M3810x Group

SINGLE-CHIP 8-BIT CMOS MICROCOMPUTER

DESCRIPTION

The M3810x group is made up of 8-bit microcomputers based on the MELPS 740 core.

The M3810x group is designed mainly for VCR control, and include four 8-bit timers, a PWM function, and a 4-bit comparator circuit.

The various microcomputers in the M3810x group include variations of internal memory size and packaging. For details, see the section on part numbering.

For details on availability of microcomputers in the M3810x group, see the section on group expansion.

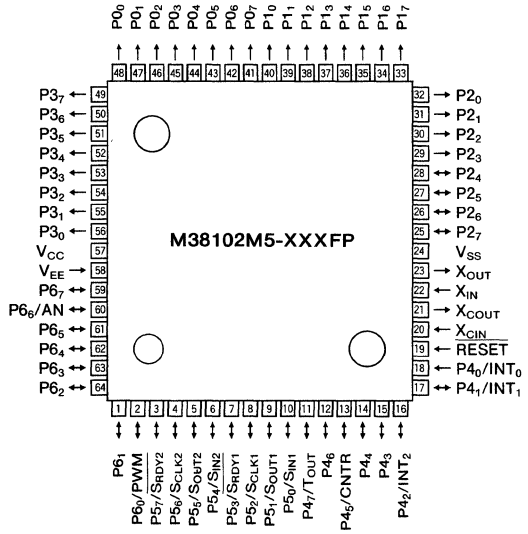
FEATURES

- Basic machine-language instructions 71
- Instruction execution time 0.95μs
  (shortest instruction at 4.19MHz oscillation frequency)
- Memory size
  ROM ..... 4K to 32K bytes
  RAM ..... 192 to 1024 bytes
- Programmable input/output ports 27
- High-breakdown-voltage output ports 28
- Interrupts ..... 11 sources, 11 vectors
- Timers ..... 8-bit×4
- Serial I/O ..... 8-bit×2 (Clock-synchronized)
- PWM output circuit ..... 14-bit×1
- Comparator circuit ..... 4-bit×1
- 2 Clock generation circuit
  Clock (X_{IN}-X_{OUT}) ..... Internal feedback amplifier
  Sub clock (X_{CIN}-X_{COUT}) ..... Internal amplifier without feedback
- Supply voltage ..... 4.0 to 5.5V
- Low power dissipation
  In high-speed operation 25mW
  (at 4.19MHz oscillation frequency)
  In low-speed operation 300μW
  (at 32kHz oscillation frequency)
- Operating temperature range ..... −10 to +85℃

APPLICATIONS

VCRs, tuners, musical instruments, office automation, etc.

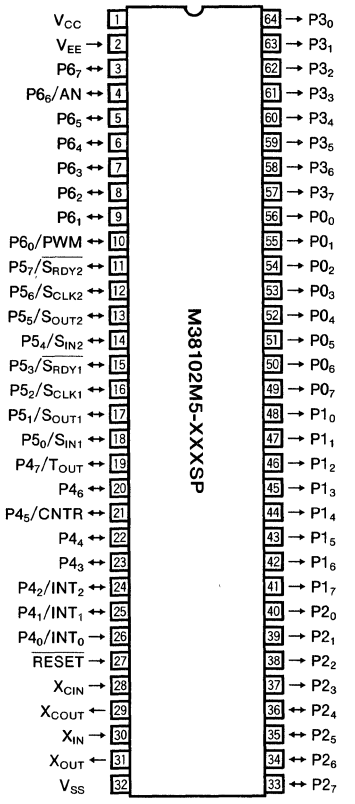
PIN CONFIGURATION (TOP VIEW)



Package type : 64P6N

64-pin plastic-molded QFP

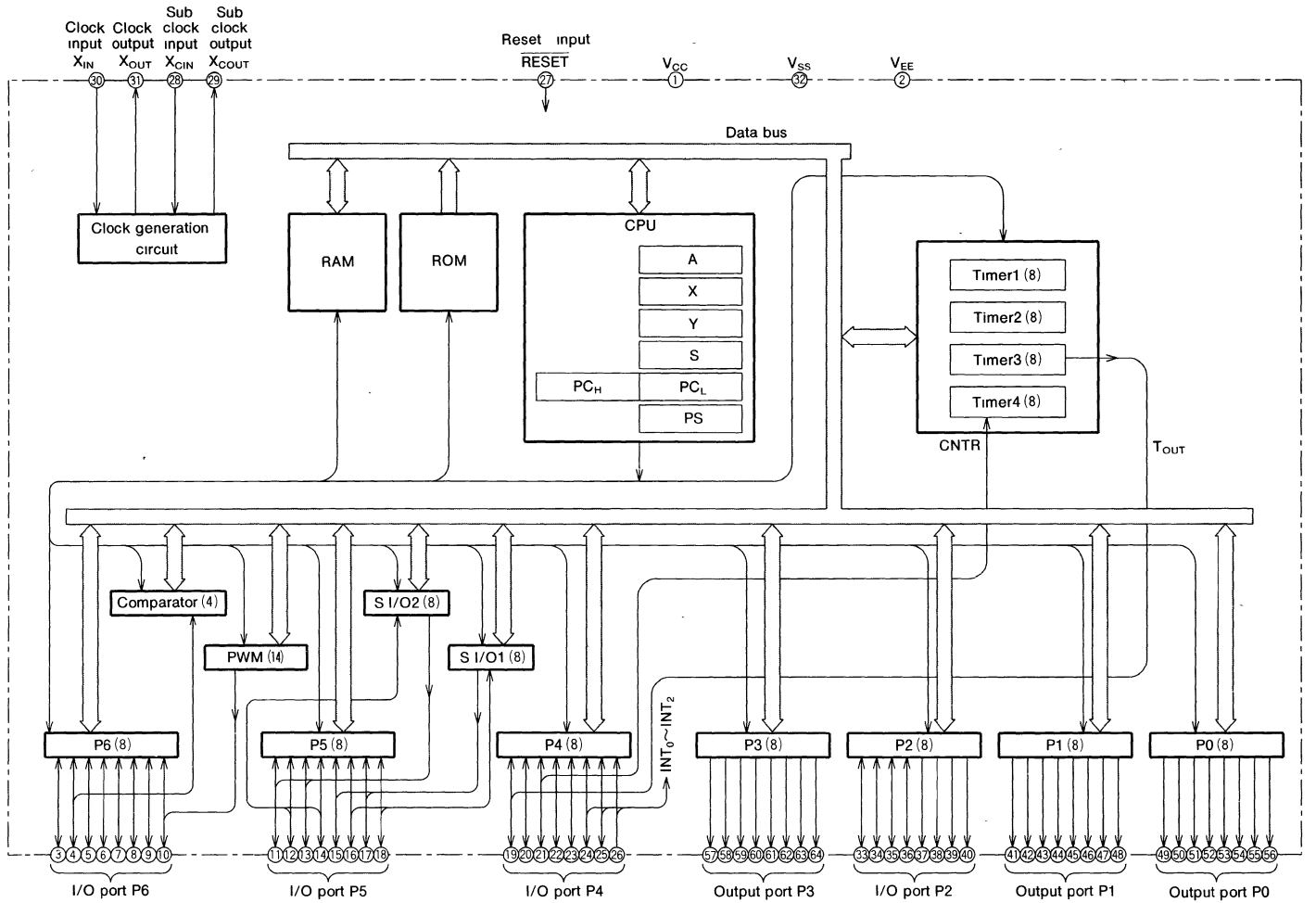
PIN CONFIGURATION (TOP VIEW)



Package type : 64P4B

64-pin shrink plastic-molded DIP

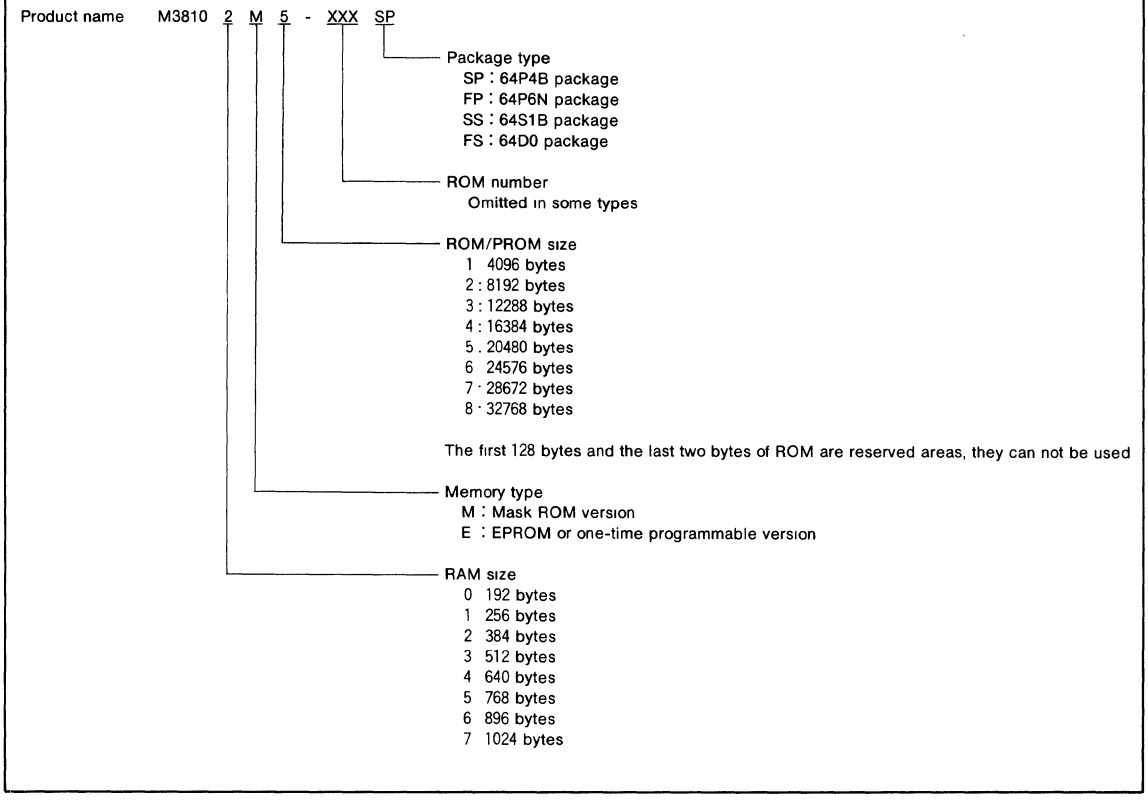
FUNCTIONAL BLOCK DIAGRAM (Package : 64P4B)



PIN DESCRIPTION

Pin	Name	Function	Alternate Function
V_{CC}, V_{SS}	Power supply	Power supply inputs 4 0 to 5 5V to V_{CC}, and 0V to V_{SS}.	
V_{EE}	Pull-down power input	Applies voltage supplied to pull-down resistors of ports P0, P1, $P2_0$-$P2_3$, and P3	
$\overline{RESET}$	Reset input	To reset the microcomputer, this pin should be kept at an "L" level for more than 2μs under high-speed operating conditions In low-speed operation start mode, internal reset is not released until the X_{CIN}-X_{COUT} clock has had time to stabilize	
X_{IN}	Clock input	Input and output signals for the internal clock generation circuit It consist of internal feedback amplifier Connect a ceramic resonator or quartz crystal between the X_{IN} and X_{OUT} pins to set the oscillation frequency If an external clock is used, connect the clock source to the X_{IN} pin and leave the X_{OUT} pin open This clock is used as system clok	
X_{OUT}	Clock output		
X_{CIN}	Sub clock input	Input and output signals for the internal sub clock generation circuit It consist of internal amplifier without feedback Connect a ceramic resonator or quartz crystal and external feedback resistor between the X_{CIN} and X_{COUT} pins If an external clock is used, connect the clock source to the X_{CIN} pin and leave the X_{COUT} pin open This clock can also be used as the system clock	
X_{COUT}	Sub clock output		
$P0_0$-$P0_7$	Output port P0	8-bit output port The output structure is high-breakdown-voltage P-channel open drain with internal pull-down resistors connected between the output and the V_{EE} pin	
$P1_0$-$P1_7$	Output port P1		
$P2_0$-$P2_3$	Output port P2	A 4-bit output port with the same function as port P0.	
$P2_4$-$P2_7$	I/O port P2	A 4-bit I/O port An I/O direction register allows each pin to be individually programmed as either input or output At reset this port is set to input mode The output structure of this port is CMOS 3-state, and the input levels are TTL compatible.	
$P3_0$-$P3_7$	Output port P3	An 8-bit output port with the same function as port P0	
$P4_0/INT_0$	Input port $P4_0$	1-bit CMOS input pin	External interrupt input pins
$P4_1/INT_1$, $P4_2/INT_2$	I/O port P4	A 7-bit CMOS I/O port with the same function as port $P2_4$-$P2_7$, with CMOS compatible input levels.	
$P4_3$, $P4_4$			
$P4_5$/CNTR			Event counter input pin
$P4_6$			
$P4_7/T_{OUT}$			Timer output pin
$P5_0/S_{IN1}$, $P5_1/S_{OUT1}$, $P5_2/S_{CLK1}$, $P5_3/S_{RDY1}$	I/O port P5	An 8-bit CMOS I/O port with the same function as port $P2_4$-$P2_7$ The output structure of this port is N-channel open drain, and the input levels are CMOS compatible Keep the input voltage of this port between 0V and V_{CC}	Serial I/O1 I/O pins
$P5_4/S_{IN2}$, $P5_5/S_{OUT2}$, $P5_6/S_{CLK2}$, $P5_7/S_{RDY2}$			Serial I/O2 I/O pins
$P6_0$/PWM	I/O port P6	An 8-bit CMOS I/O port with the same function as port $P2_4$-$P2_7$, with CMOS compatible input levels	14-bit PWM output pin
$P6_1$-$P6_5$			
$P6_6$/AN			Comparator input pin
$P6_7$			

PART NUMBERING



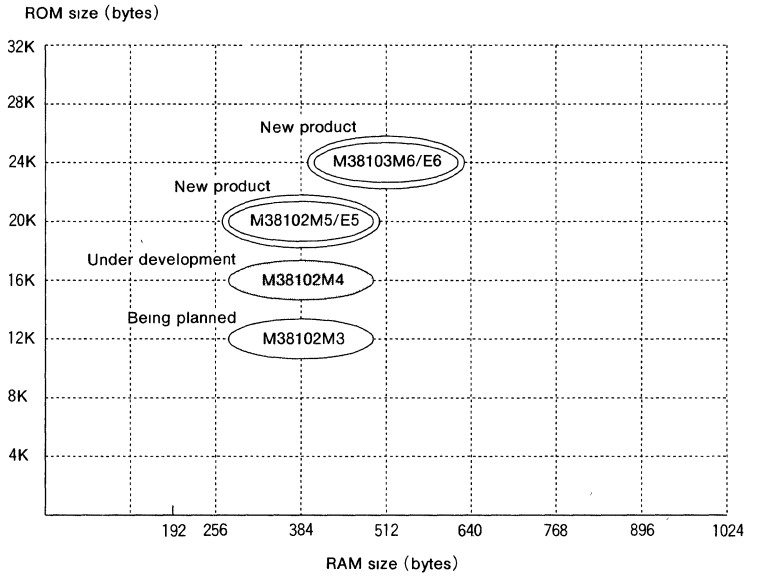
GROUP EXPANSION

Mitsubishi plans to expand the M3810x group as follows:

(1) Support for mask ROM, one-time programmable, and EPROM versions
ROM/PROM capacity ..... 12K-24K bytes
RAM capacity ..... 384-512 bytes

(2) Packages
64P4B ..... Shrink plastic molded DIP
64P6N ..... Plastic molded QFP
64S1B ..... Shrink ceramic DIP
64D0 ..... Ceramic LCC

Memory expansion plan



The development schedule and other details of products under development may be revised without notice
Currently supported products are listed below

As of March 1992

Product name	(P) ROM size (bytes)	RAM size (bytes)	Package	Remarks
M38102M5-XXXSP	20K	384	64P4B	Mask ROM version
M38102E5-XXXSP				One-time programmable version
M38102E5SP				One-time programmable version (blank)
M38102M5-XXXFP			64P6N	Mask ROM version
M38102E5-XXXFP				One-time programmable version
M38102E5FP				One-time programmable version (blank)
M38102E5SS			64S1B	EPROM version
M38102E5FS			64D0	EPROM version
M38103M6-XXXSP	24K	512	64P4B	Mask ROM version
M38103E6-XXXSP				One-time programmable version
M38103E6SP				One-time programmable version (blank)
M38103M6-XXXFP			64P6N	Mask ROM version
M38103E6-XXXFP				One-time programmable version
M38103E6FP				One-time programmable version (blank)
M38103E6SS			64S1B	EPROM version
M38103E6FS			64D0	EPROM version

FUNCTIONAL DESCRIPTION
CENTRAL PROCESSING UNIT (CPU)

Microcomputers of the M3810x group use the standard MELPS 740 instruction set. Refer to the table of MELPS 740 addressing modes and machine instructions or the MELPS 740 Software Manual for details on the instruction set.

Machine-resident MELPS 740 instructions are as follows:

The FST and SLW instructions are not available for use.

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

CPU MODE REGISTER

The CPU mode register is allocated to address $003B_{16}$.

Bits 0 and 1 of this register are processor mode bits and should always be set to "0".

The CPU mode register contains the stack page selection bit.

For details of the X_{COUT} drivability selection bit, main clock stop bit, and internal system clock selection bit, see the section on the clock generation circuit.

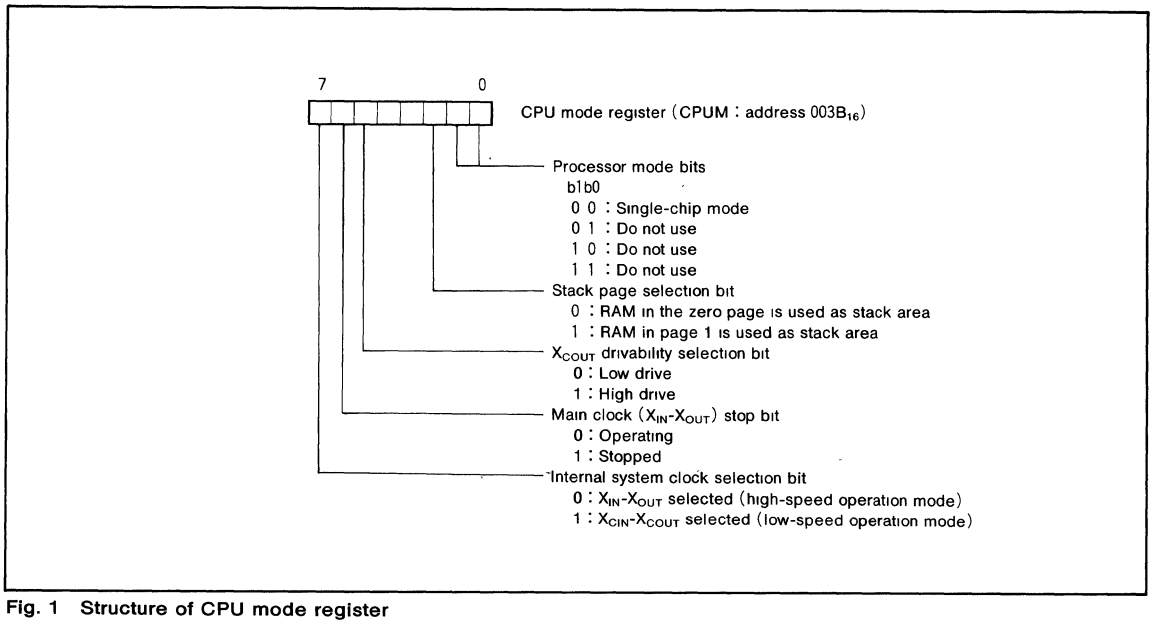


Fig. 1 Structure of CPU mode register

MEMORY

Special Function Register (SFR) Area

The Special Function Register area contains registers which control functions such as I/O ports and timers, and is located in the zero page area.

RAM

RAM is used for data storage as well for stack area.

ROM

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

Interrupt Vector Area

The interrupt vector area contains reset and interrupt vectors.

Zero Page

The 256 bytes from addresses 0000_{16} to $00FF_{16}$ are called the zero page area. The internal RAM and the special function registers (SFR) are allocated to this area.

The zero page addressing mode can be used to specify memory and register addresses in the zero page area. This dedicated zero page addressing mode enables access to this area with only 2 bytes.

Special Page

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

RAM area

RAM capacity (bytes)	Address $XXXX_{16}$
192	$00FF_{16}$
256	$013F_{16}$
384	$01BF_{16}$
512	$023F_{16}$
640	$02BF_{16}$
768	$033F_{16}$
896	$03BF_{16}$
1024	$043F_{16}$

ROM area

ROM capacity (bytes)	Address $YYYY_{16}$	Address $ZZZZ_{16}$
4096	$F000_{16}$	$F080_{16}$
8192	$E000_{16}$	$E080_{16}$
12288	$D000_{16}$	$D080_{16}$
16384	$C000_{16}$	$C080_{16}$
20480	$B000_{16}$	$B080_{16}$
24576	$A000_{16}$	$A080_{16}$
28672	9000_{16}	9080_{16}
32768	8000_{16}	8080_{16}

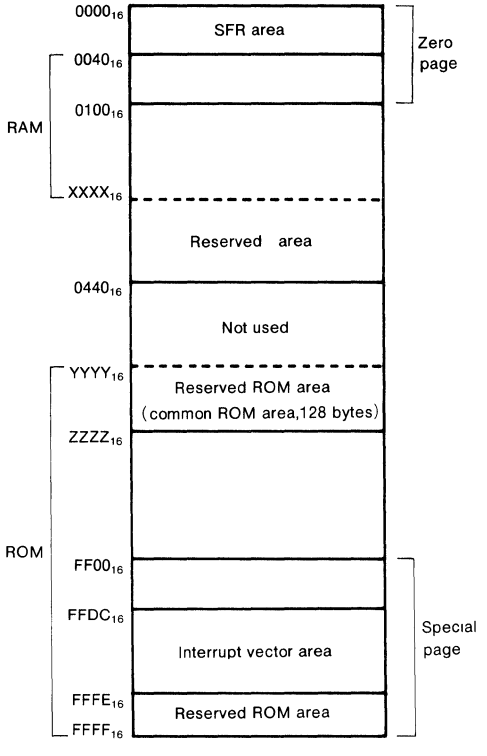


Fig. 2 Memory map diagram

0000_{16}	Port P0 (P0)
0001_{16}	
0002_{16}	Port P1 (P1)
0003_{16}	
0004_{16}	Port P2 (P2)
0005_{16}	Port P2 direction register (P2D)
0006_{16}	Port P3 (P3)
0007_{16}	
0008_{16}	Port P4 (P4)
0009_{16}	Port P4 direction register (P4D)
$000A_{16}$	Port P5 (P5)
$000B_{16}$	Port P5 direction register (P5D)
$000C_{16}$	Port P6 (P6)
$000D_{16}$	Port P6 direction register (P6D)
$000E_{16}$	
$000F_{16}$	
0010_{16}	
0011_{16}	
0012_{16}	
0013_{16}	
0014_{16}	
0015_{16}	
0016_{16}	
0017_{16}	
0018_{16}	
0019_{16}	Serial I/O1 control register (SIO1CON)
$001A_{16}$	
$001B_{16}$	Serial I/O1 register (SIO1)
$001C_{16}$	
$001D_{16}$	Serial I/O2 control register (SIO2CON)
$001E_{16}$	
$001F_{16}$	Serial I/O2 register (SIO2)

0020_{16}	
0021_{16}	
0022_{16}	
0023_{16}	
0024_{16}	Timer 1 (T1)
0025_{16}	Timer 2 (T2)
0026_{16}	Timer 3 (T3)
0027_{16}	Timer 4 (T4)
0028_{16}	Timer 12 mode register (T12M)
0029_{16}	Timer 34 mode register (T34M)
$002A_{16}$	
$002B_{16}$	PWM control register (PWMCON)
$002C_{16}$	PWM register (upper)(PWMH)
$002D_{16}$	PWM register (lower)(PWML)
$002E_{16}$	
$002F_{16}$	
0030_{16}	Comparator register (CMP)
0031_{16}	
0032_{16}	
0033_{16}	
0034_{16}	
0035_{16}	
0036_{16}	
0037_{16}	
0038_{16}	High-breakdown-voltage port control register (HVPC)
0039_{16}	
$003A_{16}$	Interrupt edge selection register (INTEDGE)
$003B_{16}$	CPU mode register (CPUM)
$003C_{16}$	Interrupt request register 1 (IREQ1)
$003D_{16}$	Interrupt request register 2 (IREQ2)
$003E_{16}$	Interrupt control register 1 (ICON1)
$003F_{16}$	Interrupt control register 2 (ICON2)

Fig. 3 Memory map of special function register (SFR)

I/O PORTS

Direction Registers

The M3810x group microprocessors have 27 programmable I/O pins arranged in four I/O ports (ports $P2_4$~$P2_7$, $P4_1$~$P4_7$, P5, and P6). The I/O ports have direction registers which determine the input/output direction of each individual pin. Each bit in a direction register corresponds to one pin, each pin can be set to be input or output.

When "0" is written to the bit corresponding to a pin, that pin becomes an input pin. When "1" is written to that bit, that pin becomes an output pin.

If data is read from a pin which is set for output, the value of the port output latch is read, not the value of the pin itself. Pins set to input are floating. If a pin set to input is written to, only the port output latch is written to and the pin remains floating.

High-Breakdown-Voltage Output Ports

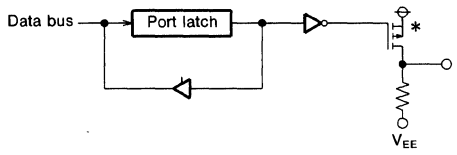
The M3810x group microprocessors have four ports with high-breakdown-voltge pins (ports P0, P1, $P2_0$~$P2_3$, and P3). The high-breakdown-voltage ports have P-channel open drain output with a breakdown voltage of V_{CC}−40V. Each pin has an internal pull-down resistor connected to V_{EE}. At reset, the P-channel output transistor of each port latch is turned off, so it is forced to the level of V_{EE} by the pull-down resistor.

Writing "1" to bit 0 of the high-breakdown-voltage port control register (address 0038_{16}) slows the transition of the output transistors to reduce transient noise. At reset, bit 0 of the high-breakdown-voltage port control register is set to "0" (strong drive).

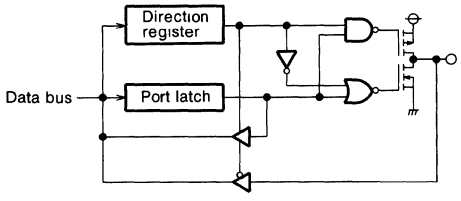
Pin	Name	Input/Output	I/O Format	Non-Port Function	Related SFRs	Diagram No
$P0_0$-$P0_7$	Port P0	Output	High-breakdown-voltage P-channel open-drain output with pull-down resistor		High-breakdown-voltage port control register	(1)
$P1_0$-$P1_7$	Port P1	Output	High-breakdown-voltage P-channel open-drain output with pull-down resistor		High-breakdown-voltage port control register	
$P2_0$-$P2_3$	Port P2	Output	High-breakdown-voltage P-channel open-drain output with pull-down resistor		High-breakdown-voltage port control register	
$P2_4$-$P2_7$		Input/output, individual bits	TTL level input CMOS 3-state output			(2)
$P3_0$-$P3_7$	Port P3	Output	High-breakdown-voltage P-channel open-drain output with pull-down resistor		High-breakdown-voltage port control register	(1)
$P4_0/INT_0$	Port P4	Input	CMOS level input	External interrupt input	Interrupt edge selection register	(3)
$P4_1/INT_1$, $P4_2/INT_2$		Input/output, individual bits	CMOS level input CMOS 3-state output			(4)
$P4_3$, $P4_4$						(2)
$P4_5$/CNTR				Event counter input	Timer 34 mode register	(4)
$P4_6$						(2)
$P4_7/T_{OUT}$				Timer 3 output	Timer 34 mode register	(5)
$P5_0/S_{IN1}$, $P5_1/S_{OUT1}$, $P5_2/S_{CLK1}$, $P5_3/\overline{S_{RDY1}}$	Port P5	Input/output, individual bits	CMOS level input N-channel open-drain output	Serial I/O1 function I/O	Serial I/O1 control register	(6) (7) (8)
$P5_4/S_{IN2}$, $P5_5/S_{OUT2}$, $P5_6/S_{CLK2}$, $P5_7/\overline{S_{RDY2}}$				Serial I/O2 function I/O	Serial I/O2 control register	(6) (7) (8)
$P6_0$/PWM	Port P6	Input/output, individual bits	CMOS level input CMOS 3-state output	14-bit PWM output	PWM control register PWML register PWMH register	(9)
$P6_1$-$P6_5$						(2)
$P6_6$/AN				Comparator input	Comparator register	(10)
$P6_7$						(2)

Note Make sure that the input level at each pin is either 0V or V_{CC} during execution of the STP instruction.
If an input level is at an intermediate potential, a current will flow in the input-stage gate

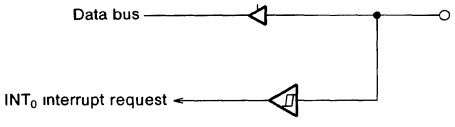
(1) Port P0, P1, $P2_0$~ $P2_3$, P3



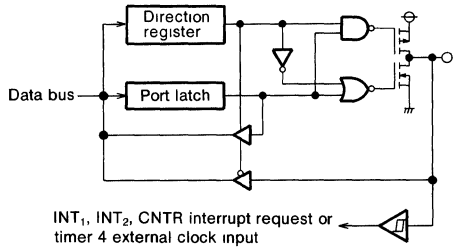
(2) Port $P2_4$~ $P2_7$, $P4_3$, $P4_4$, $P4_6$, $P6_1$~ $P6_5$, $P6_7$



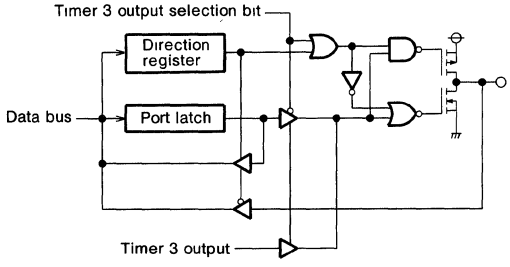
(3) Port $P4_0$



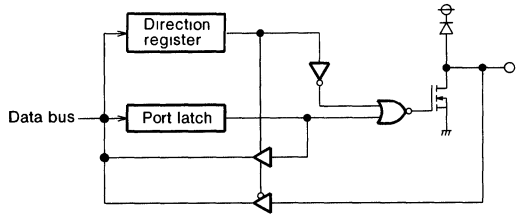
(4) Port $P4_1$, $P4_2$, $P4_5$



(5) Port $P4_7$



(6) Port $P5_0$, $P5_4$



* High-breakdown-voltage P-channel transistor

Fig. 4 Port block diagram (1)

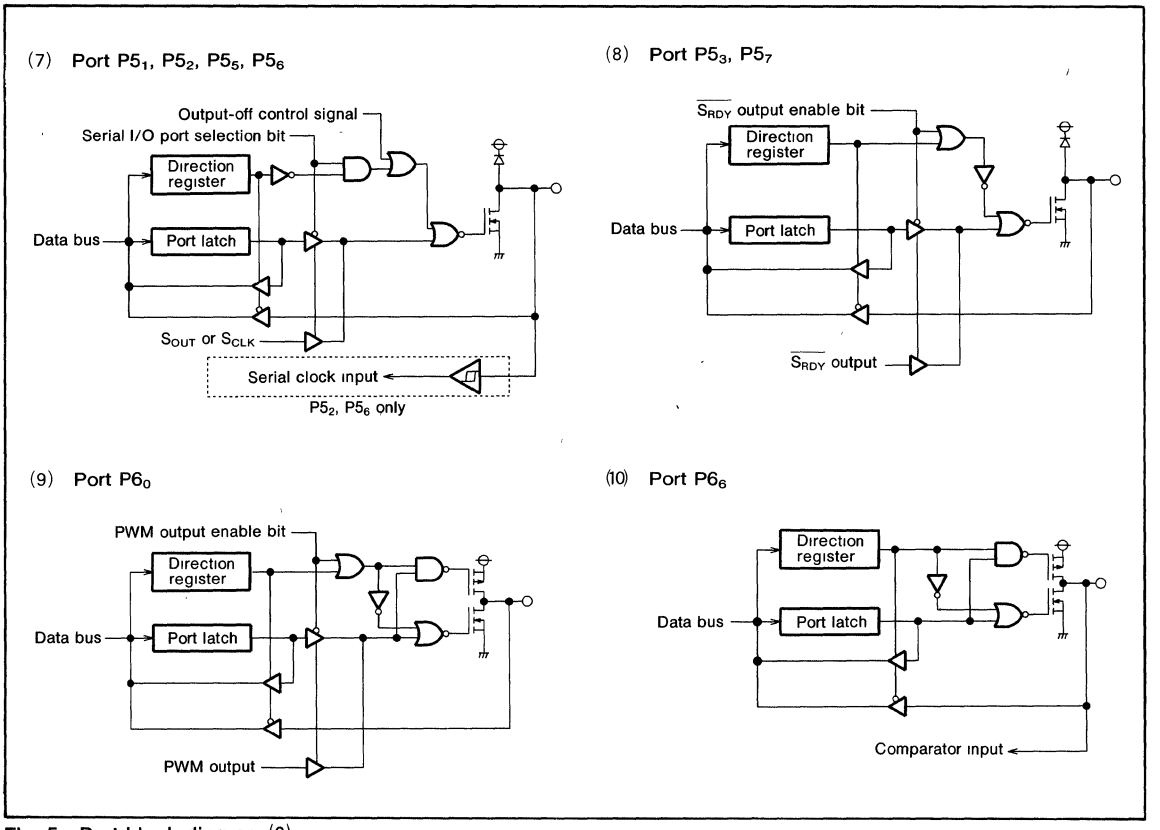


Fig. 5 Port block diagram (2)

INTERRUPTS

A total of 11 sources can generate interrupts: 4 external, 6 internal, and 1 software.

Interrupt Control

Each interrupt is controlled by an interrupt request bit, an interrupt enable bit, and the interrupt disable flag-except for the software interrupt set by the BRK instruction. An interrupt is generated if the corresponding interrupt request and enable bits are "1" and the interrupt disable flag is "0".

Interrupt enable bits can be set or cleared by software.

Interrupt request bits can be cleared by software, but cannot be set by software.

The I flag disables all interrupts except for the BRK instruction interrupt.

Interrupt Operation

When an interrupt is received, the program counter and processor status register are automatically pushed onto the stack. The interrupt disable flag is set to inhibit other interrupts from interfering. The corresponding interrupt request bit is cleared and the interrupt jump destination address is read from the vector table into the program counter.

Notes on Use

If you will change interrupt edge selection from rising edge to falling edge, interrupt request bit will be set to "1" automatically. Therefore, please make following process;

(1) Disable INT which is selected.
(2) Change INT edge selection.
(3) Clear interrupt request which is selected.
(4) Enable INT which is selected.

Table 1. Interrupt vector addresses and priorities

Interrupt cause	Priority	Vector address (Note 1)		Interrupt request generation conditions	Remarks
		High	Low		
Reset (Note 2)	1	$FFFD_{16}$	$FFFC_{16}$	At reset	Non-maskable
INT_0	2	$FFFB_{16}$	$FFFA_{16}$	At detection of either rising or falling edge of INT_0 input	External interrupt (active edge selectable)
INT_1	3	$FFF9_{16}$	$FFF8_{16}$	At detection of either rising or falling edge of INT_1 input	External interrupt (active edge selectable)
INT_2	4	$FFF7_{16}$	$FFF6_{16}$	At detection of either rising or falling edge of INT_2 input	External interrupt (active edge selectable)
Serial I/O1	5	$FFF5_{16}$	$FFF4_{16}$	At end of serial I/O1 data transfer	Valid when serial I/O1 is selected
Serial I/O2	6	$FFF3_{16}$	$FFF2_{16}$	At end of serial I/O2 data transfer	Valid when serial I/O2 is selected
Timer 1	7	$FFF1_{16}$	$FFF0_{16}$	At timer 1 overflow	
Timer 2	8	$FFEF_{16}$	$FFEE_{16}$	At timer 2 overflow	STP release timer overflow
Timer 3	9	$FFED_{16}$	$FFEC_{16}$	At timer 3 overflow	
Timer 4	10	$FFEB_{16}$	$FFEA_{16}$	At timer 4 overflow	
CNTR	11	$FFE9_{16}$	$FFE8_{16}$	At detection of either rising or falling edge of CNTR input	External interrupt (active edge selectable)
BRK instruction	12	$FFDD_{16}$	$FFDC_{16}$	At BRK instruction execution	Non-maskable software interrupt

Note 1 Vector addresses contain interrupt jump destination addresses
2 Reset function in the same way as an interrupt with the highest priority

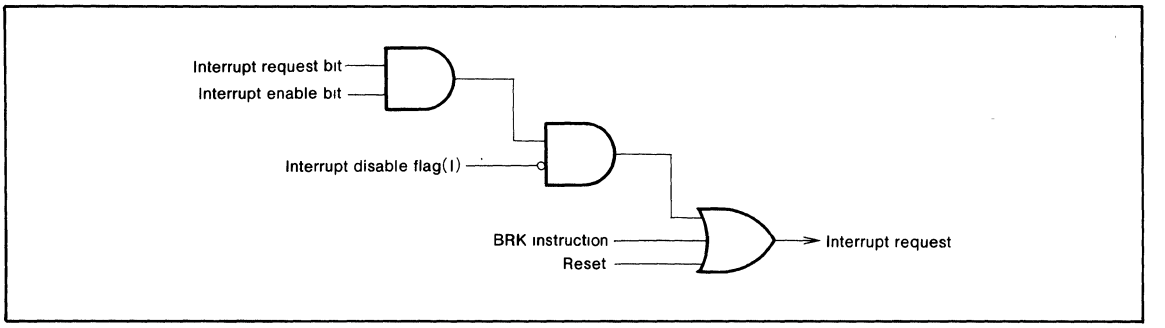


Fig. 6 Interrupt control

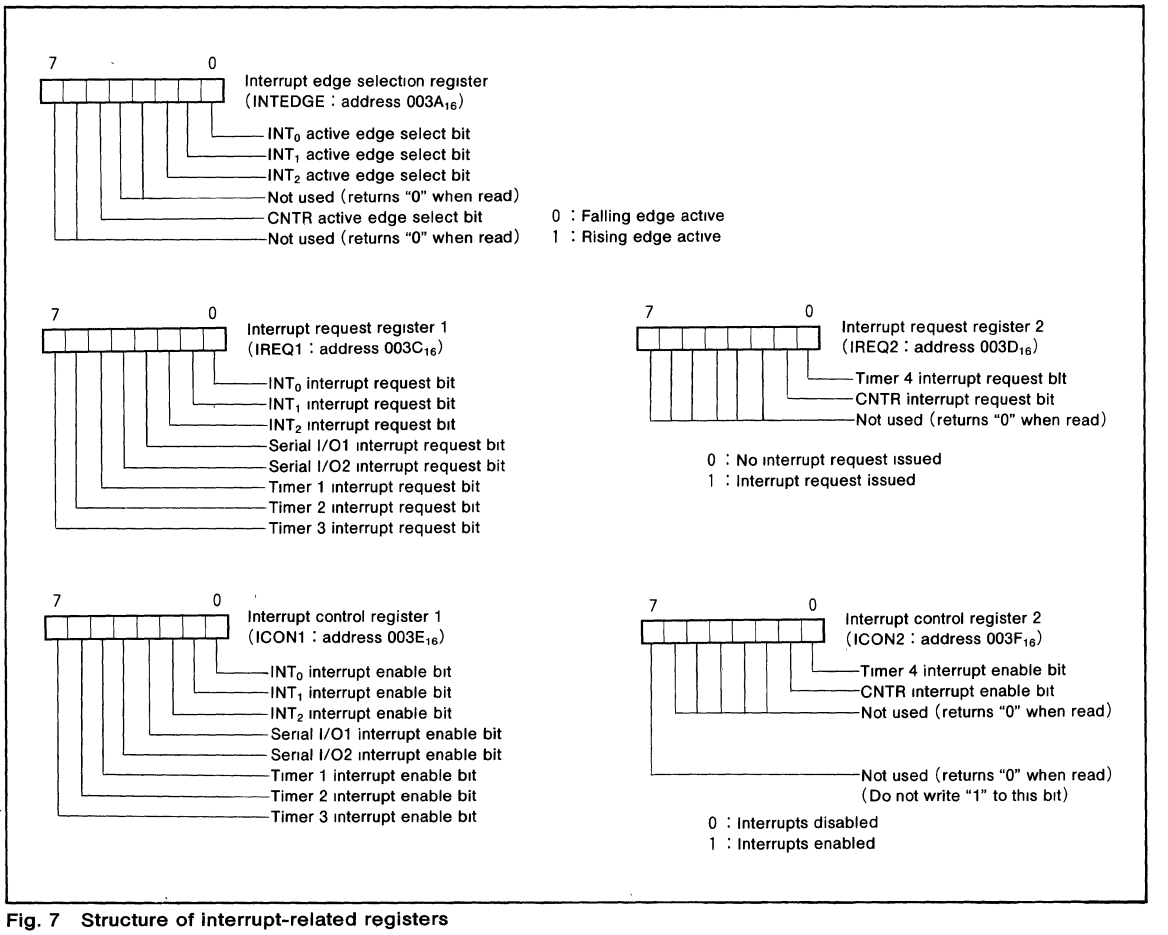


Fig. 7 Structure of interrupt-related registers

TIMERS

Microcomputers of the M3810x group have four built-in timers. The timers count down. Once a timer reaches 00_{16}, the next count pulse loads the contents of the corresponding timer latch into the timer, and sets the corresponding interrupt request bit to 1. Each timer also has a stop bit that stops the count of that timer when it is set to "1" .

Note that the system clock ϕ can be set to either high-speed mode or low-speed mode by the CPU mode register.

Timer 1 and Timer 2

The count sources of timer 1 and timer 2 can be selected by setting the timer 12 mode register.

When the chip is reset or the STP instruction is executed, all bits of the timer 12 mode register are cleared, timer 1 is set to FF_{16}, and timer 2 is set to 01_{16}.

Timer 3 and Timer 4

The count sources of timer 3 and timer 4 can be selected by setting the timer 34 mode register.

Timer 3 can also output a rectangular waveform from the $P4_7$/T_{OUT} pin. The waveform changes polarity each time timer 3 overflows.

When timer 4 is assigned to external event count mode, rising edge is active.

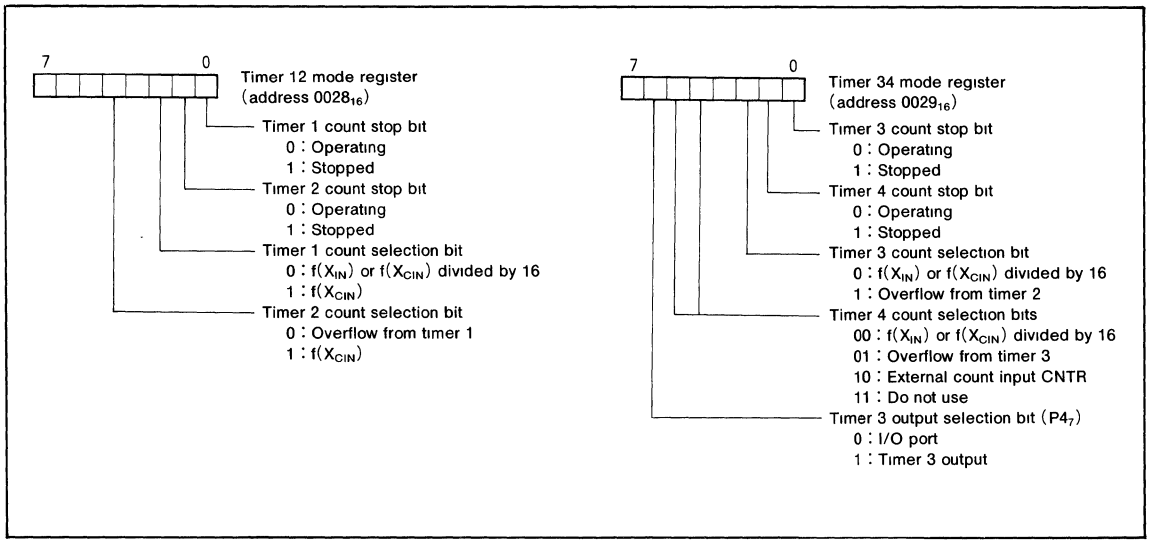


Fig. 8 Structure of timer-related registers

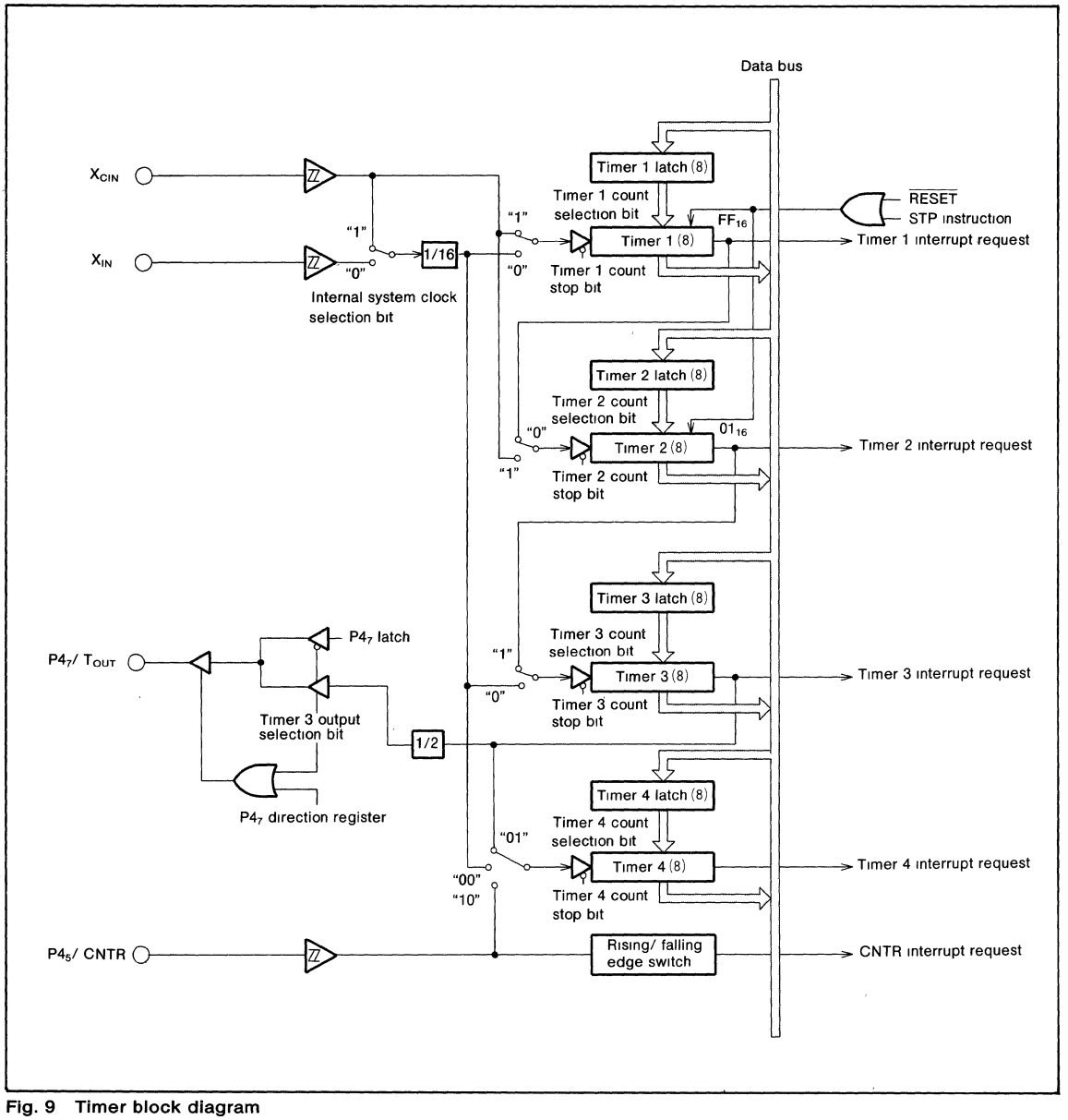


Fig. 9 Timer block diagram

SERIAL I/O

Microcomputers of the M3810x group have two built-in 8-bit clock synchronized serial I/O channels (serial I/O1 and serial I/O2).

Serial I/O1 has the same function as serial I/O2.

The I/O pins of the serial I/O function also operate as I/O port P5, and their operation is selected by the serial I/O control registers (adresses 0019_{16} and $001D_{16}$).

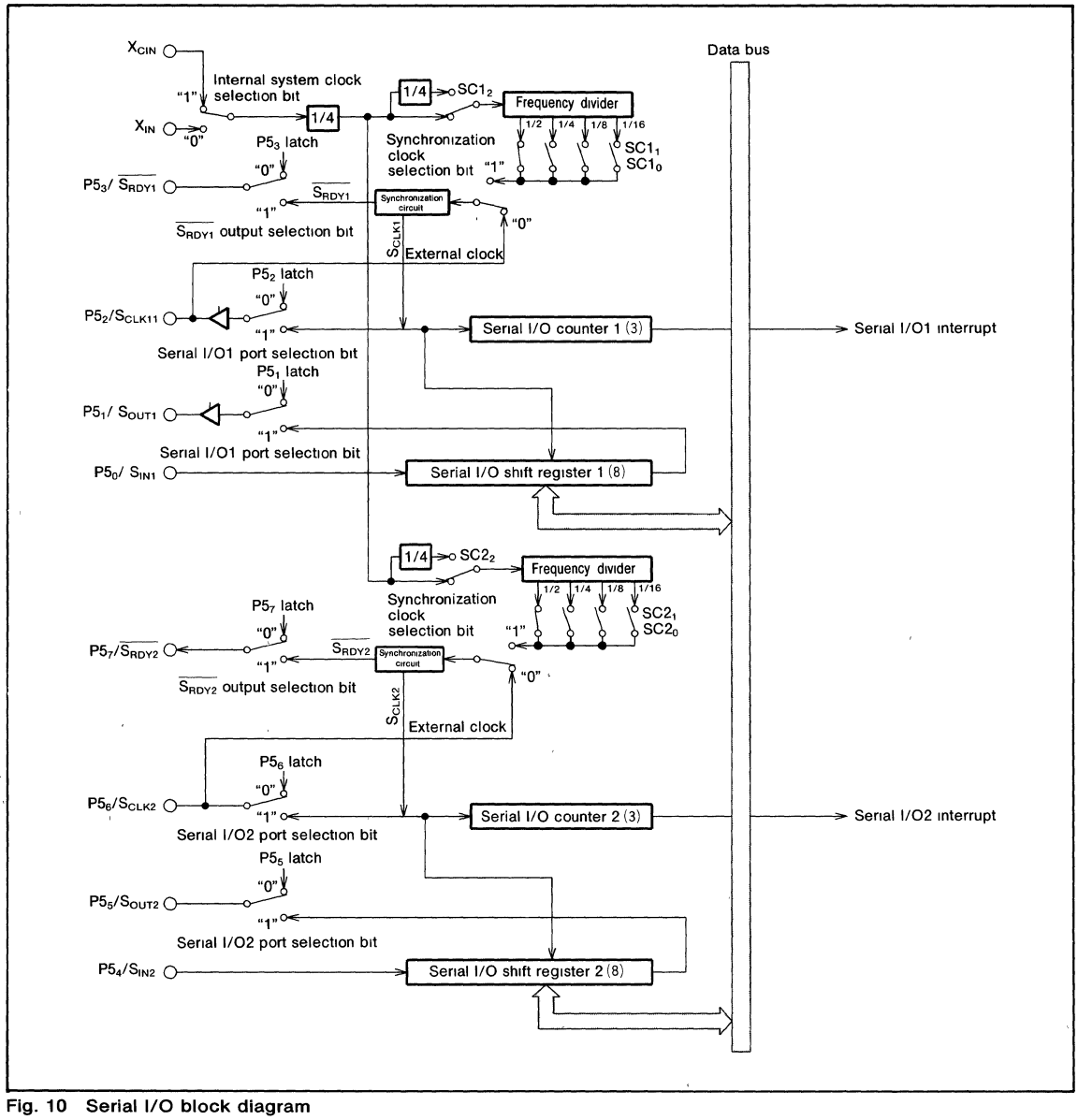


Fig. 10 Serial I/O block diagram

[Serial I/O Control Registers] SIO1CON, SIO2CON

Each of the serial I/O control registers (addresses 0019_{16} and $001D_{16}$) contains seven bits that select various control parameters of the serial I/O function.

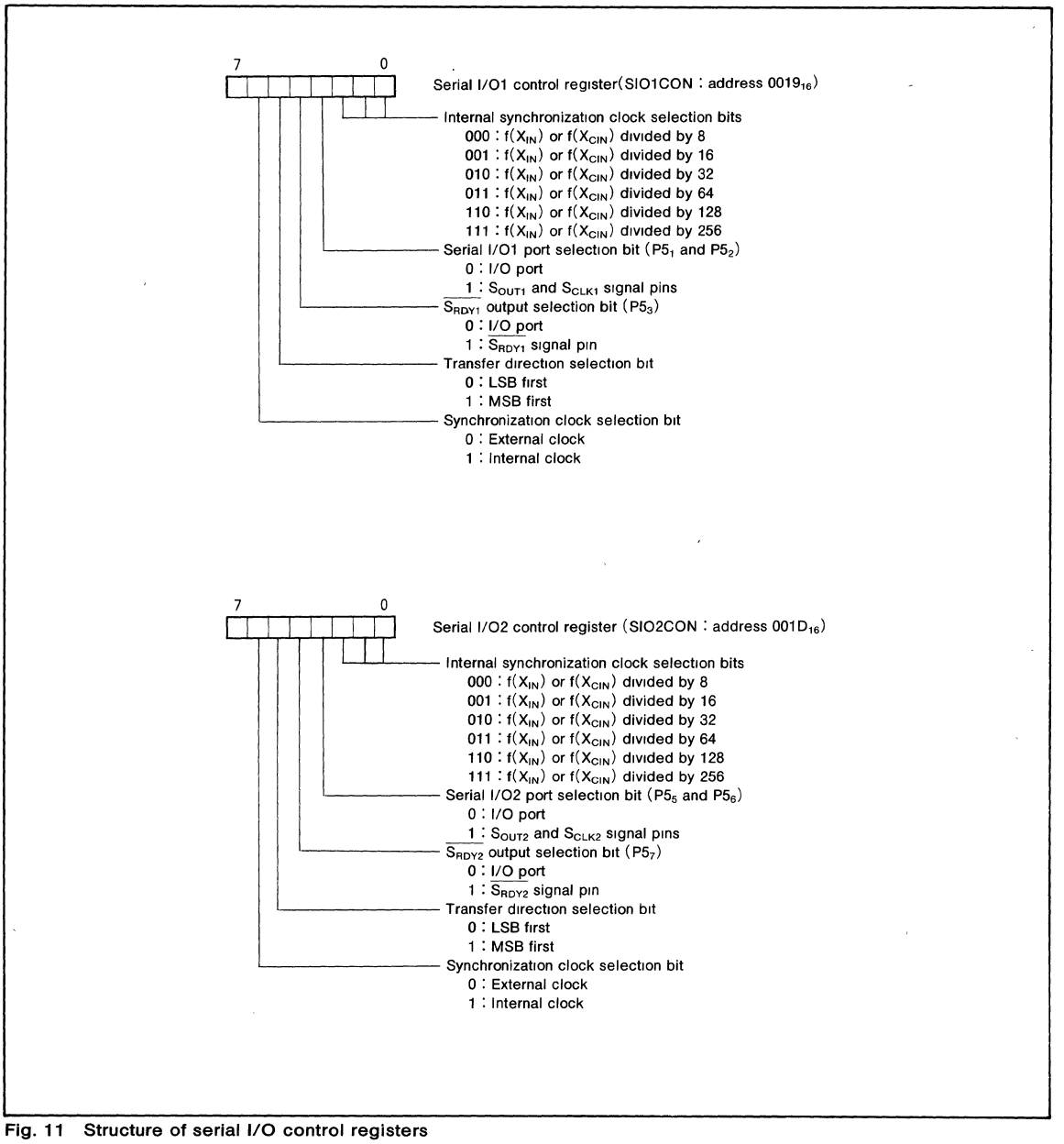


Fig. 11 Structure of serial I/O control registers

Operation In Serial I/O Mode

Either an internal clock or an external clock can be selected as the synchronization clock for serial I/O transfer. A dedicated divider is built-in as the internal clock, giving a choice of six clocks.

If internal clock is selected, transfer start is activated by a write signal to a serial I/O register (address $001B_{16}$ or $001F_{16}$). After eight bits have been transferred, the S_{OUT} pin goes to high impedance.

If external clock is selected, the clock must be controlled externally because the contents of the serial I/O register continue to shift while the transfer clock is input. In this case, note that the S_{OUT} pin does not go to high impedance at the completion of data transfer. The interrupt request bit is set at the end of the transfer of eight bits, regardless of whether the internal or external clock is selected.

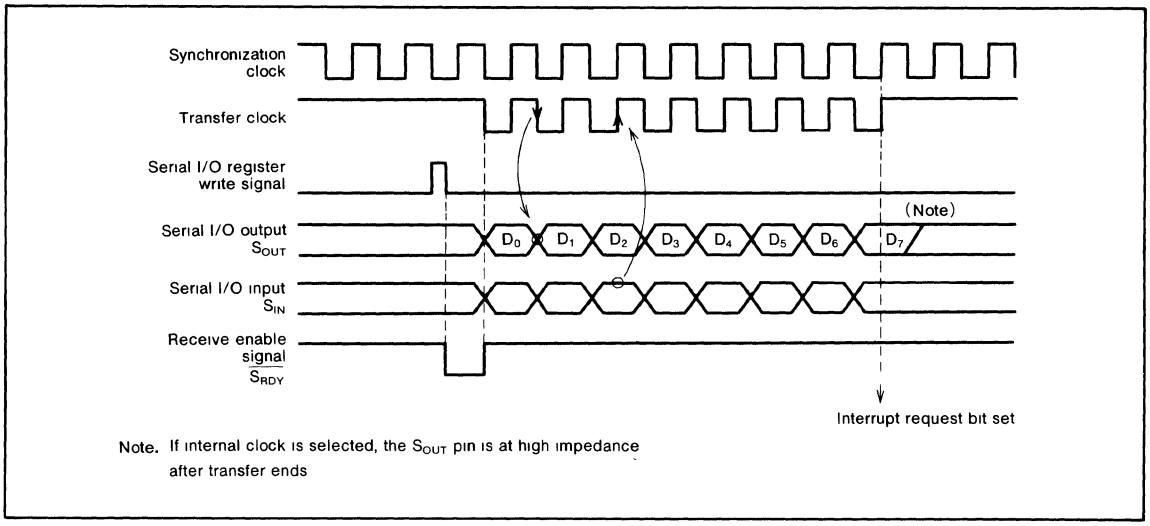


Fig. 12 Serial I/O timing (for LSB first)

PULSE WIDTH MODULATION (PWM) OUTPUT CIRCUIT

Microcomputers in the M3810x group have a PWM function with a 14-bit resolution. When the oscillation frequency X_{IN} is 4MHz, the minimum resolution bit width is 500ns and the cycle period is 8192μs. The PWM timing generator supplies a PWM control signal based on a signal that is half the frequency of the X_{IN} clock.

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

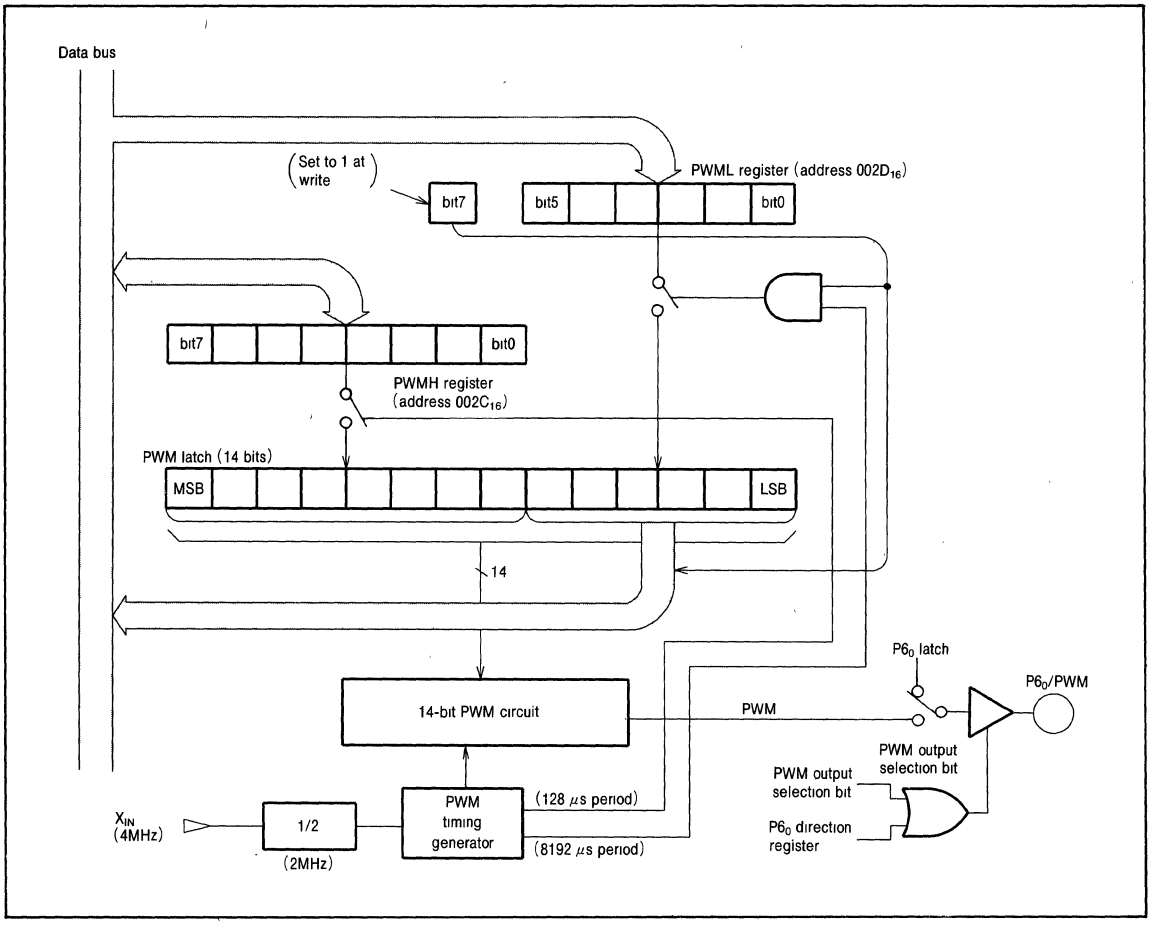


Fig. 13 PWM block diagram

(1) Date Set-up

The PWM output pin also functions as port $P6_0$. Set port $P6_0$ to be the PWM output pin by setting bit 0 of the PWM mode register (address $002B_{16}$). The upper eight bits of output data are set in the upper PWM register PWMH (address $002C_{16}$) and the lower six bits are set in the lower PWM register PWML (address $002D_{16}$).

(2) Transfer From Register to Latch

Date written to the PWML register is transferred to the PWM latch once in each PWM period (every 8192μs), and data written to the PWMH register is transferred to the PWM latch once in each sub-period (every 128μs). When the PWML register is read, the contents of the latch are read. However, bit 7 of the PWML register indicates whether the transfer to the PWM latch is completed; the transfer is completed when bit 7 is "0".

Table 2. Relationship between lower 6 bits of data and period set by the ADD bit

Lower 6 Bits of Data(PWML) (LSB)	Sub-periods tm Lengthened (m =0 to 63)
0 0 0 0 0 0	None
0 0 0 0 0 1	m=32
0 0 0 0 1 0	m=16, 48
0 0 0 1 0 0	m= 8, 24, 40, 56
0 0 1 0 0 0	m= 4, 12, 20, 28, 36, 44, 52, 60
0 1 0 0 0 0	m= 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62
1 0 0 0 0 0	m= 1, 3, 5, 7, ····· , 57, 59, 61, 63

(3) PWM Operation

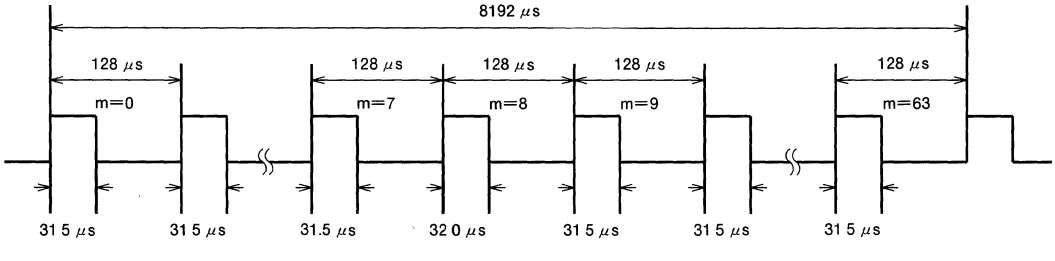
The timing of the 14-bit PWM function is shown in Fig. 16. The 14-bit PWM data is divided into the lower six bits and the upper eight bits in the PWM latch.

The upper eight bits of data determine how long an "H"-level signal is output during each sub-period. There are 64 sub-periods in each period, and each sub-period is 256 × τ (128μs) long. The signal is "H" for a length equal to N times τ, where τ is the minimum resolution (500ns).

The contents of the lower six bits of data enable the lengthening of the high signal by τ (500ns). As shown in Fig. 13, the six bits of PWML determine which sub-cycles are lengthened.

As shown in Fig. 16, the leading edge of the pulse is lengthened. By changing the length of specific sub-periods instead of simply changing the "H" duration, an accurate waveform can be duplicated without the use of complex external filters.

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



Pulse width modulation register H : 00111111
Pulse width modulation register L : 000101
Sub-periods where "H" pulse width is 32 μs : m = 8, 24, 32, 40, 56
Sub-periods where "H" pulse width is 31 5 μs : m = all other values

Fig. 14 PWM timing

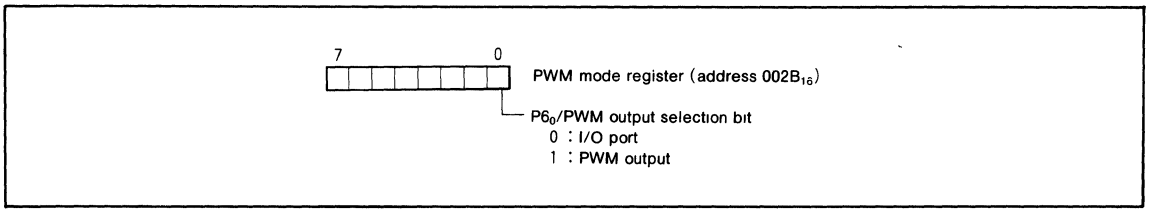


Fig. 15 Structure of PWM mode register

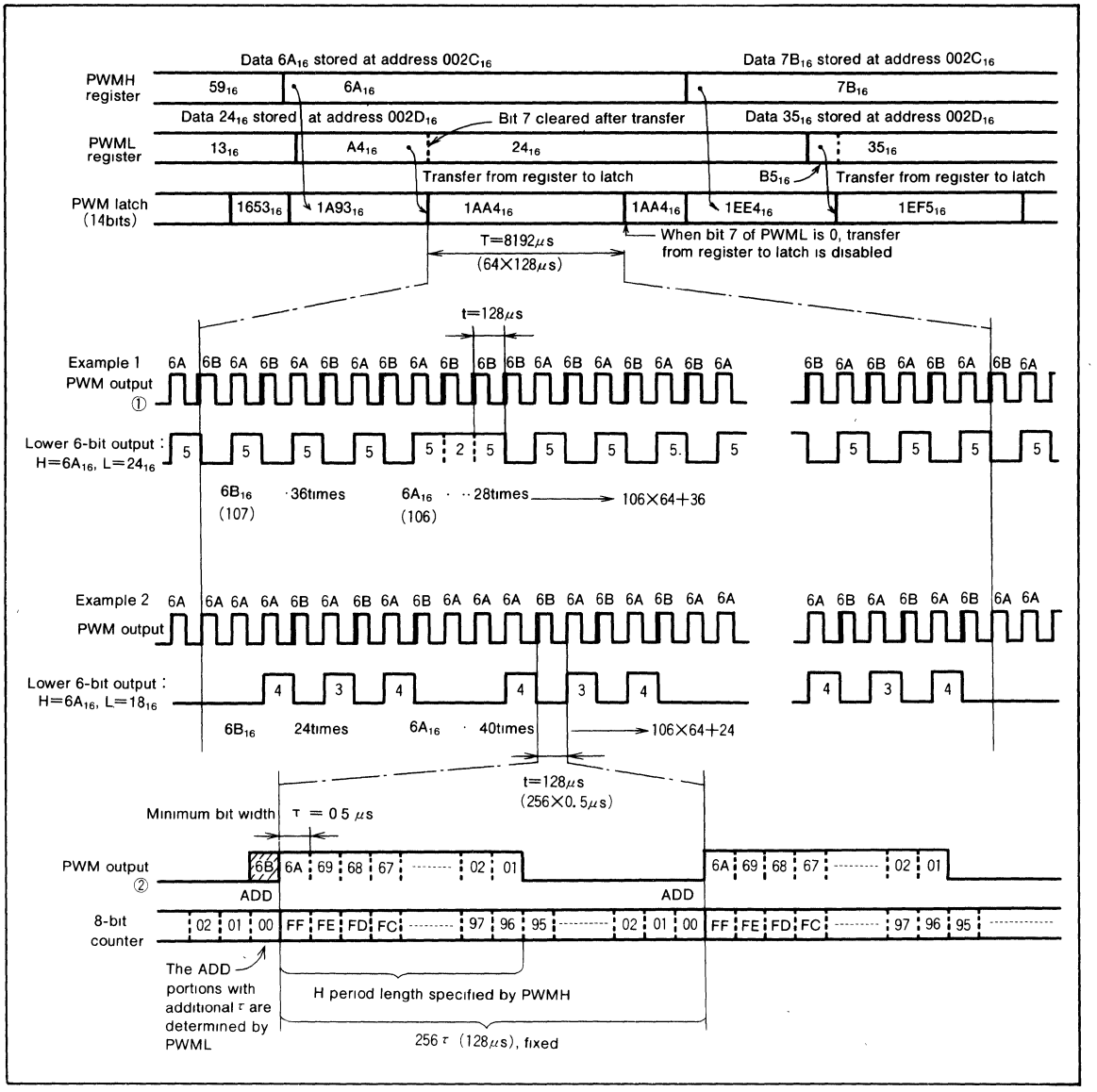


Fig. 16 14-bit PWM timing

MITSUBISHI ELECTRIC

COMPARATOR CIRCUIT

Comparator Configuration

The comparator circuit consists of a switch tree, ladder resistors, a comparator, a comparator control circuit, a comparator register (address 0030_{16}), and an analog signal input pin ($P6_6$/AN). The analog signal input pin ($P6_6$/AN) also functions as an ordinary digital port.

Comparator Register (CMP)

The comparator register is a 5-bit register of which bits 0 to 3 can be used to generate internal reference voltages in steps of 1/16 V_{CC}. The result of the comparison between the analog input voltage and an internal reference voltage is stored in bit 4 of the comparator register.

Comparator Operation

To activate the comparator, first set port $P6_6$ to input mode by setting the corresponding direction register (address $000D_{16}$) to "0"—this ensures that port $P6_6$/AN is used as an analog voltage input pin. Then write a digital value corresponding to the internal comparison voltage into bits 0 to 3 of the comparator register (address 0030_{16}). This write operation immediately activates the comparison. After 14 cycles of the system clock ϕ (the time required for the comparison), the comparison result is stored in bit 4 of the comparator.

If the analog input voltage is greater than the internal reference voltage, bit 4 is "1"; if it is less than the internal reference voltage, bit 4 is "0". To perform another comparison, the comparator must be written to again, even if the same internal reference voltage is to be used.

Table 3. Correspondence between bits 0 to 3 of the comparator register and internal reference voltage

Comparator register				Internal reference voltage
Bit 3	Bit 2	Bit 1	Bit 0	
0	0	0	0	$1/32V_{CC}$
0	0	0	1	$1/16V_{CC}+1/32V_{CC}$
0	0	1	0	$2/16V_{CC}+1/32V_{CC}$
0	0	1	1	$3/16V_{CC}+1/32V_{CC}$
0	1	0	0	$4/16V_{CC}+1/32V_{CC}$
0	1	0	1	$5/16V_{CC}+1/32V_{CC}$
0	1	1	0	$6/16V_{CC}+1/32V_{CC}$
0	1	1	1	$7/16V_{CC}+1/32V_{CC}$
1	0	0	0	$8/16V_{CC}+1/32V_{CC}$
1	0	0	1	$9/16V_{CC}+1/32V_{CC}$
1	0	1	0	$10/16V_{CC}+1/32V_{CC}$
1	0	1	1	$11/16V_{CC}+1/32V_{CC}$
1	1	0	0	$12/16V_{CC}+1/32V_{CC}$
1	1	0	1	$13/16V_{CC}+1/32V_{CC}$
1	1	1	0	$14/16V_{CC}+1/32V_{CC}$
1	1	1	1	$15/16V_{CC}+1/32V_{CC}$

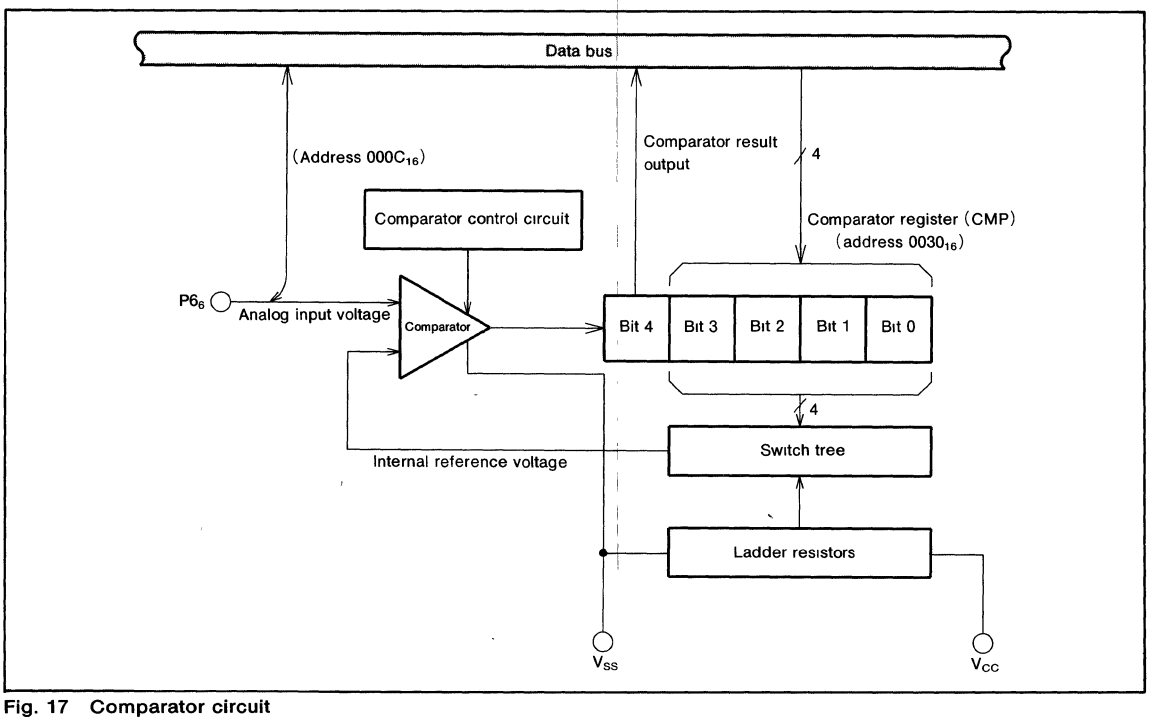


Fig. 17 Comparator circuit

RESET CIRCUIT

After a reset, the microcomputer will start in high-speed mode or low-speed mode depending on a mask-programmable option.

High-Speed Start Mode

In high-speed start mode, reset occurs if the $\overline{\text{RESET}}$ pin is held at a "L" level for at least 2μs then is returned to a "H" level (the power supply voltage should be between 4.0V and 5.5V). Both the X_{IN} and the X_{CIN} clocks begin oscillating. In order to give the X_{IN} clock time to stabilize, internal operation does not begin until after 13 X_{IN} clock cycles are complete. After the reset is completed, the program starts from the address contained in address $FFFD_{16}$ (upper byte) and address $FFFC_{16}$ (lower byte).

Low-Speed Start Mode

In low-speed start mode, reset occurs if the $\overline{\text{RESET}}$ pin is held at a "L" level for at least 2μs then is returned to a "H" level (the power supply voltage should be between 2.8V and 5.5V). The X_{IN} clock does not begin oscillating. In order to give the X_{CIN} time to stabilize, timer 1 and timer 2 are connected together and 512 cycles of the $X_{CIN}/16$ are counted before internal operation begins. After the reset is completed, the program starts from the address contained in address $FFFD_{16}$ (upper byte) and address $FFFC_{16}$ (lower byte).

If the X_{CIN} clock is stable, reset will complete after approximately 250ms (assuming $f(X_{CIN})=32.768kHz$). Immediately after a power-on, the stability of the clock circuit will determine the reset timing and will vary according to the characteristics of the oscillation circuit used.

Note on Use

Make sure that the reset input voltage is no more than 0.8V in high-speed start mode, or no more than 0.5V in low-speed start mode.

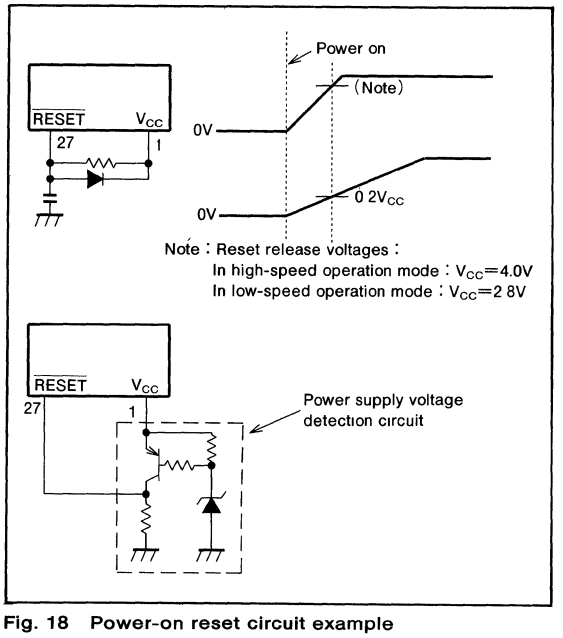


Fig. 18 Power-on reset circuit example

		Address	Register contents
(1)	Port P0 register	$(0000_{16})\cdots$	00_{16}
(2)	Port P1 register	$(0002_{16})\cdots$	00_{16}
(3)	Port P2 register	$(0004_{16})\cdots$	00_{16}
(4)	Port P2 direction register	$(0005_{16})\cdots$	00_{16}
(5)	Port P3 register	$(0006_{16})\cdots$	00_{16}
(6)	Port P4 register	$(0008_{16})\cdots$	00_{16}
(7)	Port P4 direction register	$(0009_{16})\cdots$	00_{16}
(8)	Port P5 register	$(000A_{16})\cdots$	00_{16}
(9)	Port P5 direction register	$(000B_{16})\cdots$	00_{16}
(10)	Port P6 register	$(000C_{16})\cdots$	00_{16}
(11)	Port P6 direction register	$(000D_{16})\cdots$	00_{16}
(12)	Serial I/O1 control register	$(0019_{16})\cdots$	00_{16}
(13)	Serial I/O2 control register	$(001D_{16})\cdots$	00_{16}
(14)	Timer 1 register	$(0024_{16})\cdots$	FF_{16}
(15)	Timer 2 register	$(0025_{16})\cdots$	01_{16}
(16)	Timer 3 register	$(0026_{16})\cdots$	FF_{16}
(17)	Timer 4 register	$(0027_{16})\cdots$	FF_{16}
(18)	Timer 12 mode register	$(0028_{16})\cdots$	00_{16}
(19)	Timer 34 mode register	$(0029_{16})\cdots$	00_{16}
(20)	PWM control register	$(002B_{16})\cdots$	00_{16}
(21)	Comparator	$(0030_{16})\cdots$	00_{16}
(22)	High-breakdown-voltage port control register	$(0038_{16})\cdots$	00_{16}
(23)	Interrupt edge selection register	$(003A_{16})\cdots$	00_{16}
(24)	CPU mode register	$(003B_{16})\cdots$	* * 1 0 0 0 0 0
(25)	Interrupt control register 1	$(003E_{16})\cdots$	00_{16}
(26)	Interrupt control register 2	$(003F_{16})\cdots$	00_{16}
(27)	Processor status register	$(PS)\cdots$	X X X X X 1 X X
(28)	Program counter	$(PC_H)\cdots$	Contents of address $FFFD_{16}$
		$(PC_L)\cdots$	Contents of address $FFFC_{16}$

Note : * : The initial values of bits 7 and 6 of the CPU mode register are determined by a mask option
X : Undefined
The contents of all other registers and RAM are undefined after a reset, so programs must set their initial values

Fig. 19 Internal status at reset

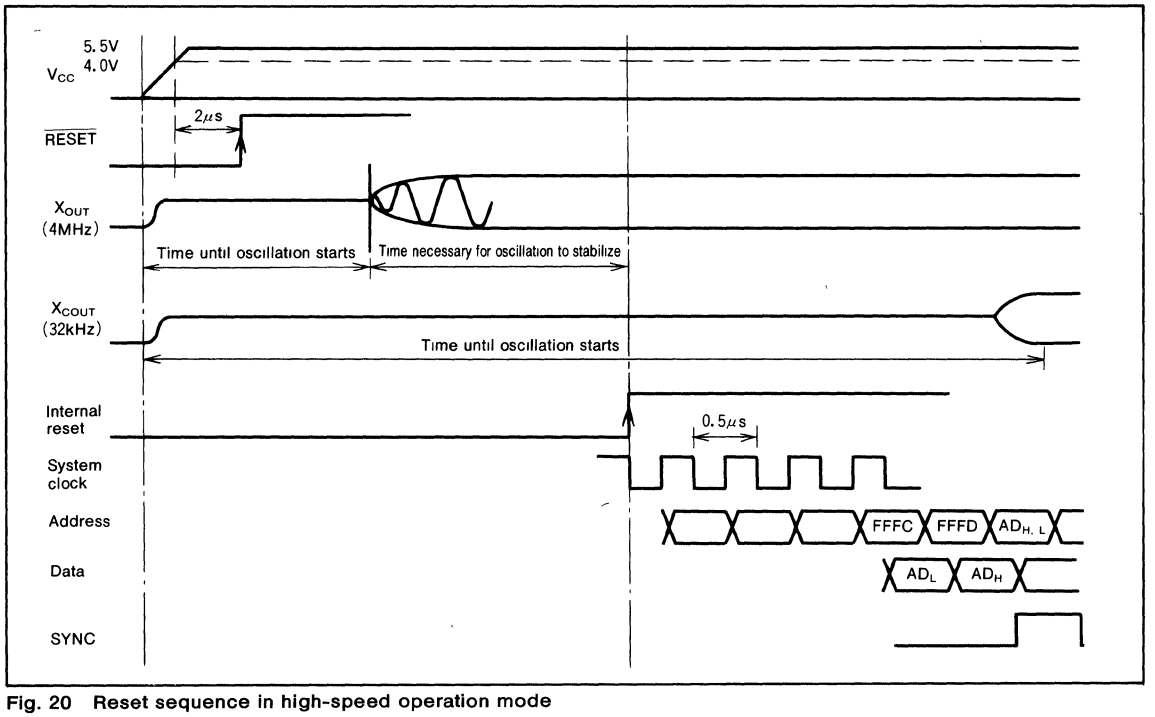


Fig. 20 Reset sequence in high-speed operation mode

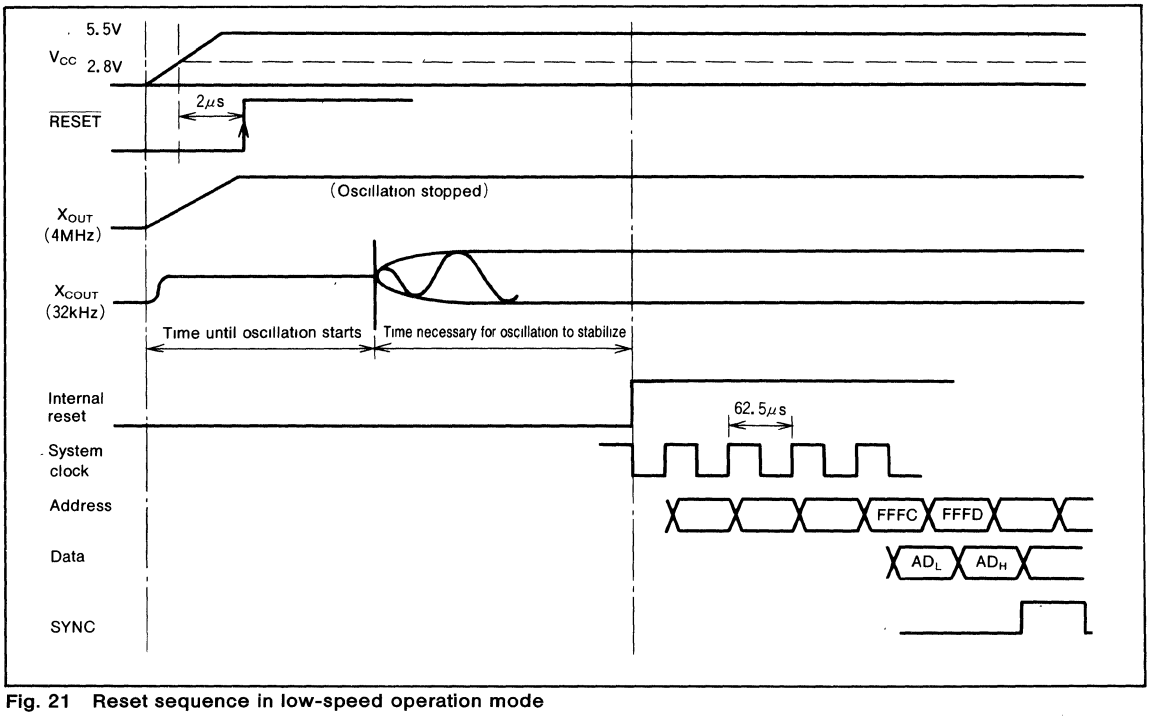


Fig. 21 Reset sequence in low-speed operation mode

CLOCK GENERATION CIRCUIT

When using an external clock signal, input the clock signal to the X_{IN} (X_{CIN}) pin and leave the X_{OUT} (X_{COUT}) pin open.If the X_{CIN} clock is not used, connect the X_{CIN} pin to V_{SS}, and leave the X_{COUT} pin open.

Either high-speed operation start mode or low-speed operation start mode can be selected by using a mask option.

(1) High-Speed Operation Start Mode

After reset has completed, the internal clock ϕ is half the frequency of X_{IN}. Immediately after power-on, both the X_{IN} and X_{CIN} clock start oscillating. To set the internal clock ϕ to low-speed mode, set bit 7 of the CPU mode register (address $003B_{16}$) to "1".

(2) Low-Speed Operation Start Mode

After reset has completed, the internal clock ϕ is half the frequency of X_{CIN}. Immediately after power-on, only the X_{CIN} clock starts oscillating. To set the internal clock ϕ to normal operation mode, first set bit 6 (CM_6) of the CPU mode register (address $003B_{16}$) to "0", the set bit 7 (CM_7) to "0" .Note that the program must allow time for oscillation to stabilize.

(3) Oscillation Control

Stop mode

If the STP instruction is executed, oscillation stops with the internal clock ϕ at an "H" level. Timer 1 is set to "FF_{16}" and timer 2 is set to "01_{16}".

Either X_{IN} or X_{CIN} divided by 16 is input to timer 1, and the output of timer 1 is connected to timer 2. The timer 1 and timer 2 interrupt enable bits must be set to disabled ("0"), so a program must set these bits before executing a STP instruction. Oscillation restarts at reset or when an external interrupt is received, but the internal clock ϕ is not supplied to the CPU until timer 2 overflows. This allows time for the clock circuit oscillation to stabilize.

Wait mode

If the WIT instruction is executed, the internal clock ϕ stops at a "H" level but the oscillator itself does not stop. The internal clock restarts if a reset occurs or when an interrupt is received. Since the oscillator does not stop, normal operation can be started immediately after the clock is restarted.

Low-speed mode

If the internal clock is generated from the sub clock (X_{CIN}), a low power consumption operation can be entered by stopping only the main clock X_{IN}. To stop the main clock, set bit 6 (CM_6) of the CPU mode register ($003B_{16}$) to "1". When the main clock X_{IN} is restarted, the program must allow enough time to for oscillation to stabilize.

Note that in low-power-consumption mode the X_{CIN}-X_{COUT} drive performance can be reduced, allowing even lower power consumption ($20\mu A$ with X_{CIN} =32kHz). To reduce the X_{CIN}-X_{COUT} drive performance, clear bit 5 (CM_5) of the CPU mode register ($003B_{16}$) to "0". At reset or when a STP instruction is executed, this bit is set to "1" and strong drive is selected to help the oscillation to start.

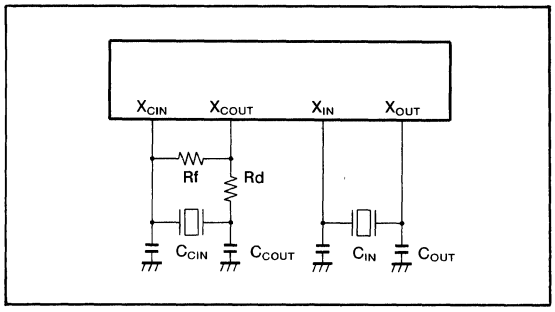


Fig. 22 Ceramic resonator circuit

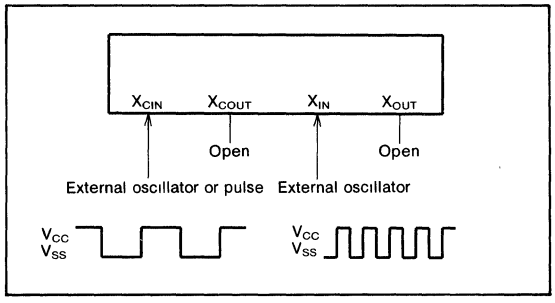
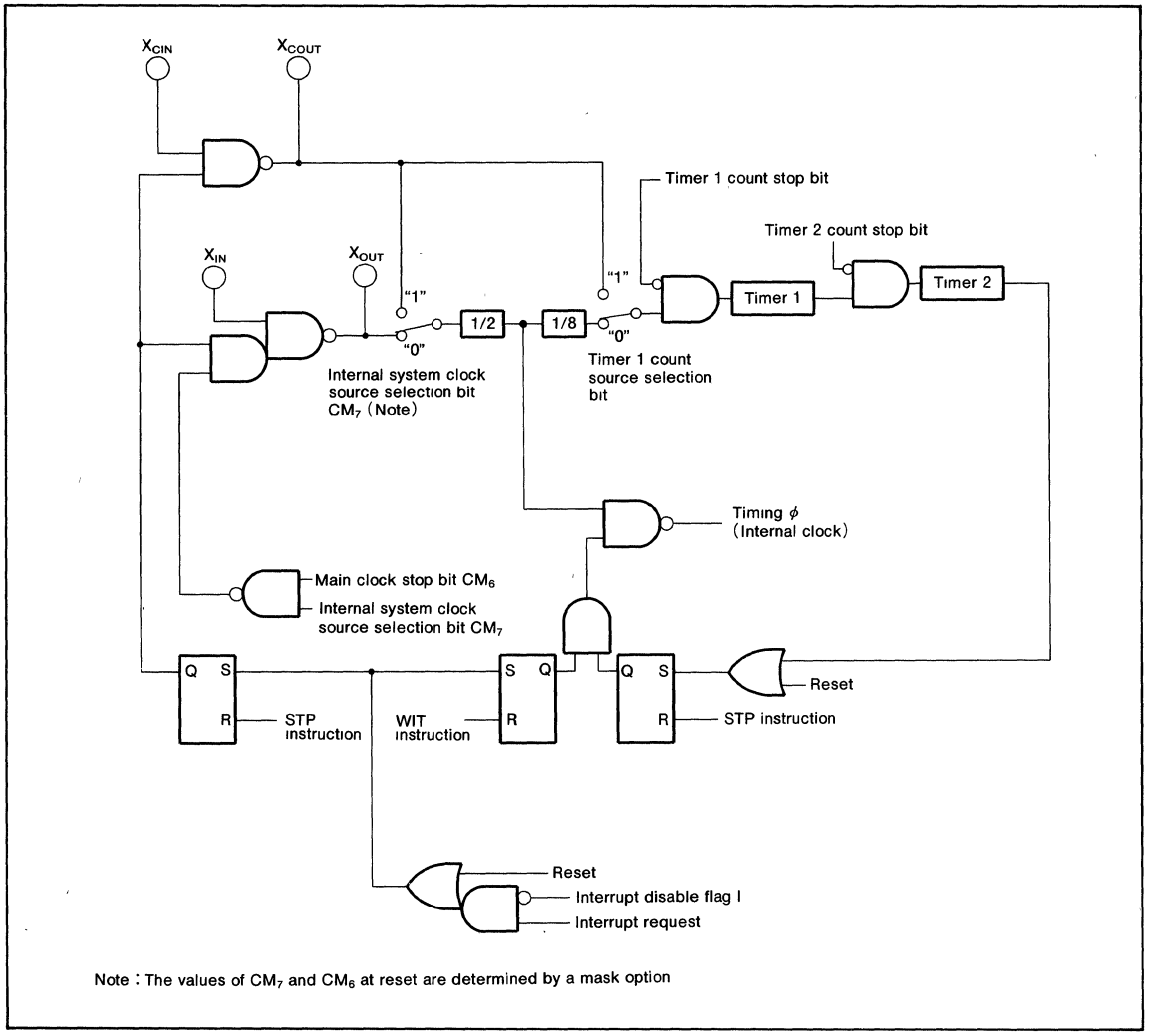
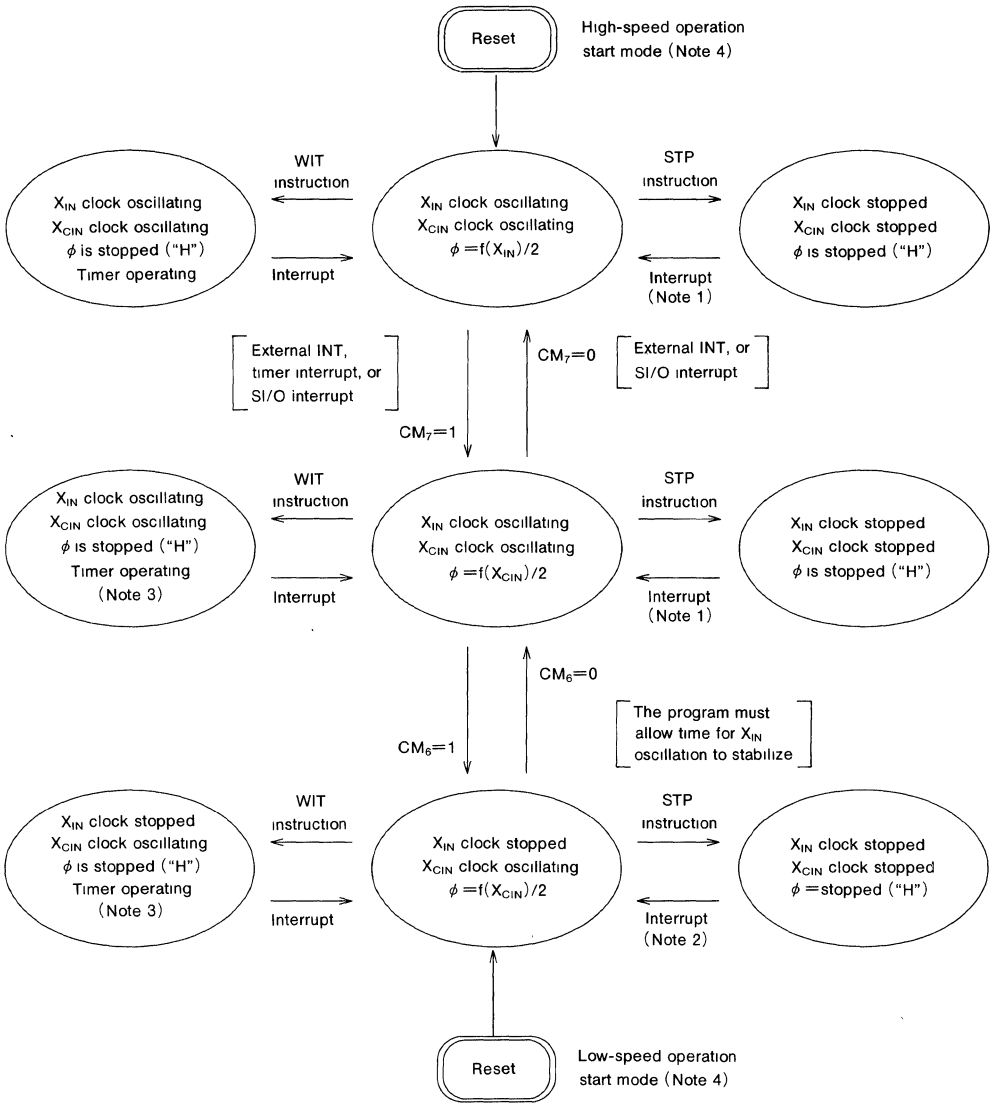


Fig. 23 External clock input circuit



Note : The values of CM_7 and CM_6 at reset are determined by a mask option

Fig. 24 System clock generation circuit block diagram



The example assumes that 4 MHz is being applied to the X_{IN} pin and 32 kHz to the X_{CIN} pin

Note 1 When the STP state is ended, a delay of approximately 2ms is automatically generated by timer 1 and timer 2
2 The delay after the STP state ends is approximately 0 25s
3 If the internal clock φ divided by 8 is used as the timer count source, the frequency of the count source is $f(X_{CIN})/16$
4 Specify this option when ordering a mask ROM version

Fig. 25 State transitions of system clock

NOTES ON PROGRAMMING

Processor Status Register

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

Interrupts

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

Decimal Calculations

To calculate in decimal notation, set the decimal mode flag (D) to "1", then execute a ADC or SBC instruction. Only the ADC and SBC instruction yield proper decimal results. After executing an ADC or SBC instruction, execute at least one instruction before executing a SEC, CLC, or CLD instruction.

In decimal mode, the values of the negative (N), overflow (V), and zero (Z) flags are invalid. The carry flag can be used to indicate whether a carry or borrow has occurred, but must be initialized before each calculation. Clear the carry flag before an ADC and set the flag before an SBC.

Timers

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

Multiplication and Division Instructions

The MUL and DIV instructions do not affect the T and D flags.
The execution of these instructions does not change the contents of the processor status register.

Ports

The contents of the port direction registers cannot be read. Programs can not use the value of a direction register as an index, or bit-test a direction register (BBC or BBS), or perform a read-modify-write instruction such as ROR, CLB, or SEB. Use instructions such as LDM and STA to set the port direction registers.

Serial I/O

When using an external clock, input "H" to the external clock input pin and clear the serial I/O interrupt request bit before executing a serial I/O transfer.
When using the internal clock, set the synchronization clock to internal clock, then clear the serial I/O interrupt request bit before executing a serial I/O transfer.

Instruction Execution Timing

The instruction execution time is obtained by multiplying the frequency of the internal clock ϕ by the number of cycles needed to execute an instruction. The number of cycles required to execute an instruction is shown in the list of machine instructions. The frequency of the internal clock ϕ is half of the X_{IN} or X_{CIN} frequency.

DATA REQUIRED FOR MASK ORDERS

The following are necessary when ordering a mask ROM production:

(1) Mask ROM Order Confirmation Form
(2) Mask Specification Form
(3) Data to be written to ROM, in EPROM form (three identical copies)

If required, specify the following option on the Mask Confirmation Form:

- Operation start mode switching option

ROM Writing Method

The built-in PROM of the blank one-time programmable version and built-in EPROM version can be read from and written to with an normal EPROM writer using a special write adapter.

Package	Name of Write Adapter
64P4B, 64S1B	PCA4738S-64
64P6N	PCA4738F-64
64D0	PCA4738L-64

The PROM of the blank one-time programmable version is not tested or screened after assembly. To ensure proper operation after writing, the procedure shown in Figure 26 is recommended to verify programming.

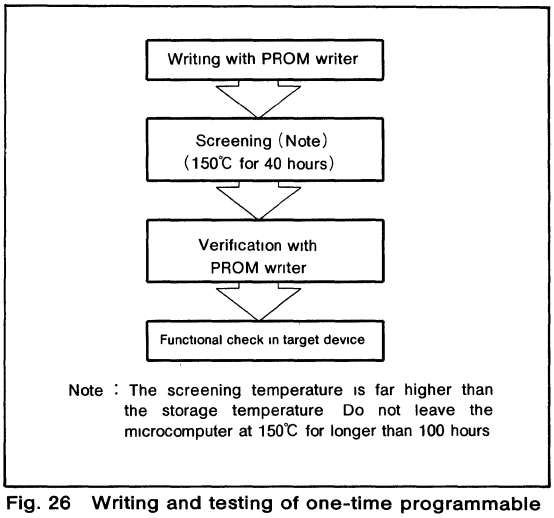


Fig. 26 Writing and testing of one-time programmable version

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Conditions	Ratings	Unit
V_{CC}	Supply voltage	All voltages measured based on the V_{SS} pin. Output transistors are isolated.	−0.3 to 7.0	V
V_{EE}	Pull-down power supply voltage		V_{CC}−40 to V_{CC}+0.3	V
V_I	Input voltage $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_0$-$P6_7$		−0.3 to V_{CC}+0.3	V
V_I	Input voltage $P4_0$		−0.3 to V_{CC}+0.3	V
V_I	Input voltage $\overline{RESET}$, X_{IN}		−0.3 to V_{CC}+0.3	V
V_I	Input voltage X_{CIN}		−0.3 to V_{CC}+0.3	V
V_O	Output voltage $P0_0$-$P0_7$, $P1_0$-$P1_7$, $P2_0$-$P2_3$, $P3_0$-$P3_7$		V_{CC}−40 to V_{CC}+0.3	V
V_O	Output voltage $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_0$-$P6_5$, $P7_0$-$P7_7$, X_{OUT}, X_{COUT}		−0.3 to V_{CC}+0.3	V
P_d	Power dissipation	T_a = 25℃	1000(Note 1)	mW
Topr	Operating temperature		−10 to 85	℃
Tstg	Storage temperature		−40 to 125	℃

Note 1 600mW in case of the flat package

RECOMMENDED OPERATING CONDITIONS (V_{CC} = 4.0 to 5.5V, T_a = −10 to 85℃, unless otherwise noted)

Symbol	Parameter		Limits			Unit
			Min	Typ	Max	
V_{CC}	Supply voltage	High-speed operation mode	4.0	5.0	5.5	V
		Low-speed operation mode	2.8	5.0	5.5	
V_{SS}	Supply voltage			0		V
V_{EE}	Pull-down power supply voltage		V_{CC}−38		V_{CC}	V
V_{IA}	Analog input voltage		0		V_{CC}	V
V_{IH}	"H" input voltage $P2_4$-$P2_7$		0.4V_{CC}		V_{CC}	V
V_{IH}	"H" input voltage $P4_0$		0.75V_{CC}		V_{CC}	V
V_{IH}	"H" input voltage $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_0$-$P6_7$		0.75V_{CC}		V_{CC}	V
V_{IH}	"H" input voltage $\overline{RESET}$		0.8V_{CC}		V_{CC}	V
V_{IH}	"H" input voltage X_{IN}, X_{CIN}		0.8V_{CC}		V_{CC}	V
V_{IL}	"L" input voltage $P2_4$-$P2_7$		0		0.16V_{CC}	V
V_{IL}	"L" input voltage $P4_0$		0		0.25V_{CC}	V
V_{IL}	"L" input voltage $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_0$-$P6_7$		0		0.25V_{CC}	V
V_{IL}	"L" input voltage $\overline{RESET}$		0		0.2V_{CC}	V
V_{IL}	"L" input voltage X_{IN}, X_{CIN}		0		0.2V_{CC}	V

RECOMMENDED OPERATING CONDITIONS (V_{CC}=4.0 to 5.5V, T_a=−10 to 85°C, unless otherwise noted)

Symbol	Parameter	Limits			Unit
		Min	Typ	Max	
$\Sigma I_{OH(peak)}$	"H" total peak output current $P0_0$-$P0_7$, $P1_0$-$P1_7$, (Note 1) $P2_0$-$P2_7$, $P3_0$-$P3_7$			−240	mA
$\Sigma I_{OH(peak)}$	"H" total peak output current $P4_1$-$P4_7$, $P6_0$-$P6_7$			−60	mA
$\Sigma I_{OL(peak)}$	"L" total peak output current $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_1$-$P6_7$			100	mA
$\Sigma I_{OL(peak)}$	"L" total peak output current $P6_0$			3.0	mA
$\Sigma I_{OH(avg)}$	"H" total average output current $P0_0$-$P0_7$, $P1_0$-$P1_7$, (Note 1) $P2_0$-$P2_7$, $P3_0$-$P3_7$			−120	mA
$\Sigma I_{OH(avg)}$	"H" total average output current $P4_1$-$P4_7$, $P6_0$-$P6_7$			−30	mA
$\Sigma I_{OL(avg)}$	"L" total average output current $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_1$-$P6_7$			50	mA
$\Sigma I_{OL(avg)}$	"L" total average output current $P6_0$			1.5	mA
$I_{OH(peak)}$	"H" peak output current $P0_0$-$P0_7$, $P1_0$-$P1_7$, $P2_0$-$P2_3$, $P3_0$-$P3_7$ (Note 2)			−40	mA
$I_{OH(peak)}$	"H" peak output current $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P6_0$-$P6_7$			−10	mA
$I_{OL(peak)}$	"L" peak output current $P2_4$-$P2_7$, $P6_1$-$P6_7$			10	mA
$I_{OL(peak)}$	"L" peak output current $P4_1$-$P4_7$, $P5_0$-$P5_7$			10	mA
$I_{OL(peak)}$	"L" peak output current $P6_0$			3.0	mA
$I_{OH(avg)}$	"H" average output current $P0_0$-$P0_7$, $P1_0$-$P1_7$, (Note 3) $P2_0$-$P2_3$, $P3_0$-$P3_7$			−18	mA
$I_{OH(avg)}$	"H" average output current $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P6_0$-$P6_7$			−5.0	mA
$I_{OL(avg)}$	"L" average output current $P2_4$-$P2_7$, $P6_1$-$P6_7$			5.0	mA
$I_{OL(avg)}$	"L" average output current $P4_1$-$P4_7$, $P5_0$-$P5_7$			10	mA
$I_{OL(avg)}$	"L" average output current $P6_0$			1.5	mA
f(CNTR)	Clock input frequency for timers 4 (duty cycle 50%)			250	kHz
$f(X_{IN})$	Main clock input oscillation frequency (Note 4)			4.2	MHz
$f(X_{CIN})$	Sub clock input oscillation frequency (Note 4, 5)		32.768	50	kHz

Note 1. The total output current is the sum of all the currents flowing through all the applicable ports The total average current is an average value measured over 100ns The total peak current is the peak value of all the currents.
2. The peak output current is the peak current flowing in each port
3. The average output current in an average value measured over 100ms
4. When the oscillation frequency has a duty cycle of 50%.
5. When using the microcomputer in low-speed mode, make sure that the sub clock's input frequency $f(X_{CIN})$ is less than $f(X_{IN})/3$

ELECTRICAL CHARACTERISTICS (V_{CC} = 4.0 to 5.5V, T_a = −10 to 85℃, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min.	Typ.	Max	
V_{OH}	"H" output voltage $P0_0$-$P0_7$, $P1_0$-$P1_7$, $P2_0$-$P2_3$, $P3_0$-$P3_7$	I_{OH}=−18mA, V_{CC}=4.5 to 5.5V	V_{CC}−2.0			V
V_{OH}	"H" output voltage $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P6_0$-$P6_7$	I_{OH}=−10mA, V_{CC}=4.5 to 5.5V	V_{CC}−2.0			V
V_{OL}	"L" output voltage $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_1$-$P6_7$	I_{OL}=10mA, V_{CC}=4.5 to 5.5V			2.0	V
V_{OL}	"L" output voltage $P6_0$	I_{OL}=1.5mA, V_{CC}=4.5 to 5.5V			0.5	V
$V_{T+}-V_{T-}$	Hysteresis $\overline{INT_0}$-$\overline{INT_2}$, S_{IN1}, S_{IN2}, CLK1, CLK2, CNTR	When using a non-port function		0.4		V
$V_{T+}-V_{T-}$	Hysteresis $\overline{RESET}$, X_{IN}	$\overline{RESET}$: V_{CC}=2.8V to 5.5V		0.5		V
$V_{T+}-V_{T-}$	Hysteresis X_{CIN}			0.5		V
I_{IH}	"H" input current $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_0$-$P6_7$	V_I=V_{CC}			5.0	μA
I_{IH}	"H" input current $P4_0$	V_I=V_{CC}			5.0	μA
I_{IH}	"H" input current $\overline{RESET}$, X_{CIN}	V_I=V_{CC}			5.0	μA
I_{IH}	"H" input current X_{IN}	V_I=V_{CC}		4		μA
I_{IL}	"L" input current $P2_4$-$P2_7$, $P4_1$-$P4_7$, $P5_0$-$P5_7$, $P6_0$-$P6_7$	V_I=V_{SS}			−5.0	μA
I_{IL}	"L" input current $P4_0$	V_I=V_{SS}			−5.0	μA
I_{IL}	"L" input current $\overline{RESET}$, X_{CIN}	V_I=V_{SS}			−5.0	μA
I_{IL}	"L" input current X_{IN}	V_I=V_{SS}		−4		μA
I_{LOAD}	Output load current $P0_0$-$P0_7$, $P1_0$-$P1_7$, $P2_0$-$P2_3$, $P3_0$-$P3_7$	V_{EE}=V_{CC}−36V, V_O=V_{CC}, With output transistors off	150	500	900	μA
I_{LEAK}	Output leakage current $P0_0$-$P0_7$, $P1_0$-$P1_7$, $P2_0$-$P2_3$, $P3_0$-$P3_7$	V_{EE}=V_{CC}−38V, V_O=V_{CC}−38V, With output transistors off (Except for reset)			−10	μA
V_{RAM}	RAM hold voltage	When clock is stopped	2.0		5.5	V
I_{CC}	Power supply current	In high-speed operation mode $f(X_{IN})$=4MHz $f(X_{CIN})$=32kHz Output transistors off Comparator operating		5	10	mA
		In high-speed operation mode $f(X_{IN})$=4MHz (in WIT state) $f(X_{CIN})$=32kHz Output transistors off Comparator stopped		1		mA
		In low-speed operation mode $f(X_{IN})$= stopped $f(X_{CIN})$=32kHz Low-power dissipation mode set (CM_5=0) Output transistors off		60	200	μA
		In low-speed operation mode $f(X_{IN})$= stopped $f(X_{CIN})$=32kHz (in WIT state) Low-power dissipation mode set (CM_5=0) Output transistors off		20	40	μA
		All oscillation stopped (in STP state) Output transistors off — T_a=25℃		0.1	1.0	μA
		All oscillation stopped (in STP state) Output transistors off — T_a=85℃			10	μA

COMPARATOR CHARACTERISTICS

(V_{CC}=4.0 to 5.5V, V_{SS}=0V, T_a=−10 to 85℃, high-speed operation mode, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min.	Typ	Max	
—	Resolution				4	Bits
—	Absolute accuracy				1/2	LSB
T_{CONV}	Conversion time				7	μs
I_{IA}	Analog port input current				5.0	μA
R_{LADDER}	Ladder resistor			30		kΩ

TIMING REQUIREMENTS (V_{CC}=4.0 to 5.5V, V_{SS}=0V, T_a=−10 to 85℃, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min	Typ	Max	
$t_{W(\overline{RESET})}$	Reset input "L" pulse width		2			μs
$t_{C(X_{IN})}$	Main clock input cycle time (X_{IN} input)		238			ns
$t_{WH(X_{IN})}$	Main clock input "H" pulse width		60			ns
$t_{WL(X_{IN})}$	Main clock input "L" pulse width		60			ns
$t_{C(X_{CIN})}$	Sub clock input cycle time (X_{CIN})		2.0			ms
$t_{W(X_{CIN})}$	Sub clock input pulse width (X_{CIN})		1.0			ms
$t_{C(CNTR)}$	CNTR input cycle time		4			μs
$t_{WH(CNTR)}$	CNTR input "H" pulse width		1.6			μs
$t_{WL(CNTR)}$	CNTR input "L" pulse width		1.6			μs
$t_{WH(INT)}$	INT_0~INT_2 input "H" pulse width		80			ns
$t_{WL(INT)}$	INT_0~INT_2 input "L" pulse width		80			ns
$t_{C(SCLK)}$	Serial clock input cycle time		1		1000	μs
$t_{WH(SCLK)}$	Serial clock input "H" pulse width		40	1		%
$t_{WL(SCLK)}$	Serial clock input "L" pulse width		40			%
$t_{r(SCLK)}$	Serial clock input clock rise time		5		50	ns
$t_{f(SCLK)}$	Serial clock input clock fall time		5		40	ns
$t_{h(SCLK-SIN)}$	Serial input hold time		0.2tc			ns
$t_{su(SCLK-SIN)}$	Serial input setup time		0.2tc			ns

SWITCHING CHARACTERISTICS (V_{CC}=4.0 to 5.5V, V_{SS}=0V, T_a=−10 to 85℃, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min	Typ	Max	
$t_{WH(SCLK)}$	Serial clock output "H" pulse width	C_L=100pF, R_L=1kΩ	$t_C/2-160$			ns
$t_{WL(SCLK)}$	Serial clock output "L" pulse width	C_L=100pF, R_L=1kΩ	$t_C/2-160$			ns
$t_{d(SCLK-SOUT)}$	Serial clock delay time				$0.2t_C$	ns
$t_{v(SCLK-SOUT)}$	Serial clock hold time		0			ns
$t_{f(SCLK)}$	Serial clock output fall time	C_L=100pF, R_L=1kΩ			40	ns
$t_{r(P_{ch}.strg)}$	P-channel high-breakdown voltage output rise time (Note 1)	C_L=100pF, V_{EE}=V_{CC}−36V		55		ns
$t_{r(P_{ch}.weak)}$	P-channel high-breakdown voltage output fall time (Note 2)	C_L=100pF, V_{EE}=V_{CC}−36V		1.8		ns

Note 1. When bit 0 of the high-breakdown voltage port control register (address 0038_{16}) is at "0"
2. When bit 0 of the high-breakdown voltage port control register (address 0038_{16}) is at "1"

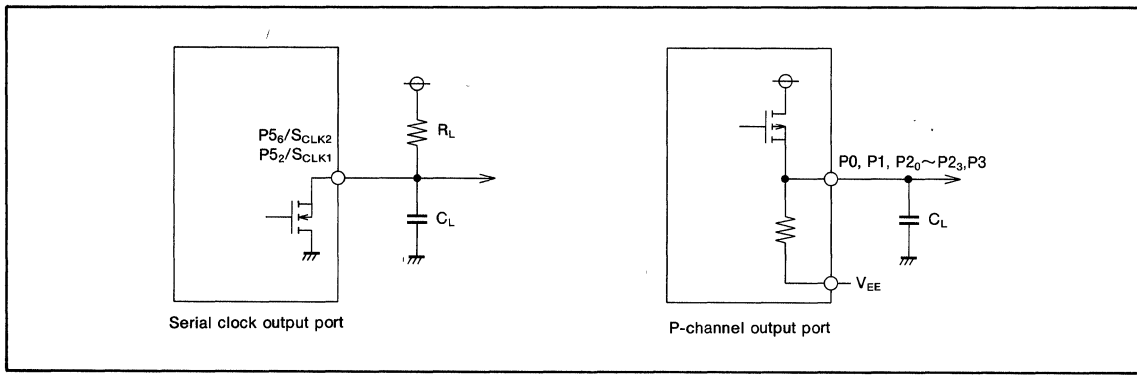


Fig. 27 Output switching characteristics measurement circuit

TIMING CHART