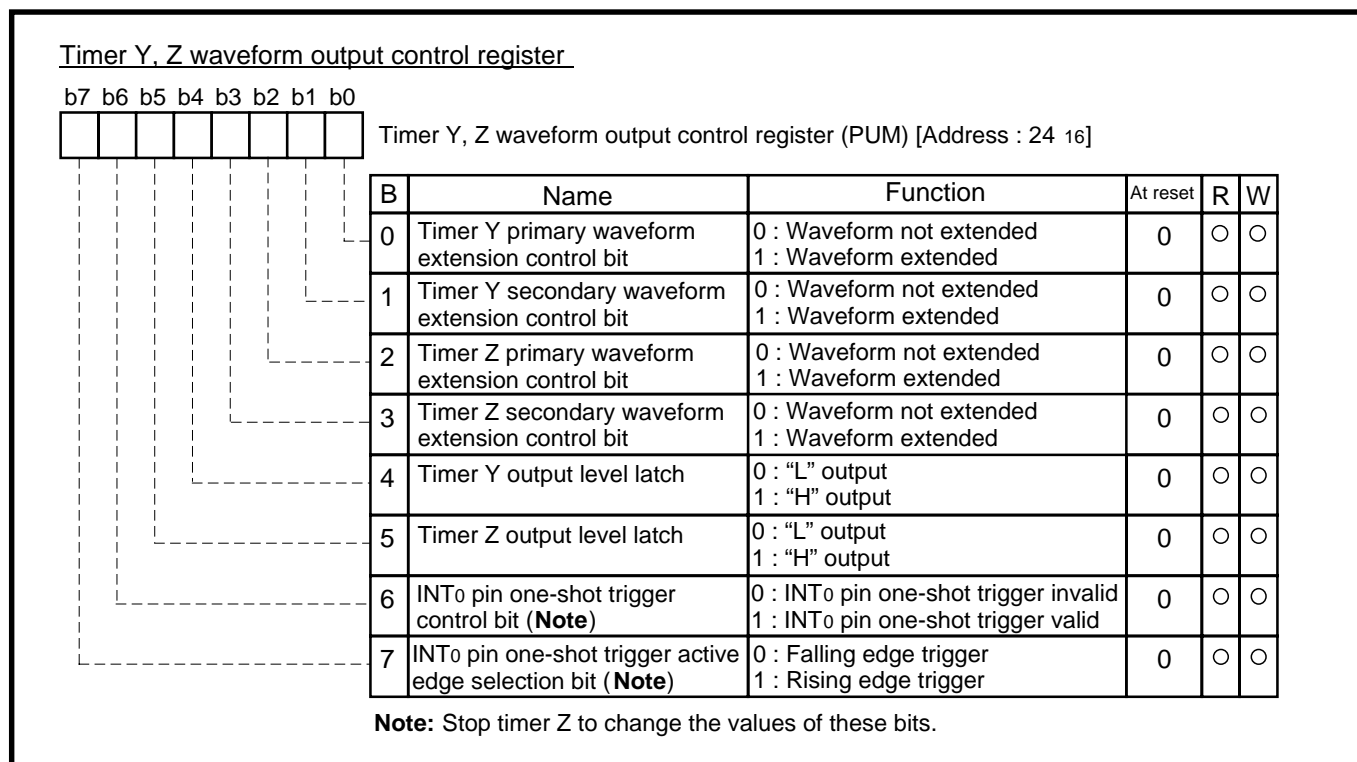


Fig. 3.5.18 Structure of Timer Y, Z waveform output control register

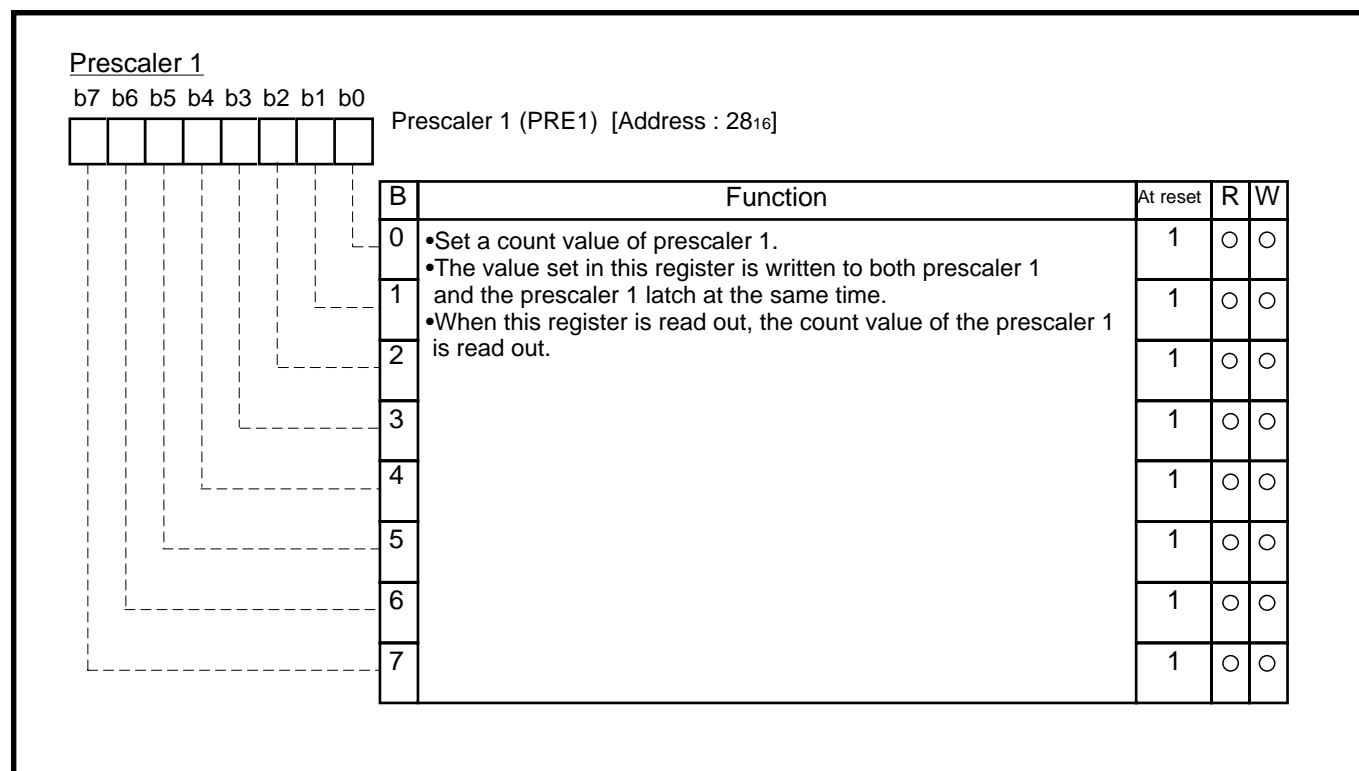


Fig. 3.5.19 Structure of Prescaler 1

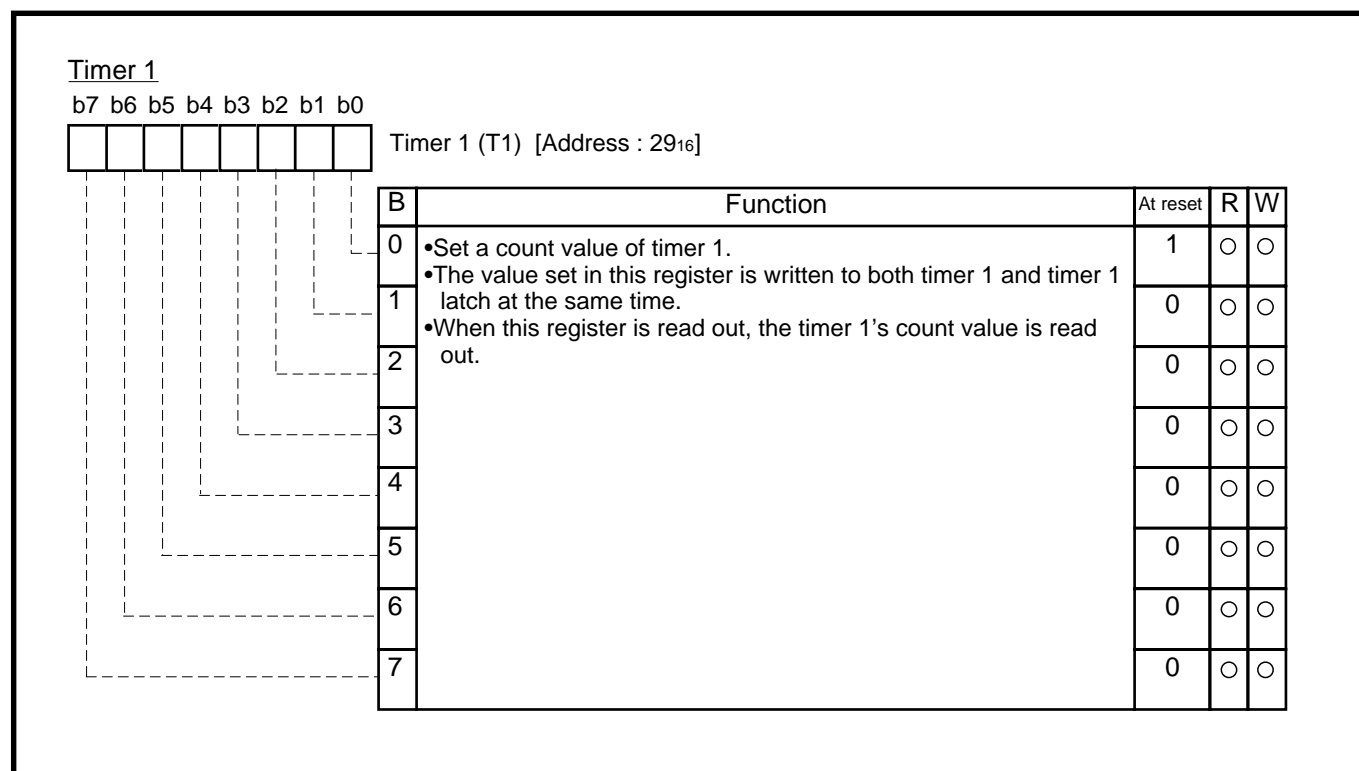


Fig. 3.5.20 Structure of Timer 1

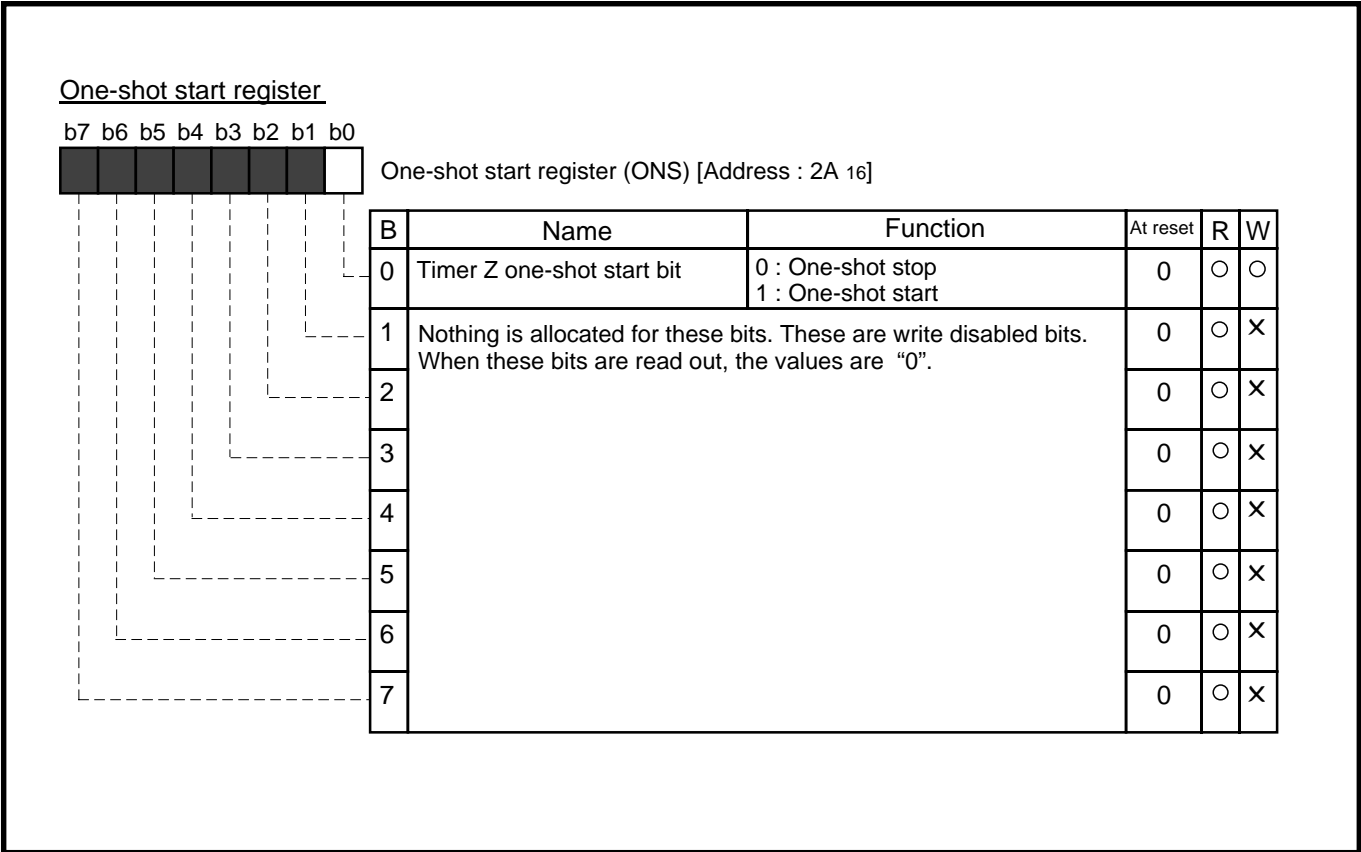


Fig. 3.5.21 Structure of One-shot start register

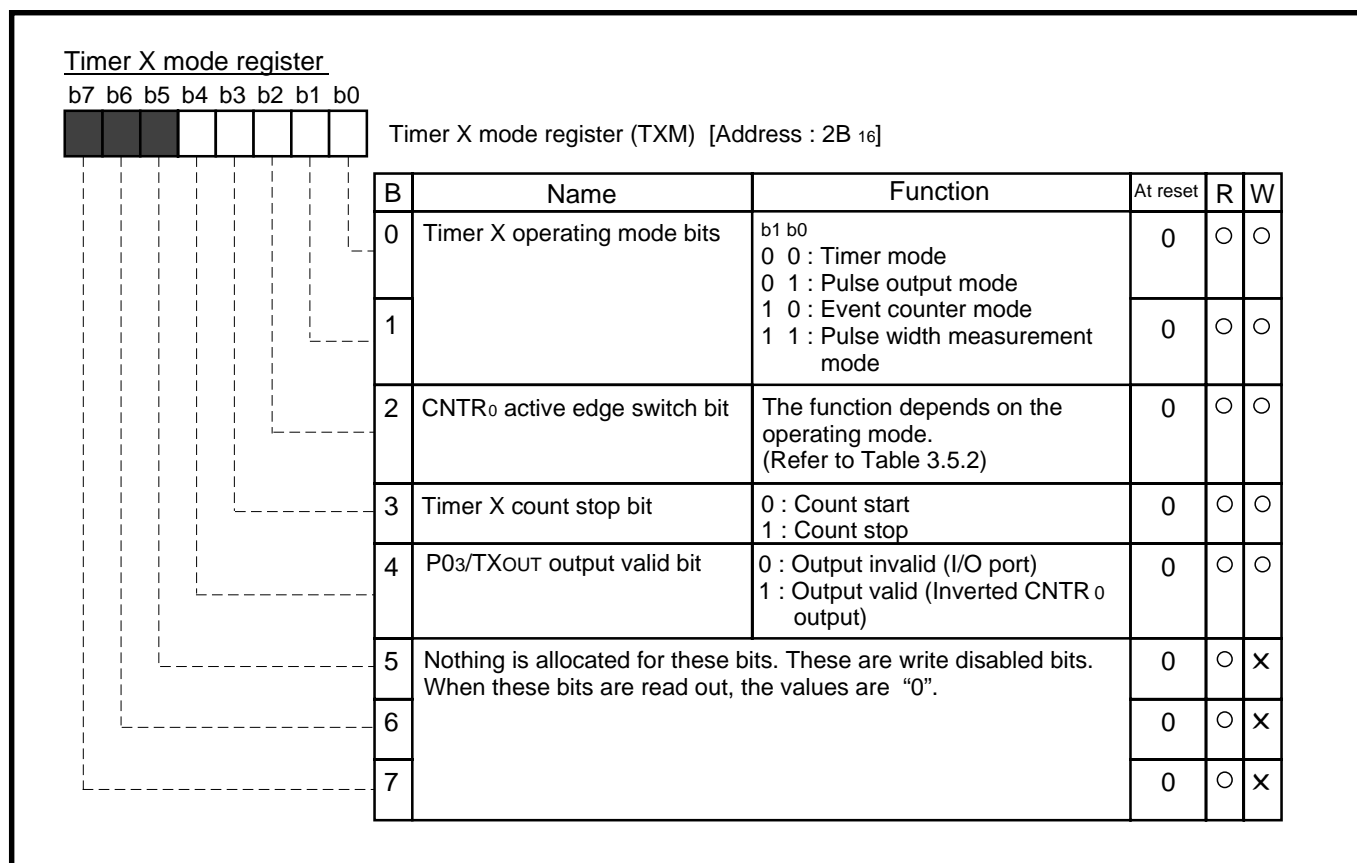


Fig. 3.5.22 Structure of Timer X mode register

Table 3.5.2 CNTR₀ active edge switch bit function

| Timer X operating modes | CNTR ₀ active edge switch bit (bit 2 of address 2B ₁₆) contents | |
|------------------------------|--|--|
| Timer mode | "0" | CNTR ₀ interrupt request occurrence: Falling edge ; No influence to timer count |
| | "1" | CNTR ₀ interrupt request occurrence: Rising edge ; No influence to timer count |
| Pulse output mode | "0" | Pulse output start: Beginning at "H" level CNTR ₀ interrupt request occurrence: Falling edge |
| | "1" | Pulse output start: Beginning at "L" level CNTR ₀ interrupt request occurrence: Rising edge |
| Event counter mode | "0" | Timer X: Rising edge count CNTR ₀ interrupt request occurrence: Falling edge |
| | "1" | Timer X: Falling edge count CNTR ₀ interrupt request occurrence: Rising edge |
| Pulse width measurement mode | "0" | Timer X: "H" level width measurement CNTR ₀ interrupt request occurrence: Falling edge |
| | "1" | Timer X: "L" level width measurement CNTR ₀ interrupt request occurrence: Rising edge |

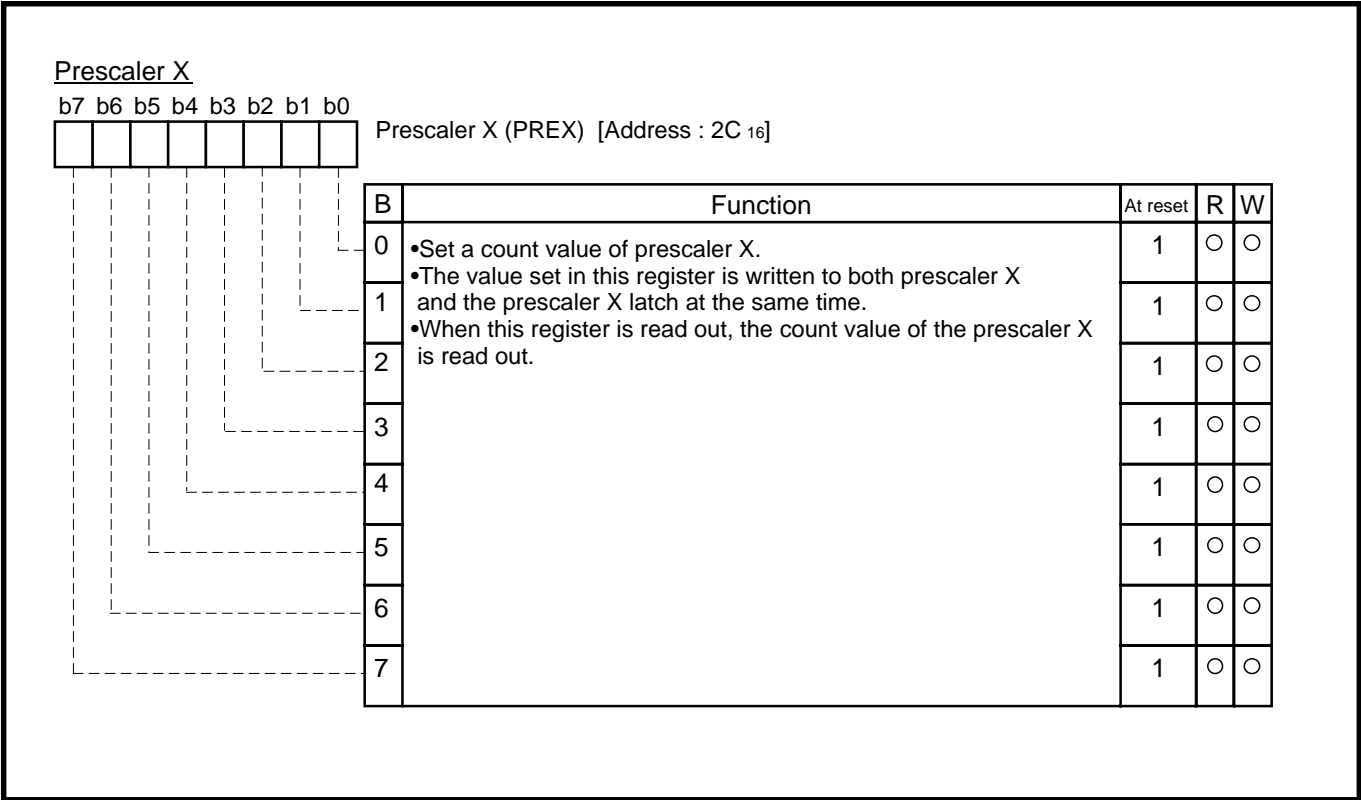


Fig. 3.5.23 Structure of Prescaler X

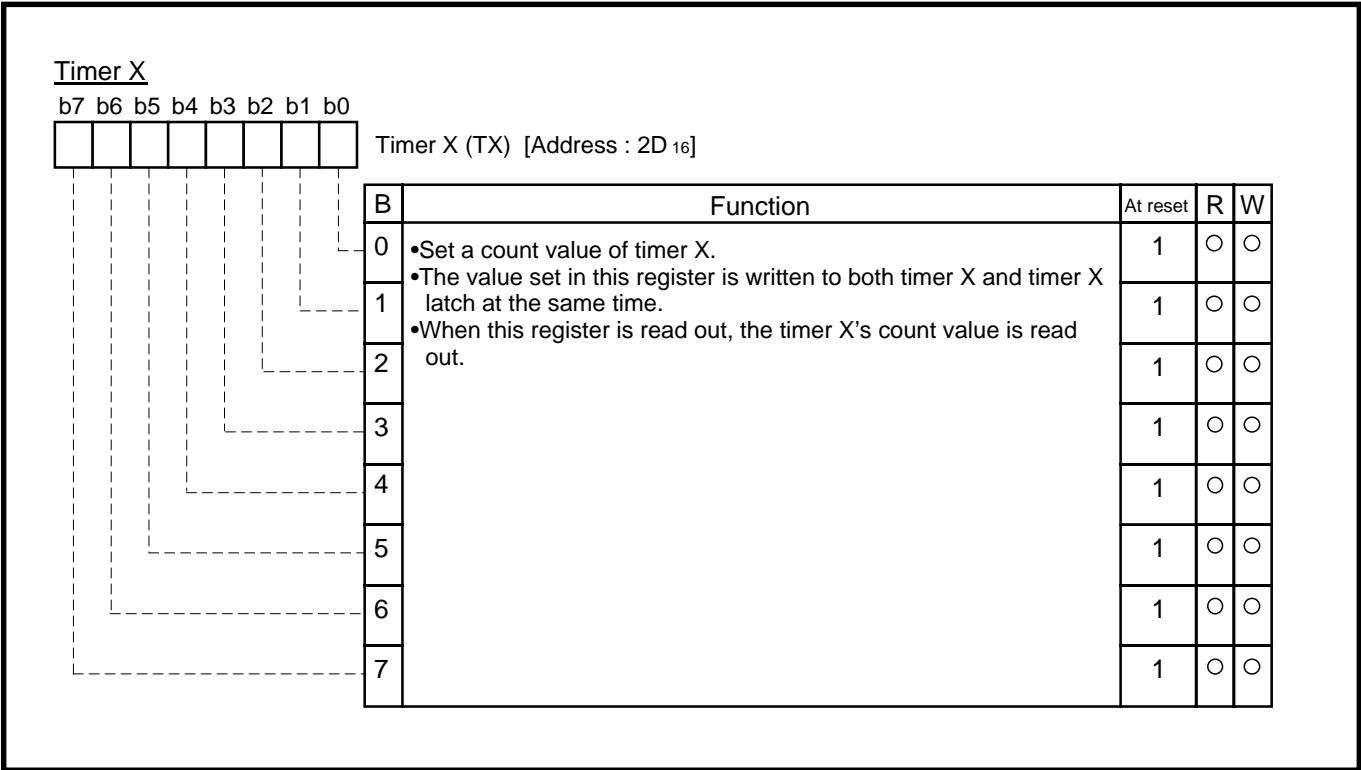


Fig. 3.5.24 Structure of Timer X

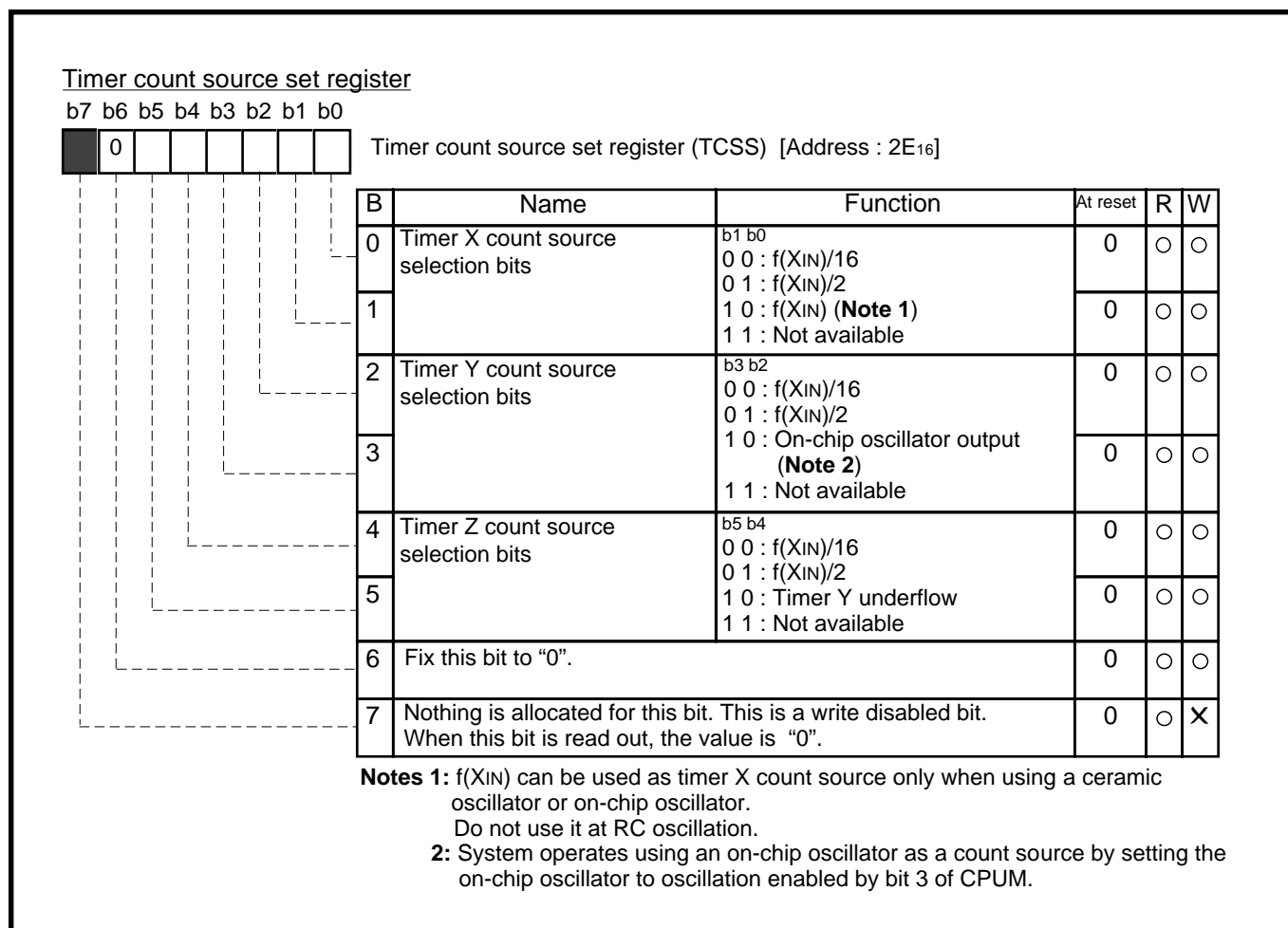


Fig. 3.5.25 Structure of Timer count source set register

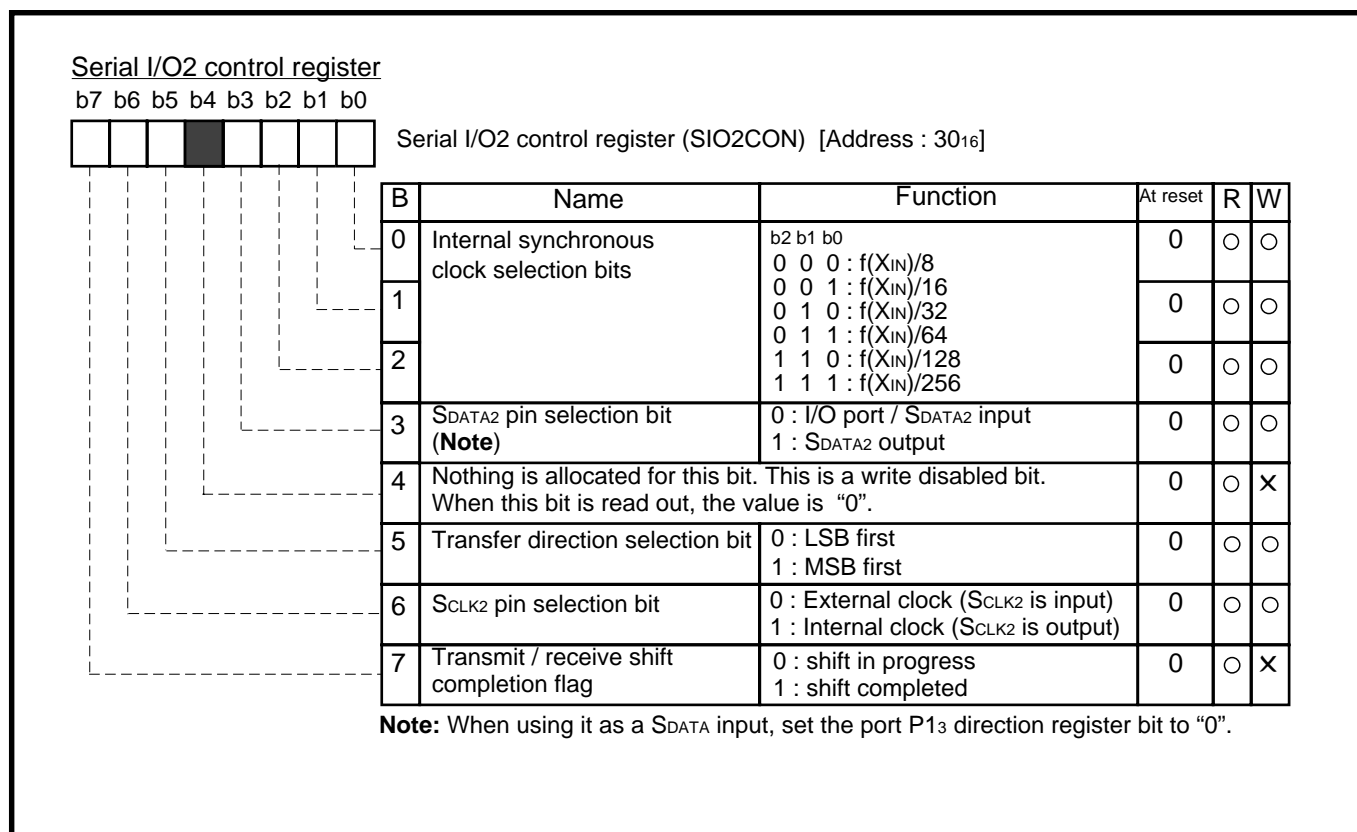


Fig. 3.5.26 Structure of Serial I/O2 control register

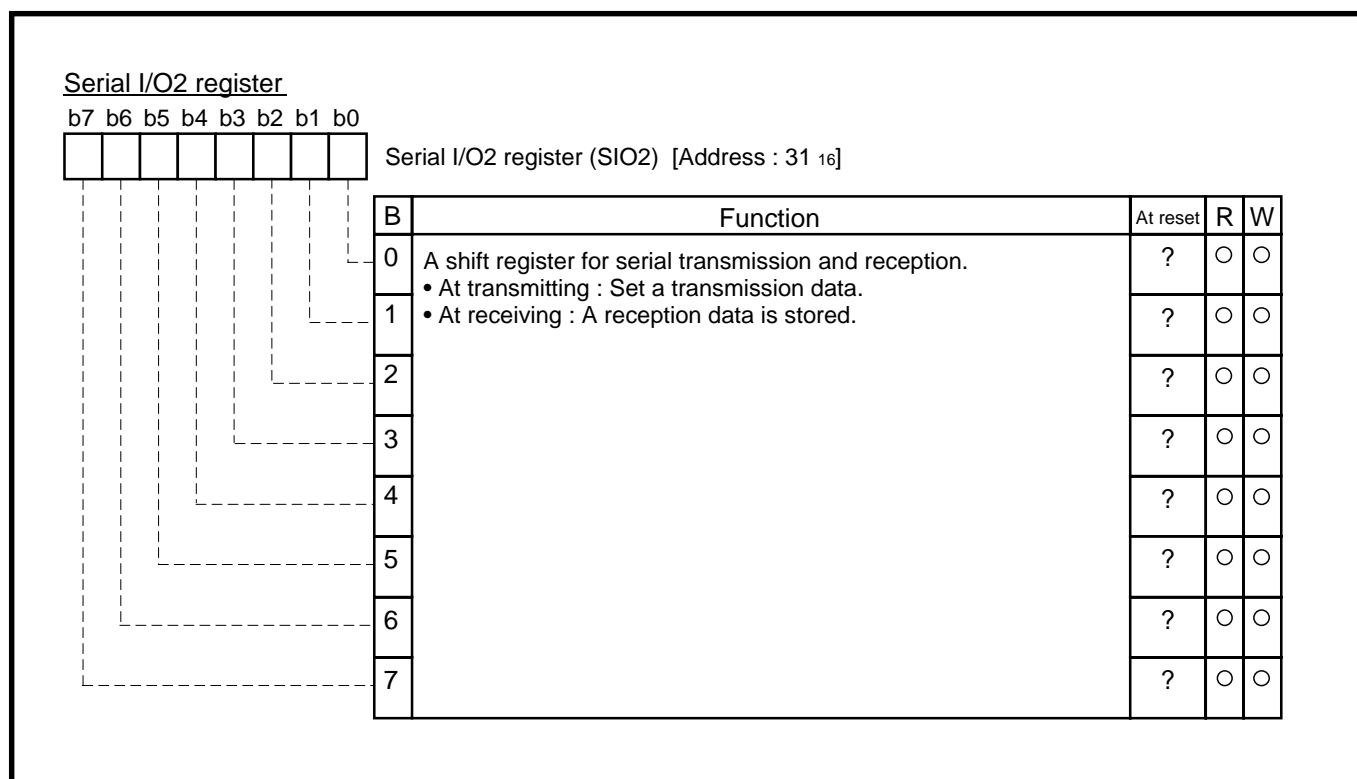


Fig. 3.5.27 Structure of Serial I/O2 register

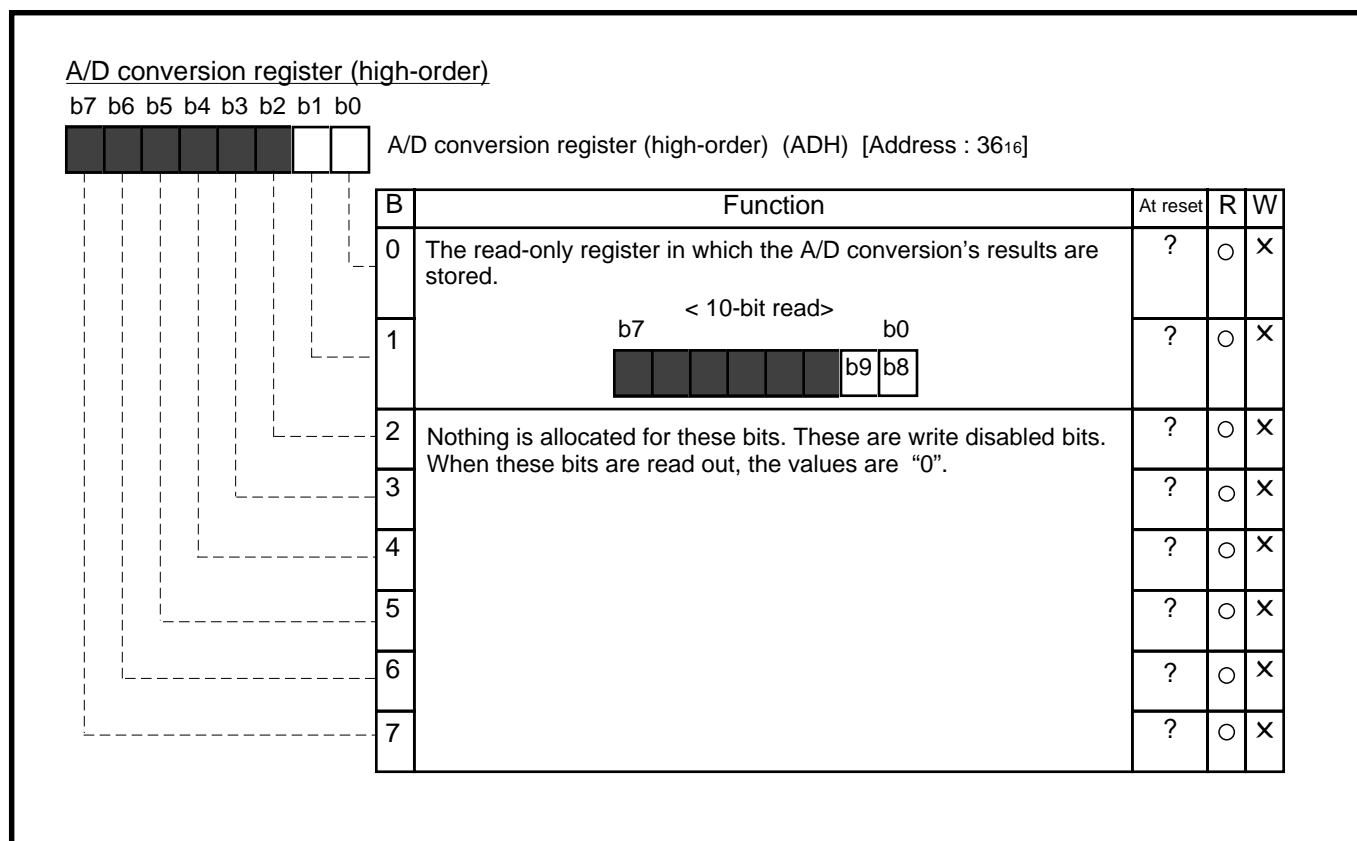


Fig. 3.5.30 Structure of A/D conversion bit register (high-order)

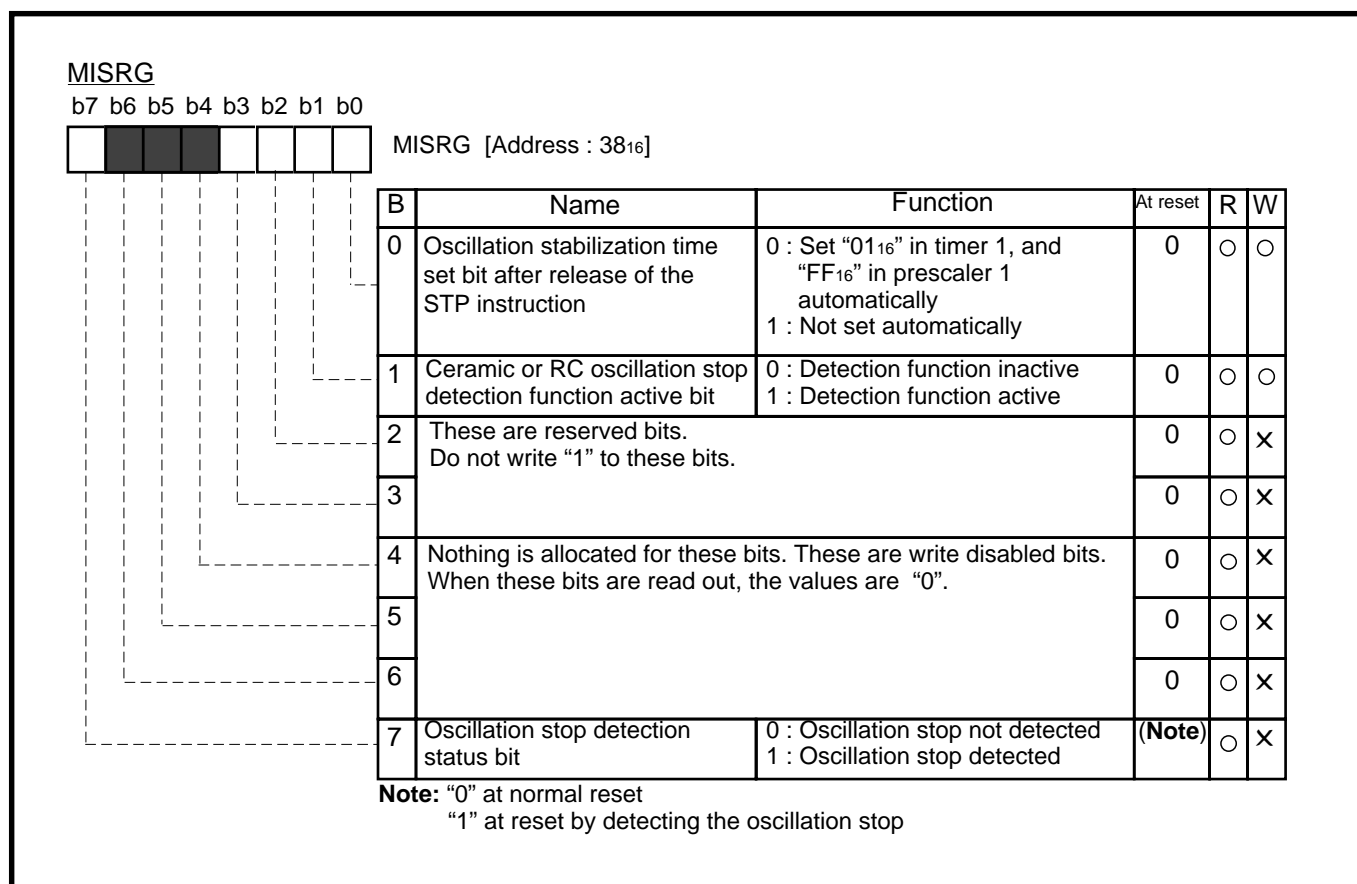


Fig. 3.5.31 Structure of MISRG

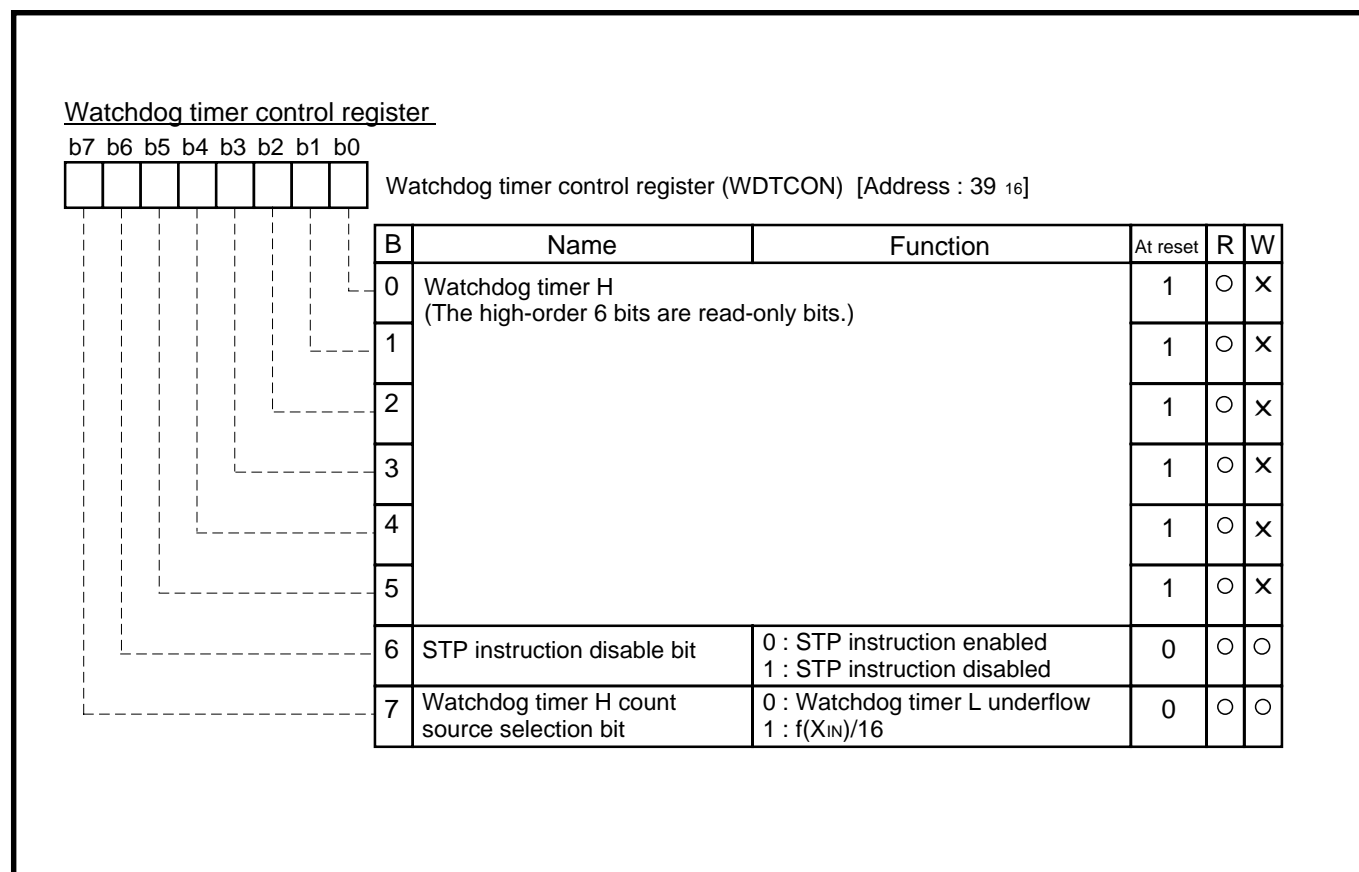


Fig. 3.5.32 Structure of Watchdog timer control register

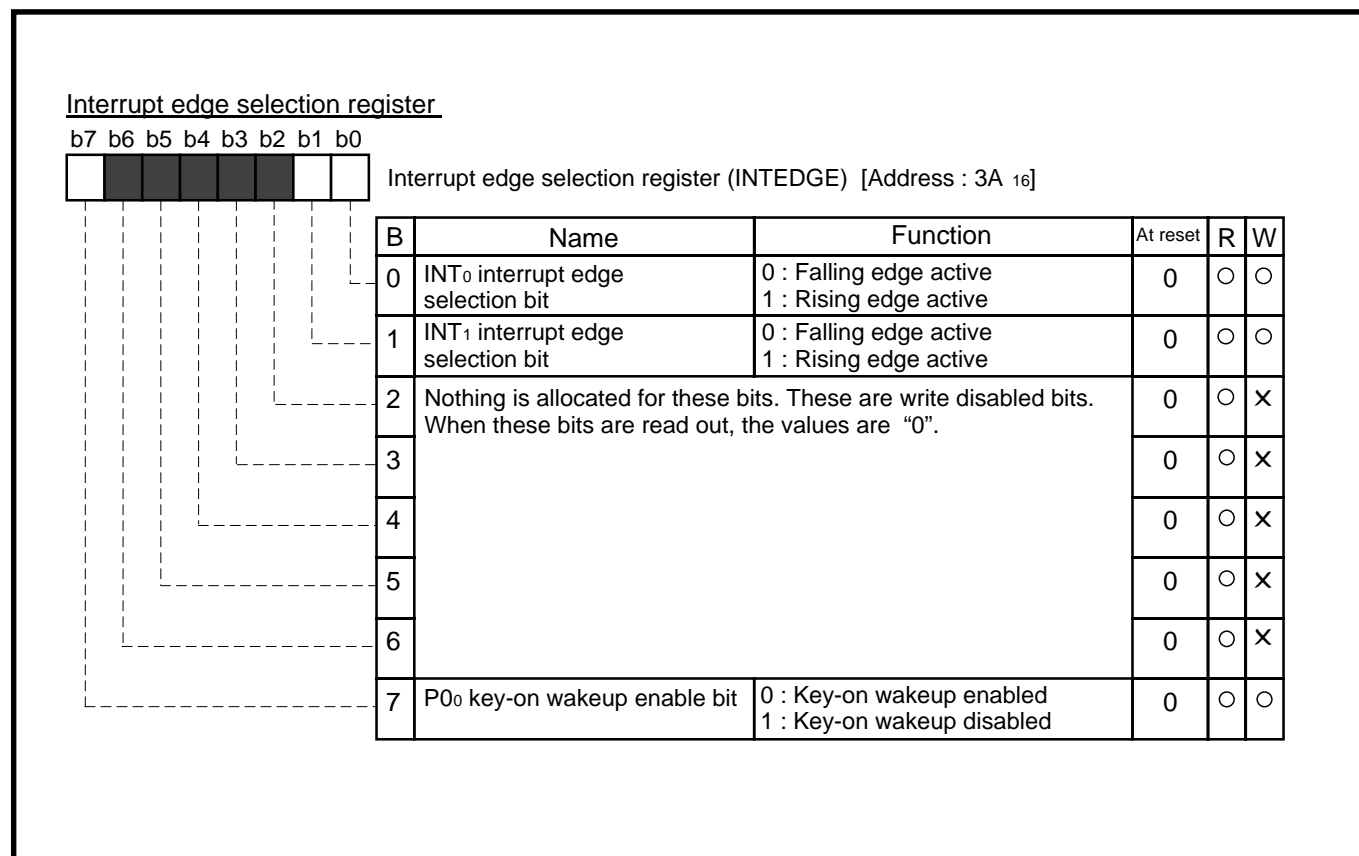


Fig. 3.5.33 Structure of Interrupt edge selection register

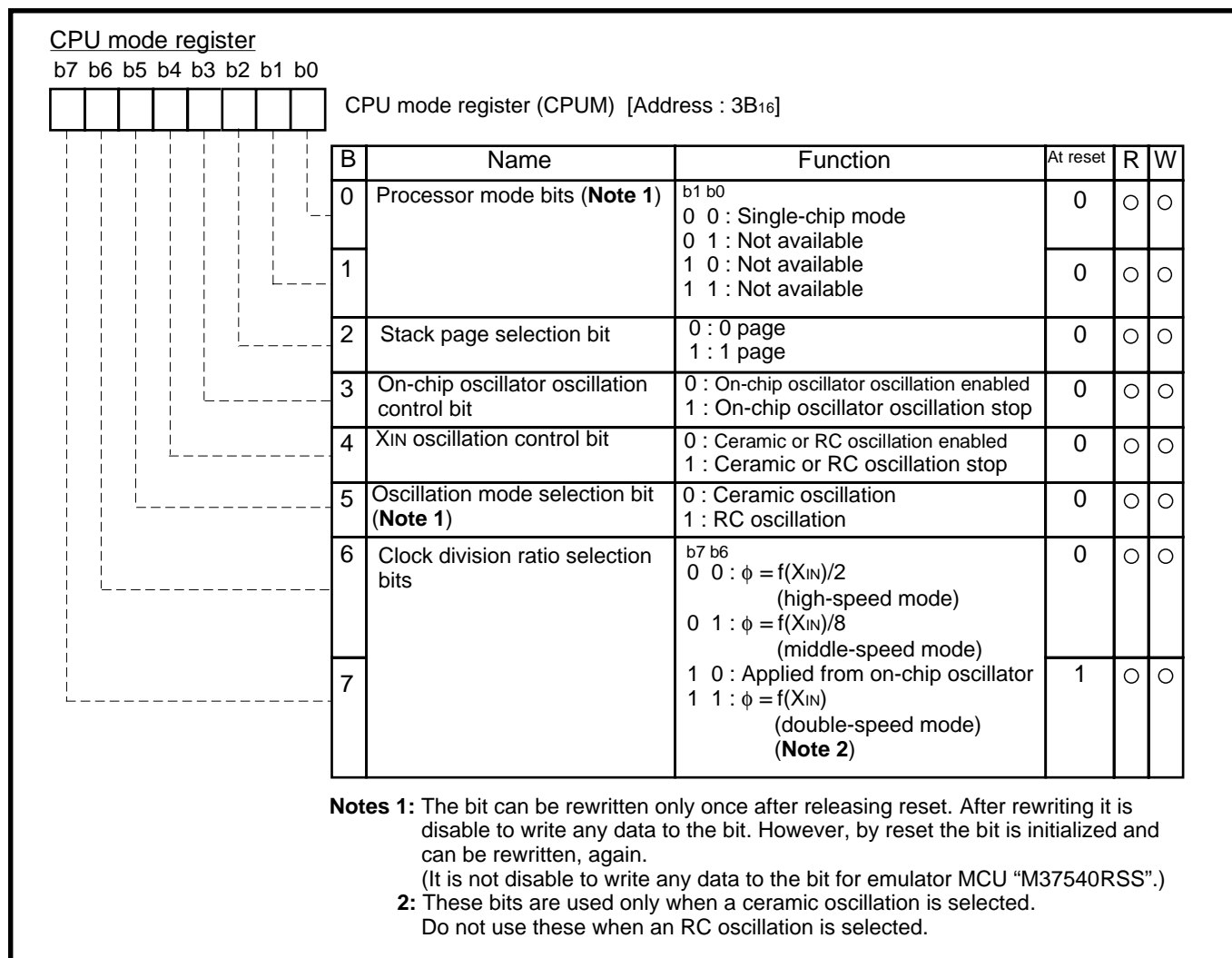


Fig. 3.5.34 Structure of CPU mode register

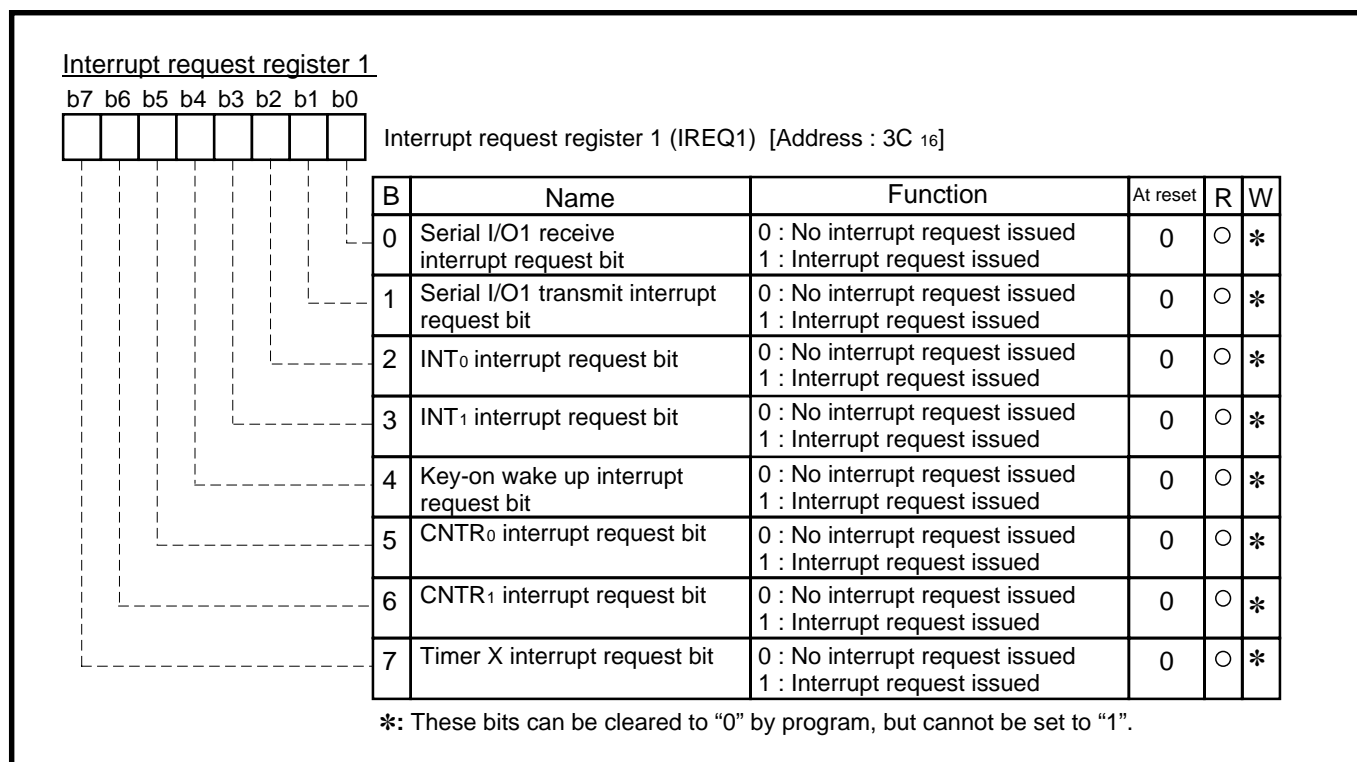


Fig. 3.5.35 Structure of Interrupt request register 1

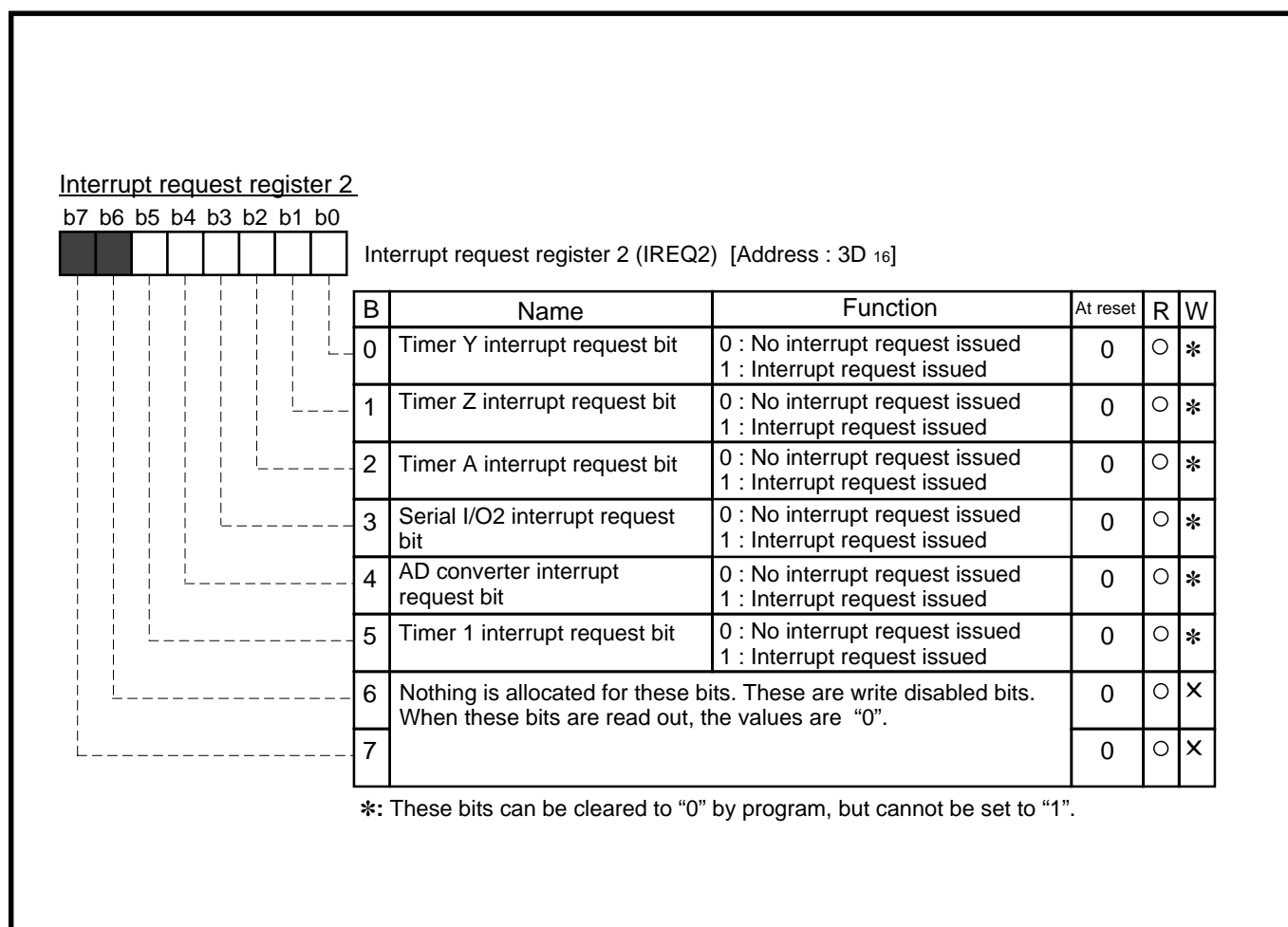


Fig. 3.5.36 Structure of Interrupt request register 2

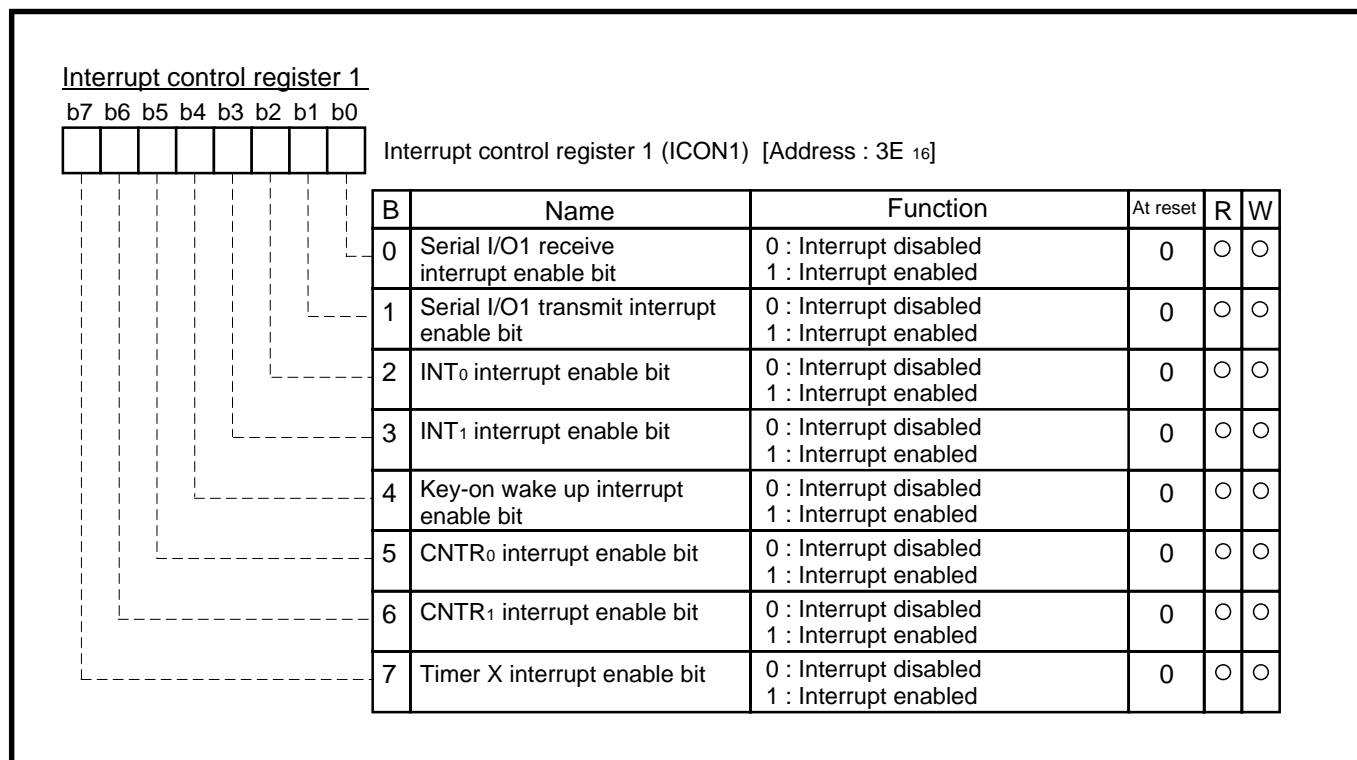


Fig. 3.5.37 Structure of Interrupt control register 1

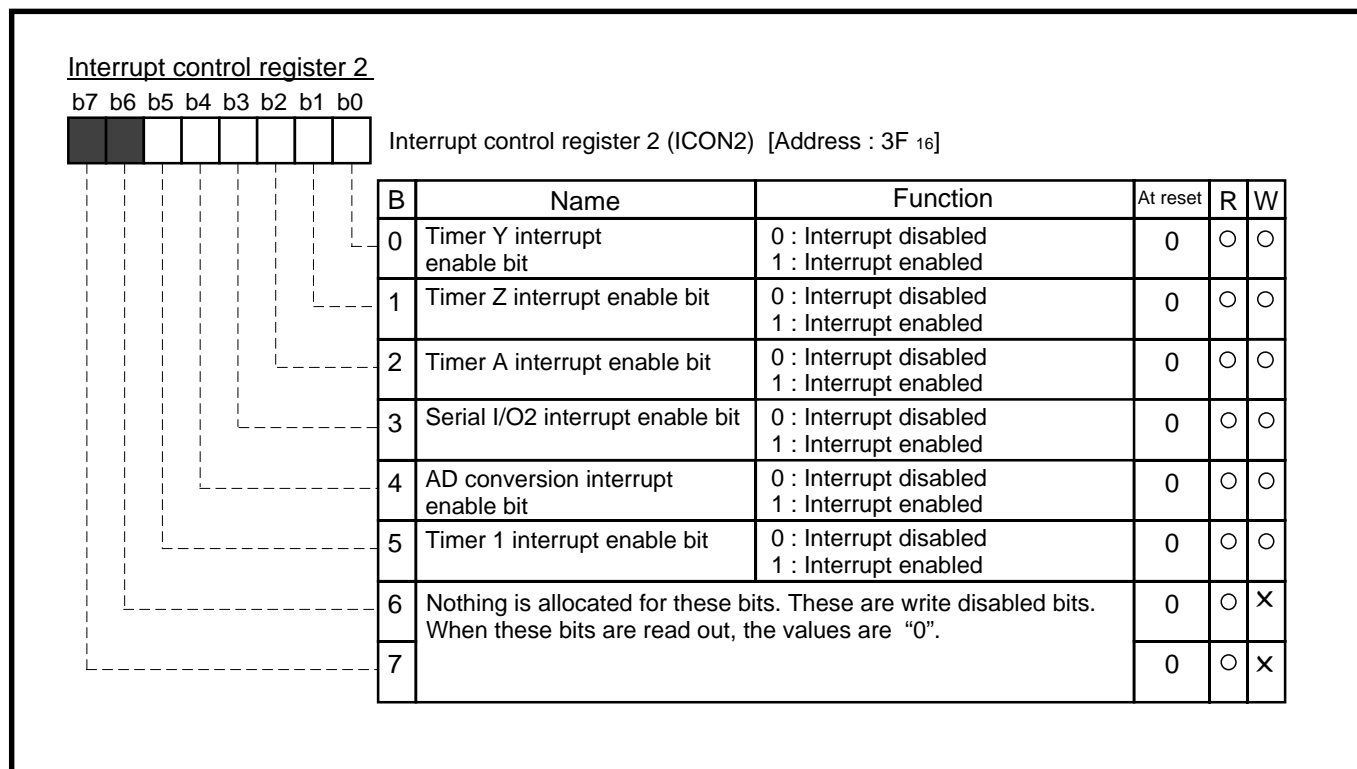


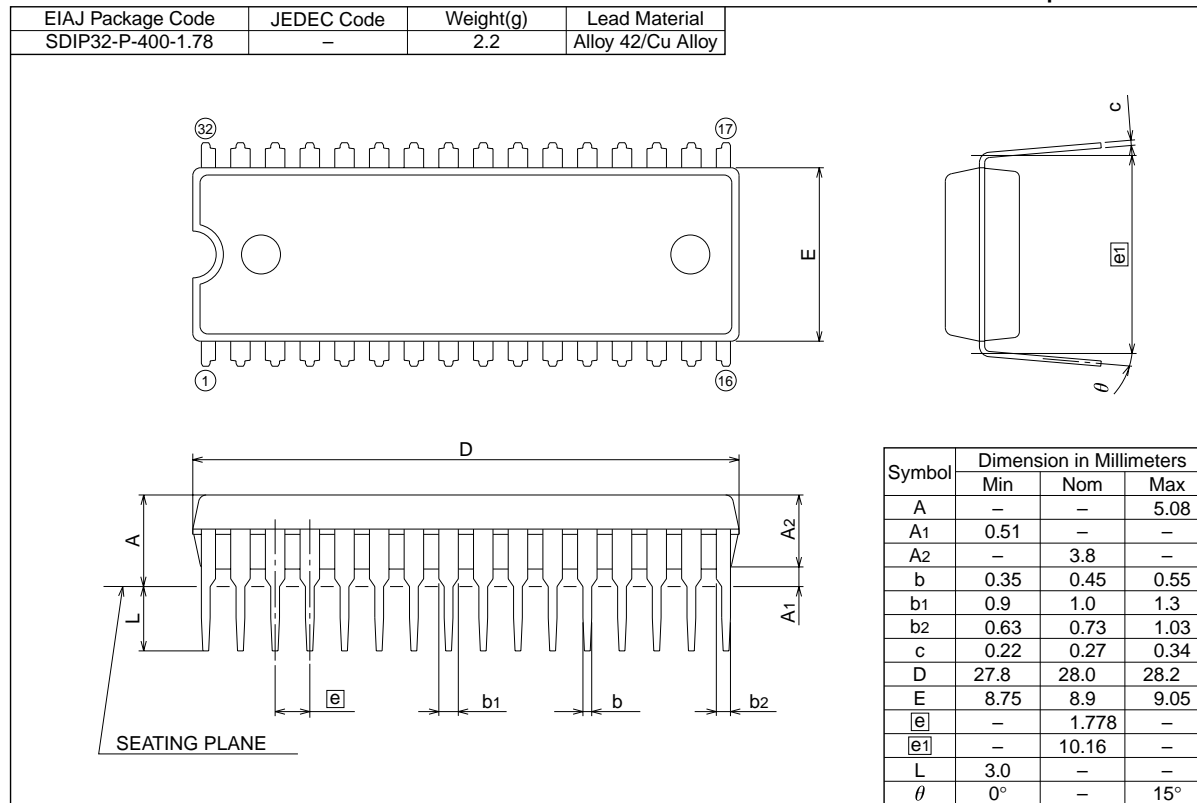
Fig. 3.5.38 Structure of Interrupt control register 2

3.6 Package outline

32P4B

Recommended

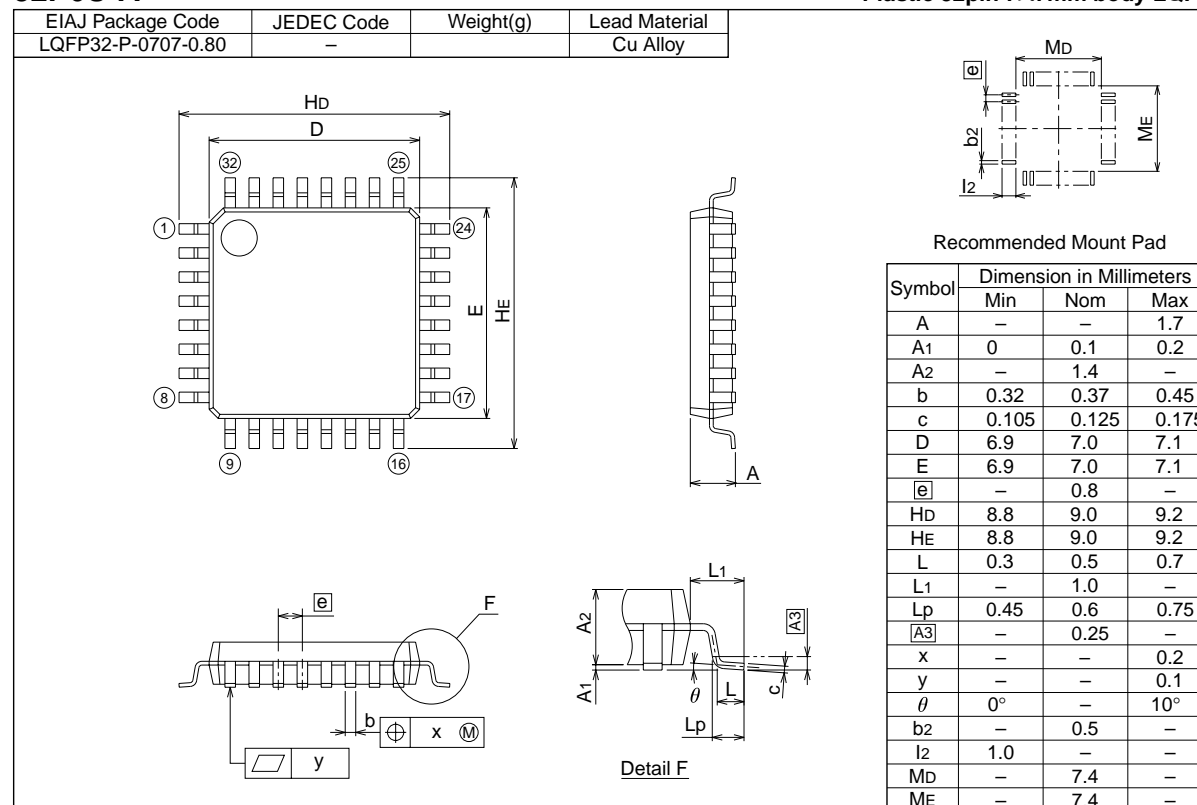
Plastic 32pin 400mil SDIP



32P6U-A

Recommended

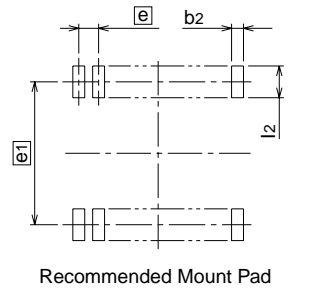
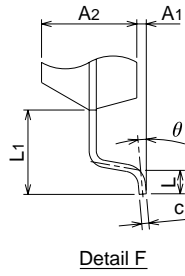
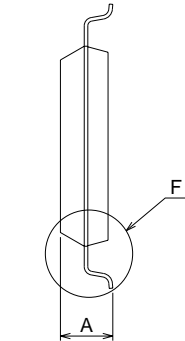
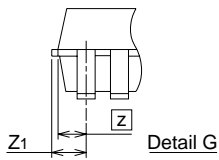
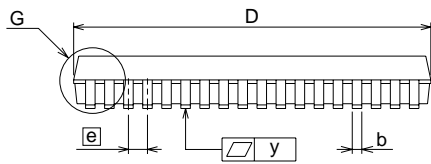
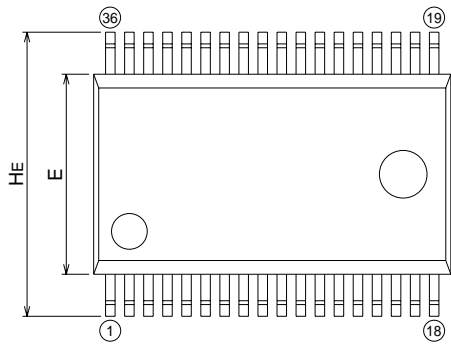
Plastic 32pin 7x7mm body LQFP



36P2R-A Recommended

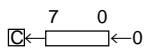
Plastic 36pin 450mil SSOP

| | | | |
|-------------------|------------|-----------|---------------|
| EIAJ Package Code | JEDEC Code | Weight(g) | Lead Material |
| SSOP36-P-450-0.80 | - | 0.53 | Alloy 42 |



| Symbol | Dimension in Millimeters | | |
|--------|--------------------------|-------|-------|
| | Min | Nom | Max |
| A | - | - | 2.4 |
| A1 | 0.05 | - | - |
| A2 | - | 2.0 | - |
| b | 0.35 | 0.4 | 0.5 |
| c | 0.13 | 0.15 | 0.2 |
| D | 14.8 | 15.0 | 15.2 |
| E | 8.2 | 8.4 | 8.6 |
| e | - | 0.8 | - |
| HE | 11.63 | 11.93 | 12.23 |
| L | 0.3 | 0.5 | 0.7 |
| L1 | - | 1.765 | - |
| Z | - | 0.7 | - |
| Z1 | - | - | 0.85 |
| y | - | - | 0.15 |
| theta | 0° | - | 10° |
| b2 | - | 0.5 | - |
| e1 | - | 11.43 | - |
| l2 | 1.27 | - | - |

3.7 Machine instructions

| Symbol | Function | Details | Addressing mode | | | | | | | | | | | | | | | | | | | | |
|-----------------------------|--|---|-----------------|---|---|-----|---|---|----|---|---|------------------|---|---|----|---|---|------------------|---|---|--|--|--|
| | | | IMP | | | IMM | | | A | | | BIT, A, R | | | ZP | | | BIT, ZP, R | | | | | |
| | | | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | | | |
| ADC (Note 1) (Note 5) | When T = 0 $A \leftarrow A + M + C$ When T = 1 $M(X) \leftarrow M(X) + M + C$ | When T = 0, this instruction adds the contents M, C, and A; and stores the results in A and C. When T = 1, this instruction adds the contents of M(X), M and C; and stores the results in M(X) and C. When T=1, the contents of A remain unchanged, but the contents of status flags are changed. M(X) represents the contents of memory where is indicated by X. | | | | 69 | 2 | 2 | | | | | | | | | | 65 | 3 | 2 | | | |
| AND (Note 1) | When T = 0 $A \leftarrow A \wedge M$ When T = 1 $M(X) \leftarrow M(X) \wedge M$ | When T = 0, this instruction transfers the contents of A and M to the ALU which performs a bit-wise AND operation and stores the result back in A. When T = 1, this instruction transfers the contents M(X) and M to the ALU which performs a bit-wise AND operation and stores the results back in M(X). When T = 1, the contents of A remain unchanged, but status flags are changed. M(X) represents the contents of memory where is indicated by X. | | | | 29 | 2 | 2 | | | | | | | | | | 25 | 3 | 2 | | | |
| ASL |  | This instruction shifts the content of A or M by one bit to the left, with bit 0 always being set to 0 and bit 7 of A or M always being contained in C. | | | | | | | 0A | 2 | 1 | | | | | | | 06 | 5 | 2 | | | |
| BBC (Note 4) | A_i or $M_i = 0?$ | This instruction tests the designated bit i of M or A and takes a branch if the bit is 0. The branch address is specified by a relative address. If the bit is 1, next instruction is executed. | | | | | | | | | | $\frac{13}{20i}$ | 4 | 2 | | | | $\frac{17}{20i}$ | 5 | 3 | | | |
| BBS (Note 4) | A_i or $M_i = 1?$ | This instruction tests the designated bit i of the M or A and takes a branch if the bit is 1. The branch address is specified by a relative address. If the bit is 0, next instruction is executed. | | | | | | | | | | $\frac{03}{20i}$ | 4 | 2 | | | | $\frac{07}{20i}$ | 5 | 3 | | | |
| BCC (Note 4) | $C = 0?$ | This instruction takes a branch to the appointed address if C is 0. The branch address is specified by a relative address. If C is 1, the next instruction is executed. | | | | | | | | | | | | | | | | | | | | | |
| BCS (Note 4) | $C = 1?$ | This instruction takes a branch to the appointed address if C is 1. The branch address is specified by a relative address. If C is 0, the next instruction is executed. | | | | | | | | | | | | | | | | | | | | | |
| BEQ (Note 4) | $Z = 1?$ | This instruction takes a branch to the appointed address when Z is 1. The branch address is specified by a relative address. If Z is 0, the next instruction is executed. | | | | | | | | | | | | | | | | | | | | | |
| BIT | $A \wedge M$ | This instruction takes a bit-wise logical AND of A and M contents; however, the contents of A and M are not modified. The contents of N, V, Z are changed, but the contents of A, M remain unchanged. | | | | | | | | | | | | | | | | 24 | 3 | 2 | | | |
| BMI (Note 4) | $N = 1?$ | This instruction takes a branch to the appointed address when N is 1. The branch address is specified by a relative address. If N is 0, the next instruction is executed. | | | | | | | | | | | | | | | | | | | | | |
| BNE (Note 4) | $Z = 0?$ | This instruction takes a branch to the appointed address if Z is 0. The branch address is specified by a relative address. If Z is 1, the next instruction is executed. | | | | | | | | | | | | | | | | | | | | | |

| Symbol | Function | Details | Addressing mode | | | | | | | | | | | | | | | | | |
|-----------------|--|--|-----------------|---|---|-----|---|---|----|---|---|--------|---|---|----|---|---|---------|---|---|
| | | | IMP | | | IMM | | | A | | | BIT, A | | | ZP | | | BIT, ZP | | |
| | | | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # |
| DEX | $X \leftarrow X - 1$ | This instruction subtracts one from the current contents of X. | CA | 2 | 1 | | | | | | | | | | | | | | | |
| DEY | $Y \leftarrow Y - 1$ | This instruction subtracts one from the current contents of Y. | 88 | 2 | 1 | | | | | | | | | | | | | | | |
| DIV | $A \leftarrow (M(\text{zz} + X + 1), M(\text{zz} + X)) / A$ $M(S) \leftarrow \text{one's complement of Remainder}$ $S \leftarrow S - 1$ | This instruction divides the 16-bit data in $M(\text{zz} + X)$ (low-order byte) and $M(\text{zz} + X + 1)$ (high-order byte) by the contents of A. The quotient is stored in A and the one's complement of the remainder is pushed onto the stack. | | | | | | | | | | | | | | | | | | |
| EOR (Note 1) | When $T = 0$ $A \leftarrow A \vee M$ When $T = 1$ $M(X) \leftarrow M(X) \vee M$ | When $T = 0$, this instruction transfers the contents of the M and A to the ALU which performs a bit-wise Exclusive OR, and stores the result in A. When $T = 1$, the contents of $M(X)$ and M are transferred to the ALU, which performs a bit-wise Exclusive OR and stores the results in $M(X)$. The contents of A remain unchanged, but status flags are changed. $M(X)$ represents the contents of memory where is indicated by X. | | | | 49 | 2 | 2 | | | | | | | 45 | 3 | 2 | | | |
| INC | $A \leftarrow A + 1$ or $M \leftarrow M + 1$ | This instruction adds one to the contents of A or M. | | | | | | | 3A | 2 | 1 | | | | E6 | 5 | 2 | | | |
| INX | $X \leftarrow X + 1$ | This instruction adds one to the contents of X. | E8 | 2 | 1 | | | | | | | | | | | | | | | |
| INY | $Y \leftarrow Y + 1$ | This instruction adds one to the contents of Y. | C8 | 2 | 1 | | | | | | | | | | | | | | | |
| JMP | If addressing mode is ABS $PCL \leftarrow ADL$ $PCH \leftarrow ADH$ If addressing mode is IND $PCL \leftarrow M(ADH, ADL)$ $PCH \leftarrow M(ADH, ADL + 1)$ If addressing mode is ZP, IND $PCL \leftarrow M(00, ADL)$ $PCH \leftarrow M(00, ADL + 1)$ | This instruction jumps to the address designated by the following three addressing modes: Absolute Indirect Absolute Zero Page Indirect Absolute | | | | | | | | | | | | | | | | | | |
| JSR | $M(S) \leftarrow PCH$ $S \leftarrow S - 1$ $M(S) \leftarrow PCL$ $S \leftarrow S - 1$ After executing the above, if addressing mode is ABS, $PCL \leftarrow ADL$ $PCH \leftarrow ADH$ if addressing mode is SP, $PCL \leftarrow ADL$ $PCH \leftarrow FF$ If addressing mode is ZP, IND, $PCL \leftarrow M(00, ADL)$ $PCH \leftarrow M(00, ADL + 1)$ | This instruction stores the contents of the PC in the stack, then jumps to the address designated by the following addressing modes: Absolute Special Page Zero Page Indirect Absolute | | | | | | | | | | | | | | | | | | |
| LDA (Note 2) | When $T = 0$ $A \leftarrow M$ When $T = 1$ $M(X) \leftarrow M$ | When $T = 0$, this instruction transfers the contents of M to A. When $T = 1$, this instruction transfers the contents of M to $M(X)$. The contents of A remain unchanged, but status flags are changed. $M(X)$ represents the contents of memory where is indicated by X. | | | | A9 | 2 | 2 | | | | | | | A5 | 3 | 2 | | | |
| LDM | $M \leftarrow nn$ | This instruction loads the immediate value in M. | | | | | | | | | | | | | 3C | 4 | 3 | | | |
| LDX | $X \leftarrow M$ | This instruction loads the contents of M in X. | | | | A2 | 2 | 2 | | | | | | | A6 | 3 | 2 | | | |
| LDY | $Y \leftarrow M$ | This instruction loads the contents of M in Y. | | | | A0 | 2 | 2 | | | | | | | A4 | 3 | 2 | | | |

| Addressing mode | | | | | | | | | | | | | | Processor status register | | | | | | | | | | | | | | | | | | |
|-----------------|----|-------|----|-----|---|--------|---|--------|----|-----|---|---------|---|---------------------------|----|--------|---|-----|---|----|----|---|----|---|---|---|---|---|---|---|---|---|
| ZP, X | | ZP, Y | | ABS | | ABS, X | | ABS, Y | | IND | | ZP, IND | | IND, X | | IND, Y | | REL | | SP | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |
| OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | N | V | T | B | D | I | Z | C | |
| | | | | | | | | | | | | | | | | | | | | | | | N | . | . | . | . | . | . | Z | . | |
| | | | | | | | | | | | | | | | | | | | | | | | N | . | . | . | . | . | . | Z | . | |
| E2 | 16 | 2 | | | | | | | | | | | | | | | | | | | | | . | . | . | . | . | . | . | . | . | |
| 55 | 4 | 2 | | | | 4D | 4 | 3 | 5D | 5 | 3 | 59 | 5 | 3 | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | 41 | 6 | 2 | 51 | 6 | 2 | | | | N | . | . | . | . | . | . | Z | . |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F6 | 6 | 2 | | | | EE | 6 | 3 | FE | 7 | 3 | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | N | . | . | . | . | . | . | Z | . | |
| | | | | | | | | | | | | | | | | | | | | | | | N | . | . | . | . | . | . | Z | . | |
| | | | | | | 4C | 3 | 3 | | | | 6C | 5 | 3 | B2 | 4 | 2 | | | | | | . | . | . | . | . | . | . | . | . | |
| | | | | | | 20 | 6 | 3 | | | | | | | 02 | 7 | 2 | | | | | | 22 | 5 | 2 | . | . | . | . | . | . | . |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B5 | 4 | 2 | | | | AD | 4 | 3 | BD | 5 | 3 | B9 | 5 | 3 | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | A1 | 6 | 2 | B1 | 6 | 2 | | | | N | . | . | . | . | . | . | Z | . |
| | | | | | | | | | | | | | | | | | | | | | | | . | . | . | . | . | . | . | . | . | |
| | | | B6 | 4 | 2 | AE | 4 | 3 | | | | BE | 5 | 3 | | | | | | | | | N | . | . | . | . | . | . | Z | . | |
| B4 | 4 | 2 | | | | AC | 4 | 3 | BC | 5 | 3 | | | | | | | | | | | | N | . | . | . | . | . | . | Z | . | |


| Symbol | Function | Details | Addressing mode | | | | | | | | | | | | | | | | | | | | |
|-----------------------------|--|---|-----------------|---|---|-----|---|---|----|---|---|-----------|---|---|----|---|---|-----------|---|---|--|--|--|
| | | | IMP | | | IMM | | | A | | | BIT, A | | | ZP | | | BIT, ZP | | | | | |
| | | | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | OP | n | # | | | |
| SBC (Note 1) (Note 5) | When T = 0 $A \leftarrow A - M - C$ When T = 1 $M(X) \leftarrow M(X) - M - C$ | When T = 0, this instruction subtracts the value of M and the complement of C from A, and stores the results in A and C. When T = 1, the instruction subtracts the contents of M and the complement of C from the contents of M(X), and stores the results in M(X) and C. A remain unchanged, but status flag are changed. M(X) represents the contents of memory where is indicated by X. | | | | E9 | 2 | 2 | | | | | | | | | | E5 | 3 | 2 | | | |
| SEB | A_i or $M_i \leftarrow 1$ | This instruction sets the designated bit i of A or M. | | | | | | | | | | 0B 20i | 2 | 1 | | | | 0F 20i | 5 | 2 | | | |
| SEC | $C \leftarrow 1$ | This instruction sets C. | 38 | 2 | 1 | | | | | | | | | | | | | | | | | | |
| SED | $D \leftarrow 1$ | This instruction set D. | F8 | 2 | 1 | | | | | | | | | | | | | | | | | | |
| SEI | $I \leftarrow 1$ | This instruction set I. | 78 | 2 | 1 | | | | | | | | | | | | | | | | | | |
| SET | $T \leftarrow 1$ | This instruction set T. | 32 | 2 | 1 | | | | | | | | | | | | | | | | | | |
| STA | $M \leftarrow A$ | This instruction stores the contents of A in M. The contents of A does not change. | | | | | | | | | | | | | | | | 85 | 4 | 2 | | | |
| STP | | This instruction resets the oscillation control F/F and the oscillation stops. Reset or interrupt input is needed to wake up from this mode. | 42 | 2 | 1 | | | | | | | | | | | | | | | | | | |
| STX | $M \leftarrow X$ | This instruction stores the contents of X in M. The contents of X does not change. | | | | | | | | | | | | | | | | 86 | 4 | 2 | | | |
| STY | $M \leftarrow Y$ | This instruction stores the contents of Y in M. The contents of Y does not change. | | | | | | | | | | | | | | | | 84 | 4 | 2 | | | |
| TAX | $X \leftarrow A$ | This instruction stores the contents of A in X. The contents of A does not change. | AA | 2 | 1 | | | | | | | | | | | | | | | | | | |
| TAY | $Y \leftarrow A$ | This instruction stores the contents of A in Y. The contents of A does not change. | A8 | 2 | 1 | | | | | | | | | | | | | | | | | | |
| TST | $M = 0?$ | This instruction tests whether the contents of M are "0" or not and modifies the N and Z. | | | | | | | | | | | | | | | | 64 | 3 | 2 | | | |
| TSX | $X \leftarrow S$ | This instruction transfers the contents of S in X. | BA | 2 | 1 | | | | | | | | | | | | | | | | | | |
| TXA | $A \leftarrow X$ | This instruction stores the contents of X in A. | 8A | 2 | 1 | | | | | | | | | | | | | | | | | | |
| TXS | $S \leftarrow X$ | This instruction stores the contents of X in S. | 9A | 2 | 1 | | | | | | | | | | | | | | | | | | |
| TYA | $A \leftarrow Y$ | This instruction stores the contents of Y in A. | 98 | 2 | 1 | | | | | | | | | | | | | | | | | | |
| WIT | | The WIT instruction stops the internal clock but not the oscillation of the oscillation circuit is not stopped. CPU starts its function after the Timer X over flows (comes to the terminal count). All registers or internal memory contents except Timer X will not change during this mode. (Of course needs VDD). | C2 | 2 | 1 | | | | | | | | | | | | | | | | | | |


Notes 1 : The number of cycles "n" is increased by 3 when T is 1.
2 : The number of cycles "n" is increased by 2 when T is 1.
3 : The number of cycles "n" is increased by 1 when T is 1.
4 : The number of cycles "n" is increased by 2 when branching has occurred.
5 : N, V, and Z flags are invalid in decimal operation mode.

| Symbol | Contents | Symbol | Contents |
|------------|---|-------------|--|
| IMP | Implied addressing mode | + | Addition |
| IMM | Immediate addressing mode | - | Subtraction |
| A | Accumulator or Accumulator addressing mode | * | Multiplication |
| BIT, A | Accumulator bit addressing mode | / | Division |
| BIT, A, R | Accumulator bit relative addressing mode | ∧ | Logical OR |
| ZP | Zero page addressing mode | ∨ | Logical AND |
| BIT, ZP | Zero page bit addressing mode | ⊕ | Logical exclusive OR |
| BIT, ZP, R | Zero page bit relative addressing mode | — | Negation |
| ZP, X | Zero page X addressing mode | ← | Shows direction of data flow |
| ZP, Y | Zero page Y addressing mode | X | Index register X |
| ABS | Absolute addressing mode | Y | Index register Y |
| ABS, X | Absolute X addressing mode | S | Stack pointer |
| ABS, Y | Absolute Y addressing mode | PC | Program counter |
| IND | Indirect absolute addressing mode | PS | Processor status register |
| ZP, IND | Zero page indirect absolute addressing mode | PCH | 8 high-order bits of program counter |
| IND, X | Indirect X addressing mode | PCL | 8 low-order bits of program counter |
| IND, Y | Indirect Y addressing mode | ADH | 8 high-order bits of address |
| REL | Relative addressing mode | ADL | 8 low-order bits of address |
| SP | Special page addressing mode | FF | FF in Hexadecimal notation |
| C | Carry flag | nn | Immediate value |
| Z | Zero flag | zz | Zero page address |
| I | Interrupt disable flag | M | Memory specified by address designation of any addressing mode |
| D | Decimal mode flag | M(X) | Memory of address indicated by contents of index register X |
| B | Break flag | M(S) | Memory of address indicated by contents of stack pointer |
| T | X-modified arithmetic mode flag | M(ADH, ADL) | Contents of memory at address indicated by ADH and ADL, in ADH is 8 high-order bits and ADL is 8 low-order bits. |
| V | Overflow flag | M(00, ADL) | Contents of address indicated by zero page ADL |
| N | Negative flag | Ai | Bit i (i = 0 to 7) of accumulator |
| | | Mi | Bit i (i = 0 to 7) of memory |
| | | OP | Opcode |
| | | n | Number of cycles |
| | | # | Number of bytes |

3.8 List of instruction code

| D7 – D4 | D3 – D0 | Hexadecimal notation | | | | | | | | | | | | | | | |
|---------|---------|----------------------|---------------|----------------|-------------|--------------|--------------|--------------|--------------|-----|---------------|----------|-------------|---------------|---------------|---------------|--------------|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
| 0000 | 0 | BRK | ORA IND, X | JSR ZP, IND | BBS 0, A | — | ORA ZP | ASL ZP | BBS 0, ZP | PHP | ORA IMM | ASL A | SEB 0, A | — | ORA ABS | ASL ABS | SEB 0, ZP |
| 0001 | 1 | BPL | ORA IND, Y | CLT | BBC 0, A | — | ORA ZP, X | ASL ZP, X | BBC 0, ZP | CLC | ORA ABS, Y | DEC A | CLB 0, A | — | ORA ABS, X | ASL ABS, X | CLB 0, ZP |
| 0010 | 2 | JSR ABS | AND IND, X | JSR SP | BBS 1, A | BIT ZP | AND ZP | ROL ZP | BBS 1, ZP | PLP | AND IMM | ROL A | SEB 1, A | BIT ABS | AND ABS | ROL ABS | SEB 1, ZP |
| 0011 | 3 | BMI | AND IND, Y | SET | BBC 1, A | — | AND ZP, X | ROL ZP, X | BBC 1, ZP | SEC | AND ABS, Y | INC A | CLB 1, A | LDM ZP | AND ABS, X | ROL ABS, X | CLB 1, ZP |
| 0100 | 4 | RTI | EOR IND, X | STP | BBS 2, A | COM ZP | EOR ZP | LSR ZP | BBS 2, ZP | PHA | EOR IMM | LSR A | SEB 2, A | JMP ABS | EOR ABS | LSR ABS | SEB 2, ZP |
| 0101 | 5 | BVC | EOR IND, Y | — | BBC 2, A | — | EOR ZP, X | LSR ZP, X | BBC 2, ZP | CLI | EOR ABS, Y | — | CLB 2, A | — | EOR ABS, X | LSR ABS, X | CLB 2, ZP |
| 0110 | 6 | RTS | ADC IND, X | MUL ZP, X | BBS 3, A | TST ZP | ADC ZP | ROR ZP | BBS 3, ZP | PLA | ADC IMM | ROR A | SEB 3, A | JMP IND | ADC ABS | ROR ABS | SEB 3, ZP |
| 0111 | 7 | BVS | ADC IND, Y | — | BBC 3, A | — | ADC ZP, X | ROR ZP, X | BBC 3, ZP | SEI | ADC ABS, Y | — | CLB 3, A | — | ADC ABS, X | ROR ABS, X | CLB 3, ZP |
| 1000 | 8 | BRA | STA IND, X | RRF ZP | BBS 4, A | STY ZP | STA ZP | STX ZP | BBS 4, ZP | DEY | — | TXA | SEB 4, A | STY ABS | STA ABS | STX ABS | SEB 4, ZP |
| 1001 | 9 | BCC | STA IND, Y | — | BBC 4, A | STY ZP, X | STA ZP, X | STX ZP, Y | BBC 4, ZP | TYA | STA ABS, Y | TXS | CLB 4, A | — | STA ABS, X | — | CLB 4, ZP |
| 1010 | A | LDY IMM | LDA IND, X | LDX IMM | BBS 5, A | LDY ZP | LDA ZP | LDX ZP | BBS 5, ZP | TAY | LDA IMM | TAX | SEB 5, A | LDY ABS | LDA ABS | LDX ABS | SEB 5, ZP |
| 1011 | B | BCS | LDA IND, Y | JMP ZP, IND | BBC 5, A | LDY ZP, X | LDA ZP, X | LDX ZP, Y | BBC 5, ZP | CLV | LDA ABS, Y | TSX | CLB 5, A | LDY ABS, X | LDA ABS, X | LDX ABS, Y | CLB 5, ZP |
| 1100 | C | CPY IMM | CMP IND, X | WIT | BBS 6, A | CPY ZP | CMP ZP | DEC ZP | BBS 6, ZP | INY | CMP IMM | DEX | SEB 6, A | CPY ABS | CMP ABS | DEC ABS | SEB 6, ZP |
| 1101 | D | BNE | CMP IND, Y | — | BBC 6, A | — | CMP ZP, X | DEC ZP, X | BBC 6, ZP | CLD | CMP ABS, Y | — | CLB 6, A | — | CMP ABS, X | DEC ABS, X | CLB 6, ZP |
| 1110 | E | CPX IMM | SBC IND, X | DIV ZP, X | BBS 7, A | CPX ZP | SBC ZP | INC ZP | BBS 7, ZP | INX | SBC IMM | NOP | SEB 7, A | CPX ABS | SBC ABS | INC ABS | SEB 7, ZP |
| 1111 | F | BEQ | SBC IND, Y | — | BBC 7, A | — | SBC ZP, X | INC ZP, X | BBC 7, ZP | SED | SBC ABS, Y | — | CLB 7, A | — | SBC ABS, X | INC ABS, X | CLB 7, ZP |

 : 3-byte instruction

 : 2-byte instruction

 : 1-byte instruction

3.9 SFR memory map

| | | | |
|--------------------|--|--------------------|---|
| 0000 ₁₆ | Port P0 (P0) | 0020 ₁₆ | Timer Y, Z mode register (TYZM) |
| 0001 ₁₆ | Port P0 direction register (P0D) | 0021 ₁₆ | Prescaler Y (PREY) |
| 0002 ₁₆ | Port P1 (P1) | 0022 ₁₆ | Timer Y secondary (TYS) |
| 0003 ₁₆ | Port P1 direction register (P1D) | 0023 ₁₆ | Timer Y primary (TYP) |
| 0004 ₁₆ | Port P2 (P2) | 0024 ₁₆ | Timer Y, Z waveform output control register (PUM) |
| 0005 ₁₆ | Port P2 direction register (P2D) | 0025 ₁₆ | Prescaler Z (PREZ) |
| 0006 ₁₆ | Port P3 (P3) | 0026 ₁₆ | Timer Z secondary (TZS) |
| 0007 ₁₆ | Port P3 direction register (P3D) | 0027 ₁₆ | Timer Z primary (TZP) |
| 0008 ₁₆ | | 0028 ₁₆ | Prescaler 1 (PRE1) |
| 0009 ₁₆ | | 0029 ₁₆ | Timer 1 (T1) |
| 000A ₁₆ | | 002A ₁₆ | One-shot start register (ONS) |
| 000B ₁₆ | | 002B ₁₆ | Timer X mode register (TXM) |
| 000C ₁₆ | | 002C ₁₆ | Prescaler X (PREX) |
| 000D ₁₆ | | 002D ₁₆ | Timer X (TX) |
| 000E ₁₆ | | 002E ₁₆ | Timer count source set register (TCSS) |
| 000F ₁₆ | | 002F ₁₆ | |
| 0010 ₁₆ | | 0030 ₁₆ | Serial I/O2 control register (SIO2CON) |
| 0011 ₁₆ | | 0031 ₁₆ | Serial I/O2 register (SIO2) |
| 0012 ₁₆ | | 0032 ₁₆ | |
| 0013 ₁₆ | | 0033 ₁₆ | |
| 0014 ₁₆ | | 0034 ₁₆ | A/D control register (ADCON) |
| 0015 ₁₆ | | 0035 ₁₆ | A/D conversion register (low-order) (ADL) |
| 0016 ₁₆ | Pull-up control register (PULL) | 0036 ₁₆ | A/D conversion register (high-order) (ADH) |
| 0017 ₁₆ | Port P1P3 control register (P1P3C) | 0037 ₁₆ | |
| 0018 ₁₆ | Transmit/Receive buffer register (TB/RB) | 0038 ₁₆ | MISRG |
| 0019 ₁₆ | Serial I/O1 status register (SIO1STS) | 0039 ₁₆ | Watchdog timer control register (WDTCN) |
| 001A ₁₆ | Serial I/O1 control register (SIO1CON) | 003A ₁₆ | Interrupt edge selection register (INTEDGE) |
| 001B ₁₆ | UART control register (UARTCON) | 003B ₁₆ | CPU mode register (CPUM) |
| 001C ₁₆ | Baud rate generator (BRG) | 003C ₁₆ | Interrupt request register 1 (IREQ1) |
| 001D ₁₆ | Timer A mode register (TAM) | 003D ₁₆ | Interrupt request register 2 (IREQ2) |
| 001E ₁₆ | Timer A (low-order) (TAL) | 003E ₁₆ | Interrupt control register 1 (ICON1) |
| 001F ₁₆ | Timer A (high-order) (TAH) | 003F ₁₆ | Interrupt control register 2 (ICON2) |

3.10 Pin configurations

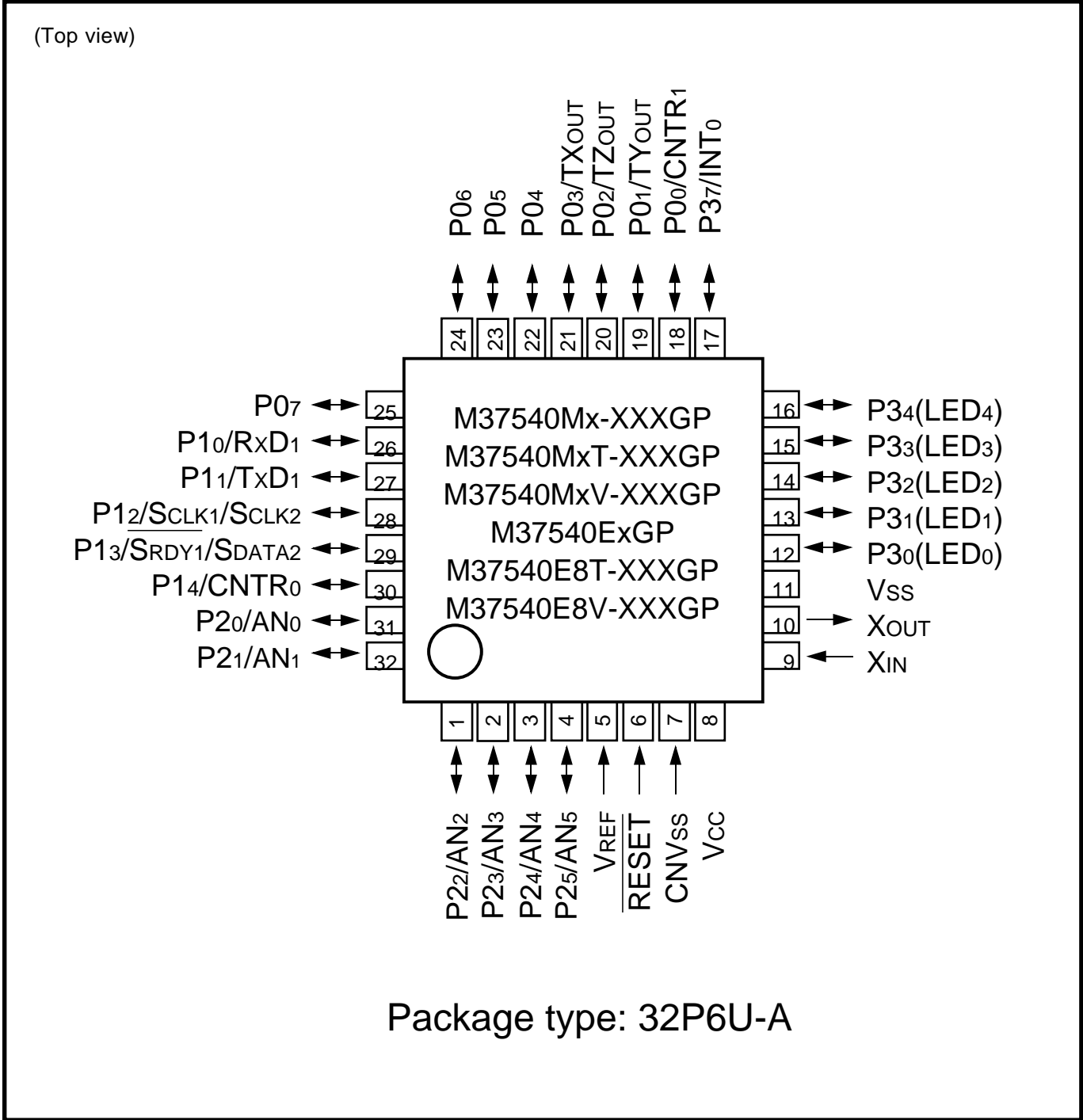


Fig. 3.10.1 32P6U-A package pin configuration

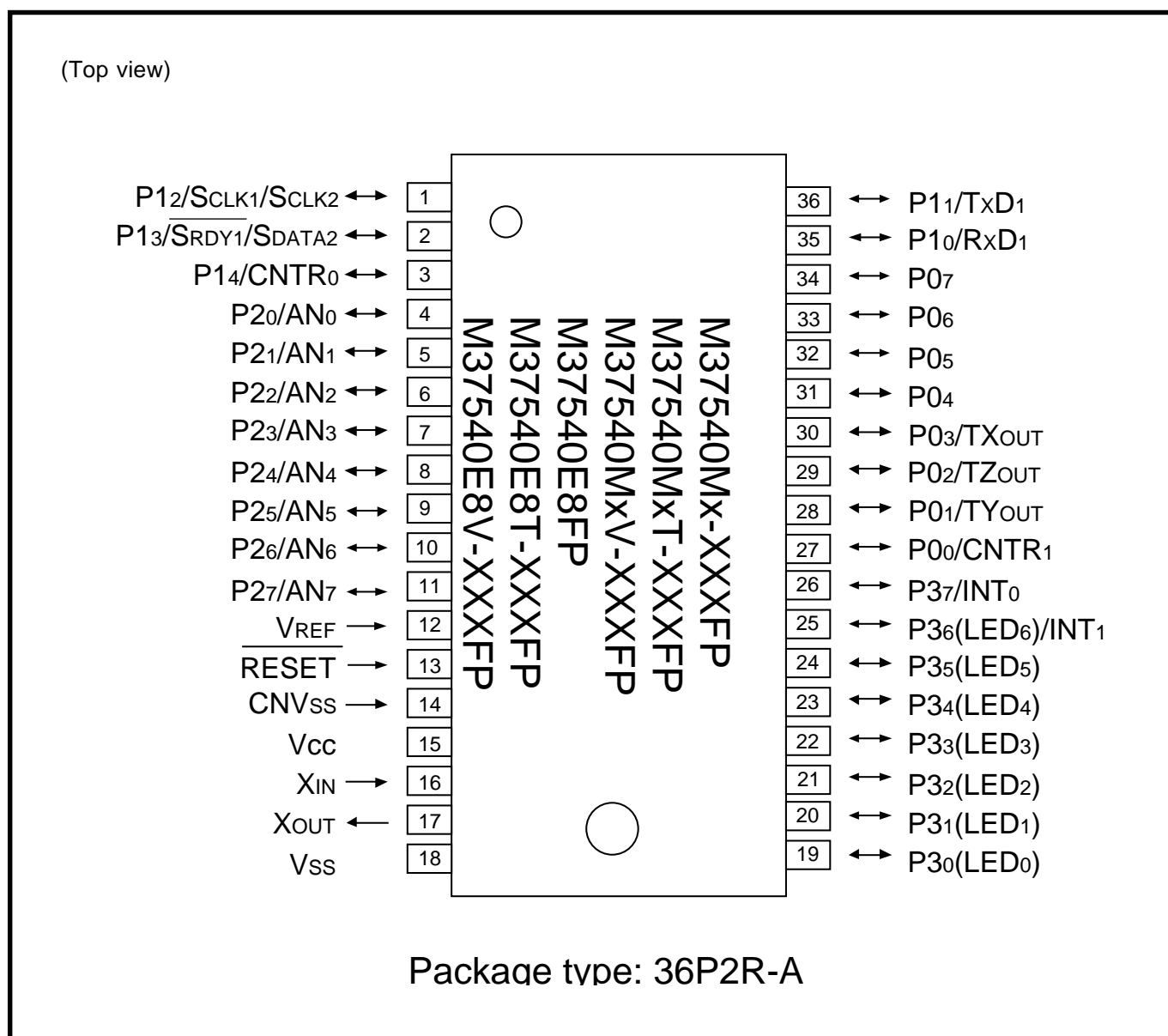


Fig. 3.10.2 36P2R-A package pin configuration

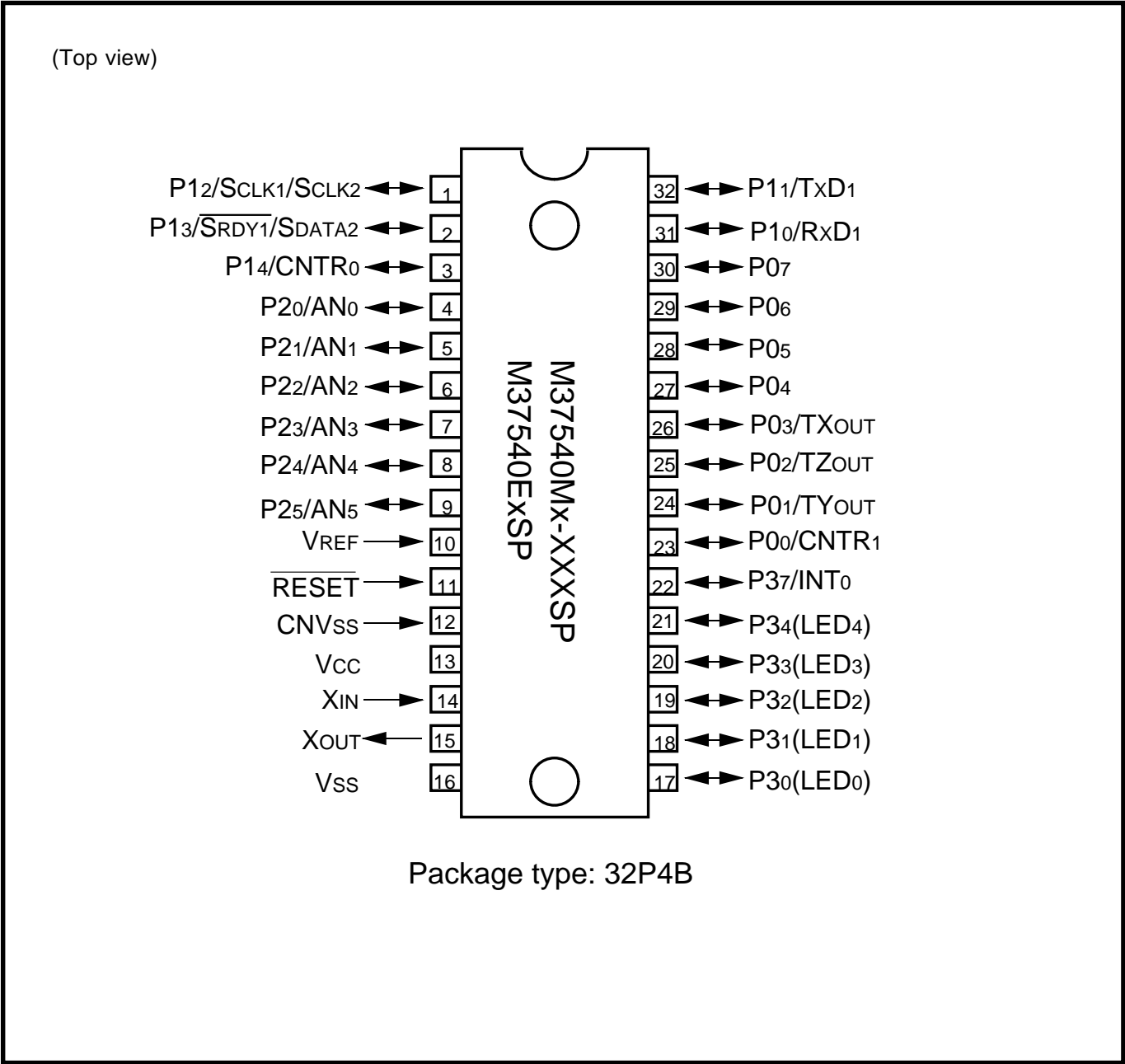


Fig. 3.10.3 32P4B package pin configuration

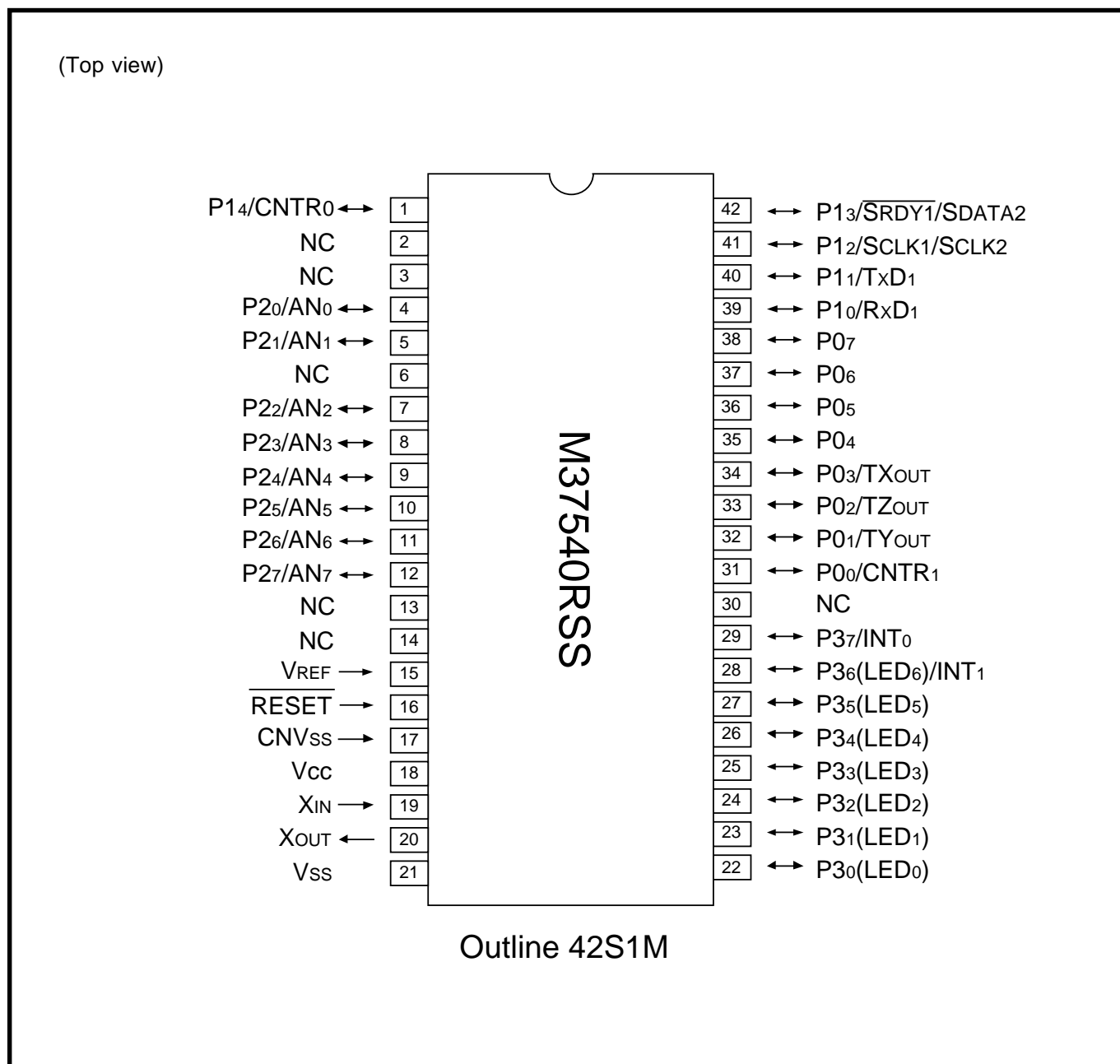


Fig. 3.10.4 42S1M package pin configuration

3.11 Differences between 7540 Group and 7531 Group

Table 3.11.1 shows the differences between 7540 Group and 7531 Group.

**Table 3.11.1 Differences between 7540 Group and 7531 Group
(Performance overview)**

| Parameter | | 7540 Group | 7531 Group |
|------------------------------------|----------------|--|---|
| Number of basic instructions | | 71 (DIV, MUL instruction added) | 69 |
| Memory sizes | ROM | 16 to 32 K bytes | 8 to 16 K bytes |
| | RAM | 512 to 768 bytes | 256 to 384 bytes |
| Input/Output ports | | Initial value: 00 ₁₆ (Ports P0 and P3 pull-up Off) | Initial value: FF ₁₆ (Ports P0 and P3 pull-up On) |
| Interrupt sources | 32-pin version | 14 sources, 14 vector (4 for external) | 11 sources, 8 vector (3 for external) |
| | 36-pin version | 15 sources, 15 vector (5 for external) | 12 sources, 8 vector (4 for external) |
| 16-bit timer | | 1 (Timer A) | ————— |
| 8-bit timer | | 3 (Timer 1, X, Y, Z) | 3 (Timer 1, 2, X) |
| Serial I/O1 | | Clock synchronous/UART | UART only |
| Clock generation circuit | | Cecamic oscillator/ Quartz-crystal oscillator/ RC oscillation/ On-chip oscillator oscillation | Cecamic oscillator/ Quartz-crystal oscillator/ RC oscillation |
| Oscillation stop detection circuit | | 1 | ————— |

Figure 3.11.1 shows the memory map of 7540 Group and 7531 Group.

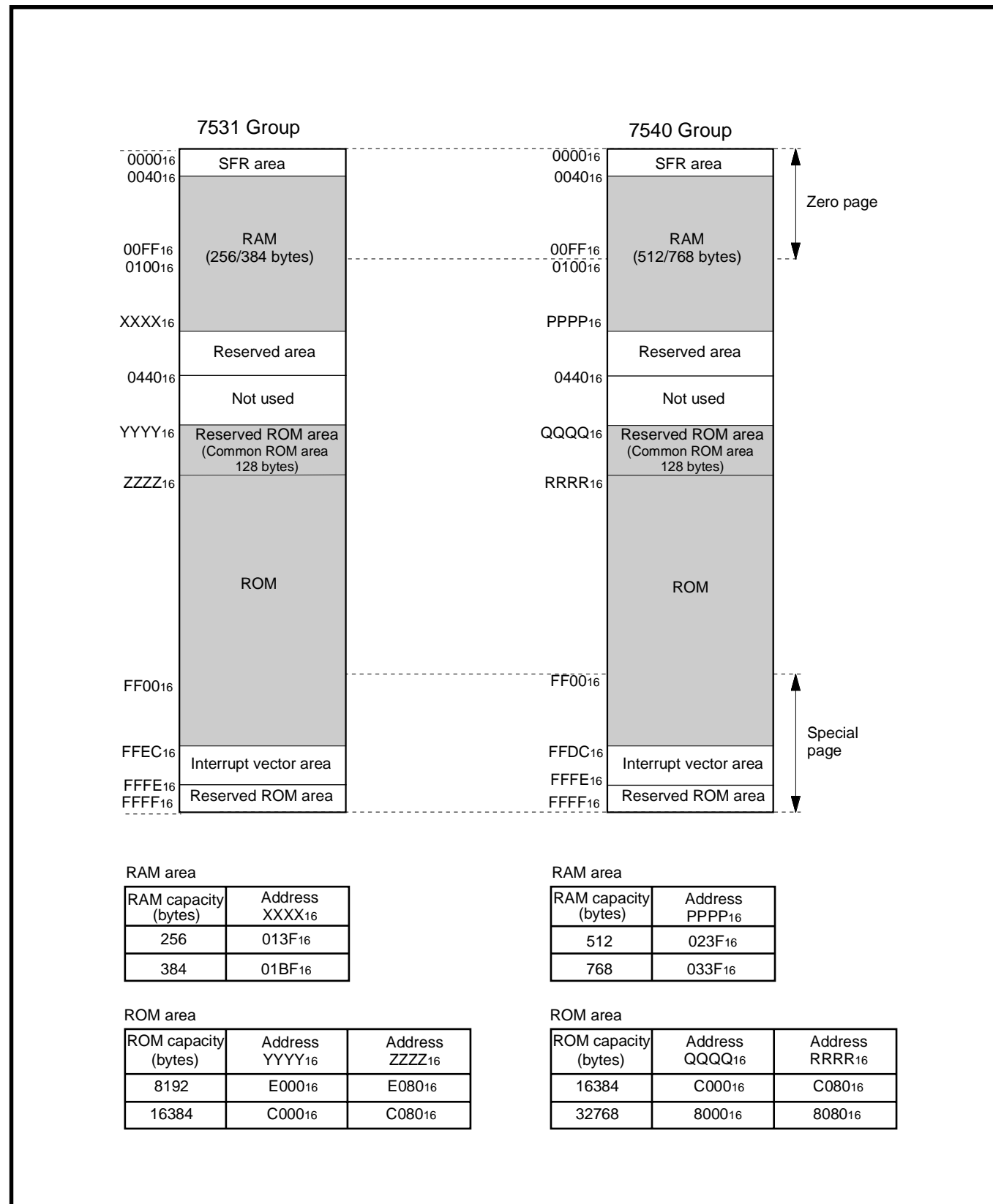


Fig. 3.11.1 Memory map of 7540 Group and 7531 Group

Figure 3.11.2 shows the memory map of interrupt vector area of 7540 Group and 7531 Group.

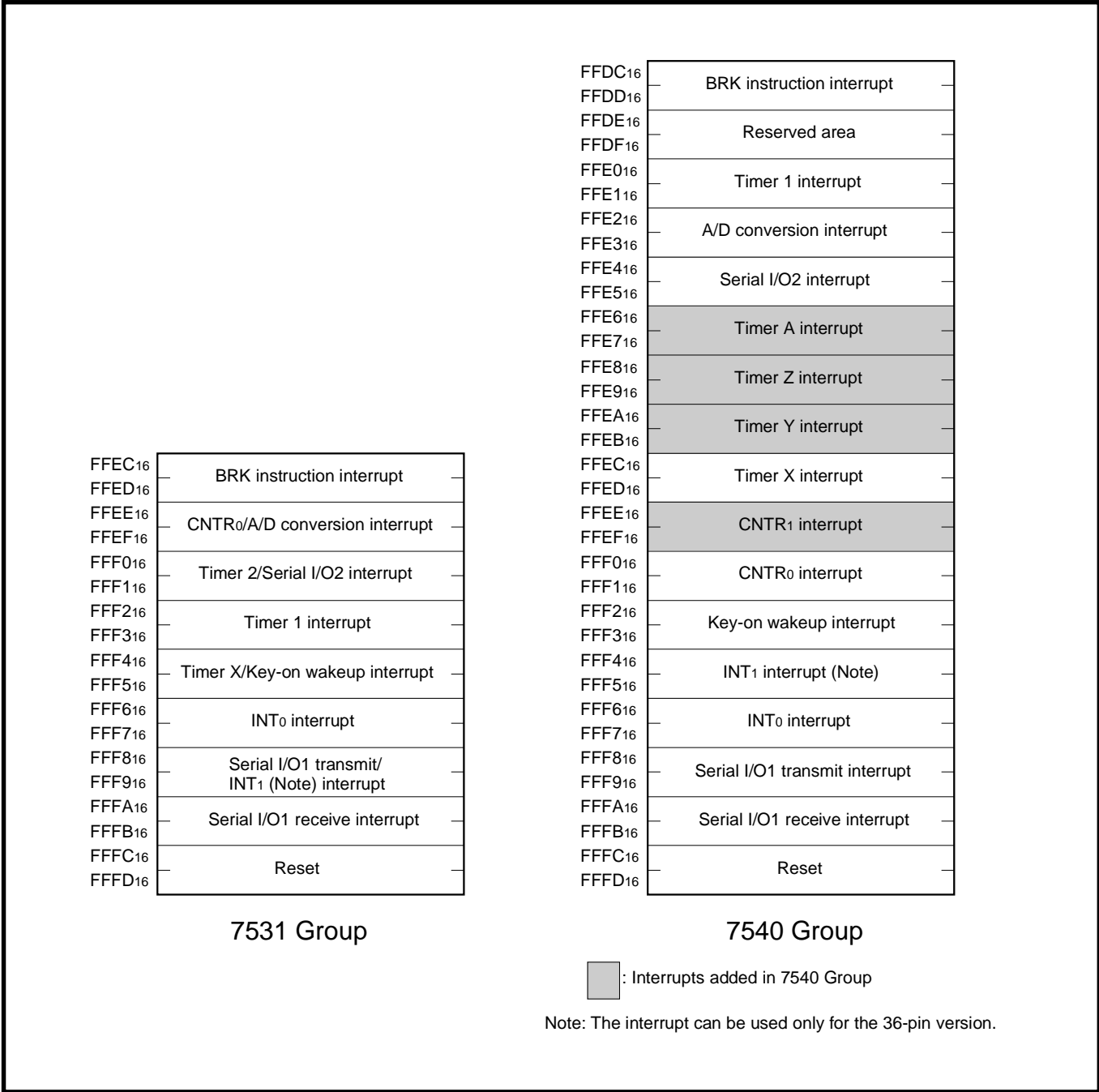


Fig. 3.11.2 Memory map of interrupt vector area of 7540 Group and 7531 Group

Figure 3.11.3 shows the timer function of 7540 Group and 7531 Group.

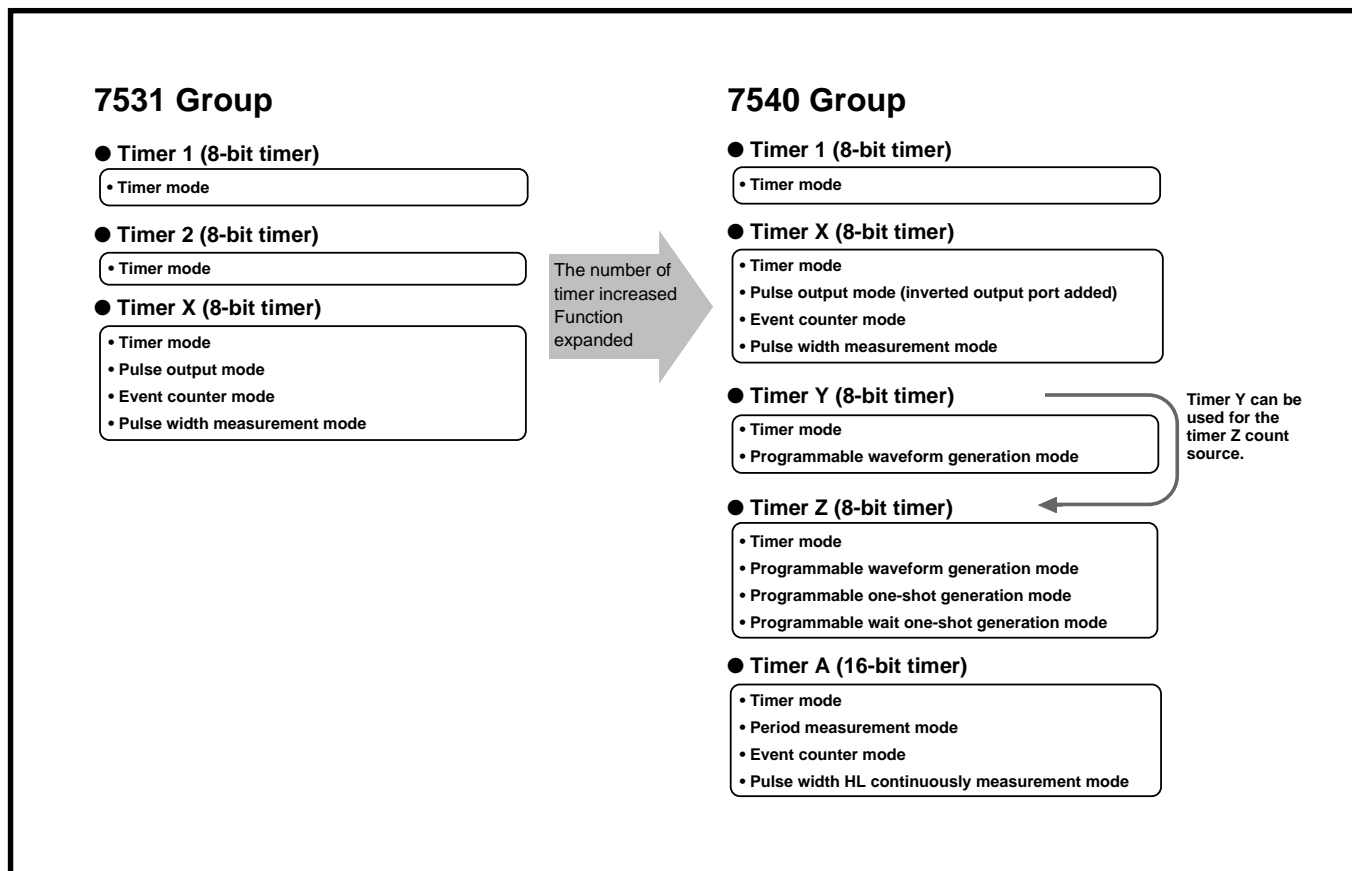


Fig. 3.11.3 Timer function of 7540 Group and 7531 Group

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7540 Group**

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