CMOS 8-BIT MICROCONTROLLER

# TMP87CH21F, TMP87CM21F
# TMP87CH21DF, TMP87CM21DF

The TMP87CH21/CM21 are the high speed and high performance 8-bit single chip microcomputers. These MCU contain, large ROM, RAM, input/output ports, LCD driver, a 8-bit A/D converter, four multi-function timer/counters, two serial interfaces, and two clock generators on chip.

| PART No. | ROM | RAM | PACKAGE | OTP MCU |
|---|---|---|---|---|
| TMP87CH21 | 16K × 8-bit | 1K × 8-bit | QFP80-P-1420-0.80B<br>LQFP80-P-1212-0.50A | TMP87PP21 |
| TMP87CM21 | 32K × 8-bit | | | |

## FEATURES

◆8-bit single chip microcomputer TLCS-870 Series
◆Instruction execution time : 0.5 μs (at 8 MHz), 122 μs (at 32.768 kHz)
◆129 types & 412 basic instructions
- Multiplication and Division (8 bits × 8 bits , 16 bits ÷ 8 bits) : 3.5 μs (at 8 MHz)
- Bit manipulations (Set/Clear/Complement/Load/Store/Test/Exclusive OR)
- 16-bit data operations
- 1-byte jump/call (Short relative jump / Vector call)

◆14 interrupt sources (External : 5, Internal : 9)
- All sources have independent latches each, and nested interrupt control is available
- 4 edge-selectable external interrupts with noise reject
- High-speed task switching by register bank changeover

◆10 Input/Output ports (Max. 52 pins)
◆Two 16-bit Timer/Counters
- Timer, Event counter, Frequency measurement, Pulse width measurement modes

◆Two 8-bit Timer/Counters
- Timer, Event counter, Capture (Pulse width/duty measurement), PWM output, PDO modes

◆Time Base Timer (Interrupt frequency : 1Hz to 16348 Hz)
◆Divider output function (frequency : 1kHz to 8 kHz)
◆Watchdog Timer
◆Two 8-bit Serial Interfaces
- Each 8 bytes transmit/receive data buffer
- Internal/external serial clock, and 4/8-bit mode6

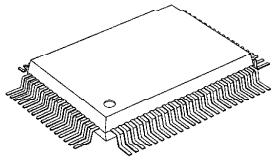
◆LCD driver
- With displaymemory
- LCD direct drive capability (Max. 32 seg × 4 com)
- 1/4, 1/3, 1/2 duty or static drive are programmably selectable

◆**8-bit** successive approximate type **A/D converter** with sample and hold
- 8 analog inputs
- Conversion time:23 μs / 144 μs (at 8 MHz)

◆Dual clock operation (optinal)
◆Five Power saving operating modes
- STOP mode :Oscillation stops. Battery/Capacitor back-up. Port output hold/high-impedance.
- SLOW mode: Low power consumption operation using low-frequency clock (32.768 kHz).
- IDLE1 mode : CPU stops, and Peripherals operate using high-frequency clock. Release by interrupts.
- IDLE2 mode : CPU stops, and Peripherals operate using high and low frequency clock. Release by interrupts.
- SLEEP mode : CPU stops, and Peripherals operate using low-frequency clock. Release by interrupts.

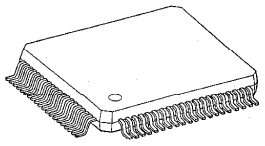
◆Operating Voltage : 2.7 to 5.5 V at 4.2 MHz / 32.768 kHz, 4.5 to 5.5 V at 8 MHz
◆Emulation Pod : BM87CP23F0A
◆MCU Probe : PN120004

QFP80-P-1420-0.80B



TMP87CH21F
TMP87CM21F

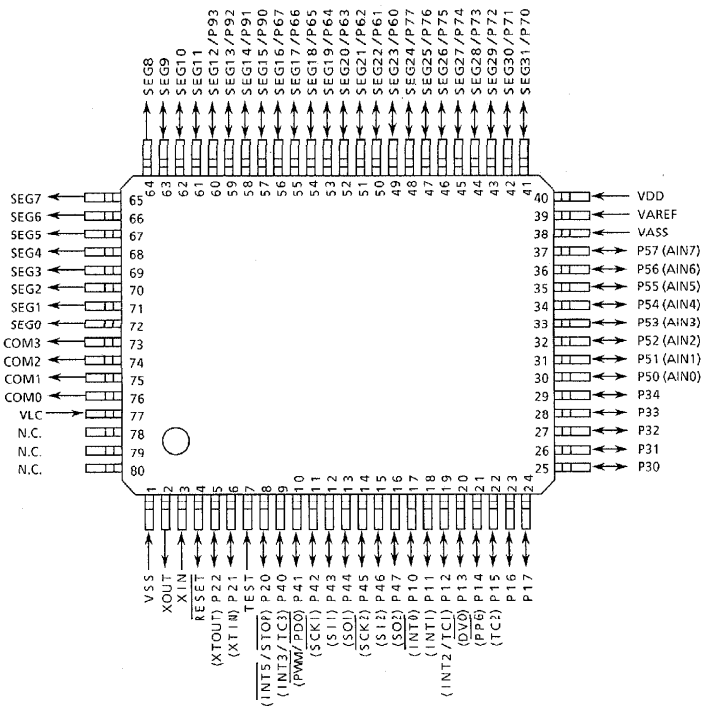
LQFP80-P-1212-0.50A



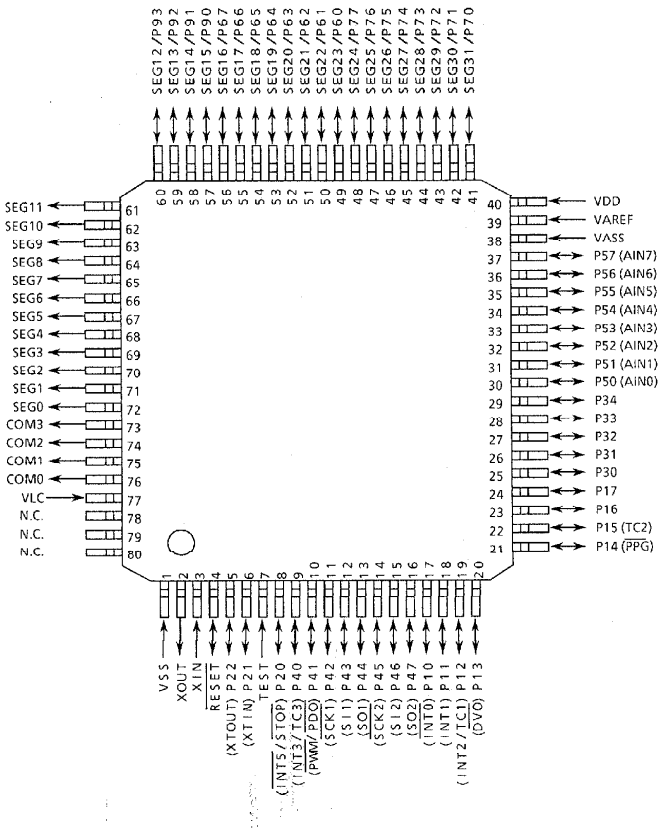
TMP87CH21DF
TMP87CM21DF

## PIN ASSIGNMENTS (TOP VIEW)

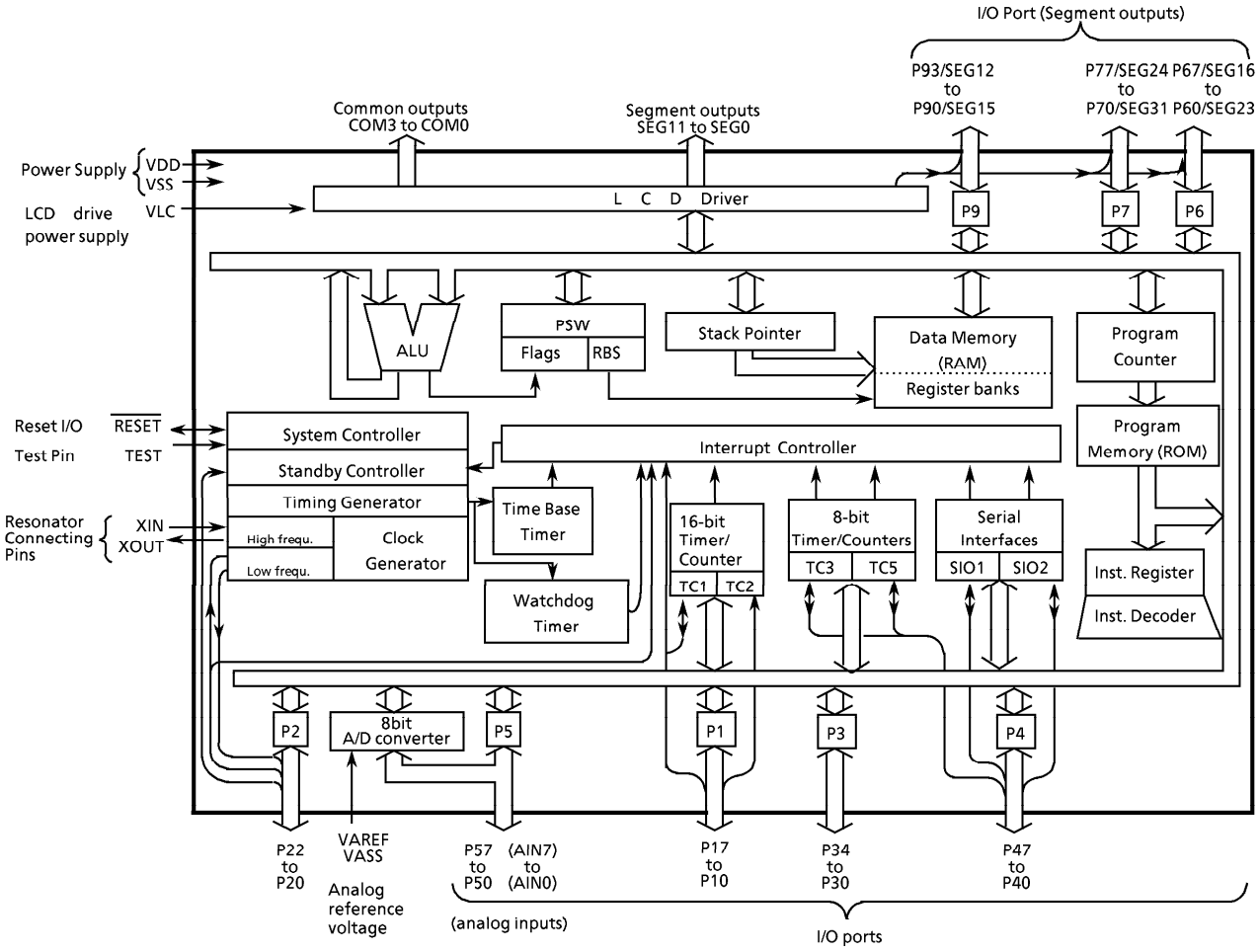
QFP80-P-1420-0.80B




LQFP80-P-1212-0.50A



## BLOCK DIAGRAM



## PIN FUNCTION

| PIN NAME | Input / Output | FUNCTION | |
|---|---|---|---|
| P17, P16 | I/O | 8-bit programmable input/output port (tri-state). | |
| P15 (TC2) | I/O (Input) | Each bit of these ports can be individually configured as an input or an output under software control. When used as timer/counter in or external interrupt input, the latch must be set to "0". When used as PPG output or divider output, the latch must be set to "1". | Timer/Counter 2 input |
| P14 ($\overline{PPG}$) | I/O (Output) | | Programmable pulse generator output |
| P13 ($\overline{DVO}$) | | | Divider output |
| P12 (INT2 / TC1) | I/O (Input) | | External interrupt input 2 or Timer/Counter 1 input |
| P11 (INT1) | | | External interrupt input 1 |
| P10 ($\overline{INT0}$) | | | External interrupt input 0 |
| P22 (XTOUT) | I/O (Output) | 3-bit input/output port with latch. When used as an input port, the latch must be set to "1". | Resonator connecting pins (32.768kHz). For inputting external clock, XTIN is used and XTOUT is opened. |
| P21 (XTIN) | I/O (Input) | | |
| P20 ($\overline{INT5}$ / $\overline{STOP}$) | | | External interrupt input 5 or STOP mode release signal input |
| P34 to P30 | I/O | 5-bit input/output port with latch. When used as input port, the latch must be set to "1". | |
| P47 (SO2) | I/O (Output) | 8-bit input/output port with latch. When used as input port or a SIO input/output port, the latch must be set to "1". | SIO2 serial data output |
| P46 (SI2) | I/O (Input) | | SIO2 serial data input |
| P45 ($\overline{SCK2}$) | I/O (I/O) | | SIO2 serial clock input/output |
| P44 (SO1) | I/O (Output) | | SIO1 serial data output |
| P43 (SI1) | I/O (Input) | | SIO1 serial data input |
| P42 ($\overline{SCK1}$) | I/O (I/O) | | SIO1 serial clock input/output |
| P41 ($\overline{PWM}$/PDO) | I/O (Output) | | 8-bit PWM output, 8-bit programmable divider output |
| P40 (INT3/TC3) | I/O (Input) | | External interrupt input 3, Timer/Counter 3 input |
| P57 (AIN07) to P50 (AIN00) | I/O (Input) | 8-bit programmable input/output port (tri-state). Each bit of the port can be individually configured as an input or an output under software control. When used as analog input, the latch must be set to "0". | A/D converter analog inputs |
| SEG31 (P70) to SEG24 (P77) | Output (I/O) | 8-bit input/output port with latch. When used as an input port, the latch must be set to "1". | LCD segment outputs. When used as segment output, the control register of P6, P7 and P9 must be set to "1". |
| SEG23 (P60) to SEG16 (P67) | Output (I/O) | | |
| SEG15 (P90) to SEG12 (P93) | Output (I/O) | | |
| SEG11 to SEG0 | Output | LCD segment outputs | |
| COM3 to COM0 | Output | LCD common outputs | |
| XIN, XOUT | Input, Output | Resonator connecting pins for high-frequency clock. For inputting external clock, XIN is used and XOUT is opened. | |
| $\overline{RESET}$ | I/O | Reset signal input or watchdog timer output/address-trap-reset output | |
| TEST | Input | Test pin for out-going test. Be fixed to low. | |
| VDD, VSS | Power Supply | + 5 V, 0 V (GND) | |
| VAREF, VASS | | Analog reference voltage inputs (High, Low) | |
| VLC | LCD drive power supply. | | |

# OPERATIONAL DESCRIPTION

## 1. CPU CORE FUNCTIONS

The CPU core consists of a CPU, a system clock controller, an interrupt controller, and a watchdog timer. This section provides a description of the CPU core, the program memory (ROM), the data memory (RAM), and the reset circuit.

### 1.1 Memory Address Map

The TLCS-870 Series is capable of addressing 64K bytes of memory. Figure 1-1 shows the memory address maps of the 87CH21/M21. In the TLCS-870 Series, the memory is organized 4 address spaces (ROM, RAM, SFR, and DBR). It uses a memory mapped I/O system, and all I/O registers are mapped in the SFR/DBR address spaces. There are 16 banks of general-purpose registers. The register banks are also assigned to the first 128 bytes of the RAM address space.

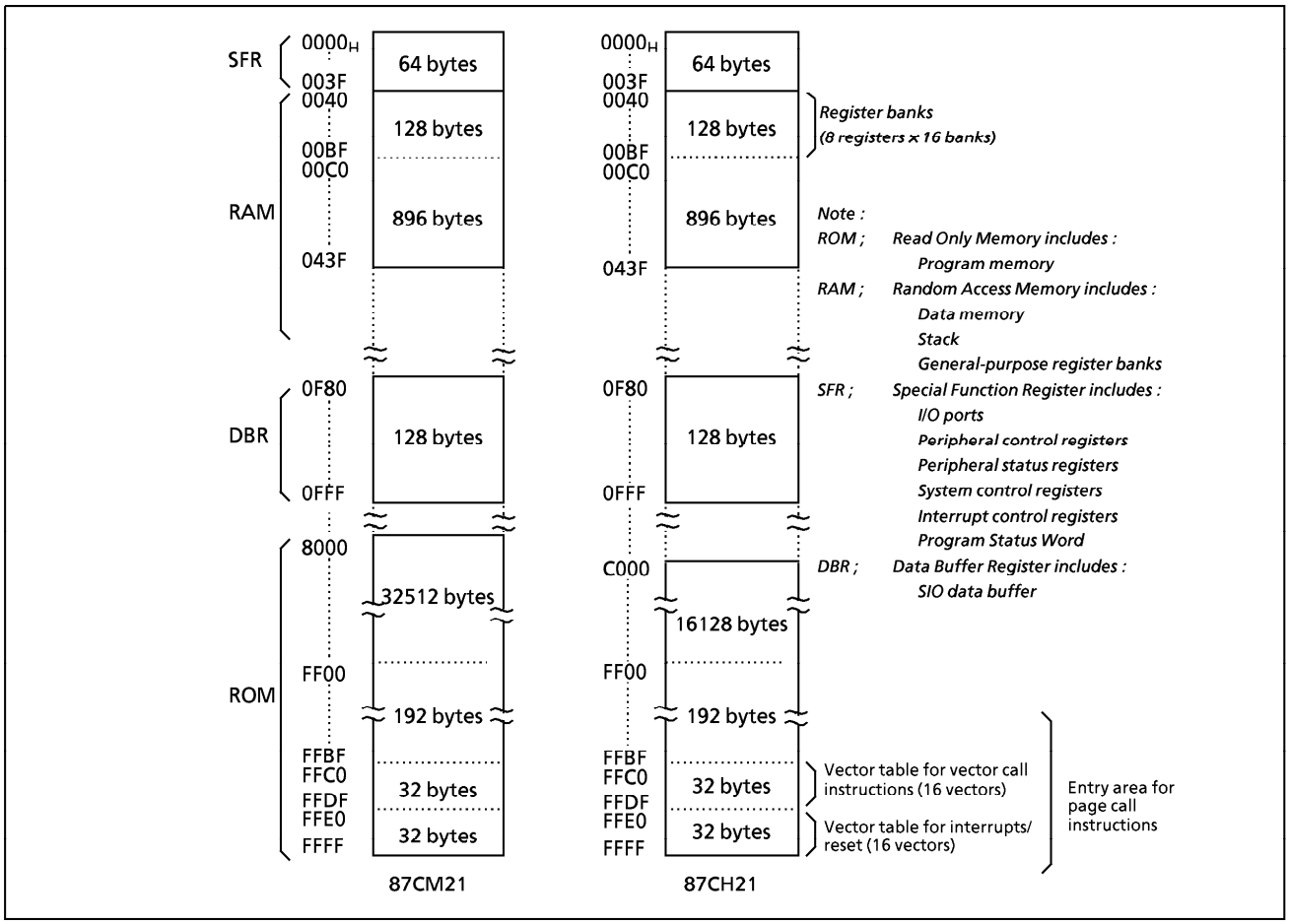



Figure 1-1. Memory Address Maps

## 1.2 Program Memory (ROM)

The 87CH21 has a 16K × 8-bit (addresses $C000_H$-$FFFF_H$), and the 87CM21 has a 32K × 8-bit (address $8000_H$-$FFFF_H$) of program memory (mask programmed ROM).
Addresses $FF00_H$-$FFFF_H$ in the program memory can also be used for special purposes.

(1) **Interrupt / Reset** vector table (addresses $FFE0_H$-$FFFF_H$)
This table consists of a reset vector and 15 interrupt vectors (2 bytes/vector). These vectors store a reset start address and interrupt service routine entry addresses.

(2) Vector table for **vector call** instructions (addresses $FFC0_H$-$FFDF_H$)
This table stores call vectors (subroutine entry address, 2 bytes/vector) for the vector call instructions [CALLV n]. There are 16 vectors. The CALLV instruction increases memory efficiency when utilized for frequently used subroutine calls (called from 3 or more locations).

(3) Entry area (addresses $FF00_H$-$FFFF_H$) for **page call** instructions
This is the subroutine entry address area for the page call instructions [CALLP n]. Addresses $FF00_H$-$FFBF_H$ are normally used because address $FFC0_H$-$FFFF_H$ are used for the vector tables.

Programs and fixed data are stored in the program memory. The instruction to be executed next is read from the address indicated by the current contents of the program counter (PC). There are relative jump and absolute jump instructions. The concepts of page or bank boundaries are not used in the program memory concerning any jump instruction.

Example: The relationship between the jump instructions and the PC.

① 5-bit PC-relative jump [JRS cc, $ + 2 + d]
E8C4H: JRS T, $ + 2 + 08H
When JF = 1, the jump is made to $E8CE_H$, which is $08_H$ added to the contents of the PC. (The PC contains the address of the instruction being executed + 2; therefore, in this case, the PC contents are $E8C4_H + 2 = E8C6_H$.)

② 8-bit PC-relative jump [JR cc, $ + 2 + d]
E8C4H : JR Z, $ + 2 + 80H
When ZF = 1, the jump is made to $E846_H$, which is $FF80_H$ ( − 128) added to the current contents of the PC.

③ 16-bit absolute jump [JP a]
E8C4H : JP 0C235H
An unconditional jump is made to address $C235_H$. The absolute jump instruction can jump anywhere within the entire 64K-bytes space.

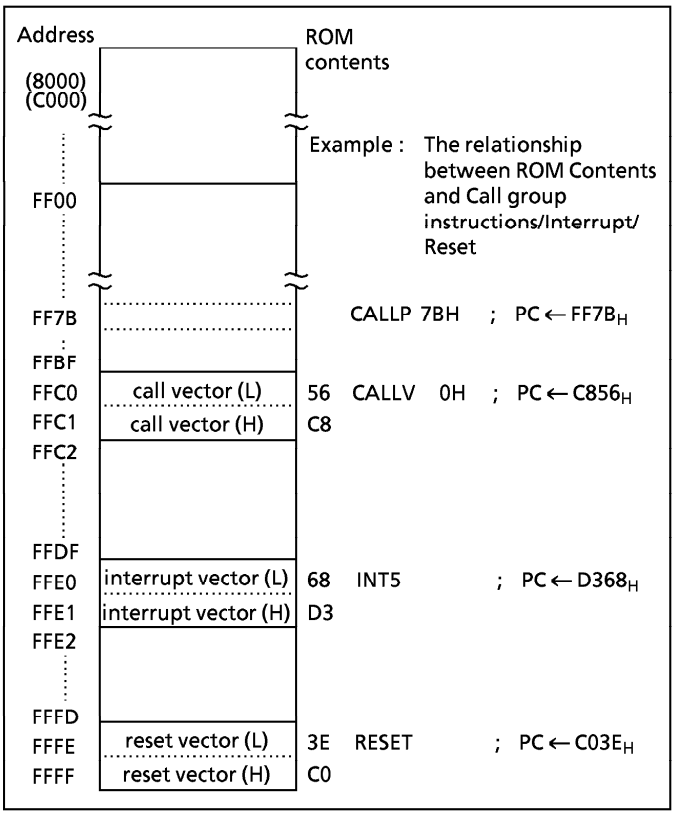



Figure 1-2. Program Memory Map

In the TLCS-870 Series, the same instruction used to access the data memory (e.g. [LD A, (HL)] ) is also used to read out fixed data (ROM data) stored in the program memory. The register-offset PC-relative addressing (PC + A) instructions can also be used, and the code conversion, table look-up and n-way multiple jump processing can easily be programmed.

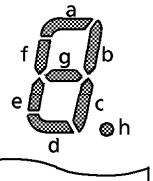
Example 1 : Loads the ROM contents at the address specified by the HL register pair contents into the accumulator (87CH21 : HL≧C000$_H$):

```
LD      A, (HL)          ; A←ROM (HL)
```

Example 2 : Converts BCD to 7-segment code (common anode LED). When A = 05$_H$, 92$_H$ is output to port P6 after executing the following program:

```
        ADD     A, TABLE – $ – 4     ; P6 ←ROM (TABLE + A)
        LD      (P6), (PC + A)
        JRS     T, SNEXT
TABLE : DB      0C0H, 0F9H, 0A4H, 0B0H, 99H, 92H, 82H, 0D8H, 80H, 98H
SNEXT :
```

*Notes : "$" is a header address of ADD instruction.*
*DB is a byte data difinition instruction.*




Example 3 : N-way multiple jump in accordance with the contents of accumulator (0≦A≦3):

```
        SHLC    A            ; if A = 00H then PC←C234H
        JP      (PC + A)       if A = 01H then PC←C378H
                               if A = 02H then PC←DA37H
                               if A = 03H then PC←E1B0H
        DW      0C234H, 0C378H, 0DA37H, 0E1B0H
```

*Note : DW is a word data definition instruction.*

```
SHLC A
JP (PC + A)
34
C2
78
C3
37
DA
B0
E1
```

## 1.3 Program Counter (PC)

The program counter (PC) is a 16-bit register which indicates the program memory address where the instruction to be executed next is stored. After reset, the user defined reset vector stored in the vector table (addresses FFFF$_H$ and FFFE$_H$) is loaded into the PC ; therefore, program execution is possible from any desired address. For example, when C0$_H$ and 3E$_H$ are stored at addresses FFFF$_H$ and FFFE$_H$, respectively, the execution starts from address C03E$_H$ after reset.

The TLCS-870 Series utilizes pipelined processing (instruction pre-fetch); therefore, the PC always indicates 2 addresses in advance. For example, while a 1-byte instruction stored at address C123$_H$ is being executed, the PC contains C125$_H$.

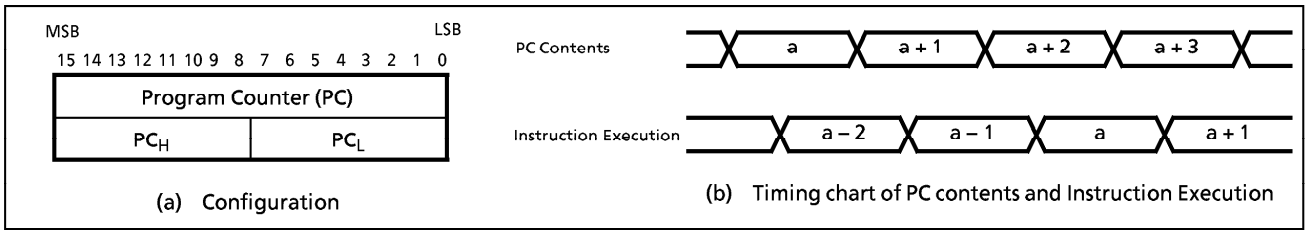



Figure 1-3. Program Counter

## 1.4 Data Memory (RAM)

The 87CH21/M21 have a 1K × 8-bit (addresses $0040_H$-$043F_H$) of data memory (static RAM). Figure 1-4 shows the data memory map.

Addresses $0000_H$-$00FF_H$ are used as a direct addressing area to enhance instructions which utilize this addressing mode; therefore, addresses $0040_H$-$00FF_H$ in the data memory can also be used for user flags or user counters.

Example 1 : If bit 2 at data memory address $00C0_H$ is "1", $00_H$ is written to data memory at address $00E3_H$; otherwise, $FF_H$ is written to the data memory at address $00E3_H$.

```
        TEST    (00C0H).2       ;  if (00C0H) 2 = 0 then jump
        JRS     T,SZERO
        CLR     (00E3H)         ;  (00E3H) ← 00H
        JRS     T,SNEXT
SZERO : LD      (00E3H), 0FFH   ;  (00E3H) ← FFH
SNEXT :
```

Example 2 : Increments the contents of data memory at address $00F5_H$, and clears to $00_H$ when $10_H$ is exceeded.

```
        INC     (00F5H)         ;  (00F5H) ← (00F5H) + 1
        AND     (00F5H), 0FH    ;  (00F5H) ← (00F5H)∧0FH
```

General-purpose register banks (8 registers × 16 banks) are also assigned to the 128 bytes of addresses $0040_H$-$00BF_H$. Access as data memory is still possible even when being used for registers. For example, when the contents of the data memory at address $0040_H$ is read out, the contents of the accumulator in the bank 0 are also read out. The stack can be located anywhere within the data memory except the register bank area. The stack depth is limited only by the free data memory size. For more details on the stack, see section "1.7 Stack and Stack Pointer".

With the 87CH21/M21, programs in data memory cannot be executed. If the program counter indicates a specific data memory address (addresses $0040_H$ - $043F_H$), an address-trap-reset is generated due to due to bus error. (Output from the $\overline{RESET}$ pin goes low.)

Example 1 : Clears RAM to "$00_H$" except the bank 0 (87CH21/M21)

```
        LD      HL, 0048H       ;  Sets start address to HL register pair
        LD      A, H            ;  Sets initial data (00H) to A register
        LD      BC, 03F7H       ;  Sets number of byte to BC register pair
SRAMCLR : LD    (HL+), A
        DEC     BC
        JRS     F, SRAMCLR
```

*Note : The data memory contents become unstable when the power supply is turned on; therefore, the data memory should be initialized by an initialization routine. Note that the general-purpuse registers are mapped in the RAM ; therefore, do not clear RAM at the current bank addresses.*

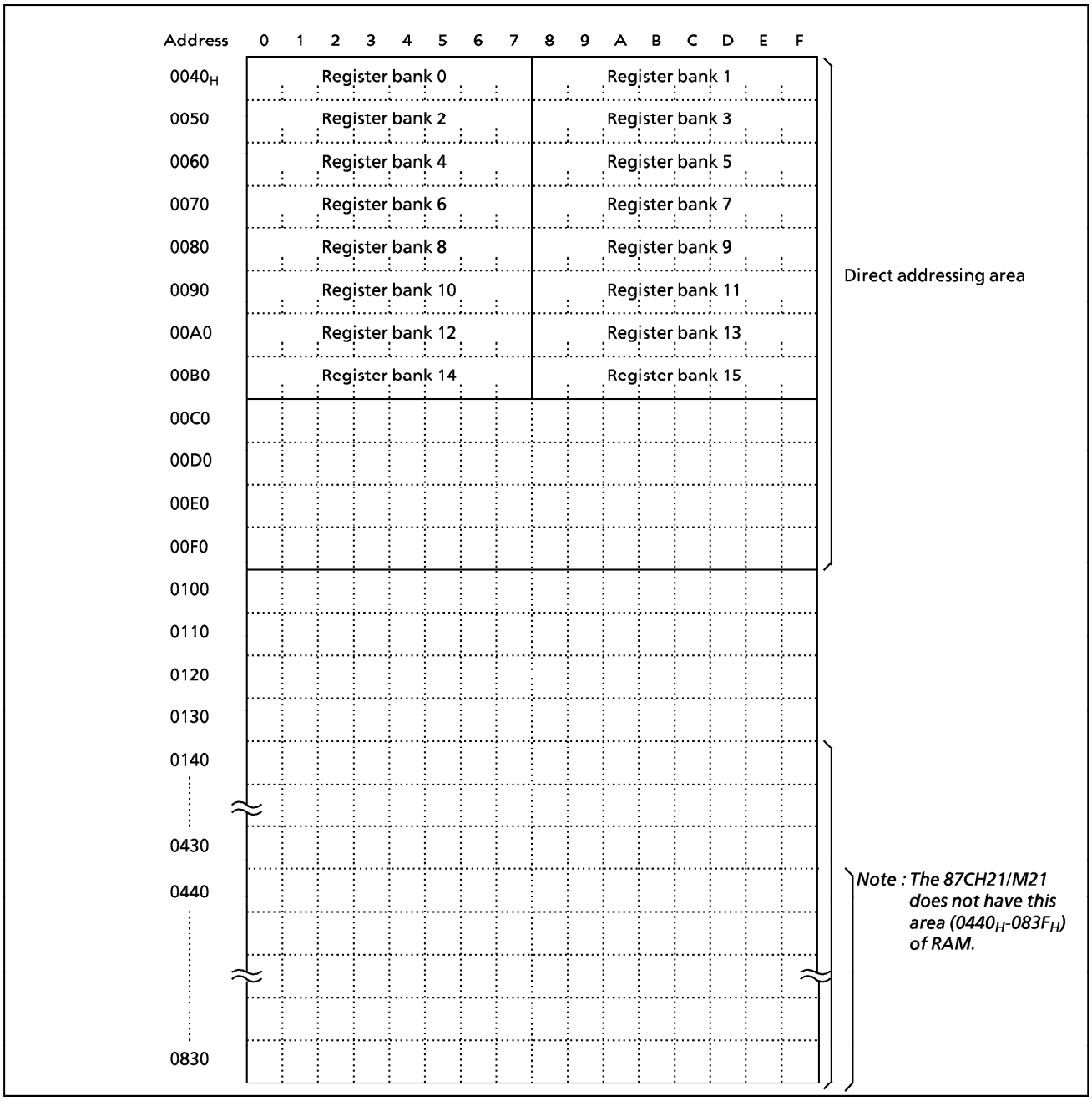



Figure 1-4. Data Memory Map

## 1.5 General-purpose Register Banks

General-purpose registers are mapped into addresses $0040_H$-$00BF_H$ in the data memory as shown in Figure 1-4. There are 16 register banks, and each bank contains eight 8-bit registers W, A, B, C, D, E, H, and L. Figure 1-5 shows the general-purpose register bank configuration.

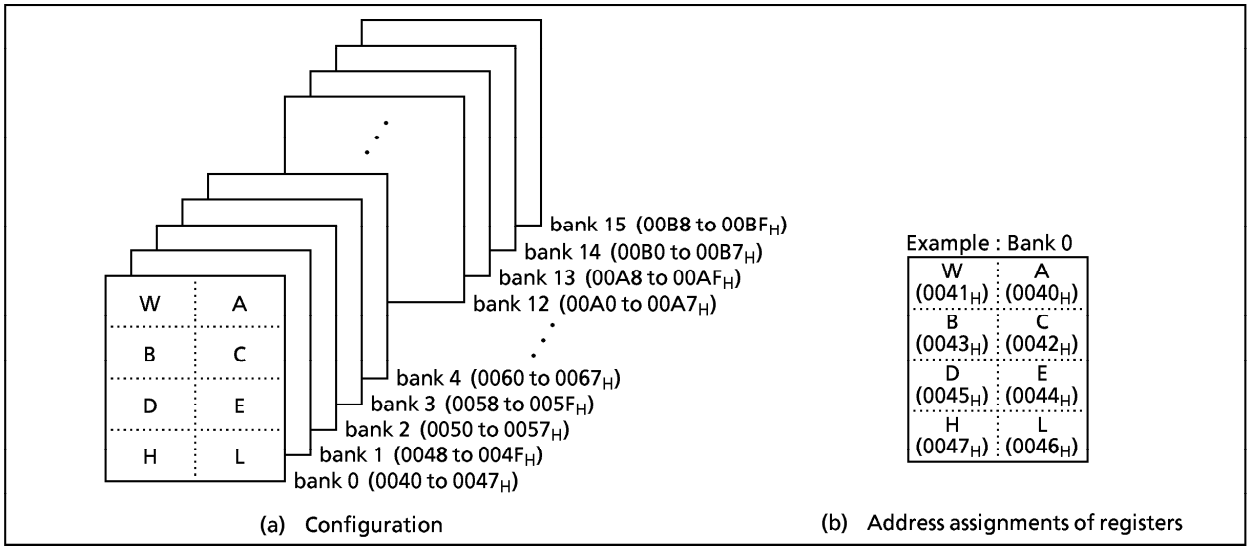



Figure 1-5. General-purpose Register Banks

In addition to access in 8-bit units, the registers can also be accessed in 16-bit units as the register pairs WA, BC, DE, and HL. Besides its function as a general-purpose register, the register also has the following functions:

(1) **A, WA**

The A register functions as an 8-bit accumulator and WA the register pair functions as a 16-bit accumulator (W is high byte and A is low byte). Registers other than A can also be used as accumulators for 8-bit operations.

```
Examples :  ①   ADD  A, B          ; Adds B contents to A contents and stores the result into A.
            ②   SUB  WA, 1234H     ; Subtracts 1234H from WA contents and stores the result into WA.
            ③   SUB  E, A          ; Subtracts A contents from E contents, and stores the result into E.
```

(2) **HL, DE**

The HL and DE specify a memory address. The HL register pair functions as data pointer (HL) /index register (HL + d) /base register (HL + C), and the DE register pair function as a data pointer (DE). The HL also has an auto-post- increment and auto-pre-decrement functions. This function simplifies multiple digit data processing, software LIFO (last-in first-out) processing, etc.

```
Example 1 :  ①   LD   A, (HL)        ; Loads the memory contents at the address specified by HL into A.
             ②   LD   A, (HL + 52H)  ; Loads the memory contents at the address specified by the value
                                     obtained by adding 52H to HL contents into A.
             ③   LD   A, (HL + C)    ; Loads the memory contents at the address specified by the value
                                     obtained by adding the register C contents to HL contents into A.
             ④   LD   A, (HL + )     ; Loads the memory contents at the address specified by HL into A.
                                     Then increments HL.
             ⑤   LD   A, ( – HL)     ; Decrements HL. Then loads the memory contents at the address
                                     specified by new HL into A.
```

The TLCS-870 Series can transfer data directly memory to memory, and operate directly between memory data and memory data. This facilitates the programming of block processing.

Example 2 : Block transfer

```
        LD      B, n – 1        ; Sets (number of bytes to transfer) – 1 to B
        LD      HL, DSTA        ; Sets destination address to HL
        LD      DE, SRCA        ; Sets source address to DE
SLOOP : LD      (HL), (DE)      ; HL ← DE
        INC     HL              ; HL ← HL + 1
        INC     DE              ; DE ← DE + 1
        DEC     B               ; B ← B – 1
        JRS     F, SLOOP        ; if B ≧ 0 then loop
```

(3) **B, C, BC**

Registers B and C can be used as 8-bit buffers or counters, and the BC register pair can be used as a 16-bit buffer or counter. The C register functions as an offset register for register-offset index addressing (refer to example 1 ③ above) and as a divisor register for the division instruction [DIV gg, C].

Example 1 : Repeat processing

```
        LD      B, n            ; Sets n as the number of repetitions to B
SREPEAT : processing            ;     (n + 1 times processing)
        DEC     B
        JRS     F, SREPEAT
```

Example 2 : Unsigned integer division (16-bit ÷ 8-bit)

```
        DIV     WA, C           ; Divides the WA contents by the C contents, places the
                                ;   quotient in A and the remainder in W.
```

The general-purpose register banks are selected by the 4-bit register bank selector (RBS). During reset, the RBS is initialized to "0". The bank selected by the RBS is called the current bank.
Together with the flag, the RBS is assigned to address $003F_H$ in the SFR as the program status word (PSW). There are 3 instructions [LD RBS, n], [PUSH PSW], [POP PSW] to access the PSW. The PSW can be also operated by the memory access instruction.

Example 1 : Incrementing the RBS

```
        INC     (003FH)         ; RBS ← RBS + 1
```

Example 2 : Reading the RBS

```
        LD      A, (003FH)      ; A ← PSW (A3-0 ← RBS, A7-4 ← Flags)
```

Highly efficient programming and high-speed task switching are possible by using bank changeover to save registers during interrupt and to transfer parameters during subroutine processing.
During interrupt, the PSW is automatically saved onto the stack. The bank used before the interrupt was accepted is restored automatically by executing an interrupt return instruction [RETI]/[RETN] ; therefore, there is no need for the RBS save/restore software processing.
The TLCS-870 Series supports a maximum of 15 interrupt sources. One bank is assigned to the main program, and one bank can be assigned to each source. Also, to increase the efficiency of data memory usage, assign the same bank to interrupt sources which are not nested.

Example: Saving /restoring registers during interrupt task using bank changeover.

```
PINT1 : LD      RBS, n          ; RBS ← n (Bank changeover)
        Interrupt processing
        RETI                    ; Maskable interrupt return (Bank restoring)
```

## 1.6 Program Status Word (PSW)

The program status word (PSW) consists of a register bank selector (RBS) and four flags, and the PSW is assigned to address $003F_H$ in the SFR.

The RBS can be read and written using the memory access instruction (e. g. [LD A, (003FH)], [LD (003FH), A], however the flags can only be read. When writing to the PSW, the change specified by the instruction is made without writing data to the flags. For example, when the instruction [LD (003FH), 05H] is executed, "5" is written to the RBS and the JF is set to "1", but the other flags are not affected.

[PUSH PSW] and [POP PSW] are the PSW access instructions.

### 1.6.1 Register Bank Selector (RBS)

The register bank selector (RBS) is a 4-bit register used to select general-purpose register banks. For example, when RBS = 2, bank 2 is currently selected. During reset, the RBS is initialized to "0".

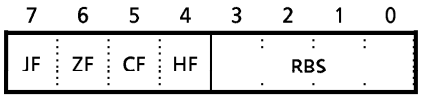



Figure 1-6. PSW (Flags, RBS) Configuration

### 1.6.2 Flags

The flags are configured with the upper 4 bits : a zero flag, a carry flag, a half carry flag and a jump status flag. The flags are set or cleared under conditions specified by the instruction. These flags except the half carry flag are used as jump condition "cc" for conditional jump instructions [JR cc, $ + 2 + d]/[JRS cc, $ + 2 + d]. After reset, the jump status flag is initialized to "1", other flags are not affected.

(1) **Zero flag (ZF)**

The ZF is set to "1" if the operation result or the transfer data is $00_H$ (for 8-bit operations and data transfers)/$0000_H$ (for 16-bit operations); otherwise the ZF is cleared to "0".

During the bit manipulation instructions [SET, CLR, and CPL], the ZF is set to "1" if the contents of the specified bit is "0"; otherwise the ZF is cleared to "0".

This flag is set to "1" when the upper 8 bits of the product are $00_H$ during the multiplication instruction [MUL], and when $00_H$ for the remainder during the division instruction [DIV]; otherwise it is cleared to "0".

(2) **Carry flag (CF)**

The CF is set to "1" when a carry out of the MSB (most significant bit) of the result occurred during addition or when a borrow into the MSB of the result occurred during subtraction; otherwise the CF is cleared to "0". During division, this flag is set to "1" when the divisor is $00_H$ (divided by zero error), or when the quotient is $100_H$ or higher (overflow error); otherwise it is cleared. The CF is also affected during the shift/rotate instructions [SHLC, SHRC, ROLC, and RORC]. The data shifted out from a register is set to the CF.

This flag is also a 1-bit register (a boolean accumulator) for the bit manipulation instructions.

Set/clear/complement are possible with the CF manipulation instructions.

Example1 : Bit manipulation (The result of exclusive-OR between bit 5 content of address $07_H$ and bit 0 content of address $9A_H$ is written to bit 2 of address $01_H$.)

```
LD      CF, (0007H) . 5      ; (0001H)2 ← (0007H)5 ∀ (009AH)0
XOR     CF, (009AH) . 0
LD      (0001H) . 2, CF
```

(3) **Half carry flag (HF)**

The HF is set to "1" when a carry occurred between bits 3 and 4 of the operation result during an 8-bit addition, or when a borrow occurred from bit 4 into bit 3 of the result during an 8-bit subtraction; otherwise the HF is cleared to "0". This flag is useful in the decimal adjustment for BCD operations (adjustments using the [DAA r], or [DAS r] instructions).

Example : BCD operation
(The A becomes $47_H$ after executing the following program when $A = 19_H$, $B = 28_H$)

```
ADD     A, B        ; A ← 41H, HF ← 1
DAA     A           ; A ← 41H + 06H = 47H (decimal-adjust)
```

(4) **Jump status flag (JF)**

Zero or carry information is set to the JF after operation (e. g. INC, ADD, CMP, TEST).
The JF provides the jump condition for conditional jump instructions [JR T/F, $ + 2 + d], [JRS T/F, $ + 2 + d] (T or F is a condition code). Jump is performed if the JF is "1" for a true condition (T), or the JF is "0" for a false condition (F).
The JF is set to "1" after executing the load/exchange/swap/nibble rotate/jump instruction, so that [JRS T, $ + 2 + d] and [JR T, $ + 2 + d] can be regarded as an unconditional jump instruction.

Example : Jump status flag and conditional jump instruction

```
INC     A
JRS     T, SLABLE1      ; Jump when a carry is caused by the immediately
 ⋮                        preceding operation instruction.
LD      A, (HL)
JRS     T, SLABLE2      ; JF is set to "1" by the immediately preceding
 ⋮                        instruction, making it an unconditional jump
                          instruction.
```

Example : The accumulator and flags become as shown below after executing the following instructions when the WA register pair, the HL register pair, the data memory at address $00C5_H$, the carry flag and the half carry flag contents being "$219A_H$", "$00C5_H$", "$D7_H$", "1" and "0", respectively.

| Instruction | Acc. after execution | Flag after execution | | | |
|---|---|---|---|---|---|
| | | JF | ZF | CF | HF |
| ADDC A, (HL) | 72 | 1 | 0 | 1 | 1 |
| SUBB A, (HL) | C2 | 1 | 0 | 1 | 0 |
| CMP A, (HL) | 9A | 0 | 0 | 1 | 0 |
| AND A, (HL) | 92 | 0 | 0 | 1 | 0 |
| LD A, (HL) | D7 | 1 | 0 | 1 | 0 |
| ADD A, 66H | 00 | 1 | 1 | 1 | 1 |

| Instruction | Acc. after execution | Flag after execution | | | |
|---|---|---|---|---|---|
| | | JF | ZF | CF | HF |
| INC A | 9B | 0 | 0 | 1 | 0 |
| ROLC A | 35 | 1 | 0 | 1 | 0 |
| RORC A | CD | 0 | 0 | 0 | 0 |
| ADD WA, 0F508H | 16A2 | 1 | 0 | 1 | 0 |
| MUL W, A | 13DA | 0 | 0 | 1 | 0 |
| SET A.5 | BA | 1 | 1 | 1 | 0 |

## 1.7 Stack and Stack Pointer

### 1.7.1 Stack

The stack provides the area in which the return address or status, etc. are saved before a jump is performed to the processing routine during the execution of a subroutine call instruction or the acceptance of an interrupt. On a subroutine call instruction [CALL a] / [CALLP n] / [CALLV n], the contents of the PC (the return address) is saved; on an interrupt acceptance, the contents of the PC and the PSW are saved (the PSW is pushed first, followed by $PC_H$ and $PC_L$). Therefore, a subroutine call occupies two bytes on the stack; an interrupt occupies three bytes.
When returning from the processing routine, executing a subroutine return instruction [RET] restores the contents to the PC from the stack; executing an interrupt return instruction [RETI] / [RETN] restores the contents to the PC and the PSW (the $PC_L$ is popped first, followed by $PC_H$ and PSW).
The stack can be located anywhere within the data memory space except the register bank area, therefore the stack depth is limited only by the free data memory size.

### 1.7.2 Stack Pointer (SP)

The stack pointer (SP) is a 16-bit register containing the address of the next free locations on the stack.

The SP is post-decremented when a subroutine call or a push instruction is executed, or when an interrupt is accepted; and the SP is pre-incremented when a return or a pop instruction is executed. Figure 1-8 shows the stacking order.

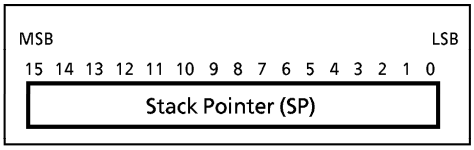



Figure 1-7. Stack Pointer

The SP is not initialized hardware-wise but requires initialization by an initialize routine (sets the highest stack address). [LD SP, mn], [LD SP, gg] and [LD gg, SP] are the SP access instructions (mn ; 16-bit immediate data, gg ; register pair).

Example 1 : To initialize the SP

```
LD      SP, 043FH       ; SP←043F_H
```

Example 2 : To read the SP

```
LD      HL, SP          ; HL←SP
```

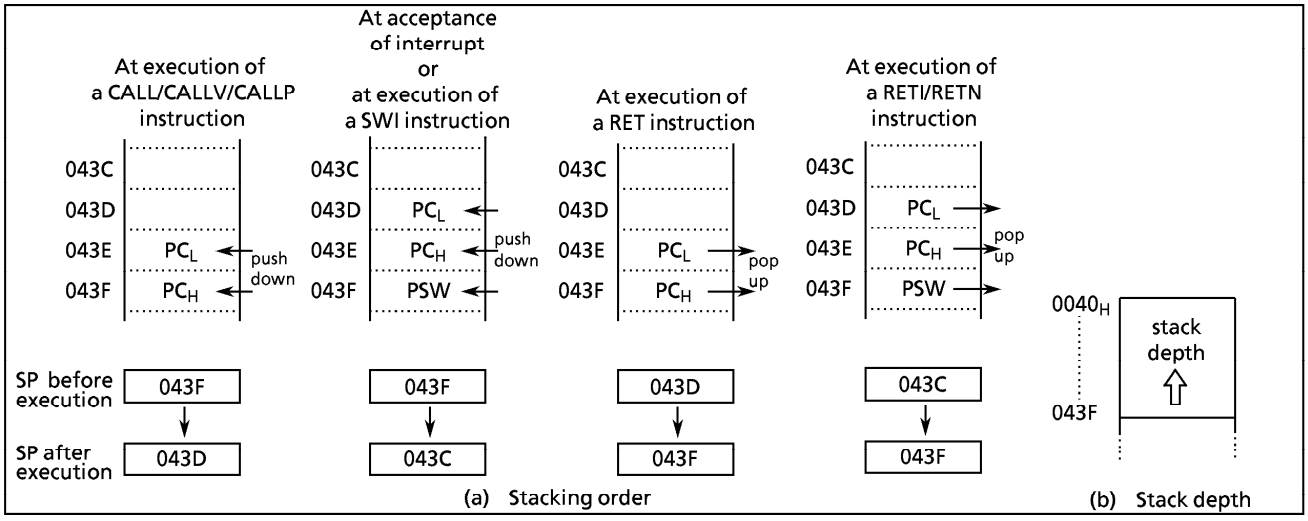



Figure 1-8. Stack

## 1.8 System Clock Controller

The system clock controller consists of a clock generator, a timing generator, and a stand-by controller.

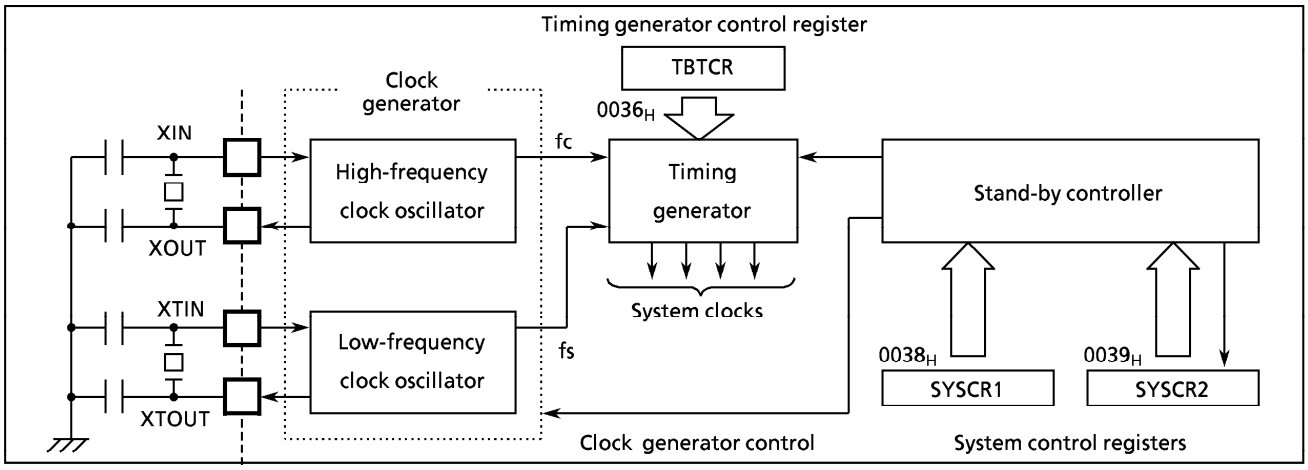



Figure 1-9. System Clock Controller

### 1.8.1 Clock Generator

The clock generator generates the basic clock which provides the system clocks supplied to the CPU core and peripheral hardware. It contains two oscillation circuits: one for the high-frequency clock and one for the low-frequency clock. Power consumption can be reduced by switching of the system clock controller to low-power operation based on the low-frequency clock.

The high-frequency (fc) and low-frequency (fs) clocks can be easily obtained by connecting a resonator between the XIN/XOUT and XTIN/XTOUT pins, respectively. Clock input from an external oscillator is also possible. In this case, external clock is applied to the XIN/XTIN pin with the XOUT/XTOUT pin not connected. The 87CH21/M21 are not provided an RC oscillation.

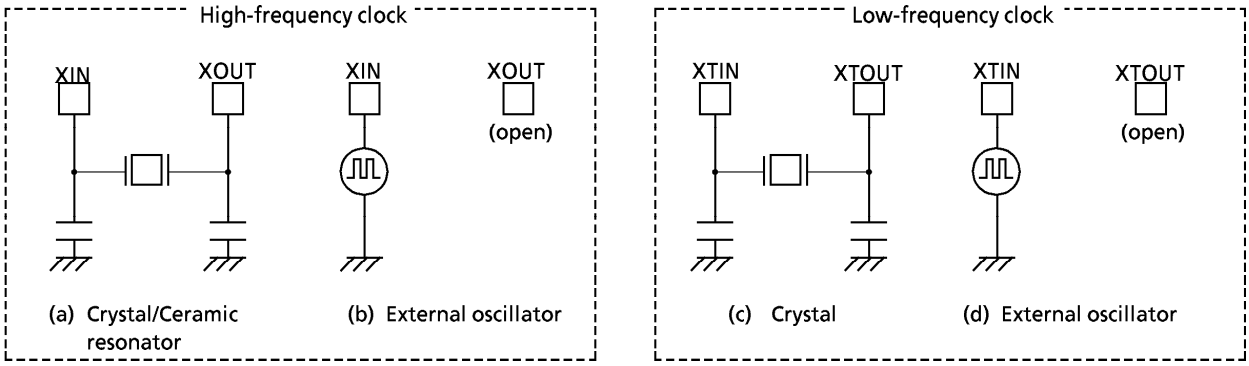



Figure 1-10. Examples of Resonator Connection

*Note : Accurate Adjustment of the Oscillation Frequency:*
*Although no hardware to externally and directly monitor the basic clock pulse is not provided, the oscillation frequency can be adjusted by making the program to output fixed frequency pulses to the port while disabling all interrupts and monitoring this pulse. With a system requiring adjustment of the oscillation frequency, the adjusting program must be created beforehand.*

### 1.8.2 Timing Generator

The timing generator generates from the basic clock the various system clocks supplied to the CPU core and peripheral hardware. The timing generator provides the following functions :

① Generation of main system clock
② Generation of divider output ($\overline{DVO}$) pulses
③ Generation of source clocks for time base timer
④ Generation of source clocks for watchdog timer
⑤ Generation of internal source clocks for timer/counters TC1 – TC3, TC5
⑥ Generation of internal clocks for serial interfaces SIO1 and SIO2
⑦ Generation of warm-up clocks for releasing STOP mode
⑧ Generation of a clock for releasing reset output

(1) Configuration of Timing Generator

The timing generator consists of a 21-stage divider with a divided-by-4 prescaler, a main system clock generator, and machine cycle counters. An input clock to the 7th stage of the divider depends on the operating mode and DV7CK (bit 4 in TBTCR) shown in Figure 1-11 as follows.

During reset and at releasing STOP mode, the divider is cleared to "0", however, the prescaler is not cleared.

① In the single-clock mode
A divided-by-256 of high-frequency clock (fc/$2^8$) is input to the 7th stage of the divider.
Do not set DVCK to "1" in the single-clock mode.

② In the dual-clock mode
During NORMAL2 or IDLE2 mode (SYSCK = 0), an input clock to the 7th stage of the divider can be selected either "fc/$2^8$" or "fs" with DV7CK.
During SLOW or SLEEP mode (SYSCK = 1), fs is automatically input to the 7th stage. To input clock to the 1st stage is stopped ; output from the 1st to 6th stages is also stopped.

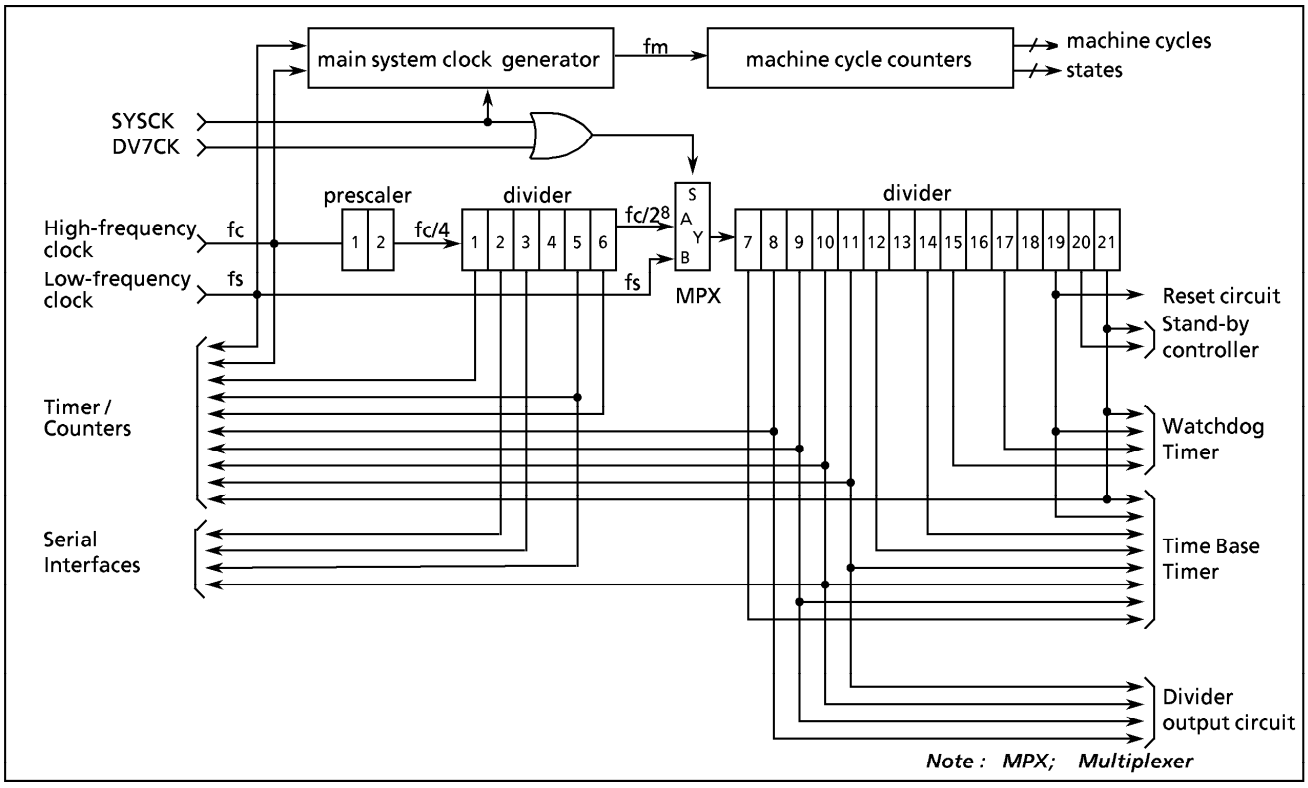



Figure 1-11. Configuration of Timing Generator

**TBTCR** ($0036_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| (DVOEN) | (DVOCK) | | **DV7CK** | (TBTEN) | (TBTCK) | | |

(Initial value: 0**0 0***)

| | | | |
|---|---|---|---|
| DV7CK | Selection of input clock to the 7th stage of the divider | 0 : fc/$2^8$ [Hz]<br>1 : fs | R/W |

*Note1 : fc ; high-frequency clock [Hz], fs ; low-frequency clock [Hz], * ; don't care*
*Note 2 : Do not set DV7CK to "1" in the single-clock mode.*
*Note 3 : Do not set DV7CK to "1" before low-frequency clock is stable in the dual-clock mode.*

Figure 1-12. Timing Generator Control Register

(2) Machine Cycle
Instruction execution and peripheral hardware operation are synchronized with the main system clock. The minimum instruction execution unit is called an "machine cycle". There are a total of 10 different types of instructions for the TLCS-870 Series: ranging from 1-cycle instructions which require one machine cycle for execution to 10-cycle instructions which require 10 machine cycles for execution.
A machine cycle consists of 4 states (S0 - S3), and each state consists of one main system clock.

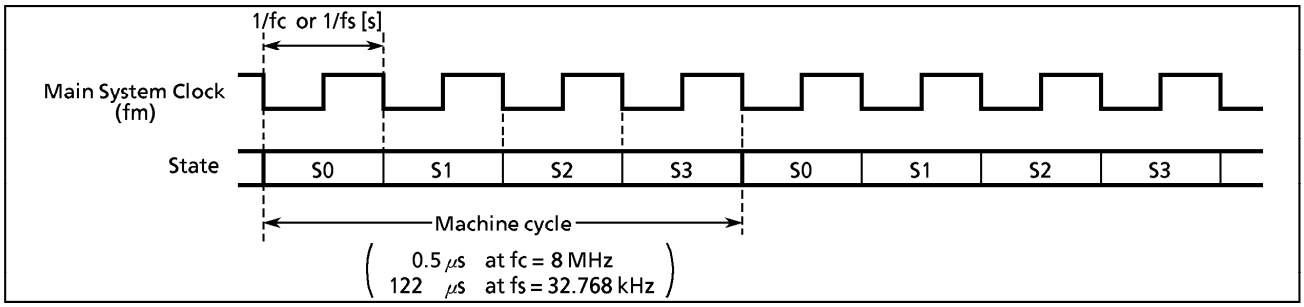



Figure 1-13. Machine Cycle

### 1.8.3 Stand-by Controller

The stand-by controller starts and stops the oscillation circuits for the high-frequency and low-frequency clocks, and switches the main system clock. There are two operating modes: single-clock and dual-clock. These modes are controlled by the system control registers (SYSCR1, SYSCR2).

(1) **Single-clock mode**

Only the oscillation circuit for the high-frequency clock is used, and P21 (XTIN) and P22 (XTOUT) pins are used as input/output ports. In the single-clock mode, the machine cycle time is 4/fc [s] (0.5 μs at fc = 8 MHz).

① NORMAL1 mode

In this mode, both the CPU core and on-chip peripherals operate using the high-frequency clock. In the case where the single-clock mode has been selected as an option, the 87CH21/M21 are placed in this mode after reset.

② IDLE1 mode

In this mode, the internal oscillation circuit remains active, and the CPU and the watchdog timer are halted; however, on-chip peripherals remain active (operate using the high-frequency clock). IDLE1 mode is started by setting IDLE bit in the system control register 2 (SYSCR2), and IDLE1 mode is released to NORMAL1 mode by an interrupt request from on-chip peripherals or external interrupt inputs. When IMF (interrupt master enable flag) is "1" (interrupt enable), the execution will resume upon acceptance of the interrupt, and the operation will return to normal after the interrupt service is completed. When IMF is "0" (interrupt disable), the execution will resume with the instruction which follows IDLE mode start instruction.

③ STOP1 mode

In this mode, the internal oscillation circuit is turned off, causing all system operations to be halted. The internal status immediately prior to the halt is held with the lowest power consumption during this mode. The output status of all output ports can be set to either output hold or high-impedance under software control.

STOP1 mode is started by setting STOP bit in the system control register 1 (SYSCR1), and STOP1 mode is released by an input (either level-sensitive or edge-sensitive can be programmably selected) to the $\overline{\text{STOP}}$ pin. After the warming-up period is completed, the execution resumes with the next instruction which follows the STOP mode start instruction.

(2) **Dual-clock mode**

Both high-frequency and low-frequency oscillation circuits are used in this mode. Pins P21 (XTIN) and P22 (XTOUT) cannot be used as input/output ports. The main system clock is obtained from the high-frequency clock in NORMAL2 and IDLE2 modes, and is obtained from the low-frequency clock in SLOW and SLEEP modes. The machine cycle time is 4/fc [s] (0.5 $\mu$s at fc = 8 MHz) in NORMAL2 and IDLE2 modes, and 4/fs [s] (122 $\mu$s at fs = 32.768 kHz) in SLOW and SLEEP modes. *Note that the 87PP21 is placed in the single-clock mode during reset.* To use the dual-clock mode, the low-frequency oscillator should be turned on by executing [SET (SYSCR2).XTEN] instruction.

① NORMAL2 mode

In this mode, the CPU core operates using the high-frequency clock. On-chip peripherals operate using the high-frequency clock and/or low-frequency clock. In case that the dual-clock mode has been selected by an option, the 87CH21/M21 are placed in this mode after reset.

② SLOW mode

This mode can be used to reduce power-consumption by turning off oscillation of the high-frequency clock. The CPU core and on-chip peripherals operate using the low-frequency clock.

Switching back and forth between NORMAL2 and SLOW modes is performed by the system control register 2.

③ IDLE2 mode

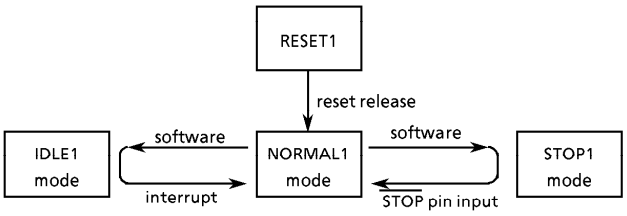
In this mode, the internal oscillation circuits remain active. The CPU and the watchdog timer are halted; however, on-chip peripherals remain active (operate using the high-frequency clock and/or the low-frequency clock). Starting and releasing of IDLE2 mode are the same as for IDLE1 mode, except that operation returns to NORMAL2 mode.

④ SLEEP mode

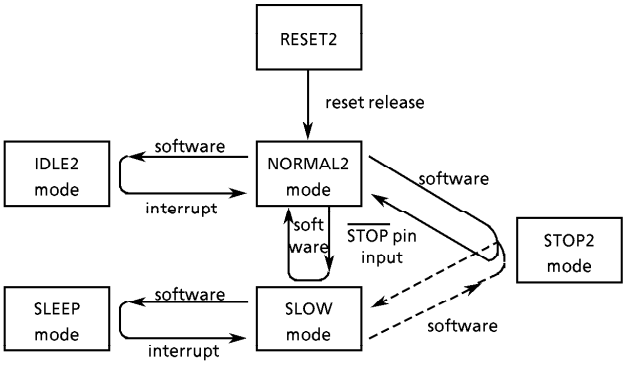
In this mode, the internal oscillation circuit of the low-frequency clock remains active. The CPU, the watchdog timer, and the internal oscillation circuit of the high- frequency clock are halted; however, on-chip peripherals remain active (operate using the low-frequency clock). Starting and releasing of SLEEP mode is the same as for IDLE1 mode, except that operation returns to SLOW mode.

⑤ STOP2 mode

As in STOP1 mode, all system operations are halted in this mode.




(a) Single-clock mode




(b) Dual-clock mode

*Note : NORMAL1 and NORMAL2 modes are generically called NORMAL; STOP1 and STOP2 are called STOP; and IDLE1, IDLE2 and SLEEP are called IDLE.*

| Operating mode | | Frequency | | CPU core | On-chip Peripherals | Machine cycle time |
|---|---|---|---|---|---|---|
| | | High-frequency | Low-frequency | | | |
| Single-Clock | RESET1 | turning on oscillation | turning off oscillation | reset | reset | 4/fc [s] |
| | NORMAL1 | | | operate | operate | |
| | IDLE1 | | | halt | | |
| | STOP1 | turning off oscillation | | | halt | — |
| Dual-Clock | RESET2 | turning on oscillation | turning on oscillation | reset | reset | 4/fc [s] |
| | NORMAL2 | | | High-frequency | operate (High and/or Low) | |
| | IDLE2 | | | halt | | |
| | SLOW | turning off oscillation | | Low-frequency | Low-frequency | 4/fs [s] |
| | SLEEP | | | halt | | |
| | STOP2 | | turning off oscillation | | halt | — |

Figure 1-14. Operating Mode Transition Diagram

System Control Register 1

**SYSCR1** ($0038_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| STOP | RELM | RETM | OUTEN | WUT | | | |

(Initial value: 0000 00**)

| | | | |
|---|---|---|---|
| STOP | STOP mode start | 0 : CPU core and peripherals remain active<br>1 : CPU core and peripherals are halted (start STOP mode) | R/W |
| RELM | Release method for STOP mode | 0 : Edge-sensitive release<br>1 : Level-sensitive release | |
| RETM | Operating mode after STOP mode | 0 : Return to NORMAL mode<br>1 : Return to SLOW mode | |
| OUTEN | Port output control during STOP mode | 0 : High-impedance<br>1 : Remain unchanged | |
| WUT | Warming-up time at releasing STOP mode | 00 : $3\times2^{19}$ / fc or $3\times2^{13}$ / fs [s]<br>01 : $2^{19}$ / fc or $2^{13}$ / fs<br>1* : Reserved | |

*Note 1 :* *Always set RETM to "0" when transiting from NORMAL1 mode to STOP1 mode and from NOMAL2 mode to STOP2 mode. Always set RETM to "1" when transiting from SLOW mode to STOP2 mode.*

*Note 2 :* *When STOP mode is released with $\overline{\text{RESET}}$ pin input, a return is made to NORMAL mode regardless of the RETM contents.*

*Note 3 :* fc ; *high-frequency clock* [Hz]
fs ; *low-frequency clock* [Hz]
* ; *don't care*

*Note 4 :* *Bits 1 and 0 in SYSCR1 are read in as undefined data when a read instruction is executed.*

System Control Register 2

**SYSCR2** ($0039_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| XEN | XTEN | SYSCK | IDLE | | | | |

(Initial value: 10/100 ****)

| | | | |
|---|---|---|---|
| XEN | High-frequency oscillator control | 0 : Turn off oscillation<br>1 : Turn on oscillation | R/W |
| XTEN | Low-frequency oscillator control | 0 : Turn off oscillation<br>1 : Turn on oscillation | |
| SYSCK | Main system clock select (write)/main system clock monitor (read) | 0 : High-frequency clock<br>1 : Low-frequency clock | |
| IDLE | IDLE mode start | 0 : CPU and watchdog timer remain active<br>1 : CPU and watchdog timer are stopped (start IDLE mode) | |

*Note 1 :* *A reset is applied ($\overline{\text{RESET}}$ pin output goes low) if both XEN and XTEN are cleared to "0".*

*Note 2 :* *Do not clear XEN to "0" when SYSCK = 0, and do not clear XTEN to "0" when SYSCK = 1.*

*Note 3 :* *WDT; watchdog timer, * ; don't care*

*Note 4 :* *Bits 3 - 0 in SYSCR2 are always read in as "1" when a read instruction is executed.*

*Note 5 :* *An optional initial value can be selected for XTEN. Always specify when ordering ES (engineering sample).*

| XTEN | operating mode after reset |
|---|---|
| 0 | Single-clock mode (NORMAL1) |
| 1 | Dual-clock mode (NORMAL2) |

Figure 1-15. System Control Registers

## 1.8.4 Operating Mode Control

(1) **STOP** mode (STOP1, STOP2)

STOP mode is controlled by the system control register 1 (SYSCR1) and the $\overline{\text{STOP}}$ pin input. The $\overline{\text{STOP}}$ pin is also used both as a port P20 and an $\overline{\text{INT5}}$ (external interrupt input 5) pin. STOP mode is started by setting STOP (bit 7 in SYSCR1 ) to "1". During STOP mode, the following status is maintained.

① Oscillations are turned off, and all internal operations are halted.

② The data memory, registers (except for DBR) and port output latches are all held in the status in effect before STOP mode was entered. The port output can be select either output hold or high-impedance by setting OUTEN ( bit 4 in SYSCR1).

③ The divider of the timing generator is cleared to "0".

④ The program counter holds the address of the instruction following the instruction which started the STOP mode.

STOP mode includes a level-sensitive release mode and an edge-sensitive release mode, either of which can be selected with RELM (bit 6 in SYSCR1).

a. Level-sensitive release mode (RELM = 1)

In this mode, STOP mode is released by setting the $\overline{\text{STOP}}$ pin high. This mode is used for capacitor back-up when the main power supply is cut off and long term battery back-up.

When the $\overline{\text{STOP}}$ pin input is high, executing an instruction which starts the STOP mode will not place in STOP mode but instead will immediately start the release sequence (warm-up). Thus, to start STOP mode in the level-sensitive release mode, it is necessary for the program to first confirm that the $\overline{\text{STOP}}$ pin input is low. The following method can be used for confirmation:

- Using an external interrupt input $\overline{\text{INT5}}$ ($\overline{\text{INT5}}$ is a falling edge-sensitive input).

Example : Starting STOP mode with an INT5 interrupt.

```
PINT5 :   TEST   (P2) . 0              ;  To reject noise, the STOP mode does not start if
          JRS    F, SINT5                  port P20 is at high
          LD     (SYSCR1), 01000000B     ;  Sets up the level-sensitive release mode.
          SET    (SYSCR1) . 7            ;  Starts STOP mode
          LDW    (IL),1110011101010111B  ;  IL12, 11, 7, 5, 3 ← 0
SINT5 :   RETI
```

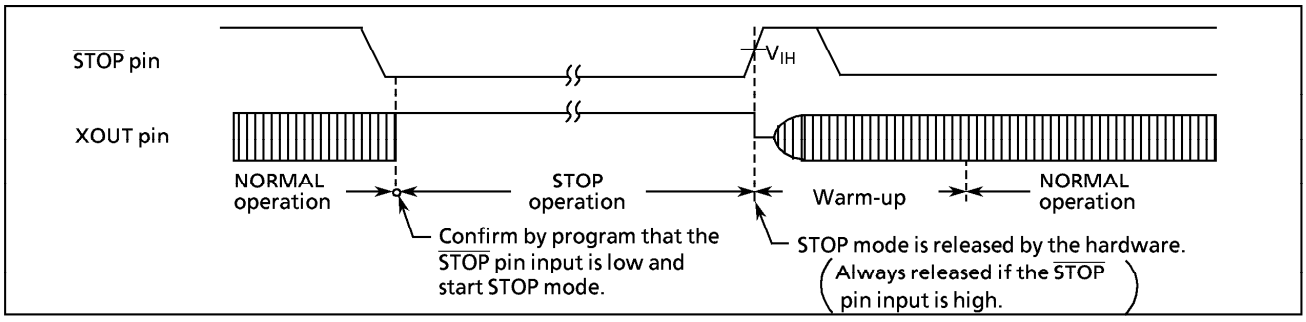



Figure 1-16. Level-sensitive Release Mode

*Note 1 : After warm-up start, even if $\overline{\text{STOP}}$ pin input is low again, STOP mode does not restart.*

*Note 2 : When changing to the level-sensitive release mode from the edge-sensitive release mode, the release mode is not switched until a rising edge of the $\overline{\text{STOP}}$ pin input is detected.*

b. Edge-sensitive release mode (RELM = 0)

In this mode, STOP mode is released by a rising edge of the $\overline{STOP}$ pin input. This is used in applications where a relatively short program is executed repeatedly at periodic intervals. This periodic signal (for example, a clock from a low-power consumption oscillator) is input to the $\overline{STOP}$ pin.

In the edge-sensitive release mode, STOP mode is started even when the $\overline{STOP}$ pin input is high.

Example : Starting STOP mode operation in the edge-sensitive release mode

```
LD          (SYSCR1), 10000000B
```

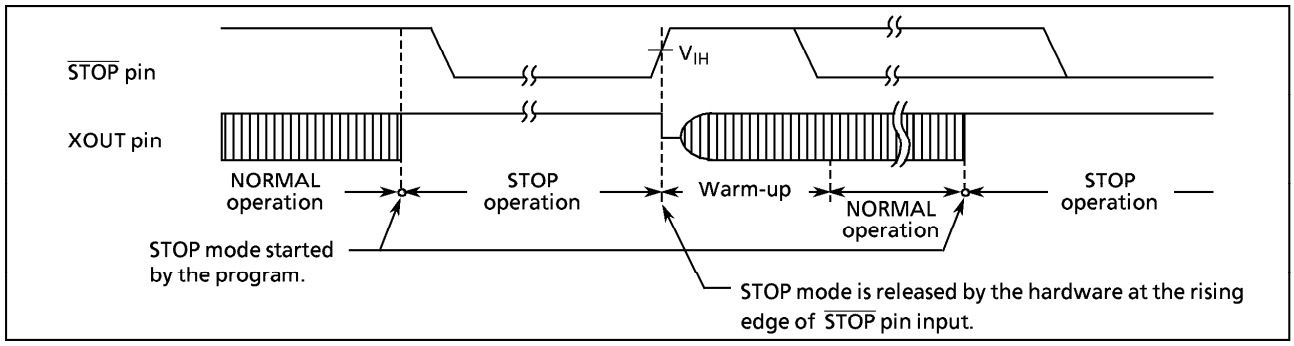



Figure 1-17. Edge-sensitive Release Mode

STOP mode is released by the following sequence:

① When returning to NORMAL2, both the high-frequency and low-frequency clock oscillators are turned on ; when returning to SLOW mode, only the low-frequency clock oscillator is turned on. When returning to NORMAL 1, only the high-frequency clock oscillator is turned on.

② A warming-up period is inserted to allow oscillation time to stabilize. During warm-up, all internal operations remain halted. Two different warming-up times can be selected with WUT ( bits 2 and 3 in SYSCR1) as determined by the resonator characteristics.

③ When the warming-up time has elapsed, normal operation resumes with the instruction following the STOP mode start instruction (e.g. [SET (SYSCR1). 7]). The start is made after the divider of the timing generator is cleared to "0".

Table 1-1. Warming-up Time example

| Return to NORMAL1 mode | | | Return to SLOW mode | |
|---|---|---|---|---|
| WUT | At fc = 4.194304 MHz | At fc = 8 MHz | WUT | At fs = 32.768 kHz |
| $3 \times 2^{19}$ / fc [s] | 375 [ms] | 196.6 [ms] | $3 \times 2^{13}$ / fs [s] | 750 [ms] |
| $2^{19}$ / fc | 125 | 65.5 | $2^{13}$ / fs | 250 |

*Note : The warming-up time is obtained by dividing the basic clock by the divider: therefore, the warming-up time may include a certain amount of error if there is any fluctuation of the oscillation frequency when STOP mode is released. Thus, the warming-up time must be considered an approximate value.*

STOP mode can also be released by setting the $\overline{RESET}$ pin low, which immediately performs the normal reset operation.

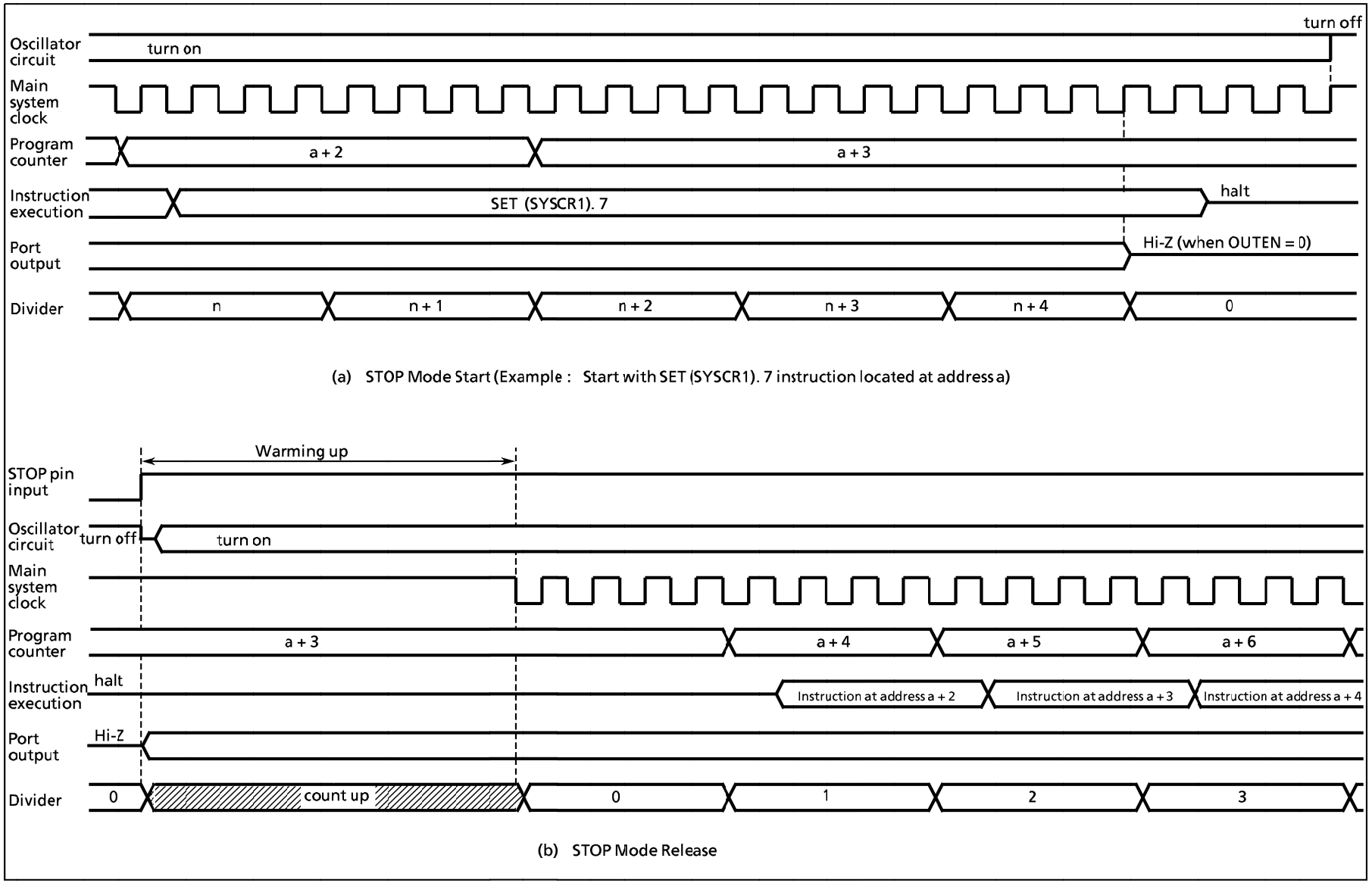



Figure 1-18. STOP Mode Start / Release

*Note : When STOP mode is released with a low hold voltage, the following cautions must be observed. The power supply voltage must be at the operating voltage level before releasing STOP mode. The $\overline{\text{RESET}}$ pin input must also be high, rising together with the power supply voltage. In this case, if an external time constant circuit has been connected, the $\overline{\text{RESET}}$ pin input voltage will increase at a slower rate than the power supply voltage. At this time, there is a danger that a reset may occur if input voltage level of the $\overline{\text{RESET}}$ pin drops below the non-inverting high-level input voltage (hysteresis input).*

(2) **IDLE** mode (IDLE1, IDLE2, SLEEP)

IDLE mode is controlled by the system control register 2 and maskable interrupts. The following status is maintained during IDLE mode.

① Operation of the CPU and watchdog timer is halted. On-chip peripherals continue to operate.
② The data memory, CPU registers and port output latches are all held in the status in effect before IDLE mode was entered.
③ The program counter holds the address of the instruction following the instruction which started IDLE mode.

Example : Starting IDLE mode.

```
SET          (SYSCR2) . 4
```

IDLE mode includes a normal release mode and an interrupt release mode. Selection is made with the interrupt master enable flag (IMF). Releasing the IDLE mode returns from IDLE1 to NORMAL1, from IDLE2 to NORMAL2, and from SLEEP to SLOW mode.

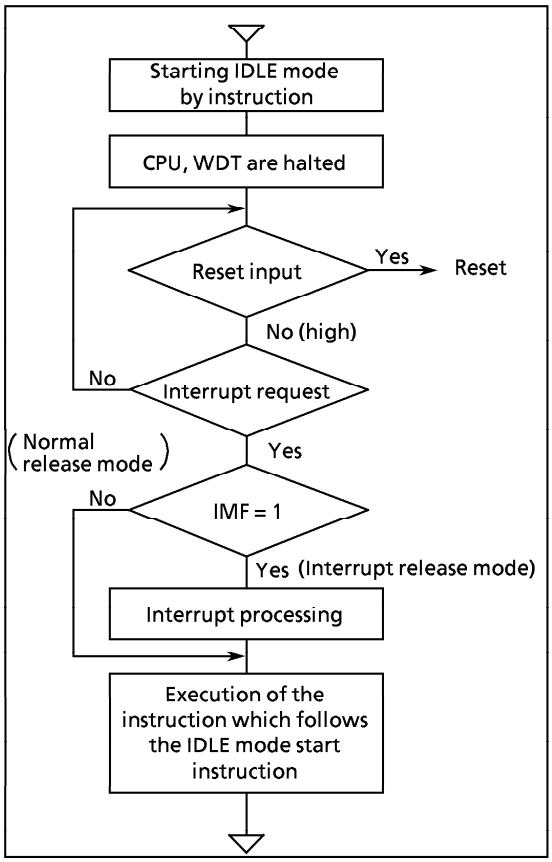



Figure 1-19. IDLE Mode

a. Normal release mode (IMF = "0")

IDLE mode is released by any interrupt source enabled by the individual interrupt enable flag (EF) or an external interrupt 0 ($\overline{\text{INT0}}$ pin) request. Execution resumes with the instruction following the IDLE mode start instruction (e.g. [SET (SYSCR2).4]).

b. Interrupt release mode (IMF = "1")

IDLE mode is released and interrupt processing is started by any interrupt source enabled with the individual interrupt enable flag (EF) or an external interrupt 0 ($\overline{\text{INT0}}$ pin) request. After the interrupt is processed, the execution resumes from the instruction following the instruction which started IDLE mode.

IDLE mode can also be released by setting the $\overline{\text{RESET}}$ pin low, which immediately performs the reset operation. After reset, the 87CH21/M21 are placed in NORMAL2 mode (the 87PP21 is placed in NORMAL1 mode).

*Note : When a watchdog timer interrupt is generated immediately before the IDLE mode is started, the watchdog timer interrupt will be processed but IDLE mode will not be started.*

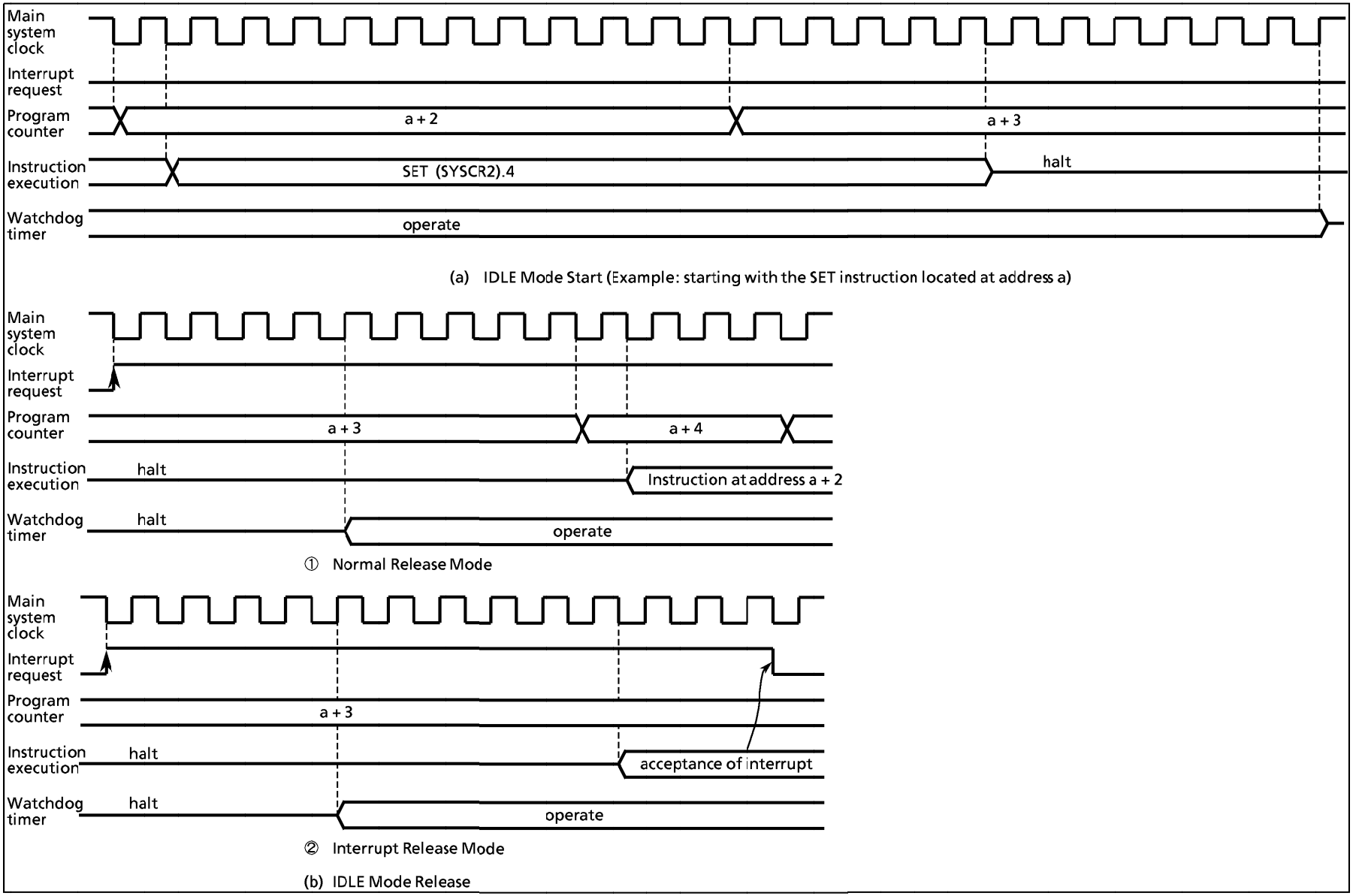



Figure 1-20. IDLE Mode Start/Release

(3) **SLOW** mode

SLOW mode is controlled by the system control register 2 (SYSCR2) and the timer/counter 2 (TC2).

a. Switching from NORMAL2 mode to SLOW mode

First, set SYSCK (bit 5 in SYSCR2) to switch the main system clock to the low-frequency clock. Next, clear XEN (bit 7 in SYSCR2) to turn off high-frequency oscillation.

When the low-frequency clock oscillation is unstable, wait until oscillation stabilizes before performing the above operations. The timer/counter 2 (TC2) can conveniently be used to confirm that low-frequency clock oscillation has stabilized.

*Note : The high frequency clock can be continued oscillation in order to return to NORMAL2 mode from SLOW mode quickly. Always turn off oscillation of high frequency clock when switching from SLOW mode to STOP mode.*

Example1 : Switching from NORMAL2 mode to SLOW mode.

```
        SET     (SYSCR2) . 5    ; SYSCK←1   (Switches the main system clock to the
                                              low-frequency clock)
        CLR     (SYSCR2) . 7    ; XEN←0     (turns off high-frequency oscillation)
```

Example2 : Switching to SLOW mode after low-frequency clock oscillation has stabilized.

```
        LD      (TC2CR), 14H    ; Sets TC2 mode
                                  (timer mode, source clock : fs)
        LDW     (TREG2), 8000H  ; Sets warming-up time
                                  (according to Xtal characteristics)
        LD      (TC2CR), 34H    ; Starts TC2
        :
PINTTC2 : LD    (TC2CR), 10H    ; Stops TC2
        SET     (SYSCR2) . 5    ; SYSCK←1
        CLR     (SYSCR2) . 7    ; XEN←0
        RETI
        :
VINTTC2 : DW    PINTTC2         ; INTTC2 vector table
```

b. Switching from SLOW mode to NORMAL2 mode

First, set XEN (bit 7 in SYSCR2) to turn on the high-frequency oscillation. When time for stabilization (warm-up) has been taken by the timer/counter 2 (TC2), clear SYSCK (bit 5 in SYSCR2) to switch the main system clock to the high-frequency clock.

SLOW mode can also be released by setting the $\overline{\text{RESET}}$ pin low, which immediately performs the reset operation. After reset, the 87CH21/M21 are placed in NORMAL mode.

*Note1 : After the SYSCK is cleared to "0", the CPU core operate using low frequency clock when the main system clock is switching from low frequency clock to high frequency clock.*

*Note2 : SLOW mode can also be released by setting the $\overline{\text{RESET}}$ pin low, which immediately performs the reset operation. After reset, the 87CH21/M21 are placed in NORMAL2 mode. (The PP21 is placed in NORMAL1 mode)*

Example : Switching from SLOW mode to NORMAL2 mode (fc = 8 MHz, warming-up time is about 7.9 ms).

```
                SET     (SYSCR2) . 7        ; XEN←1      (turns on high-frequency oscillation)
                LD      (TC2CR), 10H        ; Sets TC2 mode
                                              (timer mode, source clock: fc)
                LD      (TREG2 + 1), 0F8H   ; Sets the warming-up time
                                              (according to frequency and resonator characteristics)
                LD      (TC2CR), 30H        ; Starts TC2
                 ⋮
PINTTC2 :       LD      (TC2CR), 10H        ; Stops TC2
                CLR     (SYSCR2) . 5        ; SYSCK←0    (Switches the main system clock to the
                                                          high-frequency clcok)
                RETI
                 ⋮
VINTTC2 :       DW      PINTTC2             ; INTTC2 vector table
```

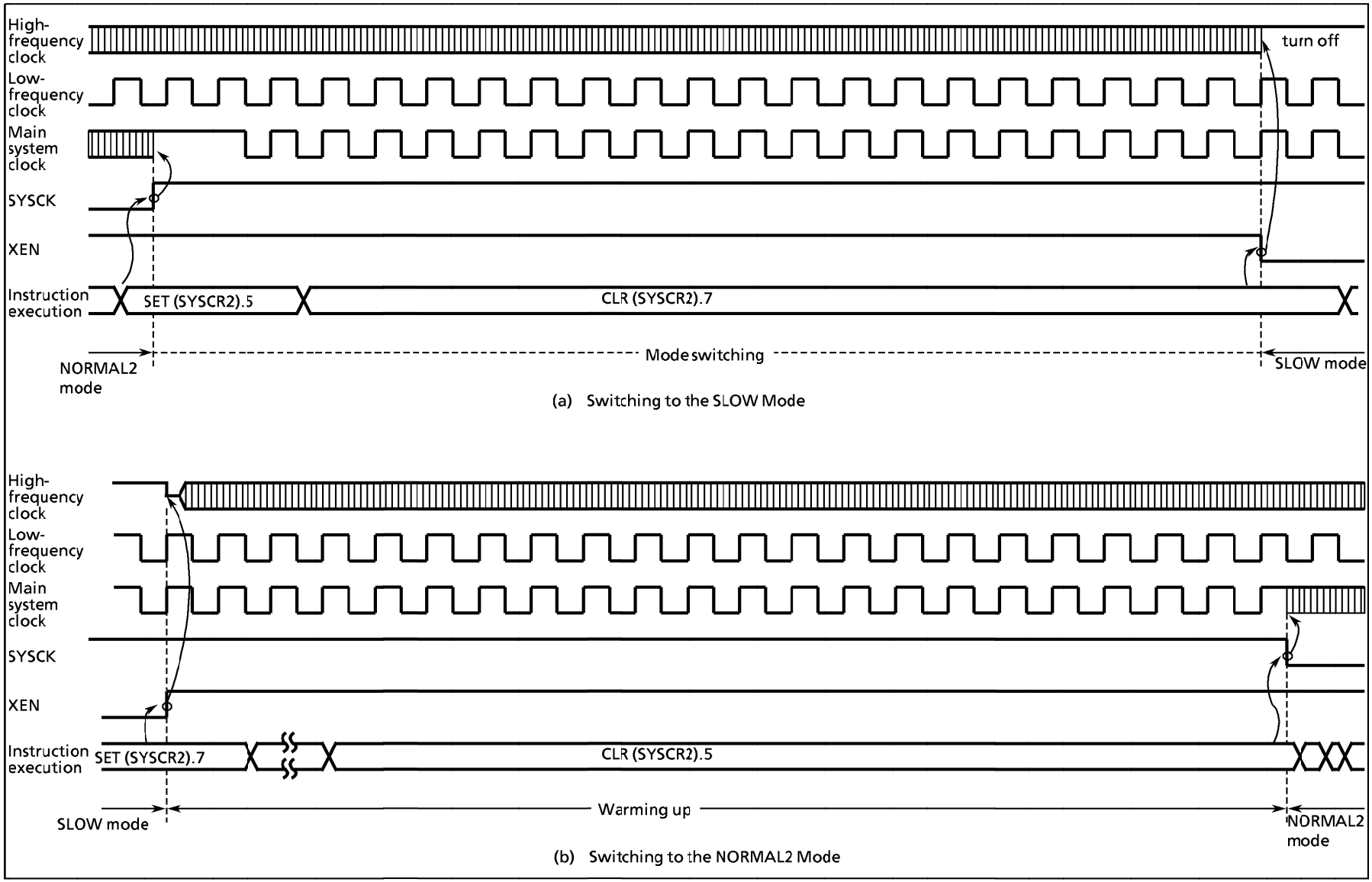



Figure 1-21. Switching between the NORMAL2 and SLOW Modes

## 1.9 Interrupt Controller

The 87CH21/M21 each have a total of 14 interrupt sources: 5 externals and 9 internals. Nested interrupt control with priorities is also possible. Two of the internal sources are pseudo non-maskable interrupts; the remainder are all maskable interrupts.

Interrupt latches (IL) that hold the interrupt requests are provided for interrupt sources. Each interrupt vector is independent.

The interrupt latch is set to "1" when an interrupt request is generated and requests the CPU to accept the interrupt. The acceptance of maskable interrupts can be selectively enabled and disabled by the program using the interrupt master enable flag (IMF) and the individual interrupt enable flags (EF). When two or more interrupts are generated simultaneously, the interrupt is accepted in the highest priority order as determined by the hardware. Figure 1-22 shows the interrupt controller.

Table 1-2. Interrupt Sources

| Interrupt Source | | | Enable Condition | Interrupt Latch | Vector Table Address | Priority |
|---|---|---|---|---|---|---|
| Internal/ External | (Reset) | | Non-Maskable | — | $FFFE_H$ | High 0 |
| Internal | INTSW | (Software interrupt) | Pseudo non-maskable | — | $FFFC_H$ | 1 |
| Internal | INTWDT | (Watchdog Timer interrupt) | | $IL_2$ | $FFFA_H$ | 2 |
| External | INT0 | (External interrupt 0) | IMF = 1, INT0EN = 1 | $IL_3$ | $FFF8_H$ | 3 |
| Internal | INTTC1 | (16-bit TC1 interrupt) | IMF · $EF_4$ = 1 | $IL_4$ | $FFF6_H$ | 4 |
| External | INT1 | (External interrupt 2) | IMF · $EF_5$ = 1 | $IL_5$ | $FFF4_H$ | 5 |
| Internal | INTTBT | (Time Base Timer interrupt) | IMF · $EF_6$ = 1 | $IL_6$ | $FFF2_H$ | 6 |
| External | INT2 | (External interrupt 2) | IMF · $EF_7$ = 1 | $IL_7$ | $FFF0_H$ | 7 |
| Internal | INTTC3 | (8-bit TC3 interrupt) | IMF · $EF_8$ = 1 | $IL_8$ | $FFEE_H$ | 8 |
| Internal | INTSIO1 | (Serial Interface 1 interrupt) | IMF · $EF_9$ = 1 | $IL_9$ | $FFEC_H$ | 9 |
| Internal | INTTC5 | (8-bit TC5 interrupt) | IMF · $EF_{10}$ = 1 | $IL_{10}$ | $FFEA_H$ | 10 |
| External | INT3 | (External interrupt 3) | IMF · $EF_{11}$ = 1 | $IL_{11}$ | $FFE8_H$ | 11 |
| reserved | | | IMF · $EF_{12}$ = 1 | $IL_{12}$ | $FFE6_H$ | 12 |
| Internal | INTSIO2 | (Serial Interface 2 interrupt) | IMF · $EF_{13}$ = 1 | $IL_{13}$ | $FFE4_H$ | 13 |
| Internal | INTTC2 | (16-bit TC2 interrupt) | IMF · $EF_{14}$ = 1 | $IL_{14}$ | $FFE2_H$ | 14 |
| External | INT5 | (External interrupt 5) | IMF · $EF_{15}$ = 1 | $IL_{15}$ | $FFE0_H$ | Low 15 |

### (1) Interrupt Latches ($IL_{15\ to\ 2}$)

Interrupt latches are provided for each source, except for a software interrupt. The latch is set to "1" when an interrupt request is generated, and requests the CPU to accept the interrupt. The latch is cleared to "0" just after the interrupt is accepted. All interrupt latches are initialized to "0" during reset.

The interrupt latches are assigned to addresses $003C_H$ and $003D_H$ in the SFR. Each latch can be cleared to "0" individually by an instruction; however, *the read-modify-write instruction such as bit manipulation or operation instructions cannot be used* (Do not clear the IL2 for a watchdog timer interrupt to "0"). Thus, interrupt requests can be cancelled and initialized by the program. Note that interrupt latches cannot be set to "1" by any instruction.

The contents of interrupt latches can be read out by an instruction. Therefore, testing interrupt requests by software is possible.

Example 1 : Clears interrupt latches

```
LDW     (IL), 1110100000111111B     ; IL12, IL10 to IL6←0
```

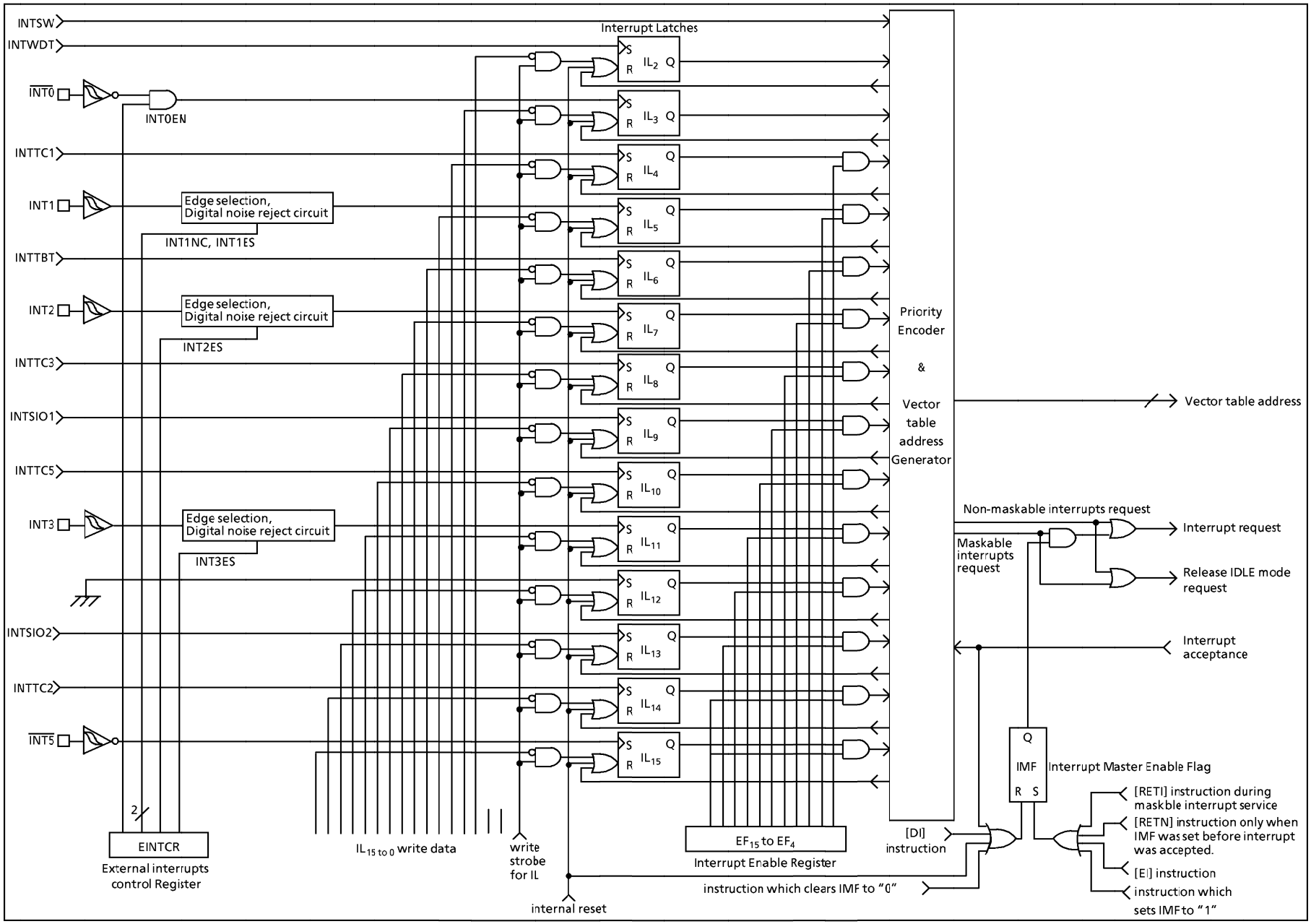



Figure 1-22. Interrupt Controller Block Diagram

Example 2 : Reads interrupt latches

```
LD      WA, (IL)        ; W←IL_H, A←IL_L
```

Example 3: Tests an interrupt latch

```
TEST    (IL).7          ; if IL_7 = 1 then jump
JR      F, SSET
```

(2) **Interrupt Enable Register** (EIR)

The interrupt enable registers (EIR) enable and disable the acceptance of interrupts except for the pseudo non-maskable interrupts (software and watchdog timer interrupts). Pseudo non-maskable interrupts are accepted regardless of the contents of the EIR; however, the pseudo non-maskable interrupts cannot be nested more than once at the same time.

The EIR consists of an interrupt master enable flag (IMF) and individual interrupt enable flags (EF). These registers are assigned to addresses $003A_H$ and $003B_H$ in the SFR, and can be read and written by an instruction (including read-modify-write instructions such as bit manipulation instructions).

① **Interrupt Master enable Flag** (IMF)

The interrupt master enable flag (IMF) enables and disables the acceptance of all interrupts, except for pseudo non-maskable interrupts. Clearing this flag to "0" disables the acceptance of all maskable interrupts. Setting to "1" enables the acceptance of interrupts.

When an interrupt is accepted, this flag is cleared to "0" to temporarily disable the acceptance of maskable interrupts. After execution of the interrupt service program, this flag is set to "1" by the maskable interrupt return instruction [RETI] to again enable the acceptance of interrupts. If an interrupt request has already been occurred, interrupt service starts immediately after execution of the [RETI] instruction.

Pseudo non-maskable interrupts are returned by the [RETN] instruction. In this case, the IMF is set to "1" only when pseudo non-maskable interrupt service is started with interrupt acceptance enabled (IMF = 1). Note that IMF remains "0" when cleared by the interrupt service program.

The IMF is assigned to bit 0 at address $003A_H$ in the SFR, and can be read and written by an instruction. IMF is normally set and cleared by the [EI] and [DI] instructions, and the IMF is initialized to "0" during reset.

② **Individual interrupt Enable Flags** ($EF_{15}$ to $EF_4$)

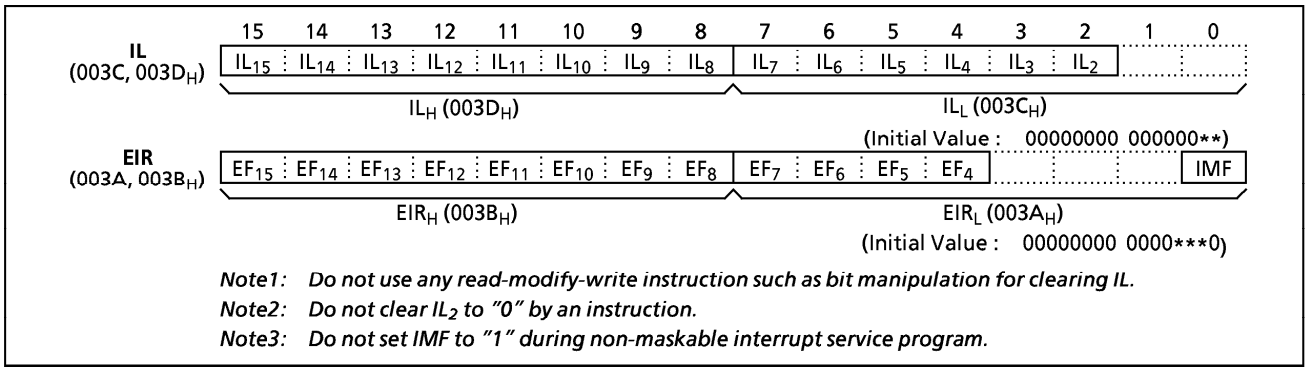
These flags enable and disable the acceptance of individual maskable interrupts, except for an external interrupt 0. Setting the corresponding bit of an individual interrupt enable flag to "1" enables acceptance of an interrupt, setting the bit to "0" disables acceptance.

Example 1 : Sets EF for individual interrupt enable, and sets IMF to "1".

```
LDW     (EIR), 1110100010100001B    ;  EF15 to EF13, EF11, EF7, EF5, IMF←1
```

Example 2 : Sets an individual interrupt enable flag to "1".

```
SET     (EIRH).4                    ;  EF12←1
```




*Note1: Do not use any read-modify-write instruction such as bit manipulation for clearing IL.*
*Note2: Do not clear $IL_2$ to "0" by an instruction.*
*Note3: Do not set IMF to "1" during non-maskable interrupt service program.*

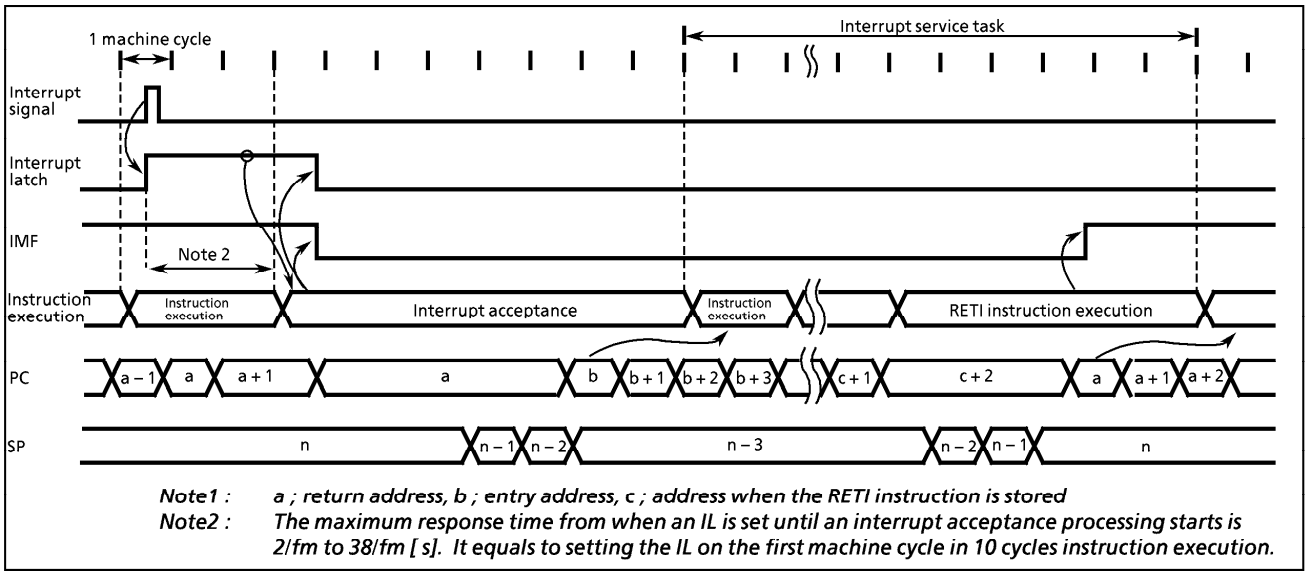
Figure 1-23. Interrupt Latch (IL) and Interrupt Enable Register (EIR)

### 1.9.1 Interrupt Sequence

An interrupt request is held until the interrupt is accepted or the interrupt latch is cleared to "0" by a reset or an instruction. Interrupt acceptance sequence requires 8 machine cycles (4 $\mu$s at fc = 8 MHz in NORMAL mode) after the completion of the current instruction execution. The interrupt service task terminates upon execution of an interrupt return instruction [RETI] (for maskable interrupts) or [RETN] (for pseudo non-maskable interrupts).

Interrupt acceptance processing is as follows:

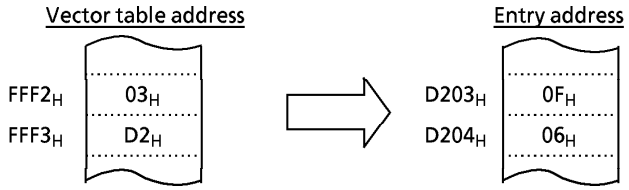
① The interrupt master enable flag (IMF) is cleared to "0" to temporarily disable the acceptance of any following maskable interrupts. When a non-maskable interrupt is accepted, the acceptance of any following interrupts is temporarily disabled.
② The interrupt latch (IL) for the interrupt source accepted is cleared to "0".
③ The contents of the program counter (PC) and the program status word (PSW) are saved (pushed) onto the stack. (pushed down in order of PSW, $PC_H$, $PC_L$). The stack pointer (SP) is three decrements.
④ The entry address of the interrupt service program is read from the vector table address corresponding to the interrupt source, and the entry address is loaded to the program counter.
⑤ The instruction stored at the entry address of the interrupt service program is executed.




*Note1 : a ; return address, b ; entry address, c ; address when the RETI instruction is stored*
*Note2 : The maximum response time from when an IL is set until an interrupt acceptance processing starts is 2/fm to 38/fm [ s]. It equals to setting the IL on the first machine cycle in 10 cycles instruction execution.*

Figure 1-24. Timing Chart of Interrupt Acceptance and Interrupt Return Instruction

Example : Correspondence between vector table address for INTTBT and the entry address of the interrupt service program.



A maskable interrupt is not accepted until the IMF is set to "1" even if a maskable interrupt of higher priority than that of the current interrupt being serviced.
When nested interrupt service is necessary, the IMF is set to "1" in the interrupt service program. In this case, acceptable interrupt sources are selectively enabled by the individual interrupt enable flags. However, an acceptance of external interrupt 0 cannot be disabled by the EF; therefore, if disablement is necessary, either the external interrupt function must be disabled in the external interrupt control register (INT0EN) or interrupt processing must be avoided by the program. (When INT0EN = 0, the interrupt latch IL3 is not set, therefore, the falling edge of the INT0 pin input cannot be detected.)

Example 1 : Disables an external interrupt 0 using INT0EN:

```
CLR     (EINTCR), INT0EN    ; INT0EN←0
```

Example 2 : Disables the processing of external interrupt 0 under the software control (using bit 0 at address $00F0_H$ as the interrupt processing disable switch):

```
PINT0 :   TEST    (00F0H) . 0        ; Returns without interrupt processing if (00F0H)0 = 1
          JRS     T, SINT0
          RETI
SINT0 :   Interrupt processing
          RETI
            ⋮
VINT0 :   DW      PINT0
```

During interrupt acceptance processing, the program counter and the program status word are automatically saved on the stack, but not the accumulator and other registers. These registers are saved by the program if necessary. Also, when nesting multiple interrupt services, it is necessary to avoid using the same data memory area for saving registers.
The following method is used to save/restore the general-purpose registers:

① General-purpose register save/restore by register bank changeove:
General-purpose registers can be saved at high-speed by switching to a register bank that is not in use. Normally, bank 0 is used for the main task and banks 1 to 15 are assigned to interrupt service tasks. To increase the efficiency of data memory utilization, the same bank is assigned for interrupt sources which are not nested.
The switched bank is automatically restored by executing an interrupt return instruction [RETI] or [RETN]. Therefore, it is not necessary for a program to save the RBS.

Example : Register Bank Changeover

```
PINTxx :    LD      RBS, n          ;  Switches to bank n (1μs at 8 MHz)
            interrupt processing
            RETI                    ;  Restores bank and Returns
```

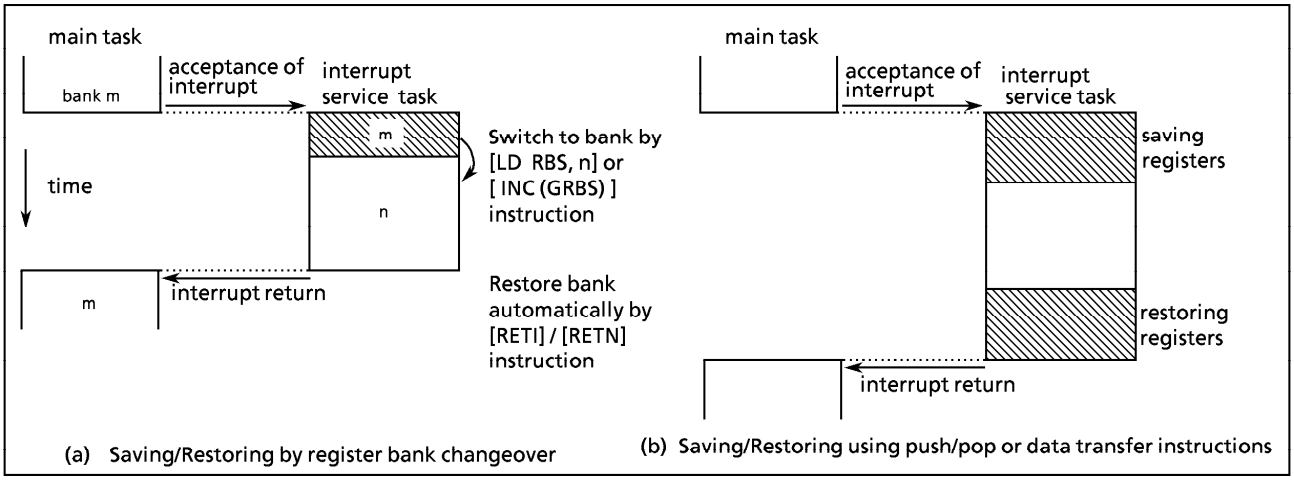
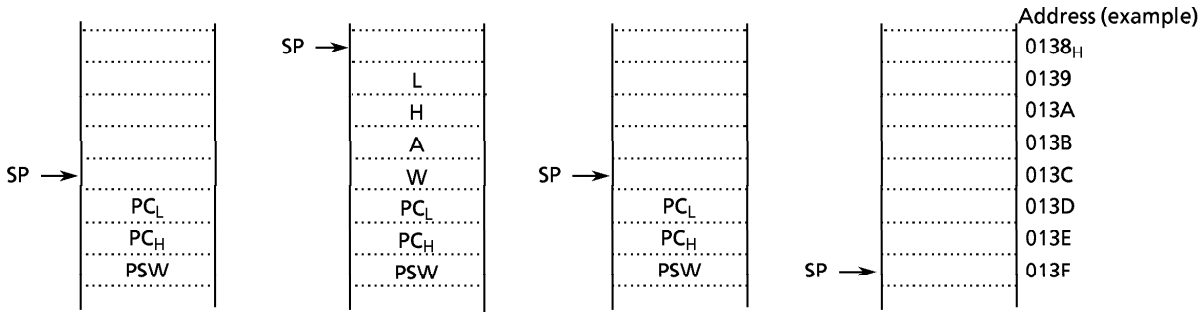



Figure 1-25. Saving/Restoring General-purpose Registers

② General-purpose register save/restore using push and pop instructions:
To save only a specific register, and when the same interrupt source occurs more than once, the general-purpose registers can be saved/restored using push/pop instructions.

```
PINTxx :    PUSH    WA          ;  Save WA register pair
            PUSH    HL          ;  Save HL register pair
            Interrupt processing
            POP     HL          ;  Restore HL register pair
            POP     WA          ;  Restore WA register pair
            RETI                ;  Return
```



③ General-purpose registers save/restore using data transfer instruction:
Data transfer instructions can be used to save only a specific general-purpose register during processing of a single interrupt.

Example : Saving/restoring a register using data transfer instructions

```
PINTxx :    LD      (GSAVA), A      ; Save A register
            interrupt processing
            LD      A, (GSAVA)      ; Restore A register
            RETI                    ; Return
```

The interrupt return instructions [RETI] / [RETN] perform the following operations.

| [RETI] Maskable interrupt return | [RETN] Non-maskable interrupt return |
|---|---|
| ① The contents of the program counter and the program status word are restored from the stack. | ① The contents of the program counter and program status word are restored from the stack. |
| ② The stack pointer is incremented 3 times. | ② The stack pointer is incremented 3 times. |
| ③ The interrupt master enable flag is set to "1". | ③ The interrupt master enable flag is set to "1" only when a non-maskable interrupt is accepted in interrupt enable status. However, the interrupt master enable flag remains at "0" when so clear by an interrupt service program. |

Interrupt requests are sampled during the final cycle of the instruction being executed. Thus, the next interrupt can be accepted immediately after the interrupt return instruction is executed.

*Note : When the interrupt processing time is longer than the interrupt request generation time, the interrupt service task is performed but not the main task.*

### 1.9.2 Software Interrupt (INTSW)

Executing the [SWI] instruction generates a software interrupt and immediately starts interrupt processing (INTSW is highest prioritized interrupt). However, if processing of a non-maskable interrupt is already underway, executing the SWI instruction will not generate a software interrupt but will result in the same operation as the [NOP] instruction. Thus, the [SWI] instruction behaves like the [NOP] instruction.

*Note : Software interrupt generates during non-maskable interrupt processing to use SWI instruction for software break in a development tool.*

Use the [SWI] instruction only for detection of the address error or for debugging.

① Address Error Detection
$FF_H$ is read if for some cause such as noise the CPU attempts to fetch an instruction from a non-existent memory address. Code $FF_H$ is the SWI instruction, so a software interrupt is generated and an address error is detected. The address error detection range can be further expanded by writing $FF_H$ to unused areas of the program memory. Address trap reset is generated for instruction fetch from a part of RAM area (address $0040_H$-$043F_H$) or SFR area ($0000_H$-$003F_H$).

② Debugging
Debugging efficiency can be increased by placing the SWI instruction at the software break point setting address.

### 1.9.3 External Interrupts

The 87CH21/M21 has five external interrupts (INT0 to INT5 : $\overline{INT0}$, INT1, INT2, INT3, $\overline{INT5}$). Three of these (INT1, INT2, INT3) have digital noise cancellation circuits (pulse inputs of less than a fixed time are cancelled as noise). Edge selection is possible with pins INT1, INT2, and INT3.

The $\overline{INT0}$/P10 pin can be selected either as an external interrupt input pin or as an I/O port. At reset, it is initialized as an input port.

Edge selection, noise cancellation control, and $\overline{INT0}$/P10 pin function selection are performed by the external interrupt control register (#0037H : EINTCR).

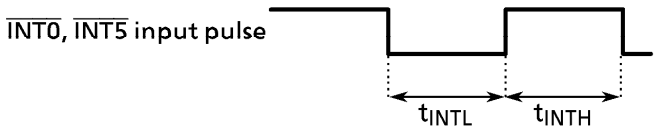
The both-edge detect function of the INT3 pin is selected by the external interrupt control register (#0037H :EINTCR and #001FH : EINT3).

Table 1-3. lists enable conditions, edge select, noise cancellation conditions. The following are notes on the usage of external interrupts:

Notes on usage of external interrupts:

*Note 1 : When INT0 to INT5 ($\overline{INT0}$, INT1, INT2, INT3, $\overline{INT5}$) are used in SLOW or SLEEP mode, the noise cancellation function is disabled. Noise cancellation time for a pulse input during operating mode transition is indeterminate.*

*Note 2 : Input pulse width for $\overline{INT0}$ and $\overline{INT5}$ must be one machine cycle or more at both high and low levels.*




$t_{INTL}, t_{INTH} > t_{cyc}$

$t_{cyc}$ = 4/fc [s] (at NORMAL 1/2 and IDLE 1/2 modes)
4/fs [s] (at SLOW and SLEEP modes)

*Note 3 : If a signal without noise is input to the external interrupt pin in NORMAL 1/2 or IDLE 1/2 mode, the maximum times from input signal edge to input latch set are as described below:*

① *INT1 pin 49/fc [s] (when INT1NC = 1)*
*193/fc [s] (when INT1NC = 0)*

② *INT2 pin 25/fc [s]*

③ *INT3 pin 25/fc [s] (when #0037H: INT3W = 0, falling or rising edge)*
*25/fc [s] (when #0037H: INT3W = 1 and #001FH: NCS (0, 0, 0) )*
*$(2^6/fc) \times 8.5 + 19/fc$ [s] (when #0037H: INT3W = 1 and #001FH: NCS (0, 0, 1) )*
*$(2^7/fc) \times 8.5 + 19/fc$ [s] (when #0037H: INT3W = 1 and #001FH: NCS (0, 1, 0) )*
*$(2^8/fc) \times 8.5 + 19/fc$ [s] (when #0037H: INT3W = 1 and #001FH: NCS (0, 1, 1) )*
*$(2^9/fc) \times 8.5 + 19/fc$ [s] (when #0037H: INT3W = 1 and #001FH: NCS (1, 0, 0) )*
*$(2^{10}/fc) \times 8.5 + 19/fc$ [s] (when #0037H: INT3W = 1 and #001FH: NCS (1, 0, 1) )*
*$(2^{11}/fc) \times 8.5 + 19/fc$ [s] (when #0037H: INT3W = 1 and #001FH: NCS (1, 1, 0) )*
*$(2^{12}/fc) \times 8.5 + 19/fc$ [s] (when #0037H: INT3W = 1 and #001FH: NCS (1, 1, 1) )*

*Note 4 : Noise cancellation/pulse receive conditions for timer/counter are as described below:*

① *TC1 pin : Less than 7/fc [s] (noise cancellation) and 24/fc [s] or more (pulse receive)*

② *TC3 pin : When INT3W = 0, less than 7/fc [s] (noise cancellation) and 24/fc [s] or more (pulse receive).*
*For when INT3W = 1, see Table 1-4.*

*Note 5 : When INT0EN = 0, interrupt latch IL3 is not set even if a falling edge is detected for $\overline{INT0}$ pin input.*

*Note 6 : Change EINTCR only when IMF = 0. After changing EINTCR, interrupt latches of external interrupt inputs must be cleared to "0" using load instruction.*

Example : Changes INT2 edge selection from rising edge to falling edge

```
DI                          ; IMF ← 0 (disables interrupt service)
LD   (EINTCR), 10000110B    ; INT2ES ← 1 (changes edge selection)
LD   (ILL), 01111111B       ; IL7 ← 0 (clears interrupt latch)
EI                          ; IMF ← 1 (enables interrupt service)
```

*Note 7 : If changing the contents of INT1ES during NORMAL1/2 mode, interrupt latch of external interrupt input INT1 must be cleared after 14 machine cycles (when INT1NC = 1) or 50 machine cycles (when INT1NC = 0) from the time of changing. During SLOW mode, 3 machine cycles are required.*

*Note 8 : In order to change of external interrupt input by rewriting the contents of INT2ES, INT3ES and INT4ES during NORMAL1/2 mode, clear interrupt latches of external interrupt inputs (INT2, INT3 and INT4) after 8 machine cycles from the time of rewriting. During SLOW mode, 3 machine cycles are required.*

*Note 9 : In order to change an edge of timer counter input by rewriting the contents of INT2ES, INT3ES and INT4ES during NORMAL1/2 mode, rewrite the contents after timer counter is stopped (TC*s = 0), that is, interrupt disable state. Then, clear interrupt laches of external interrupt inputs (INT2, INT3 and INT4) after 8 machine cycles from the time of rewriting to change to interrupt enable state. Finally, start timer counter. During SLOW mode, 3 machine cycles are required.*

Example : When changing TC1 pin inputs edge in external trigger timer mode from rising edge to falling edge. (example: TMP87CH00N)

```
                    LD (TC1CR),01001000B    ; TC1S ← 00 (stop TC1)
                    DI                      ; IMF ← 0 (disable interrupt service)
                    LD (EINTCR),00000100B   ; INT2ES ← 1 (change edge selection)
        ↑           NOP
8 machine             to
  cycles            NOP
        ↓           LD (ILL),01111111B      ; IL7 ← 0 (clear interrupt latch)
                    EI                      ; IMF ← 1 (enable interrupt service)
                    LD (TC1CR),01111000B    ; TC1S ← 11 (start TC1)
```

*Note 10 : When high-impedance is specified for port output in stop mode, port input is forcibly fixed to low level internally. Thus, interrupt latches of external interrupt inputs except $\overline{\text{INT5}}$ (P20/$\overline{\text{STOP}}$) which are also used as ports may be set to "1". To specify high-impedance for port output in stop mode, first disable interrupt service (IMF = 0), activate stop mode. After releasing stop mode, clear interrupt latches using load instruction, then, enable interrupt service.*

Example : Activating stop mode

```
LD   (SYSCR1), 01000000B    ; OUTEN ← 0 (specifies high-impedance)
DI                          ; IMF ← 0 (disables interrupt service)
SET  (SYSCR1). STOP         ; STOP ← 1 (activates stop mode)
LDW  (IL), 1111011101010111B ; IL11, 7, 5, 3 ← 0 (clears interrupt latches)
EI                          ; IMF ← 1 (enables interrupt service)
```

Table 1-3 (a). External Interrupts

| SOURCE | Pin | Secondary function | Enable Condition | Edge | | | Digital noise reject |
|---|---|---|---|---|---|---|---|
| | | | | rising | falling | both | |
| INT0 | $\overline{INT0}$ | P10 | IMF = 1, INT0EN = 1 | — | ○ | — | — (hysteresis input) |
| INT1 | INT1 | P11 | IMF · $EF_5$ = 1 | INT1ES = 0 | INT1ES = 1 | — | Note 1 ) |
| INT2 | INT2 | P12 / TC1 | IMF · $EF_7$ = 1 | INT2ES = 0 | INT2ES = 1 | — | Note 2 ) |
| INT3 | INT3 | P40 / TC3 | IMF · $EF_{11}$ = 1, INT3W = 0 | INT3ES = 0 | INT3ES = 1 | — | Note 3 ) |
| | | | IMF · $EF_{11}$ = 1, INT3W = 1 | — | — | INT3W = 1 Note) | Note 4 ) |
| INT5 | $\overline{INT5}$ | P20 / $\overline{STOP}$ | IMF · $EF_{15}$ = 1 | — | ○ | — | — (hysteresis input) |

*Note 1 : Pulses less than 15/fc [s] or 63/fc [s] are cancelled as noise. Pulses equal to or more than 48/fc [s] or 192/fc [s] are regarded as signals.*
*Note 2 : Pulses less than 7/fc [s] are cancelled as noise. Pulses equal to or more than 24/fc [s] are regarded as signals. Same applies to pin TC1.*
*Note 3 : For falling or rising edge, pulses less than 7/fc [s] are cancelled as noise. Pulses equal to or more than 24/fc [s] are regarded as signals. Same applies to pin TC3 (at one edge).*
*Note 4 : Noise cancellation conditions are as listed in Table 1-3 (b). They are applied to the INT3 pin when it is used for both-edge interrupts.*

*Note : To detect the edge at which an interrupt is generated, read bit 7 (INTEDT) in eint3cr (#001$F_H$), that is, at the beginning of the interrupt processing routine.*
*INTEDT is valid only for both-edge interrupts (INT3W = 1). INTEDT is set to 1 by an interrupt as the non-selected edge; cleared to 0 after read automatically.*
*For both-edge interrupts, rising or falling edge is selected by setting/modifying bit 3 (INT3ES) in EINTCR (#0037$_H$).*
*When rising edge is selected (INT3ES = 0), bit 7 in INTEDT (#001$F_H$) is set to 1 when a falling edge is detected at the INT3 pin. (That is, remains 0 if rising edge is detected.)*
*When falling edge is selected (INT3ES = 1), bit 7 in INTEDT: #001$F_H$ is set to 1 when a rising edge is detected at the INT3 pin. (That is, remains 0 at falling edge.)*

Table 1-3 (b). Noise reject condition for INT3 (both-edge interrupt)

| #001FH | | | max. pulse width for noise reject | min. pulse width for immediate signal |
|---|---|---|---|---|
| NCS2 | NCS1 | NCS0 | | |
| 0 | 0 | 0 | – (histeresis input) | |
| 0 | 0 | 1 | $(2^6/fc) \times 7 - 6/fc$ | $(2^6/fc) \times 8 + 5/fc$ |
| 0 | 1 | 0 | $(2^7/fc) \times 7 - 6/fc$ | $(2^7/fc) \times 8 + 5/fc$ |
| 0 | 1 | 1 | $(2^8/fc) \times 7 - 6/fc$ | $(2^8/fc) \times 8 + 5/fc$ |
| 1 | 0 | 0 | $(2^9/fc) \times 7 - 6/fc$ | $(2^9/fc) \times 8 + 5/fc$ |
| 1 | 0 | 1 | $(2^{10}/fc) \times 7 - 6/fc$ | $(2^{10}/fc) \times 8 + 5/fc$ |
| 1 | 1 | 0 | $(2^{11}/fc) \times 7 - 6/fc$ | $(2^{11}/fc) \times 8 + 5/fc$ |
| 1 | 1 | 1 | $(2^{12}/fc) \times 7 - 6/fc$ | $(2^{12}/fc) \times 8 + 5/fc$ |

*Note : In SLOW mode, set (NCS) = (0, 0, 0) .*
*In SLOW mode, the digital noise filter in the above table is disabled.*

External interrupt Control Register 1

EINTCR ($0037_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| INT1 NC | INT0 EN | | | INT3 ES | INT2 ES | INT1 ES | INT3W |

(initial value 00*0 0000)

| | | | |
|---|---|---|---|
| INT1NC | Noise reject time select | 0 : Pulses of less than 63 / fc [s] are eliminated as noise<br>1 : 〃 15 / fc [s] 〃 | R/W |
| INT0EN | P10 / $\overline{INT0}$ pin configuration | 0 : P10 input/output<br>1 : $\overline{INT0}$ pin (port P10 should be set to an input mode) | |
| INT3ES<br>INT2ES<br>INT1ES | INT3 to INT1 edge select | 0 : rising edge<br>1 : falling edge | |
| INT3W | INT3 both edge selection | 0 : refer to INT3ES<br>1 : both edge detection | |

*Note1 : fc ; High-frequency clock [Hz] * ; don't care*

Figure 1-26 (a). External Interrupt Control Register

External interrupt Control Register 2

EINT3CR ($001F_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| INT EDT | | NCS | | INT3 DET | | | |

(initial value : 0000 0***)

| | | | |
|---|---|---|---|
| INTEDT | Flag indicating an interrupt at selected edge/non-selected edge, when INT3W = 1 (for both-edge interrupts). | 0 : Interrupt at selected edge or no interrupt<br>1 : Interrupt at non-selected edge | R |
| NCS | Noise cancellation time select for INT3 digital noise filter (valid only when INT3W = 1) | 000 : No noise cancellation<br>001 : Cancels ($2^6$ / fc × 7 - 6 / fc) as noise.<br>010 : Cancels ($2^7$ / fc × 7 - 6 / fc) "<br>011 : Cancels ($2^8$ / fc × 7 - 6 / fc) "<br>100 : Cancels ($2^9$ / fc × 7 - 6 / fc) "<br>101 : Cancels ($2^{10}$ / fc × 7 - 6 / fc) "<br>110 : Cancels ($2^{11}$ / fc × 7 - 6 / fc) "<br>111 : Cancels ($2^{12}$ / fc × 7 - 6 / fc) " | R/W |
| INT3DET | INT3 interrupt detection flag | 0 : No interrupt<br>1 : Interrupt | R |

*Note 1 : INTEDT and NCS are valid only when the INT3W bit in EINTCR ($\#0037_H$) is set to 1. Therefore, when INT3W = 0, the digital noise filter set by the NCS bit is disabled.*

Figure 1-26 (b). External Interrupt Control Register 2

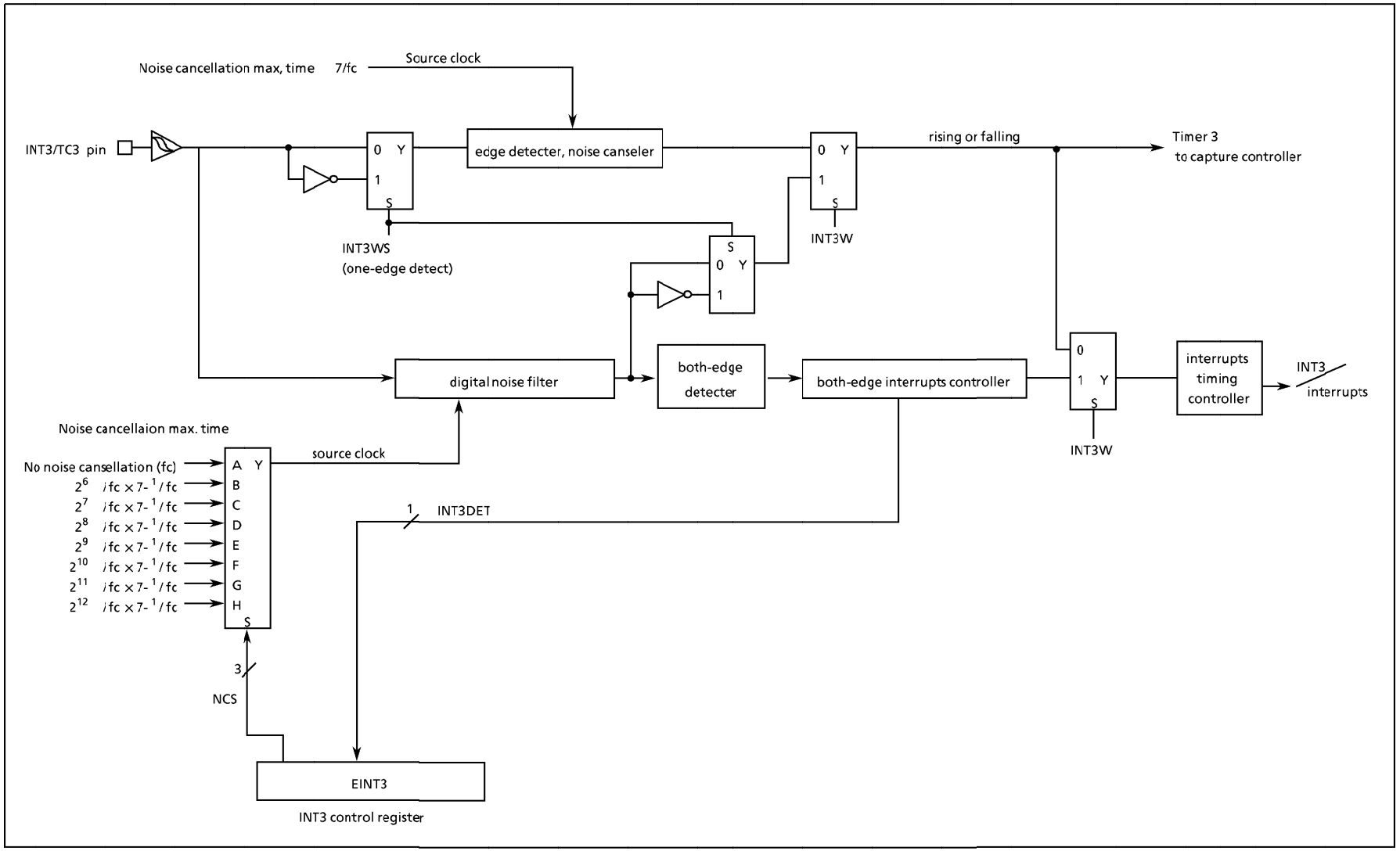



Figure1-26 (C). Bother One Edge Detictor of INT3/TC3 Pin

Notes on the usage of INT3 pin (external interrupt)

1. In the case of using the INT3 pin for one edge (either rising or falling).

> *Note : In order to set/rewrite external interrupt control register(EINTCR), set / rewirte external interrupt register in the interrupt disable state (IMF = 0). Then, enable interrupt acceptance after interrupt latch cleared.*

2. In the case of using the INT3 pin for both edge (rising and falling).

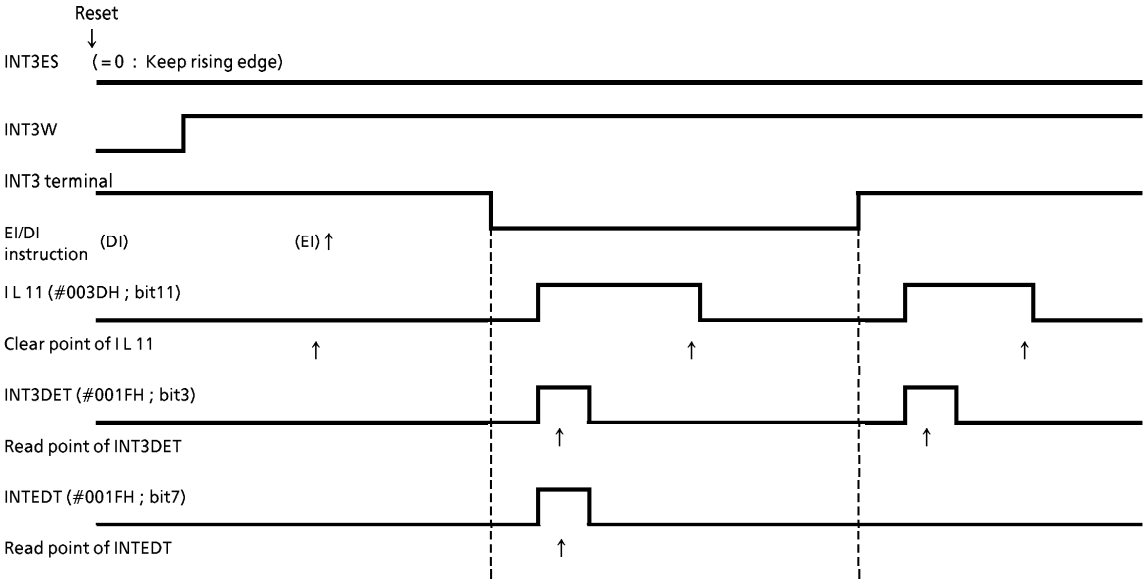
> *Note 1 : When using the INT3 pin for both edges (rising and falling), set bit 0 (INT3W) in EINTCR (#0037$_H$) to 1.*
> *Note 2 : To detect the edge at which an interrupt is generated, read bit 7 (INTEDT) in EINT3CR (#001F$_H$), that is, at the beginning of the interrupt processing routine.*
> *Note 3 : INTEDT is valid only for both-edge interrupts (INT3W = 1). INTEDT is set to 1 by an interrupt as the non-selected edge; cleared to 0 after read automatically.*
> *When rising edge is selected (INT3ES = 0), bit 7 in INTEDT (#001F$_H$) is set to 1 when a falling edge is detected at the INT3 pin. (That is, remains 0 if rising edge is detected.)*
> *When falling edge is selected (INT3ES = 1), bit 7 in INTEDT: #001F$_H$ is set to 1 when a rising edge is detected at the INT3 pin. (That is, remains 0 at falling edge.)*
> *Note 4 : In order to set/rewrite external interrupt control register(EINTCR), set / rewirte external interrupt register in the interrupt disable state (IMF = 0). Then, enable interrupt acceptance after interrupt latch cleared.*

Operation description for INT3 (both-edge interrupt) in use:

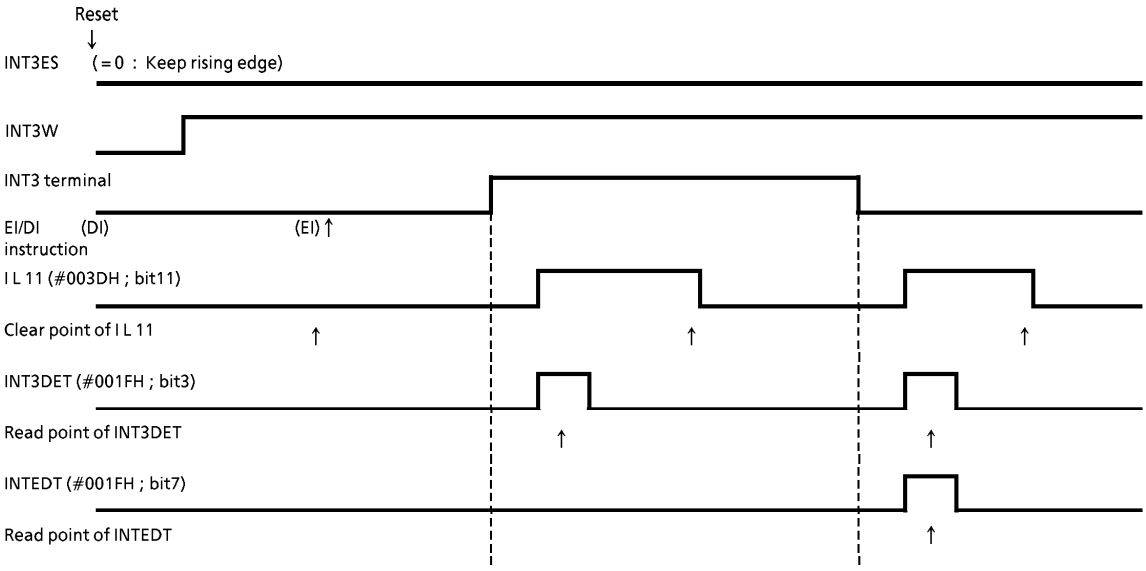
1. Operation without setting/modifying external interrupt control register (EINTCR) after reset:

   For both-edge interrupts, rising edge is selected (INT3ES = 0) and fixed.

   1) Case1 : When the initial state of the INT3 pin is high after reset:

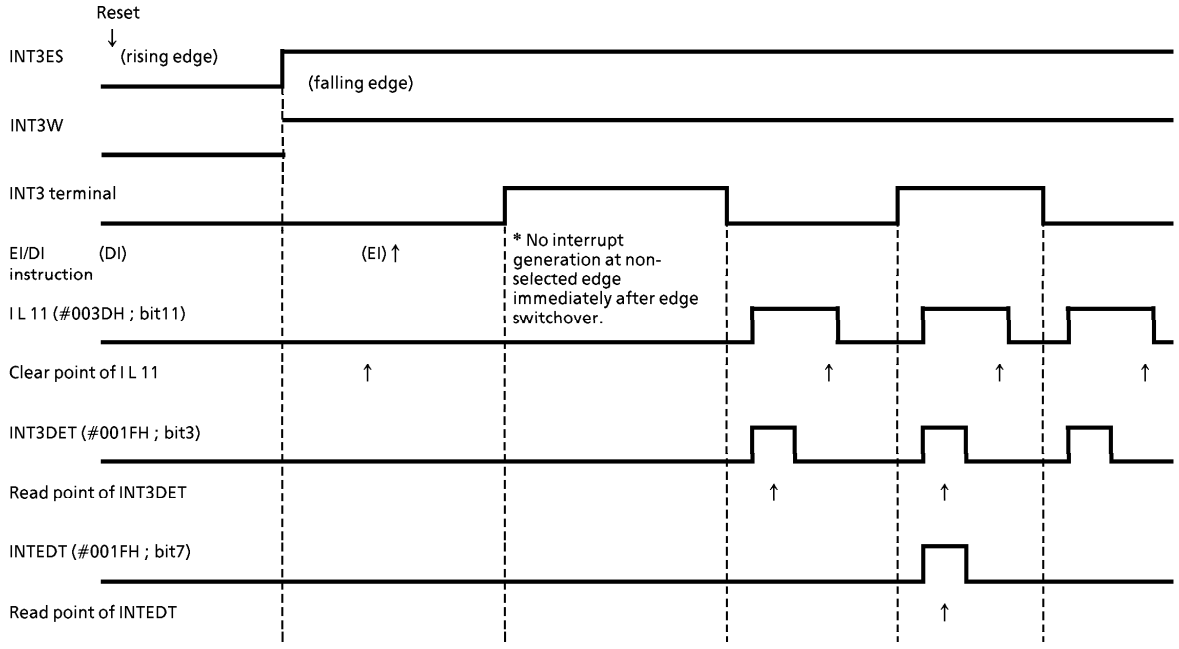



   2) Case2 : When the initial state of the INT3 pin is low after reset:

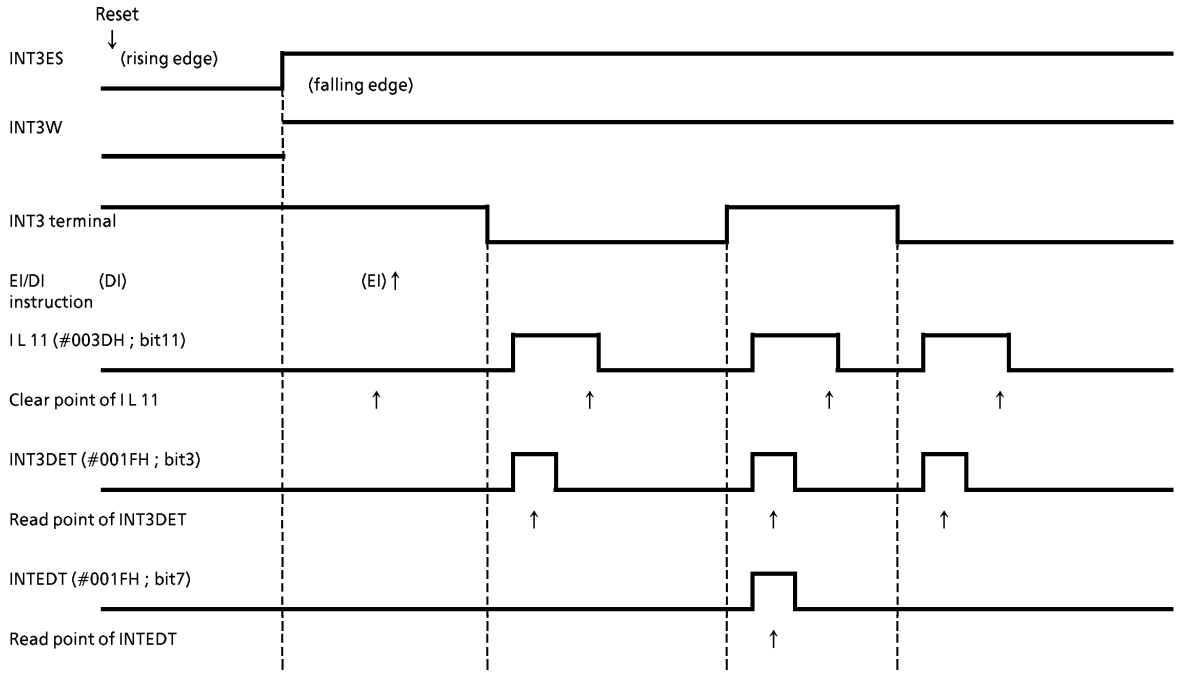


2. Operation with setting/modifying external interrupt control register (EINTCR) after reset:

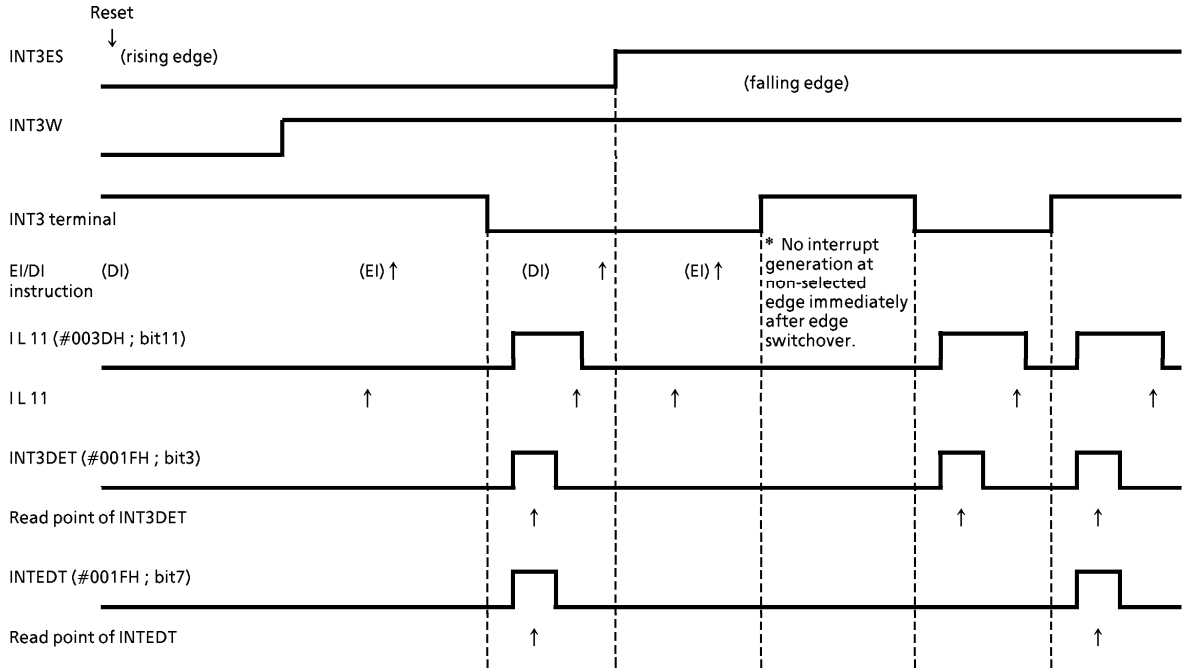
1) Case3 : When the initial state of the INT3 pin is low after reset/low at edge switchover from rising to falling:



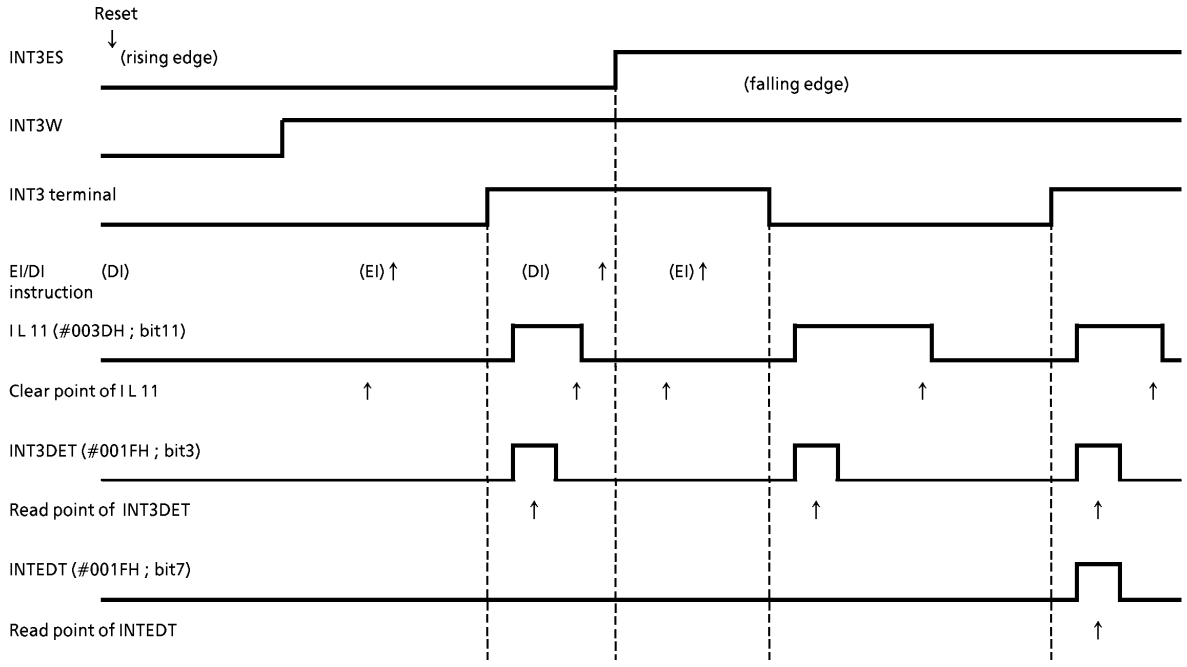

2) Case4 : When the initial state of the INT3 pin is high after reset/high at edge switchover from rising to falling:



3) Case5 : Case 5: When the initial state of the INT3 pin is high after reset/low at edge switchover from rising to falling:




4) Case6 : When the initial state of the INT3 pin is low after reset/high at edge switchover from rising to falling:



## 1.10 Watchdog Timer (WDT)

The watchdog timer rapidly detects the CPU malfunction such as endless looping caused by noise or the like, and resumes the CPU to the normal state.

The watchdog timer signal for detecting malfunction can be selected either a reset output or a non-maskable interrupt request. However, selection is possible only once after reset. At first the reset output is selected.

When the watchdog timer is not being used for malfunction detection, it can be used as a timer to generate an interrupt at fixed intervals.

### 1.10.1 Watchdog Timer Configuration

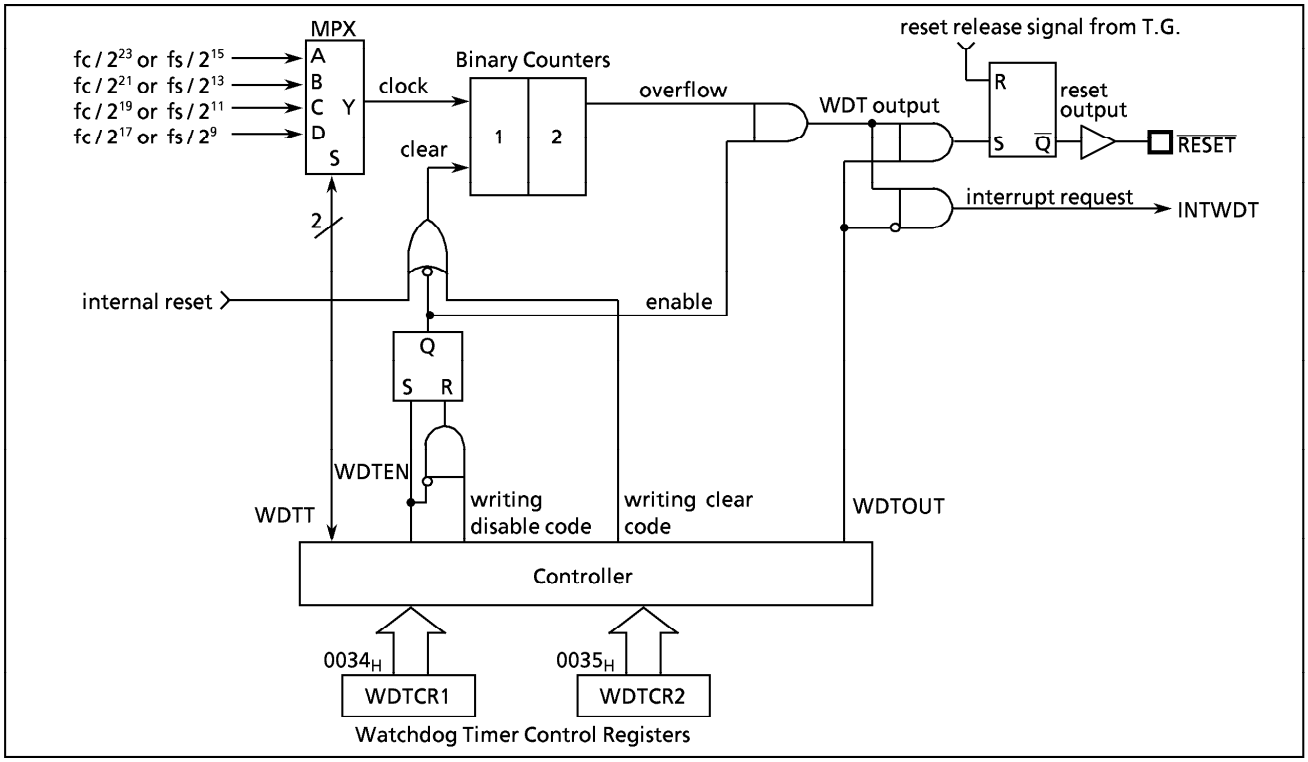



Figure 1-27. Watchdog Timer Configuration

### 1.10.2 Watchdog Timer Control

Figure 1-28 shows the watchdog timer control registers (WDTCR1, WDTCR2). The watchdog timer is automatically enabled after reset.

(1) Malfunction detection methods using the watchdog timer

The CPU malfunction is detected as follows.

① Setting the detection time, selecting output, and clearing the binary counter.

② Repeatedly clearing the binary counter within the setting detection time.

If the CPU malfunction occurs for any cause, the watchdog timer output will become active at the rising of an overflow from the binary counters unless the binary counters are cleared. At this time, when WDTOUT = 1 a reset is generated, which drives the $\overline{\text{RESET}}$ pin low to reset the internal hardware and the external circuits. When WDTOUT = 0, a watchdog timer interrupt (INTWDT) is generated.

The watchdog timer temporarily stops counting in the STOP mode including warm-up or IDLE mode, and automatically restarts (continues counting) when the STOP/IDLE mode is released.

Example : Sets the watchdog timer detection time to $2^{21}$/fc [s] and resets the CPU malfunction.

```
        LD      (WDTCR1), 00001101B   ; WDTT←10, WDTOUT←1
        LD      (WDTCR2), 4EH         ; Clears the binary counters
Within WDT                            (always clear immediately after changing WDTT)
detection time
        LD      (WDTCR2), 4EH         ; Clears the binary counters
Within WDT
detection time
        LD      (WDTCR2), 4EH         ; Clears the binary counters
```

Watchdog Timer Control Register 1

**WDTCR1** ($0034_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | | WDT EN | WDTT | | WDT OUT |

(Initial value : **** 1001)

| | | | |
|---|---|---|---|
| WDTEN | Watchdog timer enable/disable | 0 : Disable (It is necessary to write the disable code to WDTCR2)<br>1 : Enable | write only |
| WDTT | Watchdog timer detection time | 00 : $2^{25}$ / fc or $2^{17}$ / fs [s]<br>01 : $2^{23}$ / fc or $2^{15}$ / fs<br>10 : $2^{21}$ / fc or $2^{13}$ / fs<br>11 : $2^{19}$ / fc or $2^{11}$ / fs | |
| WDTOUT | Watchdog timer output select | 0 : Interrupt request<br>1 : Reset output | |

*Note 1 : WDTOUT cannot be set to "1" by program after clearing WDTOUT to "0".*
*Note 2 : fc ; High-frequency clock [Hz] fs ; Low-frequency clock [Hz] * ; don't care*
*Note 3 : WDTCR1 is a write-only register and must not be used with any of read-modify-write instructions.*
*Note 4 : Disable the watchdog timer or clear the counter just before switching to STOP mode. When the counter is cleared just before switching to STOP mode, clear the counter again subsequently to releasing STOP mode.*

Watchdog Timer Control Register 2

**WDTCR2** ($0035_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

(Initial value : **** ****)

| | | | |
|---|---|---|---|
| WDTCR2 | Watchdog timer control code write register | $4E_H$ : Watchdog timer binary counter clear (clear code)<br>$B1_H$ : Watchdog timer disable (disable code)<br>others : Invalid | write only |

*Note 1 : The disable code is invalid unless written when WDTEN = 0.*
*Note 2 : * ; don't care*

Figure 1-28. Watchdog Timer Control Registers

Table 1-4. Watchdog Timer Detection Time

| Operating mode | | | Detection time | |
|---|---|---|---|---|
| NORMAL1 | NORMAL2 | SLOW | At fc = 8MHz | At fs = 32.768kHz |
| $2^{25}$ / fc [s] | $2^{25}$ / fc, $2^{17}$ / fs | $2^{17}$ / fs | 4.194 s | 4 s |
| $2^{23}$ / fc | $2^{23}$ / fc, $2^{15}$ / fs | $2^{15}$ / fs | 1.048 ms | 1 s |
| $2^{21}$ / fc | $2^{21}$ / fc, $2^{13}$ / fs | —— | 262.1 ms | 250 ms |
| $2^{19}$ / fc | $2^{19}$ / fc, $2^{11}$ / fs | —— | 65.5 ms | 62.5 ms |

(2) Watchdog Timer Enable

The watchdog timer is enabled by setting WDTEN (bit 3 in WDTCR1) to "1". WDTEN is initialized to "1" during reset, so the watchdog timer operates immediately after reset is released.

Example : Enables watchdog timer

```
LD      (WDTCR1), 00001000B     ; WDTEN←1
```

(3) Watchdog Timer Disable

The watchdog timer is disabled by writing the disable code ($B1_H$) to WDTCR2 after clearing WDTEN (bit 3 in WDTCR1) to "0". The watchdog timer is not disabled if this procedure is reversed and the disable code is written to WDTCR2 before WDTEN is cleared to "0".

During disabling the watchdog timer, the binary counters are cleared to "0".

Example : Disables watchdog timer

```
LDW     (WDTCR1) , 0B101H       ; WDTEN←0, WDTCR1←disable code
```

### 1.10.3 Watchdog Timer Interrupt (INTWDT)

This is a pseudo non-maskable interrupt which can be accepted regardless of the contents of the EIR. If a watchdog timer interrupt or a software interrupt is already accepted, however, the new watchdog timer interrupt waits until the previous interrupt processing is completed (the end of the [RETN] instruction execution).

The stack pointer (SP) should be initialized before using the watchdog timer output as an interrupt source with WDTOUT.

Example : Watchdog timer interrupt setting up.

```
LD      SP, 023FH               ; Sets the stack pointer
LD      (WDTCR1) , 00001000B    ; WDTOUT←0
```

### 1.10.4 Watchdog Timer Reset

If the watchdog timer output becomes active, a reset is generated, which drives the $\overline{\text{RESET}}$ pin low to reset the internal hardware. The reset output time is $2^{20}$/fc [s] (131 ms at fc = 8 MHz). The $\overline{\text{RESET}}$ pin is sink open drain input / output with pull-up resistor.

*Note : The high-frequency clock oscillator also turns on when a watchdog timer reset is generated in SLOW mode. Thus, the reset output time is $2^{20}$/fc.*
*The reset output time include a certain amount of error if there is any fluctuation of the oscillation frequency when the high-frequency clock oscillator turns on. Thus, the reset output time must be considered approximate value.*

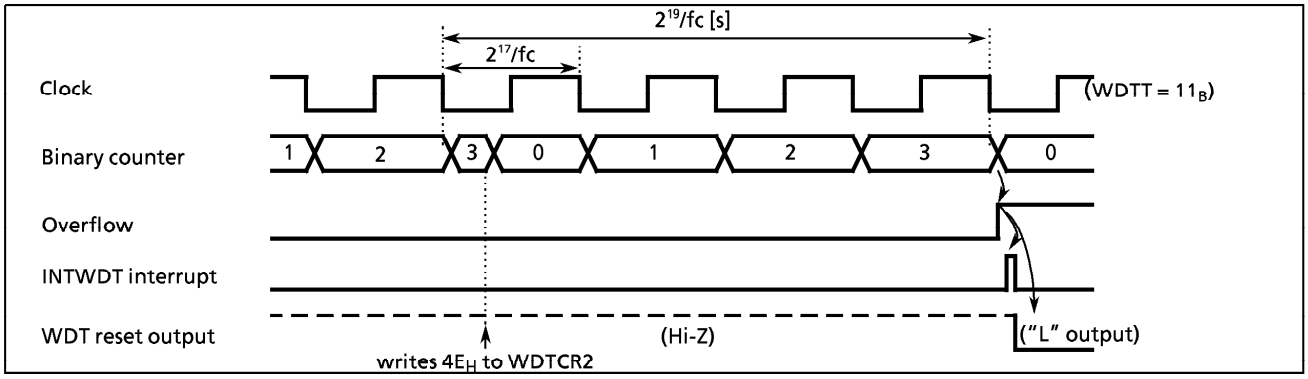



Figure 1-29. Watchdog Timer Interrupt / Reset

## 1.11 Reset Circuit

The 87CH21/M21 each have four types of reset generation procedures: an external reset input, an address trap reset, a watchdog timer reset and a system clock reset. Table 1-5 shows on-chip hardware initialization by reset action. The internal source reset circuit (watchdog timer reset, address trap reset, and system clock reset) is not initialized when power is turned on. Thus, output from the $\overline{\text{RESET}}$ pin may go low ($2^{20}$/fc [s] (131 ms at 8 MHz) when power is turned on.

Table 1-5. Initializing Internal Status by Reset Action

| On-chip Hardware | | Initial Value | On-chip Hardware | Initial Value |
|---|---|---|---|---|
| Program counter | (PC) | ($FFFF_H$) · ($FFFE_H$) | Divider of Timing generator | 0 |
| Register bank selector | (RBS) | 0 | Watchdog timer | Enable |
| Jump status flag | (JF) | 1 | Output latches of I/O ports | Refer to I/O port circuitry |
| Interrupt master enable flag | (IMF) | 0 | Control registers | Refer to each of control register |
| Interrupt individual enable flags | (EF) | 0 | | |
| Interrupt latches | (IL) | 0 | | |

### 1.11.1 External Reset Input

When the $\overline{\text{RESET}}$ pin is held at low for at least 3 machine cycles (12/fc [s]) with the power supply voltage within the operating voltage range and oscillation stable, a reset is applied and the internal state is initialized.

When the $\overline{\text{RESET}}$ pin input goes high, the reset operation is released and the program execution starts at the vector address stored at addresses $FFFE_H$ - $FFFF_H$.

The $\overline{\text{RESET}}$ pin contains a Schmitt trigger (hysteresis) with an internal pull-up resistor. A simple power-on-reset can be applied by connecting an external capacitor and a diode.

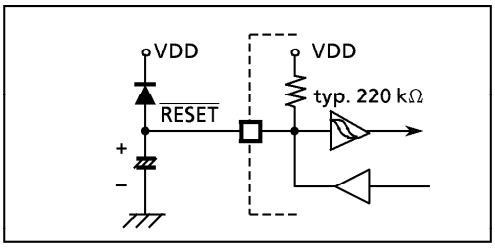
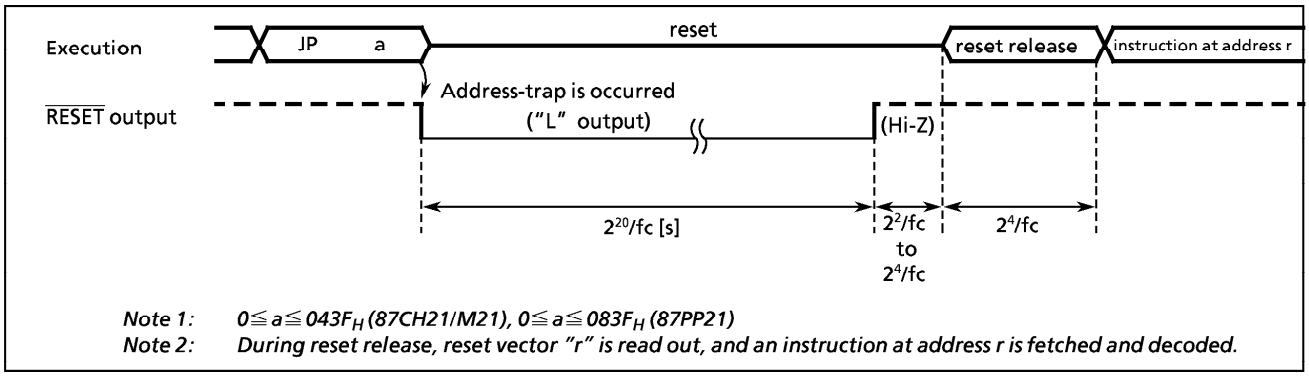



Figure 1-30. Simple Power-on-Reset Circuitry

### 1.11.2 Address-Trap-Reset

An address-trap-reset is one of fail-safe function that detects CPU malfunction such as endless looping caused by noise or the like, and returns the CPU to the normal state. If the CPU attempts to fetch an instruction from a part of RAM or SFR (address $0000_H$-$043F_H$ for 87CH21/M21), an address-trap-reset will be generated. Then, the $\overline{\text{RESET}}$ pin output will go low. The reset time is $2^{20}$/fc [s] (131 ms at 8 MHz) .




*Note 1:* $0 \leqq a \leqq 043F_H$ *(87CH21/M21),* $0 \leqq a \leqq 083F_H$ *(87PP21)*

*Note 2: During reset release, reset vector "r" is read out, and an instruction at address r is fetched and decoded.*

Figure 1-31. Address-Trap-Reset

### 1.11.3 Watchdog Timer Reset

Refer to Section "1.10 Watchdog Timer".

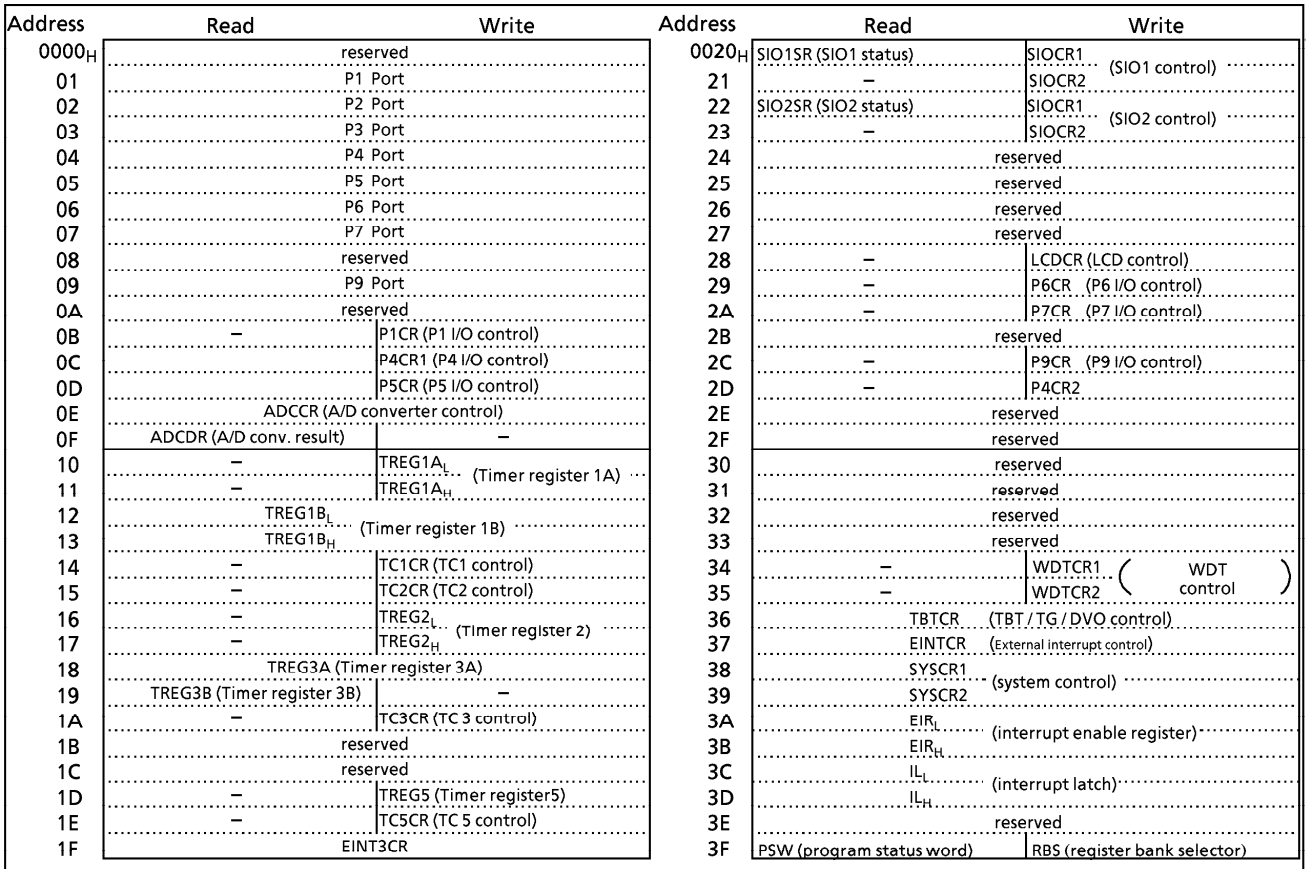
### 1.11.4 System-Clock-Reset

Clearing both XEN and XTEN (bits 7 and 6 in SYSCR2) to "0" stops both high-frequency and low-frequency oscillation, and causes the MCU to deadlock. This can be prevented by automatically generating a reset signal whenever XEN = XTEN = 0 is detected to continue the oscillation. Then, the $\overline{\text{RESET}}$ pin output goes low from high-impedance. The reset time is $2^{20}$/fc [s] (131 ms at 8MHz).

# 2. PERIPHERAL HARDWARE FUNCTIONS

## 2.1 Special Function Registers (SFR) and Data Buffer Registers (DBR)

The TLCS-870 Series uses the memory mapped I/O system, and all peripherals control and data transfers are performed through the special function registers (SFR) and data buffer registers (DBR).
The SFR are mapped to addresses $0000_H$ – $003F_H$ and the DBR to addresses $0F80_H$ – $0FFF_H$.
Figure 2-1 shows the 87CH21/M21 SFRs and DBRs.




*Note 1 : Do not access reserved areas by the program.*

*Note 2 : When defining address $003F_H$ with assembler symbols, use GPSW and GRBS.*

*Note 3 : – ; do not access.*

*Note 4 : Operations specified to writing registers and interrupt latches by read modifying write instructions (bit operation instructions such as SET, CLR, etc. , or operation instructions such as AND, OR, etc.) are not effective.*

Figure 2-1. SFR & DBR

## 2.2 I/O Ports

The 87CH21/M21 have 8 parallel input/output ports (52pins) each as follows:

| | Primary Function | Secondary Functions |
|---|---|---|
| Port P1 | 8-bit I/O port | external interrupt input, timer/counter input/output, and divider output |
| Port P2 | 3-bit I/O port | low-frequency resonator connections, external interrupt input, and STOP mode release signal input |
| Port P3 | 5-bit I/O port | ——— |
| Port P4 | 8-bit I/O port | serial interface, timer/counter input/output, external interrupt input |
| Port P5 | 8-bit I/O port | analog input |
| Port P6 | 8-bit I/O port | segment output |
| Port P7 | 8-bit I/O port | segment output |
| Port P9 | 4-bit I/O port | segment output |

Each output port contains a latch, which holds the output data. All input ports do not have latches, so the external input data should either be held externally until read or reading should be performed several times before processing. Figure 2-2 shows input/output timing examples.
External data is read from an I/O port in the S1 state of the read cycle during execution of the read instruction. This timing can not be recognized from outside, so that transient input such as chattering must be processed by the program.
Output data output changes in the S2 state of the write cycle during execution of the instruction which writes to an I/O port.

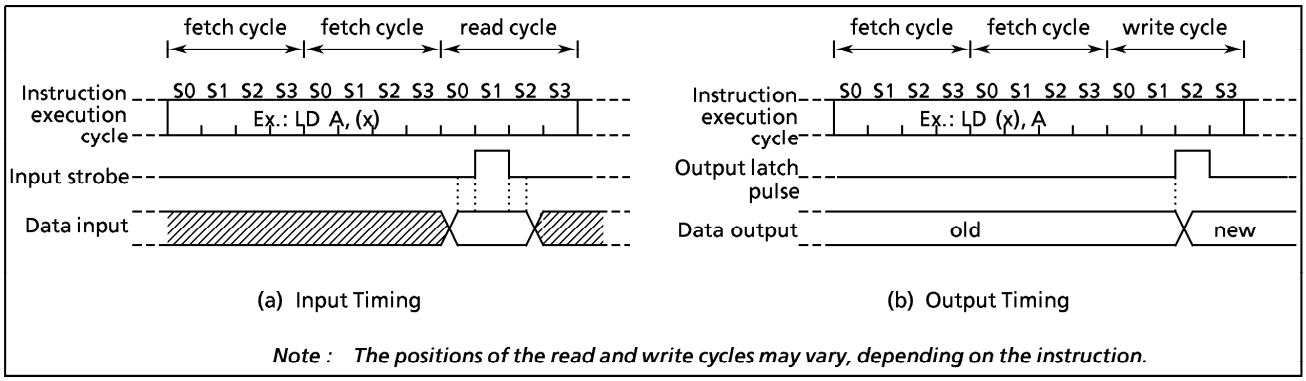



Figure 2-2. Input/Output Timing (Example)

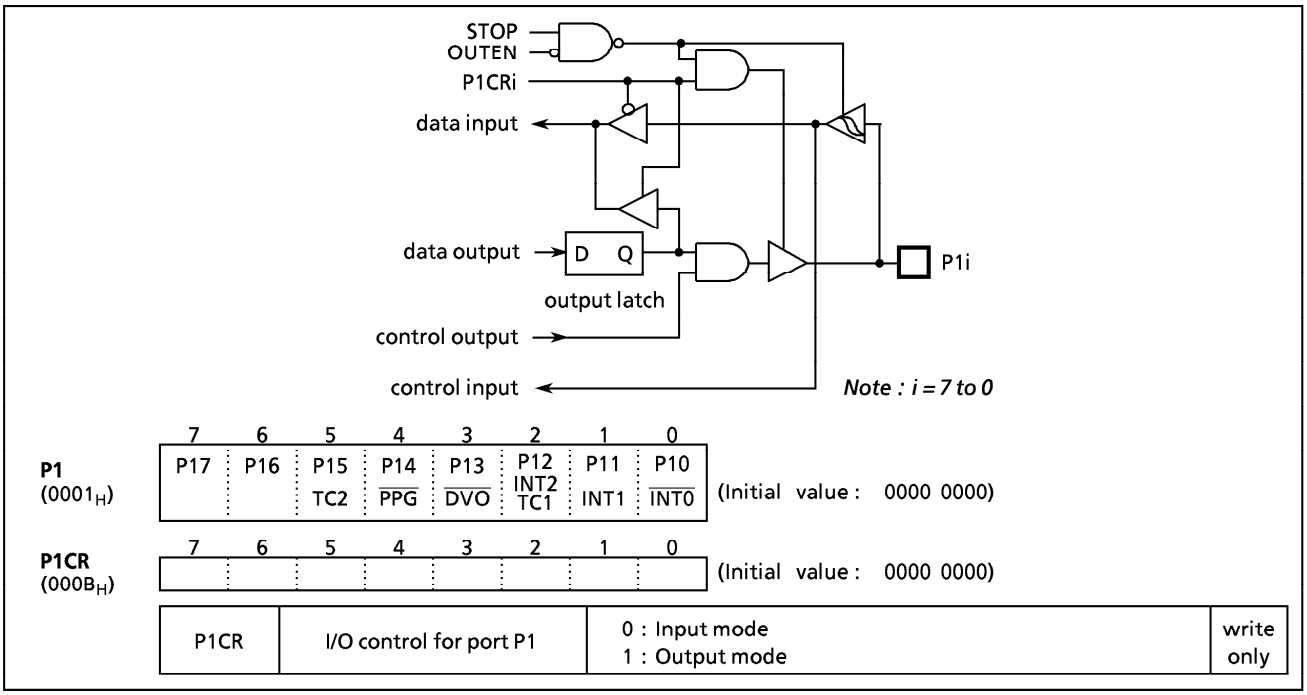
When reading an I/O port except programmable I/O ports, whether the pin input data or the output latch contents are read depends on the instructions, as shown below:

(1) Instructions that read the output latch contents
- ① XCH r, (src)
- ② CLR/SET/CPL (src).b
- ③ CLR/SET/CPL (pp).g
- ④ LD (src).b, CF
- ⑤ LD (pp) . b, CF
- ⑥ ADD/ADDC/SUB/SUBB/AND/OR/XOR (src), n
- ⑦ (src) side of ADD/ADDC/SUB/SUBB/AND/OR/XOR (src), (HL)

(2) Instructions that read the pin input data
- ① Instructions other than the above (1)
- ② (HL) side of ADD/ADDC/SUB/SUBB/AND/OR/XOR (src), (HL)

### 2.2.1 Port P1 (P17 to P10)

Port P1 is an 8-bit input/output port which can be configured as an input or an output in one-bit unit under software control. Input/output mode is specified by the corresponding bit in the port P1 input/output control register (P1CR). Port P1 is configured as an input if its corresponding P1CR bit is cleared to "0", and as an output if its corresponding P1CR bit is set to "1". During reset, the P1CR is initialized to "0", which configures port P1 as an input . The P1 output latches are also initialized to "0".
Port P1 is also used as an external interrupt input, a timer/counter input, and a divider output. When used as secondary function pin, the input pins should be set to the input mode, and the output pins should be set to the output mode and beforehand the output latch should be set to "1".
It is recommended that pins P11 and P12 should be used as external interrupt inputs, timer/counter input, or input ports. The interrupt latch is set at the rising or falling edge of the output when used as output ports.
Pin P10 ($\overline{INT0}$) can be configured as either an I/O port or an external interrupt input with INT0EN (bit 6 in EINTCR). During reset, pin P10 ($\overline{INT0}$) is configured as an input port P10.




| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
|---|---|---|---|---|---|---|---|---|---|
| **P1** ($0001_H$) | P17 | P16 | P15 TC2 | P14 $\overline{PPG}$ | P13 $\overline{DVO}$ | P12 INT2 TC1 | P11 INT1 | P10 $\overline{INT0}$ | (Initial value : 0000 0000) |
| **P1CR** ($000B_H$) | | | | | | | | | (Initial value : 0000 0000) |

| | | | |
|---|---|---|---|
| P1CR | I/O control for port P1 | 0 : Input mode<br>1 : Output mode | write only |

Figure 2-3. Port P1 and P1CR

Example : Sets P17, P16 and P14 as output ports, P13 and P11 as input ports, and the others as function pins. Internal output data is "1" for the P17 and P14 pins, and "0" for the P16 pin.

```
LD      (EINTCR), 01000000B     ; INT0EN←1
LD      (P1), 10111111B         ; P17←1, P14←1, P16←0
LD      (P1CR), 11010000B
```

*Note : The port set to an input mode reads pin input state. When used with input/output modes, output latch contents of the port set to an input mode may be placed by execution of bit operate instruction.*

### 2.2.2 Port P2 (P22 to P20)

Port P2 is a 3-bit input/output port. It is also used as an external interrupt input, and low-frequency crystal connection pins When used as an input port, or a secondary function pin, the output latch should be set to "1". During reset , the output latches are initialized to "1".

A low-frequency crystal (32.768kHz) is connected to pins P21 (XTIN) and P22 (XTOUT) in the dual-clock mode. In the single-clock mode, pins P21 and P22 can be used as normal input/output ports.

It is recommended that pin P20 should be used as an external interrupt input, a STOP mode release signal input, or an input port. If used as an output port, the interrupt latch is set on the falling edge of the output pulse.

When a read instruction is executed for port P2, bits 7 to 3 read in as indefinite.

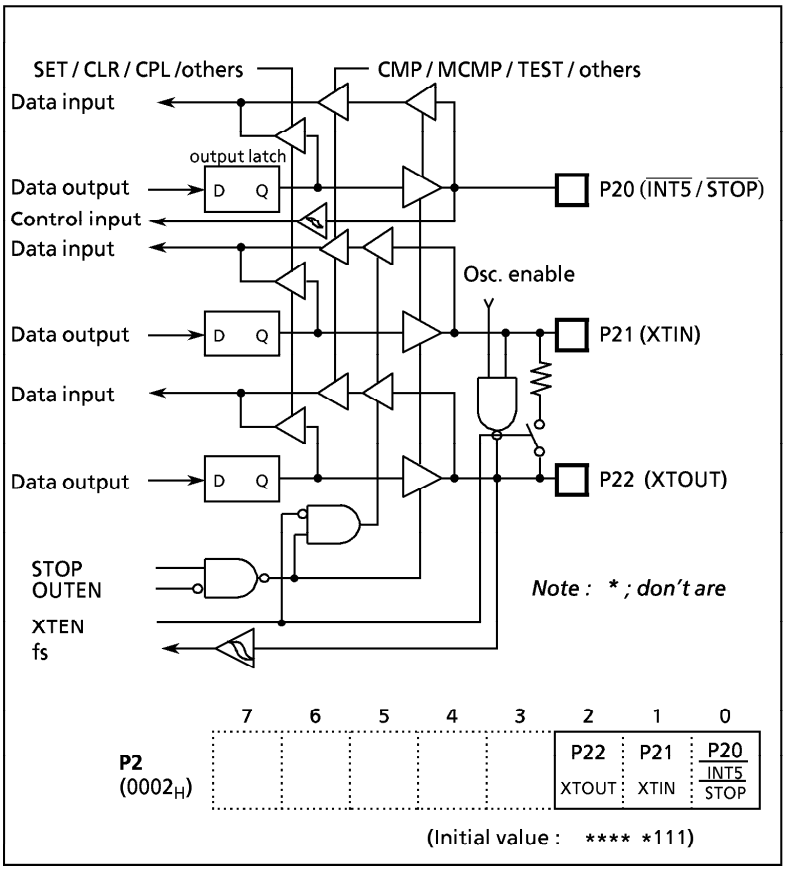



Figure 2-4. Port P2

### 2.2.3 Port P3 (P34 to P30)

Port P3 is an 5-bit input/output port. When used as an input port, the output latch should be set to "1". The output latches are initialized to "1" during reset.

Example 1: Output the immediate data $1A_H$ to the P3 port.

```
LD      (P3), 1AH       ; P3←1AH
```

Example 2: Inverts the output of the lower 4bits (P33 - P30) of the P3 port.

```
XOR     (P3), 00001111B
                ; P33 to P30←P33 to P30
```

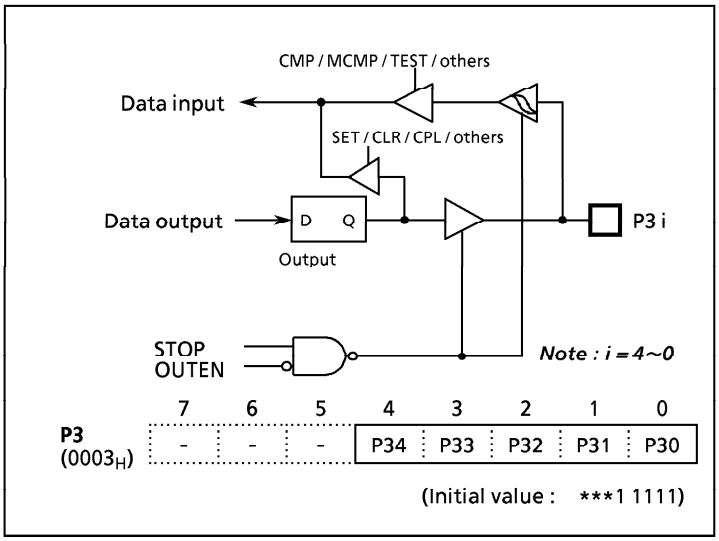



Figure 2-5. Port P3

### 2.2.4 Port P4 (P47 to P40)

Port P4 is an 8-bit input/output port, and is also used as serial interface (SIO1, SIO2) input/output. When used as an input port or a secondary function pin, the output latch should be set to "1". The output latches are initialized to "1" during reset.

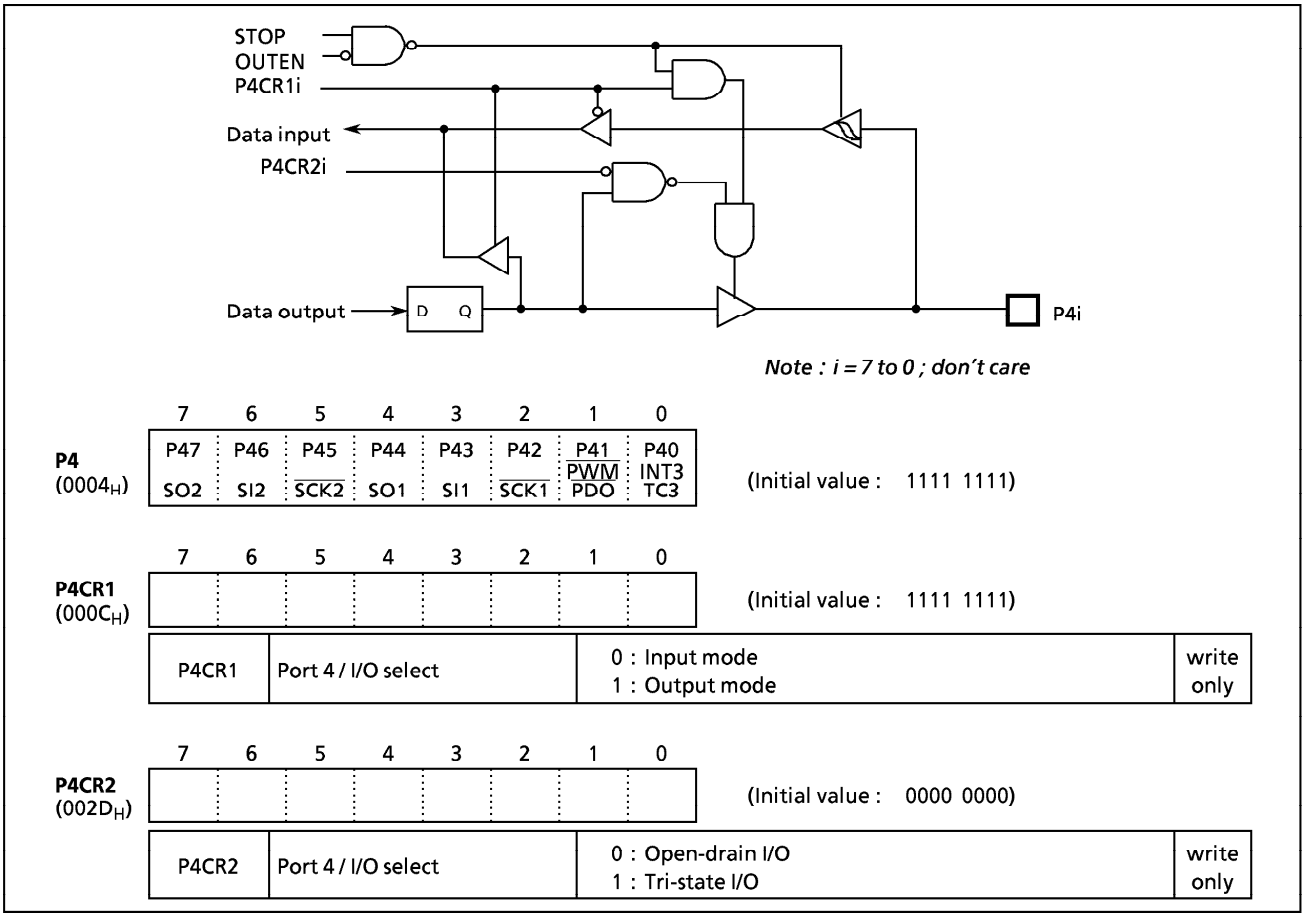
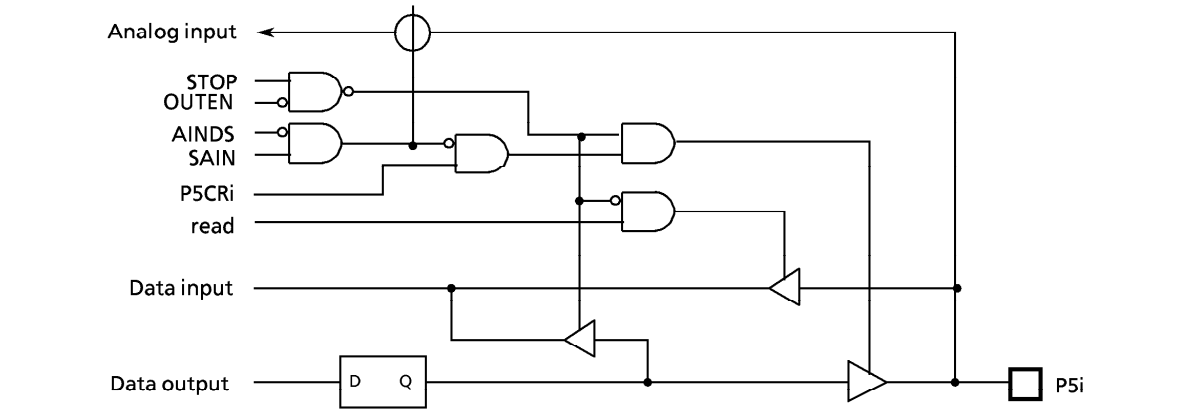



Figure 2-6. Port P4

*Note : The port set to an input mode reads pin input state. When used with input/output modes, output latch contents of the port set to an input mode may be placed by execution of bit operate instruction.*

### 2.2.5 Port P5 (P57 to P50)

Port P5 is a general-purpose 8-bit I/O port that can be specified bitwise. It is also used for analog input. Specify input or output using the P5 I/O control register (P5CR) and AINDS (bit 5 of ADCCR). At reset, the P5CR is set to 0; AINDS, to 1, setting port P5 to analog input. At reset, the output latch of port P5 is initialized to 0. The P5CR is write-only register. The pins of port P5 not specified for analog input can be used as an I/O port; to maintain accuracy, do not use them for output instructions during A/D conversion. While the A/D converter is operating, executing an input instruction writes "1" to pins specified for analog input; "1" or "0", to pins not specified for analog input depending on the pin input level.




*Note : i = 7 to 0*

**P5** ($0005_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| P57 AIN7 | P56 AIN6 | P55 AIN5 | P54 AIN4 | P53 AIN3 | P52 AIN2 | P51 AIN1 | P50 AIN0 |

(Initial value : 0000 0000)

**P5CR** ($000D_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

(Initial value : 0000 0000)

| | | | |
|---|---|---|---|
| P5CR | I/O control for port P5 | 0 : Input mode<br>1 : Output mode | write only |

*Note 1 : P5CR is a write-only register and must not be used with any of the read-modify-write instruction.*
*Note 2 : Unused analog input pins cannot be configured as output mode when AINDS = 0.*

Figure 2-7. Port P5

## 2.2.6 Ports P6 (P67 to P60), P7 (P77 to P70), P9 (P93 to P90)

Port P6 is an 8-bit input / output port and is also used as the segment output port.

Input / output mode or segement output mode is specified by the corresponding bit in the P6 port control register (P6CR). During reset, P6CR is initialized to "0", which configure port P6 as input / output. Port P6 output latches are also initialized to "1". P6CR can only be written.

**P6** ($0006_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| P67 | P66 | P65 | P64 | P63 | P62 | P61 | P60 |
| SEG16 | SEG17 | SEG18 | SEG19 | SEG20 | SEG21 | SEG22 | SEG23 |

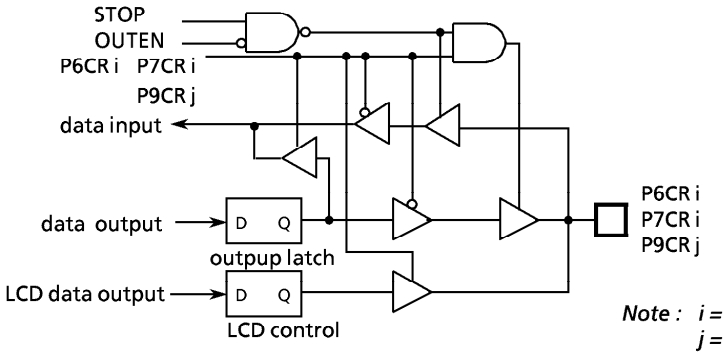
(Initial value: 1111 1111)

**P6CR** ($0029_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

(Initial value: 0000 0000)

| | | | |
|---|---|---|---|
| P6CR | Port P6 / segment output select | 0 : port P6 mode<br>1 : segment output mode | Write only |




Example : Setting the upper 2 bits of port P6 as a segment output port, and the others as input/output port.

```
LD (P6CR), 11000000B
```

**P7** ($0007_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| P77 | P76 | P75 | P74 | P73 | P72 | P71 | P70 |
| SEG24 | SEG25 | SEG26 | SEG27 | SEG28 | SEG29 | SEG30 | SEG31 |

(Initial value: 1111 1111)

**P7CR** ($002A_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

(Initial value: 0000 0000)

| | | | |
|---|---|---|---|
| P7CR | Port P7 / segment output select | 0 : port P7 mode<br>1 : segment output mode | Write only |

**P9** ($0009_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | | P93 | P92 | P91 | P90 |
| | | | | SEG12 | SEG13 | SEG14 | SEG15 |

(Initial value: 1111 1111)

**P9CR** ($002C_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

(Initial value: 0000 0000)

| | | | |
|---|---|---|---|
| P9CR | Port P9 / segment output select | 0 : port P9 mode<br>1 : segment output mode | Write only |

Figure 2-8. Port P6, P7, P9

## 2.3 Time Base Timer (TBT)

The time base timer generates time base for key scanning, dynamic displaying, etc. It also provides a time base timer interrupt (INTTBT). The time base timer is controlled by the control register (TBTCR) shown in Figure 2-10.

An INTTBT is generated on the first rising edge of source clock (the divider output of the timing generator) after the time base timer has been enabled. The divider is not cleared by the program; therefore, only the first interrupt may be generated ahead of the set interrupt period. (Figure 2-10 (b))

The interrupt frequency (TBTCK) must be selected with the time base timer disabled (both frequency selection and enabling can be performed simultaneously).

Example : Sets the time base timer frequency to fc/$2^{16}$ [Hz] and enables an INTTBT interrupt.

```
LD      (TBTCR) , 00001010B
SET     (EIRL) . 6
```

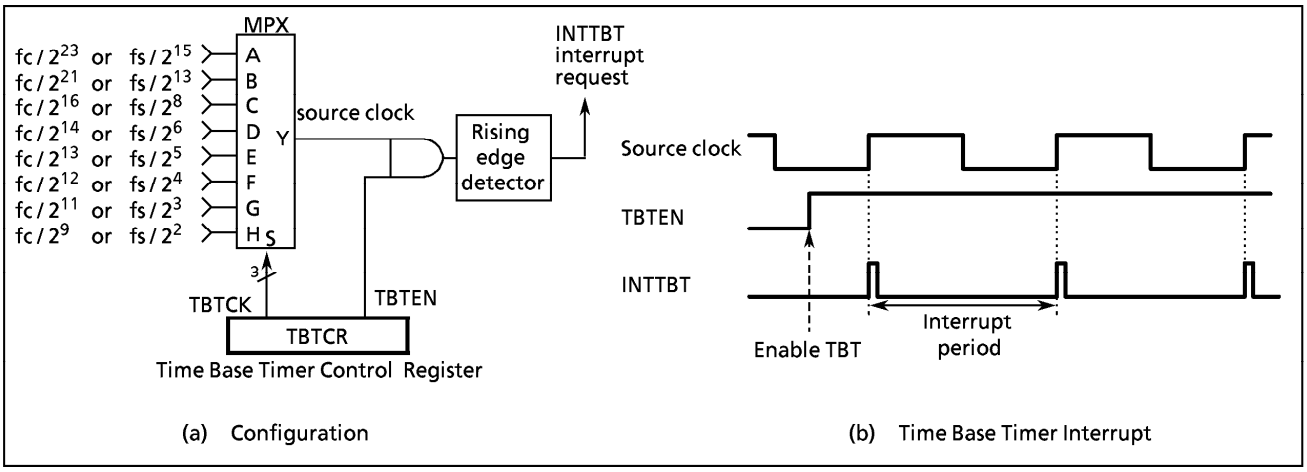



Figure 2-9. Time Base Timer

**TBTCR** ($0036_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| (DVOEN) | (DVOCK) | | (DV7CK) | TBTEN | TBTCK | | |

(Initial value : 0**0 0***)

| | | | |
|---|---|---|---|
| TBTEN | Time base timer enable/disable | 0 : Disable<br>1 : Enable | R/W |
| TBTCK | Time base timer interrupt frequency select | 000 : fc/$2^{23}$ or fs/$2^{15}$ [Hz]<br>001 : fc/$2^{21}$ or fs/$2^{13}$<br>010 : fc/$2^{16}$ or fs/$2^{8}$<br>011 : fc/$2^{14}$ or fs/$2^{6}$<br>100 : fc/$2^{13}$ or fs/$2^{5}$<br>101 : fc/$2^{12}$ or fs/$2^{4}$<br>110 : fc/$2^{11}$ or fs/$2^{3}$<br>111 : fc/$2^{9}$ or fs/2 | |

*Note : fc ; High-frequency clock [Hz], fs ; Low-frequency clock [Hz], * ; don't care*

Figure 2-10. Time Base Timer and Divider Output Control Register

Table 2-1. Time Base Timer Interrupt Frequency

| TBTCK | NORMAL1/2, IDLE1/2 mode | | SLOW, SLEEP mode | Interrupt Frequency | |
|---|---|---|---|---|---|
| | DV7CK = 0 | DV7CK = 1 | | At fc = 8 MHz | At fs = 32.768 kHz |
| 000 | $fc/2^{23}$ | $fs/2^{15}$ | $fs/2^{15}$ | 0.95 Hz | 1 Hz |
| 001 | $fc/2^{21}$ | $fs/2^{13}$ | $fs/2^{13}$ | 3.81 | 4 |
| 010 | $fc/2^{16}$ | $fs/2^{8}$ | - | 122.07 | 128 |
| 011 | $fc/2^{14}$ | $fs/2^{6}$ | - | 488.28 | 512 |
| 100 | $fc/2^{13}$ | $fs/2^{5}$ | - | 976.56 | 1024 |
| 101 | $fc/2^{12}$ | $fs/2^{4}$ | - | 1953.12 | 2048 |
| 110 | $fc/2^{11}$ | $fs/2^{3}$ | - | 3906.25 | 4096 |
| 111 | $fc/2^{9}$ | $fs/2$ | - | 15625 | 16384 |

## 2.4 Divider Output ($\overline{DVO}$)

**TBTCR** ($0036_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| DVOEN | DVOCK | | (DV7CK) | (TBTEN) | (TBTCK) | | |

(Initial value : 0**0 0***)

| | | | |
|---|---|---|---|
| DVOEN | Divider output enable/disable | 0 : Disable<br>1 : Enable | R/W |
| DVOCK | Divider output ($\overline{DVO}$) frequency selection | 00 : $fc/2^{13}$ or $fs/2^{5}$ [Hz]<br>01 : $fc/2^{12}$ or $fs/2^{4}$<br>10 : $fc/2^{11}$ or $fs/2^{3}$<br>11 : $fc/2^{10}$ or $fs/2^{2}$ | |

*Note : fc ; High-frequency clock [Hz], fs ; Low-frequency clock [Hz], * ; don't care*

Figure 2-11. Divider Output Control Register

A 50% duty pulse can be output using the divider output circuit, which is useful for piezo-electric buzzer drive. Divider output is from pin P13 ($\overline{DVO}$). The P13 output latch should be set to "1" and then the P13 should be configured as an output mode.
Divider output circuit is controlled by the control register (TBTCR) shown in Figure 2-11.

Example : 1 kHz pulse output (at fc = 8MHz)

```
SET     (P1).3              ; P13 output latch ←1
LD      (P1CR), 00001000B   ; Configures P13 as an output mode
LD      (TBTCR), 10000000B  ; DVOEN←1, DVOCK←00
```

Table 2-2. Frequency of Divider Output

| DVOCK | Frequency of Divider Output | At fc = 4.194304 MHz | At fc = 8 MHz | At fs = 32.768 kHz |
|---|---|---|---|---|
| 00 | $fc/2^{13}$ or $fs/2^{5}$ | 0.512 [kHz] | 0.976 [kHz] | 1.024 [kHz] |
| 01 | $fc/2^{12}$ $fs/2^{4}$ | 1.024 | 1.953 | 2.048 |
| 10 | $fc/2^{11}$ $fs/2^{3}$ | 2.048 | 3.906 | 4.096 |
| 11 | $fc/2^{10}$ $fs/2^{2}$ | 4.096 | 7.812 | 8.192 |

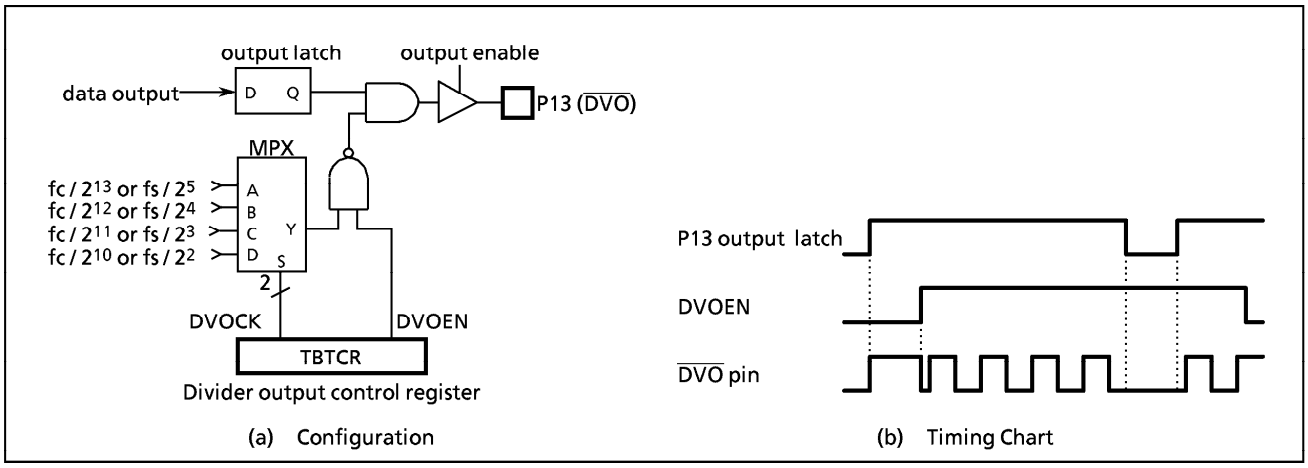



Figure 2-12. Divider Output

## 2.5 16-bit Timer/Counter 1 (TC1)

## 2.5.1 Configuration

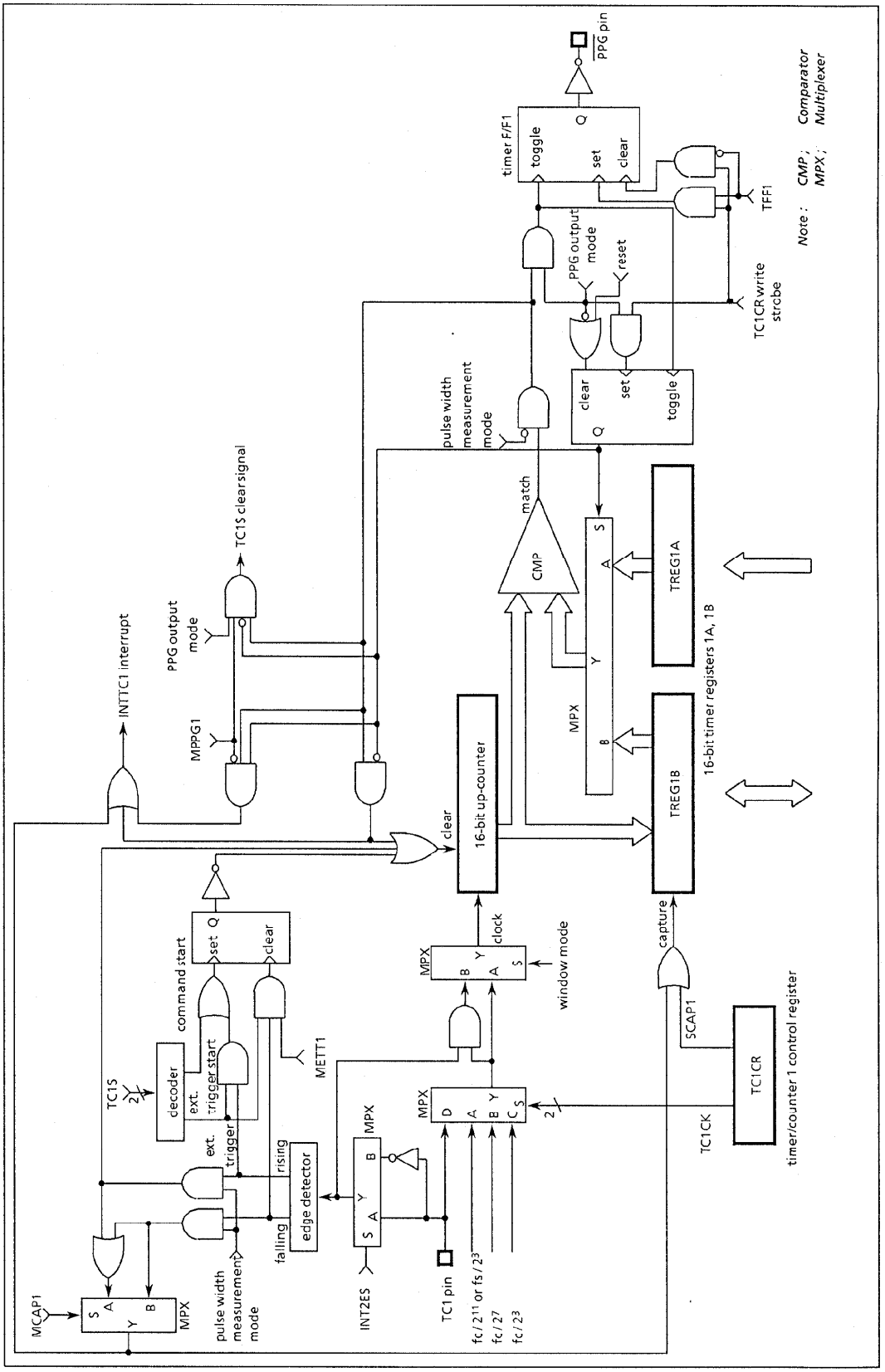



Figure 2-13. Timer/Counter 1

## 2.5.2 Control

The timer/counter 1 is controlled by a timer/counter 1 control register (TC1CR) and two 16-bit timer registers (TREG1A and TREG1B). Reset does not affect TREG1A and TREG1B.

**TREG1A** (0010, $0011_H$)

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $TREG1A_H$ ($0011_H$) | | | | | | | | $TREG1A_L$ ($0010_H$) | | | | | | | |

Write only

**TREG1B** (0012, $0013_H$)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $TREG1B_H$ ($0013_H$) | | | | | | | | $TREG1B_L$ ($0012_H$) | | | | | | | |

Read / Write (Write available in only PPG output mode )

**TC1CR** ($0014_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| TFF1 | SCAP1<br>MCAP1<br>METT1<br>MPPG1 | TC1S | | TC1CK | | TC1M | |

(Initial value : 0000 0000)

| | | | |
|---|---|---|---|
| TC1M | TC1<br>mode select | 00 : timer / external trigger timer / event counter mode<br>01 : window mode<br>10 : pulse width measurement mode<br>11 : PPG output mode | Write only |
| TC1CK | TC1<br>source clock select | 00 : internal clock $fc/2^{11}$ or $fs/2^2$ [Hz]<br>01 : internal clock $fc/2^7$<br>10 : internal clock $fc/2^3$<br>11 : external clock (TC1 pin input) | |
| TC1S | TC1<br>start control | 00 : stop & counter clear<br>01 : command start<br>10 : reserved<br>11 : external trigger start | |
| SCAP1 | software capture control | 0 : – 1 : software capture trigger (Note 3) | |
| MCAP1 | pulse width measurement control | 1 : double edge capture 1 : single edge capture | |
| METT1 | external trigger timer control | 0 : trigger start 1 : trigger start & stop | |
| MPPG1 | PPG output control | 0 : continuous pulse 1 : single pulse | |
| TFF1 | timer F/F1 control for PPG output mode | 0 : clear 1 : set | |

*Note 1 : fc ; High-frequency clock [Hz], fs ; Low-frequency clock [Hz]*

*Note 2 : Writing to the low-byte of the timer registers ($TREG1A_L$, $TREG1B_L$), the comparison is inhibited until the high-byte ($TREG1A_H$, $TREG1B_H$) is written. (Only the low-byte of the timer registers cannot be changed.) After writing to the high-byte, the comparison within 1 cycle(during instruction execution) is ignored.*

*Note 3 : Set the mode, source clock, edge (INT2ES), PPG control and timer F/F control when TC1 stops (TC1S = 00).*

*Note 4 : Software capture can be used in only timer and event counter modes. SCAP1 is automatically cleared to "0" after software capture.*

*Note 5 : Values to be loaded to timer registers must satisfy the following condition.*
*TREG1A > TREG1B > 0 (PPG output mode) ; TREG1A > 0 (others)*

*Note 6 : Always write "0" to TFF1 except the PPG output mode.*

*Note 7 : TREG1B cannot be written after setting to PPG output mode.*

*Note 8 : TC1CR is a write-only register, which cannot be accessed by any read-modify-write instruction such as bit operate, etc.*

Figure 2-14. Timer Registers and TC1 Control Register

## 2.5.3 Function

Timer/counter 1 has six operating modes: timer, external trigger timer, event counter, window, pulse width measurement, programmable pulse generator output mode.

(1) **Timer** Mode

In this mode, counting up is performed using the internal clock. The contents of TREG1A are compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared to"0". Counting up resumes after the counter is cleared. The current contents of up-counter can be transfered to TREG1B by setting SCAP1 (bit 6 in TC1CR) to "1" (software capture function). SCAP1 is automatically cleared to "0" after capaturing.

Table 2-3. Timer/Counter 1 Source Clock (Internal Clock)

| Source clock | | | Resolution | | Maximum time setting | |
|---|---|---|---|---|---|---|
| NORMAL1/2, IDLE1/2 modes | | SLOW, SLEEP modes | | | | |
| DV7CK = 0 | DV7CK = 1 | | At fc = 8 MHz | At fs = 32.768 kHz | At fc = 8 MHz | At fs = 32.768 kHz |
| $fc / 2^{11}$ | $fs / 2^3$ | $fs / 2^3$ [Hz] | 256 μs | 244.14 μs | 16.8 s | 16.0 s |
| $fc / 2^7$ | $fc / 2^7$ | – | 16 μs | – | 1.0 s | – |
| $fc / 2^3$ [Hz] | $fc / 2^3$ [Hz] | – | 1 μs | – | 65.5 ms | – |

Example 1 : Sets the timer mode with source clock $fs/2^3$ [Hz] and generates an interrupt 1 s. later (at fs = 32.768 kHz).

```
LD      (TC1CR), 00000000B      ; Sets the TC1 mode and source clock
LDW     (TREG1A), 1000H         ; Sets the timer register (1 s ÷ 2^3 / fs = 1000H)
SET     (EIRL).EF4              ; enable INTTC1
EI
LD      (TC1CR), 00010000B      ; Starts TC1
```

*Note : TC1CR is a write-only register, which cannot start by [SET(TC1CR).4] instruction.*

Example 2 : Software capture

```
LD      (TC1CR), 01010000B      ; SCAP1←1 (Captures)
LD      WA, (TREG1B)            ; Reads captured value
```

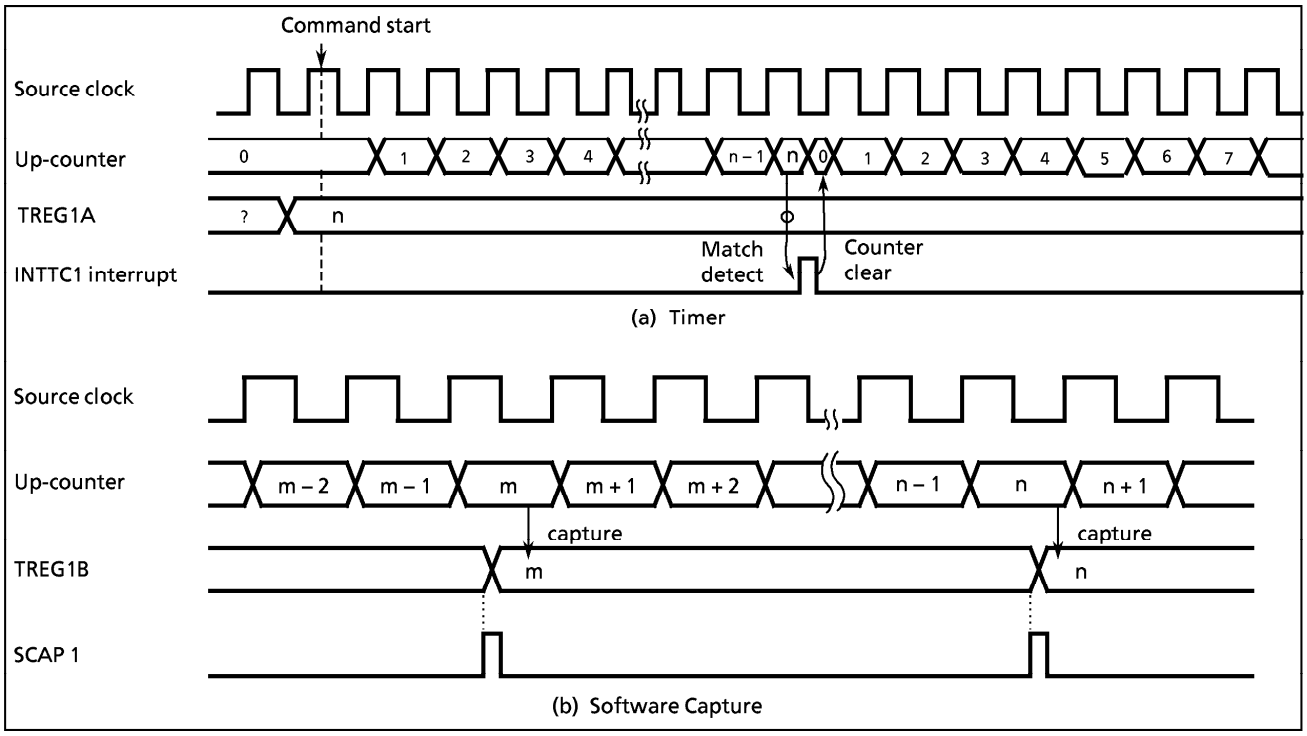



Figure 2-15. Timer Mode Timing Chart

(2) **External Trigger Timer** mode

In this mode, counting up is started by an external trigger. This trigger is the edge of the TC1 pin input. Either the rising or falling edge can be selected with INT2ES. Edge selection is the same as for the external interrupt input INT2 pin. Source clock is used an internal clock selected with TC1CK. The contents of TREG1A is compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared to"0" and halted. The counter is restarted by the selected edge of the TC1 pin input.

When the edge input is opposite to the edge input way of the count start trigger at METTI (bit 6 in TC1CR) = 1, the counter is cleared, and count stops. In this mode, pulse input with a constant pulse width generates interrupt. When METT1 is "0", the opposite edge input is ignored. The edge of TC1 pin input before match detection is also ignored.

The TC1 pin input has the same noise rejection as the INT2 pin; therefore, pulses of 7/fc [s] or less are rejected as noise. A pulse width of 24/fc [s] or more is required for edge detection in NORMAL1/2 or IDLE1/2 mode. The noise rejection circuit is turned off in SLOW and SLEEP modes. But, a pulse width of 1 machine cycle or more is required.

Example 1 :Generates interrupt after 100 $\mu$s from TC1 pin input rising edge (at fc = 8 MHz).

```
LD      (EINTCR), 00000000B     ; INT2ES←0 (rising edge)
LDW     (TREG1A), 0064H         ; 100 μs ÷ 2^3 / fc = 64H
SET     (EIRL).EF4              ; Enables INTTC1 interrupt
EI
LD      (TC1CR), 00111000B      ; Starts TC1 external trigger, METT = 0
```

Example 2 : When "L" level pulses of 4ms or more is input to TC1 pin, generates interrupt.
(at fc = 8 MHz)

```
LD      (EINTCR), 00000100B     ; INT2ES←1 ("L" level)
LDW     (TREG1A), 00FAH         ; 4 ms ÷ 2^7 / fc = FA_H
SET     (EIRL).EF4              ; Enables INTTC1 interrupt
EI
LD      (TC1CR), 01110100B      ; Starts TC1 external trigger , METT = 1
```

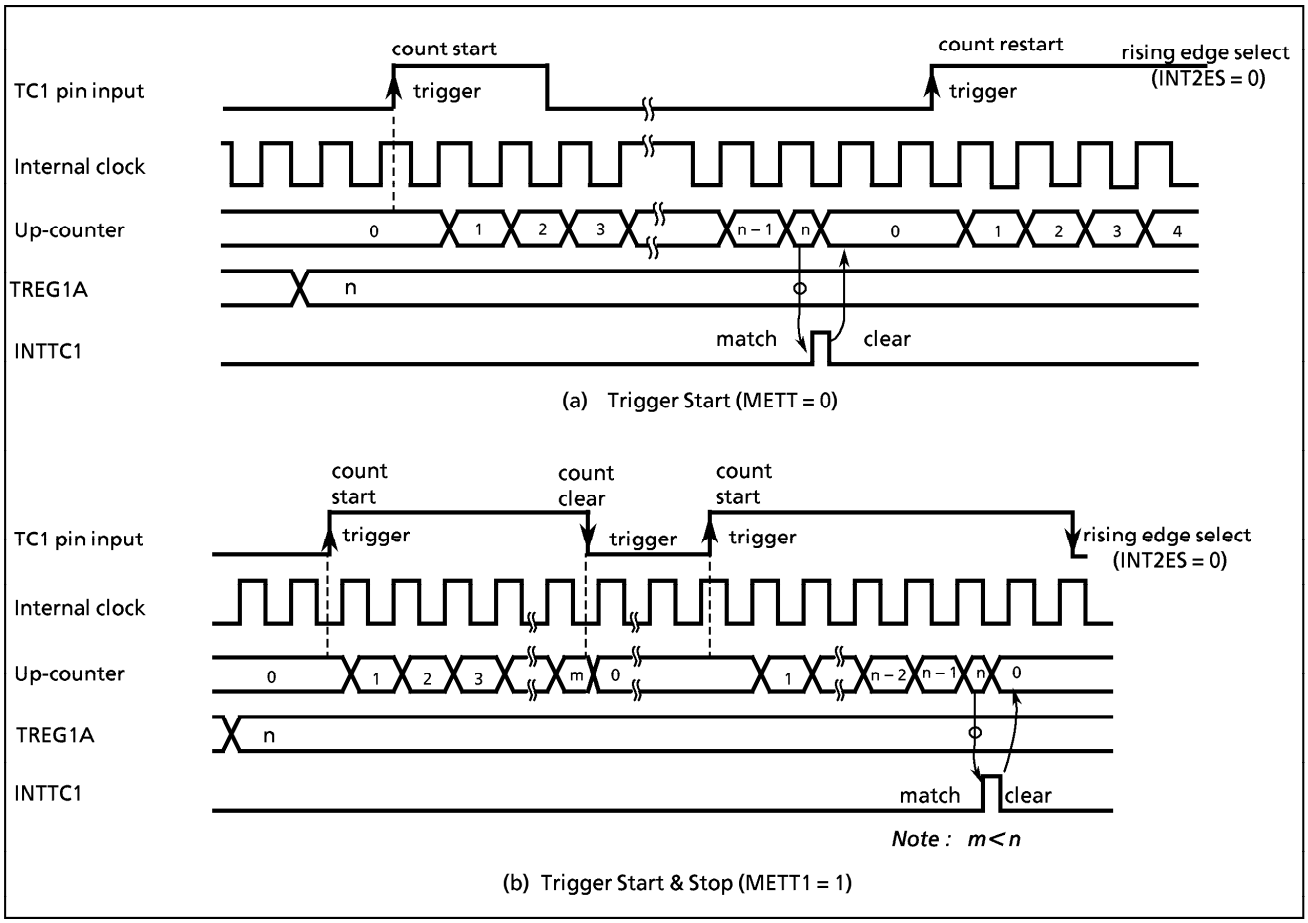



Figure 2-16. External Trigger Timer Mode Timing Chart

(3) **Event Counter** Mode

In this mode, events are counted on the edge of the TC1 pin input. Either the rising or falling edge can be selected with INT2ES in EINTCR. The contents of TREG1A are compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared. Counting up resumes after the counter is cleared. The maximum applied frequency is fc/$2^4$ [Hz] in NORMAL1/2 or IDLE1/2 mode and fs/$2^4$ [Hz] in SLOW or SLEEP mode.

Setting SCAP1 to "1" transferres the current contents of up-counter to TREG1B (software capture function). SCAP is automatically cleared after capturing.

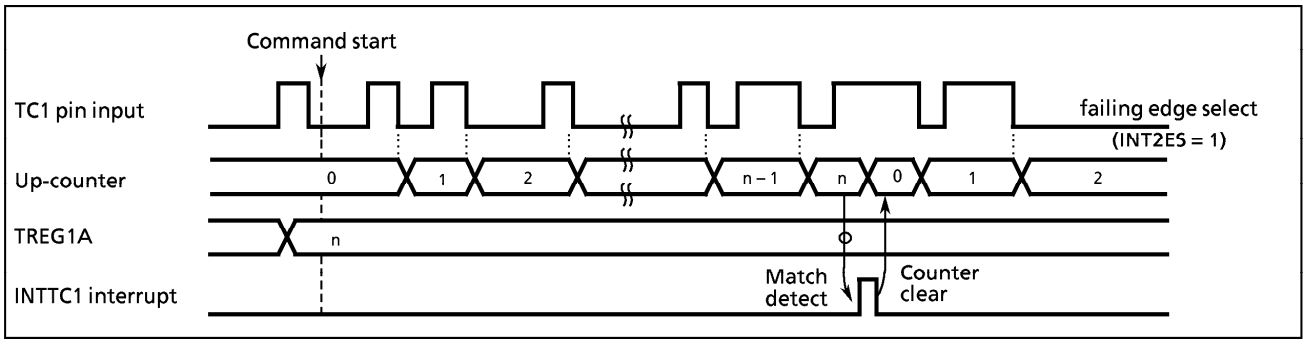



Figure 2-17. Event Counter Mode Timing Chart (INT2ES = 1)

(4) **Window** mode

Counting up is performed on the rising edge of the pulse that is the logical AND-ed product of the TC1 pin input (window pulse) and an internal clock. The contents of TREG1A are compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared. Positive or negative logic for the TC1 pin input can be selected with INT2ES. Setting SCAP1 to "1" transferes the current contents of up-counter to TREG1B. It is necessary that the maximum applied frequency (TC1 input) be such that the counter value can be analyzed by the program. That is, the frequency must be considerably slower than the selected internal clock.

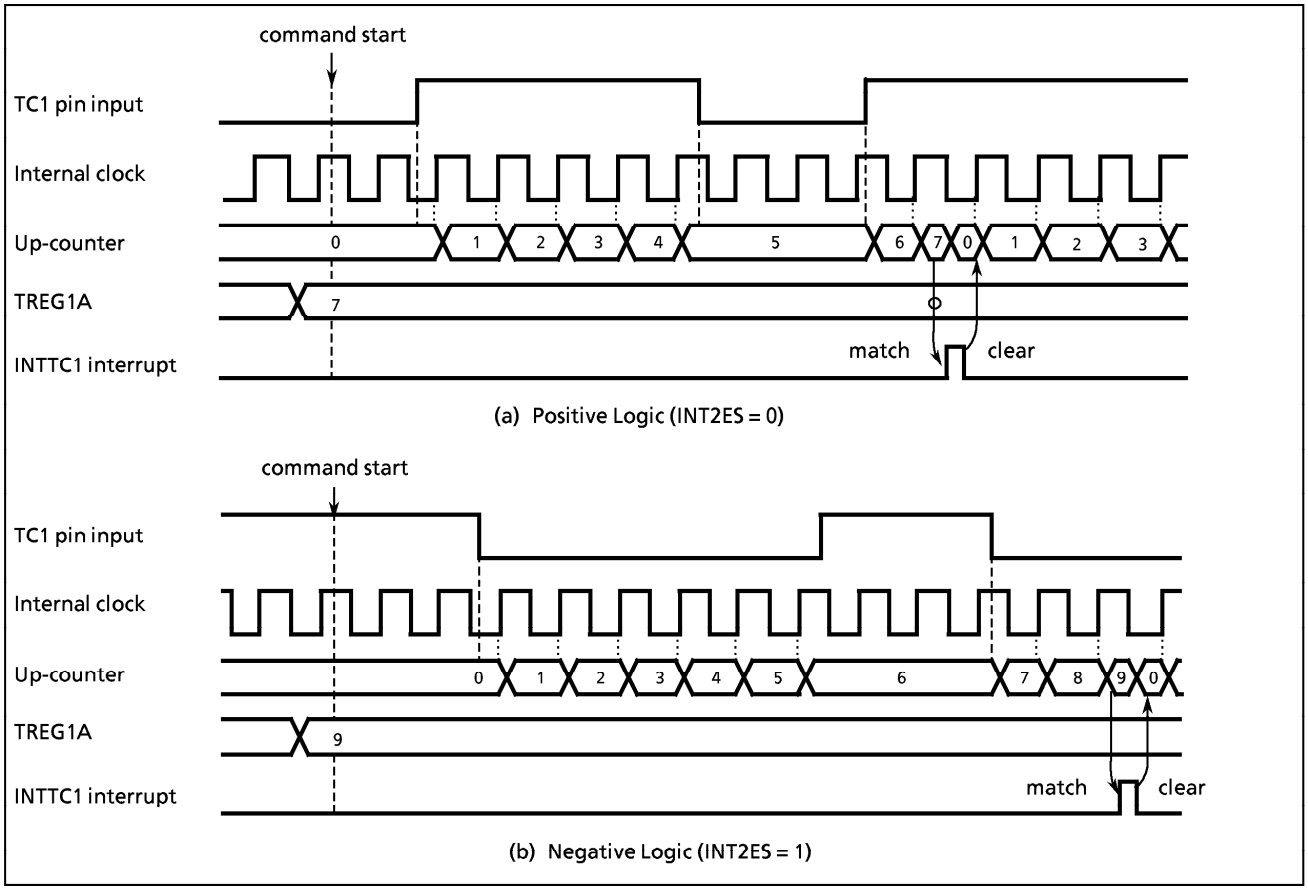


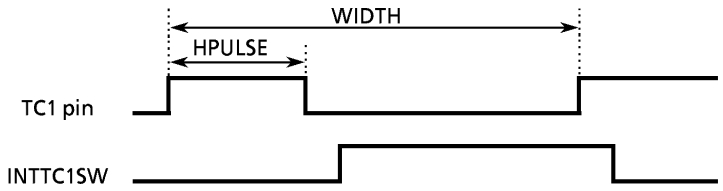

Figure 2-18. Window Mode Timing Chart

(5) **Pulse width measurement** mode

Counting is started by the external trigger (set to external trigger start by TC1S). The trigger can be selected either the rising or falling edge of the TC1 pin input. The source clock is used an internal clock. On the next falling (rising) edge, the counter contents are transferred to TREG1B and an INTTC1 interrupt is generated. The counter is cleared when the single edge capture mode is set. When double edge capture is set, the counter continues and, at the next rising (falling) edge, the counter contents are again transferred to TREG1B. If a falling (rising) edge capture value is required, it is necessary to read out TREG1B contents until a rising (falling) edge is detected. Falling or rising edge is selected with INT2ES, and single edge or double edge is selected with MCAP1 ( bit 6 in TC1CR).

Example : Duty measurement (Resolution $fc/2^7$ [Hz])

```
                CLR     (INTTC1SW). 0           ;  INTTC1 service switch initial setting
                LD      (EINTCR), 00000000B     ;  Sets the rise edge at the INT2 edge
                LD      (TC1CR), 00000110B      ;  Sets the TC1 mode and source clock
                SET     (EIRL). 4               ;  Enables INTTC1
                EI
                LD      (TC1CR), 00110110B      ;  Starts TC1 with an external trigger
                 :
PINTTC1 :       CPL     (INTTC1SW). 0           ;  Complements INTTC1 service switch
                JRS     F, SINTTC1
                LD      (HPULSE), (TREG1BL)     ;  Reads TREG1B
                LD      (HPULSE + 1), (TREG1BH)
                RETI
SINTTC1 :       LD      (WIDTH), (TREG1BL)      ;  Reads TREG1B (Period)
                LD      (WIDTH + 1), (TREG1BH)
                 :
                RETI
                 :
VINTTC1 :       DW      PINTTC1
```



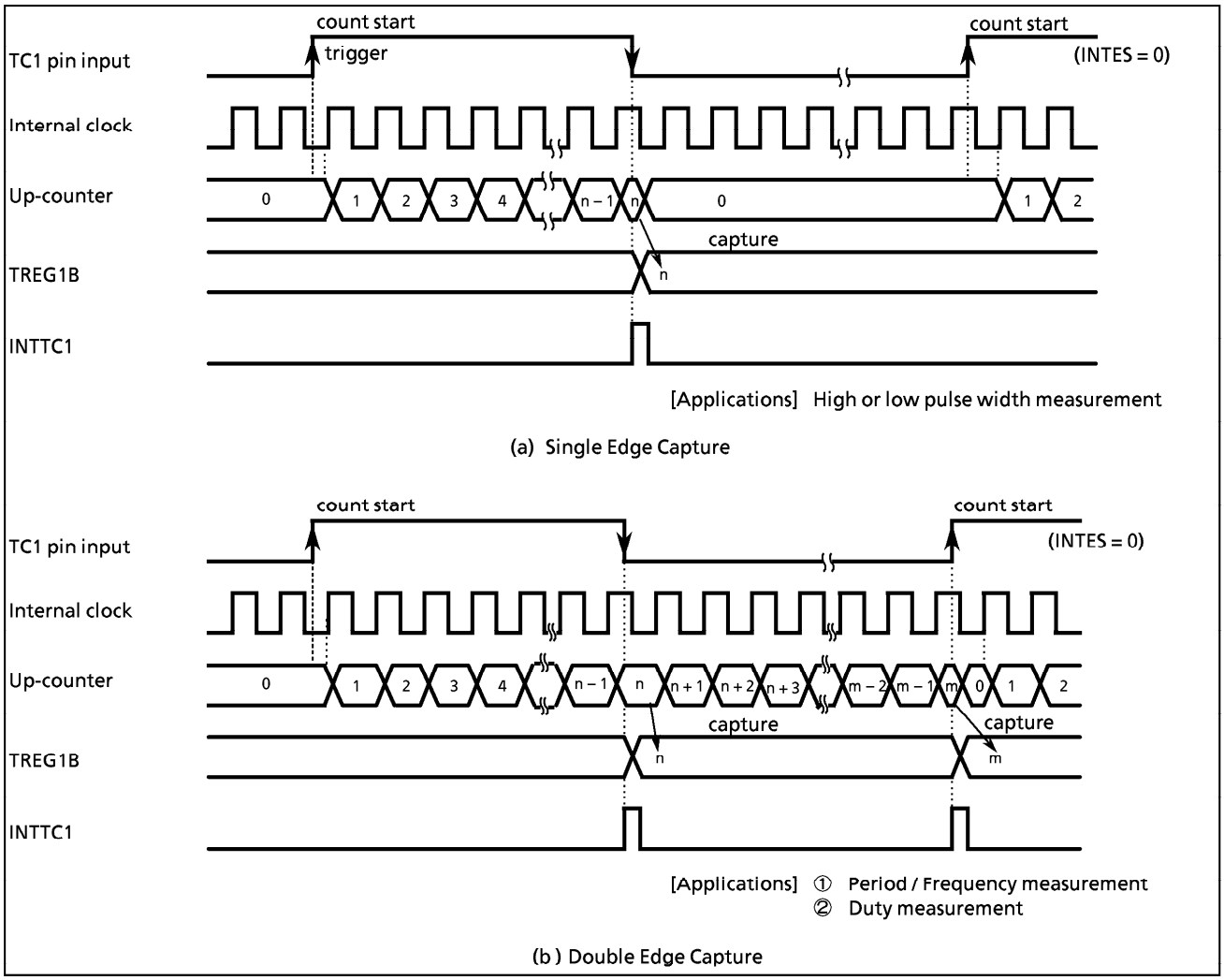



Figure 2-19. Pulse Width Measurement Mode Timing Chart

(6) **Programmable Pulse Generate** (PPG) **output** mode

Counting is started by an edge of the TC1 pin input (either the rising or falling edge can be selected) or by a command. The source clock is used an internal clock. First, the contents of TREG1B are compared with the contents of the up-counter. If a match is found, timer F/F1 output is toggled. Next, timer F/F1 is again toggled and the counter is cleared by matching with TREG1A. An INTTC1 interrupt is generated at this time. Timer F/F output is connected to the P14 ($\overline{PPG}$) pin. In the case of $\overline{PPG}$ output, set the P14 output latch to "1" and configure as an output with $P1CR_4$. Timer F/F1 is cleared to "0" during reset. The timer F/F1 value can also be set by program and either a positive or negative logic pulse output is available. Also, writing to the TREG1B is not possible unless the timer / counter 1 is set to the PPG output mode.

Example : "H" level 800 $\mu$s, "L"" level 200 $\mu$s pulse output at fc = 8 MHz

```
SET    (P1).4              ;   P14 output latch←1
LD     (P1CR), 00010000B   ;   Sets P14 to an output mode
LD     (TC1CR), 10001011B  ;   Sets PPG output mode
LDW    (TREG1A), 03E8H     ;   Sets a period (1 ms ÷ 1 μs = 03E8H)
LDW    (TREG1B), 00C8H     ;   Sets "L" level pulse width (200 μs ÷ 1 μs = 00C8H)
LD     (TC1CR), 10010011B  ;   Start
```

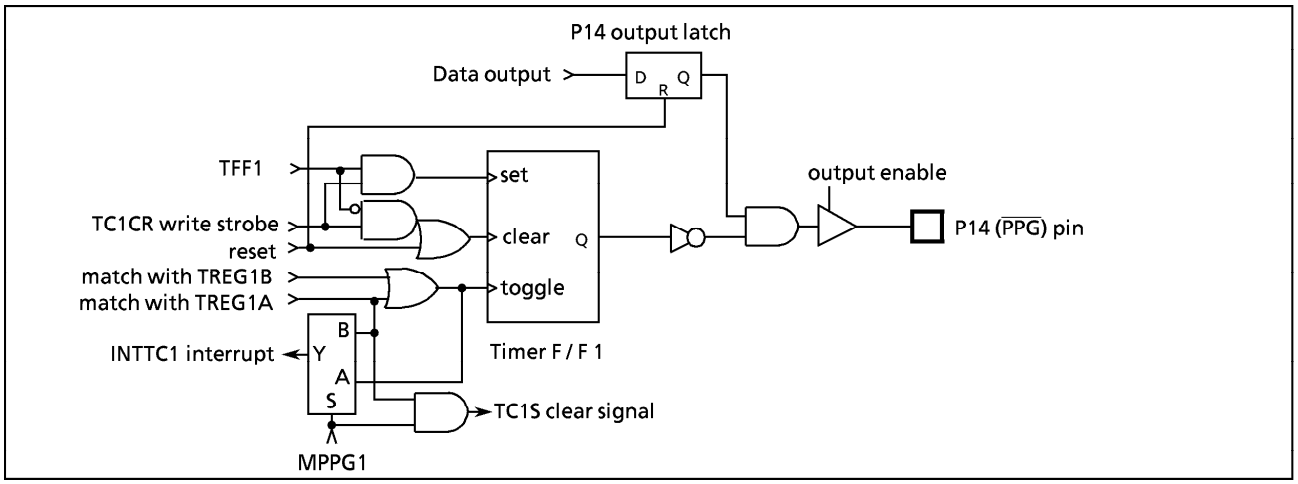



Figure 2-20. $\overline{\text{PPG}}$ Output

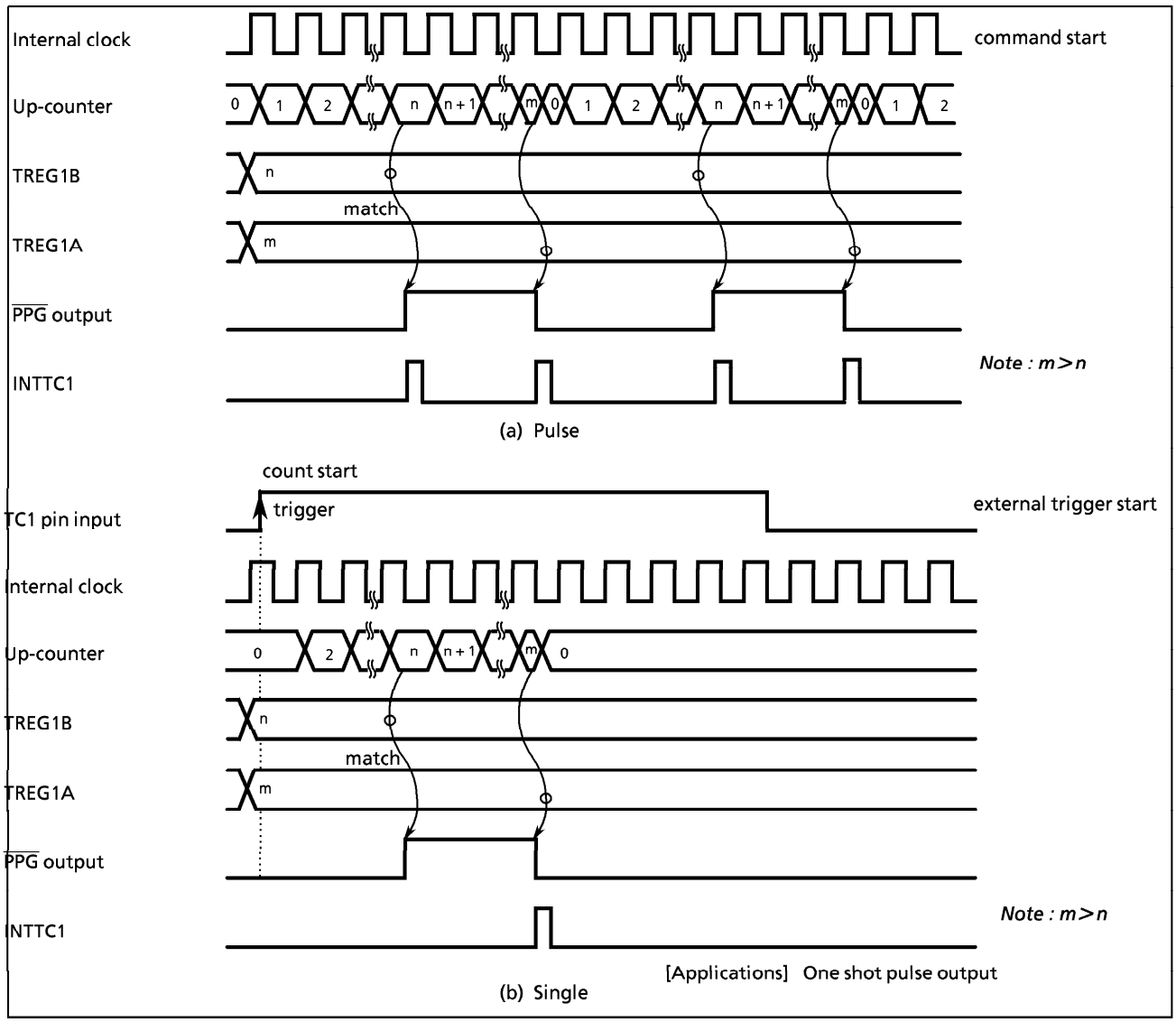



Figure 2-21. PPG Output Mode Timing Chart

## 2.6 16-bit Timer/Counter 2 (TC2)

### 2.6.1 Configuration

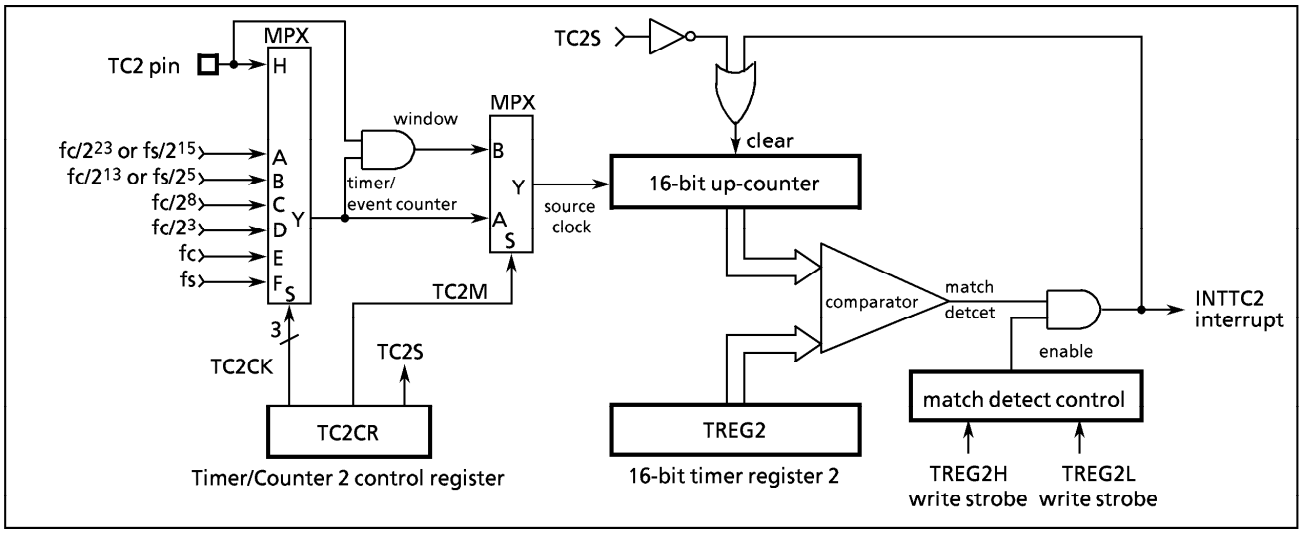



Figure 2-22. Timer/Counter 2 (TC2)

### 2.6.2 Control

The timer/counter 2 is controlled by a timer/counter 2 control register (TC2CR) and a 16-bit timer register 2 (TREG2). Reset does not affect TREG2.

**TREG2** (0016, $0017_H$)

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $TREG2_H$ ($0017_H$) | | | | | | | | $TREG2_L$ ($0016_H$) | | | | | | | |

write only

**TC2CR** ($0015_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | TC2S | TC2CK | | | | TC2M |

(Initial value : **00 00*0)

| | | | |
|---|---|---|---|
| TC2M | Timer/counter 2 operating mode select | 0 : Timer/Event counter mode<br>1 : Window mode | write only |
| TC2CK | Timer/counter 2 source clock select | 000 : Internal clock fc / $2^{23}$ or fs / $2^{15}$ [Hz]<br>001 : 〃 fc / $2^{13}$ or fs / $2^5$<br>010 : 〃 fc / $2^8$<br>011 : 〃 fc / $2^3$<br>100 : 〃 fc (Note 5)<br>101 : 〃 fs<br>110 : Reserved<br>111 : External clock (TC2 pin input) | |
| TC2S | Timer/counter 2 start control | 0 : Stop and counter clear<br>1 : Start | |

*Note 1 : fc; High-frequency clock [Hz], fs; Low-frequency clock [Hz], *; don't care*

*Note 2 : When writing to the low-byte of timer register 2 ($TREG2_L$), the comparison is inhibited until the high-byte ($TREG2_H$) is written.*
*After writing to the high-byte, any match during 1 machine cycle (instruction execution cycle) is ignored.*

*Note 3 : Set the mode and source clock when timer/counter stops (TC2S = 0).*

*Note 4 : Values to be loaded to the timer register must satisfy the following condition.*
*$TREG2 > 0$ ($TREG2_{15\sim11} > 0$ when warm-up).*

*Note 5 : "fc" can be selected as the source clock only in the timer mode during the SLOW mode.*

*Note 6 : TC2CR is a write-only register, which cannot access any of in read-modify-write instruction such as bit operate, etc.*

Figure 2-23. Timer Register 2 and TC2 Control Register

## 2.6.3 Function

The timer/counter 2 has three operating modes: timer, event counter and window modes. Also timer/counter 2 is used for warm-up when switching from SLOW mode to NORMAL2 mode.

(1) **Timer** Mode

In this mode, the internal clock is used for counting up. The contents of TREG2 are compared with the contents of up-counter. If a match is found, a timer/ counter 2 interrupt (INTTC2) is generated, and the counter is cleared. Counting up is resumed after the counter is cleared.

Also, when fc is selected as the source clock during SLOW mode, the lower 11 bits of TREG2 are ignored and an INTTC2 interrupt is generated by matching the upper 5 bits. Thus, in this case, only the $TREG2_H$ setting is necessary.

Table 2-4. Source Clock (Internal Clock) for Timer/Counter 2

| Source clock | | | | Resolution | | Maximum time setting | |
|---|---|---|---|---|---|---|---|
| NORMAL1/2, IDLE1/2 mode | | SLOW mode | SLEEP mode | | | | |
| DV7CK = 0 | DV7CK = 1 | | | At fc = 8 MHz | At fs = 32.768 kHz | At fc = 8 MHz | At fs = 32.768 kHz |
| $fc / 2^{23}$ [Hz] | $fs / 2^{15}$ [Hz] | $fs / 2^{15}$ [Hz] | $fs / 2^{15}$ [Hz] | 1.05 s | 1 s | 19.1 hour | 18.2 hour |
| $fc / 2^{13}$ | $fs / 2^{5}$ | $fs / 2^{5}$ | $fs / 2^{5}$ | 1.02 ms | 1 ms | 1.1 min | 1 min |
| $fc / 2^{8}$ | $fc / 2^{8}$ | – | – | 32 μs | – | 2.1 s | – |
| $fc / 2^{3}$ | $fc / 2^{3}$ | – | – | 1 μs | – | 65.5 ms | – |
| – | – | fc (Note) | – | 125 ns | – | 7.9 ms | – |
| fs | fs | – | – | – | 30.5 μs | – | 2 s |

*Note : "fc" can be used only in the timer mode. This is used for warm up when switching from SLOW mode to NORMAL2 mode.*

Example : Sets the timer mode with source clock $fc/2^3$ [Hz] and generates an interrupt every 25 ms (at fc = 8 MHz).

```
LD      (TC2CR), 00001100B      ; Sets the TC2 mode and source clock
LDW     (TREG2), 61A8H          ; Sets TREG2 (25ms ÷ 2^3/fc = 61A8H)
SET     (EIRH).EF14             ; Enable INTTC2
EI
LD      (TC2CR), 00101100B      ; Starts TC2
```

(2) **Event Counter** Mode

In this mode, events are counted on the rising edge of the TC2 pin input. The contents of TREG2 are compared with the contents of the up-counter. If a match is found, an INTTC2 interrupt is generated, and the counter is cleared. The maximum frequency applied to the TC2 pin is $fc/2^4$ [Hz] in NORMAL1/2 or IDLE1/2 mode, and $fs/2^4$ [Hz] in SLOW or SLEEP mode. But, a pulse width of 2 machine cycles or more is required for both "H" and "L" level.

Example : Sets the event counter mode and generates an INTT2 interrupt 640 counts later.

```
LD      (TC2CR), 00011100B      ; Sets the TC2 mode
LDW     (TREG2), 640            ; Sets TREG2
SET     (EIRH).EF14             ; Enable INTTC2
EI
LD      (TC2CR), 00111100B      ; Starts TC2
```

(3) **Window** Mode

In this mode, counting up is performed on the rising edge of the pulse that is the logical AND-ed product of the TC2 pin input (window pulse) and an internal clock. The internal clock is selected with TC2CK. The contents of TREG2 are compared with the contents of up-counter. If a match is found, an INTTC2 interrupt is generated, and the up-counter is cleared to "0". It is necessary that the maximum applied frequency (TC2 input) be such that the counter value can be analyzed by the program. That is, the frequency must be considerably slower than the selected internal clock.

Example : Inputs "H" level pulse of 120 ms or more and generates interrupt. (at fc = 8 MHz).

```
LDW     (TREG2), 0078H          ; Sets TREG2 (120 ms ÷ 2^13/fc = 0078H)
SET     (EIRH).EF14             ; Enables INTTC2 interrupt
EI
LD      (TC2CR), 00100101B      ; Starts TC2
```

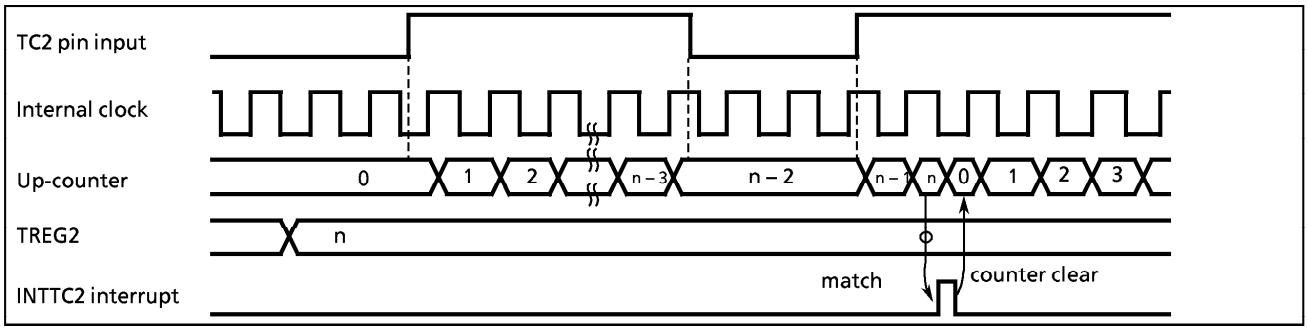



Figure 2-24. Window Mode Timing Chart

## 2.7 8-Bit Timer/Counter 3 (TC3)

### 2.7.1 Configuration

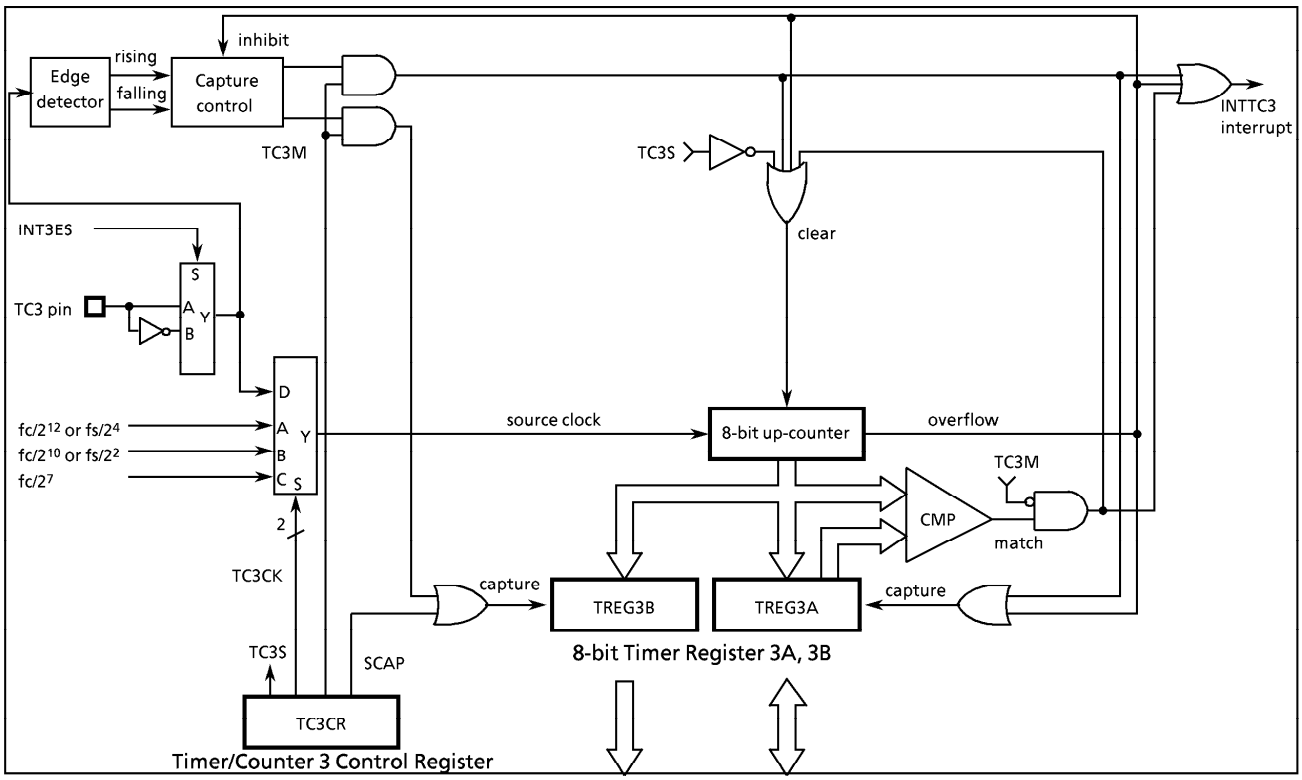



Figure 2-25. Timer/Counter 3

## 2.7.2 Control

The timer/counter 3 is controlled by a timer/counter 3 control register (TC3CR) and two 8-bit timer registers (TREG3A and TREG3B). Reset does not affect these timer registers.

TREG3A ($0018_H$) — 7 6 5 4 3 2 1 0 — Read/Write

TREG3B ($0019_H$) — Read only

TC3CR ($001A_H$) — 7 6 5 4 3 2 1 0 — (Initial value : *0*0 00*0)

| | | | |
|---|---|---|---|
| TC3M | Timer/counter 3 operation mode set | 0 : Timer/event counter<br>1 : Capture | Write only |
| TC3CK | Timer/counter 3 source clock select | 00 : Internal clock $fc/2^{12}$ or $fs/2^4$ [Hz]<br>01 : Internal clock $fc/2^{10}$ or $fs/2^2$<br>10 : Internal clock $fc/2^7$<br>11 : External clock (TC3 pin input) | |
| TC3S | Timer/counter 3 start select | 0 : Stop & clear<br>1 : Start | |
| SCAP | Software capture control | 0 : –<br>1 : Software capture | |

*Note 1 : fc ; High-frequency clock [Hz] fs ; Low-frequency clock [Hz] * ; don't care*
*Note 2 : Set the mode, the source clock and the edge selection (INT3ES) when the TC3 stops (TC3S = 0).*
*Note 3 : Values to be loaded into timer register 3A must satisfy the following condition.*
*TREG3A > 0 (in the timer/event counter mode)*
*Note 4 : Software capture can be used in only timer and event counter mode.*
*Note 5 : TC3CR is a write-only register, which cannot access any of in read-modify-write instruction such as bit operate, etc.*

Figure 2-26. Timer Register 3A/3B and TC3 Control Register

## 2.7.3 Function

The timer/counter 3 has three operating modes : timer, event counter, and capture mode.

(1) **Timer** Mode

In this mode, the internal clock is used for counting up. The contents of TREG3A are compared with the contents of up-counter. If a match is found, a timer/counter 3 interrupt (INTTC3) is generated, and the up-counter is cleared. Counting up resumes after the up-counter is cleared. The current contents of up-counter are loaded into TREG3B by setting SCAP (bit 6 in TC3CR) to "1". SCAP is automatically cleared after capturing.

Table 2-5. Source Clock (Internal Clock) for Timer Counter 3

| Source clock | | | Resolution | | Maximum time setting | |
|---|---|---|---|---|---|---|
| NORMAL1/2, IDLE1/2 mode | | SLOW, SLEEP mode | | | | |
| DV7CK = 0 | DV7CK = 1 | | At fc = 8 MHz | At fs = 32.768 kHz | At fc = 8 MHz | At fs = 32.768 kHz |
| $fc/2^{12}$ | $fs/2^4$ [Hz] | $fs/2^4$ [Hz] | 512 μs | 488.28 μs | 131.1 ms | 125 ms |
| $fc/2^{10}$ | $fs/2^2$ | – | 128 μs | 122.07 μs | 32.8 ms | 31.25 ms |
| $fc/2^7$ | | – | 16 μs | – | 4.1 ms | – |

(2) **Event Counter** Mode

In this mode, the TC3 pin input pulses are used for counting up. Either the rising or falling edge can be selected with INT3ES (bit 3 in EINTCR). The contents of TREG3A are compared with the contents of the up-counter. If a match is found, an INTTC3 interrupt is generated and the counter is cleared. The maximum applied frequency is $fc/2^4$ [Hz] in the NORMAL1/2 or IDLE1/2 mode, and $fs/2^4$ [Hz] in SLOW or SLEEP mode. Two or more machine cycles are required for both the "H" and "L" levels of the pulse width.

The current contents of up-counter are loaded into TREG3B by setting SCAP (bit 6 in TC3CR) to "1". SCAP is automatically cleared after capturing.

Example : Generates an interrupt every 0.5 s, inputing 50Hz pulses to the TC3 pin.

```
LD (TC3CR), 00001100B   ;  Sets TC3 mode and source clock
LD (TREG3A), 19H        ;  0.5 s ÷ 1 / 50 = 25 = 19H
LD (TC3CR), 00011100B   ;  Start TC3
```

(3) **Capture** Mode

The pulse width, period and duty of the TC3 pin input are measured in this mode, which can be used in decoding the remote control signals, etc. The counter is free running by the internal clock. On the rising (falling) edge of the TC3 pin input, the current contents of counter is loaded into TREG3A, then the up-counter is cleared and an INTTC3 interrupt is generated. On the falling (rising) edge of the TC3 pin input, the current contents of the counter is loaded into the TREG3B. In this case, counting continues. At the next rising (falling) edge of the TC3 pin input, the current contents of counter are loaded into TREG3A, then the counter is cleared again and an interrupt is generated. If the counter overflows before the edge is detected, $FF_H$ is set to the TREG3A and an overflow interrupt (INTTC3) is generated. During interrupt processing, it can be determined whether or not there is an overflow by checking whether or not the TREG3A value is $FF_H$. Also, after an interrupt (capture to TREG3A, or overflow detection) is generated, capture and overflow detection are halted until TREG3A has been read out; however, the counter continues.

When the TREG3A has been read out, capture and overflow detection resumes.

Thus, it is general to read out TREG3B before reading out TREG3A.

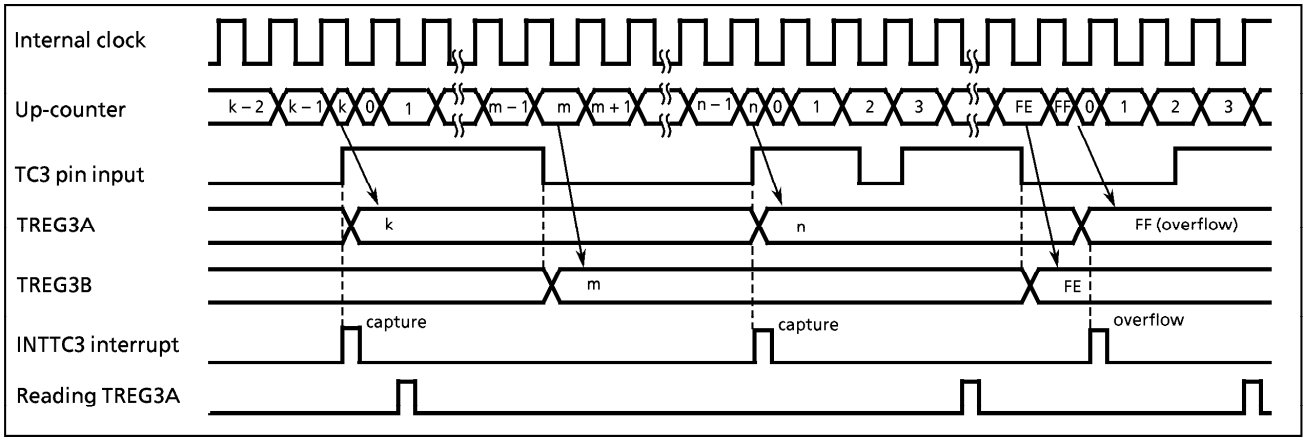



Figure 2-27. Timing Chart for Capture Mode (INT3ES = 0)

## 2.8 8-bit Timer/Counter 5 (TC5)

### 2.8.1 Configuration

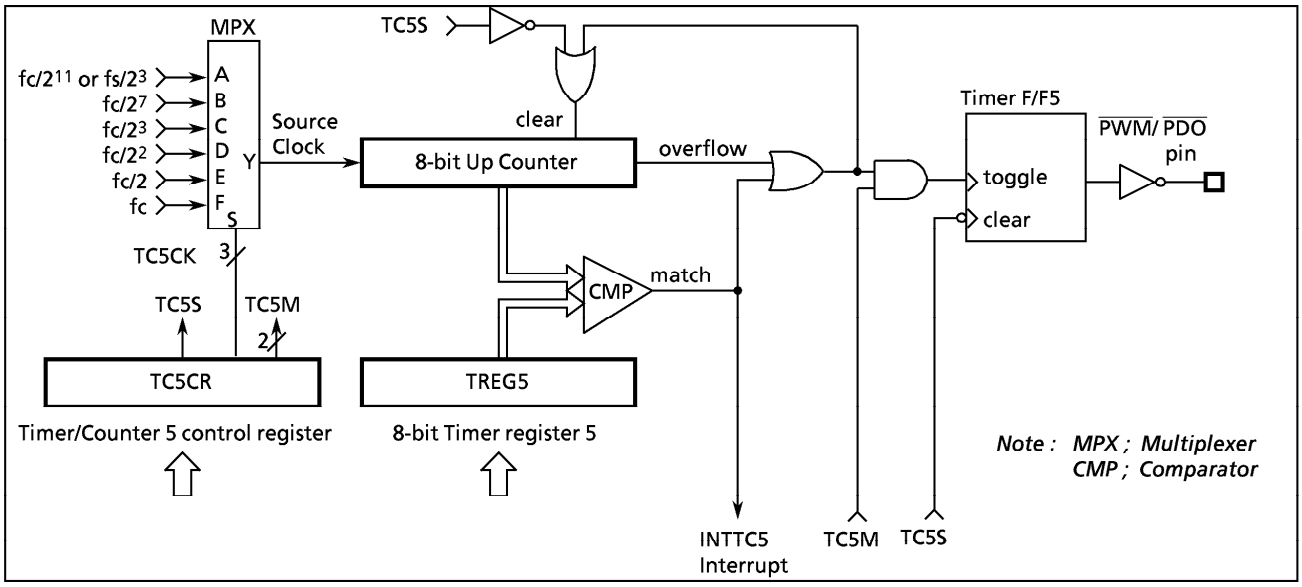



Figure 2-28. Timer/Counter 5 (TC5)

### 2.8.2 Control

The TC5 is controlled by a timer/counter 5 control register (TC5CR) and an 8-bit timer register 5 (TREG5).

**TREG5** (001DH)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Write only

**TC5CR** (001EH)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | TC5S | TC5CK | | | TC5M | |

(Initial **00 0000)

| | | | |
|---|---|---|---|
| TC5M | TC5 Operating mode select | 00 : Timer mode<br>01 : Reserved<br>10 : Progrmmable divider output (PDO) mode<br>11 : Pulse width modulation (PWM) output mode | write only |
| TC5CK | TC5 Source clock select | 000 : Reserved<br>001 : Internal clock fc/2^11 or fs/2^3 [Hz]<br>010 : Internal clock fc/2^7<br>011 : Internal clock fc/2^3<br>100 : Internal clock fc/2^2<br>101 : Internal clock fc/2<br>110 : Internal clock fc<br>111 : Reserved | |
| TC5S | TC5 Start control | 0 : Stop & clear<br>1 : Start | |

*Note 1: fc ; High-frequency clock [Hz] , fs ; Low-frequency clock [Hz] , * ; don't care*

*Note 2: The set value of timer register must satisfy the following conditions.*

*(a) When in PWM output mode, 5 < TREG5 < 251*

*(b) When in any other mode than PWM output mode, 0 < TREG5*

*Note 3: Source clock fc/2^2, fc/2, and fc cannot be used except in PWM output mode.*

*Note 4: Set the operating mode and the source clock selection when timer/counter stops (TC5S = 0) .*

Figure 2-29. Timer/Counter 5 Timer register, Control register

## 2.8.3 Function

TC5 has 3 operating modes : timer, programmable divider output, and pulse width modulation output mode.

(1) **Timer** mode

In this mode, the internal clock is used for counting up. The contents of the timer register 5 (TREG5) is compared with the contents of the up-counter. Matching with TREG5 generates a timer/counter 5 interrupt (INTTC5) and clears the counter. Counting up resumes after the counter is cleared.

Table 2-6. Source Clock (Internal clock) for TC5

| Source clock | | | resolution | | maximum setting time | |
|---|---|---|---|---|---|---|
| NORMAL1/2, IDLE1/2 mode | | SLOW, SLEEP mode | fc = 8 MHz | fs = 32.768 kHz | fc = 8 MHz | fs = 32.768 kHz |
| DV7CK = 0 | DV7CK = 1 | | | | | |
| $fc/2^{11}$ [Hz] | $fs/2^3$ [Hz] | $fs/2^3$ [Hz] | 256 μs | 244.14 μs | 65.536 ms | 62.5 ms |
| $fc/2^7$ | | – | 16 μs | | 4.096 ms | |
| $fc/2^3$ | | – | 1 μs | | 256 μs | |

(2) **Programmable divider output** (PDO) mode

The internal clock is used for counting up. The contents of the TREG5 are compared with the contents of the up-counter. The timer F/F5 output is toggled and the counter is cleared each time a match is found. The timer F/F5 output is inverted and output to the $\overline{PDO}$ (P41) pin. In the case of $\overline{PDO}$ output, set the P41 output latch to "1" and configure as an output with P4CR1. This mode can be used for 50% duty pulse output. INTTC5 interrupt is generated each time the $\overline{PDO}$ output is toggled.

Example : 1024 Hz pulse output (at fc = 4.194304 MHz)

```
SET   (P4).1              ;  P41 output latch←1
LD    (TC5CR), 00000010B  ;  Sets to TC5 modes and source clock
LD    (TREG5), 10H        ;  1/1024 ÷ 27/fc = 20H
LD    (TC5CR), 00010010B  ;  Starts TC5
```

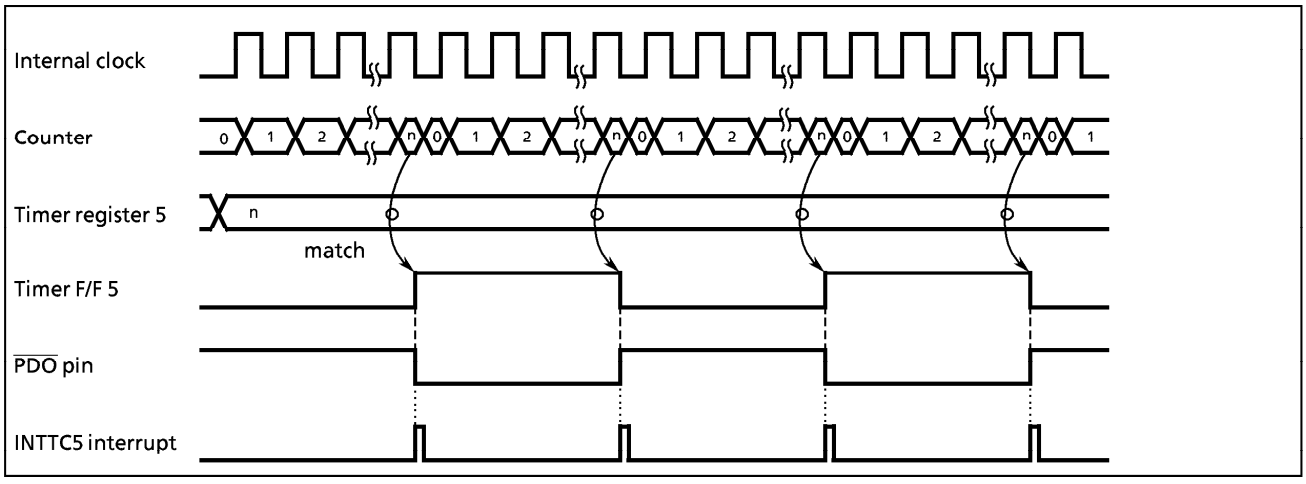



Figure 2-30. PDO Mode Timing Chart

(3) **Pulse width modulation** (PWM) **output** mode

PWM output with a resolution of 8-bits is possible. The internal clock is used for counting up. The contents of the TREG5 is compared with the contents of the up-counter. If a match is found, the timer F/F5 output is toggled. The counter continues counting and, when an overflow occurs, the timer is again toggled and the counter is cleared. The timer F/F5 output is inverted and output to the $\overline{\text{PWM}}$ (P41) pin. In the case of $\overline{\text{PWM}}$ output, set the P41 output latch to "1" and configure as an output with P4CRI. An INTTC5 interrupt is generated when an overflow occurs.

TREG5 is configured a 2- stage shift register and, during output, will not switch until one output cycle is completed even if TREG5 is overwritten; therefore, output can be altered continuously. Also, the first time, TREG5 is shifted by setting TC5S (bit 5 in TC5CR) to "1" after data are loaded to TREG5.

*Note : PWM output mode can be used in only NORMAL1/2 or IDLE1/2 mode.*

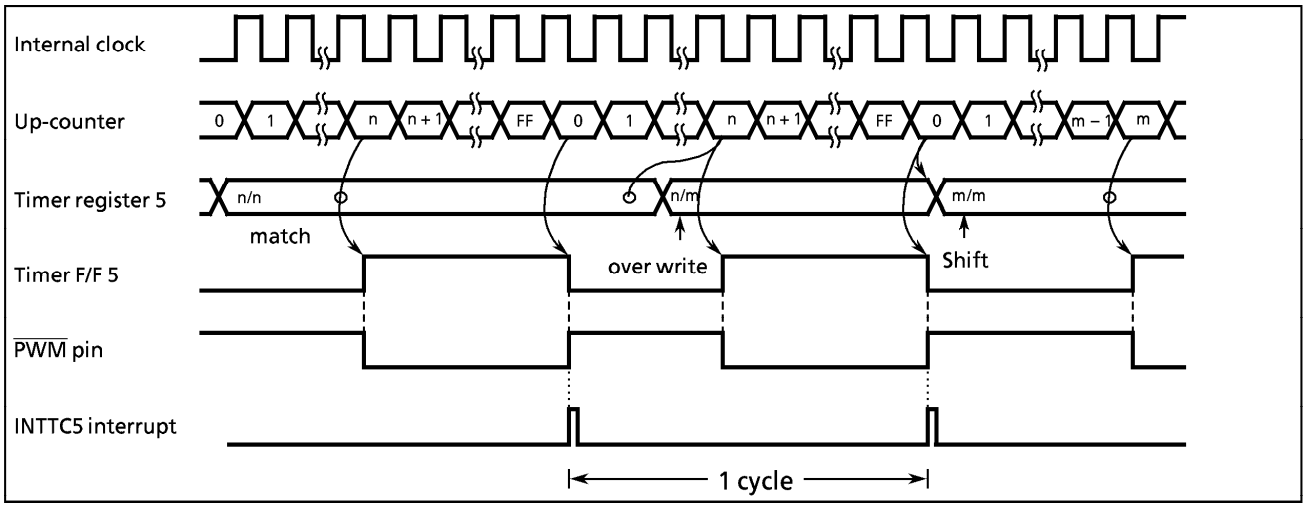



Figure 2-31. PWM Output Mode Timing Chart

Table 2-7. PWM Output Mode

| Source clock | | Resolution | | Repeat cycle | |
|---|---|---|---|---|---|
| NORMAL1/2, IDLE1/2 mode | | At fc = 8 MHz | At fc = 4.194304 MHz | At fc = 8 MHz | At fc = 4.194304 MHz |
| DV7CK = 0 | DV7CK = 1 | | | | |
| $fc/2^2$ [Hz] | | 500 ns | 953.7 ns | 128 μs | 244 μs |
| fc/2 | | 250 ns | 476.8 ns | 64 μs | 122 μs |
| fc | | 125 ns | 238.4 ns | 32 μs | 61 μs |

## 2.9 Serial Interface (SIO1, SIO2)

The 87CH21/M21 each have two clocked-synchronous 8-bit serial interfaces (SIO1 and SIO2). Each serial interface has an 8-byte transmit and receive data buffer that can automatically and continuously transfer up to 64 bits of data.

The serial interfaces are connected to external devices via pins P44 (SO1), P43 (SI1), P42 ($\overline{\text{SCK1}}$) for SIO1 and P47 (SO2), P46 (SI2), P45 ($\overline{\text{SCK2}}$) for SIO2. The serial interface pins are also used as port P4. When used as serial interface pins, the output latches of these pins should be set to "1". In the transmit mode, pins P43 and P46 can be used as normal I/O ports, and in the receive mode, the pins P44 and P47 can be used as normal I/O ports.

### 2.9.1 Configuration

The SIO1 and SIO2 have the same configuration, except for the addresses/bit positions of the control/ status registers and buffer registers.

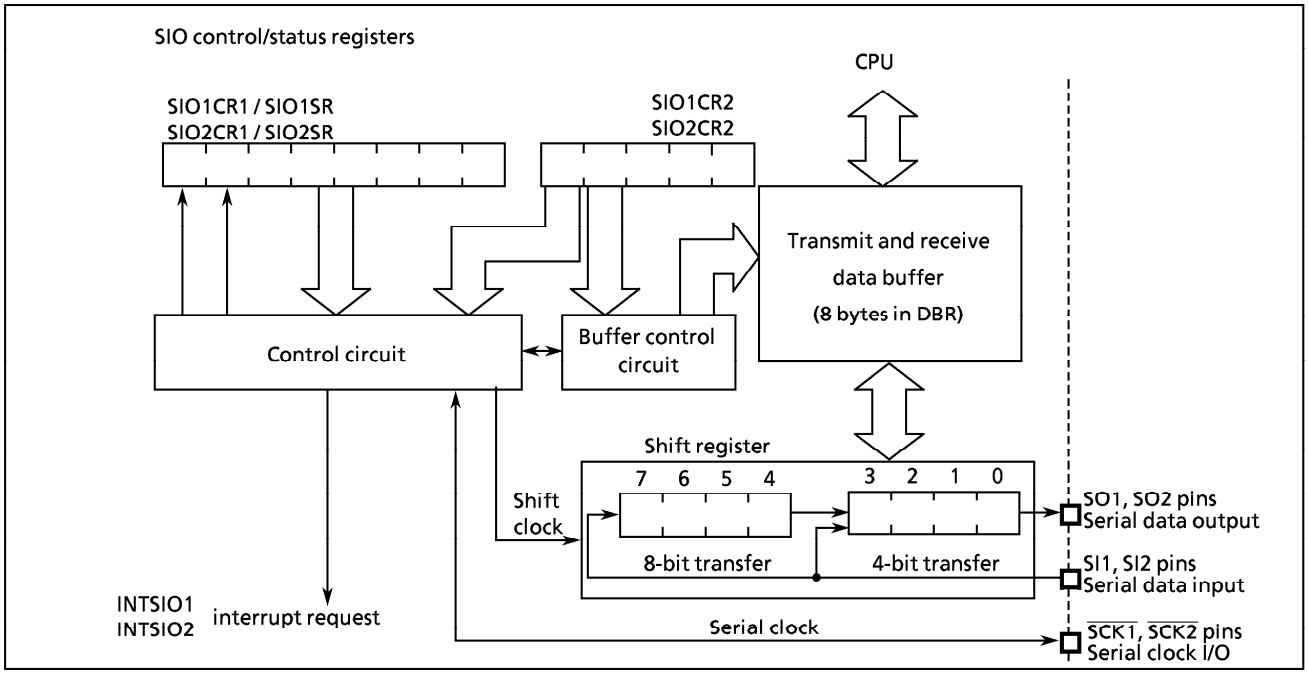



Figure 2-32. Serial Interfaces

### 2.9.2 Control

The serial interfaces are controlled by SIO control registers (SIO1CR1/SIO1CR2 or SIO2CR1/SIO2CR2). The serial interface status can be determined by reading SIO status registers (SIO1SR or SIO2SR).

The transmit and receive data buffer is controlled by the BUF (bits 2-0 in SIO1CR2/SIO2CR2). The data buffer is assigned to addresses $0FF0_H$ - $0FF7_H$ for SIO1 or $0FF8_H$ - $0FFF_H$ for SIO2 in the DBR area, and can continuously transfer up to 8 words (bytes or nibbles) at one time. When the specified number of words has been transferred, a buffer empty (in the transmit mode) or a buffer full (in the receive mode or transmit/receive mode) interrupt (INTSIO1 or INTSIO2) is generated.

When the internal clock is used as the serial clock in the 8-bit receive mode and the 8-bit transmit/receive mode, a fixed interval wait can be applied to the serial clock for each word transferred. Four different wait times can be selected with WAIT (bits 4 and 3 in SIO1CR2/SIO2CR2).

## SIO1, SIO2 Control Registers 1

**SIO1CR1** ($0020_H$)
**SIO2CR1** ($0022_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| SIOS | SIO INH | SIOM | | | SCK | | |

(Initial value : 0000 0000)

| | | | |
|---|---|---|---|
| SIOS | Indicate transfer start/stop | 0 : Stop<br>1 : Start | write only |
| SIOINH | Continue/abort transfer | 0 : Continue transfer<br>1 : Abort transfer (automatically cleared after abort) | |
| SIOM | Transfer mode select | 000 : 8-bit transmit mode<br>010 : 4-bit transmit mode<br>100 : 8-bit transmit/receive mode<br>101 : 8-bit receive mode<br>110 : 4-bit receive mode | |
| SCK | Serial clock select | 000 : Internal clock fc / $2^{13}$ or fs / $2^5$ [Hz]<br>001 : Internal clock fc / $2^8$<br>010 : Internal clock fc / $2^6$<br>011 : Internal clock fc / $2^5$<br>111 : External clock (input from $\overline{SCK}$ pin) (Output on $\overline{SCK}$ pin) | |

*Note 1 : fc ; High-frequency clock [Hz], fs ; Low-frequency clock [Hz]*

*Note 2 : Set SIOS to "0" and SIOINH to "1" when setting the transfer mode or serial clock.*

*Note 3 : SIO1CR1/SIO2CR1 are write-only registers, which cannot access any of in read-modify-write instruction such as bit operate, etc.*

## SIO1, SIO2 Status Registers

**SIO1SR** ($0020_H$)
**SIO2SR** ($0022_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| SIOF | SEF | "1" | "1" | "1" | "1" | "1" | "1" |

| | | | |
|---|---|---|---|
| SIOF | Serial transfer operating status monitor | 0 : Transfer terminated<br>1 : Transfer in process | read only |
| SEF | Shift operating status monitor | 0 : Shift operation terminated<br>1 : Shift operation in process | |

## SIO1, SIO2 Control Registers 2

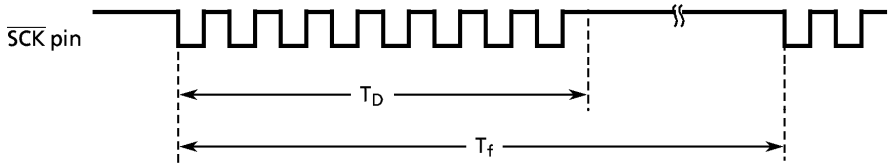
**SIO1CR2** ($0021_H$)
**SIO2CR2** ($0023_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| | | | WAIT | | BUF | | |

(Initial value: ***0 0000)

| | | | |
|---|---|---|---|
| WAIT | Wait control | Always sets "00" except 8-bit transmit/receive mode.<br>00 : $T_f = T_D$ (non-wait)<br>01 : $T_f = 2T_D$<br>10 : $T_f = 4T_D$<br>11 : $T_f = 8T_D$ (wait) | Write only |
| BUF | Number of transfer words | Buffer address used<br>SIO1 / SIO2<br>000 : 1 word transfer — $0FF0_H$ / $0FF8_H$<br>001 : 2 words transfer — 0FF0 - $0FF1_H$ / 0FF8 - $0FF9_H$<br>010 : 3 words transfer — 0FF0 - $0FF2_H$ / 0FF8 - $0FFA_H$<br>011 : 4 words transfer — 0FF0 - $0FF3_H$ / 0FF8 - $0FFB_H$<br>100 : 5 words transfer — 0FF0 - $0FF4_H$ / 0FF8 - $0FFC_H$<br>101 : 6 words transfer — 0FF0 - $0FF5_H$ / 0FF8 - $0FFD_H$<br>110 : 7 words transfer — 0FF0 - $0FF6_H$ / 0FF8 - $0FFE_H$<br>111 : 8 words transfer — 0FF0 - $0FF7_H$ / 0FF8 - $0FFF_H$ | |

*Note 1 : $T_f$: frame time, $T_D$ : data transfer time*




*Note 2 : The lower 4 bits of each buffer are used during 4-bit transfers. Zeros (0) are stored to the upper 4bits when receiving.*

*Note 3 : Transmitting starts at the lowest address. Received data are also stored starting from the lowest address to the highest address. For example, in the case of SIO1, the first buffer address transmitted is $0FF0_H$.*

*Note 4 : The value to be loaded to BUF is held after transfer is completed.*

*Note 5 : SIO1CR2/SIO2CR2 must be set when the serial interface is stopped (SIOF = 0).*

*Note 6 : SIO1CR2/SIO2CR2 are write-only registers, which cannot access any of in read-modify-write instruction such as bit operate, etc.*

*Note 7 : *; don't care*

Figure 2-33. SIO Control Registers and Status Registers

(1) Serial Clock

a. Clock Source

SCK (bits 2 - 0 in SIO1CR1/SIO2CR1) is able to select the following:

① Internal Clock

Any of four frequencies can be selected. The serial clock is output to the outside on the $\overline{SCK1}$ / $\overline{SCK2}$ pin. The $\overline{SCK}$ pin goes high when transfer starts.

When data writing (in the transmit mode) or reading (in the receive mode or the transmit/receive mode) cannot keep up with the serial clock rate, there is a wait function that automatically stops the serial clock and holds the next shift operation until the read/write processing is completed.

Table 2-8. Serial Clock Rate

| Serial clock | | | Maximum transfer rate | |
|---|---|---|---|---|
| NORMAL1/2, IDLE1/2 mode | | SLOW, SLEEP mode | | |
| DV7CK = 0 | DV7CK = 1 | | At fc = 8 MHz | At fs = 32.768 kHz |
| $fc / 2^{13}$ [Hz] | $fs / 2^5$ [Hz] | $fs / 2^5$ [Hz] | 0.954 Kbit/s | 1 Kbit/s |
| $fc / 2^8$ | $fc / 2^8$ | – | 30.5 | – |
| $fc / 2^6$ | $fc / 2^6$ | – | 122 | – |
| $fc / 2^5$ | $fc / 2^5$ | – | 244 | – |

*Note : 1 Kbit = 1024 bit*

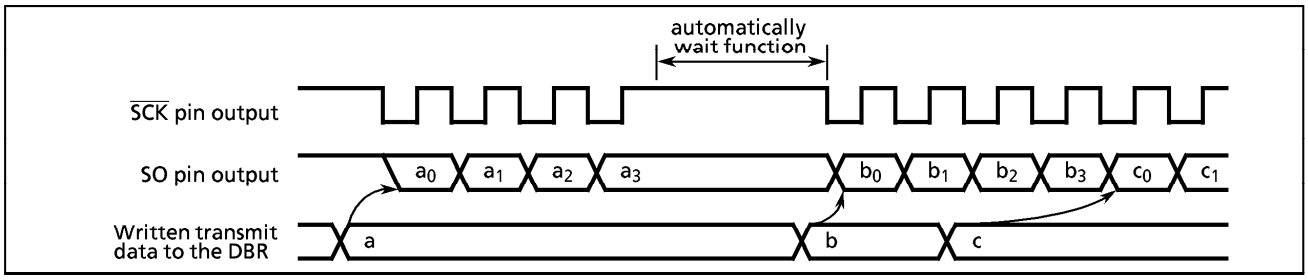
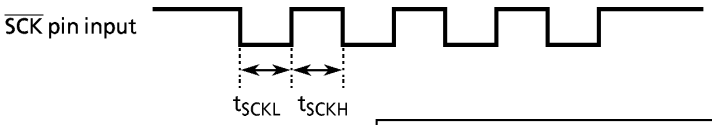



Figure 2-34. Clock Source (Internal Clock)

② External Clock

An external clock connected to the $\overline{SCK1}$ / $\overline{SCK2}$ pin is used as the serial clock. In this case, the P42 ($\overline{SCK1}$) / P45 ($\overline{SCK2}$)output latch must be set to "1". To ensure shifting, a pulse width of at least 4 machine cycles is required. Thus, the maximum transfer speed is 244K-bit/s. (at fc = 8 MHz).




*Note : tcyc = 4/fc (In NORAML1/2, IDLE1/2 modes)*
*4/fs (In SLOW, SLEEP modes)*

b. Shift edge

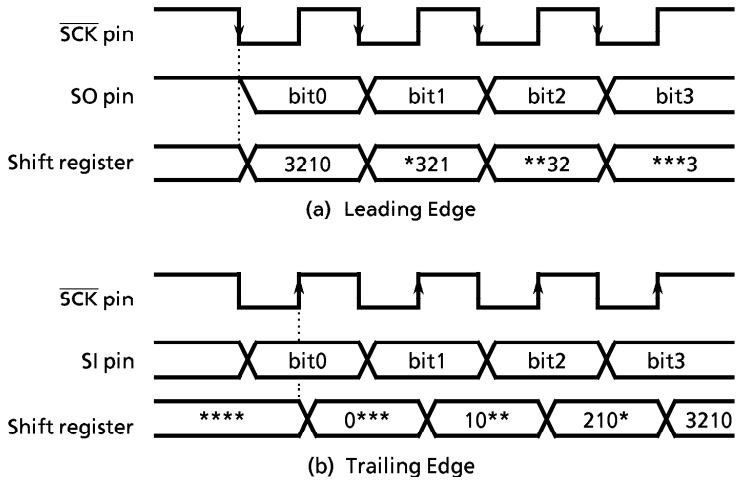
The leading edge is used to transmit, and the trailing edge is used to receive.

① Leading Edge

Transmitted data are shifted on the leading edge of the serial clock (falling edge of the $\overline{SCK}$ pin input/output).

② Trailing Edge

Received data are shifted on the trailing edge of the serial clock (rising edge of the $\overline{SCK}$ pin input/output).




*Note : * ; don't care*

Figure 2-35. Shift Edge

(2) Number of Bits to Transfer

Either 4-bit or 8-bit serial transfer can be selected. When 4-bit serial transfer is selected, only the lower 4 bits of the transmit/receive data buffer register are used. The upper 4 bits are cleared to "0" when receiving.

The data is transferred in sequence starting at the least significant bit (LSB).

(3) Number of Words to Transfer

Up to 8 words consisting of 4 bits of data (4-bit serial transfer) or 8 bits (8-bit serial transfer) of data can be transferred continuously. The number of words to be transferred is loaded to BUF.

An INTSIO interrupt is generated when the specified number of words has been transferred. If the number of words is to be changed during transfer, the serial interface must be stopped before making the change. The number of words can be changed during automatic-wait operation of an internal clock. In this case, the serial interface is not required to be stopped.

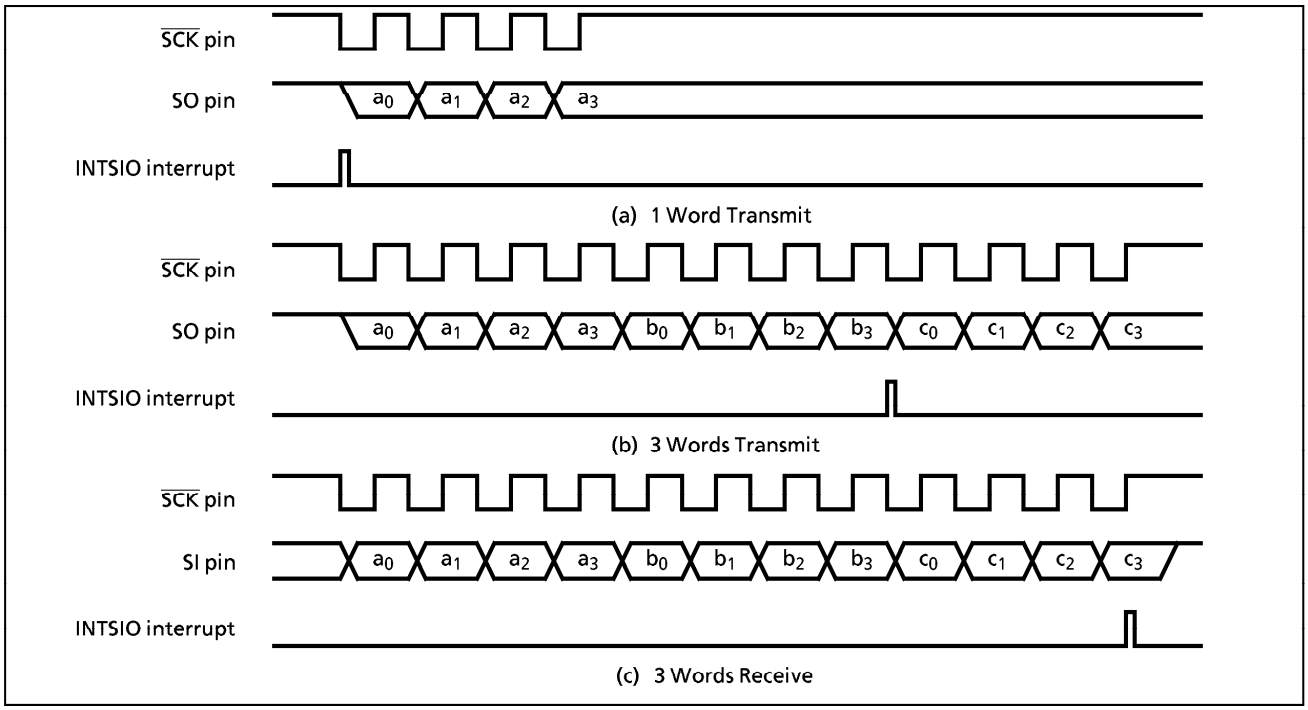



Figure 2-36. Number of Bits to Transfer (Example : 4-bit serial transfer)

## 2.9.3 Transfer Mode

SIOM (bits 5 - 3 in SIO1CR1/SIO2CR1) is used to select the transmit, receive, or transmit/receive mode.

(1) **4-bit and 8-bit Transmit** Modes

In these modes, the SIO1CR1/SIO2CR1 is set to the transmit mode and then the data to be transmitted first are written to the data buffer registers (DBR). After the data are written, the transmission is started by setting SIOS to "1". The data are then output sequentially to the SO pin in synchronous with the serial clock, starting with the least significant bit (LSB). As soon as the LSB has been output, the data are transferred from the data buffer register to the shift register. When the final data bit has been transferred and the data buffer register is empty, an INTSIO (buffer empty) interrupt is generated to request the next transmitted data.

When the internal clock is used, the serial clock will stop and an automatic-wait will be initiated if the next transmitted data are not loaded to the data buffer register by the time the number of data words specified with the BUF has been transmitted. Writing even one word of data cancels the automatic-wait; therefore, when transmitting two or more words, always write the next word before transmission of the previous word is completed.

*Note : Automatic-waits are also canceled by writing to a DBR not being used as a transmit data buffer register; therefore, during SIO do not use such DBR for other applications. For example, when 3 words are transmitted, do not use the DBR of the remained 5 words.*

When an external clock is used, the data must be written to the data buffer register before shifting next data. Thus, the transfer speed is determined by the maximum delay time from the generation of the interrupt request to writing of the data to the data buffer register by the interrupt service program.

When the transmit is started, after the SIOF goes "high" output from the S0 pin holds final bit of the last data until falling edge of the $\overline{SCK}$.

The transmission is ended by clearing SIOS to "0" at the time that the final bit of the data being shifted out has been transferred. That the transmission has ended can be determined from the status of SIOF (bit 7 in SIO1SR/SIO2SR) because SIOF is cleared to "0" when a transfer is completed.

When an external clock is used, it is also necessary to clear SIOS to "0" before shifting the next data; otherwise, dummy data will be transmitted and the operation will end.

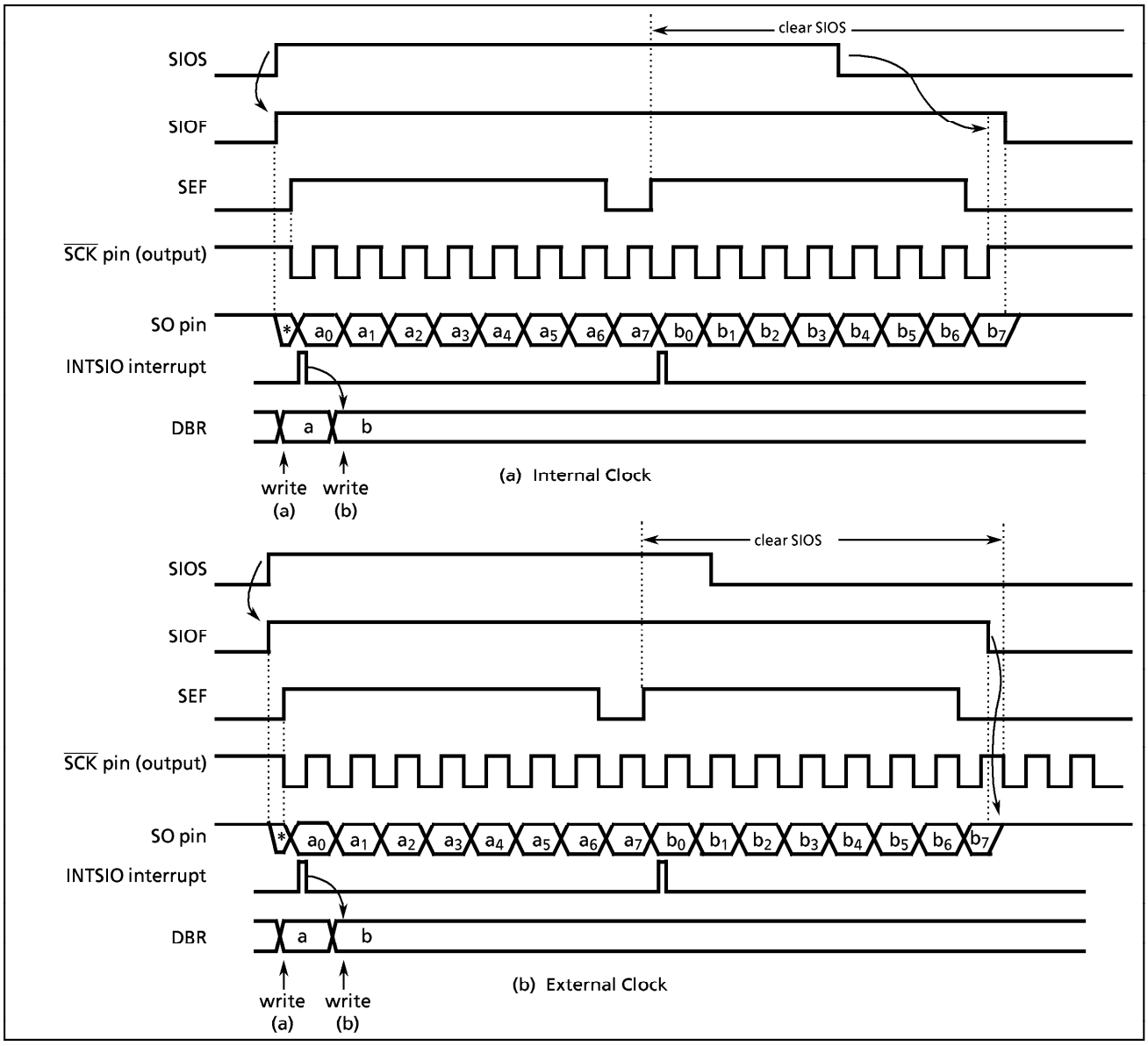



Figure 2-37. Transfer Mode (Example: 8-bit, 1 Word Transfer)

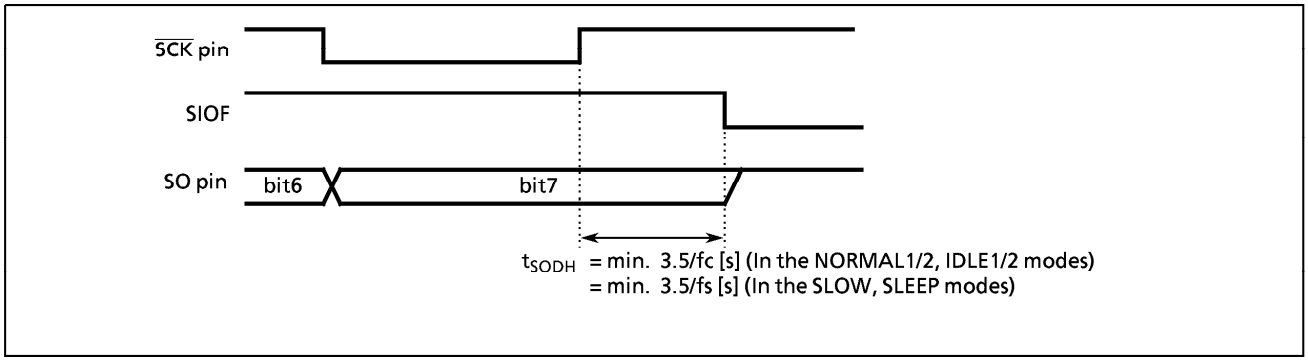



Figure 2-38. Transmitted Data Hold Time at end of transmit

(2) **4-bit and 8-bit Receive** Modes

After setting the control registers to the receive mode, set SIOS to "1" to enable receiving. The data are then transferred to the shift register via the SI pin in synchronous with the serial clock. When one word of data has been received, it is transferred from the shift register to the data buffer register (DBR). When the number of words specified with the BUF has been received, an INTSIO (buffer full) interrupt is generated to request that these data be read out. The data are then read from the data buffer registers by the interrupt service program.

When the internal clock is used, and the previous data are not read from the data buffer register before the next data are received, the serial clock will stop and an automatic-wait will be initiated until the data are read. A wait will not be initiated if even one data word has been read.

*Note : Waits are also canceled by reading a DBR not being used as a received data buffer register is read; therefore, during SIO do not use such DBR for other applications.*

When an external clock is used, the shift operation is synchronized with the external clock; therefore, the previous data are read before the next data are transferred to the data buffer register. If the previous data have not been read, the next data will not be transferred to the data buffer register and the receiving of any more data will be canceled. When an external clock is used, the maximum transfer speed is determined by the delay between the time when the interrupt request is generated and when the data received have been read.

Clear SIOS to "0" or SIOINH to "1" in buffer full interrupt service program to end receiving. When SIOS is cleared, the current data are transferred to the buffer. After SIOS cleaned, the transmissions is ended at the time that the final bit of the data being shifted has been output. That the transmission has ended can be determined from the status of SIOF (bit 7 in SIOSR). SIOF is cleared to "0" when the transmission is ended. After confirmed the receiving termination, the final receiving data is read. When SIOINH is set, the transmission is immediately ended and SIOF is cleared to "0". (The received data is ignored, and it is not required to be read out.) If the number of words is to be changed during transfer, SIOS must be cleared to "0" and BUF is rewritten after SIOF is determined to be cleared to "0" during automatic-wait operation of an external clock operation. The number of words can be changed in an internal clock. In this case, BUF must be rewritten before the received data is read out.

*Note : The buffer contents are lost when the transfer mode is switched. If it should become necessary to switch the transfer mode, end receiving by clearing SIOS to "0", read the last data and then switch the transfer mode.*

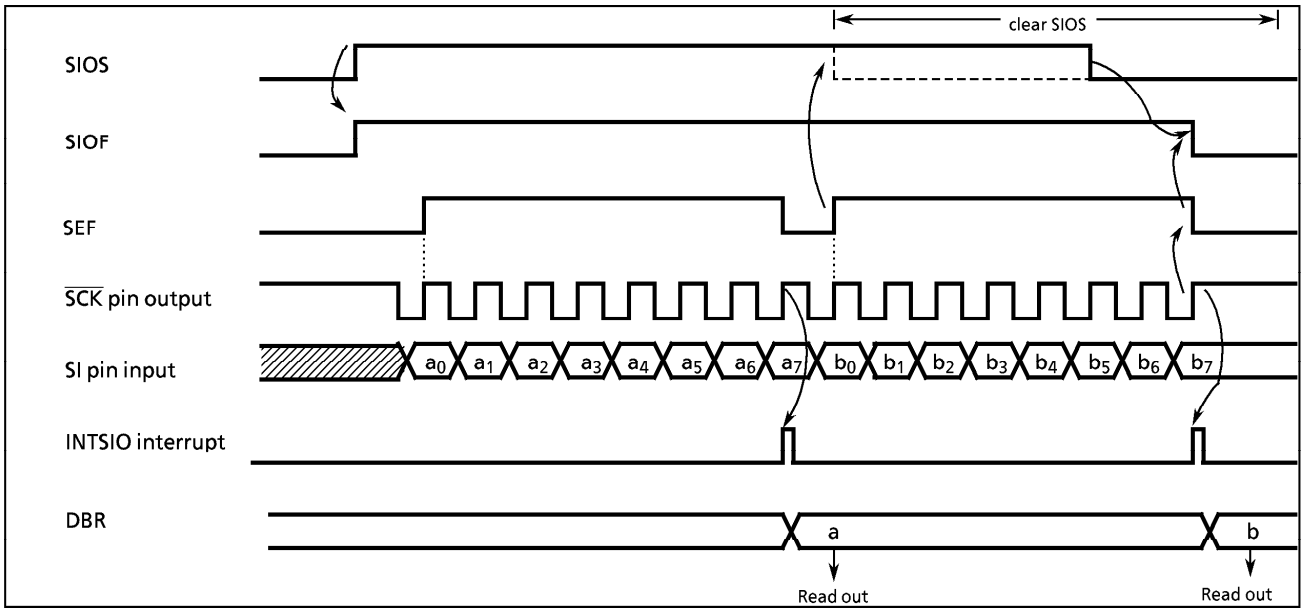



Figure 2-39. Receive Mode (Example : 8-bit, 1 word, internal clock)

(3) **8-bit Transmit/Receive** Mode

After setting the control registers to the 8-bit transmit/receive mode, write the data to be transmitted first to the data buffer registers (DBR). After that, enable transceiving by setting SIOS to "1". When transmitting, the data are output from the SO pin at leading edges of the serial clock. When receiving, the data are input to the SI pin at the trailing edges of the serial clock. 8-bit data are transferred from the shift register to the data buffer register. An INTSIO interrupt is generated when the number of data words specified with the BUF has been transferred. The interrupt service program reads the received data from the data buffer register and then writes the data to be transmitted. The data buffer register is used for both transmitting and receiving; therefore, always write the data to be transmitted after reading the received data.

When the internal clock is used, a wait is initiated until the received data are read and the next data are written. A wait will not be initiated if even one data word has been written.

When an external clock is used, the shift operation is synchronized with the external clock; therefore, it is necessary to read the received data and write the data to be transmitted next before starting the next shift operation. When an external clock is used, the transfer speed is determined by the maximum delay between generation of an interrupt request and the received data are read and the data to be transmitted next are written.

When the receive is started, after the SIOF goes "high"output from the S0 pin holds final bit of the last data until falling edge of the $\overline{SCK}$.

Clear SIOS to "0" to SIOINH to "1" in INTSIO interrupt service program to end transmit/receive mode. When SIOS is cleared, the current data are transferred to the data buffer register. The transmit/receive is ended at the time that the final bit of the data being shifted has been output. The end of transmit/receive can be determined from the status of SIOF (bit 7 in SIOSR). SIOF is cleared to "0" when the transmit/receive is ended. When SIOINH is set, the transmit/receive is immediately ended and SIOF is cleared to "0".

If the number of words is to be changed during transfer, SIOS must be cleared to "0" and BUF is rewritten after confirmed that SIOF clearing to "0". The number of words can be changed during automatic-wait operation of an internal clock. In this case, BUF must be rewritten before the final transmitted/received data is read out.

Note : *The buffer contents are lost when the transfer mode is switched. If it should become necessary to switch the transfer mode, end receiving by clearing SIOS to "0", read the last data and then switch the transfer mode.*

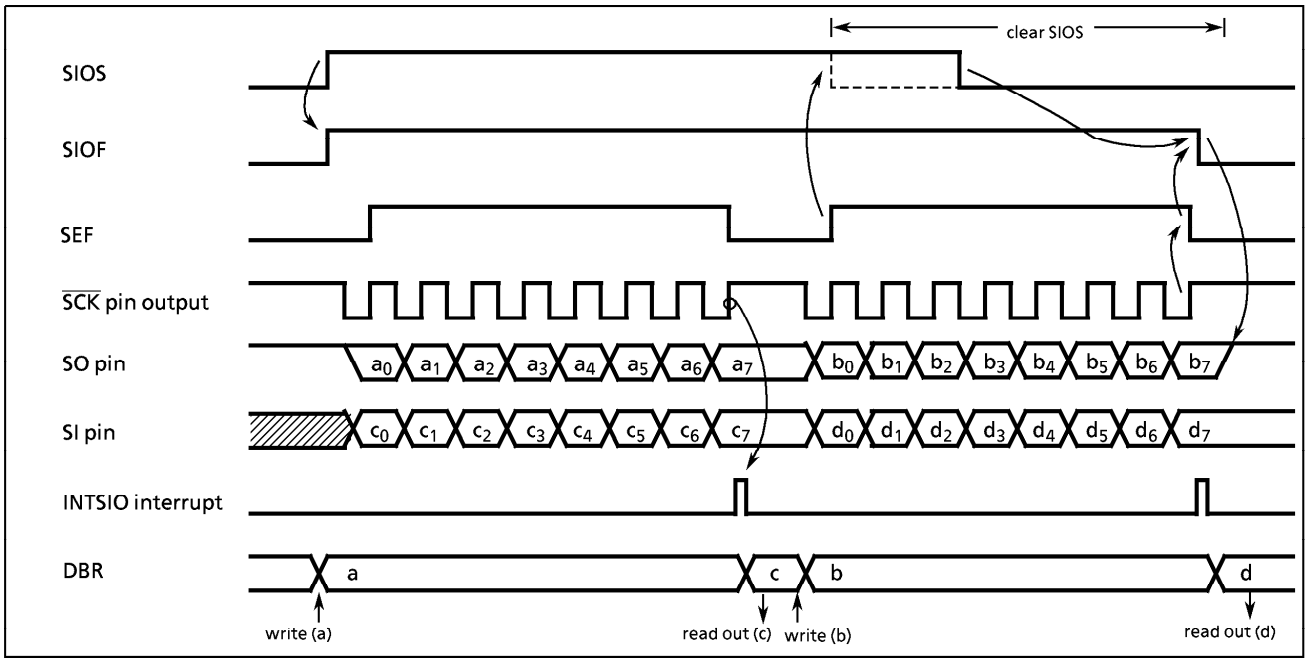



Figure 2-40. Transmit/Receive Mode (Example : 8-bit, 1word, internal clock)

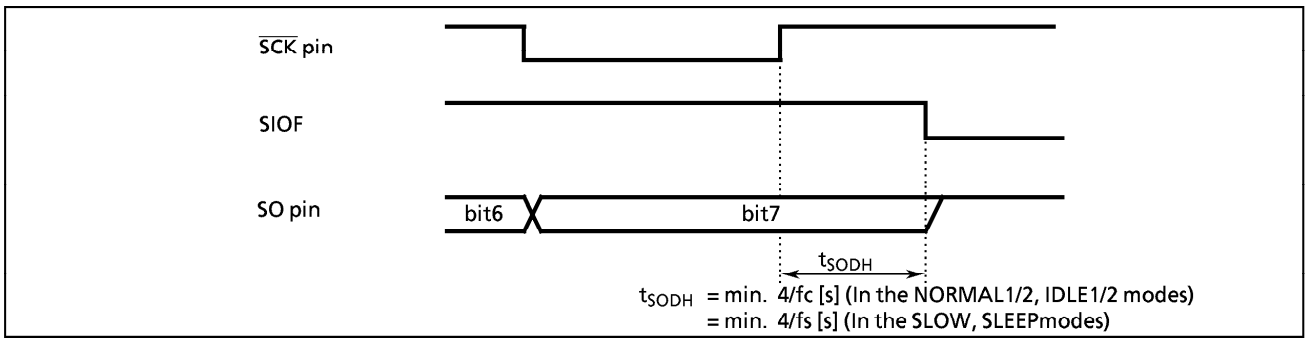



Figure 2-41. Transmitted Data Hold Time at end of transmit/receive

## 2.10 LCD Driver

The 87CH21/M21 each have a driver and control circuit to directly drive the liquid crystal device (LCD). The pins to be connected to LCD are as follows:

| | |
|---|---|
| ① Segment output port | 12 pins (SEG11 to SEG0) |
| ② Segment output or P6, P7, P9 input / output port | 20 pins (SEG31 to SEG12) |
| ③ Common output port | 4 pins (COM3 to COM0) |

In addition, VLC pin is provided as the drive power pins

The devices that can be directly driven is selectable from LCD of the following drive methods:

| | | |
|---|---|---|
| ① 1 / 4 Duty | (1 / 3 Bias) LCD ..... | Max.128 Segments (8-segment × 16 digits) |
| ② 1 / 3 Duty | (1 / 3 Bias) LCD ..... | Max. 96 Segments (8-segment × 12 digits) |
| ③ 1 / 3 Duty | (1 / 2 Bias) LCD ..... | Max. 96 Segments (8-segment × 12 digits) |
| ④ 1 / 2 Duty | (1 / 2 Bias) LCD ..... | Max. 64 Segments (8-segment × 8 digits) |
| ⑤ Static LCD | ..... | Max. 32 Segments (8-segment × 4 digits) |

### 2.10.1 Configuration

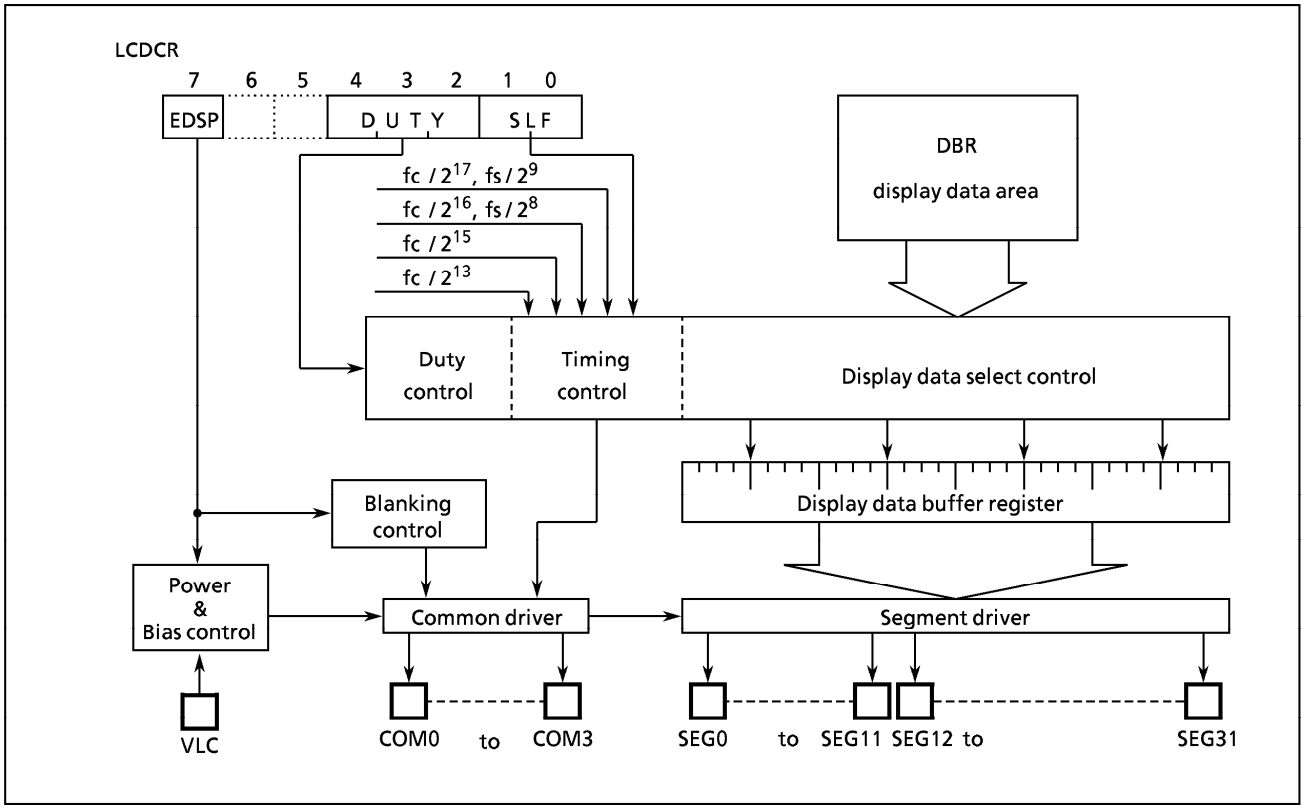



Figure 2-42. LCD driver

## 2.10.2 Control

The LCD driver is controlled by the LCD control register (LCDCR).

LCDCR ($0028_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| EDSP | | | DUTY | | | SLF | |

(Initial : 0**0 0000)

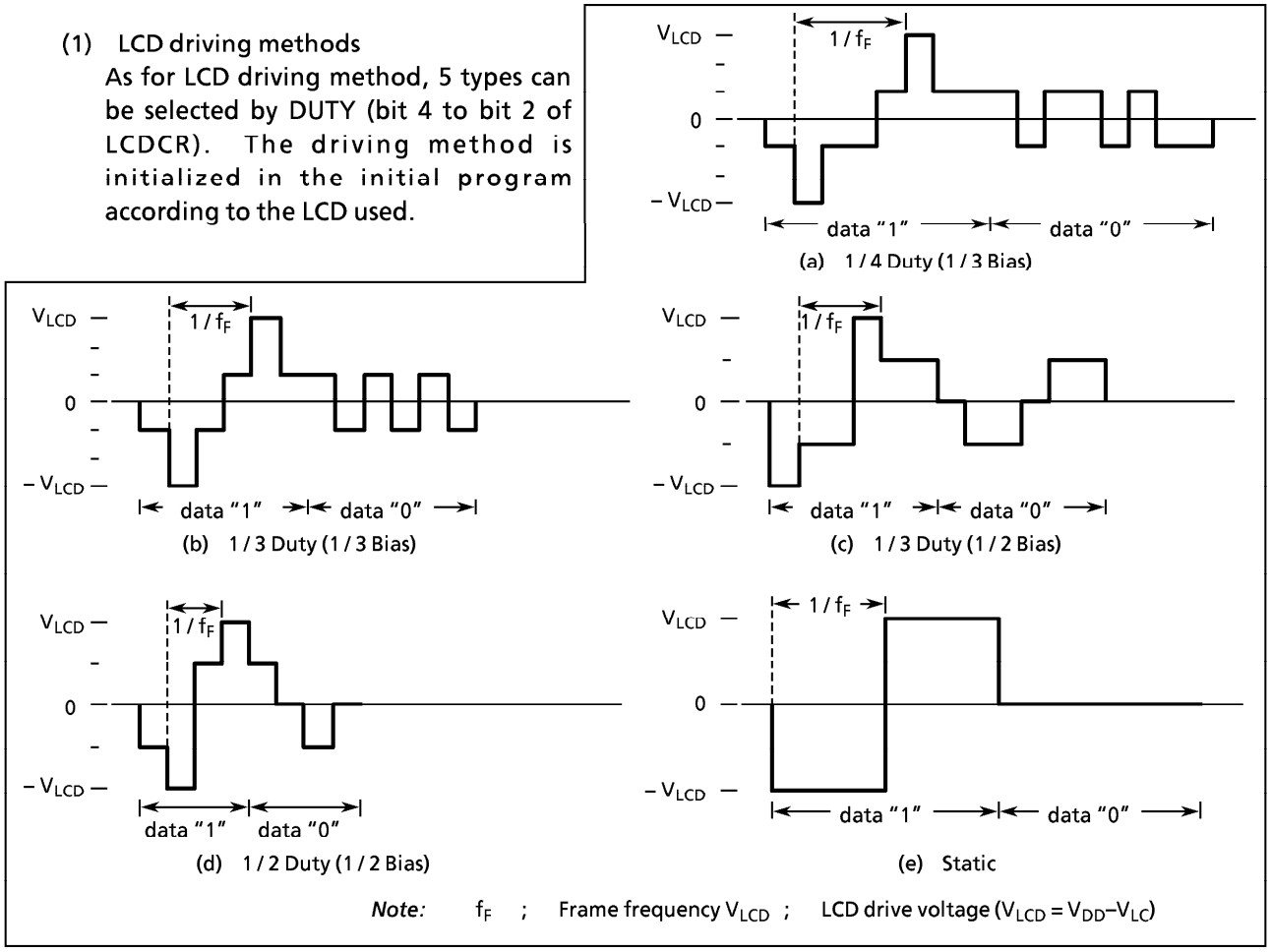
| | | | |
|---|---|---|---|
| SLF | Selection of LCD base frequency | 00 : $fc/2^{17}$ or $fs/2^9$ [Hz]<br>01 : $fc/2^{16}$ or $fs/2^8$<br>10 : $fc/2^{15}$<br>11 : $fc/2^{13}$ | Write only |
| DUTY | Selection of driving methods | 000 : 1/4 Duty (1/3 Bias)<br>001 : 1/3 Duty (1/3 Bias)<br>010 : 1/3 Duty (1/2 Bias)<br>011 : 1/2 Duty (1/2 Bias)<br>100 : Static<br>101 : reserved<br>110 : reserved<br>11* : reserved | |
| EDSP | LCD Display Control | 0 : Blanking<br>1 : Enables LCD display (Blanking is released) | |

*Note:* *fc : high-frequency clock, fs : low-frequency clock*

Figure 2-43. LCD driver control register

(1) LCD driving methods

As for LCD driving method, 5 types can be selected by DUTY (bit 4 to bit 2 of LCDCR). The driving method is initialized in the initial program according to the LCD used.




*Note:* $f_F$ ; Frame frequency $V_{LCD}$ ; LCD drive voltage ($V_{LCD} = V_{DD}-V_{LC}$)

Figure 2-44. LCD drive waveform (COM – SEG pins)

(2) Frame frequency

Frame frequency ($f_F$) is set according to driving method and base frequency as shown in the following Table 2-9. The base frequency is selected by SLF (Lower two bits of command register) according to the frequency fc and fs of the basic clock to be used.

Table 2-9. Setting of LCD Frame Frequency

a. At the single clock mode or at the dual clock mode with DVCK7 = 0

| SLF | Base frequency [Hz] | Frame frequency [Hz] | | | |
|---|---|---|---|---|---|
| | | 1 / 4 Duty | 1 / 3 Duty | 1 / 2 Duty | Static |
| 00 | $\frac{fc}{2^{17}}$ | $\frac{fc}{2^{17}}$ | $\frac{4}{3} \cdot \frac{fc}{2^{17}}$ | $\frac{4}{2} \cdot \frac{fc}{2^{17}}$ | $\frac{fc}{2^{17}}$ |
| | (fc = 8MHz) | 61 | 81 | 122 | 61 |
| 01 | $\frac{fc}{2^{16}}$ | $\frac{fc}{2^{16}}$ | $\frac{4}{3} \cdot \frac{fc}{2^{16}}$ | $\frac{4}{2} \cdot \frac{fc}{2^{16}}$ | $\frac{fc}{2^{16}}$ |
| | (fc = 4MHz) | 61 | 81 | 122 | 61 |
| 10 | $\frac{fc}{2^{15}}$ | $\frac{fc}{2^{15}}$ | $\frac{4}{3} \cdot \frac{fc}{2^{15}}$ | $\frac{4}{2} \cdot \frac{fc}{2^{15}}$ | $\frac{fc}{2^{15}}$ |
| | (fc = 4MHz) | 122 | 162 | 244 | 122 |
| 11 | $\frac{fc}{2^{13}}$ | $\frac{fc}{2^{13}}$ | $\frac{4}{3} \cdot \frac{fc}{2^{13}}$ | $\frac{4}{2} \cdot \frac{fc}{2^{13}}$ | $\frac{fc}{2^{13}}$ |
| | (fc = 1MHz) | 122 | 162 | 244 | 122 |

*Note : fc ; High-frequency clock [Hz]*

b. At the dual clock mode with DVCK7 = 1 or with SYSCK = 1

| SLF | Base frequency [Hz] | Frame frequency [Hz] | | | |
|---|---|---|---|---|---|
| | | 1 / 4 Duty | 1 / 3 Duty | 1 / 2 Duty | Static |
| 00 | $\frac{fs}{2^{9}}$ | $\frac{fs}{2^{9}}$ | $\frac{4}{3} \cdot \frac{fs}{2^{9}}$ | $\frac{4}{2} \cdot \frac{fs}{2^{9}}$ | $\frac{fs}{2^{9}}$ |
| | (fs = 32.768kHz) | 64 | 85 | 128 | 64 |
| 01 | $\frac{fs}{2^{8}}$ | $\frac{fs}{2^{8}}$ | $\frac{4}{3} \cdot \frac{fs}{2^{8}}$ | $\frac{4}{2} \cdot \frac{fs}{2^{8}}$ | $\frac{fs}{2^{8}}$ |
| | (fs = 32.768kHz) | 128 | 171 | 256 | 128 |

*Note : fs ; Low-frequency clock [Hz]*

(3) LCD drive voltage

LCD driving voltage $V_{LCD}$ is given as potential difference $V_{DD} - V_{LC}$ between pins VDD and VLC. Therefore, when the CPU voltage and LCD drive voltage are the same, VLC pin will be connected to VSS pin. The LCD lights when the potential difference between segment output and common output is $\pm V_{LCD}$. Otherwise it turns off.

During reset, the power switch of LCD driver is automatically turned off, shutting off the VLC voltage. At the same time, both segment outputs and common outputs become at GND level, turning off the LCD. The power switch is turned on to supply VLC voltage to LCD driver by setting with EDSP (bit 7 in LCDCR) to "1". After that, the power switch will not turned off even during blanking (clearing EDSP to "0") and the VLC voltage continues flow. When STOP mode starts, the power switch will be turned off. Therefore, LCD light out, and stop operation is executed at low power consumption. When STOP mode is released the status in effect immediately before the STOP operation is reinstated.

### 2.10.3 LCD Display Operation

(1) Display data setting

Display data is stored to the display data area (assigned to address 0F80 to $0F8F_H$) in the DBR. The display data which are stored in the display data area is automatically read out and sent to the LCD driver by the hardware. The LCD driver generates the segment signal and common signal according to the display data and driving method. Therefore, display patterns can be changed by only over writing the contents of display data area by the program. Figure 2-45 shows the correspondence between the display data area and SEG/COM pins.

LCD light when display data is "1" and turn off when "0". According to the driving method of LCD, the number of pixels which can be driven becomes different, and the number of bits in the display data area which is used to store display data also becomes different.

Therefore, the bits which are not used to store display data as well as the data buffer which corresponds to the addresses not connected to LCD can be used to store general user process data (see Table 2-10.)

| address | bit 7 | bit 6 | bit 5 | bit 4 | bit 3 | bit 2 | bit 1 | bit 0 |
|---|---|---|---|---|---|---|---|---|
| $0F80_H$ | SEG1 | | | | SEG0 | | | |
| 81 | SEG3 | | | | SEG2 | | | |
| 82 | SEG5 | | | | SEG4 | | | |
| 83 | SEG7 | | | | SEG6 | | | |
| 84 | SEG9 | | | | SEG8 | | | |
| 85 | SEG11 | | | | SEG10 | | | |
| 86 | SEG13 | | | | SEG12 | | | |
| 87 | SEG15 | | | | SEG14 | | | |
| 88 | SEG17 | | | | SEG16 | | | |
| 89 | SEG19 | | | | SEG18 | | | |
| 8A | SEG21 | | | | SEG20 | | | |
| 8B | SEG23 | | | | SEG22 | | | |
| 8C | SEG25 | | | | SEG24 | | | |
| 8D | SEG27 | | | | SEG26 | | | |
| 8E | SEG29 | | | | SEG28 | | | |
| 8F | SEG31 | | | | SEG30 | | | |
| | COM3 | COM2 | COM1 | COM0 | COM3 | COM2 | COM1 | COM0 |

Figure 2-45. LCD display data area (DBR)

Table 2-10. Driving method and bit for display Data

| Driving methods | bit 7/3 | bit 6/2 | bit 5/1 | bit 4/0 |
|---|---|---|---|---|
| 1 / 4 Duty | COM3 | COM2 | COM1 | COM0 |
| 1 / 3 Duty | – | COM2 | COM1 | COM0 |
| 1 / 2 Duty | – | – | COM1 | COM0 |
| Static | – | – | – | COM0 |

*Note : – ; This bit is not used for display data*

(2) Blanking

Blanking is enabled when EDSP is cleared to "0".

Blanking turns off LCD through outputting a GND level to COM/SEG pin.

### 2.10.4 Control Method of LCD Driver

(1) Initial setting

Figure 2-46 shows the flowchart of initialization.

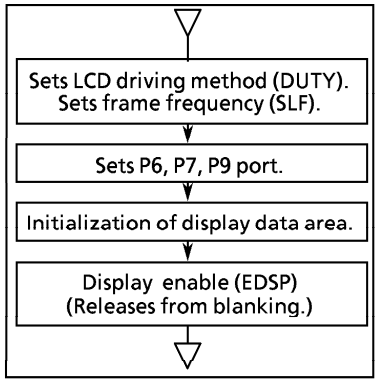



Figure 2-46. Initial Setting of LCD Driver

Example : To operate a 1/4 duty LCD of 32 segments × 4 commons at frame frequency fc/$2^{16}$ [Hz]

```
LD      (LCDCR),00000001B     ;  Sets LCD driving method and
                                 frame frequency.
LD      (P6CR),0FFH           ;  Sets P6 port as segment
                                 output .
  :       :                   ;  Sets the initial value of
                                 display data.
LD      (LCDCR),10000001B     ;  Display enable
```

(2) Store of display data

Generally, display data are prepared as fixed data in program memory (ROM) and stored in display data area by load command.

Example 1 : To display using 1/4 duty LCD a numerical value which corresponds to the LCD data stored in data memory at address $80_H$ (when pins COM and SEG are connected to LCD as in Figure 2-47), display data become as shown in Table 2-11.

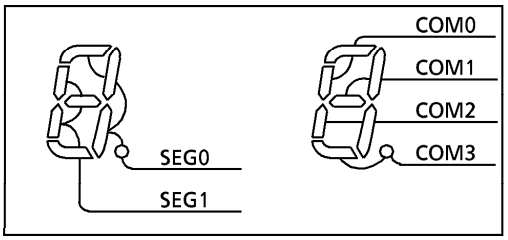



Figure 2-47. Example of COM, SEG Pin Connection (1/4 Duty)

```
        LD      A, (80H)
        ADD     A, TABLE – $ – 5
        LD      HL,0F80H
        LD      (HL), (PC + A)
        JRS     T, SNEXT
TABLE : DB      11011111B, 00000110B,
                11100011B, 10100111B,
                00110110B, 10110101B,
                11110101B, 00010111B,
                11110111B, 10110111B
SNEXT :
```

*Note : DB is a byte data difinition instruction.*

Table 2-11. Example of Display Data (1/4 Duty)

| No. | display | display data | No. | display | display data |
|---|---|---|---|---|---|
| 0 | 0. | 11011111 | 5 | 5 | 10110101 |
| 1 | 1 | 00000110 | 6 | 6 | 11110101 |
| 2 | 2 | 11100011 | 7 | 7 | 00000111 |
| 3 | 3 | 10100111 | 8 | 8 | 11110111 |
| 4 | 4 | 00110110 | 9 | 9 | 10110111 |

Example 2 : Table 2-12 shows an example of display data which are displayed using 1/2 duty LCD in the same way as Table 2-11. The connection between pins COM and SEG are the same as shown in Figure 2-48.

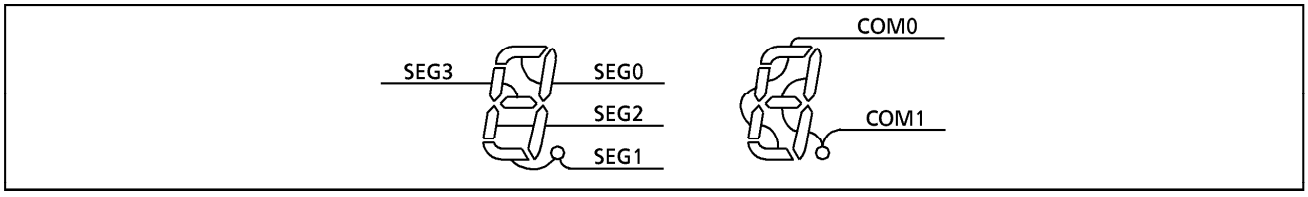



Figure 2-48. Example of COM, SEG Pin Connection

Table 2-12. Example of Display Data (1/2 Duty)

| Number | display data | | Number | display data | |
|---|---|---|---|---|---|
| | High order address | Low order address | | High order address | Low order address |
| 0 | **01**11 | **01**11 | 5 | **11**10 | **01**01 |
| 1 | **00**10 | **00**10 | 6 | **11**11 | **01**01 |
| 2 | **10**01 | **01**11 | 7 | **01**10 | **00**11 |
| 3 | **10**10 | **01**11 | 8 | **11**11 | **01**11 |
| 4 | **11**10 | **00**10 | 9 | **11**10 | **01**11 |

*Note : * ; don't care*

(3) Example of LCD drive output

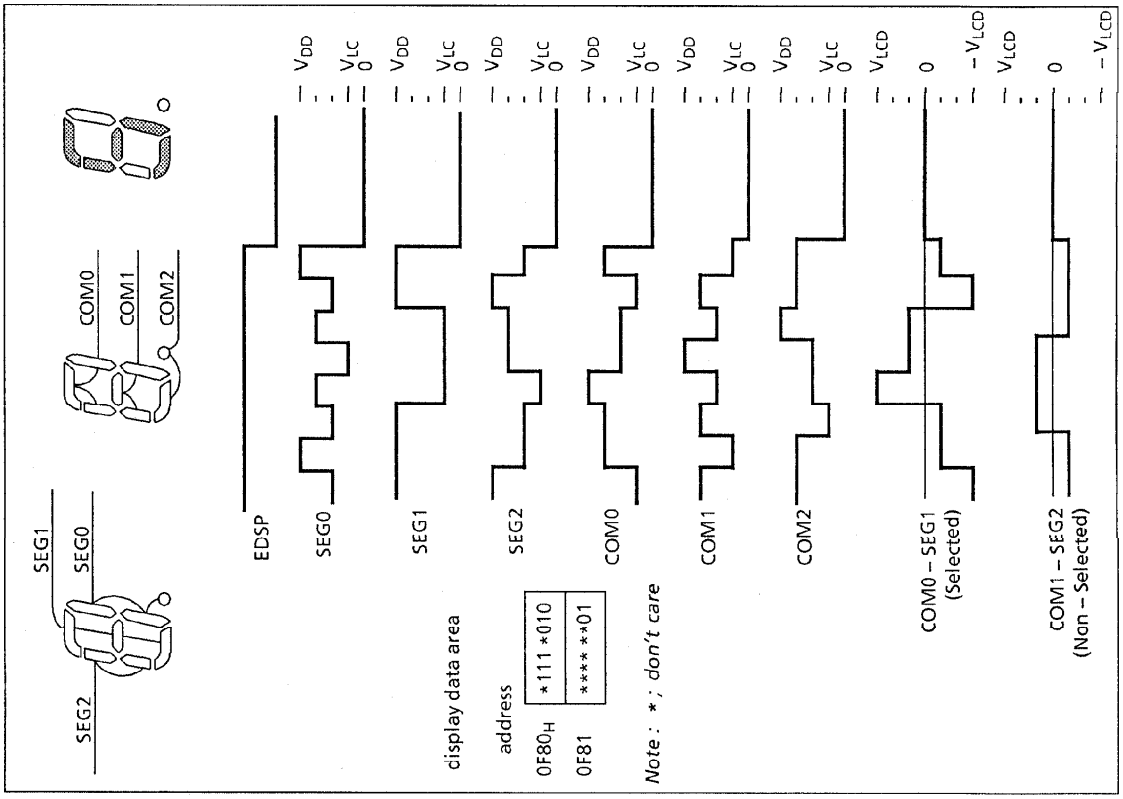



Figure 2-50. 1/3 Duty (1/3 Bias) Drive

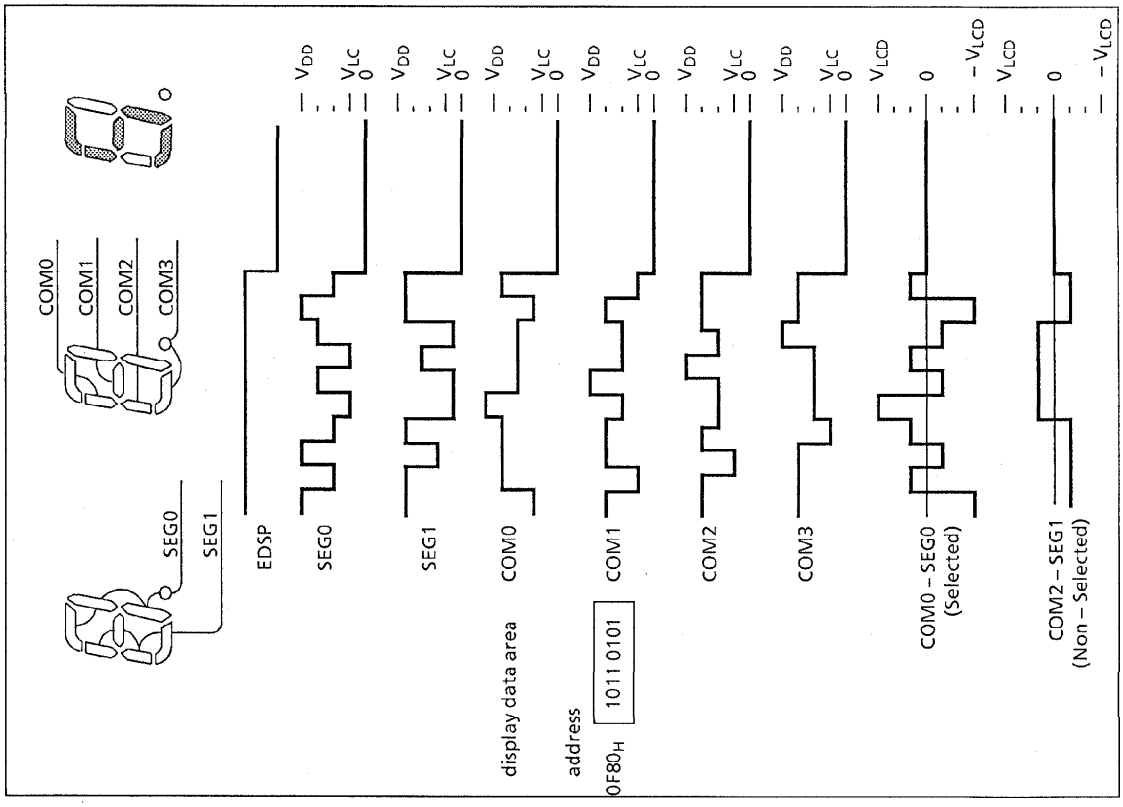



Figure 2-49. 1/4 Duty (1/3 Bias) Drive

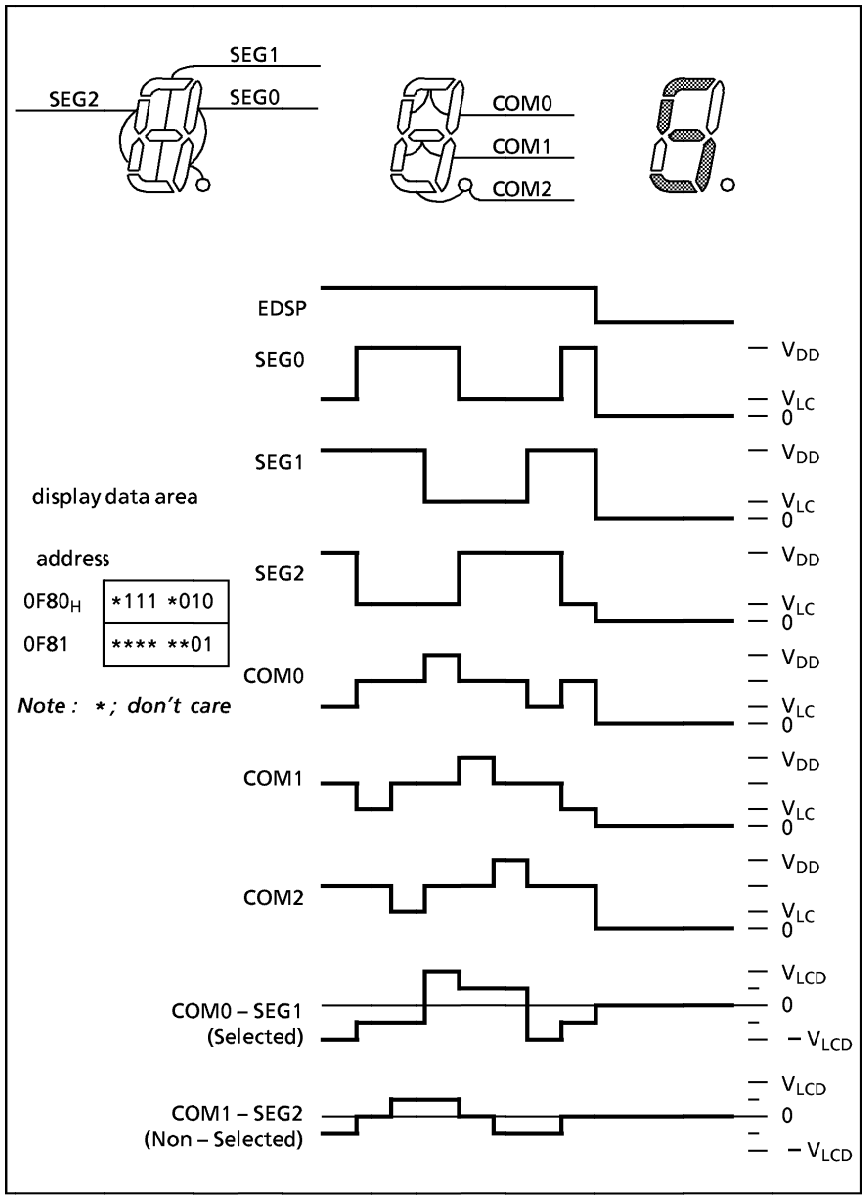



Figure 2-51. 1/3 Duty (1/2 Bias) Drive

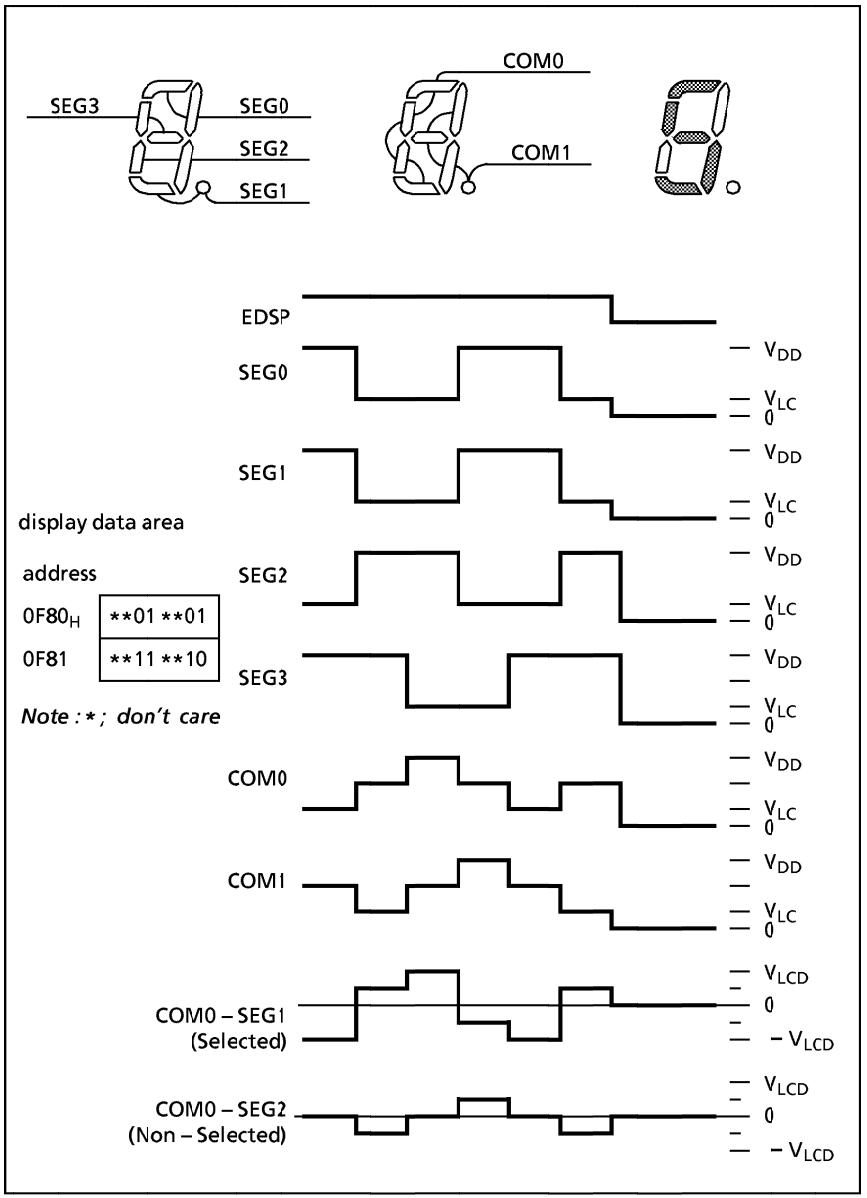



Figure 2-52. 1/2 Duty (1/2 Bias) Drive

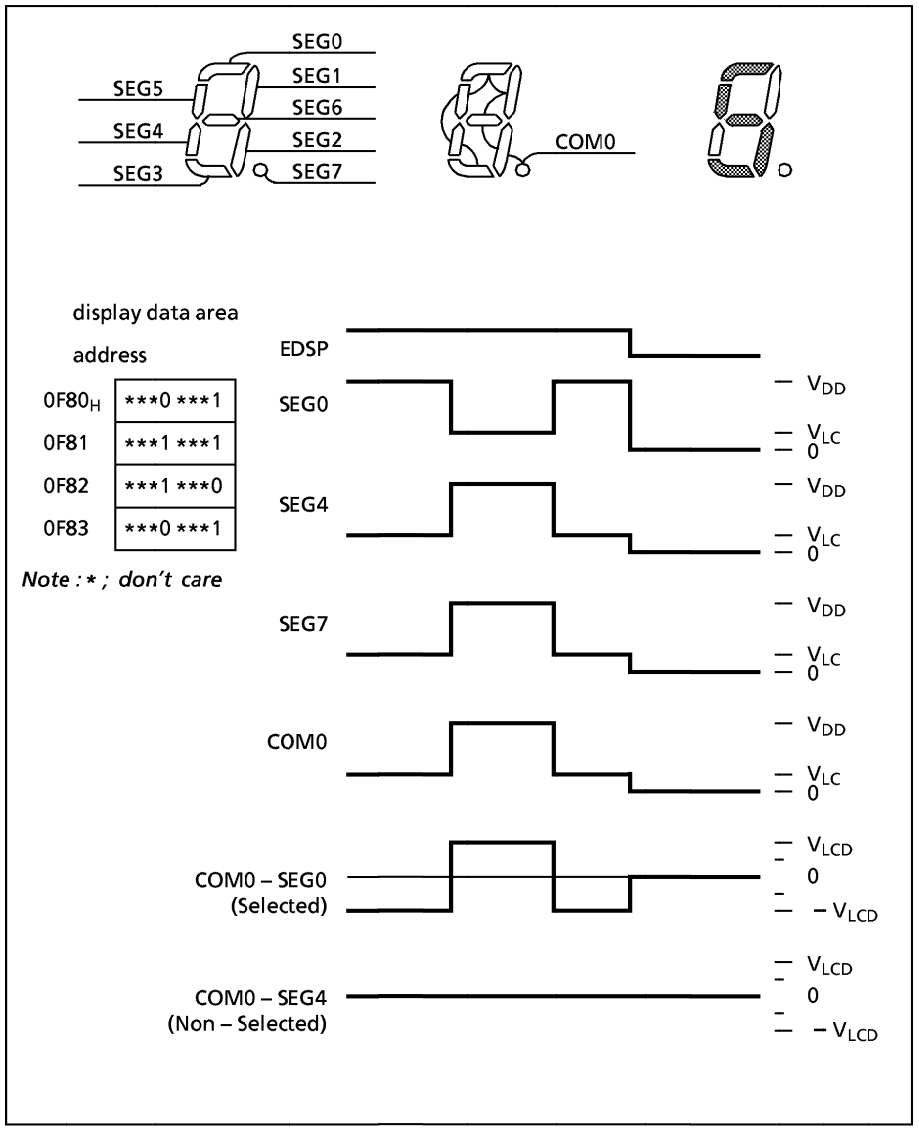



Figure 2-53. Static Drive

## 2.11 8-bit A/D Converter (ADC)

The 87CH21/M21 each have an 8-channel multiplexed-input 8-bit successive approximate type A/D converter with sample and hold.

### 2.11.1 Configuration

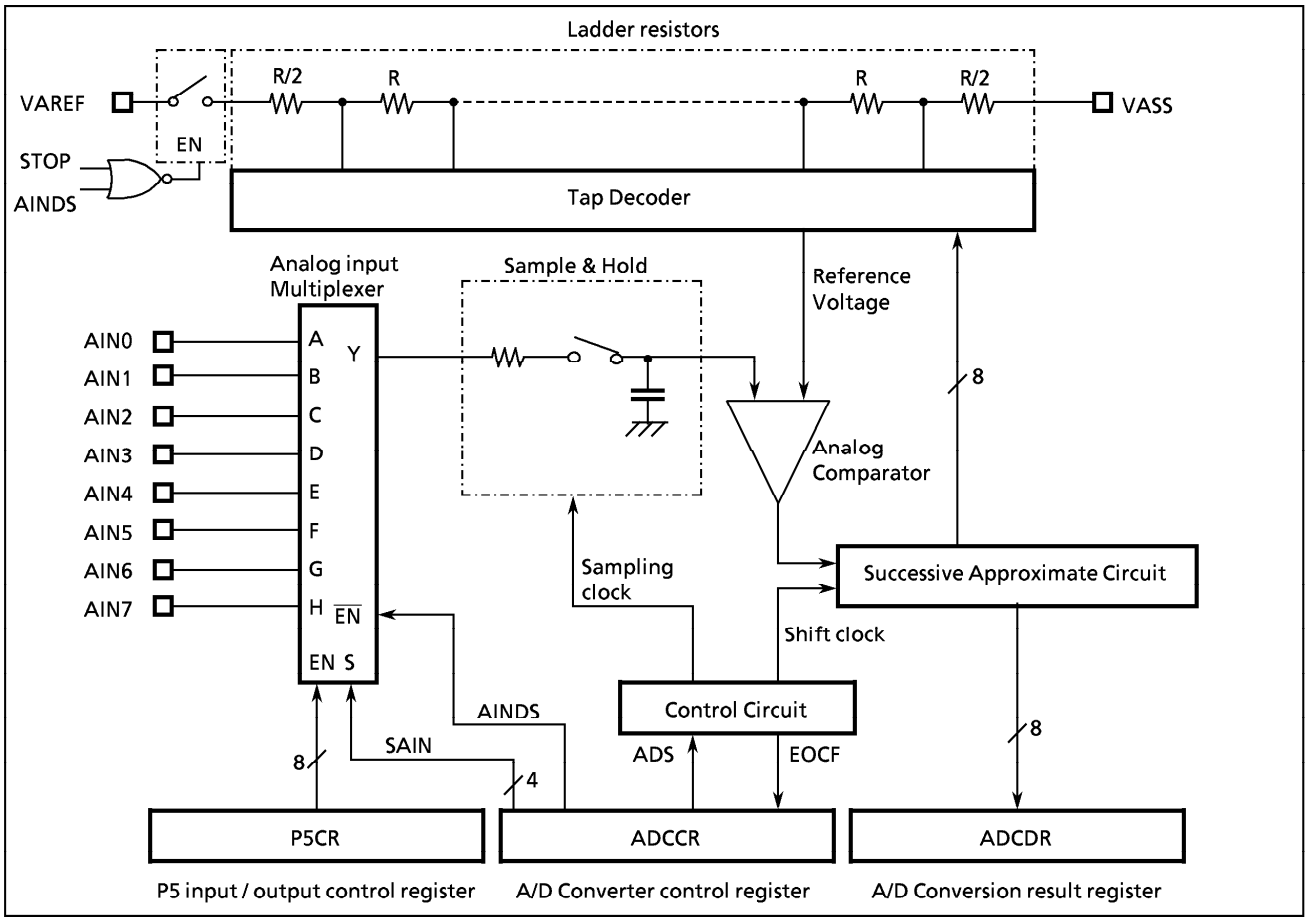



Figure 2-54. A/D Converter

### 2.11.2 Control

The A/D converter is controlled by the A/D converter control register (ADCCR). Reading EOCF in ADCCR determines the A/D converter operating state; reading the A/D conversion value register (ADCDR) determines the A/D conversion value.

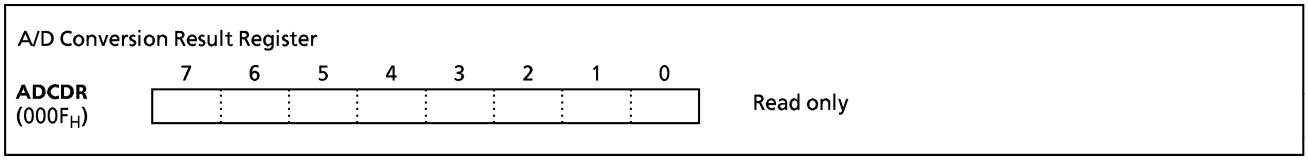



Figure 2-55. A/D Converter Result Register

A/D Converter Control Register

ADCCR ($000E_H$)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| EOCF | ADS | ACK | AINDS | SAIN | | | |

(Initial value : 0000 0000)

| | | | |
|---|---|---|---|
| SAIN | Analog input selection | 0000 : AIN00<br>0001 : AIN01<br>0010 : AIN02<br>0011 : AIN03<br>0100 : AIN04<br>0101 : AIN05<br>0110 : AIN06<br>0111 : AIN07<br>1*** : reserved | R/W |
| AINDS | Analog input control | 0 : Enable<br>1 : Disable | |
| ACK | Conversion time selection | 0 : Conversion time = 23 $\mu$s (at fc = 8 MHz)<br>1 : Conversion time = 92 $\mu$s | |
| ADS | A/D conversion start | 0 : –<br>1 : A/D conversion start | |
| EOCF | End of A/D conversion flag | 0 : Under conversion or Before conversion<br>1 : End of conversion | |

*Note 1 : * ; don't care*

*Note 2 : Select analog input when A/D converter stops.*

*Note 3 : The ADS is automatically cleared to "0" after starting conversion.*

*Note 4 : The EOCF is cleared to "0" when reading the ADCDR.*

*Note 5 : The EOCF is read-only.*

Figure 2-56. A/D converter control register and A/D conversion result register

### 2.11.3 Operation

The high side of an analog reference voltage is applied to VAREF pin, and the low side is applied to VASS pin. The reference voltage between VAREF and VASS is divided into the voltage corresponding with bits by radar resistance. The reference voltage is compared with an analog input voltage and A/D conversion is performed.

(1) Start of A/D conversion

Prior to A/D conversion start, select one pin among analog input channels (AIN7 to AIN0) using the SAIN (bit 3 - 0 in ADCCR). Clear AINDS (bit 4 in ADDCCR) to 0 and clear the channel to be used for analog input using the P5 I/O control register (P5CR).

*Note : The pin that is not used as an analog input can be used as regular input/output pins. During conversion, do not perform output instruction to maintain a precision for all of the pins.*

Set A/D conversion time using the ACK (bit 5 in ADCCR).
To start A/D conversion, set A/D conversion to "1" using the ADS (bit 6 in ADCCR).
A/D conversion time is from A/D conversion start to A/D conversion result being set in ADCDR. When ACK = 0, 184/fc [s] (46 machine cycles) is necessary. That is, when fc = 8 MHz, the A/D conversion time is 23 $\mu$s.
After A/D conversion, the EOCF (bit 7 in ADCCR) is set to "1" indicating end of conversion.
Setting the ADS to "1" during A/D conversion resumes conversion from the beginning.
The analog input voltage is sampled every 4 machine cycles after A/D conversion start.

(2) Reading of A/D conversion result

After the end of conversion, read the conversion result from the ADCDR.

The EOCF is automatically cleared to "0" when reading the ADCDR. When the conversion result is read out during A/D conversion, the invalid value is read out.

(3) A/D conversion in STOP mode

When the MCU places in the STOP mode during the A/D conversion, the conversion is terminated and the A/D conversion value become indefinite. Thus EOCF is maintained to "0" after returned from the STOP mode.

However, if the STOP mode is started after the end of conversion (EOCF = 1), the ADCDR contents are held.

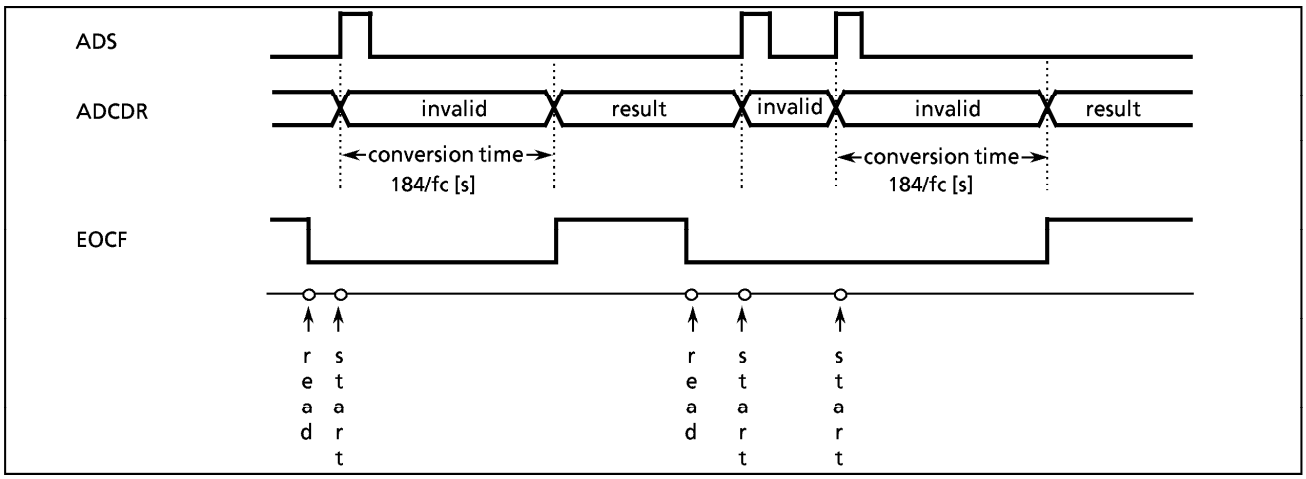



Figure 2-57. A/D conversion Timing chart

Example: After AIN pin 4 is selected as an analog input channel, A/D conversion is started. EOCF is confirmed and the converted result is read out. It is saved to address $009E_H$ in RAM.

```
    ; AIN SELECT
    LD          (ADCCR) , 00000100B     ;   selects AIN4
    ; A/D CONVERT START
    SET         (ADCCR) . 6             ;   ADS = 1
SLOOP :  TEST   (ADCCR) . 7             ;   EOCF = 1 ?
    JRS         T, SLOOP
    ; RESULT DATA READ
    LD          (9EH), (ADCDR)
```

Figure 2-58 shows the relationship between An analog input voltage and A/D converted 8-bit digital value.

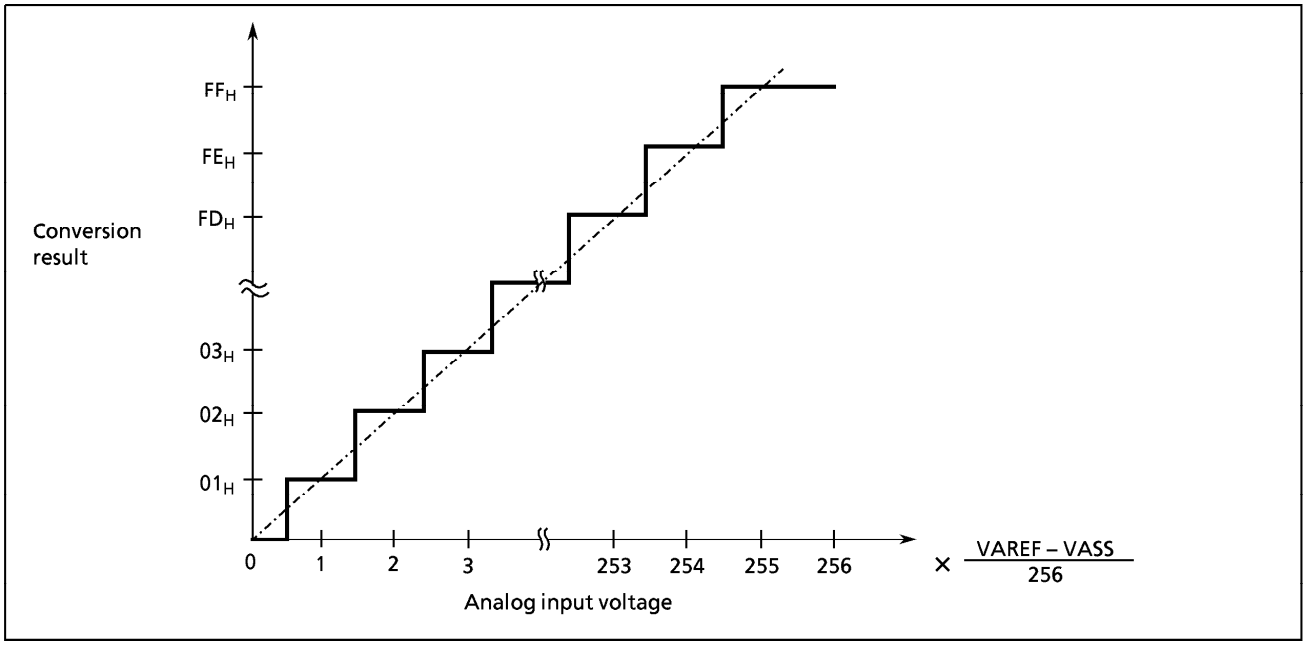
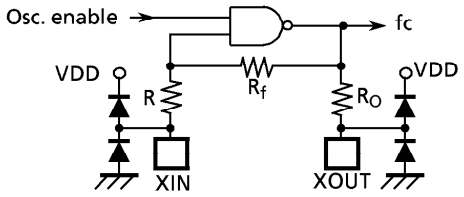
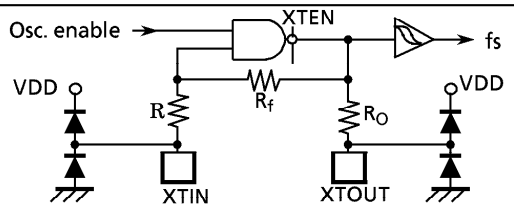
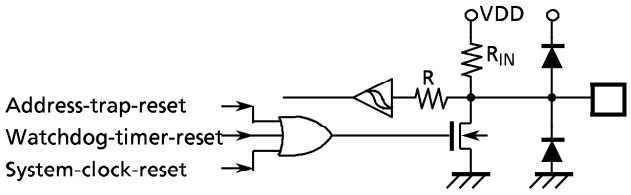
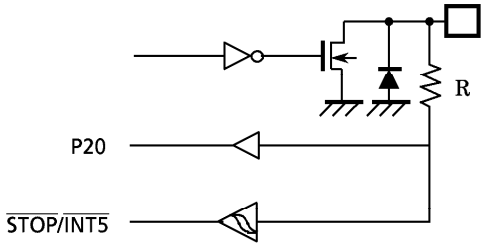
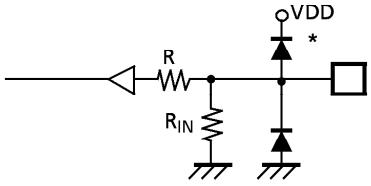



Figure2-58. Analog input voltage vs A/D conversion result (typ.)

## INPUT / OUTPUT CIRCUITRY

(1) Control pins

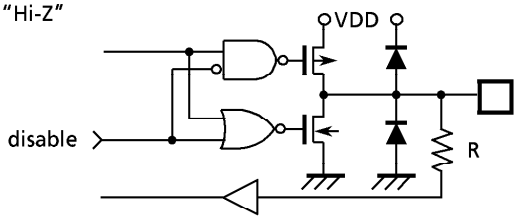
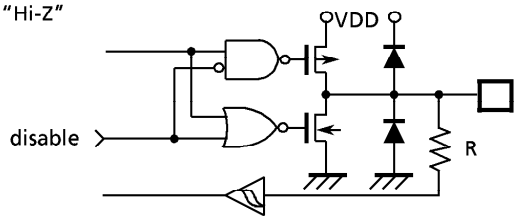
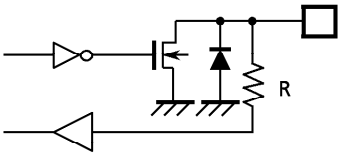
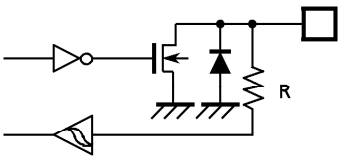
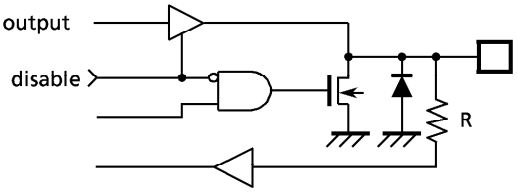
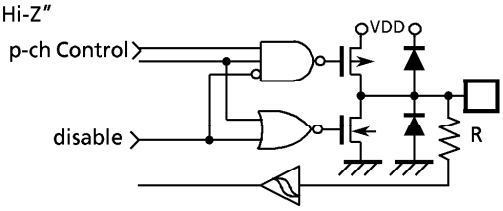
The input / output circuitries of the 87CH21/M21 control pins are shown below.
Please specify either the single-clock mode or the dual-clock mode by a code (NM1 or NM2) as an option for an operating mode during reset.

| CONTROL PIN | I/O | INPUT / OUTPUT CIRCUITRY and CODE | REMARKS |
|---|---|---|---|
| XIN<br>XOUT | Input<br>Output |  | Resonator connecting pins (high-frequency)<br>$R_f$ = 1.2 MΩ (typ.)<br>$R_o$ = 1.5 kΩ (typ.)<br>R = 1 kΩ (typ.) |
| XTIN (P21)<br>XTOUT (P22) | Input<br>Output | NM1: Refer to port P2<br>NM2:  | Resonator connecting pins (low-frequency)<br>$R_f$ = 6 MΩ (typ.)<br>$R_o$ = 220 kΩ (typ.)<br>R = 1 kΩ (typ.) |
| RESET | I/O |  | Sink open drain output<br>Hysteresis input<br>Pull-up resistor<br>$R_{IN}$ = 220 kΩ (typ.)<br>R = 1 kΩ (typ.) |
| $\overline{\text{STOP/INT5}}$<br>(P20) | Input |  | Hysteresis input<br>R = 1 kΩ (typ.) |
| TEST | Input |  | Pull-down resistor<br>$R_{IN}$ = 70 kΩ (typ.)<br>R = 1 kΩ (typ.) |

*Note1 : The TEST pin of the 87PP21 does not have a pull-down resistor. Always fix to low lvel.*
*Note2 : The 87PP21 is placed in the single-clock mode during reset.*

(2) Input/Output Ports

The input/output circuitries of the 87CH21/M21 input/output ports are shown below.

| PORT | I/O | INPUT / OUTPUT CIRCUITRY and CODE | REMARKS |
|---|---|---|---|
| P5 | I/O | initial "Hi-Z"<br>  | Tri-state I/O<br>R = 1 kΩ (typ.) |
| P1 | I/O | initial "Hi-Z"<br>  | Tri-state I/O<br>Hysteresis input<br>R = 1 kΩ (typ.) |
| P2 | I/O | initial "Hi-Z"<br>  | Sink open drain output<br>R = 1 kΩ (typ.) |
| P3 | I/O | initial "Hi-Z"<br>  | Sink open drain output<br>R = 1 kΩ (typ.) |
| P6<br>P7<br>P9 | I/O | initial "Hi-Z"<br>Segment output<br>  | Sink open drain<br>or<br>Segment output<br>R = 1 kΩ (typ.) |
| P4 | I/O | initial "Hi-Z"<br>  | Tri-state I/O<br>P41 High current output<br>R = 1 kΩ (typ.) |

## ELECTRICAL CHARACTERISTICS

### ABSOLUTE MAXIMUM RATINGS ($V_{SS}$ = 0 V)

| PARAMETER | SYMBOL | PINS | RATINGS | UNIT |
|---|---|---|---|---|
| Supply Voltage | $V_{DD}$ | | – 0.3 to 6.5 | V |
| Input Voltage | $V_{IN}$ | | – 0.3 to $V_{DD}$ + 0.3 | V |
| Output Voltage | $V_{OUT}$ | | – 0.3 to $V_{DD}$ + 0.3 | V |
| Output Current (Per 1 pin) | $I_{OUT1}$ | Ports P0, P1, P2, P3, P5, P6, P7, P8, P9, P4 (except P41) | 3.2 | mA |
| | $I_{OUT2}$ | P41 | 30 | |
| Output Current (Total) | $\Sigma I_{OUT1}$ | Ports P0, P1, P2, P3, P5, P6, P7, P8, P9, P4 (except P41) | 120 | mA |
| | $\Sigma I_{OUT2}$ | P41 | 30 | |
| Power Dissipation [Topr = 70°C] | PD | | 350 | mW |
| Soldering Temperature (time) | Tsld | | 260 (10 s) | °C |
| Storage Temperature | Tstg | | – 55 to 125 | °C |
| Operating Temperature | Topr | | – 30 to 70 | °C |

### RECOMMENDED OPERATING CONDITIONS ($V_{SS}$ = 0 V, Topr = – 30 to 70 °C)

| PARAMETER | SYMBOL | PINS | CONDITIONS | | Min. | Max. | UNIT |
|---|---|---|---|---|---|---|---|
| Supply Voltage | $V_{DD}$ | | fc = 8 MHz | NORMAL1, 2 mode | 4.5 | 5.5 | V |
| | | | | IDLE1, 2 mode | | | |
| | | | fc = 4.2 MHz | NORMAL1, 2 mode | 2.7 | | |
| | | | | IDLE1, 2 mode | | | |
| | | | fs = 32.768 kHz | SLOW mode | | | |
| | | | | SLEEP mode | | | |
| | | | | STOP mode | 2.0 | | |
| Input High Voltage | $V_{IH1}$ | Except hysteresis input | $V_{DD} \geqq 4.5$ V | | $V_{DD} \times 0.70$ | $V_{DD}$ | V |
| | $V_{IH2}$ | Hysteresis input | | | $V_{DD} \times 0.75$ | | |
| | $V_{IH3}$ | | $V_{DD} < 4.5$ V | | $V_{DD} \times 0.90$ | | |
| Input Low Voltage | $V_{IL1}$ | Except hysteresis input | $V_{DD} \geqq 4.5$ V | | 0 | $V_{DD} \times 0.30$ | V |
| | $V_{IL2}$ | Hysteresis input | | | | $V_{DD} \times 0.25$ | |
| | $V_{IL3}$ | | $V_{DD} < 4.5$ V | | | $V_{DD} \times 0.10$ | |
| Clock Frequency | fc | XIN, XOUT | $V_{DD}$ = 4.5 to 5.5 V | | 0.4 | 8.0 | MHz |
| | | | $V_{DD}$ = 2.7 to 5.5 V | | | 4.2 | |
| | fs | XTIN, XTOUT | | | 30.0 | 34.0 | kHz |

*Note : Clock frequency fc : Supply voltage range is specified in NORMAL1/2 mode and IDLE1/2 mode.*

D.C. CHARACTERISTICS ($V_{SS}$ = 0 V, Topr = – 30 to 70 °C)

| PARAMETER | SYMBOL | PINS | CONDITIONS | Min. | Typ. | Max. | UNIT |
|---|---|---|---|---|---|---|---|
| Hysteresis Voltage | $V_{HS}$ | Hysteresis inputs | | – | 0.9 | – | V |
| Input Current | $I_{IN1}$ | TEST | $V_{DD}$ = 5.5 V<br>$V_{IN}$ = 5.5 V / 0 V | – | – | ± 2 | μA |
| | $I_{IN2}$ | Open drain ports and tri-state ports | | | | | |
| | $I_{IN3}$ | $\overline{RESET}$, $\overline{STOP}$ | | | | | |
| Input Resistance | $R_{IN2}$ | $\overline{RESET}$ | | 100 | 220 | 450 | kΩ |
| Output Leakage Current | $I_{LO}$ | Open drain ports, Tri-state ports | $V_{DD}$ = 5.5 V, $V_{OUT}$ = 5.5 V | – | – | 2 | μA |
| Output High Voltage | $V_{OH1}$ | Push-pull ports P4 ports | $V_{DD}$ = 4.5 V, $I_{OH}$ = – 200 μA | 2.4 | – | – | V |
| | $V_{OH2}$ | Tri- state ports P1, P5 ports | $V_{DD}$ = 4.5 V, $I_{OH}$ = – 0.7 mA | 4.1 | – | – | |
| Output Low Voltage | $V_{OL}$ | Except XOUT and P41 | $V_{DD}$ = 4.5 V, $I_{OL}$ = 1.6 mA | – | – | 0.4 | V |
| Output Low Current | $I_{OL3}$ | P41 | $V_{DD}$ = 4.5 V, $V_{OL}$ = 1.0 V | – | 20 | – | mA |
| Supply Current in NORMAL 1 , 2 mode | $I_{DD}$ | | $V_{DD}$ = 5.5 V<br>$V_{IN}$ = 5.3 V/0.2 V<br>fc = 8 MHz<br>fs = 32.768 kHz | – | 10 | 16 | mA |
| Supply Current in IDLE 1, 2 mode | | | | – | 6 | 10 | mA |
| Supply Current in SLOW mode | | | $V_{DD}$ = 3.0 V<br>$V_{IN}$ = 2.8 V/0.2 V<br>fs = 32.768 kHz<br>LCD driver is not enable | – | 30 | 60 | μA |
| Supply Current in SLEEP mode | | | | – | 15 | 30 | μA |
| Supply Current in STOP mode | | | $V_{DD}$ = 5.5 V<br>$V_{IN}$ = 5.3 V/0.2 V | | 0.5 | 10 | μA |
| Segment Output Low Resistance | $R_{OS1}$ | SEG31-SEG0 | $V_{DD}$ = 5 V, $V_{DD}$ – $V_{LC}$ = 3 V | – | 20 | – | kΩ |
| Common Output Low Resistance | $R_{OC1}$ | COM3-COM0 | | | | | |
| Segment Output High Resistance | $R_{OS2}$ | SEG31-SEG0 | | – | 200 | – | kΩ |
| Common Output High Resistance | $R_{OC2}$ | COM3-COM0 | | | | | |
| Segment/Common Output Voltage | $V_{O2/3}$ | SEG31-SEG0 and COM3-COM0 | | 3.8 | 4.0 | 4.2 | V |
| | $V_{O1/2}$ | | | 3.3 | 3.5 | 3.7 | |
| | $V_{O1/3}$ | | | 2.8 | 3.0 | 3.2 | |

*Note 1 : Typical values show those at Topr = 25 °C , $V_{DD}$ = 5 V.*
*Note 2 : Input Current ; The current through pull-up or pull-down resistor is not included.*
*Note 3 : $I_{DD}$ ; Except for $I_{REF}$*
*Note 4 : Output resistors Ros, Roc indicate "on" when switching levels.*
*Note 5 : $V_{O2/3}$ indicates an output voltage at the 2/3 level when operating in the 1/4 or 1/3 duty mode.*
*Note 6 : $V_{O1/2}$ indicates an output voltage at the 1/2 level when operating in the 1/2 duty or static mode.*
*Note 7 : $V_{O1/3}$ indicates an output voltage at the 1/3 level when operating in the 1/4 or 1/3 duty mode.*
*Note 8 : When using LCD, it is necessary to consider values of Ros1/2 and Rbc1/2.*
*Note 9 : Times for SEG/COM output switching on : Ros1, Roc1 : $2^6$/fc, 2/fc (s)*
*Ros2, Roc2 : 1/(n, $f_F$)*
*(1/n : duty, $f_F$ : frame frequency)*

## A / D CONVERSION CHARACTERISTICS

(Topr = – 30 to 70 °C)

| PARAMETER | SYMBOL | CONDITIONS | Min. | Typ. | Max. | UNIT |
|---|---|---|---|---|---|---|
| Analog Reference Voltage | $V_{AREF}$ | $V_{AREF} - V_{ASS} \geqq 2.5$ V | 2.7 | – | $V_{DD}$ | V |
| | $V_{ASS}$ | | $V_{SS}$ | – | 1.5 | |
| Analog Input Voltage | $V_{AIN}$ | | $V_{ASS}$ | – | $V_{AREF}$ | V |
| Analog Supply Current | $I_{REF}$ | $V_{AREF}$ = 5.5 V, $V_{ASS}$ = 0.0 V | – | 0.5 | 1.0 | mA |
| Nonlinearity Error | | $V_{DD}$ = 5.0 V, $V_{SS}$ = 0.0 V<br>$V_{AREF}$ = 5.000 V<br>$V_{ASS}$ = 0.000 V<br>or<br>$V_{DD}$ = 2.7 V, $V_{SS}$ = 0.0 V<br>$V_{AREF}$ = 2.700 V<br>$V_{ASS}$ = 0.000 V | – | – | ± 1 | LSB |
| Zero Point Error | | | – | – | ± 1 | |
| Full Scale Error | | | – | – | ± 1 | |
| Total Error | | | – | – | ± 2 | |

*Note : Quantizing error is not contained in those errors.*

## A.C. CHARACTERISTICS

($V_{SS}$ = 0 V, $V_{DD}$ = 4.5 to 5.5 V, Topr = – 30 to 70 °C)

| PARAMETER | SYMBOL | CONDITIONS | Min. | Typ. | Max. | UNIT |
|---|---|---|---|---|---|---|
| Machine Cycle Time | $t_{cy}$ | In NORMAL 1, 2 mode | 0.5 | – | 10 | μs |
| | | In IDLE 1, 2 mode | | | | |
| | | In SLOW mode | 117.6 | – | 133.3 | |
| | | In SLEEP mode | | | | |
| High Level Clock Pulse Width | $t_{WCH}$ | For external clock operation (XIN input), fc = 8 MHz | 62.5 | – | – | ns |
| Low Level Clock Pulse Width | $t_{WCL}$ | | | | | |
| High Level Clock Pulse Width | $t_{WSH}$ | For external clock operation (XTIN input), fs = 32.768 kHz | 14.7 | – | – | μs |
| Low Level Clock Pulse Width | $t_{WSL}$ | | | | | |

($V_{SS}$ = 0 V, $V_{DD}$ = 2.7 to 5.5 V, Topr = – 30 to 70 °C)

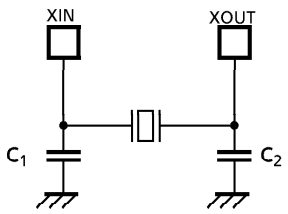
| PARAMETER | SYMBOL | CONDITIONS | Min. | Typ. | Max. | UNIT |
|---|---|---|---|---|---|---|
| Machine Cycle Time | $t_{cy}$ | In NORMAL 1, 2 mode | 0.95 | – | 10 | μs |
| | | In IDLE 1, 2 mode | | | | |
| | | In SLOW mode | 117.6 | – | 133.3 | |
| | | In SLEEP mode | | | | |
| High Level Clock Pulse Width | $t_{WCH}$ | For external clock operation (XIN input), fc = 4.2 MHz | 110 | – | – | ns |
| Low Level Clock Pulse Width | $t_{WCL}$ | | | | | |
| High Level Clock Pulse Width | $t_{WSH}$ | For external clock operation (XTIN input), fs = 32.768 kHz | 14.7 | – | – | μs |
| Low Level Clock Pulse Width | $t_{WSL}$ | | | | | |

RECOMENDED OSCILLATING CONDITION-1 (VSS = 0 V, VDD = 4.5 to 5.5 V, Topr = – 30 to 70 °C)

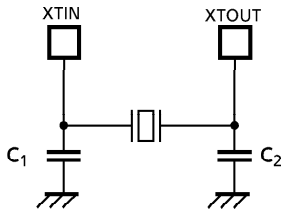
| PARAMETER | OSILLATOR | FREQUENCY | RECOMMENDER OSCILLATOR | | RECOMMENDED CONDITION $C_1$ | RECOMMENDED CONDITION $C_2$ |
|---|---|---|---|---|---|---|
| High-frequency | Ceramic Resonator | 8 MHz | KYOCERA | KBR8.0M | 30 pF | 30 pF |
| | | | Standard/Lead Type (MURATA) | CSA8.00MTZ<br>CST8.00MTW | built-in<br>30 pF | built-in<br>30 pF |
| | | | Standard/SMP Type (MURATA) | CSACS8.00MT | 30 pF | 30 pF |
| | | | Standard/Small ChipType (MURATA) | CSTCS8.00MT | built-in<br>30 pF | built-in<br>30 pF |
| | | 4 MHz | KYOCERA | KBR4.0MS | 30 pF | 30 pF |
| | Crystal Oscillator | 8 MHz | TOYOCOM | 210B 8.0000 | 20 pF | 20 pF |
| | | 4 MHz | TOYOCOM | 204B 4.0000 | | |
| Low-frequency | Crystal Oscillator | 32.768 kHz | NDK | MX-38T | 15 pF | 15 pF |

RECOMENDED OSCILLATING CONDITION-2 (VSS = 0 V, VDD = 2.7 to 5.5 V, Topr = – 30 to 70 °C)

| PARAMETER | OSILLATOR | FREQUENCY | RECOMMENDER OSCILLATOR | | RECOMMENDED CONDITION $C_1$ | RECOMMENDED CONDITION $C_2$ |
|---|---|---|---|---|---|---|
| High-frequency | Ceramic Resonator | 4 MHz | Standard/Lead Type | CSA4.00MG | 30 pF | 30pF |
| | | | (MURATA) | CST4.00MGW | built-in<br>30 pF | built-in<br>30 pF |
| | | | Standard/SMD Type (MURATA) | CSA4.00MGC<br>CSAC4.00MGCM<br>CSTC4.00MG | 30 pF | 30 pF |
| | | | | | built-in<br>30 pF | built-in<br>30 pF |
| | | | Standard/Small Chip Type | CSTCS4.00MG | built-in<br>10 pF | built-in<br>10 pF |




(1) High-frequency




(2) Low-frequency

*Note : When used in high electric field such as a picture tube, the package is recommended to be electrically shielded to maintain a regular operation.*