# 38B5 Group

SINGLE-CHIP 8-BIT CMOS MICROCOMPUTER

## DESCRIPTION

The 38B5 group is the 8-bit microcomputer based on the 740 family core technology.

The 38B5 group has six 8-bit timers, a 16-bit timer, a fluorescent display automatic display circuit, 12-channel 10-bit A-D converter, a serial I/O with automatic transfer function, which are available for controlling musical instruments and household appliances.

The 38B5 group has variations of internal memory size and packaging. For details, refer to the section on part numbering.

For details on availability of microcomputers in the 38B5 group, refer to the section on group expansion.

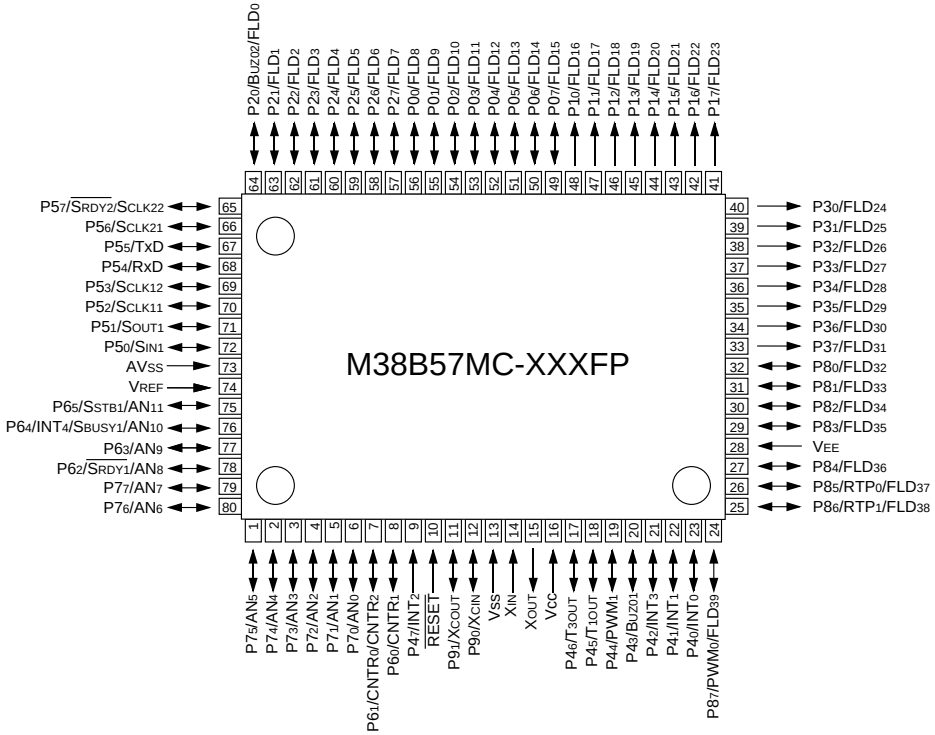
## FEATURES

- Basic machine-language instructions ..... 71
- The minimum instruction execution time ..... 0.48 $\mu$s
  (at 4.19 MHz oscillation frequency)
- Memory size
  ROM ..... 24K to 60K bytes
  RAM ..... 512 to 2048 bytes
- Programmable input/output ports ..... 55
- High-breakdown-voltage output ports ..... 36
- Software pull-up resistors ..... (Ports P5, $P6_1$ to $P6_5$, P7, $P8_4$ to $P8_7$, P9)
- Interrupts ..... 21 sources, 16 vectors
- Timers ..... 8-bit × 6, 16-bit × 1
- Serial I/O1 (Clock-synchronized) ..... 8-bit × 1
  ..... (max. 256-byte automatic transfer function)
- Serial I/O2 (UART or Clock-synchronized) ..... 8-bit × 1
- PWM ..... 14-bit × 1
  8-bit × 1 (also functions as timer 6)
- A-D converter ..... 10-bit × 12 channels
- Fluorescent display function ..... Total 40 control pins
- Interrupt interval determination function ..... 1
- Watchdog timer ..... 20-bit × 1
- Buzzer output ..... 1
- 2 Clock generating circuit
  Main clock ($X_{IN}$–$X_{OUT}$) ..... Internal feedback resistor
  Sub-clock ($X_{CIN}$–$X_{COUT}$) ..... Without internal feedback resistor
  (connect to external ceramic resonator or quartz-crystal oscillator)
- Power source voltage
  In high-speed mode ..... 4.0 to 5.5 V
  (at 4.19 MHz oscillation frequency and high-speed selected)
  In middle-speed mode ..... 2.7 to 5.5 V
  (at 4.19 MHz oscillation frequency and middle-speed selected)
  In low-speed mode ..... 2.7 to 5.5 V
  (at 32 kHz oscillation frequency and low-speed selected)
- Power dissipation
  In high-speed mode ..... 35 mW
  (at 4.19 MHz oscillation frequency)
  In low-speed mode ..... 60 µW
  (at 32 kHz oscillation frequency, at 3 V power source voltage)
- Operating temperature range ..... –20 to 85 °C

## APPLICATION

Musical instruments, VCR, household appliances, etc.

## PIN CONFIGURATION (TOP VIEW)




**Package type : 80P6N-A**
**80-pin plastic-molded QFP**

**Fig. 1 Pin Configuration of M38B57MC-XXXFP**

## FUNCTIONAL BLOCK

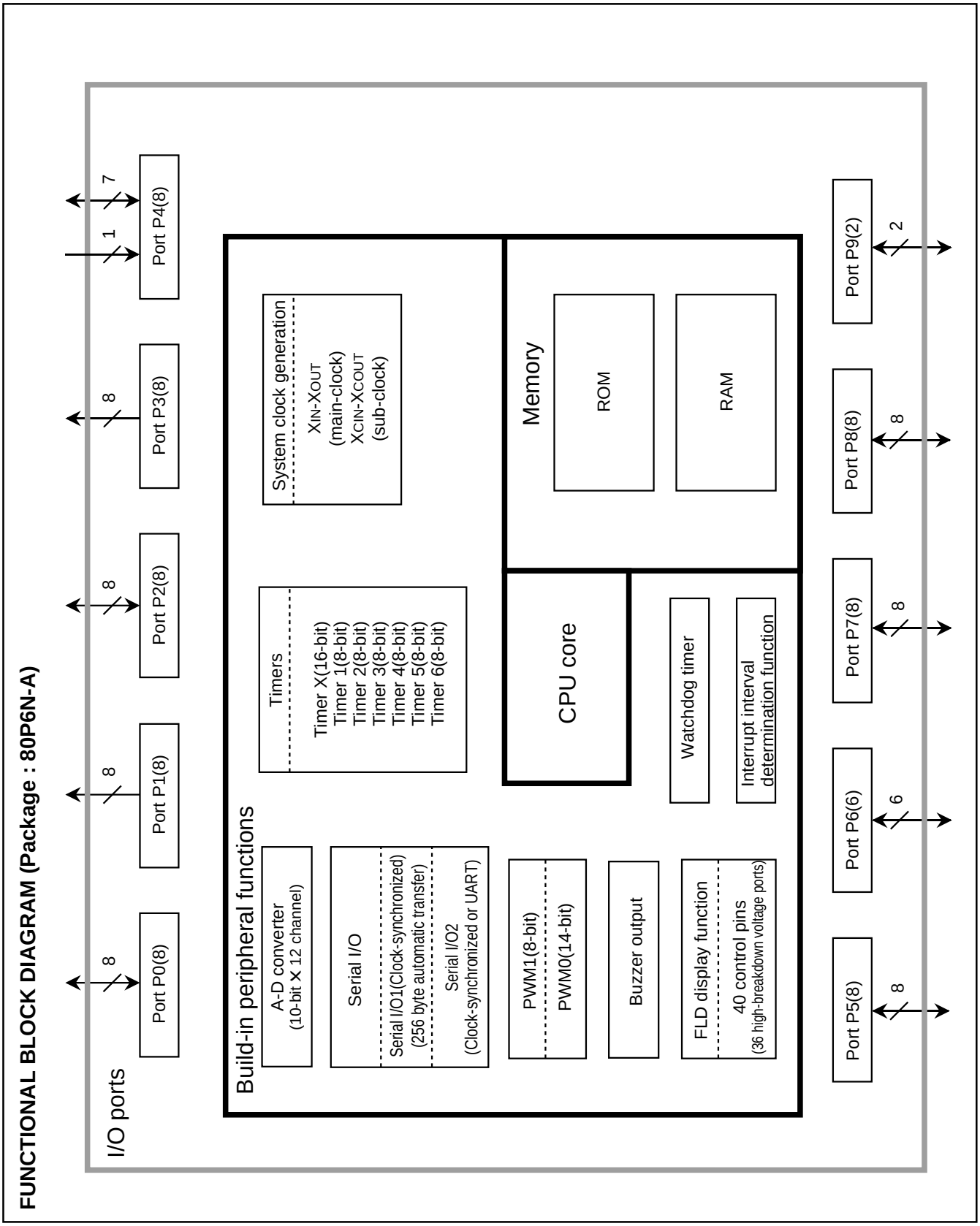



**Fig. 2 Functional Block Diagram**

## PIN DESCRIPTION

**Table 1 Pin Description (1)**

| Pin | Name | Function | Function except a port function |
|---|---|---|---|
| $V_{CC}$, $V_{SS}$ | Power source | • Apply voltage of 4.0–5.5 V to $V_{CC}$, and 0 V to $V_{SS}$. | |
| $V_{EE}$ | Pull-down power source | • Apply voltage supplied to pull-down resistors of ports P0, P1, and P3. | |
| $V_{REF}$ | Reference voltage | • Reference voltage input pin for A-D converter. | |
| AVSS | Analog power source | • Analog power source input pin for A-D converter.<br>• Connect to $V_{SS}$. | |
| $\overline{RESET}$ | Reset input | • Reset input pin for active "L." | |
| $X_{IN}$ | Clock input | • Input and output pins for the main clock generating circuit.<br>• Feedback resistor is built in between $X_{IN}$ pin and $X_{OUT}$ pin.<br>• Connect a ceramic resonator or quartz-crystal oscillator between the $X_{IN}$ and $X_{OUT}$ pins to set the oscillation frequency.<br>• When an external clock is used, connect the clock source to the $X_{IN}$ pin and leave the $X_{OUT}$ pin open.<br>• The clock is used as the oscillating source of system clock. | |
| $X_{OUT}$ | Clock output | | |
| $P0_0$/$FLD_8$–<br>$P0_7$/$FLD_{15}$ | I/O port P0 | • 8-bit I/O port.<br>• I/O direction register allows each pin to be individually programmed as either input or output.<br>• At reset, this port is set to input mode.<br>• A pull-down resistor is built in between port P0 and the $V_{EE}$ pin.<br>• CMOS compatible input level.<br>• High-breakdown-voltage P-channel open-drain output structure.<br>• At reset, this port is set to $V_{EE}$ level. | • FLD automatic display pins |
| $P1_0$/$FLD_{16}$–<br>$P1_7$/$FLD_{23}$ | Output port P1 | • 8-bit output port.<br>• A pull-down resistor is built in between port P1 and the $V_{EE}$ pin.<br>• High-breakdown-voltage P-channel open-drain output structure.<br>• At reset, this port is set to $V_{EE}$ level. | • FLD automatic display pins |
| $P2_0$/$BUZ_{02}$/<br>$FLD_0$–<br>$P2_7$/$FLD_7$ | I/O port P2 | • 8-bit I/O port with the same function as port P0.<br>• Low-voltage input level.<br>• High-breakdown-voltage P-channel open-drain output structure. | • FLD automatic display pins<br>• Buzzer output pin ($P2_0$) |
| $P3_0$/$FLD_{24}$–<br>$P3_7$/$FLD_{31}$ | Output port P3 | • 8-bit output port.<br>• A pull-down resistor is built in between port P3 and the $V_{EE}$ pin.<br>• High-breakdown-voltage P-channel open-drain output structure.<br>• At reset, this port is set to $V_{EE}$ level. | • FLD automatic display pins |
| $P4_0$/$INT_0$,<br>$P4_1$/$INT_1$,<br>$P4_2$/$INT_3$ | I/O port P4 | • 7-bit I/O port with the same function as port P0.<br>• CMOS compatible input level.<br>• N-channel open-drain output structure. | • Interrupt input pins |
| $P4_3$/$BUZ_{01}$ | | | • Buzzer output pin |
| $P4_4$/$PWM_1$ | | | • PWM output pin (Timer output pin) |
| $P4_5$/$T_{1OUT}$,<br>$P4_6$/$T_{3OUT}$ | | | • Timer output pin |
| $P4_7$/$INT_2$ | Input port P4 | • 1-bit input port.<br>• CMOS compatible input level. | • Interrupt input pin |

**Table 2 Pin Description (2)**

| Pin | Name | Function | Function except a port function |
|---|---|---|---|
| $P5_0$/$S_{IN1}$, $P5_1$/$S_{OUT1}$, $P5_2$/$S_{CLK11}$, $P5_3$/$S_{CLK12}$ | I/O port P5 | • 8-bit CMOS I/O port with the same function as port P0.<br>• CMOS compatible input level.<br>• CMOS 3-state output structure. | • Serial I/O1 function pins |
| $P5_4$/$R_XD$, $P5_5$/$T_XD$, $P5_6$/$S_{CLK21}$, $P5_7$/$\overline{S_{RDY2}}$/ $S_{CLK22}$ | | | • Serial I/O2 function pins |
| $P6_0$/$CNTR_1$ | I/O port P6 | • 1-bit I/O port with the same function as port P0.<br>• CMOS compatible input level.<br>• N-channel open-drain output structure. | • Timer input pin |
| $P6_1$/$CNTR_0$/ $CNTR_2$ | | • 5-bit CMOS I/O port with the same function as port P0.<br>• CMOS compatible input level. | • Timer I/O pin |
| $P6_2$/$\overline{S_{RDY1}}$/ $AN_8$ | | • CMOS 3-state output structure. | • Serial I/O1 function pin<br>• A-D conversion input pin |
| $P6_3$/$AN_9$ | | | • A-D conversion input pin |
| $P6_4$/$INT_4$/ $S_{BUSY1}$/$AN_{10}$, $P6_5$/$S_{STB1}$/ $AN_{11}$ | | | • Serial I/O1 function pin<br>• A-D conversion input pin<br>• Interrupt input pin ($P6_4$) |
| $P7_0$/$AN_0$– $P7_7$/$AN_7$ | I/O port P7 | • 8-bit CMOS I/O port with the same function as port P0.<br>• CMOS compatible input level.<br>• CMOS 3-state output structure. | • A-D conversion input pin |
| $P8_0$/$FLD_{32}$– $P8_3$/$FLD_{35}$ | I/O port P8 | • 4-bit I/O port with the same function as port P0.<br>• Low-voltage input level.<br>• High-breakdown-voltage P-channel open-drain output structure. | • FLD automatic display pins |
| $P8_4$/$FLD_{36}$ | | • 4-bit CMOS I/O port with the same function as port P0.<br>• Low-voltage input level. | |
| $P8_5$/$RTP_0$/ $FLD_{37}$, $P8_6$/$RTP_1$/ $FLD_{38}$ | | | • FLD automatic display pins |
| $P8_7$/$PWM_0$/ $FLD_{39}$ | | | • FLD automatic display pins<br>• 14-bit PWM output |
| $P9_0$/$X_{CIN}$, $P9_1$/$X_{COUT}$ | I/O port P9 | • 2-bit CMOS I/O port with the same function as port P0.<br>• CMOS compatible input level.<br>• CMOS 3-state output structure. | • I/O pins for sub-clock generating circuit (connect a ceramic resonator or a quarts-crystal oscillator) |

## PART NUMBERING

**Product** M38B5 **7** **M** **C** - **XXX** **FP**

**Package type**
FP : 80P6N-A package
FS : 80D0 package

**ROM number**
Omitted in some types.

**ROM/PROM size**
1 : 4096 bytes
2 : 8192 bytes
3 : 12288 bytes
4 : 16384 bytes
5 : 20480 bytes
6 : 24576 bytes
7 : 28672 bytes
8 : 32768 bytes
9 : 36864 bytes
A : 40960 bytes
B : 45056 bytes
C : 49152 bytes
D : 53248 bytes
E : 57344 bytes
F : 61440 bytes

The first 128 bytes and the last 2 bytes of ROM are reserved areas ; they cannot be used for users.

**Memory type**
M : Mask ROM version
E : EPROM or One Time PROM version

**RAM size**
0 : 192 bytes
1 : 256 bytes
2 : 384 bytes
3 : 512 bytes
4 : 640 bytes
5 : 768 bytes
6 : 896 bytes
7 : 1024 bytes
8 : 1536 bytes
9 : 2048 bytes

**Fig. 3 Part Numbering**

## GROUP EXPANSION

Mitsubishi plans to expand the 38B5 group as follows:

### Memory Type

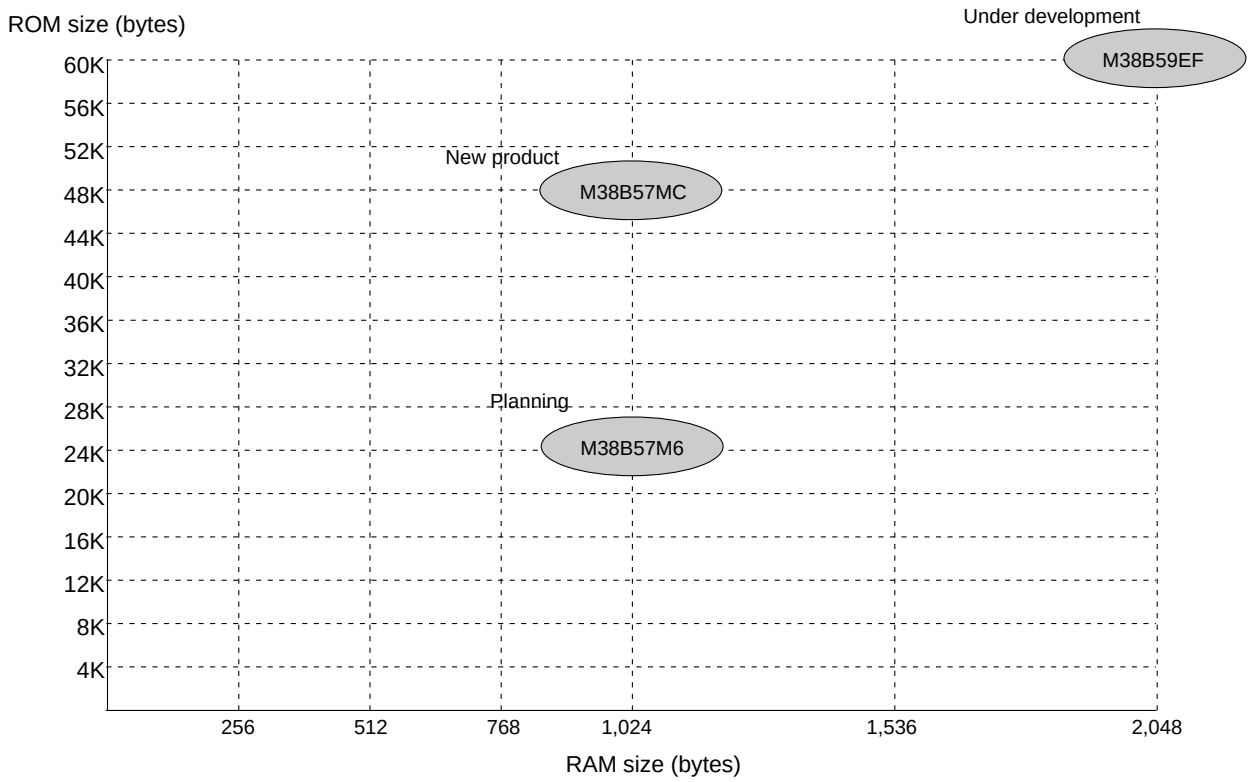
Support for Mask ROM, One Time PROM and EPROM versions.

### Memory Size

ROM/PROM size ..... 24K to 60K bytes
RAM size ..... 1024 to 2048 bytes

### Package

80P6N-A ..... 0.8 mm-pitch plastic molded QFP
80D0 ..... 0.8 mm-pitch ceramic LCC (EPROM version)




**Note :** Products under development or planning : the development schedule and specifications may be revised without notice.

**Fig. 4 Memory Expansion Plan**

Currently supported products are listed below.

**Table 3 List of Supported Products**

**As of Jan. 1998**

| Product | (P) ROM size (bytes)<br>ROM size for User ( ) | RAM size (bytes) | Package | Remarks |
|---|---|---|---|---|
| M38B57MC-XXXFP | 49152<br>(49022) | 1024 | 80P6N-A | Mask ROM version |

## FUNCTIONAL DESCRIPTION
## Central Processing Unit (CPU)

The 38B5 group uses the standard 740 family instruction set. Refer to the table of 740 family addressing modes and machine instructions or the 740 Family Software Manual for details on the instruction set.

Machine-resident 740 Family instructions are as follows:

•The FST and SLW instructions cannot be used.

•The MUL, DIV, WIT and STP instructions can be used.

## [CPU Mode Register] CPUM

The CPU mode register contains the stack page selection bit and internal system clock control bits. The CPU mode register is allocated at address 003B16.

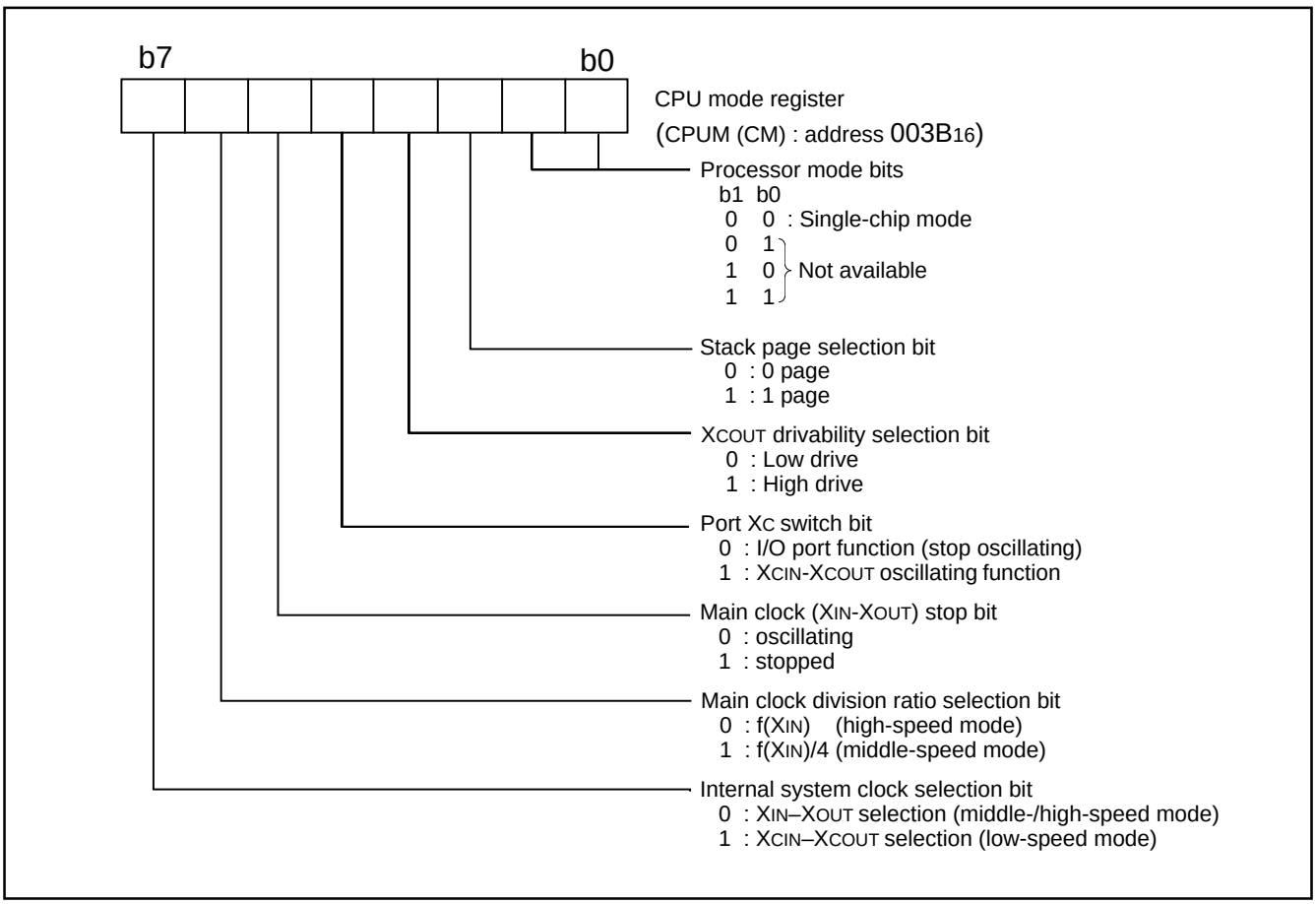



**Fig. 5 Structure of CPU Mode Register**

## Memory

### Special function register (SFR) area

The special function register (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 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 other areas are user areas for storing programs.

### Interrupt vector area

The interrupt vector area contains reset and interrupt vectors.

### Zero page

The 256 bytes from addresses $0000_{16}$ to $00FF_{16}$ 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

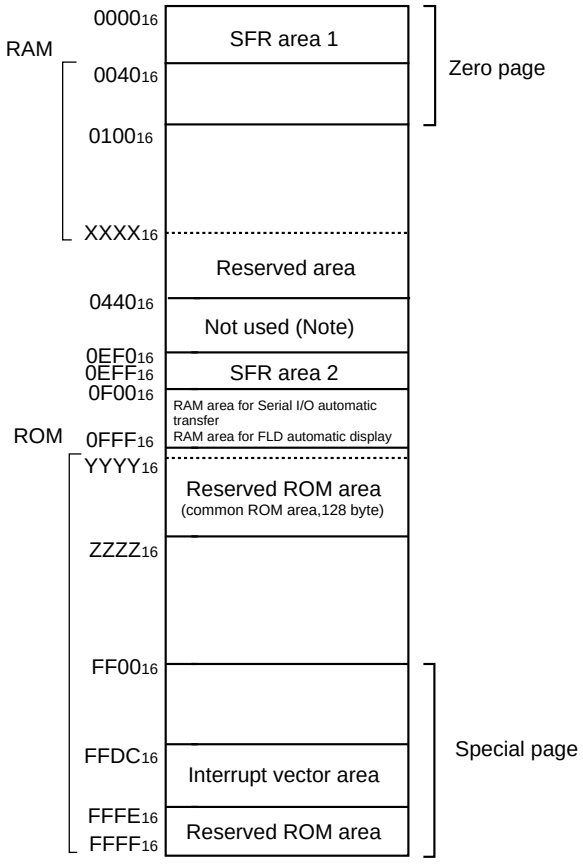
The 256 bytes from addresses $FF00_{16}$ to $FFFF_{16}$ are called the special page area. The special page addressing mode can be used to specify memory addresses in the special page area. Access to this area with only 2 bytes is possible in the special page addressing mode.

RAM area

| RAM size (byte) | Address XXXX16 |
|---|---|
| 192 | $00FF_{16}$ |
| 256 | $013F_{16}$ |
| 384 | $01BF_{16}$ |
| 512 | $023F_{16}$ |
| 640 | $02BF_{16}$ |
| 768 | $033F_{16}$ |
| 896 | $03BF_{16}$ |
| 1024 | $043F_{16}$ |
| 1536 | $063F_{16}$ |
| 2048 | $083F_{16}$ |

ROM area

| ROM size (byte) | Address YYYY16 | Address ZZZZ16 |
|---|---|---|
| 4096 | $F000_{16}$ | $F080_{16}$ |
| 8192 | $E000_{16}$ | $E080_{16}$ |
| 12288 | $D000_{16}$ | $D080_{16}$ |
| 16384 | $C000_{16}$ | $C080_{16}$ |
| 20480 | $B000_{16}$ | $B080_{16}$ |
| 24576 | $A000_{16}$ | $A080_{16}$ |
| 28672 | $9000_{16}$ | $9080_{16}$ |
| 32768 | $8000_{16}$ | $8080_{16}$ |
| 36864 | $7000_{16}$ | $7080_{16}$ |
| 40960 | $6000_{16}$ | $6080_{16}$ |
| 45056 | $5000_{16}$ | $5080_{16}$ |
| 49152 | $4000_{16}$ | $4080_{16}$ |
| 53248 | $3000_{16}$ | $3080_{16}$ |
| 57344 | $2000_{16}$ | $2080_{16}$ |
| 61440 | $1000_{16}$ | $1080_{16}$ |




**Note**: When 1024 bytes or more are used as RAM area, this area can be used.

**Fig. 6 Memory Map Diagram**

| | | | |
|---|---|---|---|
| $0000_{16}$ | Port P0 (P0) | $0020_{16}$ | Timer 1 (T1) |
| $0001_{16}$ | Port P0 direction register (P0D) | $0021_{16}$ | Timer 2 (T2) |
| $0002_{16}$ | Port P1 (P1) | $0022_{16}$ | Timer 3 (T3) |
| $0003_{16}$ | | $0023_{16}$ | Timer 4 (T4) |
| $0004_{16}$ | Port P2 (P2) | $0024_{16}$ | Timer 5 (T5) |
| $0005_{16}$ | Port P2 direction register (P2D) | $0025_{16}$ | Timer 6 (T6) |
| $0006_{16}$ | Port P3 (P3) | $0026_{16}$ | PWM control register (PWMCON) |
| $0007_{16}$ | | $0027_{16}$ | Timer 6 PWM register (T6PWM) |
| $0008_{16}$ | Port P4 (P4) | $0028_{16}$ | Timer 12 mode register (T12M) |
| $0009_{16}$ | Port P4 direction register (P4D) | $0029_{16}$ | Timer 34 mode register (T34M) |
| $000A_{16}$ | Port P5 (P5) | $002A_{16}$ | Timer 56 mode register (T56M) |
| $000B_{16}$ | Port P5 direction register (P5D) | $002B_{16}$ | Watchdog timer control register (WDTCON) |
| $000C_{16}$ | Port P6 (P6) | $002C_{16}$ | Timer X (low-order) (TXL) |
| $000D_{16}$ | Port P6 direction register (P6D) | $002D_{16}$ | Timer X (high-order) (TXH) |
| $000E_{16}$ | Port P7 (P7) | $002E_{16}$ | Timer X mode register 1 (TXM1) |
| $000F_{16}$ | Port P7 direction register (P7D) | $002F_{16}$ | Timer X mode register 2 (TXM2) |
| $0010_{16}$ | Port P8 (P8) | $0030_{16}$ | Interrupt interval determination register (IID) |
| $0011_{16}$ | Port P8 direction register (P8D) | $0031_{16}$ | Interrupt interval determination control register (IIDCON) |
| $0012_{16}$ | Port P9 (P9) | $0032_{16}$ | A-D control register (ADCON) |
| $0013_{16}$ | Port P9 direction register (P9D) | $0033_{16}$ | A-D conversion register (low-order) (ADL) |
| $0014_{16}$ | PWM register (high-order) (PWMH) | $0034_{16}$ | A-D conversion register (high-order) (ADH) |
| $0015_{16}$ | PWM register (low-order) (PWM L) | $0035_{16}$ | |
| $0016_{16}$ | Baud rate generator (BRG) | $0036_{16}$ | |
| $0017_{16}$ | UART control register (UARTCON) | $0037_{16}$ | |
| $0018_{16}$ | Serial I/O1 automatic transfer data pointer (SIO1DP) | $0038_{16}$ | |
| $0019_{16}$ | Serial I/O1 control register 1 (SIO1CON1) | $0039_{16}$ | Interrupt source switch register (IFR) |
| $001A_{16}$ | Serial I/O1 control register 2 (SIO1CON2) | $003A_{16}$ | Interrupt edge selection register (INTEDGE) |
| $001B_{16}$ | Serial I/O1 register/Transfer counter (SIO1) | $003B_{16}$ | CPU mode register (CPUM) |
| $001C_{16}$ | Serial I/O1 control register 3 (SIO1CON3) | $003C_{16}$ | Interrupt request register 1(IREQ1) |
| $001D_{16}$ | Serial I/O2 control register (SIO2CON) | $003D_{16}$ | Interrupt request register 2(IREQ2) |
| $001E_{16}$ | Serial I/O2 status register (SIO2STS) | $003E_{16}$ | Interrupt control register 1(ICON1) |
| $001F_{16}$ | Serial I/O2 transmit/receive buffer register (TB/RB) | $003F_{16}$ | Interrupt control register 2(ICON2) |

| | | | |
|---|---|---|---|
| $0EF0_{16}$ | Pull-up control register 1 (PULL1) | $0EF8_{16}$ | FLD data pointer (FLDDP) |
| $0EF1_{16}$ | Pull-up control register 2 (PULL2) | $0EF9_{16}$ | Port P0FLD/port switch register (P0FPR) |
| $0EF2_{16}$ | P1FLDRAM write disable register (P1FLDRAM) | $0EFA_{16}$ | Port P2FLD/port switch register (P2FPR) |
| $0EF3_{16}$ | P3FLDRAM write disable register (P3FLDRAM) | $0EFB_{16}$ | Port P8FLD/port switch register (P8FPR) |
| $0EF4_{16}$ | FLDC mode register (FLDM) | $0EFC_{16}$ | Port P8FLD output control register (P8FLDCON) |
| $0EF5_{16}$ | Tdisp time set register (TDISP) | $0EFD_{16}$ | Buzzer output control register (BUZCON) |
| $0EF6_{16}$ | Toff1 time set register (TOFF1) | $0EFE_{16}$ | |
| $0EF7_{16}$ | Toff2 time set register (TOFF2) | $0EFF_{16}$ | |

**Fig. 7 Memory Map of Special Function Register (SFR)**

## I/O Ports
## [Direction Registers] PiD

The 38B5 group has 55 programmable I/O pins arranged in eight individual I/O ports (P0, P2, $P4_0$–$P4_6$, and P5–P9). The I/O ports have direction registers which determine the input/output direction of each individual pin. Each bit in a direction register corresponds to one pin, and each pin can be set to be input port or output port. When "0" is written to the bit corresponding to a pin, that pin becomes an input pin. When "1" is written to that pin, that pin becomes an output pin. If data is read from a pin set to output, the value of the port output latch is read, not the value of the pin itself. Pins set to input (the bit corresponding to that pin must be set to "0") are floating and the value of that pin can be read. If a pin set to input is written to, only the port output latch is written to and the pin remains floating.

## [High-Breakdown-Voltage Output Ports]

The 38B5 group microprocessors have 5 ports with high-breakdown-voltage pins (ports P0–P3 and $P8_0$–$P8_3$). The high-breakdown-voltage ports have P-channel open-drain output with Vcc- 45 V of breakdown voltage. Each pin in ports P0, P1, and P3 has an internal pull-down resistor connected to $V_{EE}$. At reset, the P-channel output transistor of each port latch is turned off, so that it goes to $V_{EE}$ level ("L") by the pull-down resistor.

Writing "1" (weak drivability) to bit 7 of the FLDC mode register (address $0EF4_{16}$) shows the rising transition of the output transistors for reducing transient noise. At reset, bit 7 of the FLDC mode register is set to "0" (strong drivability).

## [Pull-up Control Register] PULL

Ports P5, $P6_1$–$P6_5$, P7, $P8_4$–$P8_7$ and P9 have built-in programmable pull-up resistors. The pull-up resistors are valid only in the case that the each control bit is set to "1" and the corresponding port direction registers are set to input mode.

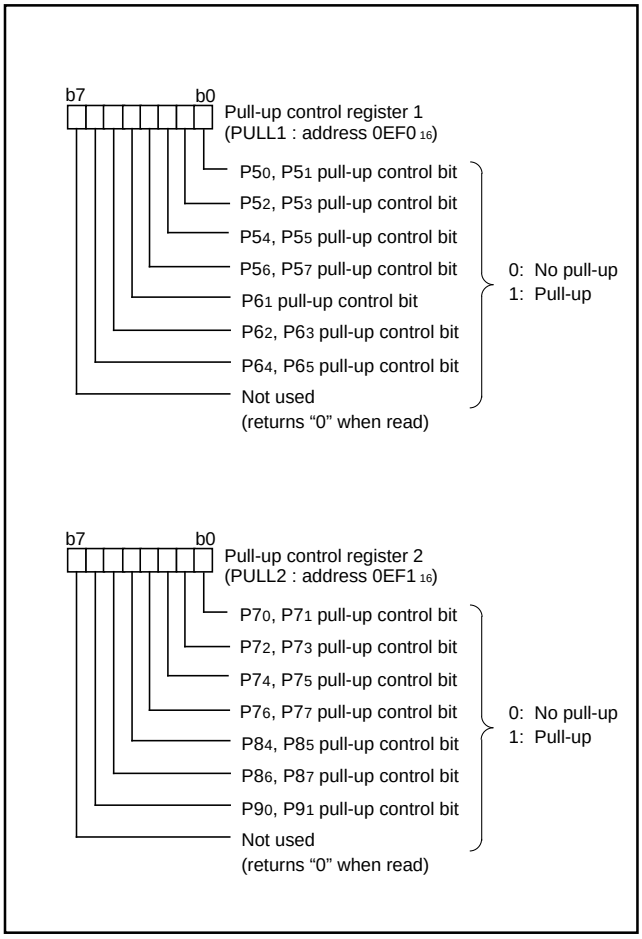



**Fig. 8 Structure of Pull-up Control Registers (PULL1 and PULL2)**

**Table 4 List of I/O Port Functions (1)**

| Pin | Name | Input/Output | I/O Format | Non-Port Function | Related SFRs | Ref.No. |
|---|---|---|---|---|---|---|
| $P0_0$/$FLD_8$–$P0_7$/$FLD_{15}$ | Port P0 | Input/output, individual bits | CMOS compatible input level<br>High-breakdown voltage P-channel open-drain output with pull-down resistor | FLD automatic display function | FLDC mode register<br>Port P0FLD/port switch register | (1) |
| $P1_0$/$FLD_{16}$–$P1_7$/$FLD_{23}$ | Port P1 | Output | High-breakdown voltage P-channel open-drain output with pull-down resistor | | FLDC mode register | (2) |
| $P2_0$/$BUZ_{02}$/$FLD_0$ | Port P2 | Input/output, individual bits | Low-voltage input level<br>High-breakdown voltage P-channel open-drain output | Buzzer output ($P2_0$) | FLDC mode register<br>Port P2FLD/port switch register | (3) |
| $P2_1$/$FLD_1$–$P2_7$/$FLD_7$ | | | | | Buzzer output control register | (1) |
| $P3_0$/$FLD_{24}$–$P3_7$/$FLD_{31}$ | Port P3 | Output | High-breakdown voltage P-channel open-drain output with pull-down resistor | | FLDC mode register | (2) |
| $P4_0$/$INT_0$, $P4_1$/$INT_1$, $P4_2$/$INT_3$ | Port P4 | Input/output, individual bits | CMOS compatible input level<br>N-channel open-drain output | External interrupt input | Interrupt edge selection register | (4) |
| $P4_3$/$BUZ_{01}$ | | | | Buzzer output | Buzzer output control register | (5) |
| $P4_4$/$PWM_1$ | | | | PWM output | Timer 56 mode register | (6) |
| $P4_5$/$T_{1OUT}$ | | | | Timer output | Timer 12 mode register | (7) |
| $P4_6$/$T_{3OUT}$ | | | | Timer output | Timer 34 mode register | (7) |
| $P4_7$/$INT_2$ | | Input | CMOS compatible input level | External interrput input | Interrupt edge selection register<br>Interrupt interval determination control register | (8) |
| P50/SIN1 | Port P5 | Input/output, individual bits | CMOS compatible input level<br>CMOS 3-state output | Serial I/O1 function I/O | Serial I/O1 control register 1, 2 | (9) |
| $P5_1$/$SOUT_1$, $P5_2$/$SCLK_{11}$, $P5_3$/$SCLK_{12}$ | | | | | | (10) |
| $P5_4$/RxD, | | | | Serial I/O2 function I/O | Serial I/O2 control register | (9) |
| $P5_5$/TxD, $P5_6$/$SCLK_{21}$ | | | | | UART control register | (10) |
| $P5_7$/$\overline{SRDY_2}$/$SCLK_{22}$ | | | | | | (11) |
| $P6_0$/$CNTR_1$ | Port P6 | | CMOS compatible input level<br>N-channel open-drain output | External count I/O | Interrupt edge selection register | (4) |
| $P6_1$/$CNTR_0$/$CNTR_2$ | | | CMOS compatible input level<br>CMOS 3-state output | | | (12) |
| $P6_2$/$\overline{SRDY_1}$/$AN_8$ | | | | Serial I/O1 function I/O<br>A-D conversion input | Serial I/O1 control register 1, 2<br>A-D control register | (13) |
| $P6_3$/$AN_9$ | | | | A-D conversion input | A-D control register | (14) |
| $P6_4$/$INT_4$/$SBUSY_1$/$AN_{10}$ | | | | Serial I/O1 function I/O<br>A-D conversion input<br>External interrupt input | Serial I/O1 control register 1, 2<br>A-D control register<br>Interrupt edge selection register | (15) |
| $P6_5$/$SSTB_1$/$AN_{11}$ | | | | Serial I/O1 function I/O<br>A-D conversion input | Serial I/O1 control register 1, 2<br>A-D control register | (16) |
| $P7_0$/$AN_0$–$P7_7$/$AN_7$ | Port P7 | | | A-D conversion input | A-D control register | (14) |

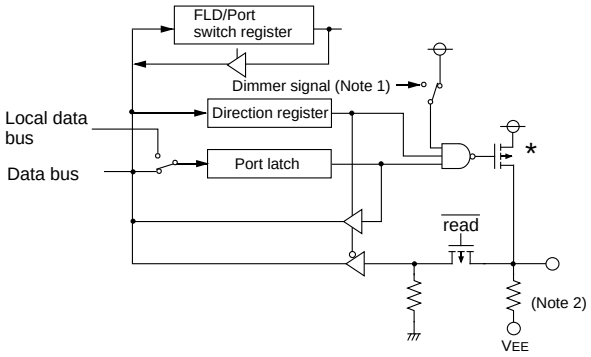
**Table 5 List of I/O Port Functions (2)**

| Pin | Name | Input/Output | I/O Format | Non-Port Function | Related SFRs | Ref.No. |
|---|---|---|---|---|---|---|
| $P8_0$/$FLD_{32}$–$P8_3$/$FLD_{35}$ | Port P8 | Input/output, individual bits | Low-voltage input level<br>High-breakdown voltage P-channel open-drain output | FLD automatic display function | FLDC mode register<br>Port P8FLD/port switch register | (1) |
| $P8_4$/$FLD_{36}$ | | | Low-voltage input level<br>CMOS 3-state output | | | (17) |
| $P8_5$/$RTP_0$/$FLD_{37}$, $P8_6$/$RTP_1$/$FLD_{38}$ | | | | FLD automatic display function<br>Real time port output | FLDC mode register<br>Port P8FLD/port switch register<br>Timer X mode register 2 | (18) |
| $P8_7$/$PWM_0$/$FLD_{39}$ | | | | FLD automatic display function<br>PWM output | FLDC mode register<br>Port P8FLD/port switch register<br>PWM control register | (19) |
| $P9_0$/$X_{CIN}$ | Port P9 | | CMOS compatible input level<br>CMOS 3-state output | Sub-clock generating circuit I/O | CPU mode register | (20) |
| $P9_1$/$X_{COUT}$ | | | | | | (21) |

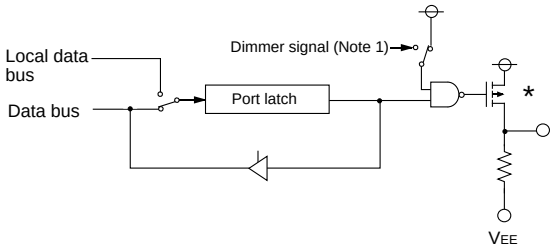
**Notes 1 :** How to use double-function ports as function I/O ports, refer to the applicable sections.

**2 :** Make sure that the input level at each pin is either 0 V or Vcc during execution of the STP instruction.
When an input level is at an intermediate potential, a current will flow from Vcc to Vss through the input-stage gate.

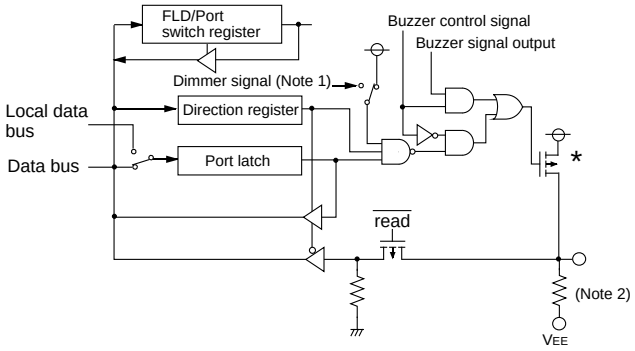
(1) Ports P0, P21–P27, P80–P83



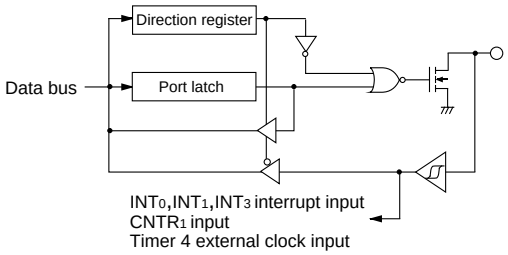

(2) Ports P1, P3



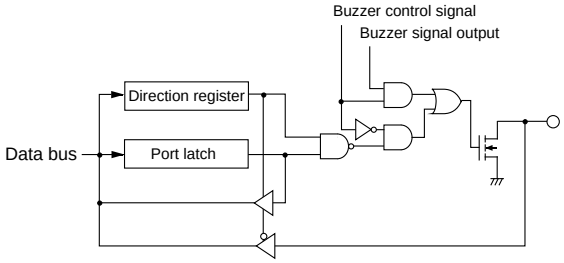

(3) Port P20



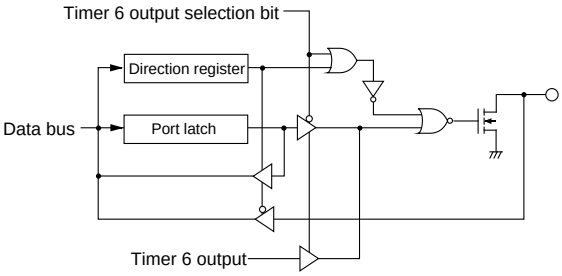

(4) Ports P40–P42, P60



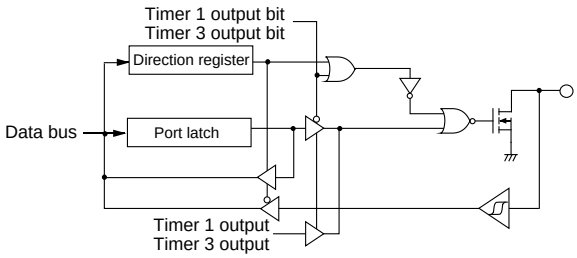

(5) Port P43



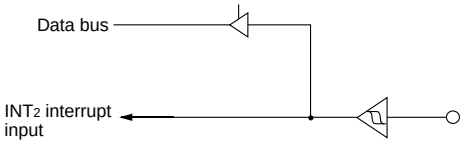

(6) Port P44




(7) Ports P45, P46



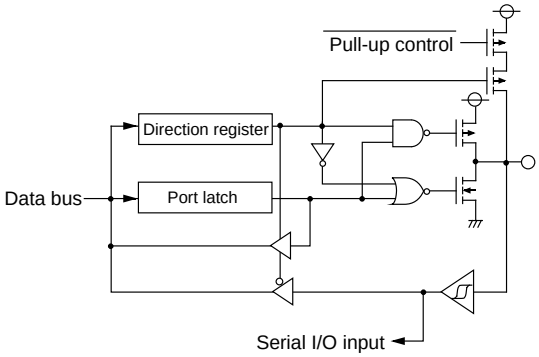

(8) Port P47



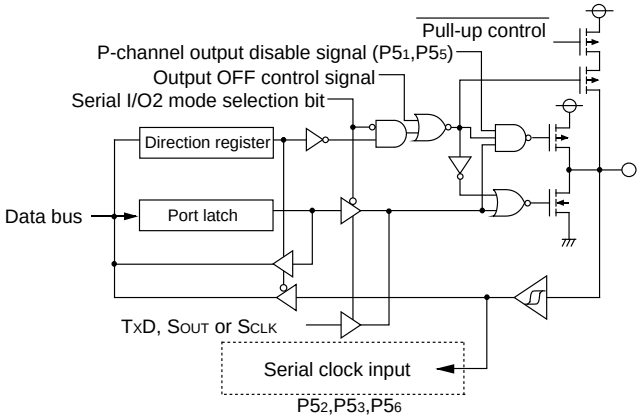

* High-breakdown-voltage P-channel transistor
Notes 1: The dimmer signal sets the Toff timing.
2: A pull-down resistor is not built in to ports P2 and P8.

**Fig. 9 Port Block Diagram (1)**

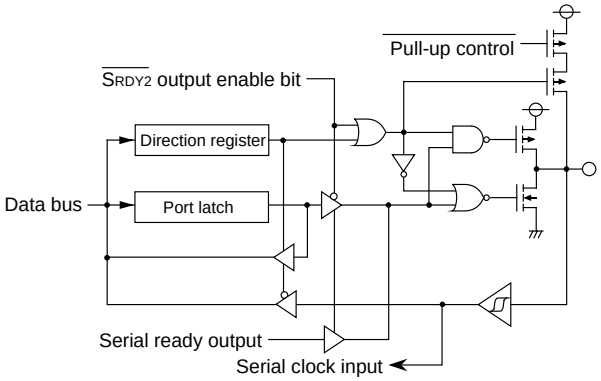
(9) Ports P5$_0$, P5$_4$



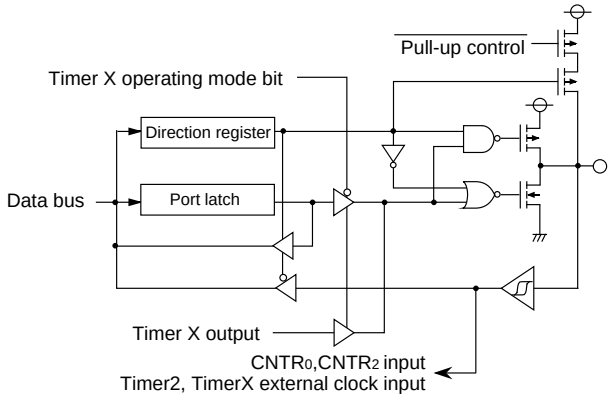

(10) Ports P5$_1$–P5$_3$, P5$_5$, P5$_6$



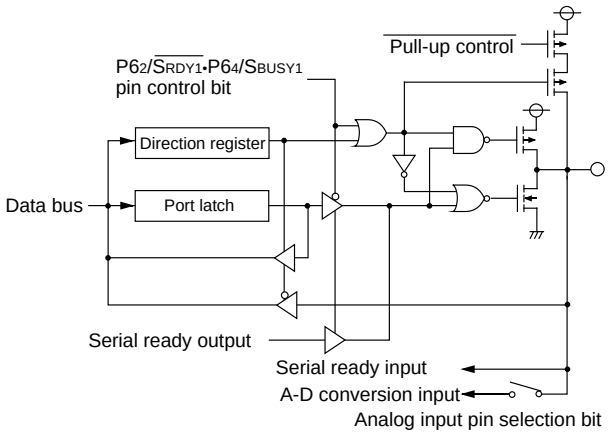

(11) Port P5$_7$




(12) Port P6$_1$




(13) Port P6$_2$




(14) Ports P6$_3$, P7

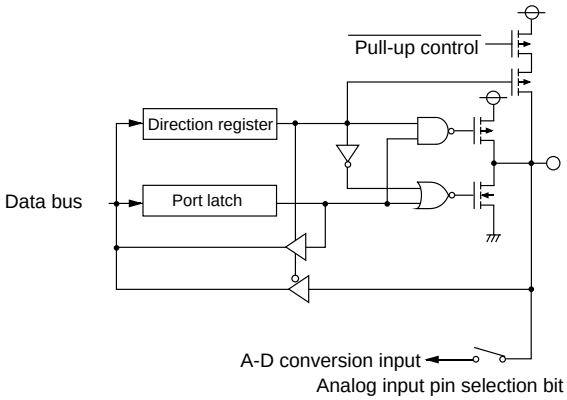



**Fig. 10 Port Block Diagram (2)**

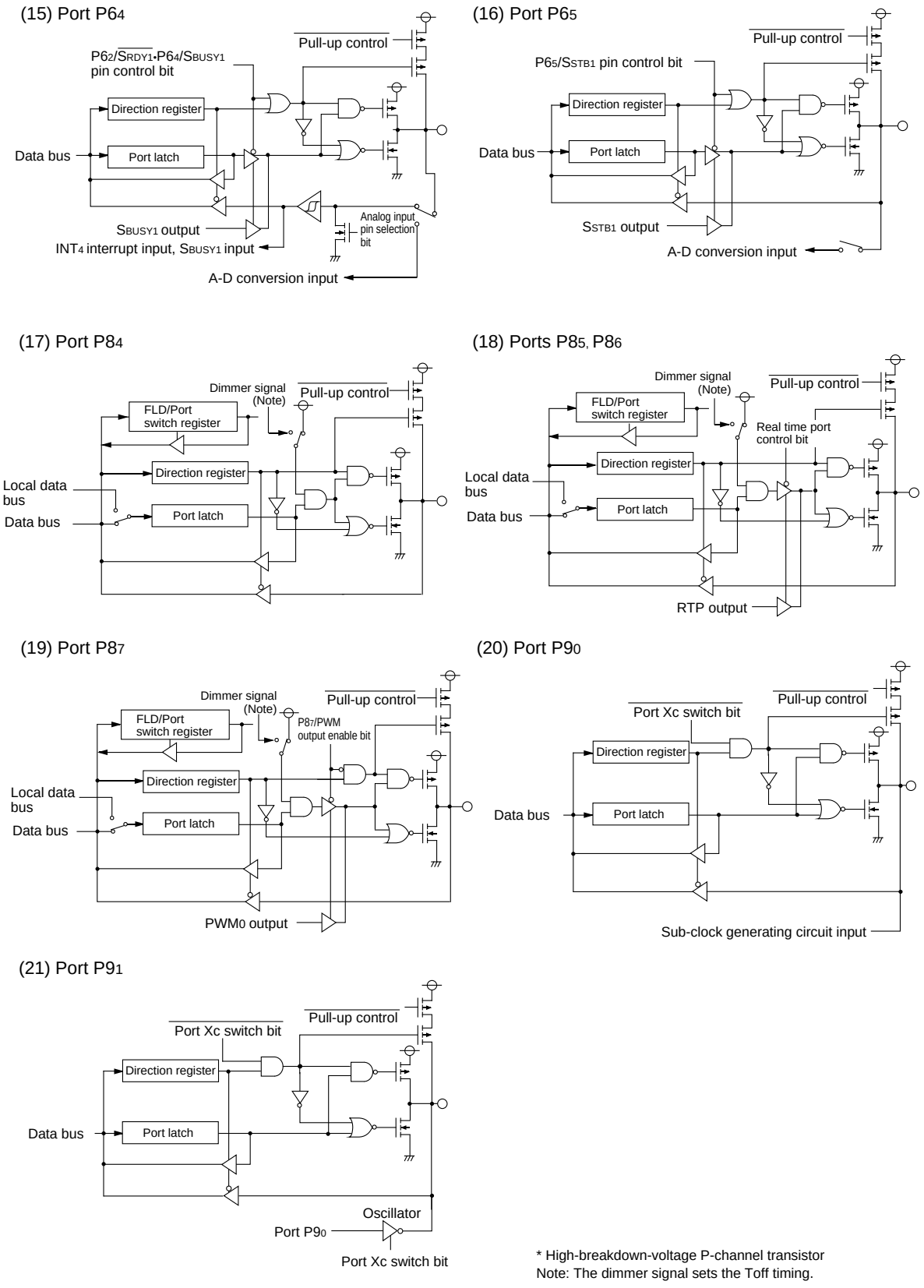



**Fig. 11 Port Block Diagram (3)**

## Interrupts

Interrupts occur by twenty one sources: five external, fifteen internal, and one software.

## (1) Interrupt Control

Each interrupt except the BRK instruction interrupt have both an interrupt request bit and an interrupt enable bit, and is controlled by the interrupt disable flag. An interrupt occurs if the corresponding interrupt request and enable bits are “1” and the interrupt disable flag is “0.” Interrupt enable bits can be set or cleared by software. Interrupt request bits can be cleared by software, but cannot be set by software. The BRK instruction interrupt and reset cannot be disabled with any flag or bit. The I flag disables all interrupts except the BRK instruction interrupt and reset. If several interrupts requests occurs at the same time the interrupt with highest priority is accepted first.

## (2) Interrupt Operation

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

1. The contents of the program counter and processor status register are automatically pushed onto the stack.
2. The interrupt disable flag is set and the corresponding interrupt request bit is cleared.
3. The interrupt jump destination address is read from the vector table into the program counter.

## ■Notes on Use

When the active edge of an external interrupt ($INT_0$–$INT_4$) is set or when switching interrupt sources in the same vector address, the corresponding interrupt request bit may also be set. Therefore, please take following sequence:

(1) Disable the external interrupt which is selected.
(2) Change the active edge in interrupt edge selection register
(3) Clear the set interrupt request bit to “0.”
(4) Enable the external interrupt which is selected.

**Table 6 Interrupt Vector Addresses and Priority**

| Interrupt Source | Priority | Vector Addresses **(Note 1)** | | Interrupt Request Generating Conditions | Remarks |
|---|---|---|---|---|---|
| | | High | Low | | |
| Reset **(Note 2)** | 1 | FFFD16 | FFFC16 | At reset | Non-maskable |
| INT0 | 2 | FFFB16 | FFFA16 | At detection of either rising or falling edge of INT0 input | External interrupt (active edge selectable) |
| INT1 | 3 | FFF916 | FFF816 | At detection of either rising or falling edge of INT1 input | External interrupt (active edge selectable) |
| INT2 | 4 | FFF716 | FFF616 | At detection of either rising or falling edge of INT2 input | External interrupt (active edge selectable) |
| Remort control/ counter overflow | | | | At 8-bit counter overflow | Valid when interrupt interval determination is operating |
| Serial I/O1 | 5 | FFF516 | FFF416 | At completion of data transfer | Valid when serial I/O1 ordinary mode is selected |
| Serial I/O1 automatic transfer | | | | At completion of the last data transfer | Valid when serial I/O1 automatic transfer mode is selected |
| Timer X | 6 | FFF316 | FFF216 | At timer X underflow | |
| Timer 1 | 7 | FFF116 | FFF016 | At timer 1 underflow | |
| Timer 2 | 8 | FFEF16 | FFEE16 | At timer 2 underflow | STP release timer underflow |
| Timer 3 | 9 | FFED16 | FFEC16 | At timer 3 underflow | |
| Timer 4 | 10 | FFEB16 | FFEA16 | At timer 4 underflow | |
| Timer 5 | 11 | FFE916 | FFE816 | At timer 5 underflow | |
| Timer 6 | 12 | FFE716 | FFE616 | At timer 6 underflow | |
| Serial I/O2 receive | 13 | FFE516 | FFE416 | At completion of serial I/O2 data receive | |
| INT3 | 14 | FFE316 | FFE216 | At detection of either rising or falling edge of INT3 input | External interrupt (active edge selectable) |
| Serial I/O2 transmit | | | | At completion of data transmit | |
| INT4 | 15 | FFE116 | FFE016 | At detection of either rising or falling edge of INT4 input | External interrupt (active edge selectable) Valid when INT4 interrupt is selected |
| A-D conversion | | | | At completion of A-D conversion | Valid when A-D conversion is selected |
| FLD blanking | 16 | FFDF16 | FFDE16 | At falling edge of the last timing immediately before blanking period starts | Valid when FLD blanking interrupt is selected |
| FLD digit | | | | At rising edge of each digit | Valid when FLD digit interrupt is selected |
| BRK instruction | 17 | FFDD16 | FFDC16 | At BRK instruction execution | Non-maskable software interrupt |

**Notes 1 :** Vector addresses contain interrupt jump destination addresses.
**2 :** Reset function in the same way as an interrupt with the highest priority.

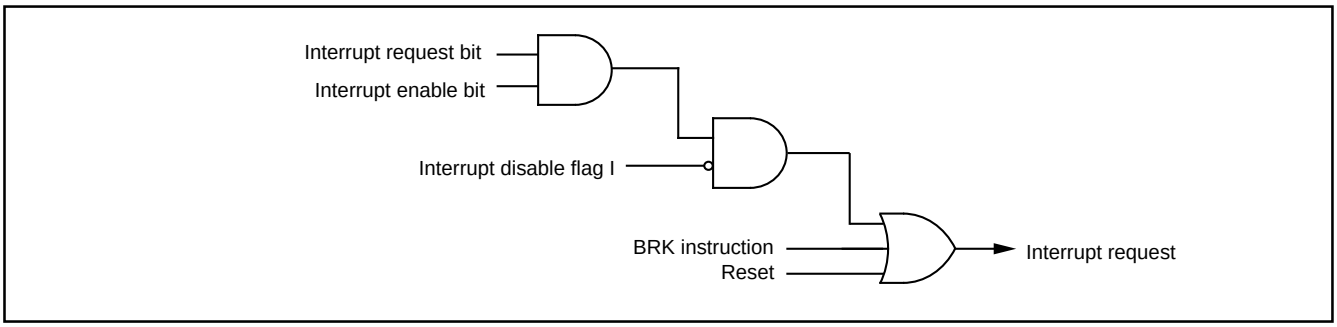



**Fig. 12 Interrupt Control**

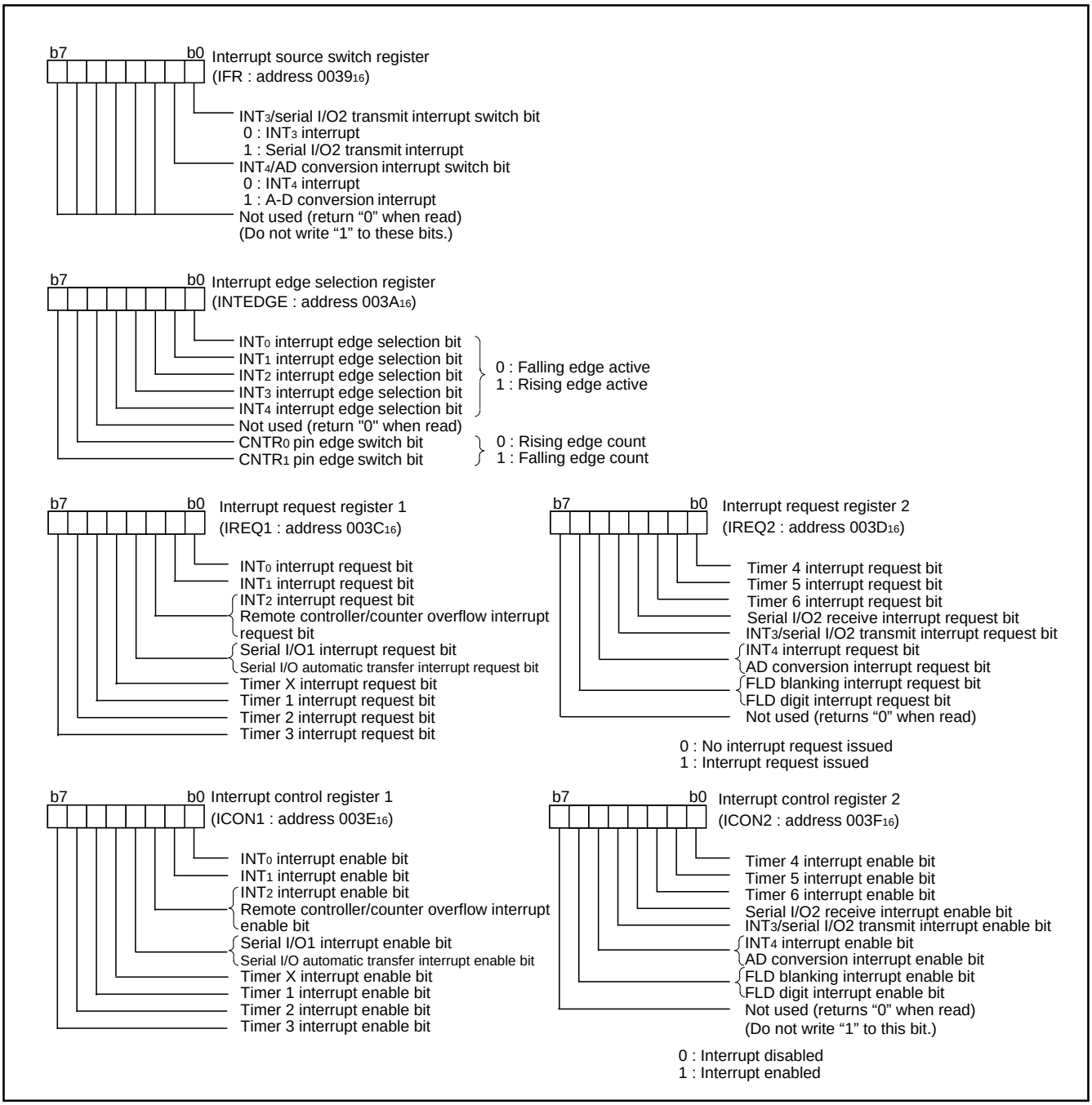



**Fig. 13 Structure of Interrupt Related Registers**

## Timers
### 8-Bit Timer

The 38B5 group has six built-in timers : Timer 1, Timer 2, Timer 3, Timer 4, Timer 5, and Timer 6.

Each timer has the 8-bit timer latch. All timers are down-counters. When the timer reaches "$00_{16}$," an underflow occurs with the next count pulse. Then the contents of the timer latch is reloaded into the timer and the timer continues down-counting. When a timer underflows, the interrupt request bit corresponding to that timer is set to "1."

The count can be stopped by setting the stop bit of each timer to "1."

The internal system clock can be set to either the high-speed mode or low-speed mode with the CPU mode register. At the same time, timer internal count source is switched to either f($X_{IN}$) or f($X_{CIN}$).

**●Timer 1, Timer 2**

The count sources of timer 1 and timer 2 can be selected by setting the timer 12 mode register. A rectangular waveform of timer 1 underflow signal divided by 2 is output from the $P4_5/T_{1OUT}$ pin. The waveform polarity changes each time timer 1 overflows. The active edge of the external clock $CNTR_0$ can be switched with the bit 6 of the interrupt edge selection register.

At reset or when executing the STP instruction, all bits of the timer 12 mode register are cleared to "0," timer 1 is set to "$FF_{16}$," and timer 2 is set to "$01_{16}$."

**●Timer 3, Timer 4**

The count sources of timer 3 and timer 4 can be selected by setting the timer 34 mode register. A rectangular waveform of timer 3 underflow signal divided by 2 is output from the $P4_6/T_{3OUT}$ pin. The waveform polarity changes each time timer 3 overflows. The active edge of the external clock $CNTR_1$ can be switched with the bit 7 of the interrupt edge selection register.

**●Timer 5, Timer 6**

The count sources of timer 5 and timer 6 can be selected by setting the timer 56 mode register. A rectangular waveform of timer 6 underflow signal divided by 2 is output from the $P4_4/PWM_1$ pin. The waveform polarity changes each time timer 6 overflows.

**●Timer 6 $PWM_1$ Mode**

Timer 6 can output a rectangular waveform with "H" duty cycle n/(n+m) from the $P4_4/PWM_1$ pin by setting the timer 56 mode register (refer to Figure 16). The n is the value set in timer 6 latch (address $0025_{16}$) and m is the value in the timer 6 PWM register (address $0027_{16}$). If n is "0," the PWM output is "L," if m is "0," the PWM output is "H" (n = 0 is prior than m = 0). In the PWM mode, interrupts occur at the rising edge of the PWM output.

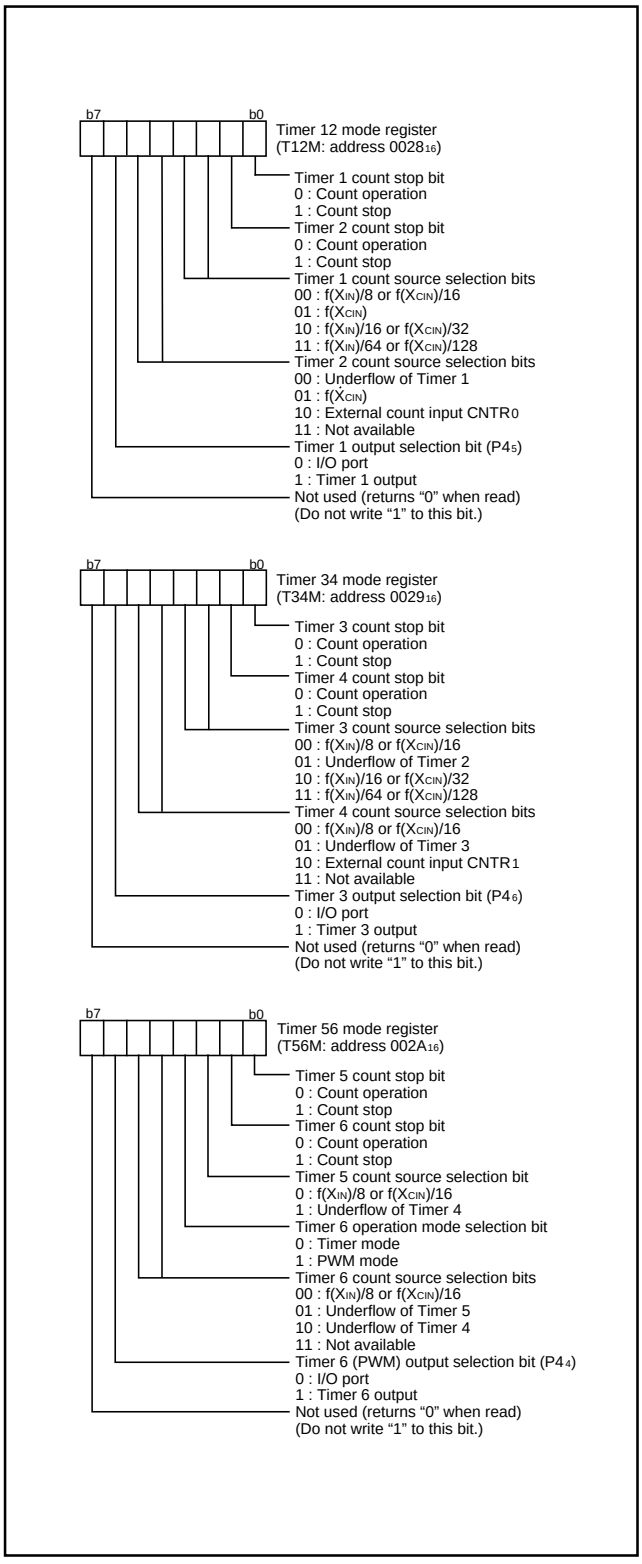



**Fig. 14 Structure of Timer Related Register**

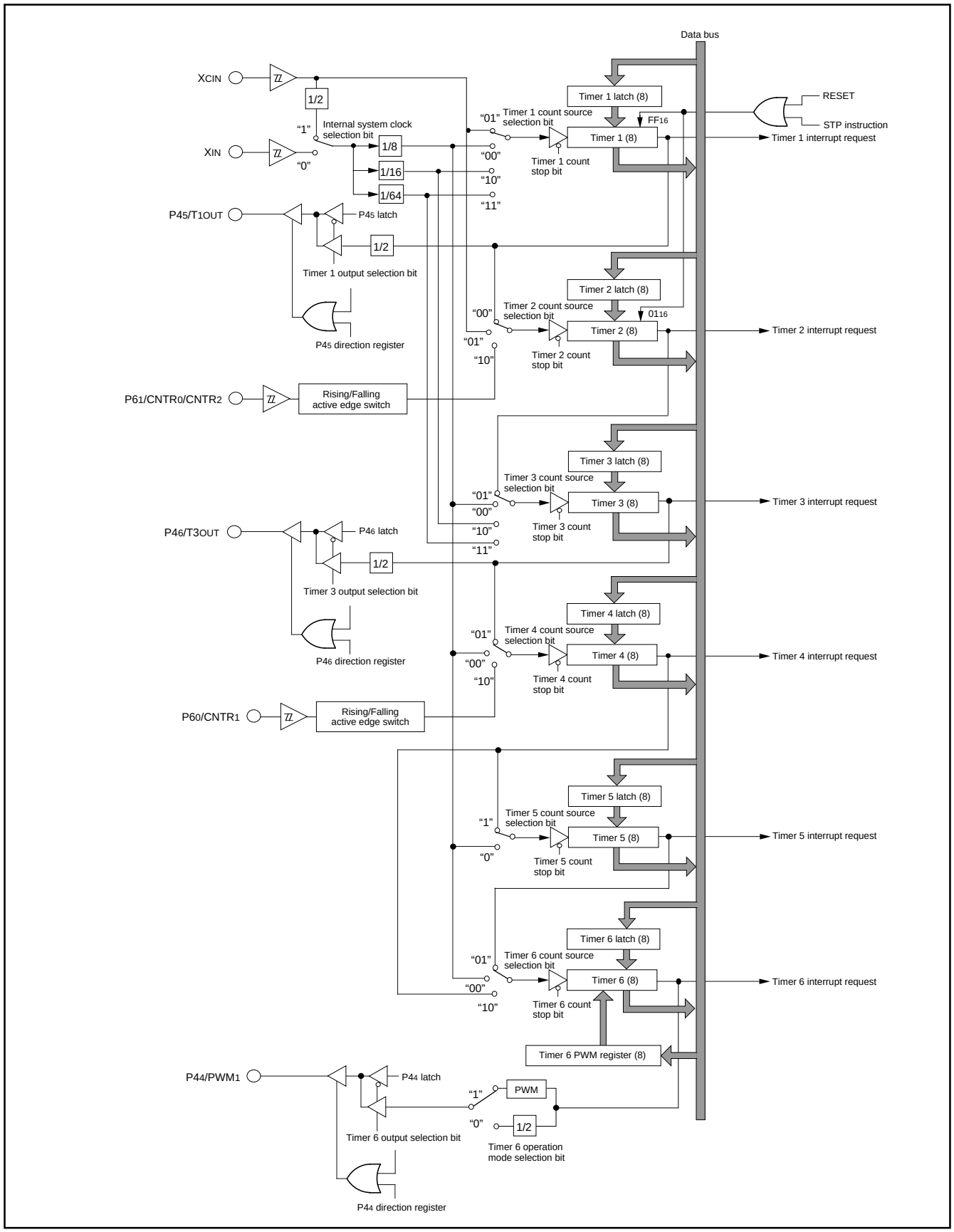
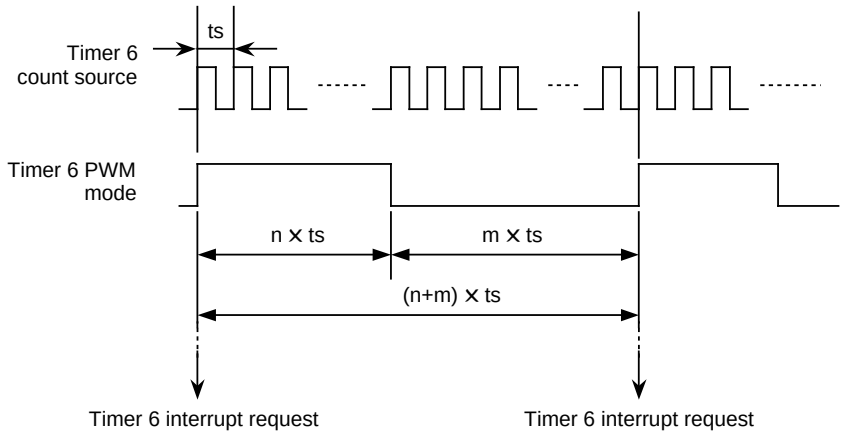



**Fig. 15 Block Diagram of Timer**




**Note:** PWM waveform (duty : n/(n + m) and period: (n + m) × ts) is output.
n : setting value of Timer 6
m: setting value of Timer 6 PWM register
ts: period of Timer 6 count source

**Fig. 16 Timing Chart of Timer 6 PWM1 Mode**

## 16-Bit Timer

Timer X is a 16-bit timer that can be selected in one of four modes by the Timer X mode register 1, 2 and can be controlled the timer X write and the real time port by setting the timer X mode registers.
Read and write operation on 16-bit timer must be performed for both high- and low-order bytes. When reading a 16-bit timer, read from the high-order byte first. When writing to 16-bit timer, write to the low-order byte first. The 16-bit timer cannot perform the correct operation when reading during write operation, or when writing during read operation.

**●Timer X**

Timer X is a down-counter. When the timer reaches "$0000_{16}$," an underflow occurs with the next count pulse. Then the contents of the timer latch is reloaded into the timer and the timer continues down-counting. When a timer underflows, the interrupt request bit corresponding to that timer is set to "1."

**(1) Timer mode**

A count source can be selected by setting the Timer X count source selection bits (bits 1 and 2) of the Timer X mode register 1.

**(2) Pulse output mode**

Each time the timer underflows, a signal output from the $CNTR_2$ pin is inverted. Except for this, the operation in pulse output mode is the same as in timer mode. When using a timer in this mode, set the port shared with the $CNTR_2$ pin to output.

**(3) Event counter mode**

The timer counts signals input through the $CNTR_2$ pin. Except for this, the operation in event counter mode is the same as in timer mode. When using a timer in this mode, set the port shared with the $CNTR_2$ pin to input.

**(4) Pulse width measurement mode**

A count source can be selected by setting the Timer X count source selection bits (bits 1 and 2) of the Timer X mode register 1. When $CNTR_2$ active edge switch bit is "0," the timer counts while the input signal of the $CNTR_2$ pin is at "H." When it is "1," the timer counts while the input signal of the $CNTR_2$ pin is at "L." When using a timer in this mode, set the port shared with the $CNTR_2$ pin to input.

## ■ Note

**•Timer X Write Control**

If the timer X write control bit is "0," when the value is written in the address of timer X, the value is loaded in the timer X and the latch at the same time.
If the timer X write control bit is "1," when the value is written in the address of timer X, the value is loaded only in the latch. The value in the latch is loaded in timer X after timer X underflows.
When the value is written in latch only, unexpected value may be set in the high-order counter if the writing in high-order latch and the underflow of timer X are performed at the same timing.

**•Real Time Port Control**

While the real time port function is valid, data for the real time port are output from ports $P8_5$ and $P8_6$ each time the timer X underflows. (However, if the real time port control bit is changed from "0" to "1," data are output without the timer X.) When the data for the real time port is changed while the real time port function is valid, the changed data are output at the next underflow of timer X.
Before using this function, set the corresponding port direction registers to output mode.

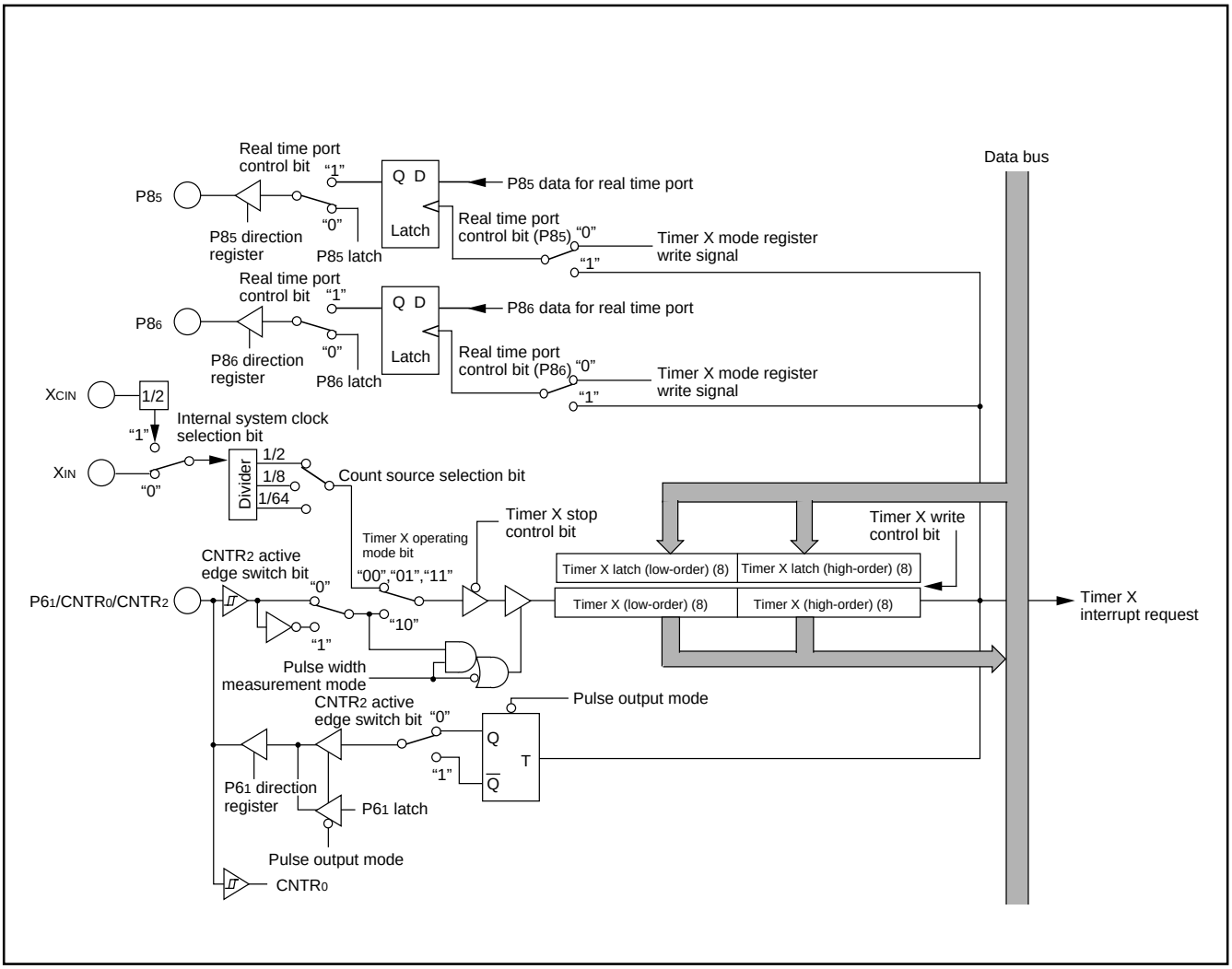



**Fig. 17 Block Diagram of Timer X**

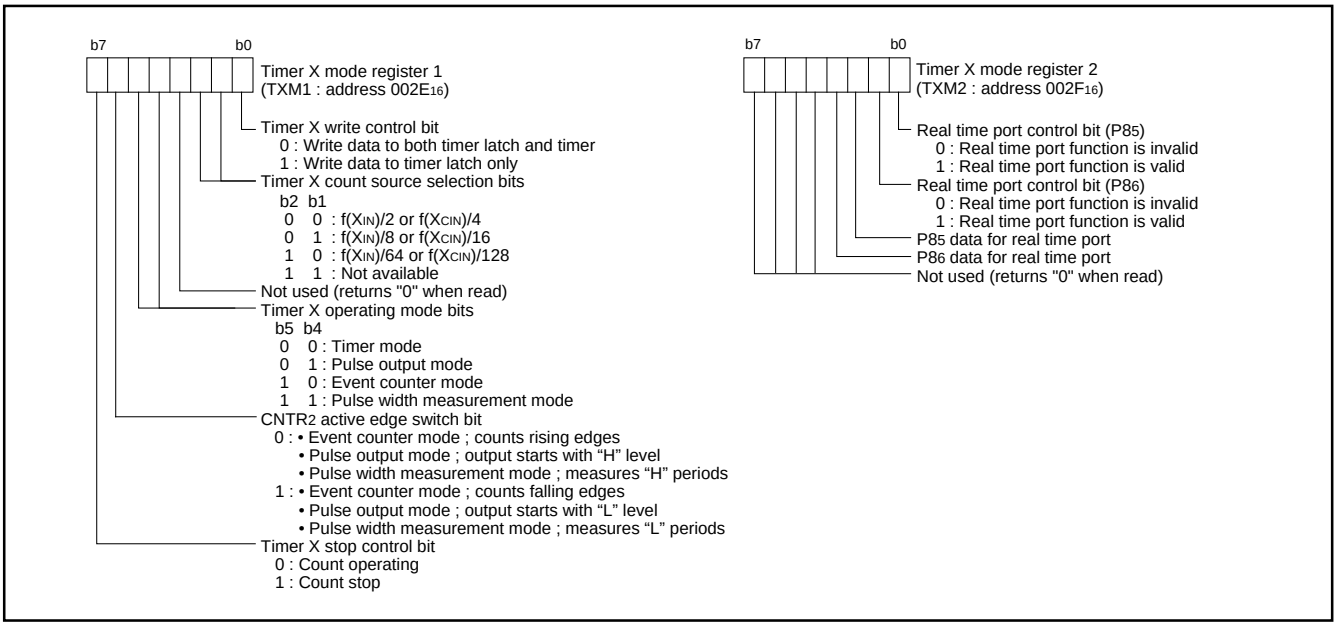



**Fig. 18 Structure of Timer X Related Registers**

## Serial I/O

### ●Serial I/O1

Serial I/O1 is used as the clock synchronous serial I/O and has an ordinary mode and an automatic transfer mode. In the automatic transfer mode, serial transfer is performed through the serial I/O automatic transfer RAM which has up to 256 bytes (addresses $0F00_{16}$ to $0FFF_{16}$: addresses $0F60_{16}$ to $0FFF_{16}$ are also used as FLD automatic display RAM).

The $P6_2/\overline{SRDY1}/AN_8$, $P6_4/INT_4/SBUSY1/AN_{10}$, and $P6_5/SSTB1/AN_{11}$ pins each have a handshake I/O signal function and can select either "H" active or "L" active for active logic.

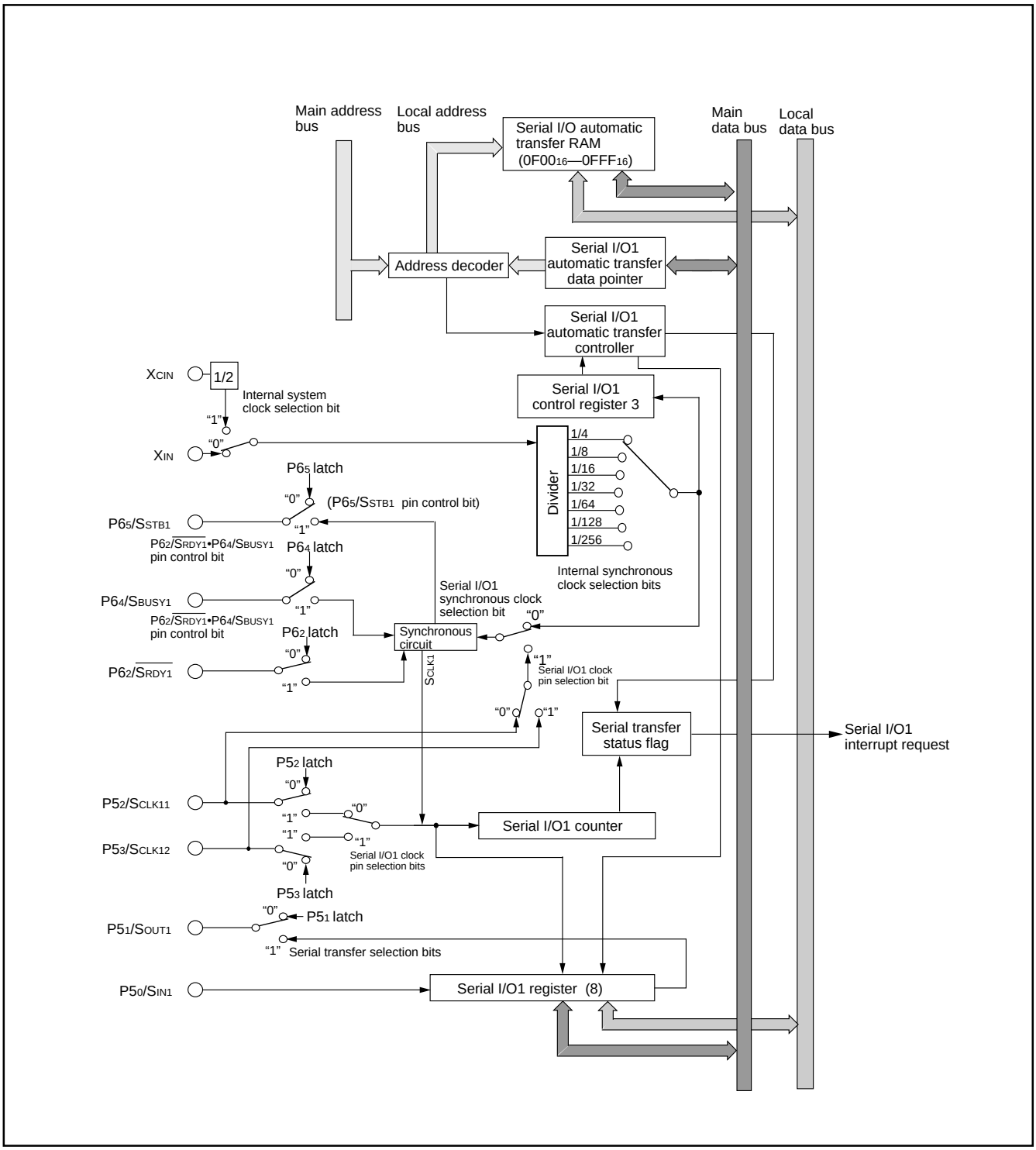



**Fig. 19 Block Diagram of Serial I/O1**

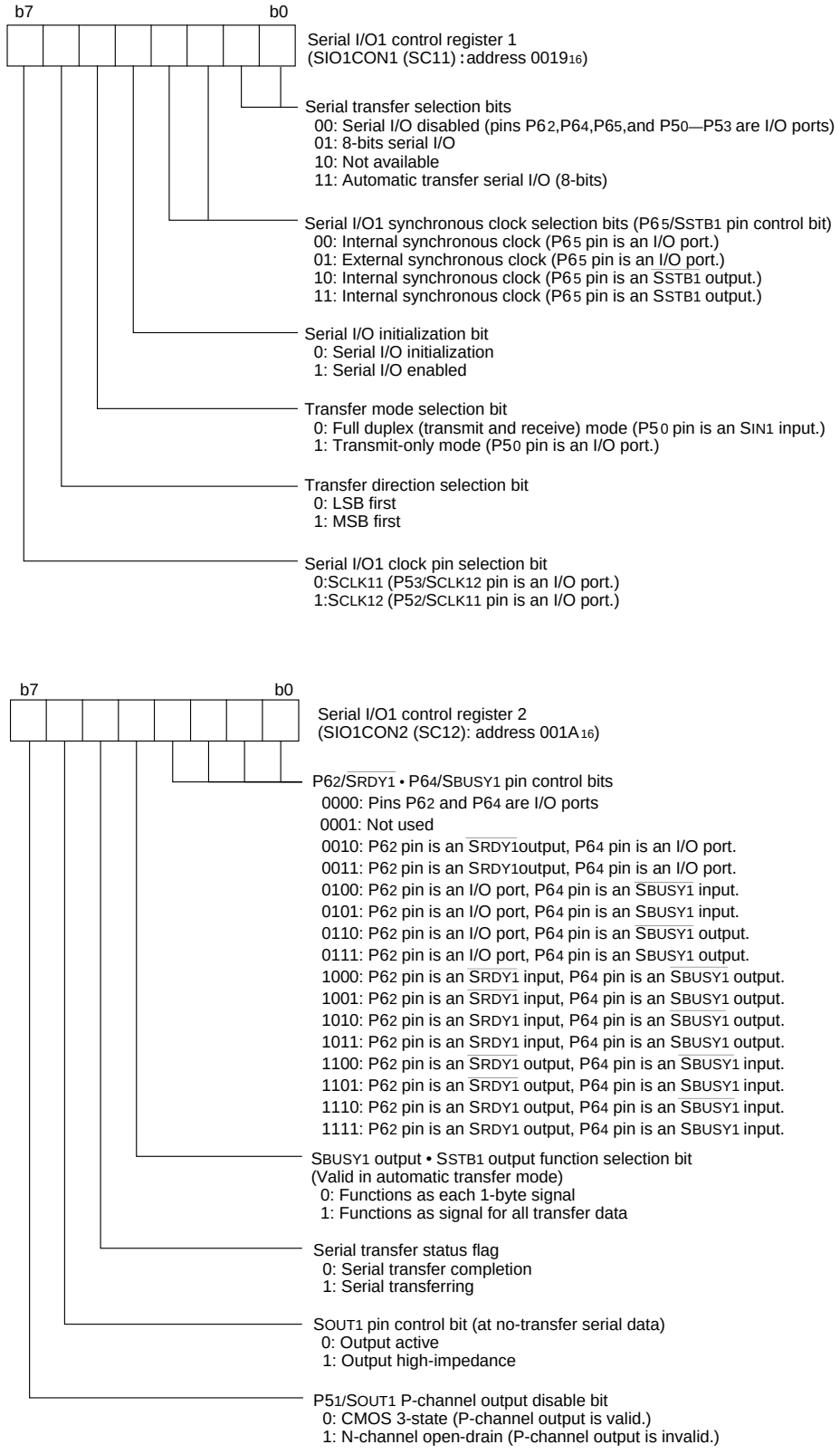



**Fig. 20 Structure of Serial I/O1 Control Registers 1, 2**

**(1) Serial I/O1 Operation**

Either the internal synchronous clock or external synchronous clock can be selected by the serial I/O1 synchronous clock selection bits (b2 and b3 of address $0019_{16}$) of serial I/O1 control register 1 as synchronous clock for serial transfer.

The internal synchronous clock has a built-in dedicated divider where 7 different clocks are selected by the internal synchronous clock selection bits (b5, b6 and b7 of address $001C_{16}$) of serial I/O1 control register 3.

The $P6_2/\overline{S_{RDY1}}/AN_8$, $P6_4/INT_4/S_{BUSY1}/AN_{10}$, and $P6_5/S_{STB1}/AN_{11}$ pins each select either I/O port or handshake I/O signal by the serial I/O1 synchronous clock selection bits (b2 and b3 of address $0019_{16}$) of serial I/O1 control register 1 as well as the $P6_2/\overline{S_{RDY1}}$ • $P6_4/S_{BUSY1}$ pin control bits (b0 to b3 of address $001A_{16}$) of serial I/O1 control register 2.

For the $S_{OUT1}$ being used as an output pin, either CMOS output or N-channel open-drain output is selected by the $P5_1/S_{OUT1}$ P-channel output disable bit (b7 of address $001A_{16}$) of serial I/O1 control register 2.

Either output active or high-impedance can be selected as a $S_{OUT1}$ pin state at serial non-transfer by the $S_{OUT1}$ pin control bit (b6 of address $001A_{16}$) of serial I/O1 control register 2. However, when the external synchronous clock is selected, perform the following setup to put the $S_{OUT1}$ pin into a high-impedance state.

When the $S_{CLK1}$ input is "H" after completion of transfer, set the $S_{OUT1}$ pin control bit to "1."

When the $S_{CLK1}$ input goes to "L" after the start of the next serial transfer, the $S_{OUT1}$ pin control bit is automatically reset to "0" and put into an output active state.

Regardless of whether the internal synchronous clock or external synchronous clock is selected, the full duplex mode and the transmit-only mode are available for serial transfer, one of which is selected by the transfer mode selection bit (b5 of address $0019_{16}$) of serial I/O1 control register 1.

Either LSB first or MSB first is selected for the I/O sequence of the serial transfer bit strings by the transfer direction selection bit (b6 of address $0019_{16}$) of serial I/O1 control register 1.

When using serial I/O1, first select either 8-bit serial I/O or automatic transfer serial I/O by the serial transfer selection bits (b0 and b1 of address $0019_{16}$) of serial I/O1 control register 1, after completion of the above bit setup. Next, set the serial I/O initialization bit (b4 of address $0019_{16}$) of serial I/O1 control register 1 to "1" (Serial I/O enable) .

When stopping serial transfer while data is being transferred, regardless of whether the internal or external synchronous clock is selected, reset the serial I/O initialization bit (b4) to "0."

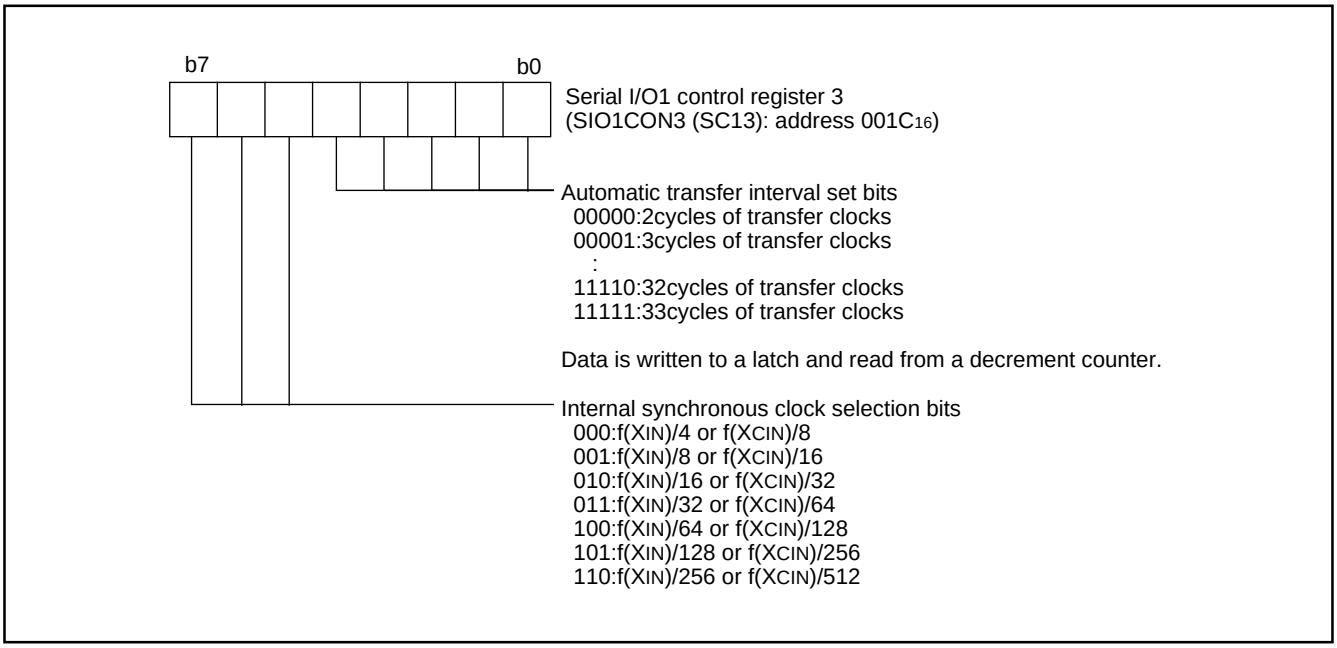



**Fig. 21 Structure of Serial I/O1 Control Register 3**

**(2) 8-bit Serial I/O Mode**

Address 001B16 is assigned to the serial I/O1 register.

When the internal synchronous clock is selected, a serial transfer of the 8-bit serial I/O is started by a write signal to the serial I/O1 register (address 001B16).

The serial transfer status flag (b5 of address 001A16) of serial I/O1 control register 2 indicates the shift register status of serial I/O1, and is set to "1" by writing into the serial I/O1 register, which becomes a transfer start trigger and reset to "0" after completion of 8-bit transfer. At the same time, a serial I/O1 interrupt request occurs.

When the external synchronous clock is selected, the contents of the serial I/O1 register are continuously shifted while transfer clocks are input to SCLK1. Therefore, the clock needs to be controlled externally.

**(3) Automatic Transfer Serial I/O Mode**

The serial I/O1 automatic transfer controller controls the write and read operations of the serial I/O1 register, so the function of address 001B16 is used as a transfer counter (1-byte units).

When performing serial transfer through the serial I/O automatic transfer RAM (addresses 0F0016 to 0FFF16), it is necessary to set the serial I/O1 automatic transfer data pointer (address 001816) beforehand.

Input the low-order 8 bits of the first data store address to be serially transferred to the automatic transfer data pointer set bits.

When the internal synchronous clock is selected, the transfer interval for each 1-byte data can be set by the automatic transfer interval set bits (b0 to b4 of address 001C16) of serial I/O1 control register 3 in the following cases:

1. When using no handshake signal
2. When using the SRDY1 output, SBUSY1 output, and SSTB1 output of the handshake signal independently
3. When using a combination of SRDY1 output and SSTB1 output or a combination of SBUSY1 output and SSTB1 output of the handshake signal

It is possible to select one of 32 different values, namely 2 to 33 cycles of the transfer clock, as a setting value.

When using the SBUSY1 output and selecting the SBUSY1 output • SSTB1 output function selection bit (b4 of address 001A16) of serial I/O1 control register 2 as the signal for all transfer data, provided that the automatic transfer interval setting is valid, a transfer interval is placed before the start of transmission/reception of the first data and after the end of transmission/reception of the last data.

For SSTB1 output, regardless of the contents of the SBUSY1 output • SSTB1 output function selection bit (b4), the transfer interval for each 1-byte data is longer than the set value by 2 cycles.

Furthermore, when using a combination of SBUSY1 output and SSTB1 output as a signal for all transfer data, the transfer interval after the end of transmission/reception of the last data is longer than the set value by 2 cycles.

When the external synchronous clock is selected, automatic transfer interval setting is disabled.

After completion of the above bit setup, if the internal synchronous clock is selected, automatic serial transfer is started by writing the value of "number of transfer bytes - 1" into the transfer counter (address 001B16).

When the external synchronous clock is selected, write the value of "number of transfer bytes - 1" into the transfer counter and input an internal system clock interval of 5 cycles or more. After that, input transfer clock to SCLK1.

As a transfer interval for each 1-byte data transfer, input an internal system clock interval of 5 cycles or more from the clock rise time of the last bit.

Regardless of whether the internal or external synchronous clock is selected, the automatic transfer data pointer and the transfer counter are decremented after each 1-byte data is received and then written into the automatic transfer RAM. The serial transfer status flag (b5 of address 001A16) is set to "1" by writing data into the transfer counter. Writing data becomes a transfer start trigger, and the serial transfer status flag is reset to "0" after the last data is written into the automatic transfer RAM. At the same time, a serial I/O1 interrupt request occurs.

The values written in the automatic transfer data pointer set bits (b0 to b7 of address 001816) and the automatic transfer interval set bits (b0 to b4 of address 001C16) are held in the latch.

When data is written into the transfer counter, the values latched in the automatic transfer data pointer set bits (b0 to b7) and the automatic transfer interval set bits (b0 to b4) are transferred to the decrement counter.

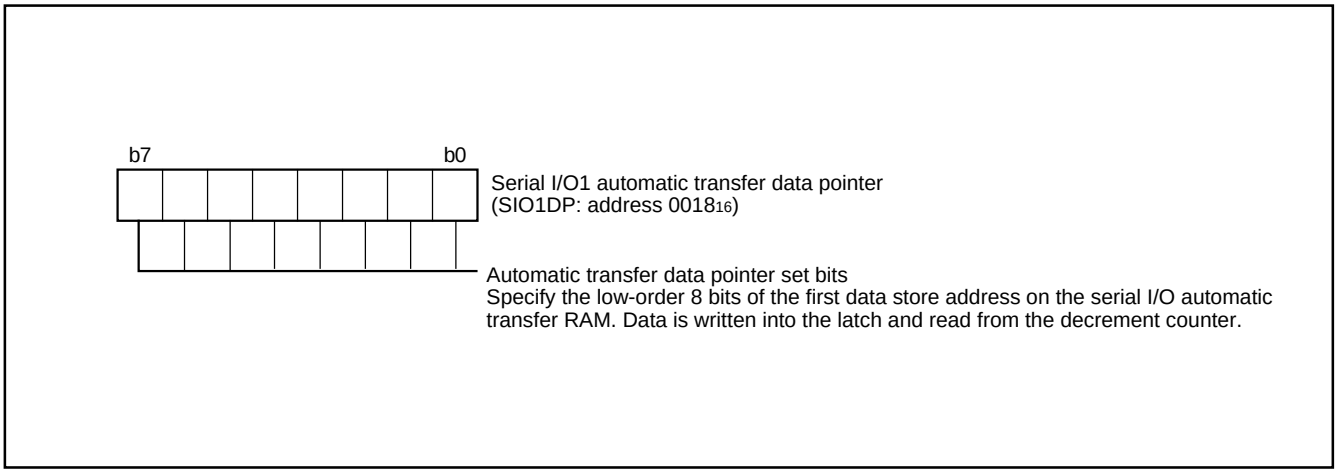



**Fig. 22 Structure of Serial I/O1 Automatic Transfer Data Pointer**

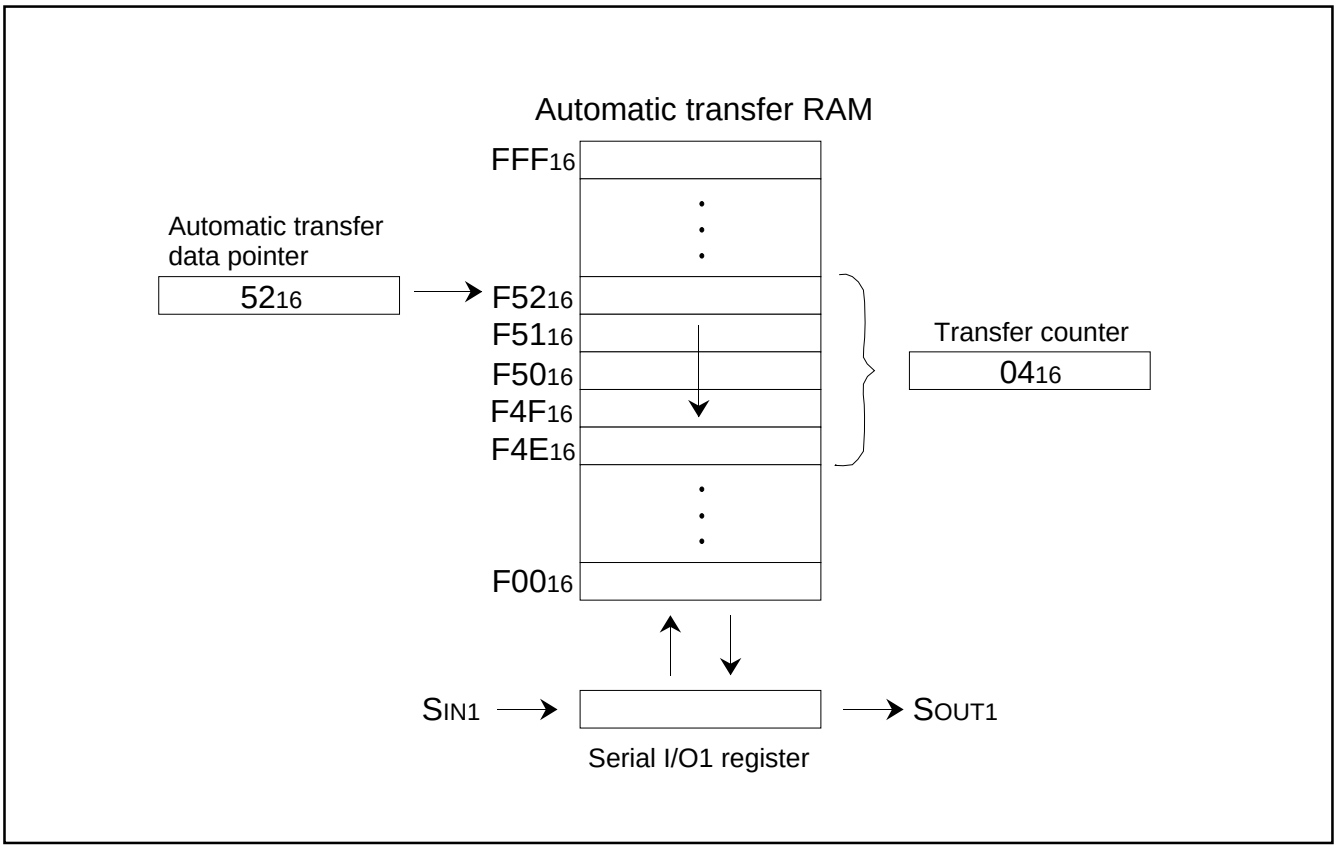



**Fig. 23 Automatic Transfer Serial I/O Operation**

**(4) Handshake Signal**

**1. SSTB1 output signal**

The SSTB1 output is a signal to inform an end of transmission/reception to the serial transfer destination . The SSTB1 output signal can be used only when the internal synchronous clock is selected.

In the initial status, namely, in the status in which the serial I/O initialization bit (b4) is reset to "0," the SSTB1 output goes to "L," or the $\overline{\text{SSTB1}}$ output goes to "H."

At the end of transmit/receive operation, when the data of the serial I/O1 register is all output from SOUT1, pulses are output in the period of 1 cycle of the transfer clock so as to cause the SSTB1 output to go "H" or the $\overline{\text{SSTB1}}$ output to go "L." After that, each pulse is returned to the initial status in which SSTB1 output goes to "L" or the $\overline{\text{SSTB1}}$ output goes to "H."

Furthermore, after 1 cycle, the serial transfer status flag (b5) is reset to "0."

In the automatic transfer serial I/O mode, whether the SSTB1 output is to be active at an end of each 1-byte data or after completion of transfer of all data can be selected by the SBUSY1 output • SSTB1 output function selection bit (b4 of address 001A16) of serial I/O1 control register 2.

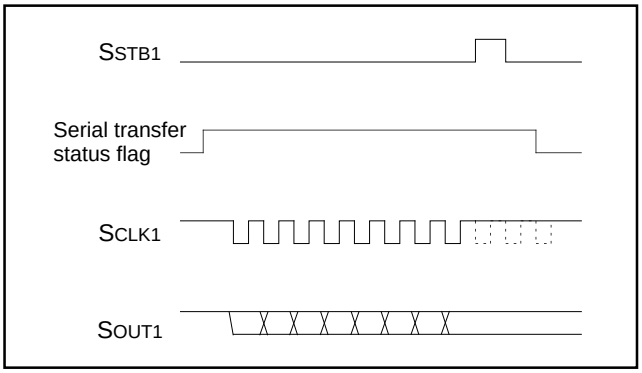



**Fig. 24 SSTB1 Output Operation**

**2. SBUSY1 input signal**

The SBUSY1 input is a signal which receives a request for a stop of transmission/reception from the serial transfer destination.

When the internal synchronous clock is selected, input an "H" level signal into the SBUSY1 input and an "L" level signal into the $\overline{\text{SBUSY1}}$ input in the initial status in which transfer is stopped.

When starting a transmit/receive operation, input an "L" level signal into the SBUSY1 input and an "H" level signal into the $\overline{\text{SBUSY1}}$ input in the period of 1.5 cycles or more of the transfer clock. Then, transfer clocks are output from the SCLK1 output.

When an "H" level signal is input into the SBUSY1 input and an "L" level signal into the $\overline{\text{SBUSY1}}$ input after a transmit/receive operation is started, this transmit/receive operation are not stopped immediately and the transfer clocks from the SCLK1 output is not stopped until the specified number of bits are transmitted and received.

The handshake unit of the 8-bit serial I/O is 8 bits and that of the automatic transfer serial I/O is 8 bits.

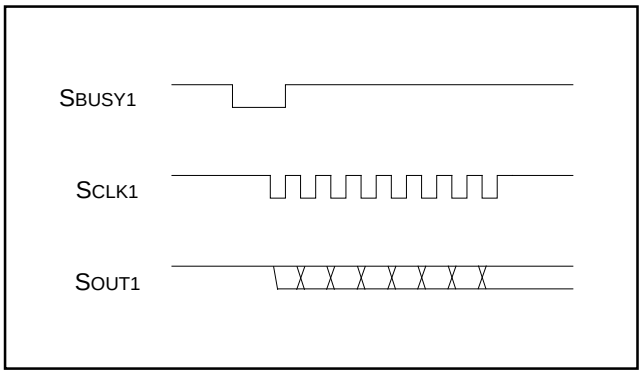



**Fig. 25 SBUSY1 Input Operation (internal synchronous clock)**

When the external synchronous clock is selected, input an "H" level signal into the SBUSY1 input and an "L" level signal into the $\overline{\text{SBUSY1}}$ input in the initial status in which transfer is stopped. At this time, the transfer clocks to be input in SCLK1 become invalid.

During serial transfer, the transfer clocks to be input in SCLK1 become valid, enabling a transmit/receive operation, while an "L" level signal is input into the SBUSY1 input and an "H" level signal is input into the $\overline{\text{SBUSY1}}$ input.

When changing the input values in the SBUSY1 input and the $\overline{\text{SBUSY1}}$ input at these operations, change them when the SCLK1 input is in a high state.

When the high impedance of the SOUT1 output is selected by the SOUT1 pin control bit (b6), the SOUT1 output becomes active, enabling serial transfer by inputting a transfer clock to SCLK1, while an "L" level signal is input into the SBUSY1 input and an "H" level signal is input into the $\overline{\text{SBUSY1}}$ input.

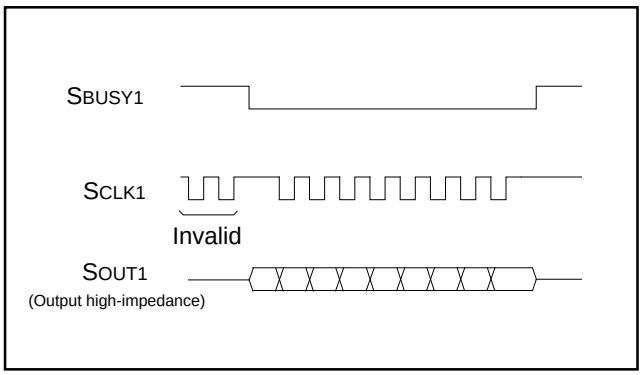



**Fig. 26 SBUSY1 Input Operation (external synchronous clock)**

**3. SBUSY1 output signal**

The SBUSY1 output is a signal which requests a stop of transmission/reception to the serial transfer destination. In the automatic transfer serial I/O mode, regardless of the internal or external synchronous clock, whether the SBUSY1 output is to be active at transfer of each 1-byte data or during transfer of all data can be selected by the SBUSY1 output • SSTB1 output function selection bit (b4).

In the initial status, the status in which the serial I/O initialization bit (b4) is reset to "0," the SBUSY1 output goes to "H" and the $\overline{\text{SBUSY1}}$ output goes to "L."

When the internal synchronous clock is selected, in the 8-bit serial I/O mode and the automatic transfer serial I/O mode (SBUSY1 output function outputs in 1-byte units), the SBUSY1 output goes to "L" and the $\overline{\text{SBUSY1}}$ output goes to "H" before 0.5 cycle (transfer clock) of the timing at which the transfer clock from the SCLK1 output goes to "L" at a start of transmit/receive operation.

In the automatic transfer serial I/O mode (the SBUSY1 output function outputs all transfer data), the SBUSY1 output goes to "L" and the $\overline{\text{SBUSY1}}$ output goes to "H" when the first transmit data is written into the serial I/O1 register (address $001B_{16}$).

When the external synchronous clock is selected, the SBUSY1 output goes to "L" and the $\overline{\text{SBUSY1}}$ output goes to "H" when transmit data is written into the serial I/O1 register to start a transmit operation, regardless of the serial I/O transfer mode.

At termination of transmit/receive operation, the SBUSY1 output returns to "H" and the $\overline{\text{SBUSY1}}$ output returns to "L", the initial status, when the serial transfer status flag is set to "0", regardless of whether the internal or external synchronous clock is selected.

Furthermore, in the automatic transfer serial I/O mode (SBUSY1 output function outputs in 1-byte units), the SBUSY1 output goes to "H" and the $\overline{\text{SBUSY1}}$ output goes to "L" each time 1-byte of receive data is written into the automatic transfer RAM.

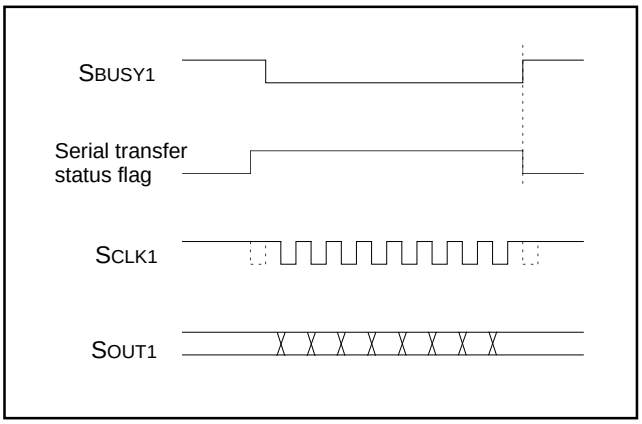



**Fig. 27 SBUSY1 Output Operation (internal synchronous clock, 8-bits serial I/O)**

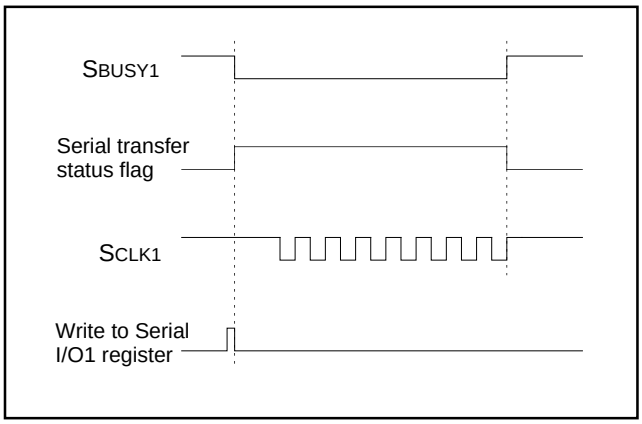



**Fig. 28 SBUSY1 Output Operation (external synchronous clock, 8-bits serial I/O)**

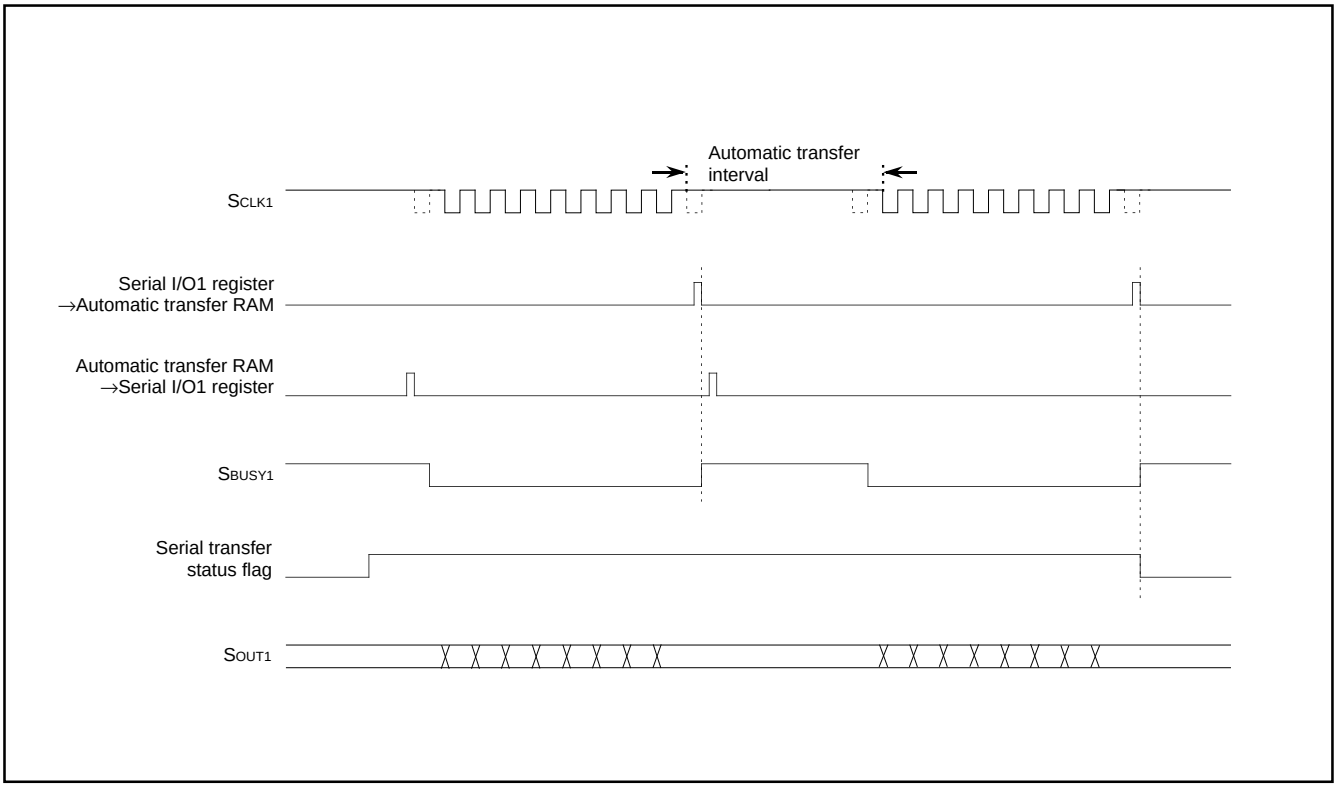



**Fig. 29 SBUSY1 Output Operation in Automatic Transfer Serial I/O Mode (internal synchronous clock, SBUSY1 output function outputs each 1-byte)**

**4. SRDY1 output signal**

The SRDY1 output is a transmit/receive enable signal which informs the serial transfer destination that transmit/receive is ready. In the initial status, when the serial I/O initialization bit (b4) is reset to "0," the SRDY1 output goes to "L" and the $\overline{\text{SRDY1}}$ output goes to "H". After transmitted data is stored in the serial I/O1 register (address $001B_{16}$) and a transmit/receive operation becomes ready, the SRDY1 output goes to "H" and the $\overline{\text{SRDY1}}$ output goes to "L". When a transmit/receive operation is started and the transfer clock goes to "L", the SRDY1 output goes to "L" and the $\overline{\text{SRDY1}}$ output goes to "H".

**5. SRDY1 input signal**

The SRDY1 input signal becomes valid only when the SRDY1 input and the SBUSY1 output are used. The SRDY1 input is a signal for receiving a transmit/receive ready completion signal from the serial transfer destination.

When the internal synchronous clock is selected, input a low level signal into the SRDY1 input and a high level signal into the $\overline{\text{SRDY1}}$ input in the initial status in which the transfer is stopped.

When an "H" level signal is input into the SRDY1 input and an "L" level signal is input into the $\overline{\text{SRDY1}}$ input for a period of 1.5 cycles or more of transfer clock, transfer clocks are output from the SCLK1 output and a transmit/receive operation is started.

After the transmit/receive operation is started and an "L" level signal is input into the SRDY1 input and an "H" level signal into the $\overline{\text{SRDY1}}$ input, this operation cannot be immediately stopped.

After the specified number of bits are transmitted and received, the transfer clocks from the SCLK1 output is stopped. The handshake unit of the 8-bit serial I/O and that of the automatic transfer serial I/O are of 8 bits.

When the external synchronous clock is selected, the SRDY1 input becomes one of the triggers to output the SBUSY1 signal.

To start a transmit/receive operation (SBUSY1 output: "L," $\overline{\text{SBUSY1}}$ output: "H"), input an "H" level signal into the SRDY1 input and an "L" level signal into the $\overline{\text{SRDY1}}$ input, and also write transmit data into the serial I/O1 register.

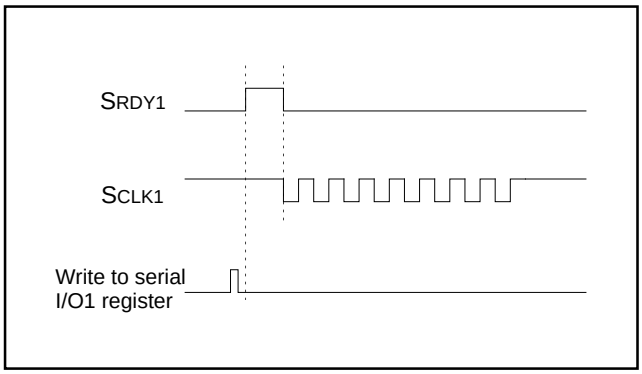



**Fig. 30 SRDY1 Output Operation**

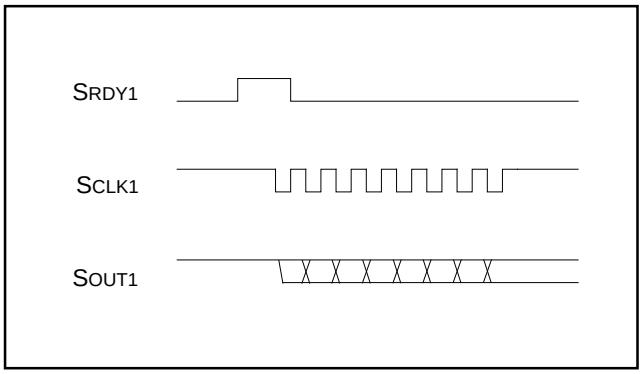



**Fig. 31 SRDY1 Input Operation (internal synchronous clock)**

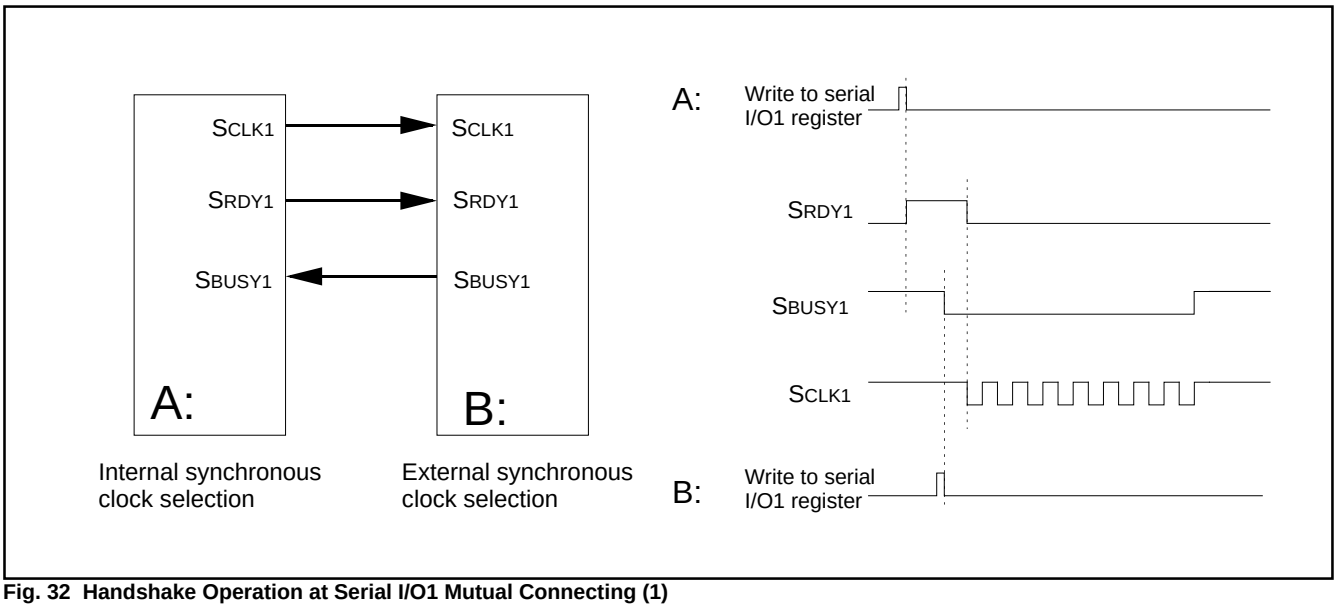



**Fig. 32 Handshake Operation at Serial I/O1 Mutual Connecting (1)**

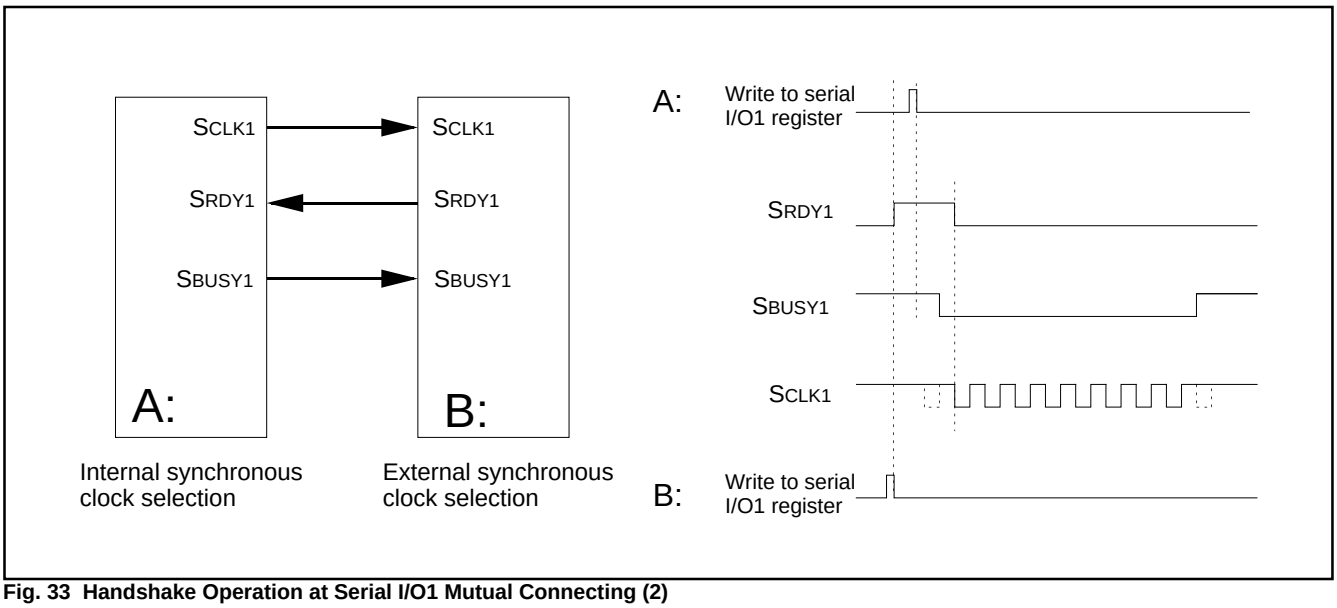



**Fig. 33 Handshake Operation at Serial I/O1 Mutual Connecting (2)**

## ●Serial I/O2

Serial I/O2 can be used as either clock synchronous or asynchronous (UART) serial I/O. A dedicated timer (baud rate generator) is also provided for baud rate generation during serial I/O2 operation.

**(1) Clock Synchronous Serial I/O Mode**

The clock synchronous serial I/O mode can be selected by setting the serial I/O2 mode selection bit (b6) of the serial I/O2 control register (address $001D_{16}$) to "1." For clock synchronous serial I/O, the transmitter and the receiver must use the same clock for serial I/O2 operation. If an internal clock is used, transmit/receive is started by a write signal to the serial I/O2 transmit/receive buffer register (TB/RB) (address $001F_{16}$).

When $P5_7$ ($S_{CLK22}$) is selected as a clock I/O pin, $\overline{S_{RDY2}}$ output function is invalid, and $P5_6$ ($S_{CLK21}$) is used as an I/O port.

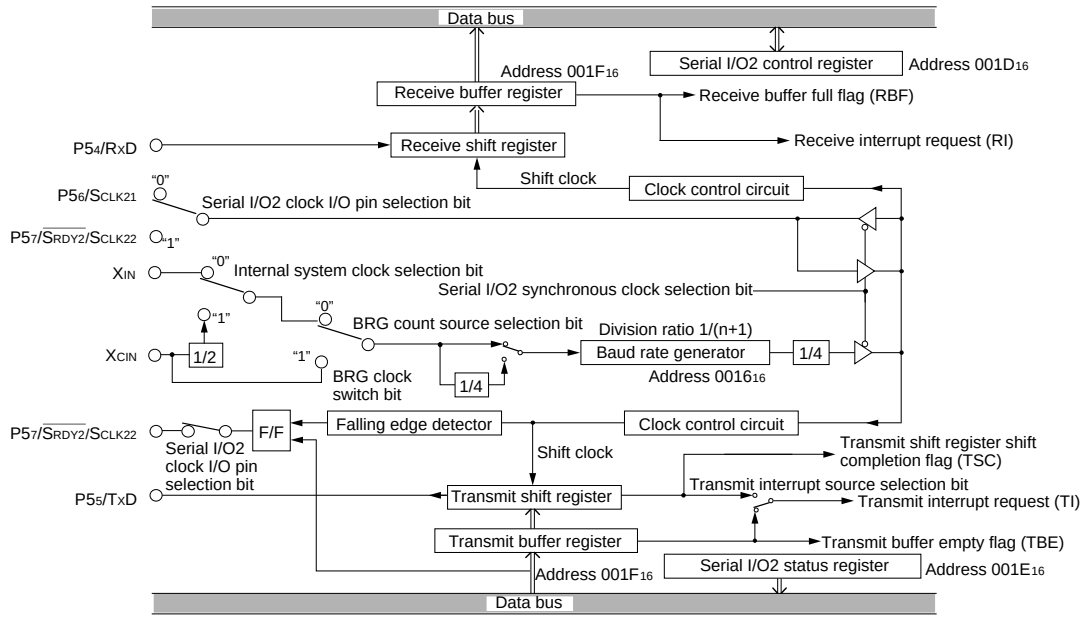
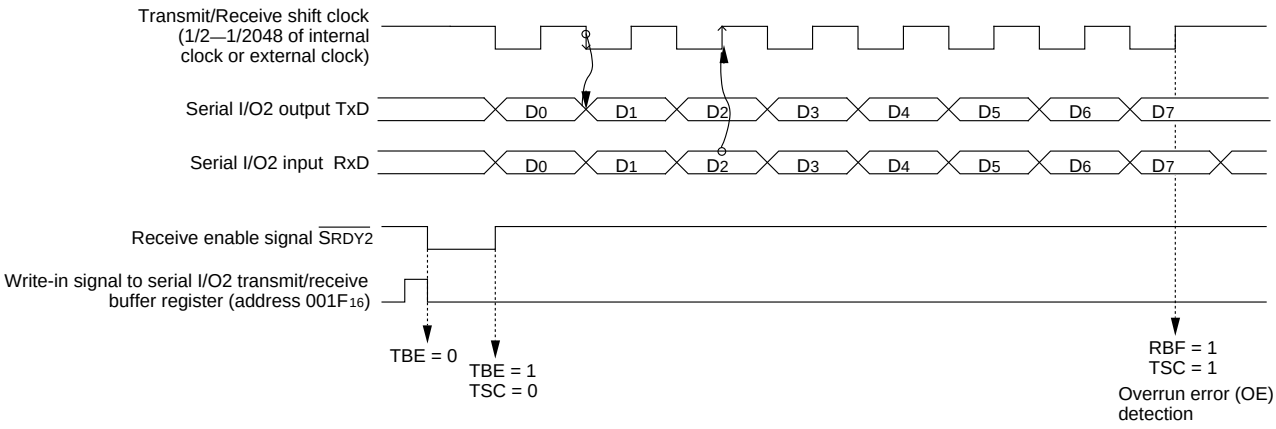



**Fig. 34 Block Diagram of Clock Synchronous Serial I/O2**




Notes 1 : The transmit interrupt (TI) can be selected to occur either when the transmit buffer has emptied (TBE=1) or after the transmit shift operation has ended (TSC=1), by setting transmit interrupt source selection bit (TIC) of the serial I/O2 control register.
2 : If data is written to the transmit buffer register when TSC=0, the transmit clock is generated continuously and serial data is output continuously from the TxD pin.
3 : The receive interrupt (RI) is set when the receive buffer full flag (RBF) becomes "1."

**Fig. 35 Operation of Clock Synchronous Serial I/O2 Function**

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

The asynchronous serial I/O (UART) mode can be selected by clearing the serial I/O2 mode selection bit (b6) of the serial I/O2 control register (address 001D16) to "0." Eight serial data transfer formats can be selected and the transfer formats used by the transmitter and receiver must be identical.

The transmit and receive shift registers each have a buffer (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, and receive data is read from the receive buffer. The transmit buffer can also hold the next data to be transmitted, and the receive buffer can receive 2-byte data continuously.

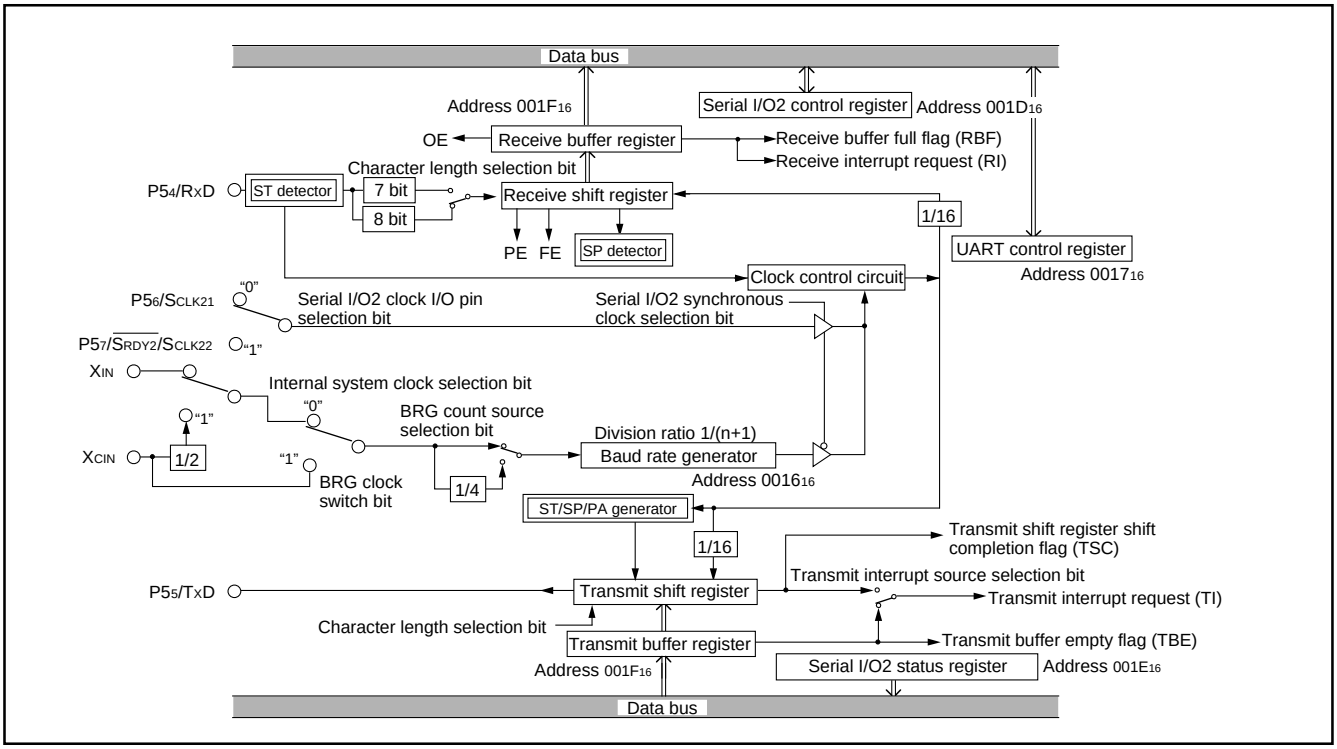



**Fig. 36 Block Diagram of UART Serial I/O2**

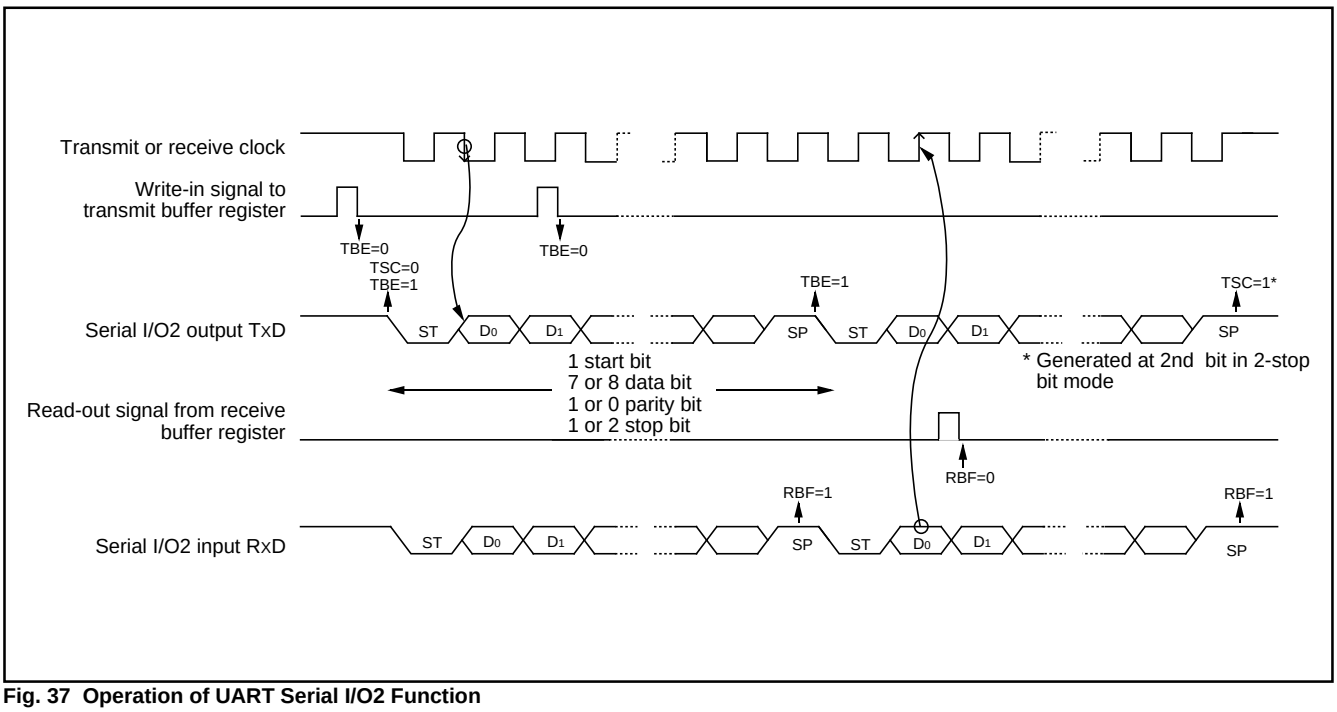



**Fig. 37 Operation of UART Serial I/O2 Function**

## [Serial I/O2 Control Register] SIO2CON (001D16)

The serial I/O2 control register contains eight control bits for serial I/O2 functions.

## [UART Control Register] UARTCON (001716)

This is a 5 bit register containing four control bits (b0 to b3), which are valid when UART is selected and set the data format of data receive/transfer, and one control bit (b4), which is always valid and sets the output structure of the P55/TxD pin.

## [Serial I/O2 Status Register] SIO2STS (001E16)

The read-only serial I/O2 status register consists of seven flags (b0 to b6) which indicate the operating status of the serial I/O2 function and various errors. Three of the flags (b4 to b6) are only valid in the UART mode. The receive buffer full flag (b1) is cleared to “0” when the receive buffer is read.

The error detection is performed at the same time data is transferred from the receive shift register to the receive buffer register, and the receive buffer full flag is set. A writing to the serial I/O2 status register clears error flags OE, PE, FE, and SE (b3 to b6, respectively).

Writing “0” to the serial I/O2 enable bit (SIOE : b7 of the serial I/O2 control register) also clears all the status flags, including the error flags.

All bits of the serial I/O2 status register are initialized to “0” at reset, but if the transmit enable bit (b4) of the serial I/O2 control register has been set to “1,” the transmit shift register shift completion flag (b2) and the transmit buffer empty flag (b0) become “1.”

## [Serial I/O2 Transmit Buffer Register/Receive Buffer Register] TB/RB (001F16)

The transmit buffer and the receive buffer are located in 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".

## [Baud Rate Generator] BRG (001616)

The baud rate generator determines the baud rate for serial transfer. With the 8-bit counter having a reload register, 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.

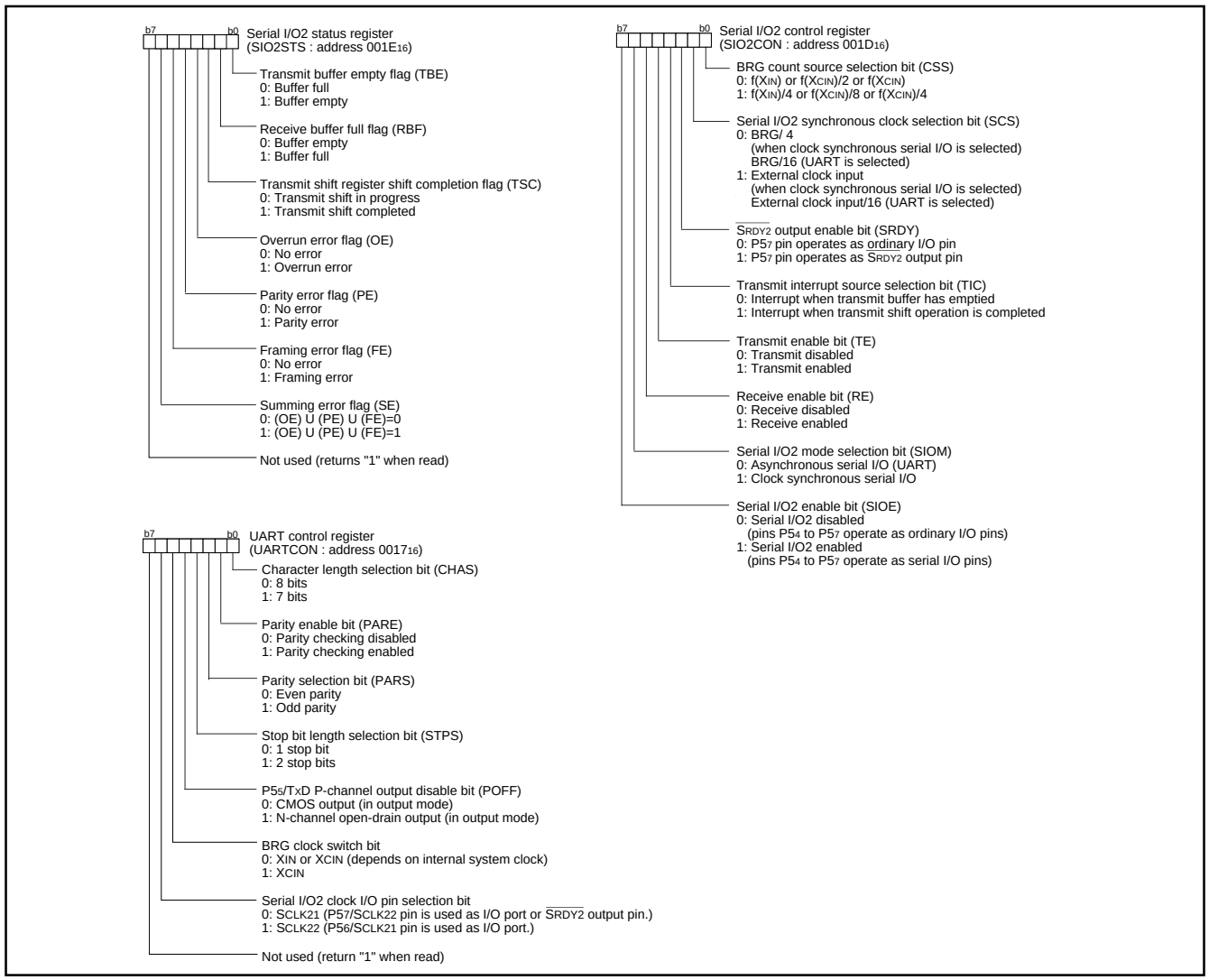



**Fig. 38 Structure of Serial I/O2 Related Register**

## FLD Controller

The 38B5 group has fluorescent display (FLD) drive and control circuits.

The FLD controller consists of the following components:

- 40 pins for FLD control pins
- FLDC mode register
- FLD data pointer
- FLD data pointer reload register
- Tdisp time set register
- Toff1 time set register
- Toff2 time set register
- Port P0FLD/port switch register
- Port P2FLD/port switch register
- Port P8FLD/port switch register
- Port P8 FLD output control register
- FLD automatic display RAM (max. 160 bytes)

A gradation display mode can be used for bright/dark display as a display function.

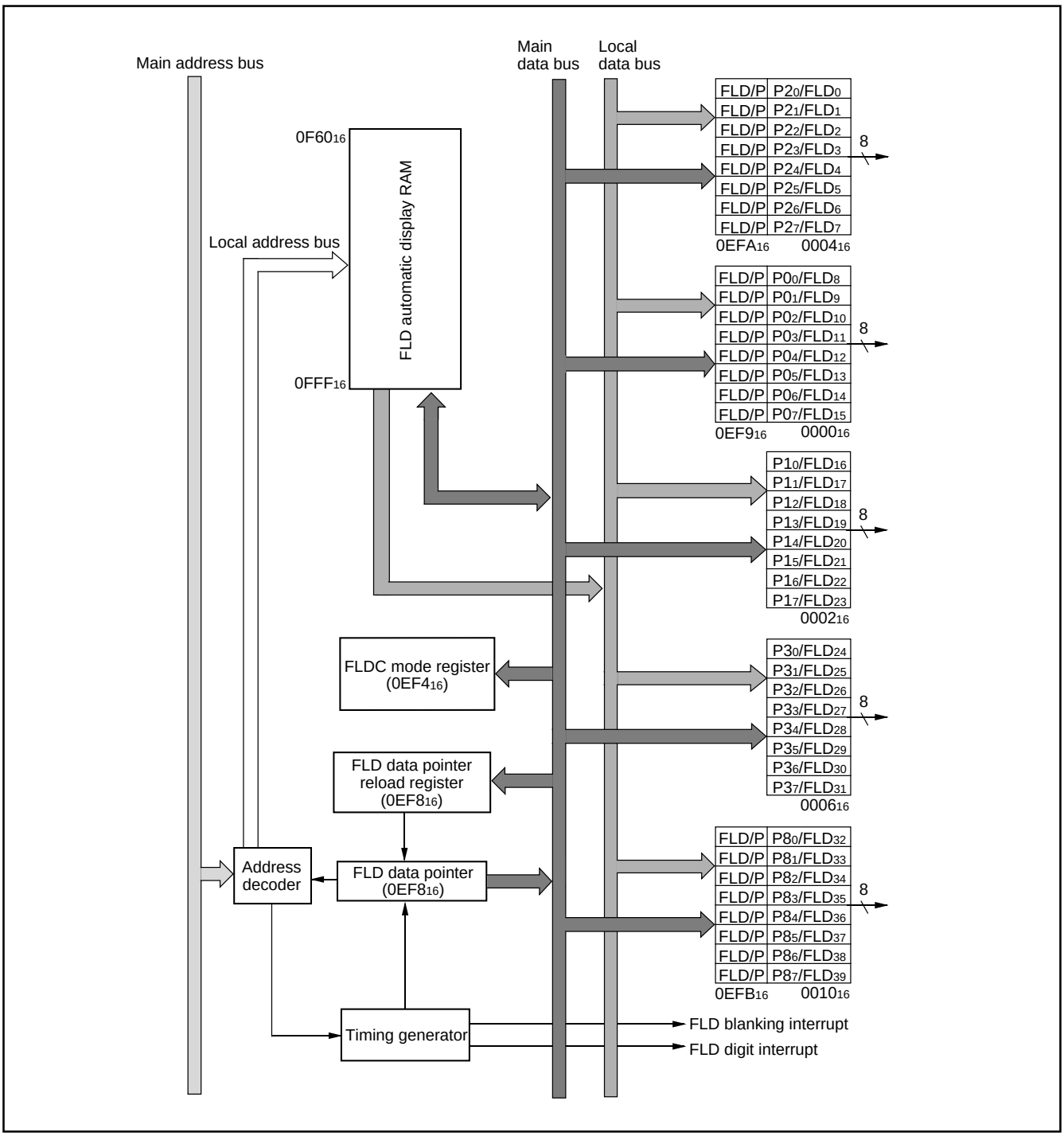
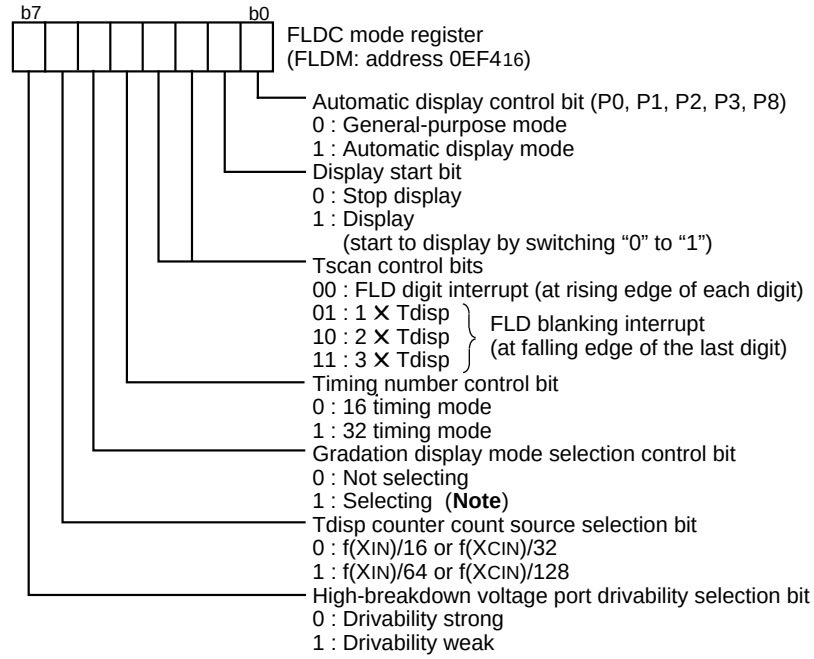



**Fig. 39 Block Diagram for FLD Control Circuit**

## [FLDC Mode Register] FLDM

The FLDC mode register is a 8-bit register respectively which is used to control the FLD automatic display and to set the blanking time Tscan for key-scan.




**Note:** When a gradation display mode is selected, a number of timing is max. 16 timing.
(Set the timing number control bit to “0.”)

**Fig. 40 Structure of FLDC Mode Register**

## FLD automatic display pins

When the automatic display control bits of the FLDC mode register (address 0EF4$_{16}$) are set to “1,” the ports of P0, P1, P2, P3 and P8 are used as FLD automatic display pins.

When using the FLD automatic display mode, set each port to the FLD pin or the general-purpose port using the respective switch register in accordance with the number of segments and the number of digits.

This setting is performed by writing a value into the FLD/port switch register (addresses 0EF9$_{16}$ to 0EFB$_{16}$) of each port.

This setting can be performed in units of bit. When “0” is set, the port is set to the general-purpose port. When “1” is set, the port is set to the FLD pin. There is no restriction on whether the FLD pin is to be used as a segment pin or a digit pin.

**Table 7 Pins in FLD Automatic Display Mode**

| Port Name | Automatic Display Pins | Setting Method |
|---|---|---|
| P0, P2, P8$_0$–P8$_3$ | FLD$_0$–FLD$_{15}$<br>FLD$_{32}$–FLD$_{35}$ | The individual bits of the FLD/port switch register (addresses 0EF9$_{16}$–0EFB$_{16}$) can be set each pin either FLD port (“1”) or general-purpose port (“0”). |
| P1, P3 | FLD$_{16}$–FLD$_{31}$ | None (FLD only) |
| P8$_4$–P8$_7$ | FLD$_{36}$–FLD$_{39}$ | The individual bits of the FLD/port switch register (address 0EFB$_{16}$) can be set each pin to either FLD port (“1”) or general-purpose port (“0”).<br>The output can be reversed by the port P8 FLD output control register (address 0EFC$_{16}$).<br>The port output format is the CMOS output format. When using the port as a display pin, a driver must be installed externally. |

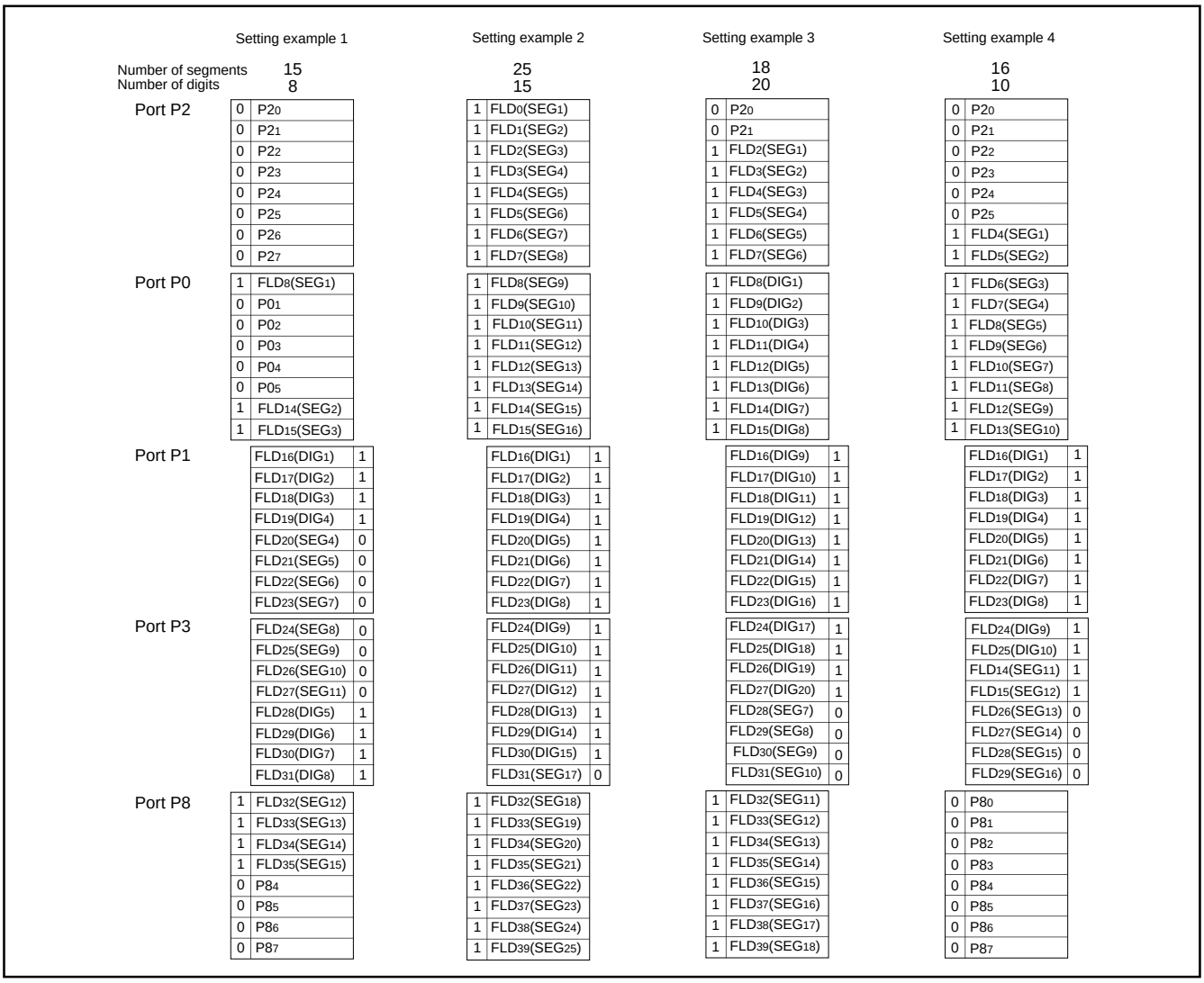



**Fig. 41 Segment/Digit Setting Example**

## FLD automatic display RAM

The FLD automatic display RAM uses the 160 bytes of addresses $0F60_{16}$ to $0FFF_{16}$. For FLD, the 3 modes of 16-timing ordinary mode, 16-timing•gradation display mode and 32-timing mode are available depending on the number of timings and the presence/absence of gradation display.

The automatic display RAM in each mode is as follows:

(1) 16-timing•Ordinary Mode

The 80 bytes of addresses $0FB0_{16}$ to $0FFF_{16}$ are used as a FLD display data store area. Because addresses $0F60_{16}$ to $0FAF_{16}$ are not used as the automatic display RAM, they can be the ordinary RAM or serial I/O automatic reverse RAM.

(2) 16-timing•Gradation Display Mode

The 160 bytes of addresses $0F60_{16}$ to $0FFF_{16}$ are used. The 80 bytes of addresses $0FB0_{16}$ to $0FFF_{16}$ are used as an FLD display data store area, while the 80 bytes of addresses $0F60_{16}$ to $0FAF_{16}$ are used as a gradation display control data store area.

(3) 32-timing Mode

The 160 bytes of addresses $0F60_{16}$ to $0FFF_{16}$ are used as an FLD display data store area.

### [FLD Data Pointer and FLD Data Pointer Reload Register] FLDDP ($0EF8_{16}$)

Both the FLD data pointer and FLD data pointer reload register are 8-bit registers assigned at address $0EF8_{16}$. When writing data to this address, the data is written to the FLD data pointer reload register; when reading data from this address, the value in the FLD data pointer is read.

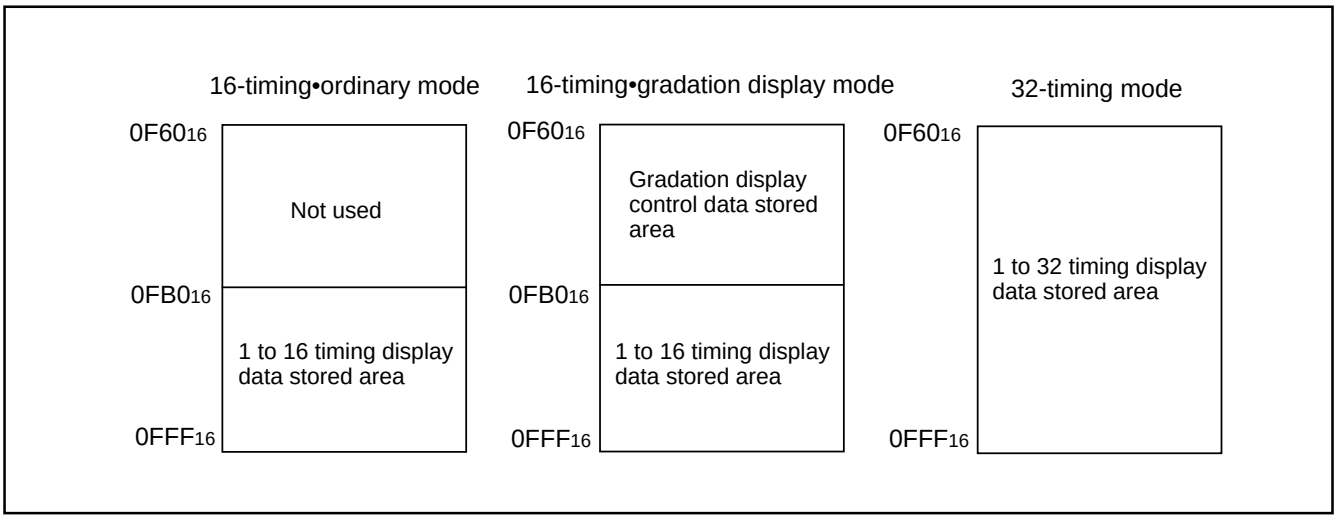



**Fig. 42 FLD Automatic Display RAM Assignment**

## Data setup

(1) 16-timing•Ordinary Mode

The area of addresses 0FB0$_{16}$ to 0FFF$_{16}$ are used as a FLD automatic display RAM.

When data is stored in the FLD automatic display RAM, the last data of FLD port P2 is stored at address 0FB0$_{16}$, the last data of FLD port P0 is stored at address 0FC0$_{16}$, the last data of FLD port P1 is stored at address 0FD0$_{16}$, the last data of FLD port P3 is stored at address 0FE0$_{16}$, and the last data of FLD port P8 is stored at address 0FF0$_{16}$, to assign in sequence from the last data respectively.

The first data of the FLD port P2, P0, P1, P3, and P8 is stored at an address which adds the value of (the timing number – 1) to the corresponding address 0FB0$_{16}$, 0FC0$_{16}$, 0FD0$_{16}$, 0FE0$_{16}$, and 0FF0$_{16}$.

Set the FLD data pointer reload register to the value given by the number of digits – 1. “1” is always written to bit 6, and “0” is always written to bit 5. Note that “0” is always read from bits 6 and 5 when reading.

(2) 16-timing•Gradation Display Mode

Display data setting is performed in the same way as that of the 16-timing•ordinary mode. Gradation display control data is arranged at an address resulting from subtracting 0050$_{16}$ from the display data store address of each timing and pin. Bright display is performed by setting “0,” and dark display is performed by setting “1.”

(3) 32-timing Mode

The area of addresses 0F60$_{16}$ to 0FFF$_{16}$ are used as a FLD automatic display RAM.

When data is stored in the FLD automatic display RAM, the last data of FLD port P2 is stored at address 0F60$_{16}$, the last data of FLD port P0 is stored at address 0F80$_{16}$, the last data of FLD port P1 is stored at address 0FA0$_{16}$, the last data of FLD port P3 is stored at address 0FC0$_{16}$, and the last data of FLD port P8 is stored at address 0FE0$_{16}$, to assign in sequence from the last data respectively.

The first data of the FLD port P2, P0, P1, P3, and P8 is stored at an address which adds the value of (the timing number – 1) to the corresponding address 0F60$_{16}$, 0F80$_{16}$, 0FA0$_{16}$, 0FC0$_{16}$, and 0FE0$_{16}$.

Set the FLD data pointer reload register to the value given by the number of digits–1. “1” is always written to bit 6, and “0” is always written to bit 5. Note that “0” is always read from bits 6 and 5 when reading.

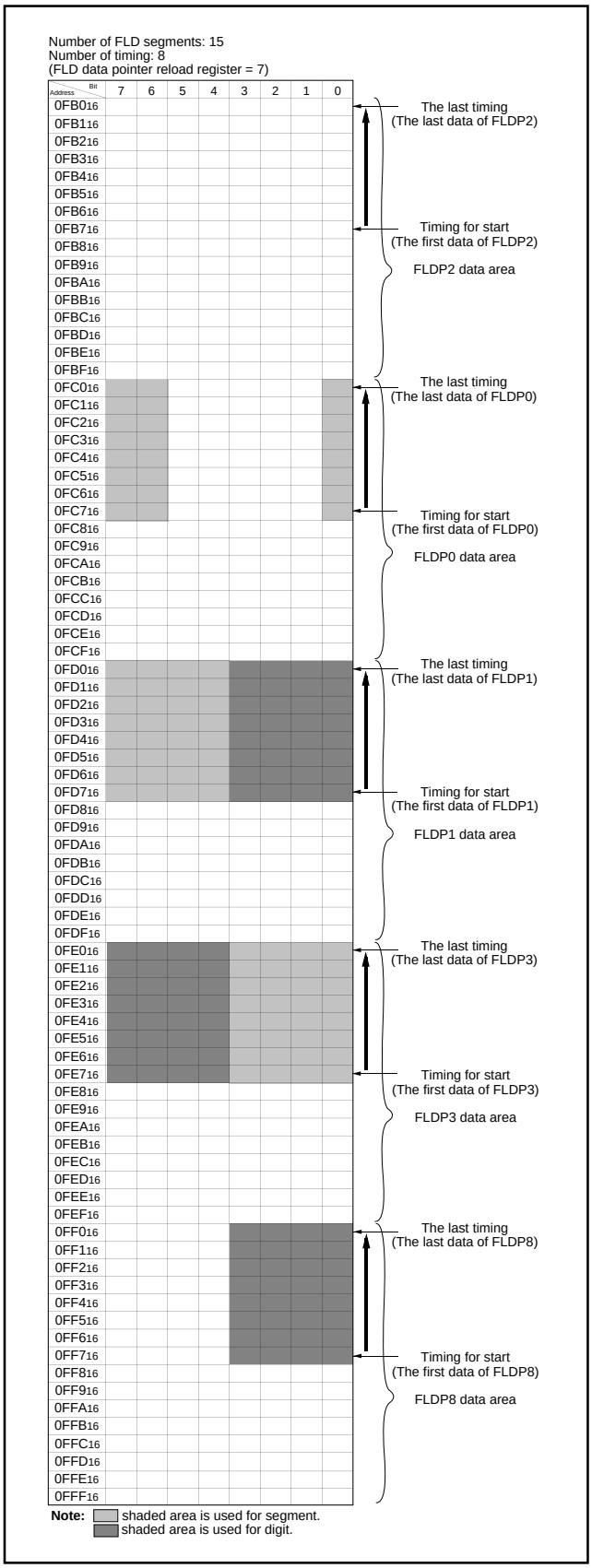



**Fig. 43 Example of Using the FLD Automatic Display RAM in 16-timing•Ordinary Mode**

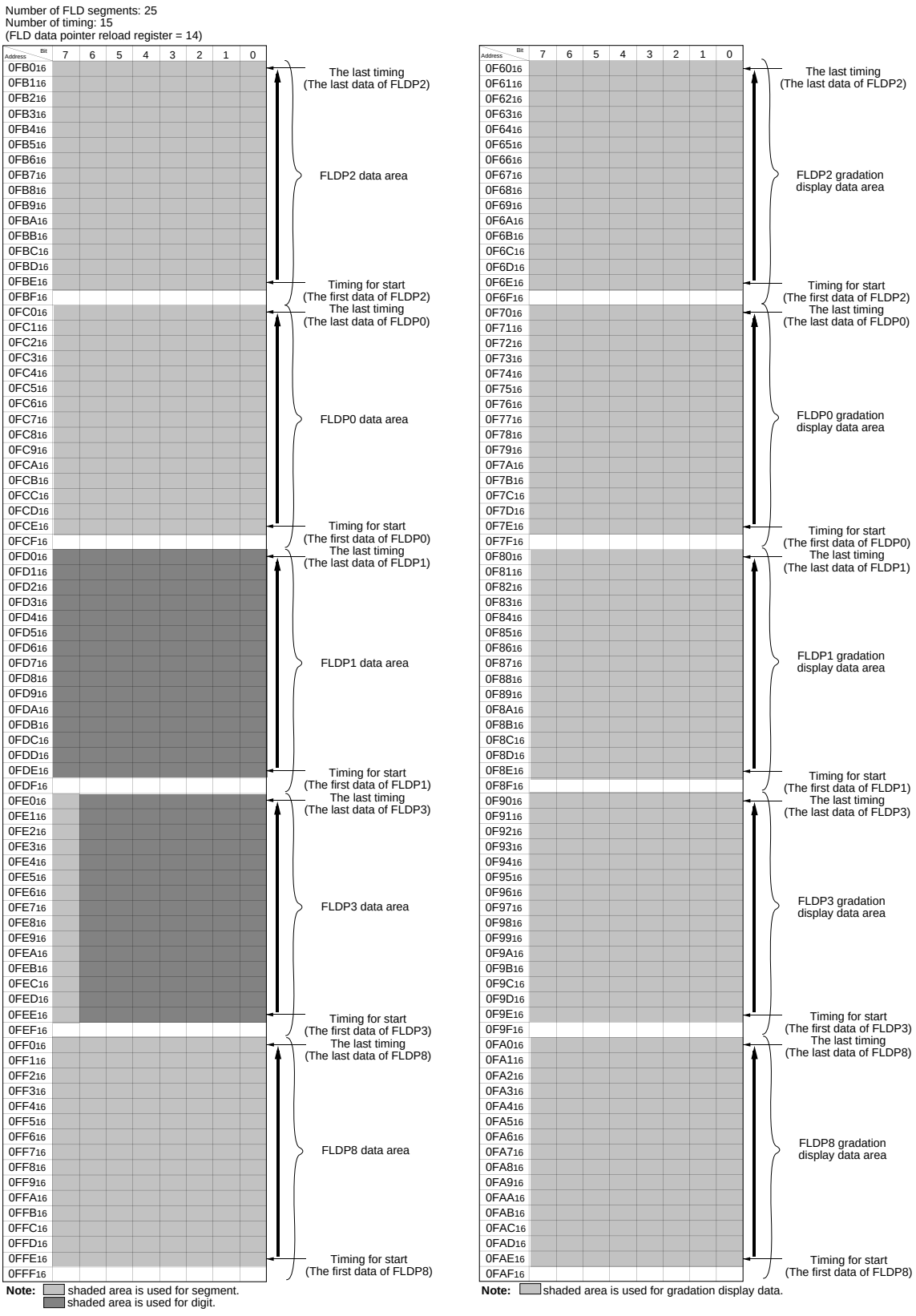



**Fig. 44 Example of Using the FLD Automatic Display RAM in 16-timing•Gradation Display Mode**

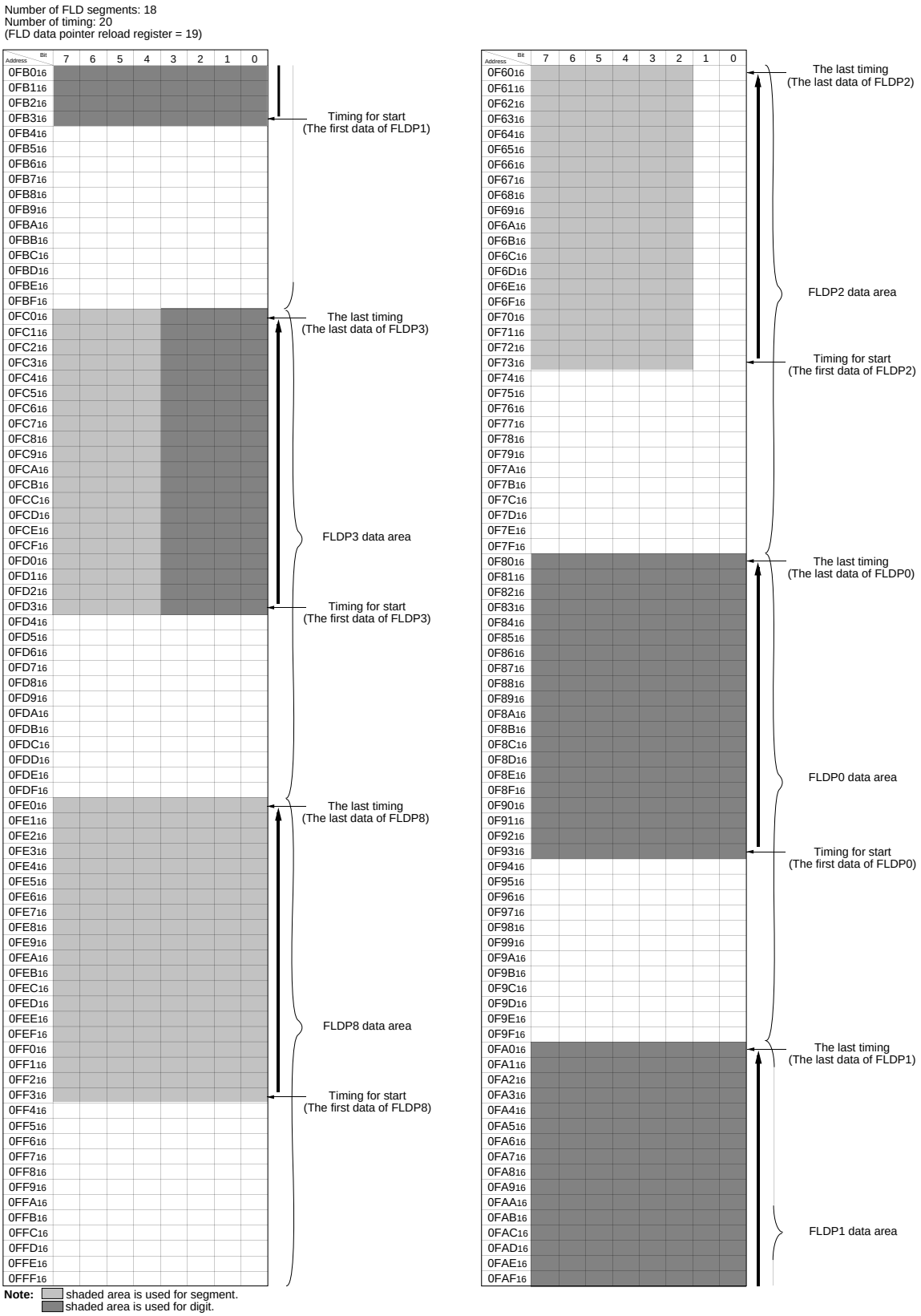



**Fig. 45 Example of Using the FLD Automatic Display RAM in 32-timing Mode**

## Digit data protect function

The FLD automatic display RAM is provided with a data protect function that disables the RAM area data to be rewritten as digit data.

This function can disable data from being written in optional bits in the RAM area corresponding to P1 to P3. A programming load can be reduced by protecting an area that requires no change after data such as digit data is written.

Write digit data beforehand; then set “1” in the corresponding bits. With this, the setting is completed.

The data protect area becomes the maximum RAM area of P1 and P3. For example, when bit 0 of P1 is protected in the 16-timing•ordinary mode, bits 0 of RAM addresses $0FD0_{16}$ to $0FDF_{16}$ can be protected. Likewise, in the 16-timing•gradation display mode, bits 0 of addresses $0FD0_{16}$ to $0FDF_{16}$ and $0F80_{16}$ to $0F8F_{16}$ can be protected. In the 32-timing mode, bits 0 of addresses $0FA0_{16}$ to $0FBF_{16}$ can be protected.

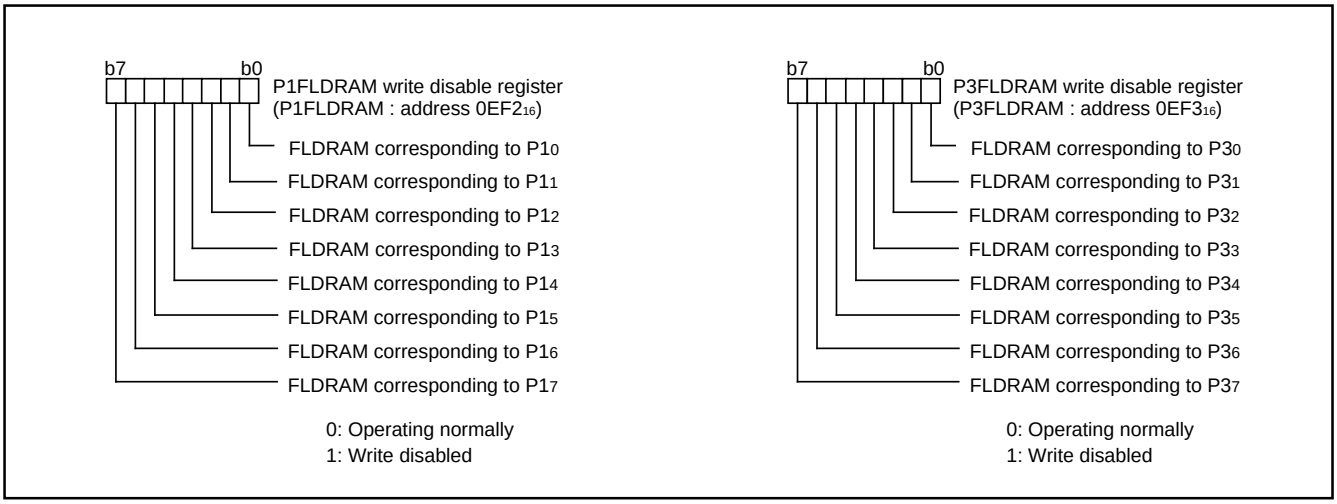



**Fig. 46 Structure of FLDRAM Write Disable Register**

## Setting method when using the grid scan type FLD

When using the grid scan type FLD, set “1” in the RAM area corresponding to the digit ports that output “1” at each timing. Set “0” in the RAM area corresponding to the other digit ports.

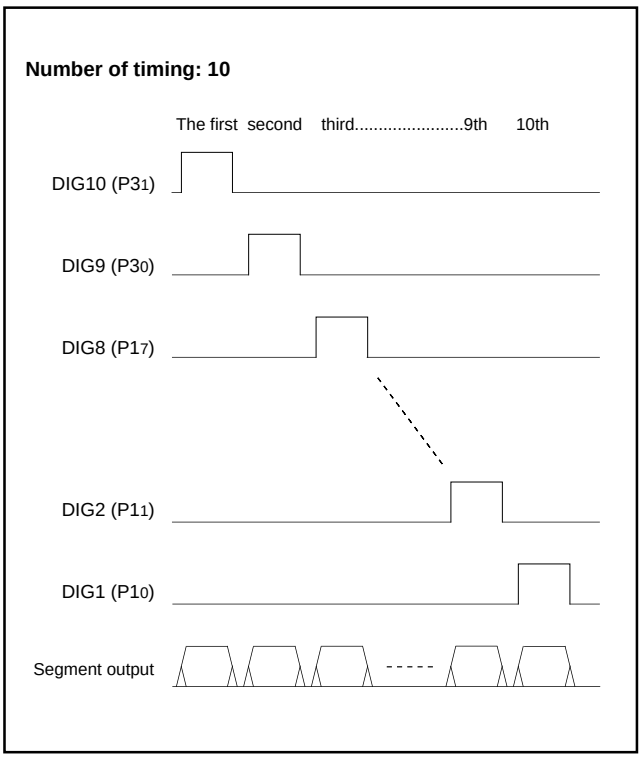



**Fig. 47 Example of Digit Timing Using Grid Scan Type**

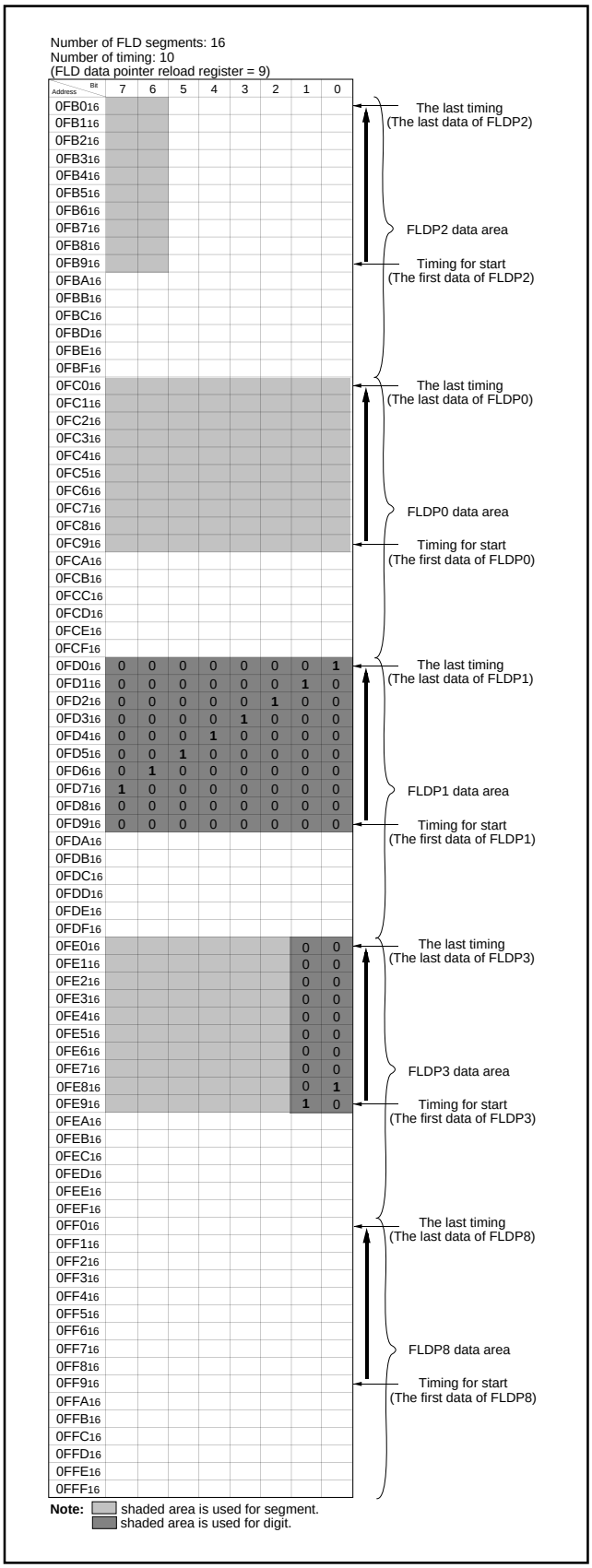



**Fig. 48 Example of Using the FLD Automatic Display RAM Using Grid Scan Type**

## Timing setting

Each timing is set by the FLDC mode register, Tdisp time set register, Toff1 time set register, and Toff2 time set register.

**•Tdisp time setting**

Set the Tdisp time by the Tdisp counter count source selection bit of the FLDC mode register and the Tdisp time set register. Supposing that the value of the Tdisp time set register is n, the Tdisp time is represented as Tdisp = (n+1) × t (t: count source synchronization).

When the Tdisp counter count source selection bit of the FLDC mode register is "0" and the value of the Tdisp time set register is 200 ($C8_{16}$), the Tdisp time is: Tdisp = (200+1) × 4 (at $X_{IN}$= 4 MHz) = 804 µs. When reading the Tdisp time set register, the value in the counter is read out.

**•Toff1 time setting**

Set the Toff1 time by the Toff1 time set register.

Supposing that the value of the Toff1 time set register is n1, the Toff1 time is represented as Toff1 = n1 × t.

When the Tdisp counter count source selection bit of the FLDC mode register is "0" and the value of the Toff1 time set register is 30 ($1E_{16}$), Toff1 = 30 × 4 (at $X_{IN}$ = 4 MHz) = 120 µs.

**•Toff2 time setting**

Set the Toff2 time by the Toff2 time set register.

Supposing that the value of the Toff2 time set register is n2, the Toff2 time is represented as Toff2 = n2 × t.

When the Tdisp counter count source selection bit of the FLDC mode register is "0" and the value of the Toff2 time set register is 180 ($B4_{16}$), Toff2 = 180 × 4 (at $X_{IN}$ = 4 MHz) = 720 µs.

This Toff2 time setting is valid only for FLD ports which are in the gradation display mode and whose gradation display control RAM value is "1."

## FLD automatic display start

To perform FLD automatic display, set the following registers.

•Port P0FLD/port switch register
•Port P2FLD/port switch register
•Port P8FLD/port switch register
•FLDC mode register
•Tdisp time set register
•Toff1 time set register
•Toff2 time set register
•FLD data pointer

FLD automatic display mode is selected by writing "1" to the bit 0 of the FLDC mode register (address $0EF4_{16}$), and the automatic display is started by writing "1" to bit 1. During FLD automatic display, bit 1 of the FLDC mode register (address $0EF4_{16}$) always keeps "1," and FLD automatic display can be interrupted by writing "0" to bit 1.

## Key-scan

When a key-scan is performed with the segment during key-scan blanking period Tscan, take the following sequence:

1. Write "0" to bit 0 of the FLDC mode register (address $0EF4_{16}$).
2. Set the port corresponding to the segment for key-scan to the output port.
3. Perform the key-scan.
4. After the key-scan is performed, write "1" to bit 0 of FLDC mode register (address $0EF4_{16}$).

## ■ Note

When performing a key-scan according to the above steps 1 to 4, take the following points into consideration.

1. Do not set "0" in bit 1 of the FLDC mode register (address $0EF4_{16}$).
2. Do not set "1" in the ports corresponding to digits.

## P8$_4$ to P8$_7$ FLD Output Reverse Function

$P8_4$ to $P8_7$ are provided with a function to reverse the polarity of the FLD output. This function is useful in adjusting the polarity when using an externally installed driver.

The output polarity can be reversed by setting bit 0 of the port P8 FLD output control register to "1."

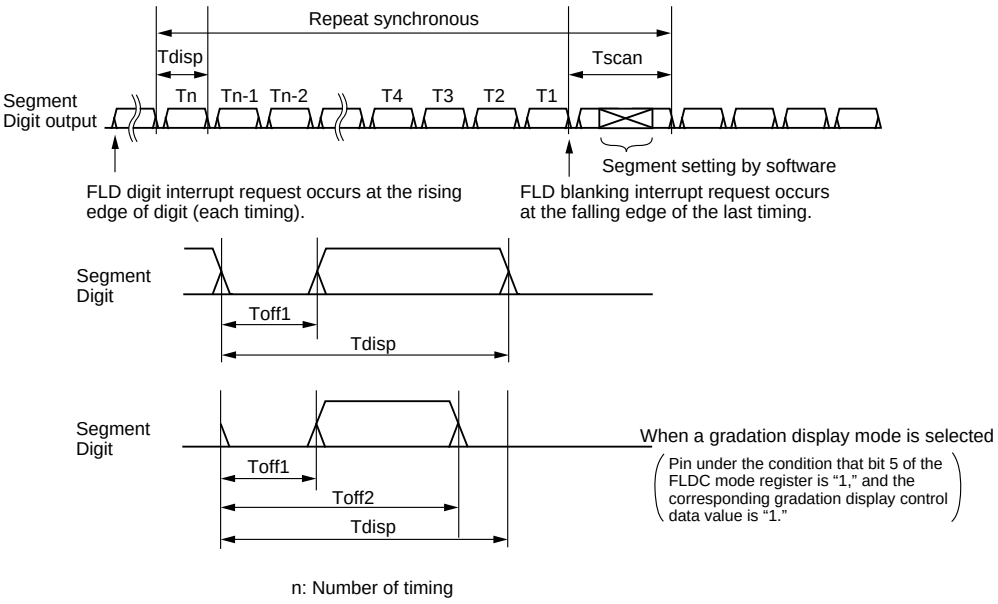



**Fig. 49 FLDC Timing**

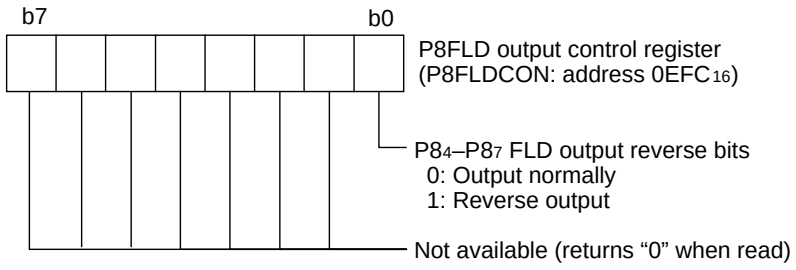



**Fig. 50 Structure of P8FLD Output Control Register**

## A-D Converter

The 38B5 group has a 10-bit A-D converter. The A-D converter performs successive approximation conversion.

## [A-D Conversion Register] AD

One of these registers is a high-order register, and the other is a low-order register. The high-order 8 bits of a conversion result is stored in the A-D conversion register (high-order) (address $0034_{16}$), and the low-order 2 bits of the same result are stored in bit 7 and bit 6 of the A-D conversion register (low-order) (address $0033_{16}$). During A-D conversion, do not read these registers.

## [A-D Control Register] ADCON

This register controls A-D converter. Bits 3 to 0 are analog input pin selection bits. Bit 4 is an AD conversion completion bit and "0" during A-D conversion. This bit is set to "1" upon completion of A-D conversion.

A-D conversion is started by setting "0" in this bit.

## [Comparison Voltage Generator]

The comparison voltage generator divides the voltage between $AV_{SS}$ and $V_{REF}$, and outputs the divided voltages.

## [Channel Selector]

The channel selector selects one of the input ports $P7_7/AN_7$–$P7_0/AN_0$, and $P6_5/S_{STB1}/AN_{11}$–$P6_2/\overline{S_{RDY1}}/AN_8$ and inputs it to the comparator.

When port $P6_4$ is selected as an analog input pin, an external interrupt function ($INT_4$) is invalid.

## [Comparator and Control Circuit]

The comparator and control circuit compares an analog input voltage with the comparison voltage and stores the result in the A-D conversion register. When an A-D conversion is completed, the control circuit sets the AD conversion completion bit and the AD conversion interrupt request bit to "1."

Note that the comparator is constructed linked to a capacitor, so set $f(X_{IN})$ to at least 250 kHz during A-D conversion. Use a CPU system clock dividing the main clock $X_{IN}$ as the internal system clock.

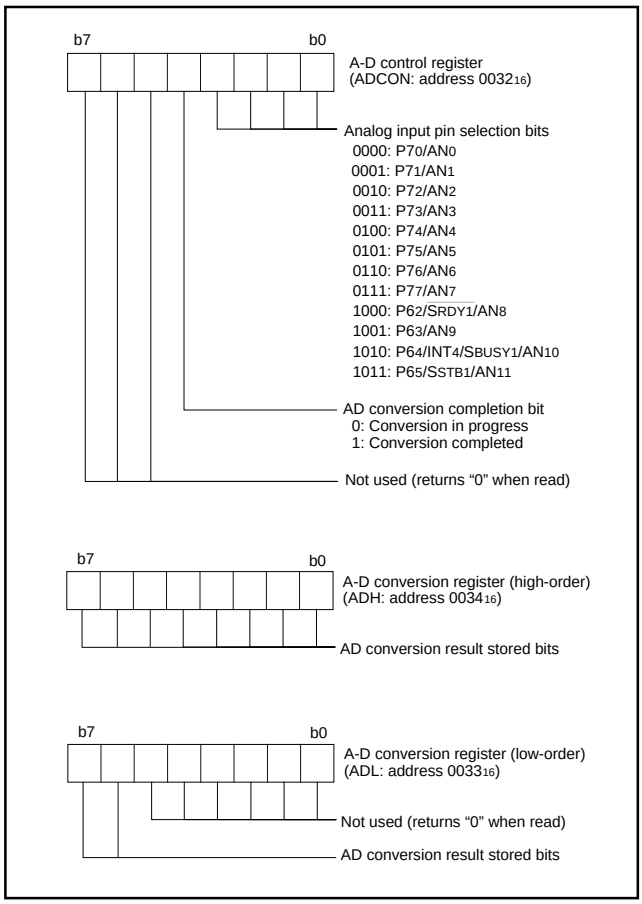



**Fig. 51 Structure of A-D Control Register**

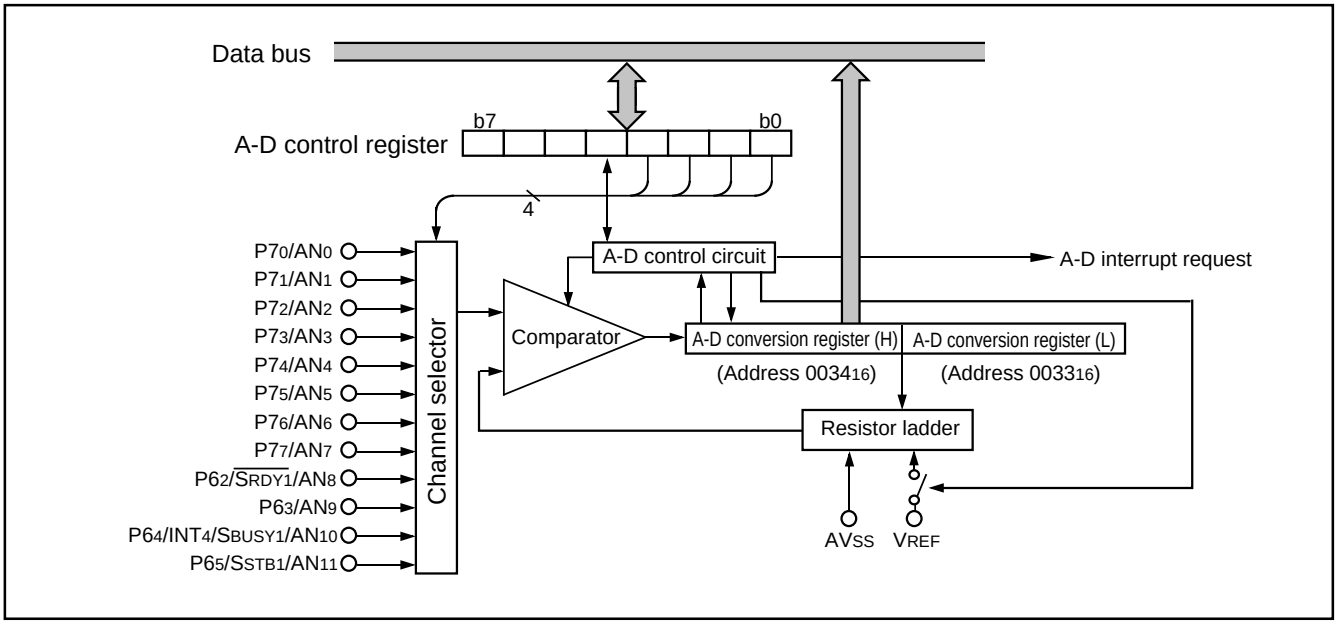



**Fig. 52 Block Diagram of A-D Converter**

## Pulse Width Modulation (PWM)

The 38B5 group has a PWM function with a 14-bit resolution. When the oscillation frequency $X_{IN}$ is 4 MHz, the minimum resolution bit width is 250 ns and the cycle period is 4096 µs. The PWM timing generator supplies a PWM control signal based on a signal that is the frequency of the $X_{IN}$ clock.

The explanation in the rest of this data sheet assumes $X_{IN}$ = 4 MHz.

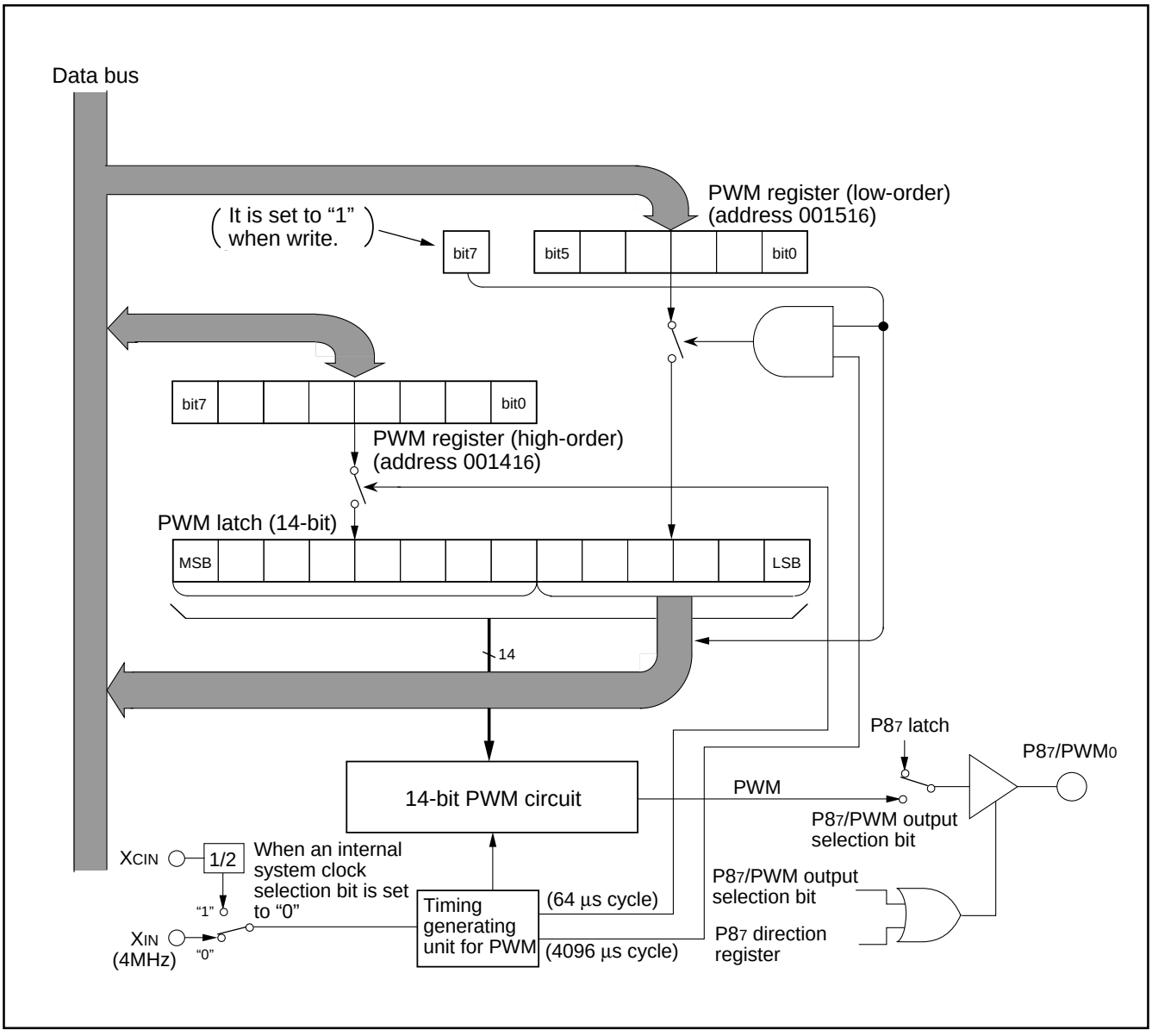



**Fig. 53 PWM Block Diagram**

**1. Data setup**

The PWM output pin also function as port $P8_7$. Set port $P8_7$ to be the PWM output pin by setting bit 0 of the PWM control register (address $0026_{16}$) to "1." The high-order 8 bits of output data are set in the high-order PWM register PWMH (address $0014_{16}$) and the low-order 6 bits are set in the low-order PWM register PWML (address $0015_{16}$).

**2. PWM operation**

The timing of the 14-bit PWM function is shown in Figure 56.

The 14-bit PWM data is divided into the low-order 6 bits and the high-order 8 bits in the PWM latch.

The high-order 8 bits of data determine how long an "H" level signal is output during each sub-period. There are 64 sub-periods in each period, and each sub-period t is 256 × $\tau$ (= 64 µs) long. The signal's "H" has a length equal to N times $\tau$, and its minimum resolution = 250 ns.

The last bit of the sub-period becomes the ADD bit which is specified either "H" or "L," by the contents of PWML. As shown in Table 8, the ADD bit is decided either "H" or "L."

That is, only in the sub-period tm shown in Table 8 in the PWM cycle period T = 64t, the "H" duration is lengthened during the minimum resolution width $\tau$ period in comparison with the other period.

For example, if the high-order eight bits of the 14-bit data are "$03_{16}$" and the low-order six bits are "$05_{16}$," the length of the "H" level output in sub-periods $t_8$, $t_{24}$, $t_{32}$, $t_{40}$ and $t_{56}$ is 4 $\tau$, and its length 3 $\tau$ in all other sub-periods.

Time at the "H" level of each sub-period almost becomes equal because the time becomes length set in the high-order 8 bits or becomes the value plus $\tau$, and this sub-period t (= 64 µs, approximate 15.6 kHz) becomes cycle period approximately.

**3. Transfer from register to latch**

Data written to the PWML register is transferred to the PWM latch once in each PWM period (every 4096 µs), and data written to the PWMH register is transferred to the PWM latch once in each sub-period (every 64 µs). When the PWML register is read, the contents of the latch are read. However, bit 7 of the PWML register indicates whether the transfer to the PWM latch is completed; the transfer is completed when bit 7 is "0."

**Table 8 Relationship between Low-order 6-bit Data and Setting Period of ADD Bit**

| Low-order 6-bit data (LSB) | Sub-periods tm lengthened (m = 0 to 63) |
|---|---|
| 0 0 0 0 0 0 | None |
| 0 0 0 0 0 1 | m = 32 |
| 0 0 0 0 1 0 | m = 16, 48 |
| 0 0 0 1 0 0 | m = 8, 24, 40, 56 |
| 0 0 1 0 0 0 | m = 4, 12, 20, 28, 36, 44, 52, 60 |
| 0 1 0 0 0 0 | m = 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62 |
| 1 0 0 0 0 0 | m = 1, 3, 5, 7, ....., 57, 59, 61, 63 |

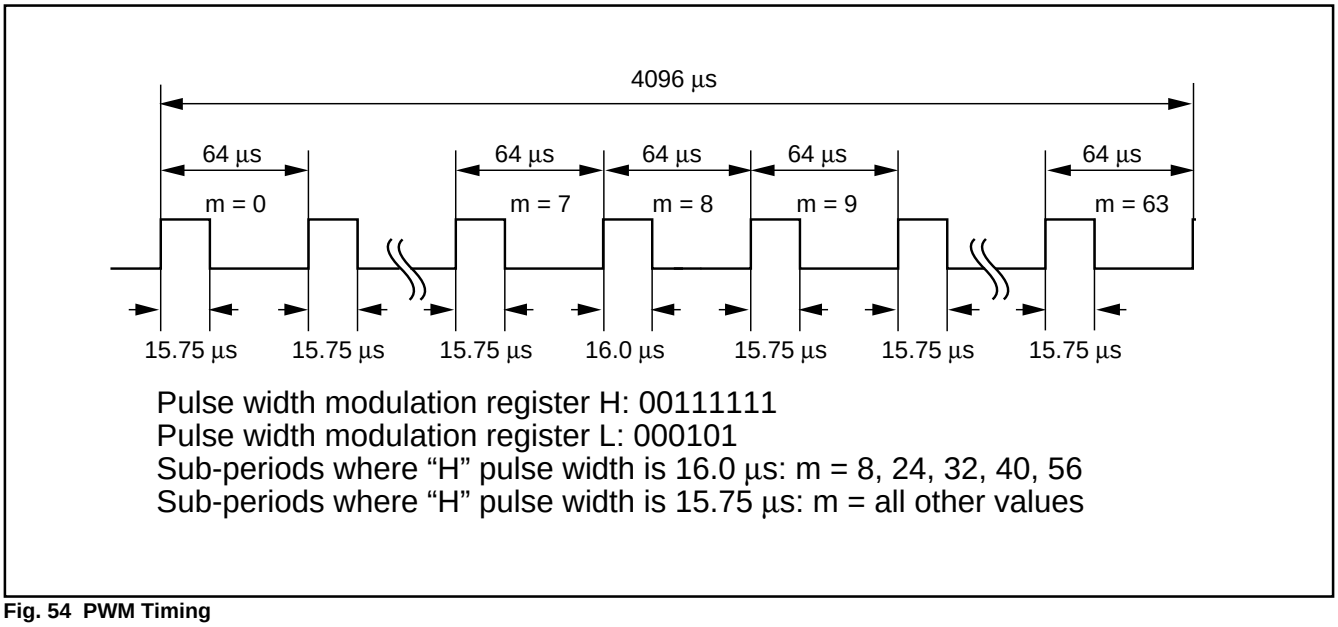



**Fig. 54 PWM Timing**

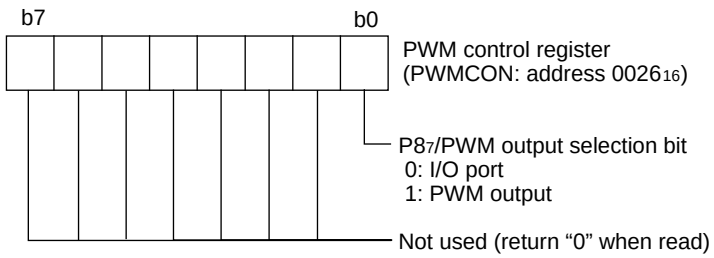



**Fig. 55 Structure of PWM Control Register**

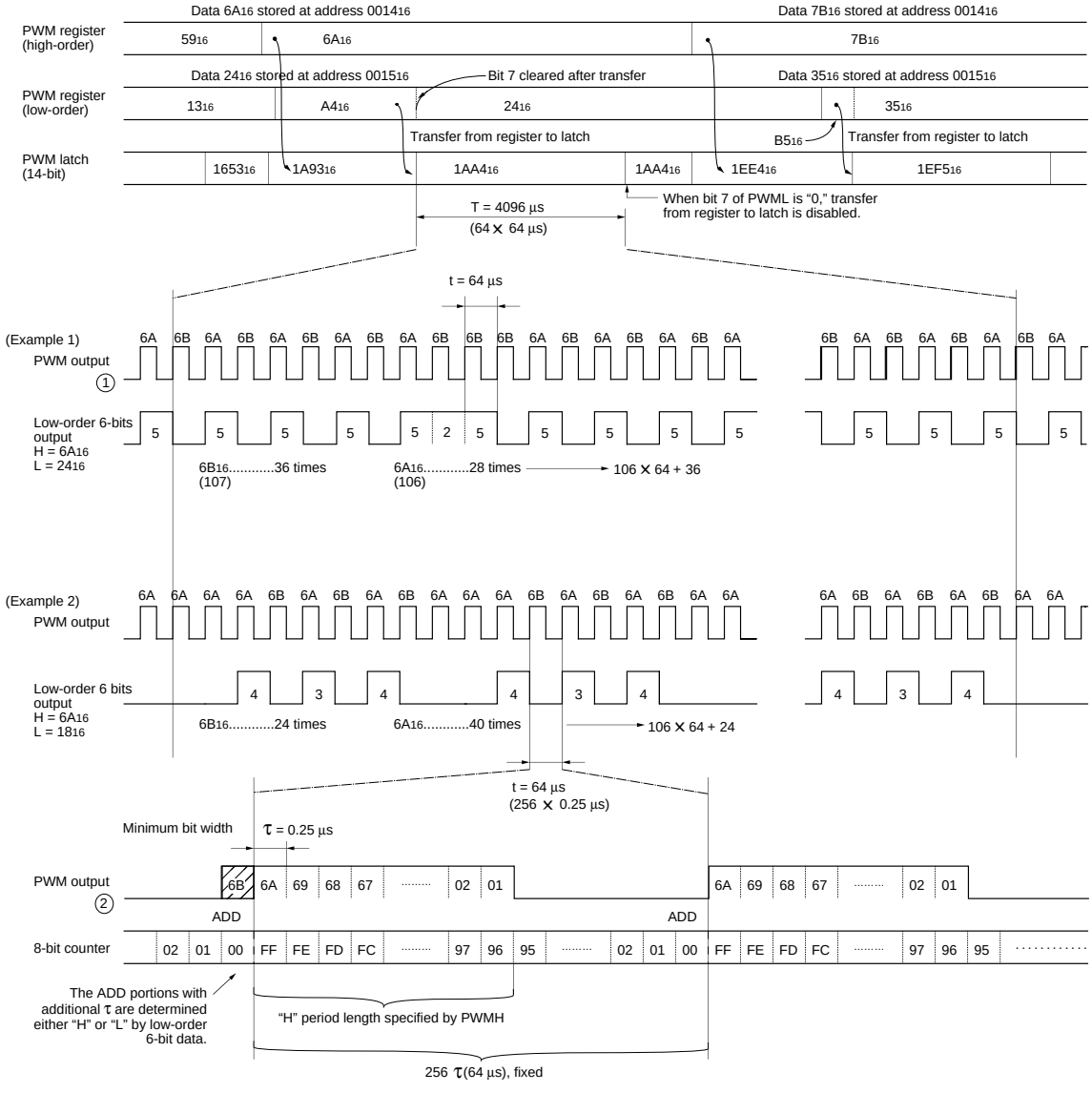



**Fig. 56 14-bit PWM Timing**

## Interrupt Interval Determination Function

The 38B5 group has an interrupt interval determination circuit.
This interrupt interval determination circuit has an 8-bit binary up counter. Using this counter, it determines a duration of time from the rising edge (falling edge) of an input signal pulse on the $P4_7/INT_2$ pin to the rising edge (falling edge) of the signal pulse that is input next.
How to determine the interrupt interval is described below.

1. Enable the $INT_2$ interrupt by setting bit 2 of the interrupt control register 1 (address $003E_{16}$). Select the rising interval or falling interval by setting bit 2 of the interrupt edge selection register (address $003A_{16}$).
2. Set bit 0 of the interrupt interval determination control register (address $0031_{16}$) to "1" (interrupt interval determination operating).
3. Select the sampling clock of 8-bit binary up counter by setting bit 1 of the interrupt interval determination control register. When writing "0," $f(X_{IN})/128$ is selected (the sampling interval: 32 µs at $f(X_{IN})$ = 4.19 MHz); when "1," $f(X_{IN})/256$ is selected (the sampling interval: 64 µs at $f(X_{IN})$ = 4.19 MHz).
4. When the signal of polarity which is set on the $INT_2$ pin (rising or falling edge) is input, the 8-bit binary up counter starts counting up of the selected counter sampling clock.
5. When the signal of polarity above 4 is input again, the value of the 8-bit binary up counter is transferred to the interrupt interval determination register (address $0030_{16}$), and the remote control interrupt request occurs. Immediately after that, the 8-bit binary up counter continues to count up again from "$00_{16}$."
6. When count value reaches "$FF_{16}$," the 8-bit binary up counter stops counting up. Then, simultaneously when the next counter sampling clock is input, the counter sets value "$FF_{16}$" to the interrupt interval determination register to generate the counter overflow interrupt request.

**Noise filter**

The $P4_7/INT_2$ pin builds in the noise filter.
The noise filter operation is described below.

1. Select the sampling clock of the input signal with bits 2 and 3 of the interrupt interval determination control register. When not using the noise filter, set "00."
2. The $P4_7/INT_2$ input signal is sampled in synchronization with the selected clock. When sampling the same level signal in a series of three sampling, the signal is recognized as the interrupt signal, and the interrupt request occurs.
   When setting bit 4 of interrupt interval determination control register to "1," the interrupt request can occur at both rising and falling edges.
   When using the noise filter, set the minimum pulse width of the $INT_2$ input signal to 3 cycles or more of the sample clock.

**Note:** In the low-speed mode ($CM_7$ = 1), the interrupt interval determination function cannot operate.

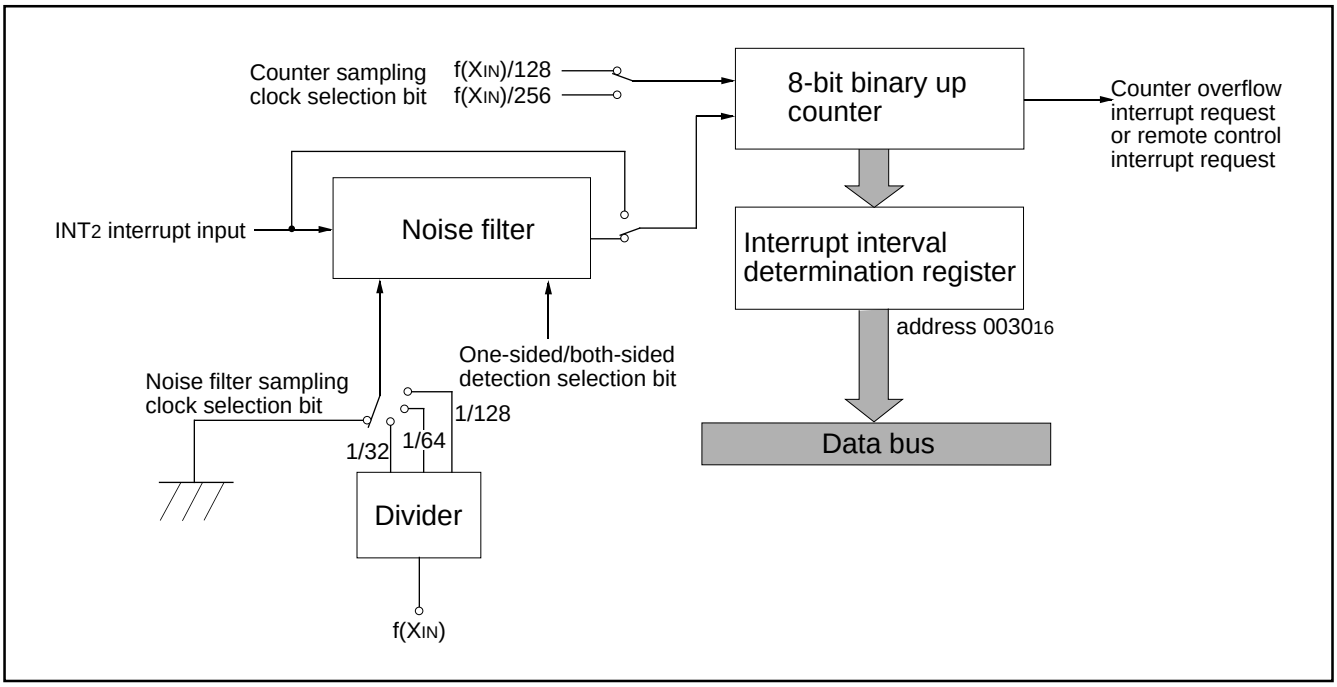



**Fig. 57 Interrupt Interval Determination Circuit Block Diagram**

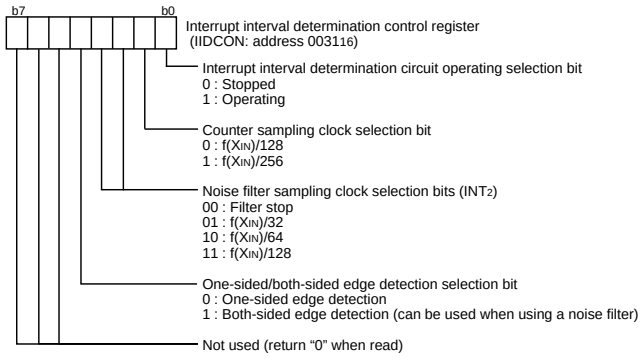



**Fig. 58 Structure of Interrupt Interval Determination Control Register**

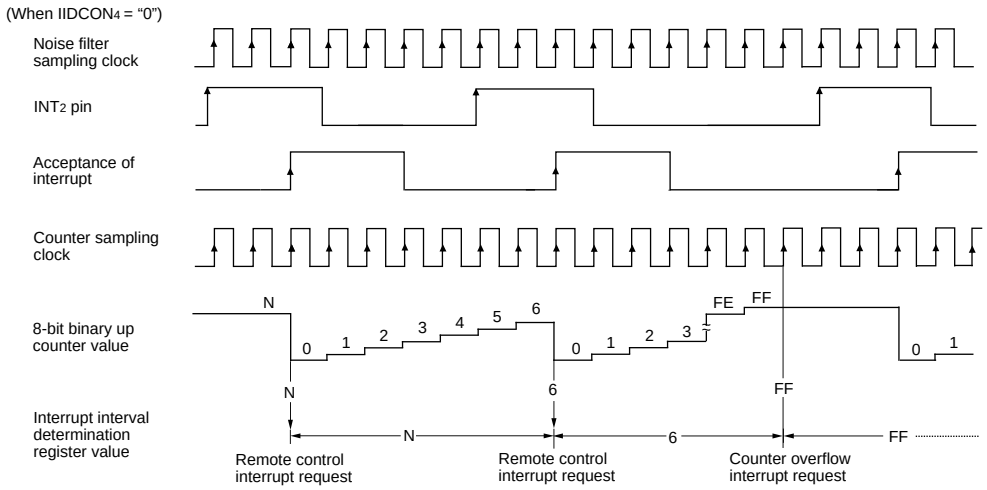



**Fig. 59 Interrupt Interval Determination Operation Example (at rising edge active)**

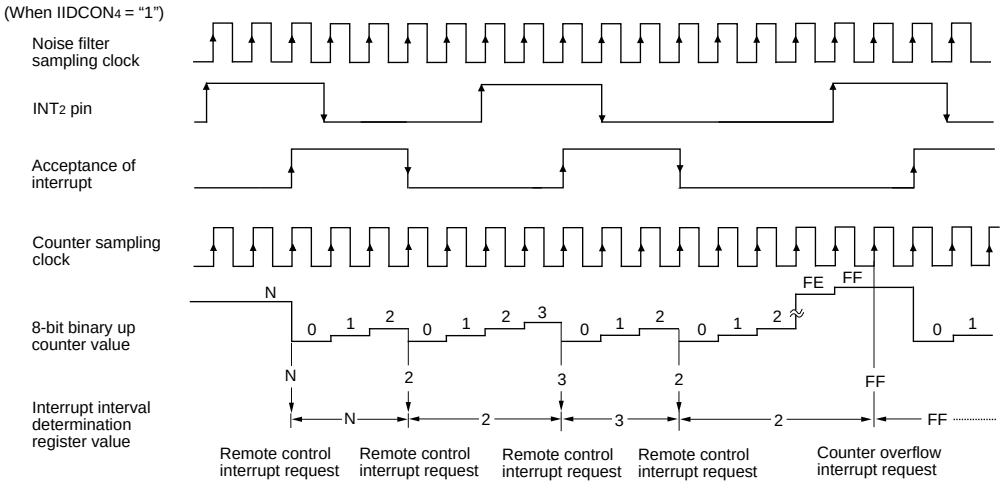



**Fig. 60 Interrupt Interval Determination Operation Example (at both-sided edge active)**

## Watchdog Timer

The watchdog timer gives a mean of returning to the reset status when a program cannot run on a normal loop (for example, because of a software runaway). The watchdog timer consists of an 8-bit watchdog timer L and a 12-bit watchdog timer H.

**●Standard operation of watchdog timer**

When any data is not written into the watchdog timer control register (address 002B16) after resetting, the watchdog timer is in the stop state. The watchdog timer starts to count down by writing an optional value into the watchdog timer control register (address 002B16) and an internal reset occurs at an underflow of the watchdog timer H. Accordingly, programming is usually performed so that writing to the watchdog timer control register (address 002B16) may be started before an underflow. When the watchdog timer control register (address 002B16) is read, the values of the 6 high-order bits of the watchdog timer H, STP instruction disable bit, and watchdog timer H count source selection bit are read.

**(1) Initial value of watchdog timer**

At reset or writing to the watchdog timer control register (address 002B16), a watchdog timer H is set to "FFF16" and a watchdog timer L to "FF16."

**(2) Watchdog timer H count source selection bit operation**

Bit 7 of the watchdog timer control register (address 002B16) permits selecting a watchdog timer H count source. When this bit is set to "0," the underflow signal of watchdog timer L becomes the count source. The detection time is set then to f(XIN) = 2.1 s at 4 MHz frequency and f(XCIN) = 512 s at 32 kHz frequency.
When this bit is set to "1," the count source becomes the signal divided by 8 for f(XIN) (or divided by 16 for f(XCIN)). The detection time in this case is set to f(XIN) = 8.2 ms at 4 MHz frequency and f(XCIN) = 2 s at 32 KHz frequency. This bit is cleared to "0" after resetting.

**(3) Operation of STP instruction disable bit**

Bit 6 of the watchdog timer control register (address 002B16) permits disabling the STP instruction when the watchdog timer is in operation.
When this bit is "0," the STP instruction is enabled.
When this bit is "1," the STP instruction is disabled.
Once the STP instruction is executed, an internal resetting occurs. When this bit is set to "1," it cannot be rewritten to "0" by program. This bit is cleared to "0" after resetting.

## ■ Note

When releasing the stop mode, the watchdog timer performs its count operation even in the stop release waiting time. Be careful not to cause the watchdog timer H to underflow in the stop release waiting time, for example, by writing data in the watchdog timer control register (address 002B16) before executing the STP instruction.

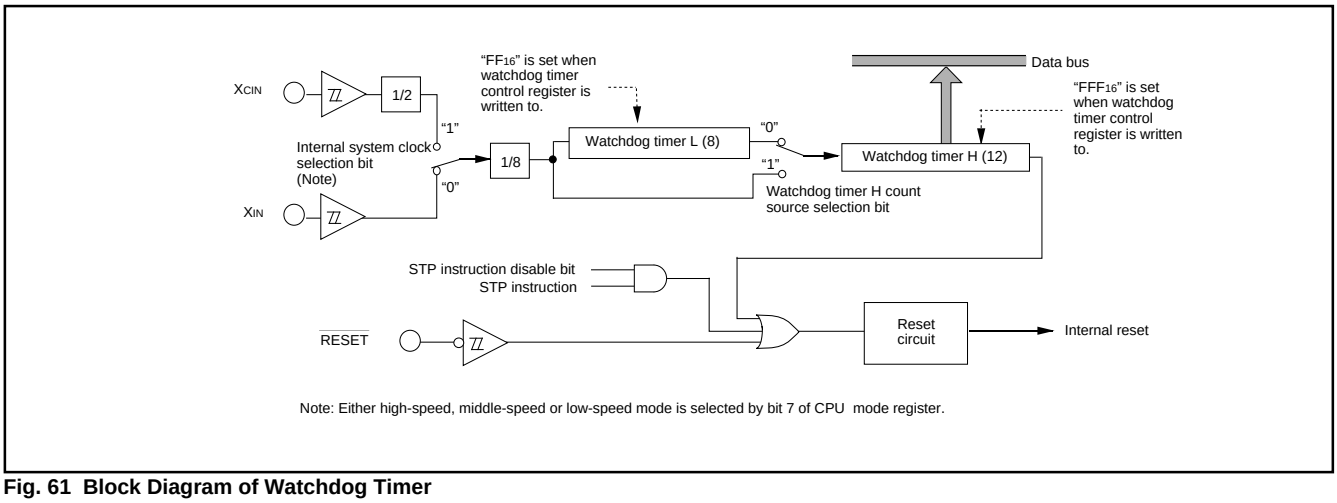



**Fig. 61 Block Diagram of Watchdog Timer**

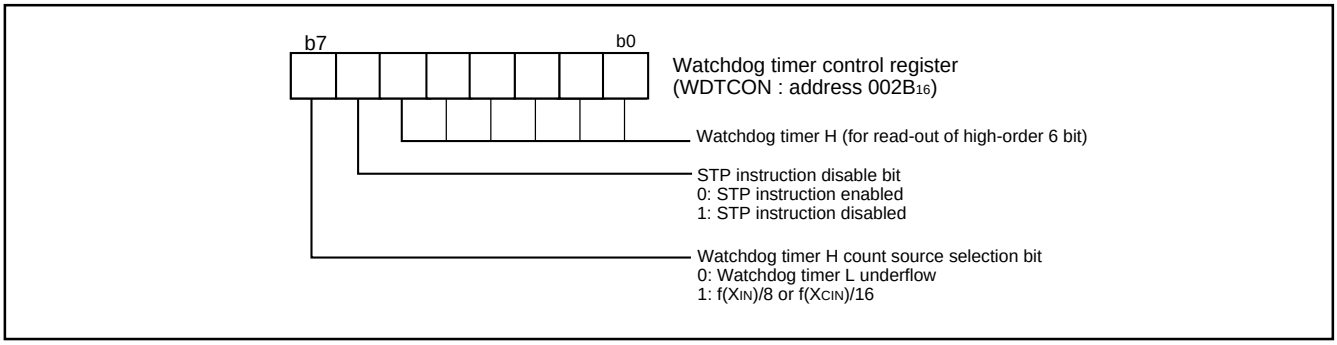



**Fig. 62 Structure of Watchdog Timer Control Register**

## Buzzer Output Circuit

The 38B5 group has a buzzer output circuit. One of 1 kHz, 2 kHz and 4 kHz (at $X_{IN}$ = 4.19 MHz) frequencies can be selected by the buzzer output control register (address $0EFD_{16}$). Either $P4_3/BUZ0_1$ or $P2_0/BUZ0_2/FLD_0$ can be selected as a buzzer output port by the output port selection bits (b2 and b3 of address $0EFD_{16}$).
The buzzer output is controlled by the buzzer output ON/OFF bit (b4).

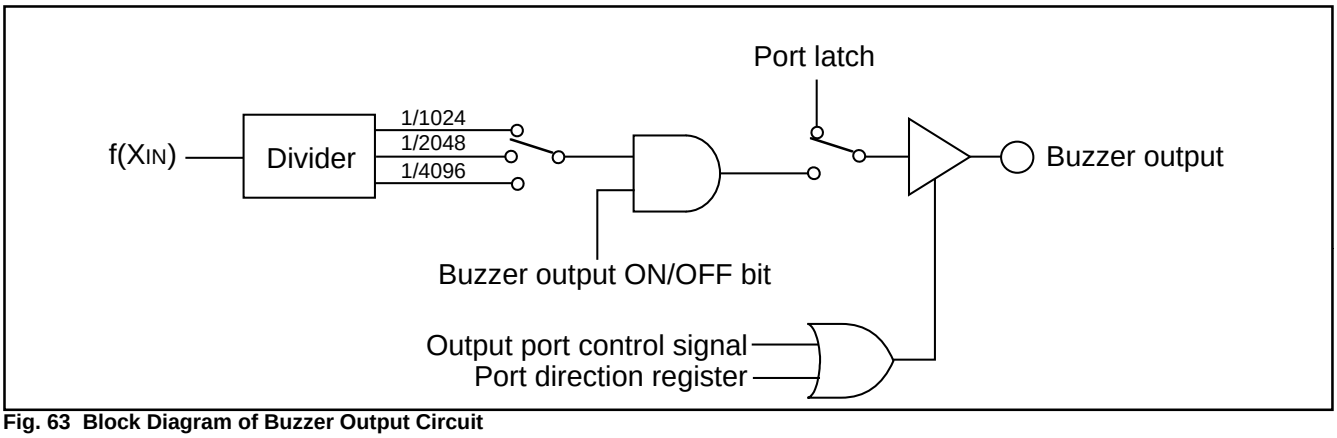



**Fig. 63 Block Diagram of Buzzer Output Circuit**

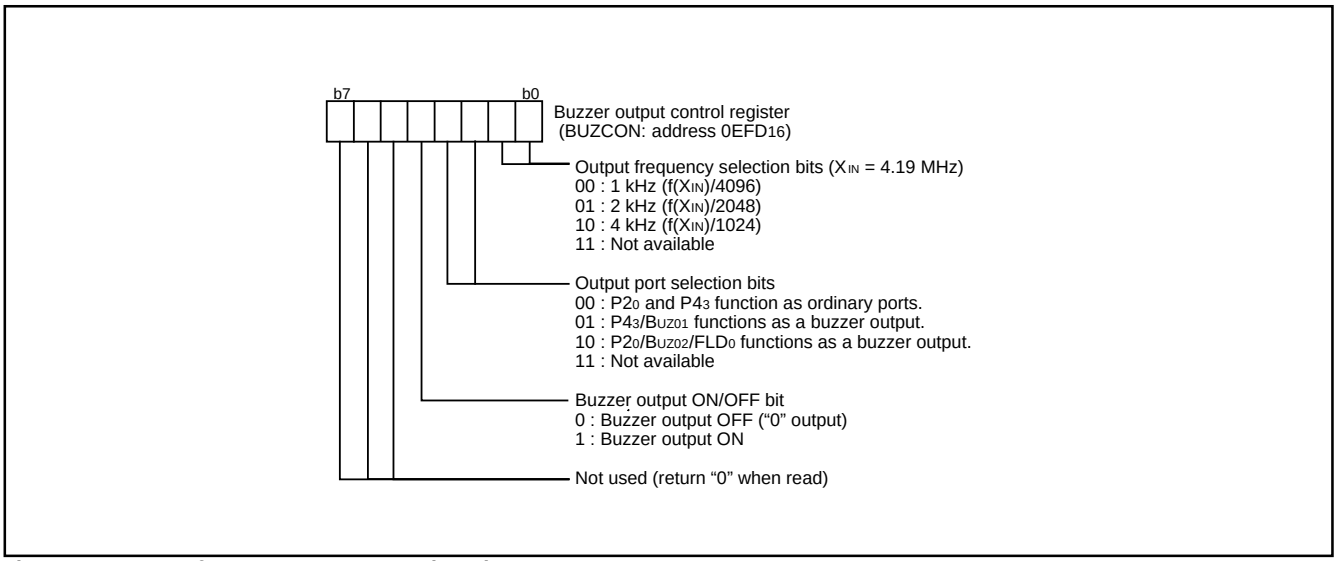



**Fig. 64 Structure of Buzzer Output Control Register**

## Reset Circuit

To reset the microcomputer, $\overline{\text{RESET}}$ pin should be held at an “L” level for 2 µs or more. Then the $\overline{\text{RESET}}$ pin is returned to an “H” level (the power source voltage should be between 2.7 V and 5.5 V, and the oscillation should be stable), reset is released. After the reset is completed, the program starts from the address contained in address $\text{FFFD}_{16}$ (high-order byte) and address $\text{FFFC}_{16}$ (low-order byte). Make sure that the reset input voltage is less than 0.5 V for $V_{CC}$ of 2.7 V (switching to the high-speed mode, a power source voltage must be between 4.0 V and 5.5 V).

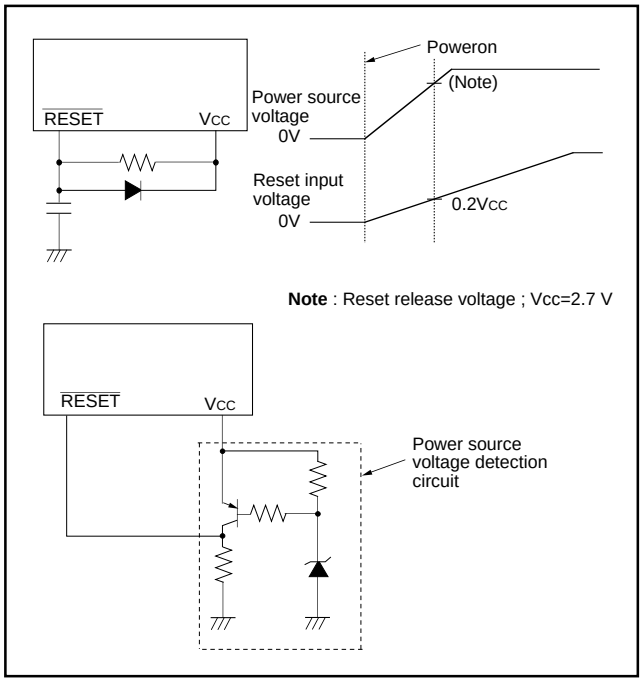
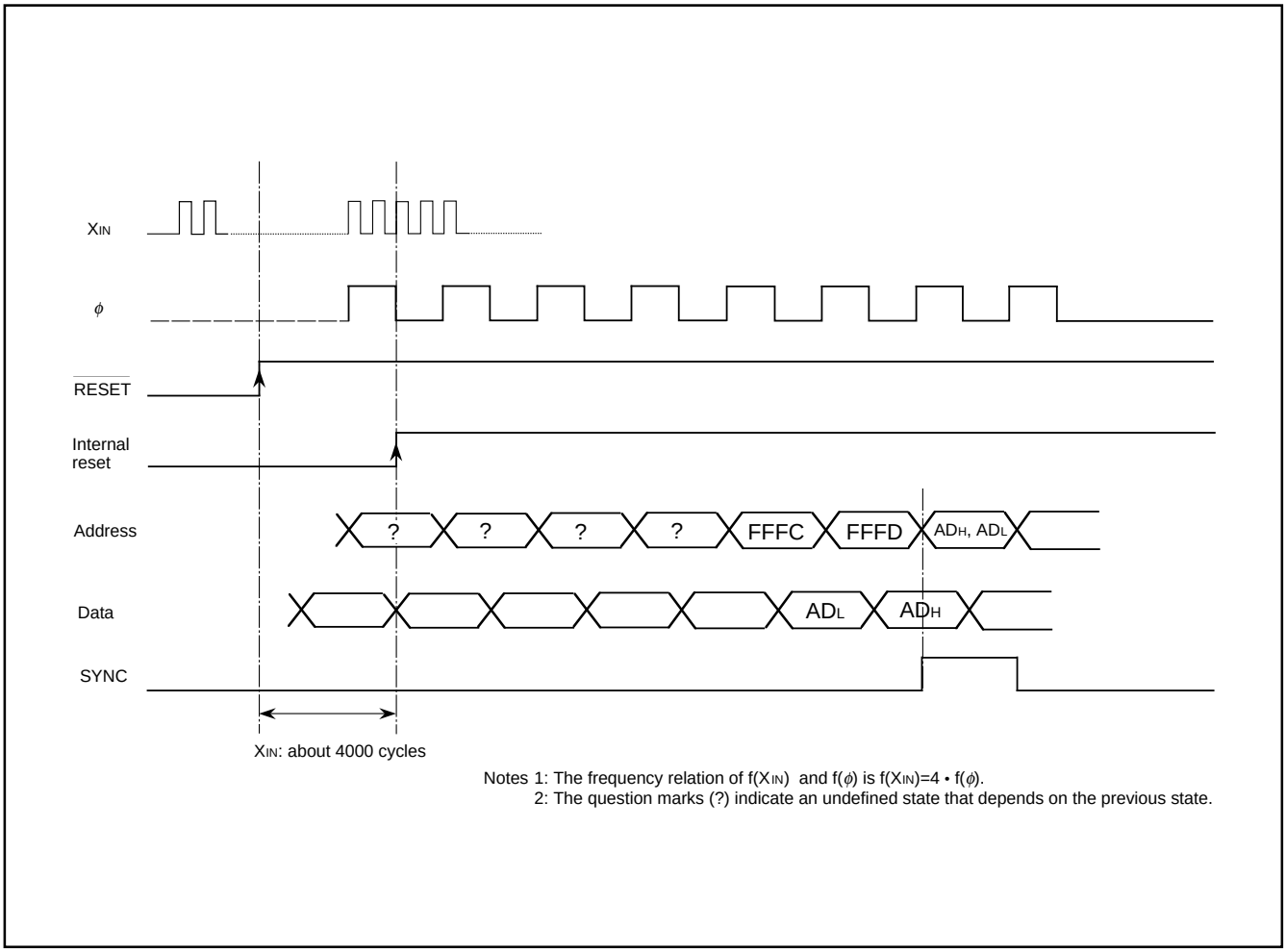



**Fig. 65 Reset Circuit Example**




Notes 1: The frequency relation of f($X_{IN}$) and f($\phi$) is f($X_{IN}$)=4 • f($\phi$).
2: The question marks (?) indicate an undefined state that depends on the previous state.

**Fig. 66 Reset Sequence**

| | Address | Register contents |
|---|---|---|
| (1) Port P0 | $0000_{16}$ | $00_{16}$ |
| (2) Port P0 direction register | $0001_{16}$ | $00_{16}$ |
| (3) Port P1 | $0002_{16}$ | $00_{16}$ |
| (4) Port P2 | $0004_{16}$ | $00_{16}$ |
| (5) Port P2 direction register | $0005_{16}$ | $00_{16}$ |
| (6) Port P3 | $0006_{16}$ | $00_{16}$ |
| (7) Port P4 | $0008_{16}$ | $00_{16}$ |
| (8) Port P4 direction register | $0009_{16}$ | $00_{16}$ |
| (9) Port P5 | $000A_{16}$ | $00_{16}$ |
| (10) Port P5 direction register | $000B_{16}$ | $00_{16}$ |
| (11) Port P6 | $000C_{16}$ | $00_{16}$ |
| (12) Port P6 direction register | $000D_{16}$ | $00_{16}$ |
| (13) Port P7 | $000E_{16}$ | $00_{16}$ |
| (14) Port P7 direction register | $000F_{16}$ | $00_{16}$ |
| (15) Port P8 | $0010_{16}$ | $00_{16}$ |
| (16) Port P8 direction register | $0011_{16}$ | $00_{16}$ |
| (17) Port P9 | $0012_{16}$ | $00_{16}$ |
| (18) Port P9 direction register | $0013_{16}$ | $00_{16}$ |
| (19) UART control register | $0017_{16}$ | $80_{16}$ |
| (20) Serial I/O1 control register 1 | $0019_{16}$ | $00_{16}$ |
| (21) Serial I/O1 control register 2 | $001A_{16}$ | $00_{16}$ |
| (22) Serial I/O1 control register 3 | $001C_{16}$ | $00_{16}$ |
| (23) Serial I/O2 control register | $001D_{16}$ | $00_{16}$ |
| (24) Serial I/O2 status register | $001E_{16}$ | $80_{16}$ |
| (25) Timer 1 | $0020_{16}$ | $FF_{16}$ |
| (26) Timer 2 | $0021_{16}$ | $01_{16}$ |
| (27) Timer 3 | $0022_{16}$ | $FF_{16}$ |
| (28) Timer 4 | $0023_{16}$ | $FF_{16}$ |
| (29) Timer 5 | $0024_{16}$ | $FF_{16}$ |
| (30) Timer 6 | $0025_{16}$ | $FF_{16}$ |
| (31) PWM control register | $0026_{16}$ | $00_{16}$ |
| (32) Timer 12 mode register | $0028_{16}$ | $00_{16}$ |

| | Address | Register contents |
|---|---|---|
| (33) Timer 34 mode register | $0029_{16}$ | $00_{16}$ |
| (34) Timer 56 mode register | $002A_{16}$ | $00_{16}$ |
| (35) Watchdog timer control register | $002B_{16}$ | $3F_{16}$ |
| (36) Timer X (low-order) | $002C_{16}$ | $FF_{16}$ |
| (37) Timer X (high-order) | $002D_{16}$ | $FF_{16}$ |
| (38) Timer X mode register 1 | $002E_{16}$ | $00_{16}$ |
| (39) Timer X mode register 2 | $002F_{16}$ | $00_{16}$ |
| (40) Interrupt interval determination control register | $0031_{16}$ | $00_{16}$ |
| (41) A-D control register | $0032_{16}$ | $10_{16}$ |
| (42) Interrupt source switch register | $0039_{16}$ | $00_{16}$ |
| (43) Interrupt edge selection register | $003A_{16}$ | $00_{16}$ |
| (44) CPU mode register | $003B_{16}$ | 0 1 0 0 1 0 0 0 |
| (45) Interrupt request register 1 | $003C_{16}$ | $00_{16}$ |
| (46) Interrupt request register 2 | $003D_{16}$ | $00_{16}$ |
| (47) Interrupt control register 1 | $003E_{16}$ | $00_{16}$ |
| (48) Interrupt control register 2 | $003F_{16}$ | $00_{16}$ |
| (49) Pull-up control register 1 | $0EF0_{16}$ | $00_{16}$ |
| (50) Pull-up control register 2 | $0EF1_{16}$ | $00_{16}$ |
| (51) P1FLDRAM write disable register | $0EF2_{16}$ | $00_{16}$ |
| (52) P3FLDRAM write disable register | $0EF3_{16}$ | $00_{16}$ |
| (53) FLDC mode register | $0EF4_{16}$ | $00_{16}$ |
| (54) Tdisp time set register | $0EF5_{16}$ | $00_{16}$ |
| (55) Toff1 time set register | $0EF6_{16}$ | $FF_{16}$ |
| (56) Toff2 time set register | $0EF7_{16}$ | $FF_{16}$ |
| (57) Port P0FLD/port switch register | $0EF9_{16}$ | $00_{16}$ |
| (58) Port P2FLD/port switch register | $0EFA_{16}$ | $00_{16}$ |
| (59) Port P8FLD/port switch register | $0EFB_{16}$ | $00_{16}$ |
| (60) Port P8FLD output control register | $0EFC_{16}$ | $00_{16}$ |
| (61) Buzzer output control register | $0EFD_{16}$ | $00_{16}$ |
| (62) Processor status register | (PS) | X X X X X 1 X X |
| (63) Program counter | ($PC_H$) | $FFFD_{16}$ contents |
| | ($PC_L$) | $FFFC_{16}$ contents |

X: Not fixed
Since the initial values for other than above mentioned registers and RAM contents are indefinite at reset, they must be set.

**Fig. 67 Internal Status at Reset**

## Clock Generating Circuit

The 38B5 group has two built-in oscillation circuits. An oscillation circuit can be formed by connecting a resonator between XIN and XOUT (XCIN and XCOUT). Use the circuit constants in accordance with the resonator manufacturer's recommended values. No external resistor is needed between XIN and XOUT since a feedback resistor exists on-chip. However, an external feedback resistor is needed between XCIN and XCOUT.

Immediately after power on, only the XIN oscillation circuit starts oscillating, and XCIN and XCOUT pins function as I/O ports.

## ●Frequency control

**(1) Middle-speed mode**

The internal system clock is the frequency of XIN divided by 4. After reset, this mode is selected.

**(2) High-speed mode**

The internal system clock is the frequency of XIN.

**(3) Low-speed mode**

The internal system clock is the frequency of XCIN divided by 2.

**■Note**

If you switch the mode between middle/high-speed and low-speed, stabilize both XIN and XCIN oscillations. The sufficient time is required for the sub clock to stabilize, especially immediately after power on and at returning from stop mode. When switching the mode between middle/high-speed and low-speed, set the frequency on condition that f(XIN) > 3f(XCIN).

**(4) Low power consumption mode**

The low power consumption operation can be realized by stopping the main clock XIN in low-speed mode. To stop the main clock, set bit 5 of the CPU mode register to "1." When the main clock XIN is restarted (by setting the main clock stop bit to "0"), set enough time for oscillation to stabilize.

By clearing furthermore the XCOUT drivability selection bit (b3) of CPU mode register to "0," low power consumption operation of less than 200 µA (f(XCIN) = 32 kHz) can be realized by reducing the drivability between XCIN and XCOUT. At reset or during STP instruction execution this bit is set to "1" and a strong drivability that has an easy oscillation start is set.

## ●Oscillation control

**(1) Stop mode**

If the STP instruction is executed, the internal system clock stops at an "H" level, and XIN and XCIN oscillators stop. Timer 1 is set to "FF16" and timer 2 is set to "0116."

Either XIN divided by 8 or XCIN divided by 16 is input to timer 1 as count source, and the output of timer 1 is connected to timer 2. The bits of the timer 12 mode register are cleared to "0." Set the interrupt enable bits of the timer 1 and timer 2 to disabled ("0") before executing the STP instruction. Oscillator restarts when an external interrupt is received, but the internal system clock is not supplied to the CPU until timer 1 underflows. This allows time for the clock circuit oscillation to stabilize.

**(2) Wait mode**

If the WIT instruction is executed, the internal system clock stops at an "H" level. The states of XIN and XCIN are the same as the state before executing the WIT instruction. The internal system clock restarts at reset or when an interrupt is received. Since the oscillator does not stop, normal operation can be started immediately after the clock is restarted.

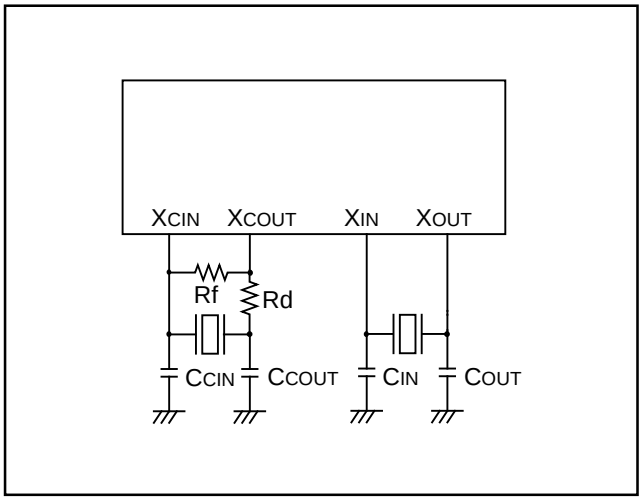



**Fig. 68 Ceramic Resonator Circuit**

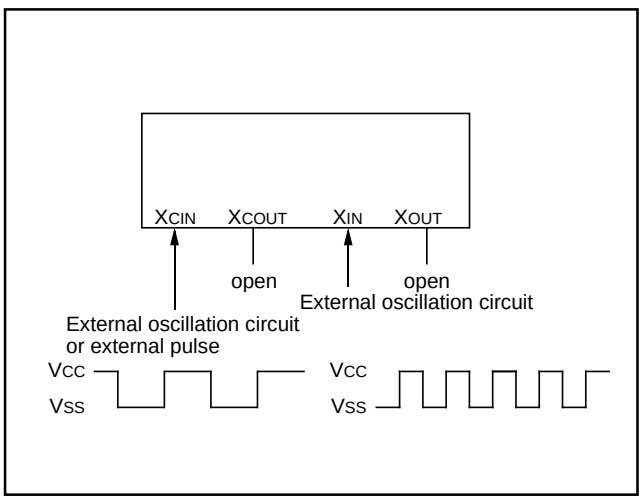
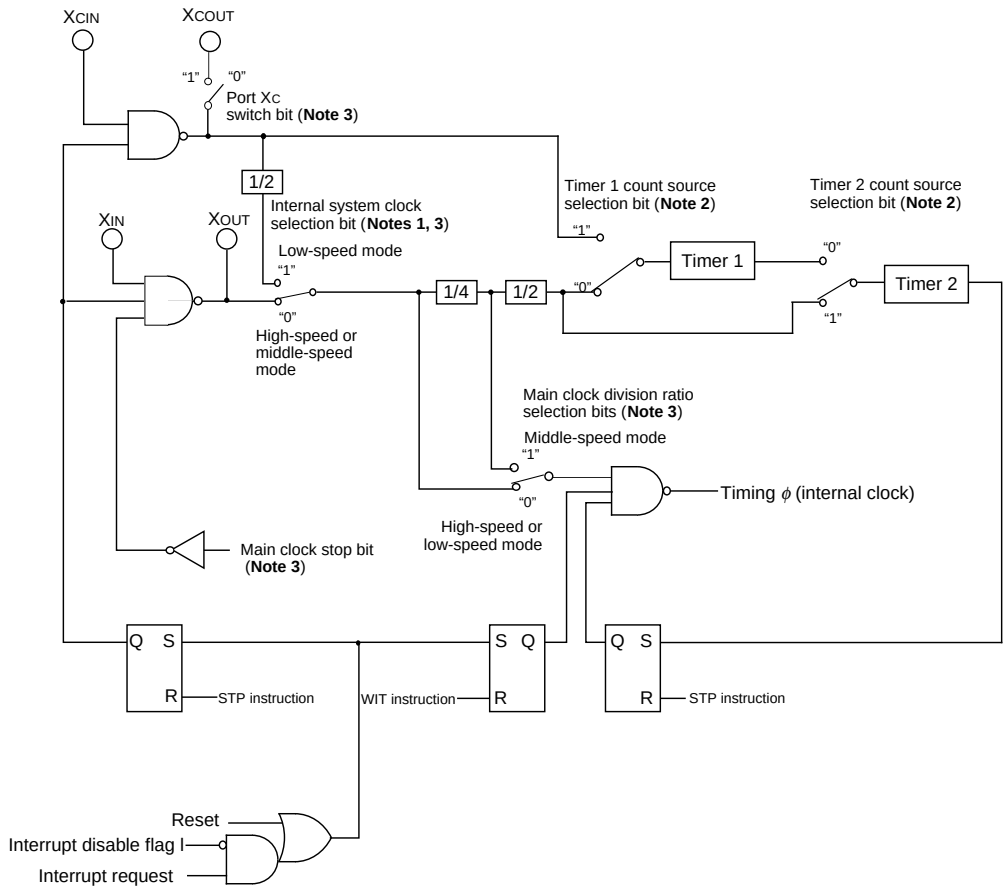
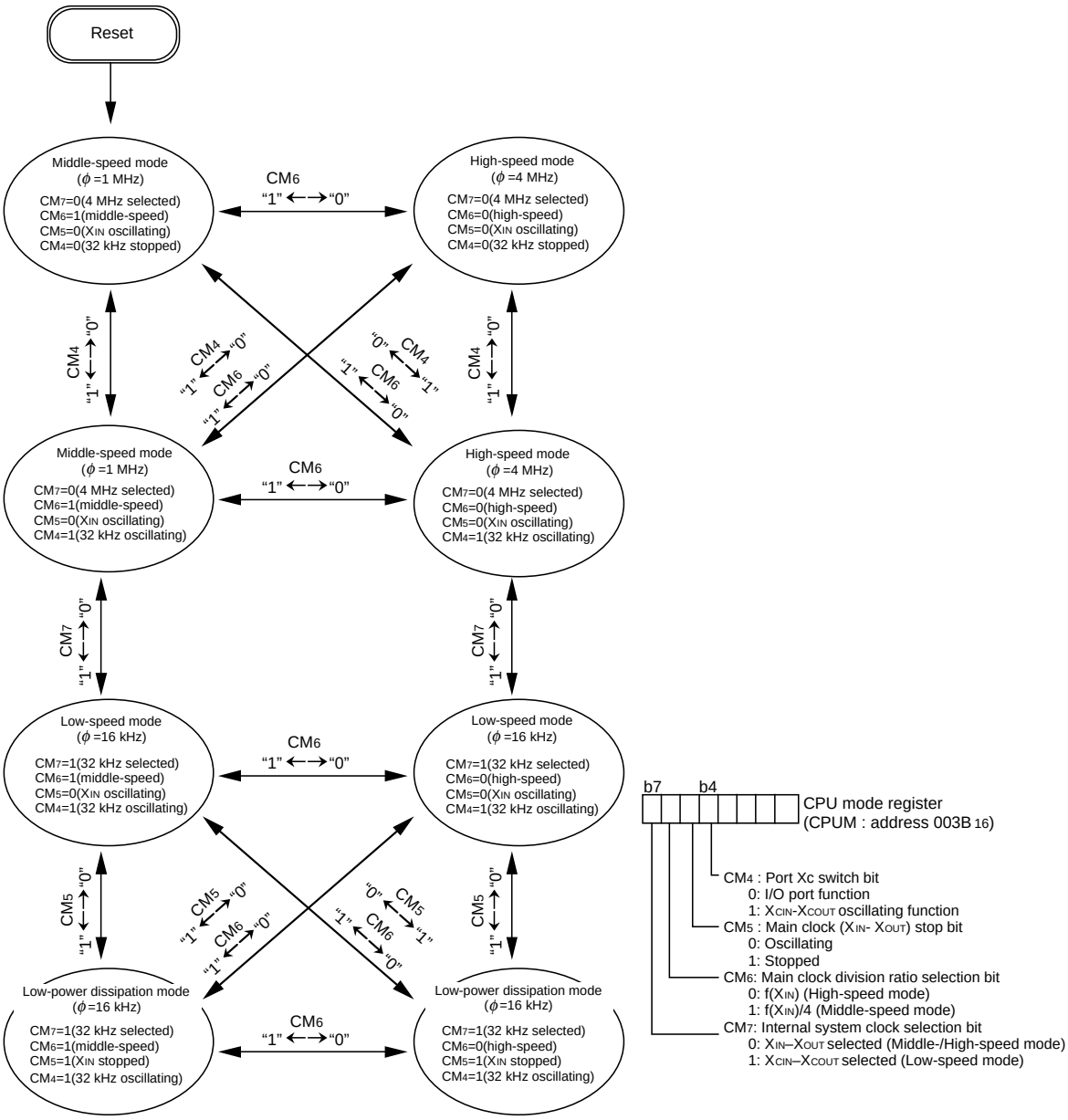



**Fig. 69 External Clock Input Circuit**




**Notes 1:** When low-speed mode is selected, set the port Xc switch bit (b4) to "1."
**2:** Refer to the structure of the timer 12 mode register.
**3:** Refer to the structure of the CPU mode register.

**Fig. 70 Clock Generating Circuit Block Diagram**




**Notes 1:** Switch the mode by the allows shown between the mode blocks. (Do not switch between the mode directly without an allow.)
**2:** The all modes can be switched to the stop mode or the wait mode and return to the source mode when the stop mode or the wait mode is ended.
**3:** Timer operates in the wait mode.
**4:** When the stop mode is ended, a delay of approximately 1 ms occurs by Timer 1 in middle-/high-speed mode.
**5:** When the stop mode is ended, a delay of approximately 0.25 s occurs by Timer 1 in low-speed mode.
**6:** The example assumes that 4 MHz is being applied to the X IN pin and 32 kHz to the X CIN pin. $\phi$ indicates the internal system clock.

**Fig. 71 State Transitions of System Clock**

## NOTES ON PROGRAMMING

### Processor Status Register

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

### Interrupts

The contents of the interrupt request bits do not change immediately after they have been written. After writing to an interrupt request register, execute at least one instruction before performing a BBC or BBS instruction.

### Decimal Calculations

- To calculate in decimal notation, set the decimal mode flag (D) to "1," then execute an ADC or SBC instruction. Only the ADC and SBC instructions yield proper decimal results. After executing an ADC or SBC instruction, execute at least one instruction before executing a SEC, CLC, or CLD instruction.
- In decimal mode, the values of the negative (N), overflow (V), and zero (Z) flags are invalid.

### Timers

If a value n (between 0 and 255) is written to a timer latch, the frequency division ratio is 1/(n+1).

### Multiplication and Division Instructions

- The index X mode (T) and the decimal mode (D) flags do not affect the MUL and DIV instruction.
- The execution of these instructions does not change the contents of the processor status register.

### Ports

The contents of the port direction registers cannot be read. The following cannot be used:

- The data transfer instruction (LDA, etc.)
- The operation instruction when the index X mode flag (T) is "1"
- The addressing mode which uses the value of a direction register as an index
- The bit-test instruction (BBC or BBS, etc.) to a direction register
- The read-modify-write instructions (ROR, CLB, or SEB, etc.) to a direction register.

Use instructions such as LDM and STA, etc., to set the port direction registers.

### Serial I/O

- Using an external clock

  When using an external clock, input "H" to the external clock input pin and clear the serial I/O interrupt request bit before executing serial I/O transfer and serial I/O automatic transfer.
- Using an internal clock

  When using an internal clock, set the synchronous clock to the internal clock, then clear the serial I/O interrupt request bit before executing a serial I/O transfer and serial I/O automatic transfer.

### A-D Converter

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

Therefore, make sure that f($X_{IN}$) is at least on 250 kHz during an A-D conversion.

Do not execute the STP or WIT instruction during an A-D conversion.

### Instruction Execution Time

The instruction execution time is obtained by multiplying the frequency of the internal system clock by the number of cycles needed to execute an instruction.

The number of cycles required to execute an instruction is shown in the list of machine instructions.

The frequency of the internal system clock is the same of the $X_{IN}$ frequency in high-speed mode.

### At STP Instruction Release

At the STP instruction release, all bits of the timer 12 mode register are cleared.

The $X_{COUT}$ drivability selection bit (the CPU mode register) is set to "1" (high drive) in order to start oscillating.

## NOTES ON USE

### Notes on Built-in EPROM Version

The $P4_7$ pin of the One Time PROM version or the EPROM version functions as the power source input pin of the internal EPROM.

Therefore, this pin is set at low input impedance, thereby being affected easily by noise.

To prevent a malfunction due to noise, insert a resistor (approx. 5 kΩ) in series with the $P4_7$ pin.

## 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)

## ROM PROGRAMMING METHOD

The built-in PROM of the blank One Time PROM version and the EPROM 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 9 Special Programming Adapter**

| Package | Name of Programming Adapter |
|---|---|
| 80P6N-A | PCA7438F-80A |
| 80D0 | PCA7438L-80A |

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 72 is recommended to verify programming.

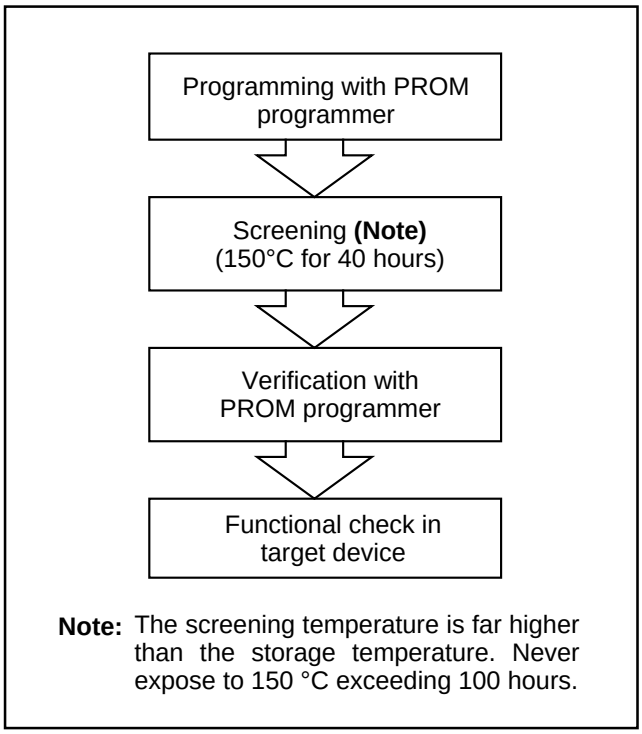



**Fig. 72 Programming and Testing of One Time PROM Version**

## ELECTRICAL CHARACTERISTICS

## ABSOLUTE MAXIMUM RATINGS

**Table 10 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 7.0 | V |
| $V_{EE}$ | Pull-down power source voltage | | | $V_{CC}$ – 45 to $V_{CC}$ +0.3 | V |
| $V_I$ | Input voltage | $P4_7$, $P5_0$–$P5_7$, $P6_1$–$P6_5$, $P7_0$–$P7_7$, $P8_4$–$P8_7$, $P9_0$, $P9_1$ | | –0.3 to $V_{CC}$ +0.3 | V |
| $V_I$ | Input voltage | $P4_0$–$P4_6$, $P6_0$ | | –0.3 to 13 | V |
| $V_I$ | Input voltage | $P0_0$–$P0_7$, $P2_0$–$P2_7$, $P8_0$–$P8_3$ | | $V_{CC}$ – 45 to $V_{CC}$ +0.3 | V |
| $V_I$ | Input voltage | $\overline{RESET}$, $X_{IN}$ | | –0.3 to $V_{CC}$ +0.3 | V |
| $V_I$ | Input voltage | $X_{CIN}$ | | –0.3 to $V_{CC}$ +0.3 | V |
| $V_O$ | Output voltage | $P0_0$–$P0_7$, $P1_0$–$P1_7$, $P2_0$–$P2_7$, $P3_0$–$P3_7$, $P8_0$–$P8_3$ | | $V_{CC}$ – 45 to $V_{CC}$ +0.3 | V |
| $V_O$ | Output voltage | $P5_0$–$P5_7$, $P6_1$–$P6_5$, $P7_0$–$P7_7$, $P8_4$–$P8_7$, $P9_0$, $P9_1$, $X_{OUT}$, $X_{COUT}$ | | –0.3 to $V_{CC}$ +0.3 | V |
| $V_O$ | Output voltage | $P4_0$–$P4_6$, $P6_0$ | | –0.3 to 13 | V |
| $P_d$ | Power dissipation | | Ta = 25°C | 600 | mW |
| $T_{opr}$ | Operating temperature | | | –20 to 85 | °C |
| $T_{stg}$ | Storage temperature | | | –40 to 125 | °C |

## RECOMMENDED OPERATING CONDITIONS

**Table 11 Recommended Operating Conditions (1)** ($V_{CC}$ = 4.0 to 5.5V, Ta = –20 to 85°C, unless otherwise noted)

| Symbol | Parameter | | Limits | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min. | Typ. | Max. | |
| $V_{CC}$ | Power source voltage | in high-speed mode | 4.0 | 5.0 | 5.5 | V |
| | | in middle-/low-speed mode | 2.7 | 5.0 | 5.5 | V |
| $V_{SS}$ | Power source voltage | | | 0 | | V |
| $V_{EE}$ | Pull-down power source voltage | | $V_{CC}$ – 43 | | $V_{CC}$ | V |
| $V_{REF}$ | Analog reference voltage (when A-D converter is used) | | 2.0 | | $V_{CC}$ | V |
| $AV_{SS}$ | Analog power source voltage | | | 0 | | V |
| $V_{IA}$ | Analog input voltage | $AN_0$–$AN_{11}$ | 0 | | $V_{CC}$ | V |
| $V_{IH}$ | “H” input voltage | $P4_0$–$P4_7$, $P5_0$–$P5_7$, $P6_0$–$P6_5$, $P7_0$–$P7_7$, $P9_0$, $P9_1$ | 0.75$V_{CC}$ | | $V_{CC}$ | V |
| $V_{IH}$ | “H” input voltage | $P8_4$–$P8_7$ | 0.4$V_{CC}$ | | $V_{CC}$ | V |
| $V_{IH}$ | “H” input voltage | $P0_0$–$P0_7$ | 0.8$V_{CC}$ | | $V_{CC}$ | V |
| $V_{IH}$ | “H” input voltage | $P2_0$–$P2_7$, $P8_0$–$P8_3$ | 0.52$V_{CC}$ | | $V_{CC}$ | V |
| $V_{IH}$ | “H” input voltage | $\overline{RESET}$ | 0.8$V_{CC}$ | | $V_{CC}$ | V |
| $V_{IH}$ | “H” input voltage | $X_{IN}$, $X_{CIN}$ | 0.8$V_{CC}$ | | $V_{CC}$ | V |
| $V_{IL}$ | “L” input voltage | $P4_0$–$P4_7$, $P5_0$–$P5_7$, $P6_0$–$P6_5$, $P7_0$–$P7_7$, $P9_0$, $P9_1$ | 0 | | 0.25$V_{CC}$ | V |
| $V_{IL}$ | “L” input voltage | $P8_4$–$P8_7$ | 0 | | 0.16$V_{CC}$ | V |
| $V_{IL}$ | “L” input voltage | $P0_0$–$P0_7$, $P2_0$–$P2_7$, $P8_0$–$P8_3$ | 0 | | 0.2$V_{CC}$ | V |
| $V_{IL}$ | “L” input voltage | $\overline{RESET}$ | 0 | | 0.2$V_{CC}$ | V |
| $V_{IL}$ | “L” input voltage | $X_{IN}$, $X_{CIN}$ | 0 | | 0.2$V_{CC}$ | V |
| $I_{OH(peak)}$ | “H” total peak output current (Note 1) | $P0_0$–$P0_7$, $P1_0$–$P1_7$, $P2_0$–$P2_7$, $P3_0$–$P3_7$, $P8_0$–$P8_3$ | | | –240 | mA |
| $I_{OH(peak)}$ | “H” total peak output current (Note 1) | $P5_0$–$P5_7$, $P6_1$–$P6_5$, $P7_0$–$P7_7$, $P9_0$, $P9_1$ | | | –60 | mA |
| $I_{OL(peak)}$ | “L” total peak output current (Note 1) | $P5_0$–$P5_7$, $P6_0$–$P6_5$, $P7_0$–$P7_7$, $P9_0$, $P9_1$ | | | 100 | mA |
| $I_{OL(peak)}$ | “L” total peak output current (Note 1) | $P4_0$–$P4_6$, $P8_4$–$P8_7$ | | | 60 | mA |
| $I_{OH(avg)}$ | “H” total average output current (Note 1) | $P0_0$–$P0_7$, $P1_0$–$P1_7$, $P2_0$–$P2_7$, $P3_0$–$P3_7$, $P8_0$–$P8_7$ | | | –120 | mA |
| $I_{OH(avg)}$ | “H” total average output current (Note 1) | $P5_0$–$P5_7$, $P6_1$–$P6_5$, $P7_0$–$P7_7$, $P9_0$, $P9_1$ | | | –30 | mA |
| $I_{OL(avg)}$ | “L” total average output current (Note 1) | $P5_0$–$P5_7$, $P6_0$–$P6_5$, $P7_0$–$P7_7$, $P9_0$, $P9_1$ | | | 50 | mA |
| $I_{OL(avg)}$ | “L” total average output current (Note 1) | $P4_0$–$P4_6$, $P8_4$–$P8_7$ | | | 30 | mA |
| $I_{OH(peak)}$ | “H” peak output current (Note 2) | $P0_0$–$P0_7$, $P1_0$–$P1_7$, $P2_0$–$P2_7$, $P3_0$–$P3_7$, $P8_0$–$P8_3$ | | | –40 | mA |
| $I_{OH(peak)}$ | “H” peak output current (Note 2) | $P5_0$–$P5_7$, $P6_1$–$P6_5$, $P7_0$–$P7_7$, $P8_4$–$P8_7$, $P9_0$, $P9_1$ | | | –10 | mA |
| $I_{OL(peak)}$ | “L” peak output current (Note 2) | $P5_0$–$P5_7$, $P6_1$–$P6_5$, $P7_0$–$P7_7$, $P8_4$–$P8_7$, $P9_0$, $P9_1$ | | | 10 | mA |
| $I_{OL(peak)}$ | “L” peak output current (Note 2) | $P4_0$–$P4_6$, $P6_0$ | | | 30 | mA |
| $I_{OH(avg)}$ | “H” average output current (Note 3) | $P0_0$–$P0_7$, $P1_0$–$P1_7$, $P2_0$–$P2_7$, $P3_0$–$P3_7$, $P8_0$–$P8_3$ | | | –18 | mA |
| $I_{OH(avg)}$ | “H” average output current (Note 3) | $P5_0$–$P5_7$, $P6_0$–$P6_5$, $P7_0$–$P7_7$, $P8_4$–$P8_7$, $P9_0$, $P9_1$ | | | –5 | mA |
| $I_{OL(avg)}$ | “L” average output current (Note 3) | $P5_0$–$P5_7$, $P6_1$–$P6_5$, $P7_0$–$P7_7$, $P8_4$–$P8_7$, $P9_0$, $P9_1$ | | | 5 | mA |
| $I_{OL(avg)}$ | “L” average output current (Note 3) | $P4_0$–$P4_6$, $P6_0$ | | | 15 | mA |

**Notes 1:** 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.
**2:** The peak output current is the peak current flowing in each port.
**3:** The average output current $I_{OL}$ (avg), $I_{OH}$ (avg) in an average value measured over 100 ms.

**Table 12 Recommended Operating Conditions (2)** ($V_{CC}$ = 4.0 to 5.5V, Ta = –20 to 85°C, unless otherwise noted)

| Symbol | Parameter | Limits | | | Unit |
|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | |
| f(CNTR0)<br>f(CNTR1) | Clock input frequency for timers 2, 4, and X (duty cycle 50 %) | | | 250 | kHz |
| f($X_{IN}$) | Main clock input oscillation frequency (Note 1) | | | 4.2 | MHz |
| f($X_{CIN}$) | Sub-clock input oscillation frequency (Note 1, 2) | | 32.768 | 50 | kHz |

**Notes 1:** When the oscillation frequency has a duty cycle of 50%.
**2:** When using the microcomputer in low-speed mode, set the sub-clock input oscillation frequency on condition that f($X_{CIN}$) < f($X_{IN}$)/3.

## ELECTRICAL CHARACTERISTICS

**Table 13 Electrical Characteristics (1)** ($V_{CC}$ = 4.0 to 5.5V, Ta = –20 to 85°C, unless otherwise noted)

| Symbol | Parameter | | Test conditions | Limits | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | Min. | Typ. | Max. | |
| $V_{OH}$ | "H" output voltage | P00–P07, P10–P17, P20–P27, P30–P37, P80–P83 | $I_{OH}$ = –18 mA | $V_{CC}$–2.0 | | | V |
| $V_{OH}$ | "H" output voltage | P50–P57, P60–P65, P70–P77, P84–P87, P90, P91 | $I_{OH}$ = –10 mA | $V_{CC}$–2.0 | | | V |
| $V_{OL}$ | "L" output voltage | P50–P57, P61–P65, P84–P87, P90, P91 | $I_{OL}$ = 10 mA | | | 2.0 | V |
| $V_{OL}$ | "L" output voltage | P40–P46, P60 | $I_{OL}$ = 15 mA | | 0.6 | 2.0 | V |
| $V_{T+}$–$V_{T-}$ | Hysteresis | P40–P42, P44–P47, P5, P60, P61, P64 | | | 0.4 | | V |
| $V_{T+}$–$V_{T-}$ | Hysteresis | $\overline{RESET}$, $X_{IN}$ | | | 0.5 | | V |
| $V_{T+}$–$V_{T-}$ | Hysteresis | $X_{CIN}$ | | | 0.5 | | V |
| $I_{IH}$ | "H" input current | P47, P50–P57, P61–P65, P70–P77, P84–P87 | $V_I$ = $V_{CC}$ | | | 5.0 | µA |
| $I_{IH}$ | "H" input current | P40–P46, P60 | $V_I$ = 12 V | | | 10.0 | µA |
| $I_{IH}$ | "H" input current | P20–P27, P80–P83 (Note) | $V_I$ = $V_{CC}$ | | | 5.0 | µA |
| $I_{IH}$ | "H" input current | $\overline{RESET}$, $X_{CIN}$ | $V_I$ = $V_{CC}$ | | | 5.0 | µA |
| $I_{IH}$ | "H" input current | $X_{IN}$ | $V_I$ = $V_{CC}$ | | 4.0 | | µA |
| $I_{IL}$ | "L" input current | P40–P47, P60 | $V_I$ = $V_{SS}$ | | | –5.0 | µA |
| $I_{IL}$ | "L" input current | P50–P57, P61–P65, P70–P77, P84–P87, P90, P91 | $V_I$ = $V_{SS}$<br>Pull-up "off" | | | –5.0 | µA |
| | | | $V_{CC}$ = 5 V, $V_I$ = $V_{SS}$<br>Pull-up "on" | –30 | –70 | –140 | µA |
| | | | $V_{CC}$ = 3 V, $V_I$ = $V_{SS}$<br>Pull-up "on" | –6.0 | –25 | –45 | µA |
| $I_{IL}$ | "L" input current | P20–P27, P80–P83 (Note) | $V_I$ = $V_{SS}$ | | | –5.0 | µA |
| $I_{IL}$ | "L" input current | $\overline{RESET}$, $X_{CIN}$ | $V_I$ = $V_{SS}$ | | | –5.0 | µA |
| $I_{IL}$ | "L" input current | $X_{IN}$ | $V_I$ = $V_{SS}$ | | –4.0 | | µA |
| $I_{LOAD}$ | Output load current | P00–P07, P10–P17, P30–P37 | $V_{EE}$ = $V_{CC}$–43 V, $V_{OL}$ = $V_{CC}$<br>Output transistors "off" | 300 | 600 | 900 | µA |
| $I_{LEAK}$ | Output leak current | P00–P07, P10–P17, P20–P27, P30–P37, P80–P83 | $V_{EE}$ = $V_{CC}$–43 V, $V_{OL}$ = $V_{CC}$<br>–43 V Output transistors "off" | | | –10 | µA |
| $I_{READH}$ | "H" read current | | $V_I$ = 5 V | | 1 | | µA |
| $V_{RAM}$ | RAM hold voltage | | When clock is stopped | 2 | | 5.5 | V |

**Note:** Except when reading ports P2 or P8.

**Table 14 Electrical Characteristics (2)** ($V_{CC}$ = 4.0 to 5.5V, Ta = –20 to 85°C, unless otherwise noted)

| Symbol | Parameter | Test conditions | | Limits | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | Min. | Typ. | Max. | |
| $I_{CC}$ | Power source current | High-speed mode<br>$f(X_{IN})$ = 4.2 MHz<br>$f(X_{CIN})$ = 32 kHz<br>Output transistors “off” | | | 7.5 | 15 | mA |
| | | High-speed mode<br>$f(X_{IN})$ = 4.2 MHz (in WIT state)<br>$f(X_{CIN})$ = 32 kHz<br>Output transistors “off” | | | 1 | | mA |
| | | Middle-speed mode<br>$f(X_{IN})$ = 4.2 MHz<br>$f(X_{CIN})$ = stopped<br>Output transistors “off” | | | 3 | | mA |
| | | Middle-speed mode<br>$f(X_{IN})$ = 4.2 MHz (in WIT state)<br>$f(X_{CIN})$ = stopped<br>Output transistors “off” | | | 1 | | mA |
| | | Low-speed mode<br>$f(X_{IN})$ = stopped<br>$f(X_{CIN})$ = 32 kHz<br>Low-power dissipation mode ($CM_3$ = 0)<br>Output transistors “off” | | | 60 | 200 | µA |
| | | Low-speed mode<br>$f(X_{IN})$ = stopped<br>$f(X_{CIN})$ = 32 kHz (in WIT state)<br>Low-power dissipation mode ($CM_3$ = 0)<br>Output transistors “off” | | | 20 | 40 | µA |
| | | Increment when A-D conversion is executed | | | 0.6 | | mA |
| | | All oscillation stopped (in STP state)<br>Output transistors “off” | Ta = 25°C | | 0.1 | 1 | µA |
| | | | Ta = 85°C | | | 10 | µA |

## A-D CONVERTER CHARACTERISTICS

**Table 15 A-D Converter Characteristics**

($V_{CC}$ = 4.0 to 5.5V, $V_{SS}$ = 0V, Ta = –20 to 85°C, $f(X_{IN})$ = 250 kHz to 4.2 MHz in high-speed mode, unless otherwise noted)

| Symbol | Parameter | Test conditions | Limits | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min. | Typ. | Max. | |
| — | Resolution | | | | 10 | Bits |
| — | Absolute accuracy (excluding quantization error) | $V_{CC}$ = $V_{REF}$ = 5.12 V | | ±1 | ±2.5 | LSB |
| $T_{CONV}$ | Conversion time | | 61 | | 62 | tc($\phi$) |
| $IV_{REF}$ | Reference input current | $V_{REF}$ = 5.0 V | 50 | 150 | 200 | µA |
| $I_{IA}$ | Analog port input current | | | 0.5 | 5.0 | µA |
| $R_{LADDER}$ | Ladder resistor | | | 35 | | kΩ |

## TIMING REQUIREMENTS

**Table 16 Timing Requirements** ($V_{CC}$ = 4.0 to 5.5V, $V_{SS}$ = 0V, Ta = –20 to 85°C, unless otherwise noted)

| Symbol | Parameter | Limits | | | Unit |
|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | |
| $t_W(\overline{RESET})$ | Reset input “L” pulse width | 2.0 | | | µs |
| $t_C(X_{IN})$ | Main clock input cycle time ($X_{IN}$ input) | 238 | | | ns |
| $t_{WH}(X_{IN})$ | Main clock input “H” pulse width | 60 | | | ns |
| $t_{WL}(X_{IN})$ | Main clock input “L” pulse width | 60 | | | ns |
| $t_C(X_{CIN})$ | Sub-clock input cycle time ($X_{CIN}$ input) | 20 | | | µs |
| $t_{WH}(X_{CIN})$ | Sub-clock input “H” pulse width | 5.0 | | | µs |
| $t_{WL}(X_{CIN})$ | Sub-clock input “L” pulse width | 5.0 | | | µs |
| $t_C$(CNTR) | $CNTR_0$, $CNTR_1$ input cycle time | 4.0 | | | µs |
| $t_{WH}$(CNTR) | $CNTR_0$, $CNTR_1$ input “H” pulse width | 1.6 | | | µs |
| $t_{WL}$(CNTR) | $CNTR_0$, $CNTR_1$ input “L” pulse width | 1.6 | | | µs |
| $t_{WH}$(INT) | $INT_0$ to $INT_4$ input “H” pulse width | 80 | | | ns |
| $t_{WL}$(INT) | $INT_0$ to $INT_4$ input “L” pulse width | 80 | | | ns |
| $t_C(S_{CLK})$ | Serial I/O clock input cycle time | 0.95 | | | µs |
| $t_{WH}(S_{CLK})$ | Serial I/O clock input “H” pulse width | 400 | | | ns |
| $t_{WL}(S_{CLK})$ | Serial I/O clock input “L” pulse width | 400 | | | ns |
| $t_{su}(S_{CLK}–S_{IN})$ | Serial I/O input set up time | 200 | | | ns |
| $t_h(S_{CLK}–S_{IN})$ | Serial I/O input hold time | 200 | | | ns |

## SWITCHING CHARACTERISTICS

**Table 17 Switching Characteristics** ($V_{CC}$ = 4.0 to 5.5V, $V_{SS}$ = 0V, Ta = –20 to 85°C, unless otherwise noted)

| Symbol | Parameter | Test conditions | Limits | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min. | Typ. | Max. | |
| $t_{WH}(S_{CLK})$ | Serial I/O clock output “H” pulse width | $C_L$ = 100 pF | $t_C(S_{CLK})/2–160$ | | | ns |
| $t_{WL}(S_{CLK})$ | Serial I/O clock output “L” pulse width | $C_L$ = 100 pF | $t_C(S_{CLK})/2–160$ | | | ns |
| $t_d(S_{CLK}–S_{OUT})$ | Serial I/O output delay time | | | | 0.2 tc | ns |
| $t_v(S_{CLK}–S_{OUT})$ | Serial I/O output valid time | | 0 | | | ns |
| $t_r(S_{CLK})$ | Serial I/O clock output rising time | $C_L$ = 100 pF | | | 40 | ns |
| $t_f(S_{CLK})$ | Serial I/O clock output falling time | $C_L$ = 100 pF | | | 40 | ns |
| $t_r$(Pch–strg) | P-channel high-breakdown voltage output rising time (Note 1) | $C_L$ = 100 pF<br>$V_{EE} = V_{CC}–43$ V | | 55 | | ns |
| $t_r$(Pch–weak) | P-channel high-breakdown voltage output rising time (Note 2) | $C_L$ = 100 pF<br>$V_{EE} = V_{CC}–43$ V | | 1.8 | | µs |

**Notes 1:** When bit 7 of the FLDC mode register (address $0EF4_{16}$) is at “0”.
**2:** When bit 7 of the FLDC mode register (address $0EF4_{16}$) is at “1”.

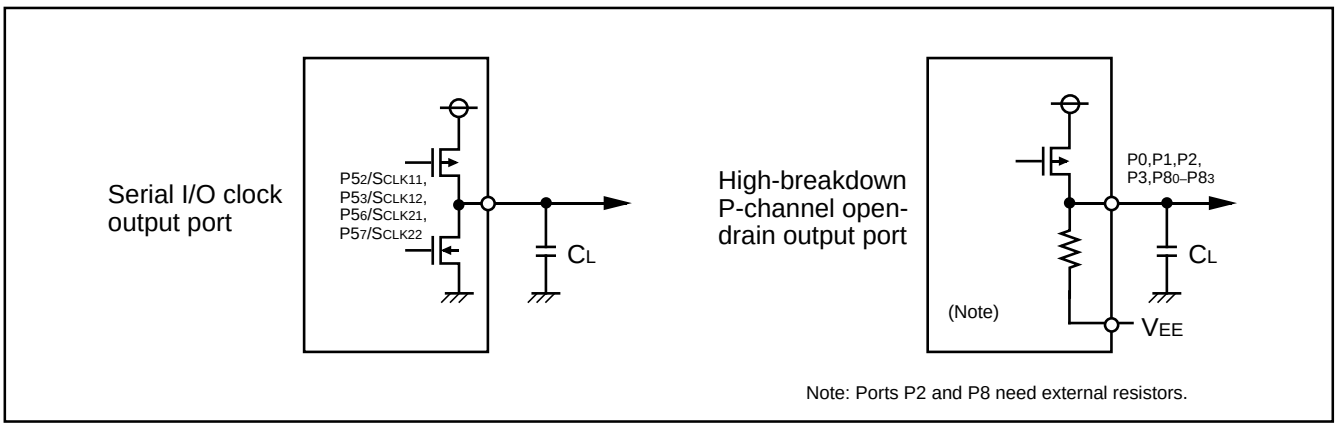



**Fig. 73 Circuit for Measuring Output Switching Characteristics**

## Timing Diagram

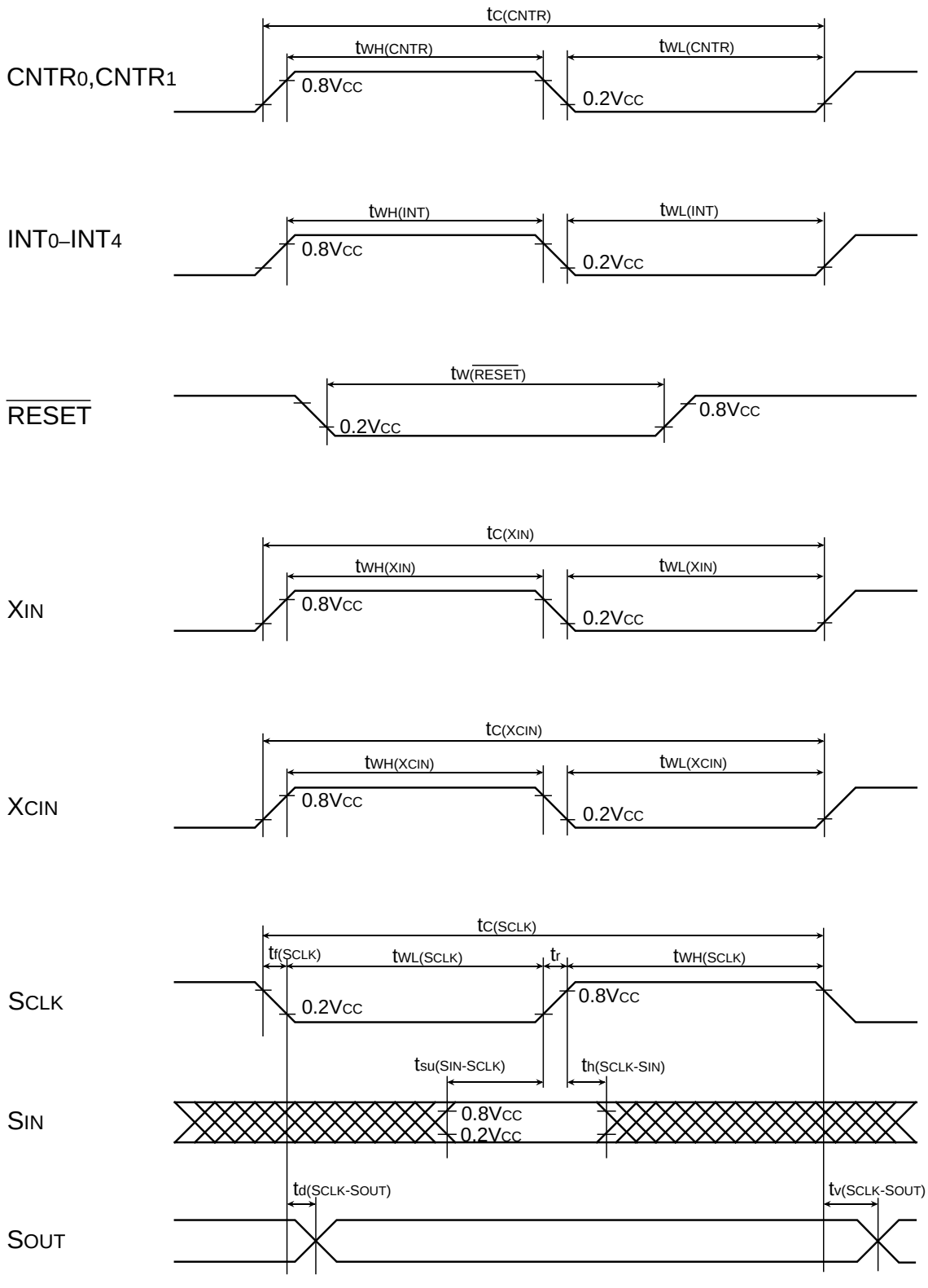



**Fig. 74 Timing Diagram**

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