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MICROCOMPUTER MN101C

MN101C457

LSI User's Manual

Pub.No.21445-010E

Panasonic

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About This Manual

The MN101C457 offers a choice of masked ROM version or user-programmable EPROM version (MN101CP427).

16K	MN101C457	512
16K	MN101CP427	512

Unit : byte

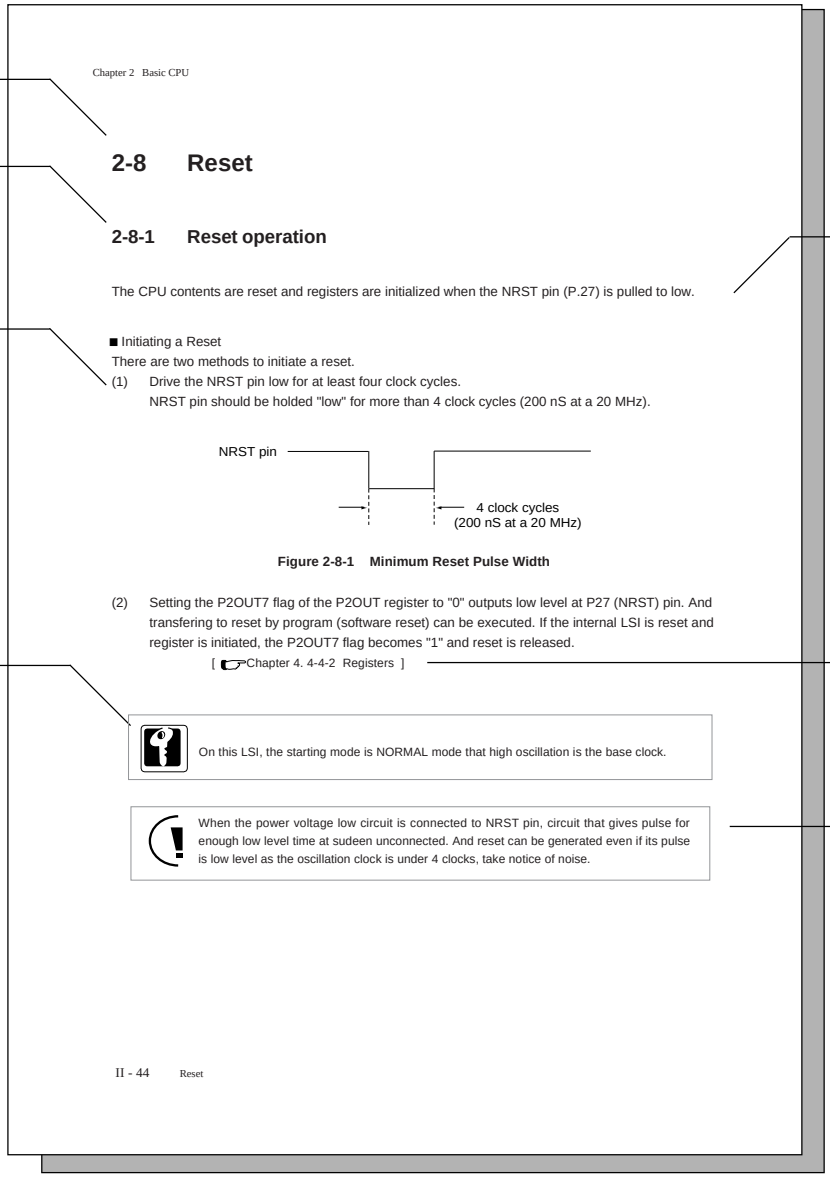
■Organization

In this LSI manual, the LSI functions are presented in the folowing order : overview, CPU basic functions, interrupt functions, port functions, timer functions, serial interface functions, and other peripheral hardware functions. Each section contains overview of function, block diagram, control register, operation, and setting example.

■Manual Configuration

Each section of this manual consists of a title, summary, main text, key information, precautions and warnings, and references.

The layout and definition of each section are shown below.



Subtitle

Sub-subtitle
The smallest block in this manual.

Main text

Key information
Important information from the main text.

Summary
Introduction to the section.

References
References for the main text.

Precautions and warnings
Precautions are listed in case of lost functionality or damage. Be sure to read.

■Finding Desired Information

This manual provides three methods for finding desired information quickly and easily.

(1) Consult the index at the front of the manual to locate the beginning of each section.
(2) Consult the table of contents at the front of the manual to locate desired titles.
(3) Chapter names are located at the top outer corner of each page, and section titles are located at the bottom outer corner of each page.

■Related Manuals

Note that the following related documents are available.

"MN101C Series LSI User's Manual"
<Describes the device hardware.>
"MN101C Series Instruction Manual"
<Describes the instruction set.>
"MN101C Series Cross-assembler User's Manual"
<Describes the assembler syntax and notation.>
"MN101C Series C Compiler User's Manual: Usage Guide"
<Describes the installation, the commands, and options of the C Compiler.>
"MN101C Series C Compiler User's Manual: Language Description"
<Describes the syntax of the C Compiler.>
"MN101C Series C Compiler User's Manual: Library Reference"
<Describes the standard library of the C Compiler.>
"MN101C Series C Source Code Debugger User's Manual"
<Describes the use of C source code debugger.>
"MN101C Series PanaX Series Installation Manual"
<Describes the installation of C compiler, cross-assembler and C source code debugger and the procedure for bringing up the in-circuit emulator.>

■Where to Send Inquires

We welcome your questions, comments, and suggestions. Please contact the semiconductor design center closest to you. See the last page of this manual for a list of addresses and telephone numbers.

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Chapter 1 Overview

1-1 Overview

1-1-1 Overview

The MN101C series of 8-bit single-chip microcontrollers incorporate multiple types of peripheral functions. This chip series is well suited for VCR, MD, TV, CD, LD, printer, telephone, home automation, pager, air conditioner, PPC remote control, fax machine, musical instrument, and other applications.

This LSI brings to embedded microcomputer applications flexible, optimized hardware configurations and a simple efficient instruction set. This LSI has internal ROM 16 KB and RAM 512 bytes. Peripheral functions include 4 external interrupts*1, 8 internal interrupts including NMI, 5 timer counters, 1 set of serial interface, A/D converter, watchdog timer, buzzer output and remote control output. The configuration of this microcontroller is well suited for application such as a system controller in a VCR selection timer, CD player, or MD.

48-pin TQFP package type has two oscillation systems (max. 20 MHz/32 kHz) contained on the chip, the system clock can be switched to high speed oscillation (**NORMAL mode**), or to low speed oscillation (**SLOW mode**). The system clock is generated by dividing the oscillation clock.

For example, in case of NORMAL mode, when the oscillation source (fosc) is 8 MHz, **minimum instructions execution time** is for 250 ns, and when fosc is 20 MHz, it is 100 ns.

3 types of package are available: 42-pin SDIP, 44-pin QFP and 48-pin TQFP

*1 3 external interrupts for other types of package except 48-pin TQFP package type.

1-1-2 Product Summary

This manual describes the following models of the MN101C457 series. These products have same peripheral functions.

Table 1-1-1 Product Summary

Model	ROM Size	RAM Size	Classification
MN101C457	16 KB	512 bytes	Mask ROM version
MN101CP427	16 KB	512 bytes	EPROM version

1-2 Hardware Functions

CPU Core **MN101C Core**

- LOAD-STORE architecture (3-stage pipeline)
- Half-byte instruction set / Handy addressing
- Memory addressing space is 256 KB
- Minimum instruction execution time

High speed mode	0.10 µs	/	20 MHz	(4.5 V to 5.5 V)
	0.238 µs	/	8.39 MHz	(2.7 V to 5.5 V)
	0.477 µs	/	4.19 MHz	(2.0 V to 5.5 V) *1
Low speed mode	125 µs	/	32 kHz	(2.0 V to 5.5 V) *1 *4

- Operation modes
  - NORMAL mode (High speed oscillation)
  - SLOW mode (Low speed oscillation)*4
  - HALT mode
  - STOP mode

Memory modes **<Single chip mode>**

Internal ROM *2	16 KB *3
Internal RAM *2	512 bytes

*1 : EPROM vers. is 2.7 V to 5.5 V.

*2 : Differs depending upon the model. [☞ Chapter 1. 1-1-2 Product Summary]

*3 : 1 byte of internal ROM is reserved for ROM option.
[☞ Chapter 1. 1-6-1 ROM Option]

*4 : Provided only for 48-pin TQFP package type.

Interrupts **8 Internal interrupts**

< Non-maskable interrupt (NMI) >
- Incorrect code execution interrupt and Watchdog timer interrupt

< Timer interrupts >
- Timer 2 interrupt
- Timer 3 interrupt
- Timer 4 interrupt
- Timer 5 interrupt
- Time base interrupt

< Serial interface interrupts >
- Serial interface 0 interrupt (Synchronous + Half-duplex UART)

< A/D interrupt >
- A/D converter interrupt

4 External interrupts (3 external interrupts for other package types except 48-pin TQFP package type)
- IRQ0 : Edge selectable. With / Without noise filter.
- IRQ1 : Edge selectable. With / Without noise filter.
  AC zero cross detector
- IRQ2 : Edge selectable.
- IRQ3 : Edge selectable.*4

Timers **5 timers (4 can operate independently)**

- 8-Bit timer for general use	1 set
- 8-Bit timer for general use (UART baud rate timer)	1 set
- 8-Bit free-running timer	1 set
Time base timer	1 set
- 16-Bit timer for general use	1 set

Timer 2 (8-Bit timer for general use)
- Square wave output (Timer pulse output), PWM output, Event count,
- Clock source
  fs, fs/4, fx *4, TM2IO pin input

Timer 3 (8-Bit timer for general use or UART baud rate timer)
- Square wave output (Timer pulse output), Event counter, Serial interface transfer clock output, 16-Bit cascade connection function (connect to timer 2), Remote control carrier output
- Clock source
  fosc, fs/4, fs/16, TM3IO pin input

Timer 4 (16-Bit timer for general use)
- Square wave output (Timer pulse output), PWM output, Event count Input capture function
- Clock source
  fosc, fs/4, fs/16, TM4IO pin input

Timer 5 (8-Bit free-running timer, Time base timer)

❑ **8-Bit free-running timer**

- Clock source

  fosc, fs/4, fx *4, $fosc/2^{13}$, $fx/2^{13}$ *4

❑ **Time base timer**

- Interrupt generation cycle

  $fosc/2^{7}$, $fosc/2^{8}$, $fosc/2^{9}$, $fosc/2^{10}$, $fosc/2^{13}$,
  $fx/2^{7}$ *4, $fx/2^{8}$ *4, $fx/2^{9}$ *4, $fx/2^{10}$ *4, $fx/2^{13}$ *4

at 32.768 kHz for low speed oscillation input can be set to measure one minute intervals

Watchdog timer

- Watchdog timer frequency can be selected from $fs/2^{16}$, $fs/2^{18}$, $fs/2^{20}$ as ROM option.
- On detection of errors, hardware reset is done by force in LSI.

Remote control output

Based on the timer 3 output, a remote control carrier with duty cycle of 1/2 or 1/3 can be output.

Buzzer output Output frequency can be selected from $fs/2^{9}$, $fs/2^{10}$, $fs/2^{11}$, $fs/2^{12}$.

A/D converter **10 bits X 8 channels input**

Serial interface **1 type**

Serial interface 0 (Half-duplex UART / Synchronous serial interface)

❑**Synchronous serial interface**

- Transfer clock source

  fs/2, fs/4, fs/16, UART baud rate timer (timer 3) output, External clock

- MSB/LSB can be selected as the first bit to be transferred. Any transfer size from 1 to 8 bits can be selected.

❑**Half-duplex UART (Baud rate timer : Timer 3)**

- Parity check, overrun error, framing error detection
- Transfer size 7 to 8 bits can be selected.
- When using timer 3, the transfer rate for a 12 MHz oscillation are 19200/9600/4800/2400/1200/300 bps.

LED driver	**8 pins**	
Port	**I/O ports**	**27 pins** *5
	- LED (large current) driver pins	8 pins
	Input ports	**12 pins** *6
	- dual function for External interrupt	4 pins *7
	(One pin can also be used for zero-cross input.)	
	- dual function for A/D input	8 pins
	Special pins	
	- Operation mode input pin	1 pin
	- Reset input pin	1 pin
	- Power pin	2 pins
	- Oscillation pin	4 pins *8
Package	**42-pin SDIP**	
	code name : SDIP042-P-0600	
	44-pin QFP (10 mm square / 0.8 mm pitch)	
	code name : *QFP044-P-1010	
	48-pin TQFP (7 mm square / 0.5 mm pitch)	
	code name : TQFP048-P-0707B	

*5 : 42-pin SDIP package type	25 pins
44-pin QFP package type	26 pins
*6 : For the package types except 48 pin TQFP package type	11 pins
*7 : For the package types except 48 pin TQFP package type	3 pins
*8 : For the package types except 48 pin TQFP package type	2 pins

1-3 Pin Description

1-3-1 Pin Configuration

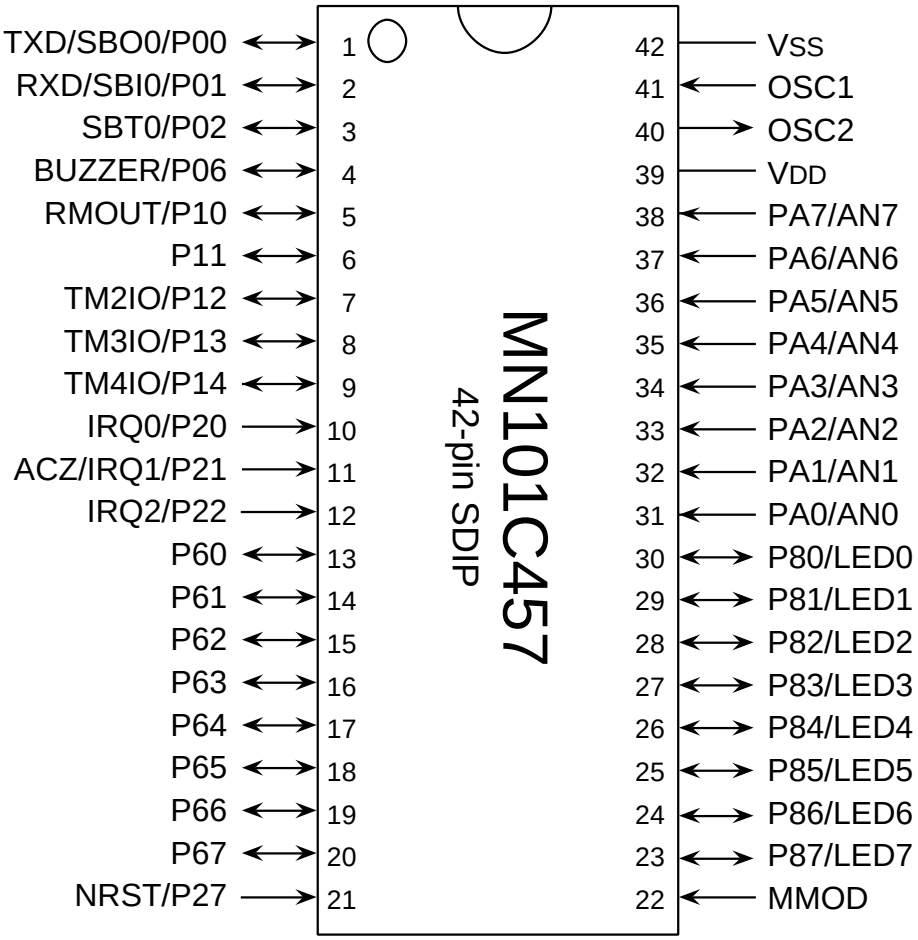


Figure 1-3-1 Pin Configuration (42-SDIP : Top view)

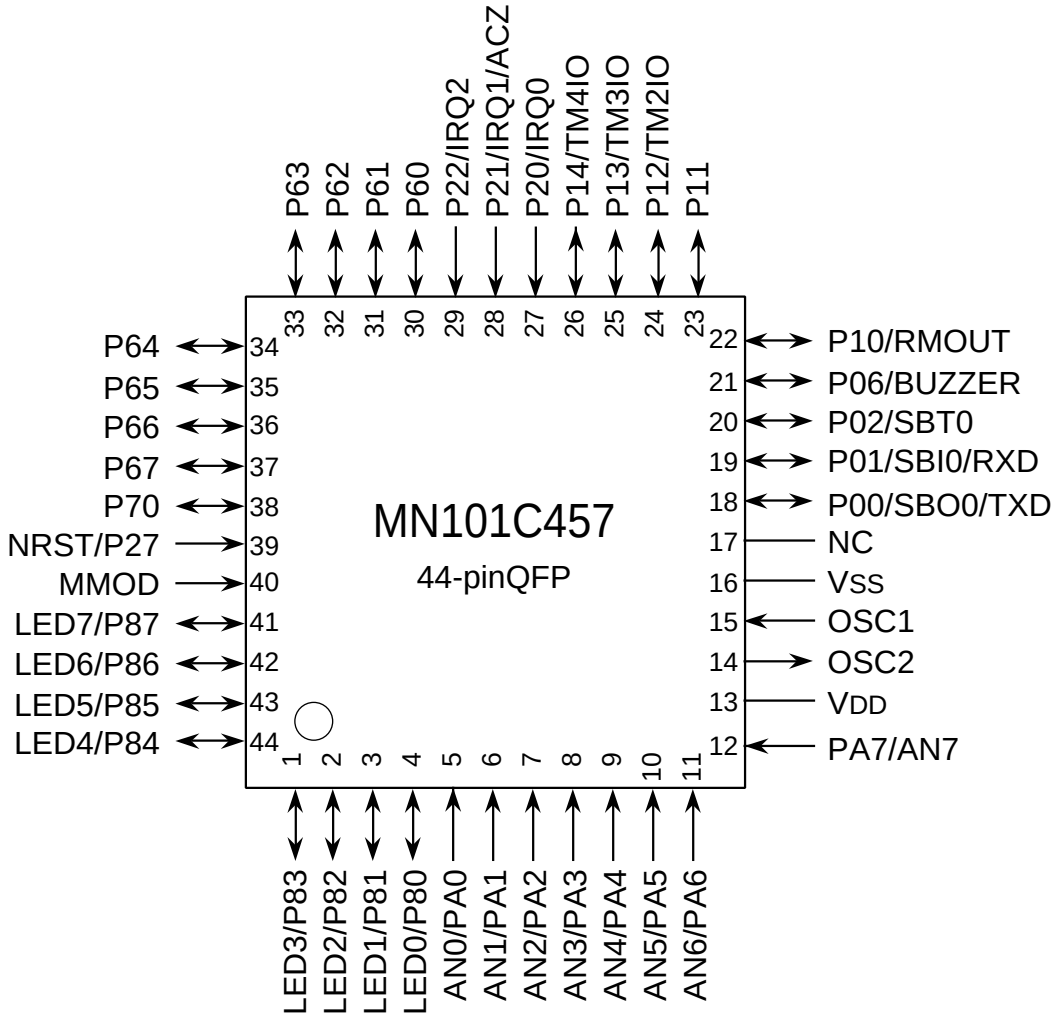


Figure 1-3-2 Pin Configuration (44-QFP : Top view)

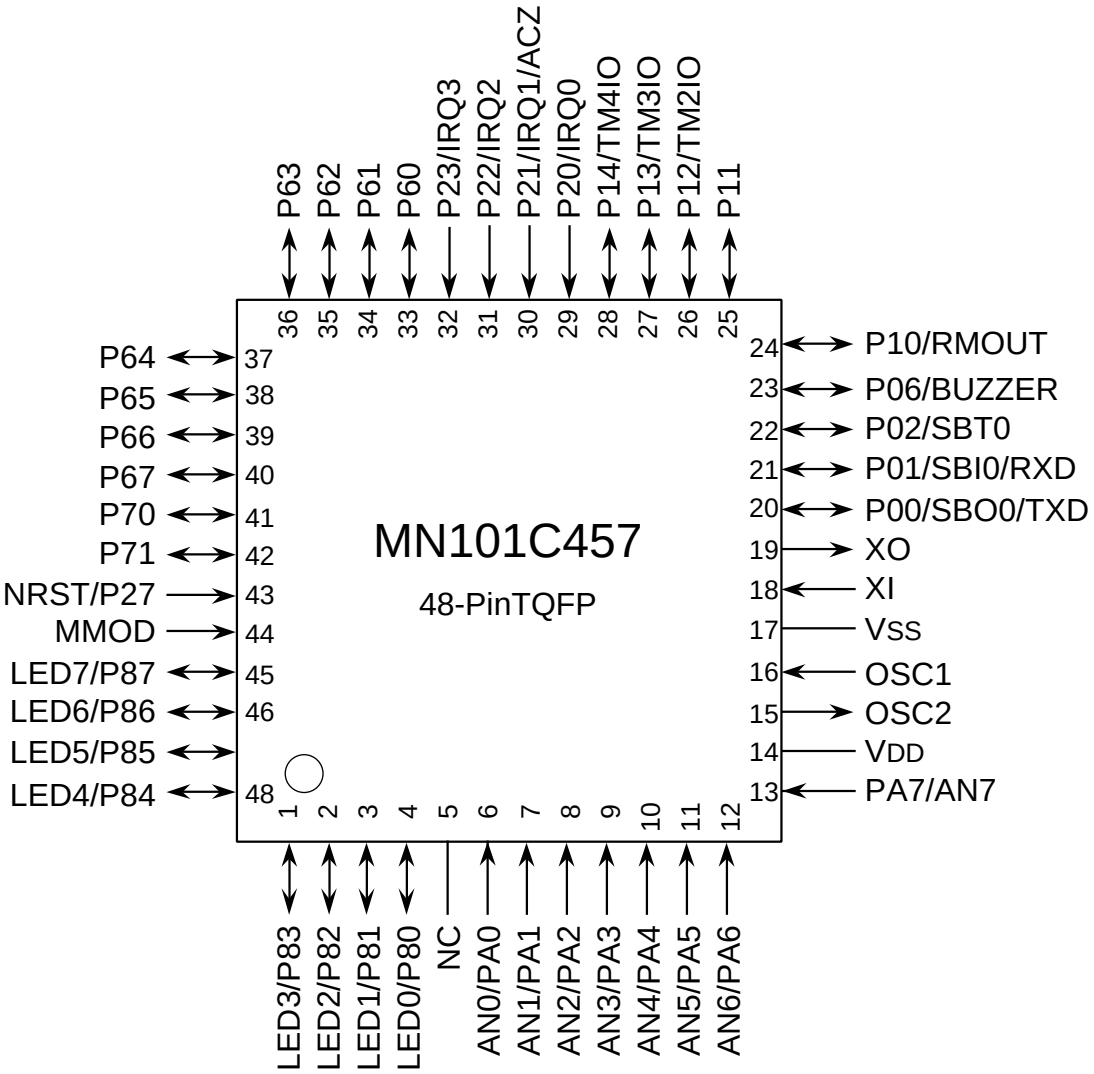


Figure 1-3-3 Pin Configuration (48-TQFP : Top view)

1-3-2 Pin Specification

Table 1-3-1 Pin Specification

Pins	Special Functions	I/O	Direction Control	Pin Control	Functions Description
P00	SBO0 TXD	in/out	P0DIR0	P0PLU0	SBO0 : Serial Interface 0 transmission data output TXD : UART transmission data output
P01	SBI0 RXD	in/out	P0DIR1	P0PLU1	SBI0 : Serial Interface 0 reception data input RXD : UART reception data input
P02	SBT0	in/out	P0DIR2	P0PLU2	SBT0 : Serial Interface 0 clock I/O
P06	BUZZER	in/out	P0DIR6	P0PLU6	BUZZER : Buzzer output
P10	RMOUT	in/out	P1DIR0	P1PLU0	RMOUT : Remote control carrier output
P11		in/out	P1DIR1	P1PLU1	
P12	TM2IO	in/out	P1DIR2	P1PLU2	TM2IO : Timer 2 I/O
P13	TM3IO	in/out	P1DIR3	P1PLU3	TM3IO : Timer 3 I/O
P14	TM4IO	in/out	P1DIR4	P1PLU4	TM4IO : Timer 4 I/O
P20	IRQ0	in	-	P2PLU0	IRQ0 : External interrupt 0
P21	IRQ1 ACZ	in	-	P2PLU1	IRQ1 : External interrupt 1 ACZ : Zero-cross input
P22	IRQ2	in	-	P2PLU2	IRQ2 : External interrupt 2
P23*1	IRQ3	in	-	P2PLU3	IRQ3 : External interrupt 3
P27	NRST	in	-	-	NRST : Reset
P60		in/out	P6DIR0	P6PLU0	
P61		in/out	P6DIR1	P6PLU1	
P62		in/out	P6DIR2	P6PLU2	
P63		in/out	P6DIR3	P6PLU3	
P64		in/out	P6DIR4	P6PLU4	
P65		in/out	P6DIR5	P6PLU5	
P66		in/out	P6DIR6	P6PLU6	
P67		in/out	P6DIR7	P6PLU7	
P70*2		in/out	P7DIR0	P7PLUD0	
P71*1		in/out	P7DIR1	P7PLUD1	
P80	LED0	in/out	P8DIR0	P8PLU0	LED0 : LED driver pin 0
P81	LED1	in/out	P8DIR1	P8PLU1	LED1 : LED driver pin 1
P82	LED2	in/out	P8DIR2	P8PLU2	LED2 : LED driver pin 2
P83	LED3	in/out	P8DIR3	P8PLU3	LED3 : LED driver pin 3
P84	LED4	in/out	P8DIR4	P8PLU4	LED4 : LED driver pin 4
P85	LED5	in/out	P8DIR5	P8PLU5	LED5 : LED driver pin 5
P86	LED6	in/out	P8DIR6	P8PLU6	LED6 : LED driver pin 6
P87	LED7	in/out	P8DIR7	P8PLU7	LED7 : LED driver pin 7
PA0	AN0	in	-	PAPLUD0	AN0 : Analog 0 input
PA1	AN1	in	-	PAPLUD1	AN1 : Analog 1 input
PA2	AN2	in	-	PAPLUD2	AN2 : Analog 2 input
PA3	AN3	in	-	PAPLUD3	AN3 : Analog 3 input
PA4	AN4	in	-	PAPLUD4	AN4 : Analog 4 input
PA5	AN5	in	-	PAPLUD5	AN5 : Analog 5 input
PA6	AN6	in	-	PAPLUD6	AN6 : Analog 6 input
PA7	AN7	in	-	PAPLUD7	AN7 : Analog 7 input

*1 : Allocated only to 48-pin TQFP package type
*2 : Not allocated to 42-pin SDIP package type

1-3-3 Pin Functions

Note that Pin NO. described on this table are only for 48-pin TQFP package type.
[☞ Fig. 1-3-3 Pin Configuration]

Table 1-3-2 Pin Function Summary (1/5)

Name	No. (80 pin)	I/O	Other Function	Function	Description
VSS VDD	17 14			Power supply pin	Supply 2.0 V to 5.5 V to VDD and 0 V to VSS.
OSC1 OSC2	16 15	Input Output		Clock input pin Clock output pin	Connect these oscillation pins to ceramic or crystal oscillators for high-frequency clock operation. If the clock is an external input, connect it to OSC1 and leave OSC2 open. The chip will not operate with an external clock when using either the STOP or SLOW modes.
XI XO	18 19	Input Output		Clock input pin Clock output pin	Connect these oscillation pins to crystal oscillators for low-frequency clock operation. If the clock is an external input, connect it to XI and leave XO open. The chip will not operate with an external clock when using the STOP mode. If these pins are not used, connect XI to VSS and leave XO open. * These pins are not allocated to 42-SDIP, 44-QFP package type
NRST	43	Input	P27	Reset pin [Active low]	This pin resets the chip when power is turned on, is allocated to P27 and contains an internal pull-up resistor (Typ.35 kΩ). Setting this pin low initializes the internal state of the device. The reset will be released by setting this pin to high input level. The hardware waits for the system clock to stabilize, then processes the reset interrupt. Also, if "0" is written to P27 and the reset is initiated by software, a low level voltage will be output. The output has an n-channel open-drain configuration. If a capacitor is to be inserted between NRST and VDD, it is recommended that a discharge diode be placed between NRST and VDD.
P00 P01 P02 P06	20 21 22 23	I/O	SBO0, TXD SBI0, RXD SBT0 BUZZER	I/O port 0	4-Bit CMOS tri-state I/O port. Each bit can be set individually as either an input or output by the P0DIR register. A pull-up resistor for each bit can be selected individually by the P0PLU register. At reset, the input mode is selected and pull-up resistors are disabled (high impedance output).
P10 P11 P12 P13 P14	24 25 26 27 28	I/O	RMOUT TM2IO TM3IO TM4IO	I/O port 1	5-Bit CMOS tri-state I/O port. Each bit can be set individually as either an input or output by the P1DIR register. A pull-up resistor for each bit can be selected individually by the P1PLU register. At reset, the input mode is selected and pull-up resistors are disabled (high impedance output).

Table 1-3-3 Pin Function Summary (2/5)

Name	No. (80 pin)	I/O	Other Function	Function	Description
P20 P21 P22 P23	29 30 31 32	Input	IRQ0 IRQ1, ACZ IRQ2 IRQ3	Input port 2	4-Bit input port. A pull-up resistor for each bit can be selected individually by the P2PLU register. At reset, pull-up resistors are disabled. *P23 is not allocated to 42-SDIP, 44-QFP package type
P27	43	Input	NRST	Input port 2	P27 has an n-channel open-drain configuration. When "0" is written and the reset is initiated by software, a low level voltage will be output.
P60 P61 P62 P63 P64 P65 P66 P67	33 34 35 36 37 38 39 40	I/O		I/O port 6	8-Bit CMOS tri-state I/O port. Each bit can be set individually as either an input or output by the P6DIR register. A pull-up resistor for each bit can be selected individually by the P6PLU register. At reset, when the input mode is selected, pull-up resistors are disabled (high impedance output).
P70 P71	45 46	I/O		I/O port 7	8-Bit CMOS tri-state I/O port. Each bit can be set individually as either an input or output by the P7DIR register. A pull-up or pull-down resistor for each bit can be selected individually by the P7PLUD register. However, pull-up and pull-down resistors cannot be mixed. At reset, when the input mode is selected, pull-up resistors are disabled (high impedance output). *P70,P71 are not allocated to 42-SDIP package type *P71 is not allocated to 44-QFP package type
P80 P81 P82 P83 P84 P85 P86 P87	4 3 2 1 48 47 46 45	I/O	LED0 LED1 LED2 LED3 LED4 LED5 LED6 LED7	I/O port 8	8-Bit CMOS tri-state I/O port. Each individual bit can be switched to an input or output by the P8DIR register. A pull-up resistor for each bit can be selected individually by the P8PLU register. When configured as outputs, these pins can drive LEDs directly. At reset, when the input mode is selected, pull-up resistors are disabled (high impedance output).
PA0 PA1 PA2 PA3 PA4 PA5 PA6 PA7	6 7 8 9 10 11 12 13	Input	AN0 AN1 AN2 AN3 AN4 AN5 AN6 AN7	Input port A	8-Bit input port. A pull-up or pull-down resistor for each bit can be selected individually by the PAPLUD resister. However, pull-up and pull-down resistors cannot be mixed. At reset, when the PA0 to PA7 input mode is selected and pull- up resistors are disabled.

Table 1-3-4 Pin Function Summary (3/5)

Name	No. (80 pin)	I/O	Other Function	Function	Description
SBO0	20	Output	P00, TXD	Serial interface transmission data output pins	Transmission data output pins for serial interfaces 0. The output configuration, either CMOS push-pull or n-channel open-drain can be selected. Pull-up resistors can be selected by the P0PLU register. Select output mode by the P0DIR register, and serial data output mode by serial mode register (SC0MD3). These can be used as normal I/O pins when the serial interface is not used.
SBI0	21	Input	P01, RXD	Serial interface received data input pins	Receive data input pins for serial interfaces 0. Pull-up resistors can be selected by the P0PLU register. Select input mode by the P0DIR register, and serial input mode by the serial mode register (SC0MD3). These can be used as normal I/O pins when the serial interface is not used.
SBT0	22	I/O	P02 P05	Serial interface clock I/O pins	Clock I/O pins for serial interfaces 0. The output configuration, either CMOS push-pull or n-channel open-drain can be selected. Pull-up resistors can be selected by the P0PLU register. Select clock I/O for each communication mode by the P0DIR register and serial mode register (SC0MD3). These can be used as normal I/O pins when the serial interface is not used.
TXD	20	Output	SBO0, P00	UART transmission data output pin	In the serial interface in UART mode, this pin is configured as the transmission data output pin. The output configuration, either CMOS push-pull or n-channel open-drain can be selected. Pull-up resistors can be selected by the P0PLU resister. Select output mode by the P0DIR register, and serial data output by serial 0 mode register 3 (SC0MD3). This can be used as normal I/O pin when the serial interface is not used.

Table 1-3-5 Pin Function Summary (4/5)

Name	No. (80 pin)	I/O	Other Function	Function	Description
RXD	21	Input	SBI0, P01	UART received data input pin	In the serial interface in UART mode, this pis is configured as the received data input pin. Pull-up resistors can be selected by the P0PLU register. Set this pin to the input mode by the P0DIR register, and to the serial input mode by the serial 0 mode register 3 (SC0MD3). This can be used as normal I/O pin when the serial interface is not used.
TM2IO TM3IO	26 27	I/O	P12 P13	Timer I/O pins	Event counter clock input pins, timer output and PWM signal output pins for 8-bit timers 2 to 3. To use these pins as event clock inputs, configure these pins to input mode through the P1DIR register. When the pins are used as input pins, pull-up resistors can be specified by the P1PLU register. For timer output, PWM signal output, select the special function pin by the port 1 output mode register (P1OMD) and set to the output mode by the P1DIR register. When not used for timer I/O, these can be used as normal I/O pins.
RMOUT	24	I/O	P10	Remote control transmission signal output pin	Output pin for remote control transmission signal with a carrier signal. For remote control carrier output, select the special function pin by the port 1 output mode register (P1OMD) and set to the output mode by the P1DIR register. This can be used as a normal I/O pin when remote control is not used.
BUZZER	23	Output	P06	Buzzer output	Piezoelectric buzzer driver pin. The driving frequency can be selected by the DLYCTR register. Select output mode by the P0DIR register and select P06 buzzer output by the DLYCTR register. When not used for buzzer output, this pin can be used as a normal I/O pin.
TM4IO	28	I/O	P14	Timer I/O pin	Event counter clock input pin, timer output and PWM signal output pin for 16-bit timer 4. To use this pin as event clock input, configure this as input pins through the P1DIR register. In the input mode, pull-up resistors can be selected by the P1PLU register. For timer output, PWM signal output, select the special function pin by the port 1 output mode register (P1OMD), and set to the output mode by the P1DIR register. When not used for timer I/O, this can be used as normal I/O pin.

Table 1-3-6 Pin Function Summary (5/5)

Name	No. (80 pin)	I/O	Other Function	Function	Description
AN0 AN1 AN2 AN3 AN4 AN5 AN6 AN7	62 63 64 1 2 3 4 5	Input	PA0 PA1 PA2 PA3 PA4 PA5 PA6 PA7	Analog input pins	Analog input pins for an 8-channel, 10-bit A/D converter. When not used for analog input, these pins can be used as normal input pins.
IRQ0 IRQ1 IRQ2 IRQ3	29 30 31 32	Input	P20 P21, ACZ P22 P23	External interrupt input pins	External interrupt input pins. The valid edge for IRQ0 to 3 can be selected through the IRQnICR register. IRQ1 is an external interrupt pin that is able to determine AC zero crossings. When these are not used for interrupts, these can be used as normal input pins. *IRQ3 pin is not allocated to 42-SDIP and 44-QFP package types.
ACZ	30	Input	P21, IRQ1	AC zero-cross detection input pin	An input pin for an AC zero-cross detection circuit. The AC zero-cross detection circuit outputs a high level when the input is at an intermediate level. Otherwise It outputs a low level voltage. ACZ input signal is connected to the P21 input circuit and to the IQR1 interrupt circuit. When the AC zero-cross detection circuit is not used, this pin can be used as a normal P21 input. The selection is set by the P21IM flag of the FLOAT1 register.
MMOD	44	Input		Test mode switch input pin	This pin sets the test mode and needs to be set always to "L".

1-4 Block Diagram

1-4-1 Block Diagram

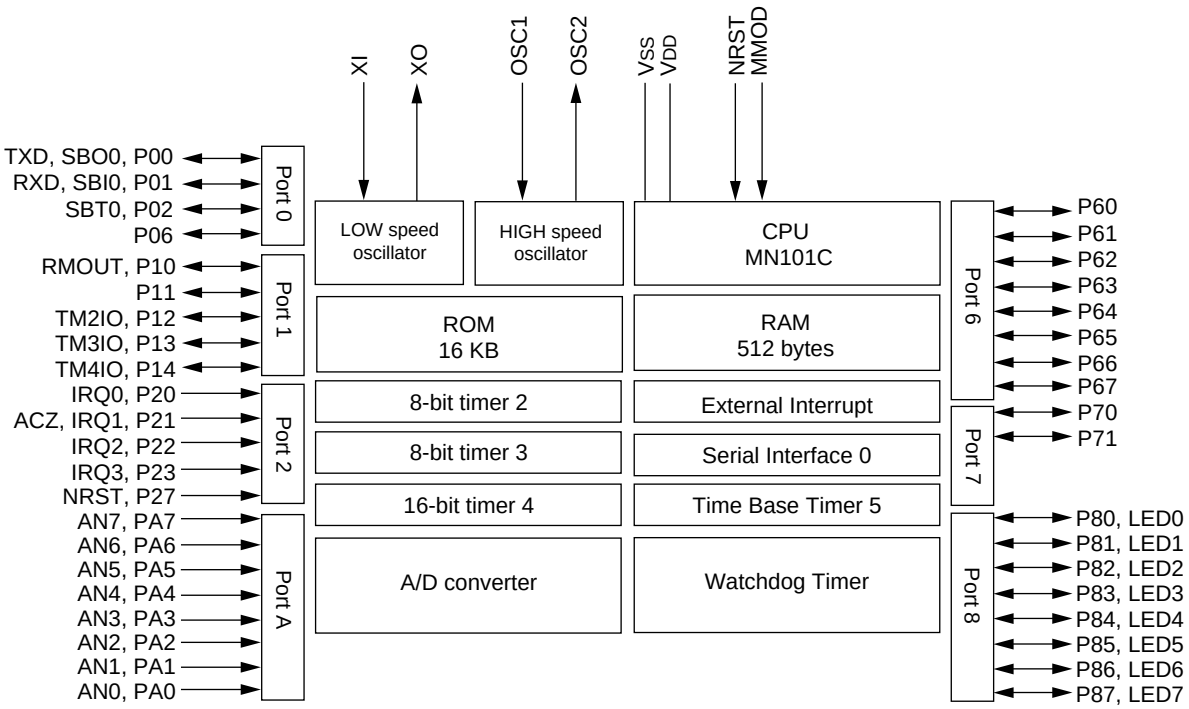


Figure 1-4-1 Block Diagram (48-TQFP package type)

1-5 Electrical Characteristics

This LSI user's manual describes the standard specification. System clock (fs) is : 1/2 of high speed oscillation at NORMAL mode, or 1/4 of low speed oscillation at SLOW mode. Please ask our sales offices for its own product specifications.

Contents \ Model	MN101C457
Structure	CMOS integrated circuit
Application	General purpose
Function	8-Bit single-chip microcontroller

1-5-1 Absolute Maximum Ratings*2,*3 (voltages referenced to V_{SS})

No.	Parameter		Symbol	Rating	Unit
1	Power supply voltage		V_{DD}	- 0.3 to +7.0	V
2	Input clamp current (ACZ)		I_C	- 500 to +500	µA
3	Input pin voltage		V_I	- 0.3 to V_{DD} +0.3	V
4	Output pin voltage		V_O	- 0.3 to V_{DD} +0.3	
5	I/O pin voltage		V_{IO1}	- 0.3 to V_{DD} +0.3	
6	Peak output current	Port 8	I_{OL1} (peak)	30	mA
7		Other than port 8	I_{OL2} (peak)	20	
8		All pins	I_{OH} (peak)	- 10	
9	Average output current *1	Port 8	I_{OL1} (avg)	20	
10		Other than port 8	I_{OL2} (avg)	15	
11		All pins	I_{OH} (avg)	- 5	
12	Power dissipation		P_D	400	mW
13	Operating ambient temperature		T_{opr}	- 40 to +85	°C
14	Storage temperature		T_{stg}	- 55 to +125	

*1 Applied to any 100 ms period.

*2 Connect at least one bypass capacitor of 0.1 µF or larger between the power supply pin and the ground for latch-up prevention.

*3 The absolute maximum ratings are the limit values beyond which the LSI may be damaged and proper operation is not assured.

1-5-2 Operating Conditions [NORMAL mode : fs=fosc/2, SLOW mode : fs=fx/4]

Ta=-40 °C to +85 °C V_{DD}=2.0 V (2.7 V) to 5.5 V V_{SS}=0 V
EPROM vers. is in ( ).

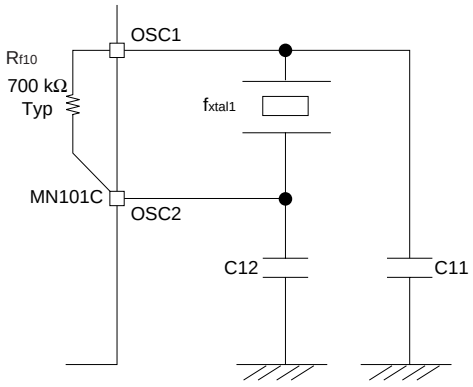
Parameter		Symbol	Conditions	Rating			Unit
				MIN	TYP	MAX	
Power supply voltage							
1	Power supply voltage	V_{DD1}	fosc≤20.0 MHz	4.5		5.5	V
2		V_{DD2}	fosc≤8.39 MHz	2.7		5.5	
3		V_{DD3}	fosc≤4.19 MHz	2.0 (2.7)		5.5	
4		V_{DD4} *1	fx=32 kHz	2.0 (2.7)		5.5	
5	Voltage to maintain RAM data	V_{DD5}	During STOP mode	1.8		5.5	
Operation speed *2							
6	Miniumum instruction execution time	t_{c1}	V_{DD}=4.5 V to 5.5 V	0.100			µs
7		t_{c2}	V_{DD}=2.7 V to 5.5 V	0.238			
8		t_{c3}	V_{DD}=2.0 V (2.7 V) to 5.5 V	0.477			
9		t_{c4} *1	V_{DD}=2.0 V (2.7 V) to 5.5 V	40		125	

*1 Applied only to 48-pin TQFP package type

*2 tc1, tc2, tc3 : 1/2 of high speed oscillation at NORMAL mode
tc4 : 1/4 of low speed oscillation at SLOW mode

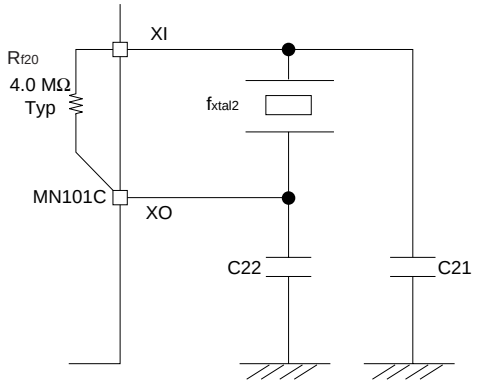
Ta=-40 °C to +85 °C V_{DD}=2.0 V (2.7 V) to 5.5 V V_{SS}=0 V
EPROM vers. is in ( ).

	Parameter	Symbol	Conditions	Rating			Unit
				MIN	TYP	MAX	
Crystal oscillator 1 Fig. 1-5-1							
10	Crystal frequency	f_{xtal1}	depending on operating voltage	1.0		20.0	MHz
11	External capacitors	C_{11}			20		pF
12		C_{12}			20		
13	Internal feedback resistor	R_{f10}			700		kΩ
Crystal oscillator 2 Fig. 1-5-2							
14	Crystal frequency	f_{xtal2}		32.768		100	kHz
15	External capasitors	C_{21}			20		pF
16		C_{22}			20		
17	Internal feedback resistor	R_{f20}			4.0		MΩ



The feedback resistor is built-in.

Figure 1-5-1 Crystal Oscillator 1



The feedback resistor is built-in.

Figure 1-5-2 Crystal Oscillator 2

Connect external capacitors that suit for used oscillator. When crystal oscillator or ceramic oscillator is used, the oscillation frequency is changed depending on condenser. Consult the oscillator manufacturer to select the suitable external capacitor.

Ta=-40 °C to +85 °C V_{DD}=2.0 V (2.7 V) to 5.5 V V_{SS}=0 V
EPROM vers. is in ( ).

Parameter		Symbol	Conditions	Rating			Unit
				MIN	TYP	MAX	
External clock input 1 OSC1 (OSC2 is unconnected)							
18	Clock frequency	f_{osc}		1.0		20.0	MHz
19	High level pulse width	t_{wh1}	*3 Fig. 1-5-3	20.0			ns
20	Low level pulse width	t_{wl1}		20.0			
21	Rising time	t_{wr1}	Fig. 1-5-3			5.0	
22	Falling time	t_{wf1}				5.0	
External clock input 2 XI (XO is unconnected) *1							
23	Clock frequency	f_x		32.768		100	kHz
24	High level pulse width	t_{wh2}	*3 Fig. 1-5-4	3.5			µs
25	Low level pulse width	t_{wl2}		3.5			
26	Rising time	t_{wr2}	Fig. 1-5-4			20	ns
27	Falling time	t_{wf2}				20	

*3 The clock duty rate should be 45% to 55%.

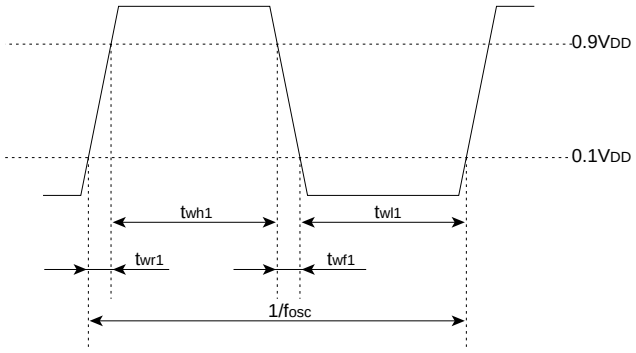


Figure 1-5-3 OSC1 Timing Chart

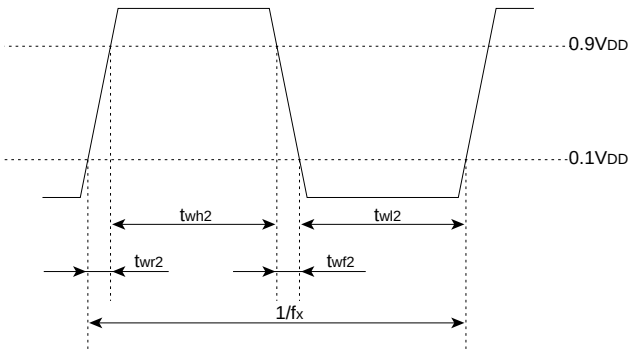


Figure 1-5-4 XI Timing Chart

1-5-3 DC Characteristics

Ta=-40 °C to +85 °C V_{DD}=2.0 V (2.7 V) to 5.5 V V_{SS}=0 V
EPROM vers. is in ( ).

Parameter		Symbol	Conditions	Rating			Unit
				MIN	TYP	MAX	
Power supply current (no load at output pin) *1							
1	Power supply current	I_{DD1}	fosc=20.0 MHz V_{DD}=5 V (fs=fosc/2)		15	40	mA
2		I_{DD2}	fosc=8.39 MHz V_{DD}=5 V (fs=fosc/2)		6	18	
3		I_{DD3} *2	fx=32 kHz V_{DD}=3 V (fs=fx/4)			100	µA
4	Supply current during HALT mode	I_{DD4} *2	fx=32 kHz V_{DD}=3 V Ta=25 °C			8	
5		I_{DD5} *2	fx=32 kHz V_{DD}=3 V Ta=-40 °C to +85 °C			18	
6	Supply current during STOP mode	I_{DD6}	V_{DD}=5 V Ta=25 °C		0	2	
7		I_{DD7}	V_{DD}=5 V Ta=-40 °C to +85 °C		0	20 t.b.a.	

*1 Measured under conditions of no load.

- The supply current during operation, I_{DD1}(I_{DD2}), is measured under the following conditions : After all I/O pins are set to input mode and the oscillation is set to <NORMAL mode>, the MMOD pin is at V_{SS} level, the input pins are at V_{DD} level, and a 20 MHz (8.39 MHz) square wave of V_{DD} and V_{SS} amplitudes is input to the OSC1 pin.
- The supply current during operation, I_{DD3}, is measured under the following conditions : After all I/O pins are set to input mode and the oscillation is set to <SLOW mode>, the MMOD pin is at V_{SS} level, the input pins are at V_{DD} level, and a 32 kHz square wave of V_{DD} and V_{SS} amplitudes is input to the XI pin.
- The supply current during HALT mode, I_{DD4}, is measured under the following conditions : After all I/O pins are set to input mode and the oscillation is set to <HALT mode>, the MMOD pin is at V_{SS} level, the input pins are at V_{DD} level, and an 32 kHz square wave of V_{DD} and V_{SS} amplitudes is input to the XI pin.
- The supply current during STOP mode, I_{DD6} is measured under the following conditions : After the oscillation is set to <STOP mode>, the MMOD pin is at V_{SS} level, the input pins are at V_{DD} level, and the OSC1 and XI pins are unconnected.

*2 Parameters of I_{DD3} and I_{DD4}(I_{DD5}) are applied only to 48-pin TQFP package type.

Ta=-40 °C to +85 °C V_{DD}=2.0 V (2.7 V) to 5.5 V V_{SS}=0 V
EPROM vers. is in ( ).

	Parameter	Symbol	Conditions	Rating			Unit
				MIN	TYP	MAX	
Input pin 1 MMOD							
8	Input high voltage 1	V_{IH1}		0.9 V_{DD}		V_{DD}	V
9	Input low voltage 1	V_{IL1}		0		0.2 V_{DD}	
10	Input leakage current	I_{LK1}	V_I=0 V to V_{DD}			± 10	µA
Input pin 2 P20, P22 to P23(Schmitt trigger input)							
11	Input high voltage	V_{IH2}		0.8 V_{DD}		V_{DD}	V
12	Input low voltage	V_{IL2}		0		0.2 V_{DD}	
13	Input leakage current	I_{LK2}	V_I=0 V to V_{DD}			± 10	µA
14	Input high current	I_{IH2}	V_{DD}=5.0 V V_I=1.5 V Pull-up resistor ON	-30	-100	-300	
Input pin 3-1 P21(Schmitt trigger input)							
15	Input high voltage	V_{IH3}		0.8 V_{DD}		V_{DD}	V
16	Input low voltage	V_{IL3}		0		0.2 V_{DD}	
17	Input leakage current	I_{LK3}	V_I=0 V to V_{DD}			± 10	µA
18	Input high current	I_{IH3}	V_{DD}=5.0 V V_I=1.5 V Pull-up resistor ON	-30	-100	-300	
Input pin 3-2 P21(at used as ACZ)							
19	Input high voltage 1	V_{DHH}	V_{DD}=5.0 V Fig. 1-5-5	4.5		V_{DD}	V
20	Input low voltage 1	V_{DLH}		V_{SS}		3.5	
21	Input high voltage 2	V_{DHL}		1.5		V_{DD}	
22	Input low voltage 2	V_{DLL}		V_{SS}		0.5	
23	Input leakage current	I_{LK4}	V_I=0 V to V_{DD}			± 10	µA
24	Input clamp current	I_{C4}	V_{DD}=5.0 V V_I>V_{DD} V_I<0 V			± 400	
ACZ pins							
25	Rising time	t_{rs}	Fig. 1-5-5	30			µs
26	Falling time	t_{fs}		30			

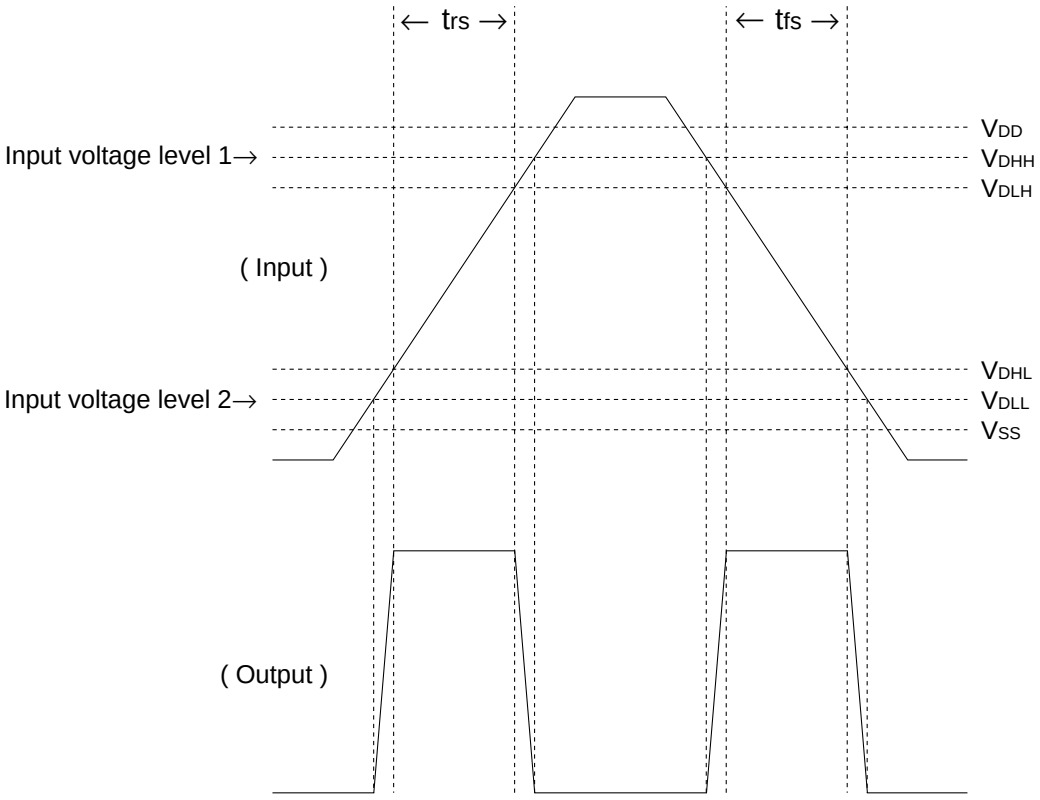


Figure 1-5-5 AC Zero-Cross Detector

Ta=-40 °C to +85 °C V_{DD}=2.0 V (2.7 V) to 5.5 V V_{SS}=0 V
EPROM vers. is in ( ).

Parameter		Symbol	Conditions	Rating			Unit
				MIN	TYP	MAX	
Input pin 4 PA 0 to PA 7							
27	Input high voltage 1	V_{IH5}		0.8 V_{DD}		V_{DD}	V
28	Input high voltage 2	V_{IH6}	V_{DD}=4.5 V to 5.5 V	0.7 V_{DD}		V_{DD}	
29	Input low voltage 1	V_{IL5}		0		0.2 V_{DD}	
30	Input low voltage 2	V_{IL6}	V_{DD}=4.5 V to 5.5 V	0		0.3 V_{DD}	
31	Input leakage current	I_{LK5}	V_I =0 V to V_{DD}			± 2	µA
32	Input high current	I_{IH5}	V_{DD}=5.0 V V_I =1.5 V Pull-up resistor ON	-30	-100	-300	
33	Input low current	I_{IL5}	V_{DD}=5.0 V V_I =3.5 V Pull-down resistor ON	80	180	400	
I/O pin 5 P27 (NRST)							
34	Input high voltage	V_{IH7}		0.9 V_{DD}		V_{DD}	V
35	Input low voltage	V_{IL7}		0		0.2 V_{DD}	
36	Input high current	I_{IH7}	V_{DD}=5.0 V V_I =1.5 V Pull-up resistor ON	-30	-100	-300	µA
I/O pin 6 P00 to P06, P10 to P14							
37	Input high voltage	V_{IH8}		0.8 V_{DD}		V_{DD}	V
38	Input low voltage	V_{IL8}		0		0.2 V_{DD}	
39	Input leakage current	I_{LK8}	V_I =0 V to V_{DD}			± 10	µA
40	Input high current	I_{IH8}	V_{DD}=5.0 V V_I =1.5 V Pull-up resistor ON	-30	-100	-300	
41	Output high voltage	V_{OH8}	V_{DD}=5.0 V I_{OH}=-0.5 mA	4.5			V
42	Output low voltage	V_{OL8}	V_{DD}=5.0 V I_{OL}=1.0 mA			0.5	
I/O pin 7 P60 to P67							
43	Input high voltage 1	V_{IH9}		0.8 V_{DD}		V_{DD}	V
44	Input high voltage 2	V_{IH10}	V_{DD}=4.5 V to 5.5 V	0.7 V_{DD}		V_{DD}	
45	Input low voltage 1	V_{IL9}		0		0.2 V_{DD}	
46	Input low voltage 2	V_{IL10}	V_{DD}=4.5 V to 5.5 V	0		0.3 V_{DD}	
47	Input leakage current	I_{LK9}	V_I =0 V to V_{DD}			± 10	µA
48	Input high current	I_{IH9}	V_{DD}=5.0 V V_I =1.5 V Pull-up resistor ON	-30	-100	-300	
49	Output high voltage	V_{OH9}	V_{DD}=5.0 V I_{OH}=-0.5 mA	4.5			V
50	Output low voltage	V_{OL9}	V_{DD}=5.0 V I_{OL}=1.0 mA			0.5	

Ta=-40 °C to +85 °C V_{DD}=2.0 V (2.7 V) to 5.5 V V_{SS}=0 V
EPROM vers. is in ( ).

	Parameter	Symbol	Conditions	Rating			Unit
				MIN	TYP	MAX	
Input pin 8 P70 to P71 *3							
51	Input high voltage 1	V_{IH11}		0.8 V_{DD}		V_{DD}	V
52	Input high voltage 2	V_{IH12}	V_{DD}=4.5 V to 5.5 V	0.7 V_{DD}		V_{DD}	
53	Input low voltage 1	V_{IL11}		0		0.2 V_{DD}	
54	Input low voltage 2	V_{IL12}	V_{DD}=4.5 V to 5.5 V	0		0.3 V_{DD}	
55	Input leakage current	I_{LK11}	V_I =0 V to V_{DD}			± 10	µA
56	Input high current	I_{IH11}	V_{DD}=5.0 V V_I =1.5 V Pull-up resistor ON	-30	-100	-300	
57	Input low current	I_{IL11}	V_{DD}=5.0 V V_I =3.5 V Pull-down resistor ON	80	180	400	
58	Output high voltage	V_{OH11}	V_{DD}=5.0 V I_{OH}=-0.5 mA	4.5			V
59	Output low voltage	V_{OL11}	V_{DD}=5.0 V I_{OL}=1.0 mA			0.5	
I/O pin 9 P80 to P87							
60	Input high voltage 1	V_{IH13}		0.8 V_{DD}		V_{DD}	V
61	Input high voltage 2	V_{IH14}	V_{DD}=4.5 V to 5.5 V	0.7 V_{DD}		V_{DD}	
62	Input low voltage 1	V_{IL13}		0		0.2 V_{DD}	
63	Input low voltage 2	V_{IL14}	V_{DD}=4.5 V to 5.5 V	0		0.3 V_{DD}	
64	Input leakage current	I_{LK13}	V_I =0 V to V_{DD}			± 10	µA
65	Input high current	I_{IH13}	V_{DD}=5.0 V V_I =1.5 V Pull-up resistor ON	-30	-100	-300	
66	Output high voltage	V_{OH13}	V_{DD}=5.0 V I_{OH}=-0.5 mA	4.5			V
67	Output low voltage	V_{OL13}	V_{DD}=5.0 V I_{OL}=15 mA			1.0	

*3 P70 to P71 are not allocated to 42-pin SDIL package type.
P71 is not allocated to 44-pin QFP package type.

1-5-4 A/D Converter Characteristics

Ta=-40 °C to +85 °C V_{DD}=2.0 V (2.7 V) to 5.5 V V_{SS}=0 V
EPROM vers. is in ( ).

	Parameter	Symbol	Conditions	Rating			Unit
				MIN	TYP	MAX	
1	Resolution					10	Bits
2	Non-linearity error 1		V_{DD}=5.0 V V_{SS}=0 V T_{AD}=800 ns			± 3	LSB
3	Differential non-linearity error 1					± 3	
4	Non-linearity error 2		V_{DD} =5.0 V V_{SS}=0 V f_{OSC}=32 kHz *1			± 5	
5	Differential non-linearity error 2					± 5	
6	Zero transition voltage		V_{DD}=5.0 V V_{SS}=0 V T_{AD}=800 ns		30	100	mV
7	Full-scale transition voltage				30	100	
8	A/D conversion time		T_{AD}=800 ns	9.6			µs
9			fx=32 kHz *1			183	
10	Sampling time		f_{OSC}=8 MHz	1.0		36	
11			fx=32 kHz *1		30.5		
12	Analog input voltage			V_{SS}		V_{DD}	V
13	Analog input leakage current		V_{ADIN}=0 V to 5.0 V unselected channel			± 2	µA

*1 Applied only to 48-pin TQFP package type.

1-6 Option

1-6-1 ROM Option

This LSI and the internal EPROM can specify the watchdog timer frequency, select the packages and disenable the watchdog timer during operation by bit 2 to 0 of the ROM option address.

■ROM Option Bits

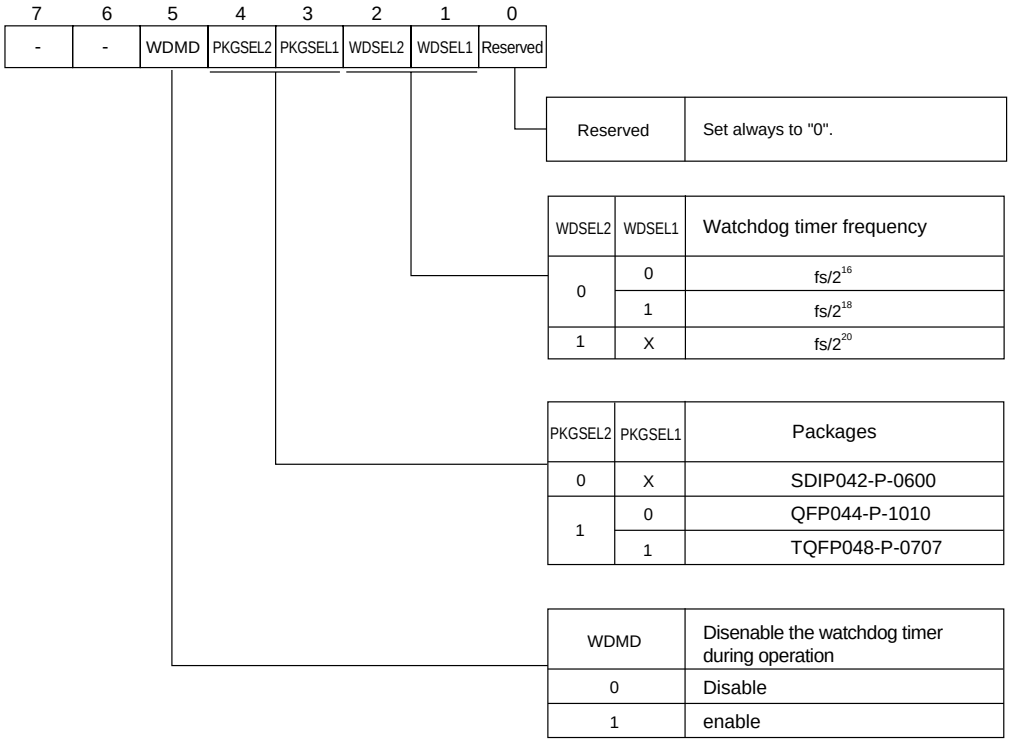


Figure 1-6-1 ROM Option Bits

Table 1-6-1 ROM Option Address

Model	ROM option address
MN101C457	x'07FFF'
MN101CP427	x'07FFF'

Once started, watchdog timer cannnot be stopped if WDMD(bp5) is set to "0".
In this setup, when WDEN flag of watchdog timer control register(WDCTR) is set to "0" , counter operation cannnot be stopped except upper 2 bits of the watchdog timer.

1-6-2 Option Check List

Date :

SE No.

Model Name	MN101C

1. Watchdog timer frequency

$fs/2^{16}$	☐
$fs/2^{18}$	☐
$fs/2^{20}$	☐
Unused	☐

2. Packages

SDIP042-P-0750	☐
QFP044-P-1010	☐
TQFP048-P-0707	☐

2. Disenable watchdog timer during operation

Disable	☐
Enable	☐

Signature

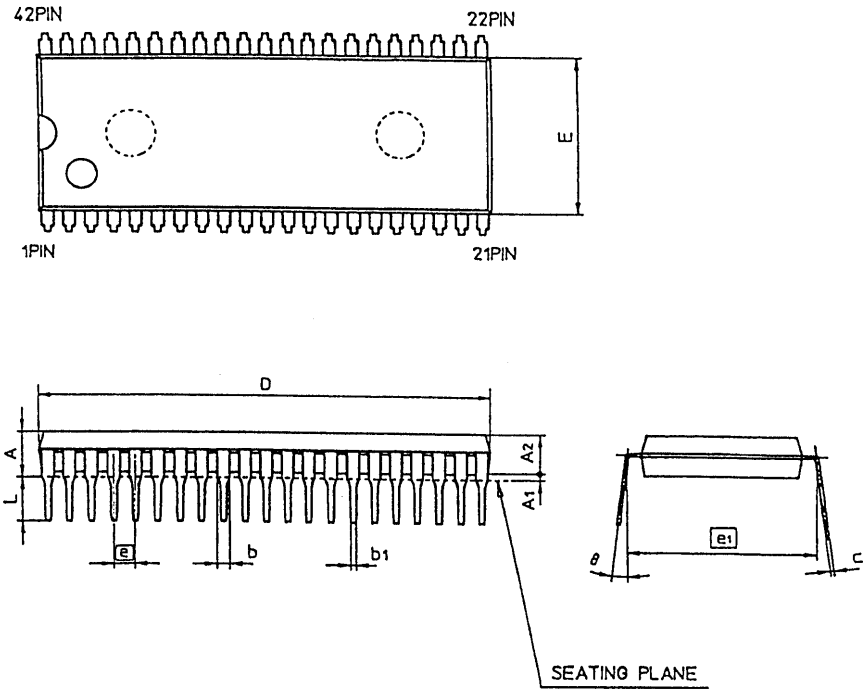
This check list is subjected to change. Please request the most recent check list from the sales office when doing ROM release.

Option of this product is used a part of the built-in ROM.
Please set data on the address of the option when doing ROM release.

1-7 Package Dimension

Package Code : SDIP042-P-0600

Units : mm



Symbol	Dimension in Millimeters		
	Min	Nom	Max
A	4.0	4.3	4.6
A1	—	1.0	—
A2	3.1	3.3	3.5
b	0.9	1.0	1.1
b1	0.4	0.5	0.6
b2	—	—	—
c	0.25	0.25	0.45
D	36.7	37.0	37.3
E	12.8	13.0	13.2
e	—	1.778	—
e1	—	15.24	—
L	3.0	3.3	3.6
θ	0		15

Sealing material :	EPOXY resin
Lead material :	Fe-Ni
Lead surface processing :	Solder plate

Figure 1-7-1 42-Pin SDIP

The package dimension is subjected to change. Before using this product, please obtain product specifications from the sales office.

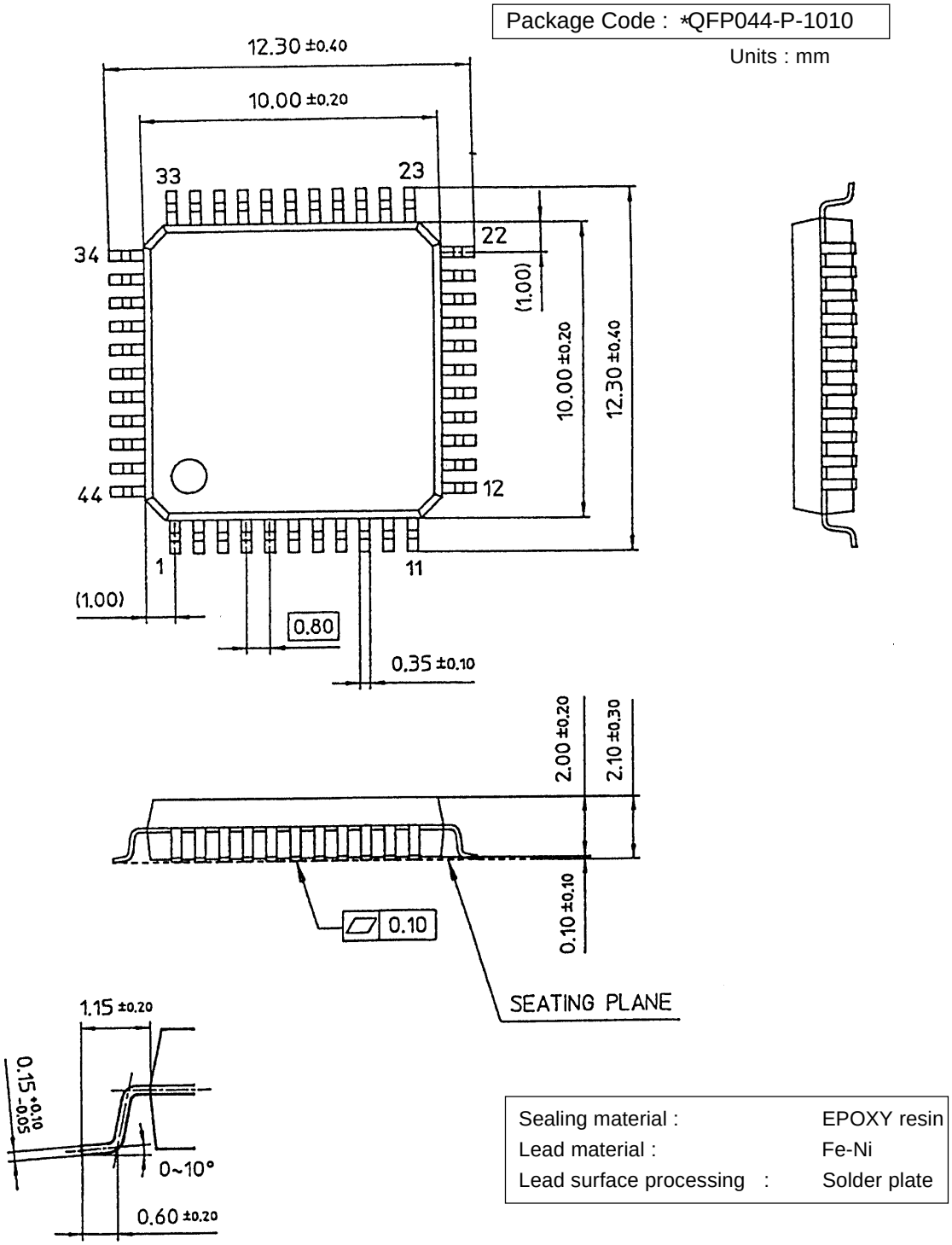
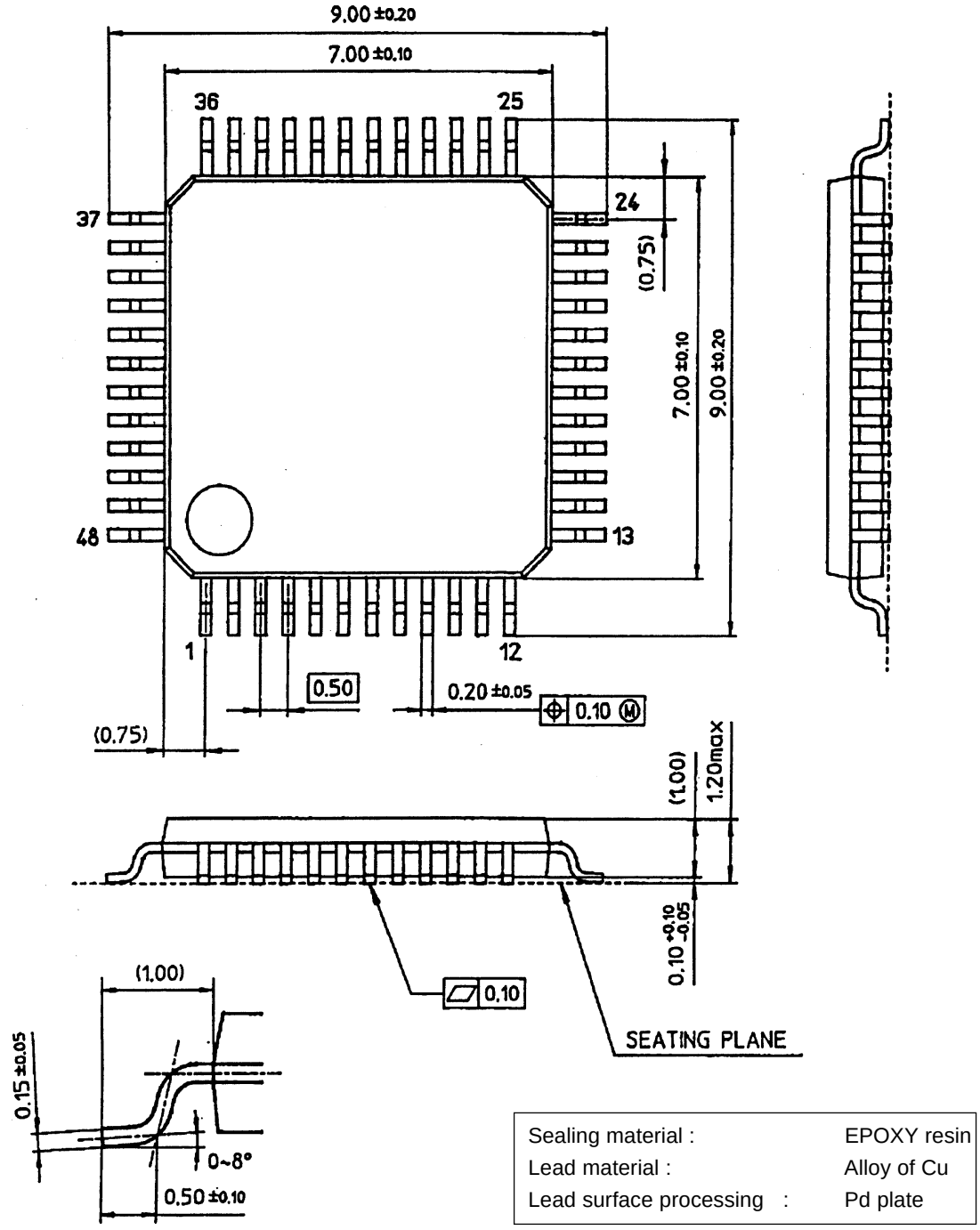


Figure 1-7-2 44-Pin QFP

> The package dimension is subjected to change. Before using this product, please obtain product specifications from the sales office.

Package Code : TQFP048-P-0707B

Units : mm



Sealing material :	EPOXY resin
Lead material :	Alloy of Cu
Lead surface processing :	Pd plate

Figure 1-7-3 48-Pin TQFP

The package dimension is subjected to change. Before using this product, please obtain product specifications from the sales office.

1-8 Precautions

1-8-1 General Usage

■Connection of V_{DD} pin, and V_{SS} pin

All V_{DD} pins should be connected directly to the power supply and all V_{SS} pins should be connected to ground in the external. Please consider the LSI chip orientation before mounting it on to the printed circuit board. Incorrect connection may lead a fusion and break a micro controller.

■Cautions for Operation

(1) If you install the product close to high-field emissions (under the cathode ray tube, etc), shield the package surface to ensure normal performance.

(2) Each model has different operating condition,
- Operation temperature should be well considered. For example, if temperature is over the operating condition, its operation may be executed wrongly.
- Operation voltage should be also well considered. If the operation voltage is over the operation range, it can be shortened the length of its life. If the operation voltage is below the operating range, it operation may be wrong.

1-8-2 Unused Pins

■Unused Pins (only for output)
Set unused pins (only for output) open.

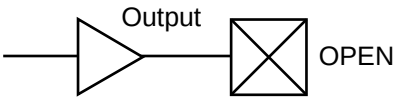


Figure 1-8-1 Unused Pins (only for output)

■Unused Pins (only for input)
Insert 10 kΩ to 100 kΩ resistor to unused pins (only for input) for pull-up or pull-down. If the input is unstable, Pch transistor and Nch transistor of input inverter are on, and through current goes to the input circuit. That increases current consumption and causes power supply noise.

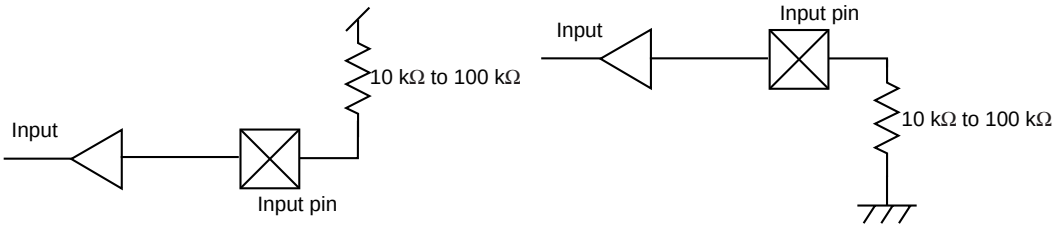


Figure 1-8-2 Unused Pins (only for input)

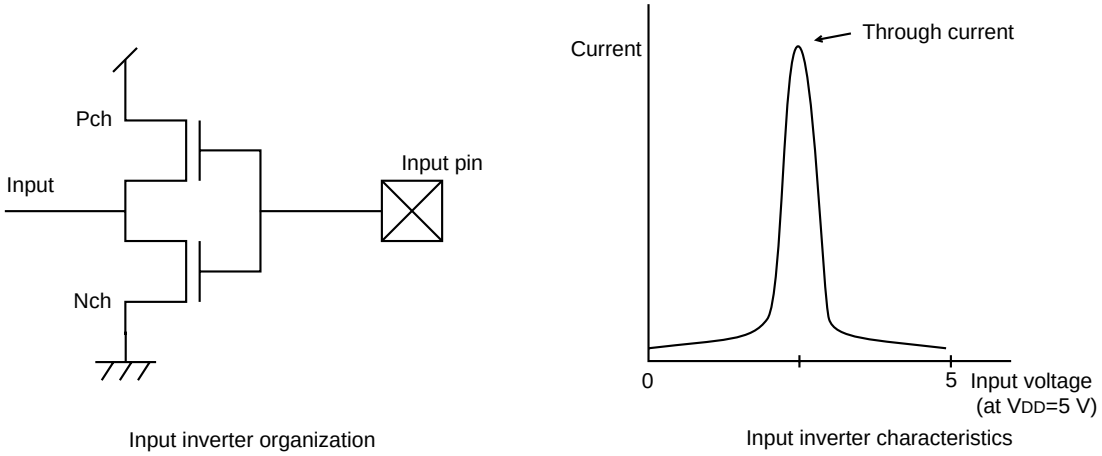


Figure 1-8-3 Input Inverter Organization and Characteristics

■Unused pins (for I/O)

Unused I/O pins should be set according to pins' condition at reset. If the output is high impedance (Pch / Nch transistor : output off) at reset, to stabilize input, set 10 kΩ to 100 kΩ resistor to be pull-up or pull-down. If the output is on at reset, set them open.

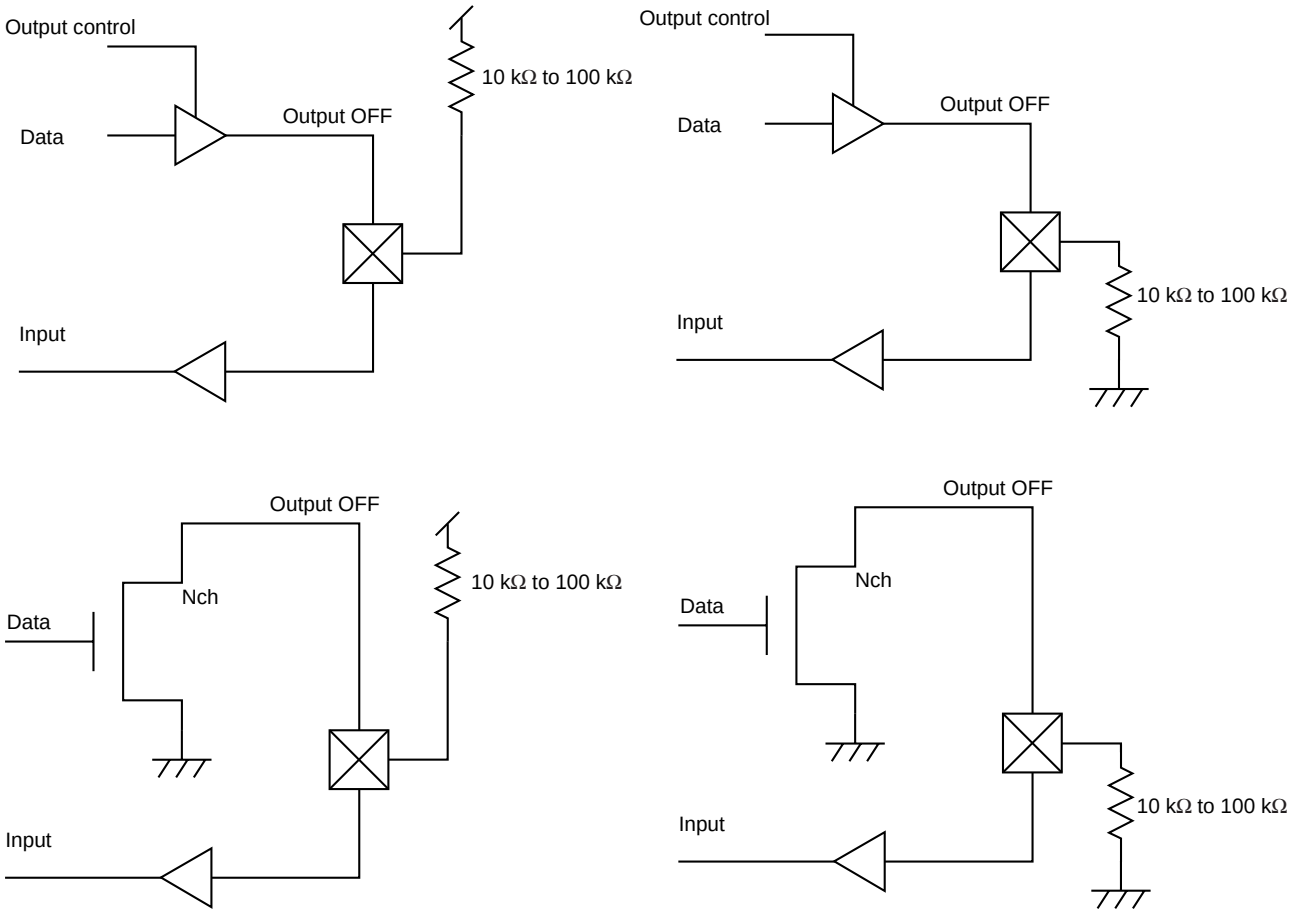


Figure 1-8-4 Unused I/O pins (high impedance output at reset)

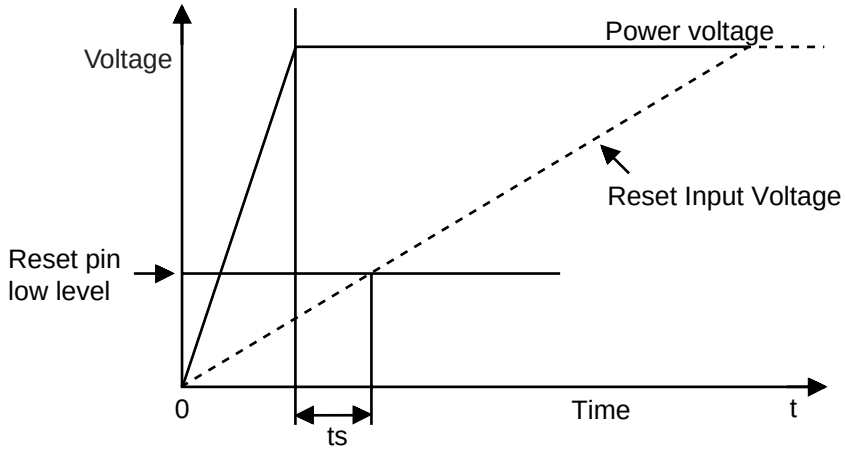
1-8-3 Power Supply

■The Relation between Power Supply and Input Pin Voltage

Input pin voltage should be supplied only after power supply is on. If the input pin voltage is applied before power supply is on, a latch up occurs and causes the destruction of micro controller by a large current flow.

■The Relation between Power Supply and Reset Input Voltage

After power supply is on, reset pin voltage should be low for sufficient time, ts, before rising, in order to be recognized as a reset signal.



[☞ Chapter 2. 2-5-1 Reset Operation]

Figure 1-8-5 Power Supply and Reset Input Voltage

1-8-4 Power Supply Circuit

■Cautions for Setting Circuits with V_{DD}

The CMOS logic microcontroller is high speed and high density. So, the power circuit should be designed, taking into consideration of AC line noise, ripple caused by LED driver. Figure 1-8-6 shows an example for emitter follower type power supply circuit.

■An Example for Emitter Follower Type Power Supply Circuit

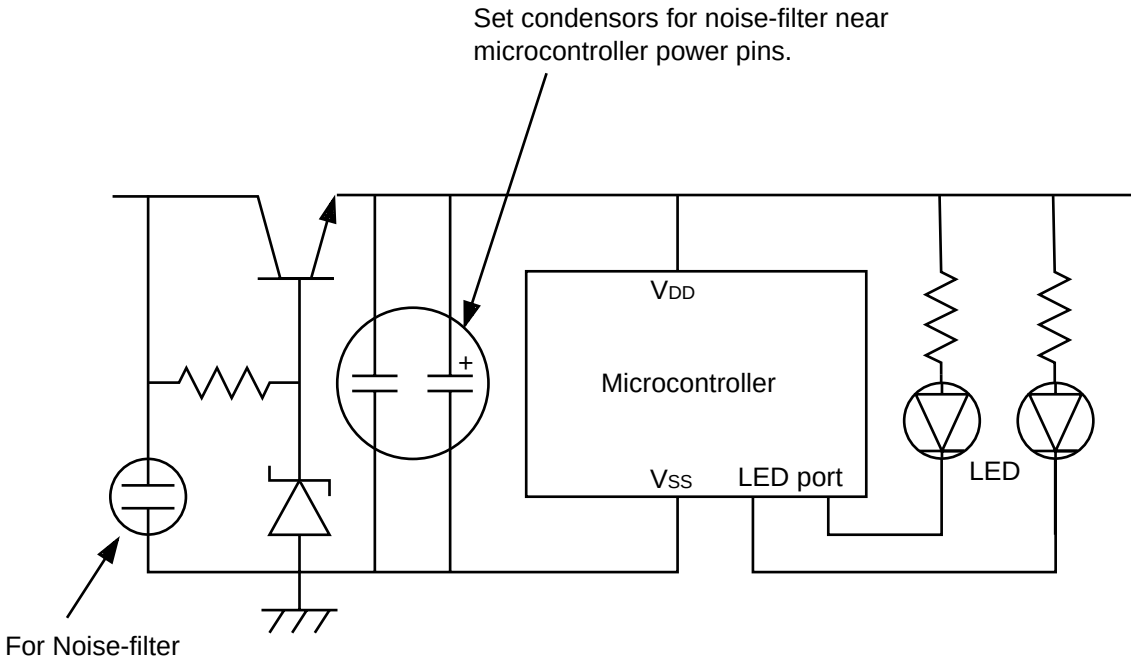


Figure 1-8-6 An Example for Emitter Follower Type Power Supply Circuit

Chapter 2 CPU Basics

2-1 Overview

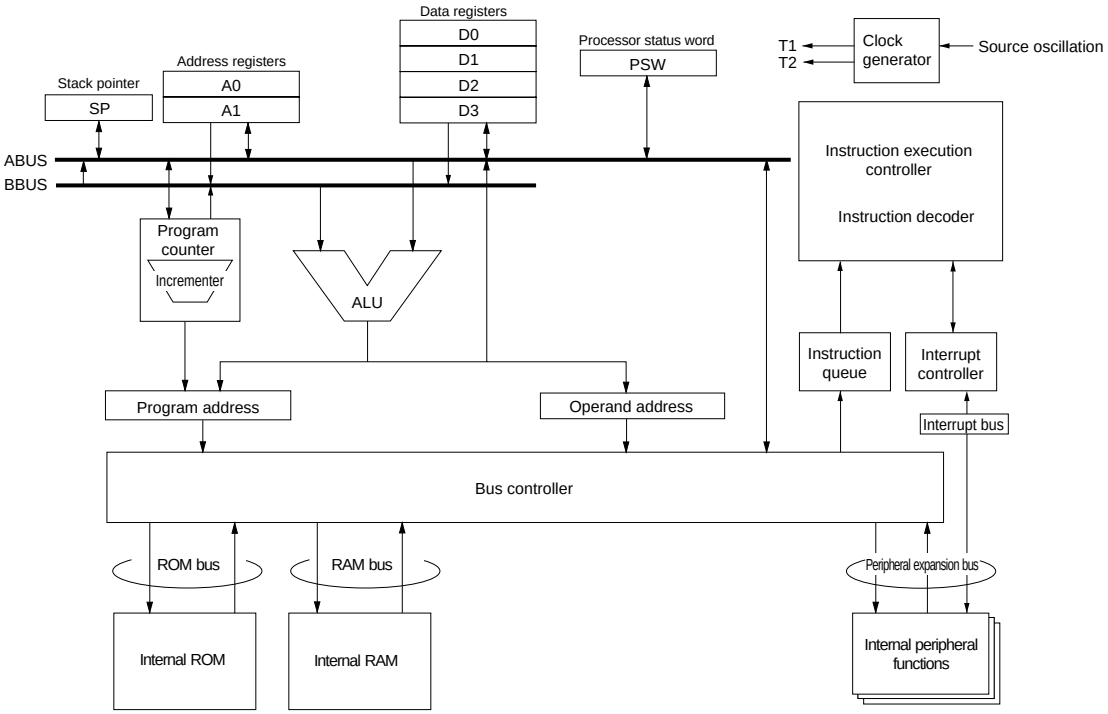
The MN101C series has a flexible optimized hardware configuration. It is a high speed CPU with a simple and efficient instruction set. Specific features are as follows:

1. Minimized code sizes with instruction lengths based on 4-bit increments
   The series keeps code sizes down by adopting a minimum instruction length of one byte and variable instruction lengths based on 4-bit increments.
2. Minimum instruction execution time is one system clock cycle.
3. Minimized register set that simplifies the architecture and supports C language
   The instruction set has been determined, depending on the size and capacity of hardware, after an analysis of embedded application programing code and creation code by C language compiler. Therefore, the set is simple instruction using the minimal register set required for C language compiler. [☞ "MN101C LSI User's Manual" (Architecture Instructions)]

Table 2-1-1 Basic Specifications

Structure	Load / store architecture	
	Six registers	Data : 8-bit x 4 Address : 16-bit x 2
	Other	PC : 19-bit PSW : 8-bit SP : 16-bit
Instructions	Number of instructions	37
	Addressing modes	9
	Instruction length	Basic portion : 1 byte (min.) Extended portion : 0.5-byte x n (0≤n≤9)
Basic performance	Internal operationg frequency (max.) 10 MHz	
	Instruction execution	Min. 1 cycle
	Inter-register operation	Min. 2 cycles
	Load / store	Min. 2 cycles
	Conditional branch	2 to 3 cycles
Pipeline	3-stage (instruction fetch, decode, execution)	
Address space	256 KB (max. 64 KB for data)	
External bus	Address	18-bit (max.)
	Data	8-bit
	Minimum bus cycle	1 system clock cycle
Interrupt	Vector interrupt	3 interrupt levels
Low-power dissipation mode	STOP mode	
	HALT mode	

2-1-1 Block Diagram



Clock generator	Uses a clock oscillator circuit driven by an external crystal or ceramic resonator to supply clock signals to CPU blocks.
Program counter	Generates addresses for the instructions to be inserted into the instruction queue. Normally incremented by sequencer indication, but may be set to branch destination address or ALU operation result when branch instructions or interrupts occur.
Instruction queue	Stores up to 2 bytes of pre-fetched instructions.
Instruction decoder	Decodes the instruction queue, sequentially generates the control signals needed for instruction execution, and executes the instruction by controlling the blocks within the chip.
Instruction execution controller	Controls CPU block operations in response to the result decoded by the instruction decoder and interrupt requests.
ALU	Executes arithmetic operations, logic operations, shift operations, and calculates operand addresses for register relative indirect addressing mode.
Internal ROM, RAM	Assigned to the execution program, data and stack region.
Address register	Stores the addresses specifying memory for data transfer. Stores the base address for register relative indirect addressing mode.
Data register	Holds data for operations. Two 8-bit registers can be connected to form a 16-bit register.
Interrupt controller	Detects interrupt requests from peripheral functions and requests CPU shift to interrupt processing.
Bus controller	Controls connection of CPU internal bus and CPU external bus.
Internal peripheral functions	Includes peripheral functions (timer, serial interface, A/D converter, etc.). Peripheral functions vary with model.

Figure 2-1-1 Block Diagram and Function

2-1-2 CPU Control Registers

This LSI locates the peripheral circuit registers in memory space (x'03F00' to x'03FFF') with memory-mapped I/O. CPU control registers are also located in this memory space.

Table 2-1-2 CPU Control Registers

Registers	Address	R/W	Function	Pages
CPUM	x'03F00'	R/W *1	CPU mode control register	II - 19
MEMCTR	x'03F01'	R/W	Memory control register	II - 16
Reserved	x'03FE0'	-	For debugger	-
NMICR	x'03FE1'	R/W	Non maskable interrupt control register	III - 16
xxxICR	x'03FE2' | x'03FFE'	R/W	Maskable interrupt control register	III - 17 to 27
Reserved	x'03FFF'	-	Reserved (For reading interrupt vector data on interrupt process)	-

*1 Part of the register is only readable

2-1-3 Instruction Execution Controller

The instruction execution controller consists of four blocks: memory, instruction queue, instruction registers, and instruction decoder.

Instructions are fetched in 1-byte units, and temporarily stored in the 2-byte instruction queue. Transfer is made in 1-byte or half-byte units from the instruction queue to the instruction register to be decoded by the instruction decoder.

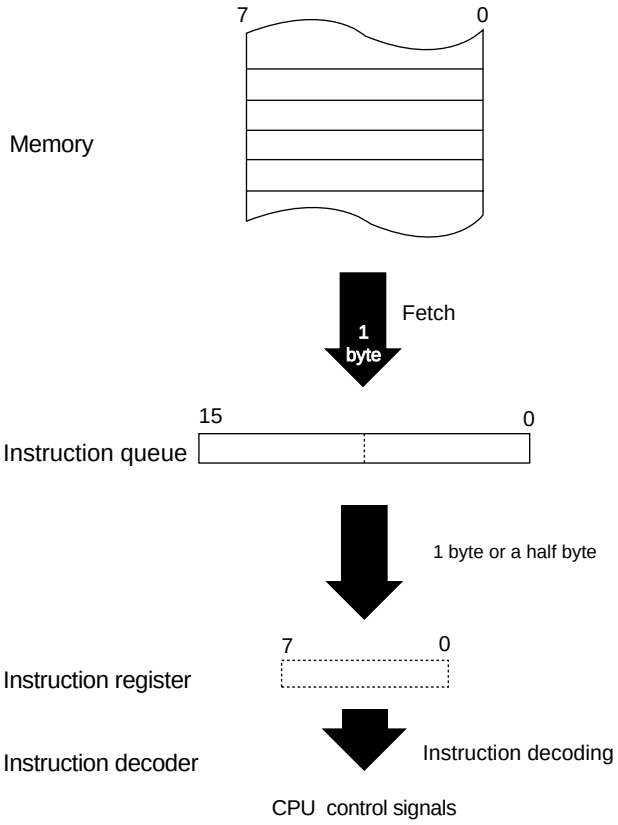


Figure 2-1-2 Instruction Execution Controller Configuration

2-1-4 Pipeline Process

Pipeline process means that reading and decoding are executed at the same time on different instructions, then instructions are executed without stopping. Pipeline process makes instruction execution continual and speedy. This process is executed with instruction queue and instruction decoder.

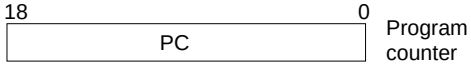
Instruction queue is buffer that fetches the second instruction in advance. That is controlled to fetch the next instruction when instruction queue is empty at each cycle on execution. At the last cycle of instruction execution, the first word (operation code) of executed instruction is stored to instruction register. At that time, the next operand or operation code is fetched to instruction queue, so that the next instruction can be executed immediately, even if register direct (da) or immediate (imm) is required at the first cycle of the next instruction execution. But on some other instruction such as branch instruction, instruction queue becomes empty on the time that the next operation code to be executed is stored to instruction register at the last cycle. Therefore, only when instruction queue is empty, and direct address (da) or immediate data (imm) are required, instruction queue keeps waiting for a cycle.

Instruction queue is controlled automatically by hardware so that there is no need to be controlled by software. But when instruction execution time is estimated, operation of instruction queue should be into consideration. Instruction decoder generates control signal at each cycle of instruction execution by micro program control. Instruction decoder uses pipeline process to decode instruction queue at one cycle before control signal is needed.

2-1-5 Registers for Address

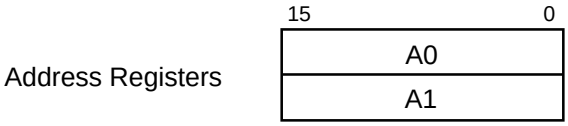
Registers for address include program counter (PC), address registers (A0, A1), and stack pointer (SP).

■Program Counter (PC)
This register gives the address of the currently executing instruction. It is 19 bits wide to provide access to a 256 KB address space in half byte (4-bit increments). The LSB of the program counter is used to indicate half byte instruction. The program counter value after reset is stored from the value of vector table at the address of x'04000'.



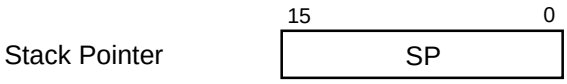
■Address Registers (A0, A1)

These registers are used as address pointers specifying data locations in memory. They support the operations involved in address calculations (i.e. addition, subtraction and comparison). Those pointers are 2 bytes data. Transfers between these registers and memory are always in 16-bit units. Either odd or even address can be transferred. At reset, the value of address register is undefined.



■Stack Pointer (SP)

This register gives the address of the byte at the top of the stack. It is decremented during push operations and incremented during pop operations. At reset, the value of SP is undefined.



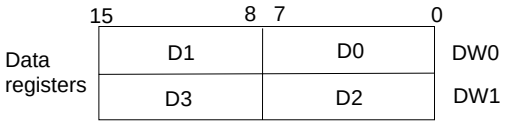
2-1-6 Registers for Data

Registers for data include four data registers (D0, D1, D2, D3).

■Data Registers (D0, D1, D2, D3)

Data registers D0 to D3 are 8-bit general-purpose registers that support all arithmetic, logical and shift operations. All registers can be used for data transfers with memory.

The four data registers may be paired to form the 16-bit data registers DW0 (D0+D1) and DW1 (D2+D3). At reset, the value of Dn is undefined.



2-1-7 Processor Status Word

Processor status word (PSW) is an 8-bit register that stores flags for operation results, interrupt mask level, and maskable interrupt enable. PSW is automatically pushed onto the stack when an interrupt occurs and is automatically popped when return from the interrupt service routine.

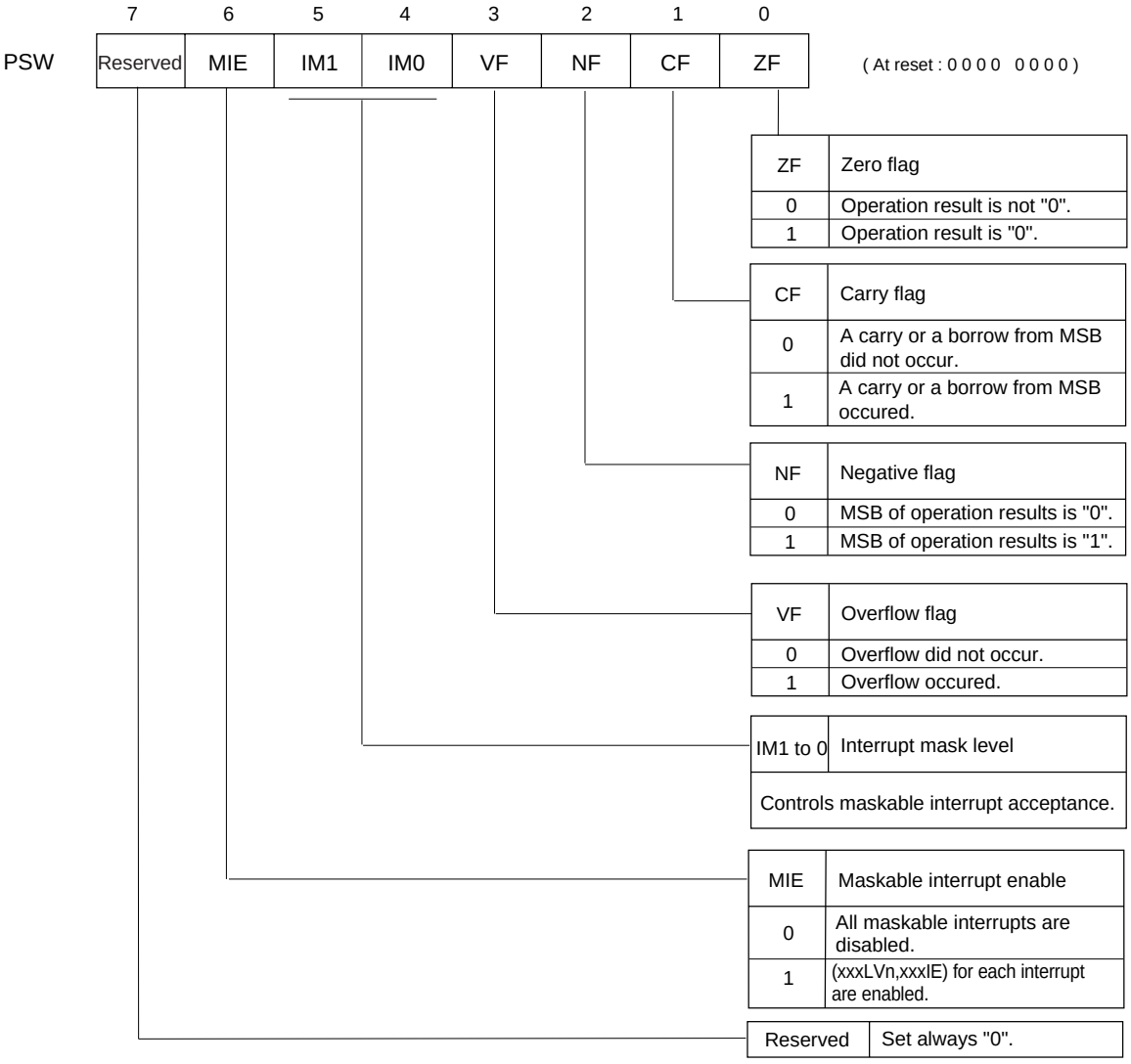


Figure 2-1-3 Processor Status Word (PSW)

■Zero Flag (ZF)
Zero flag (ZF) is set to "1", when all bits are '0' in the operation result. Otherwise, zero flag is cleared to "0".

■Carry Flag (CF)
Carry flag (CF) is set to "1", when a carry from or a borrow to the MSB occurs. Carry flag is cleared to "0", when no carry or borrow occurs.

■Negative Flag (NF)
Negative flag (NF) is set to "1" when MSB is '1' and reset to "0" when MSB is '0'. Negative flag is used to handle a signed value.

■Overflow Flag (VF)
Overflow flag (VF) is set to "1", when the arithmetic operation results overflow as a signed value. Otherwise, overflow flag is cleared to "0".
Overflow flag is used to handle a signed value.

■Interrupt Mask Level (IM1 and IM0)
Interrupt mask level (IM1 and IM0) controls the maskable interrupt acceptance in accordance with the interrupt factor interrupt priority for the interrupt control circuit in the CPU. The two-bit control flag defines levels '0' to '3'. Level 0 is the highest mask level. The interrupt request will be accepted only when the level set in the interrupt level flag (xxxLVn) of the interrupt control register (xxxICR) is higher than the interrupt mask level. When the interrupt is accepted, the level is reset to IM1-IM0, and interrupts whose mask levels are the same or lower are rejected during the accepted interrupt processing.

Table 2-1-3 Interrupt Mask Level and Interrupt Acceptance

	Interrupt mask level		Priority	Acceptable interrupt levels
	IM1	IM0		
Mask level 0	0	0	High	Non-maskable interrupt (NMI) only
Mask level 1	0	1	.	NMI, Level 0
Mask level 2	1	0	.	NMI, Level 0 to 1
Mask level 3	1	1	Low	NMI, Level 0 to 2

■Maskable Interrupt Enable (MIE)
Maskable interrupt enable flag (MIE) enables/disables acceptance of maskable interrupts by the CPU's internal interrupt acceptance circuit. A '1' enables maskable interrupts; a '0' disables all maskable interrupts regardless of the interrupt mask level (IM1-IM0) setting in PSW.
This flag is not changed by interrupts.

2-1-8 Addressing Modes

This LSI supports the nine addressing modes.

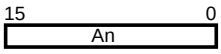
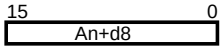
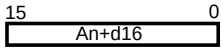
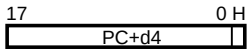
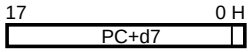
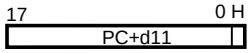
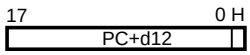
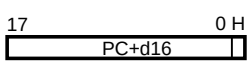
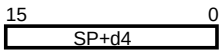
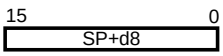
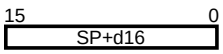
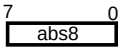
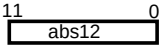
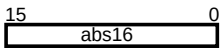
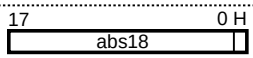
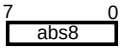
Each instruction uses a combination of the following addressing modes.

1) Register direct
2) Immediate
3) Register indirect
4) Register relative indirect
5) Stack relative indirect
6) Absolute
7) RAM short
8) I/O short
9) Handy

These addressing modes are well-suited for C language compilers. All of the addressing modes can be used for data transfer instructions. In modes that allow half-byte addressing, the relative value can be specified in half-byte (4-bit) increments, so that instruction length can be shorter. Handy addressing reuses the last memory address accessed and is only available with the MOV and MOVW instructions. Combining handy addressing with absolute addressing will reduce the code size. For transfer data between memory, 7 addressing modes ; register indirect, register relative indirect, stack relative indirect, absolute, RAM short, I/O short, handy can be used. For operation instruction, register direct and immediate can be used. Refer to instruction's manual for the MN101C series.

This LSI is designed for 8-bit data access. It is possible to transfer data in 16-bit increments with odd or even addresses.

Table 2-1-4 Addressing Modes

Addressing mode		Effective address	Explanation
Register direct	Dn/DWn An/SP PSW	-	Directly specifies the register. Only internal registers can be specified.
Immediate	imm4/imm8 imm16	-	Directly specifies the operand or mask value appended to the instruction code.
Register indirect	(An)		Specifies the address using an address register.
Register relative indirect	(d8, An)		Specifies the address using an address register with 8-bit displacement.
	(d16, An)		Specifies the address using an address register with 16-bit displacement.
	(d4, PC) (branch instructions only)	 * 1	Specifies the address using the program counter with 4-bit displacement and H bit.
	(d7, PC) (branch instructions only)	 * 1	Specifies the address using the program counter with 7-bit displacement and H bit.
	(d11, PC) (branch instructions only)	 * 1	Specifies the address using the program counter with 11-bit displacement and H bit.
	(d12, PC) (branch instructions only)	 * 1	Specifies the address using the program counter with 12-bit displacement and H bit.
	(d16, PC) (branch instructions only)	 * 1	Specifies the address using the program counter with 16-bit displacement and H bit.
Stack relative indirect	(d4, SP)		Specifies the address using the stack pointer with 4-bit displacement.
	(d8, SP)		Specifies the address using the stack pointer with 8-bit displacement.
	(d16, SP)		Specifies the address using the stack pointer with 16-bit displacement.
Absolute	(abs8)		Specifies the address using the operand value appended to the instruction code. Optimum operand length can be used to specify the address.
	(abs12)		
	(abs16)		
	(abs18) (branch instructions only)	 * 1	
RAM short	(abs8)		Specifies an 8-bit offset from the address x'00000'.
I/O short	(io8)		Specifies an 8-bit offset from the top address (x'03F00') of the special function register area.
Handy	(HA)	-	Reuses the last memory address accessed and is only available with the MOV and MOVW instructions. Combined use with absolute addressing reduces code size.

* 1 H: half-byte bit

2-2 Memory Space

2-2-1 Memory Mode

ROM is the read only area and RAM is the memory area which contains readable/writable data. In addition to these, peripheral resources such as memory-mapped special registers are allocated.

In single chip mode, the system consists of only internal memory.

MMOD pin should be fixed to "L" level, or "H" level. Do not change the setup of MMOD pin after reset.

2-2-2 Single-chip Mode

In single-chip mode, the system consists of only internal memory. This is the optimized memory mode and allows construction of systems with the highest performance.

The single-chip mode uses only internal ROM and internal RAM. The MN101C series devices offer up to 12 KB of RAM and up to 224 KB of ROM.

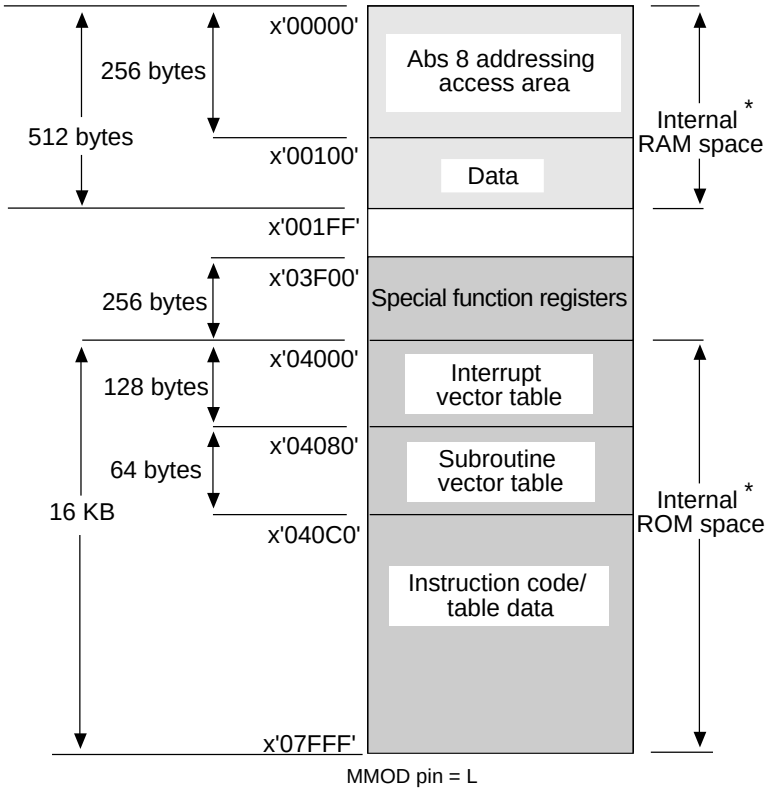


Figure 2-2-1 Single-chip Mode

* Differs depending upon the model.
[☞ Table 2-2-1. Internal ROM / Internal RAM]

Table 2-2-1 Internal ROM / Internal RAM

Model	Internal RAM		Internal ROM	
	Address	bytes	Address	bytes
MN101C457	X'00000'to X'001FF'	512	X'04000' to X'07FFF'	16 K
MN101CP427	X'00000' to X'001FF'	512	X'04000' to X'07FFF'	16 K

x'07FFF' should be reserved for ROM option.

2-2-3 Special Function Registers

The MN101C series locates the special function registers (I/O spaces) at the addresses x'03F00' to x'03FFF' in memory space. The special function registers of this LSI are located as shown below.

Table 2-2-2 Register Map

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
03F0X	CPUM	MEMCTR	WDCTR	DLYCTR												
03F1X	P0OUT	P1OUT	P2OUT			P5OUT	P6OUT	P7OUT	P8OUT							
03F2X	P0IN	P1IN	P2IN			P5IN	P6IN	P7IN	P8IN		PAIN					
03F3X	P0DIR	P1DIR				P5DIR	P6DIR	P7DIR	P8DIR	P10MD	PAIMD					
03F4X	P0PLU	P1PLU	P2PLU			P5PLU	P6PLU	P7PLUD	P8PLU		PAPLUD	FLOAT1				
03F5X	SC0MD0	SC0MD1	SC0MD2	SC0MD3	SC0CTR	SC0TBR	SC0RXB									
03F6X			TM2BC	TM3BC	TM4BCL	TM4BCH	TM4ICL	TM4ICH	TM5BC							
03F7X			TM2OC	TM3OC	TM4OCL	TM4OCH			TM5OC							
03F8X			TM2MD	TM3MD	TM4MD				TM5MD	RMCTR	NFCTR					
03F9X	ANCTR0	ANCTR1	ANBUF0	ANBUF1												
03FAX																
03FBX																
03FCX																
03FDX																
03FEX		NMICR	IRQ0ICR	IRQ1ICR			TM2ICR	TBICR	SC0ICR		ADICR	IRQ2ICR	IRQ3ICR		TM3ICR	TM4ICR
03FFX	TM5ICR															

CPU mode, memory control	
I/O ports	Port output
	Port input
	I/O mode control
	Resistor control
Serial I/F control	
Timer control	
A/D control	
Reserved	
Interrupt control	

2-3 Bus Interface

2-3-1 Bus Controller

The MN101C series provides separate buses to the internal memory and internal peripheral circuits to reduce bus line loads. Therefore, this series realizes faster operation.

There are three such buses: ROM bus, RAM bus, and peripheral expansion bus (I/O bus). They connect to the internal ROM, internal RAM, and internal peripheral circuits respectively. The bus control block controls the parallel operation of instruction read and data access. A functional block diagram of the bus controller is given below.

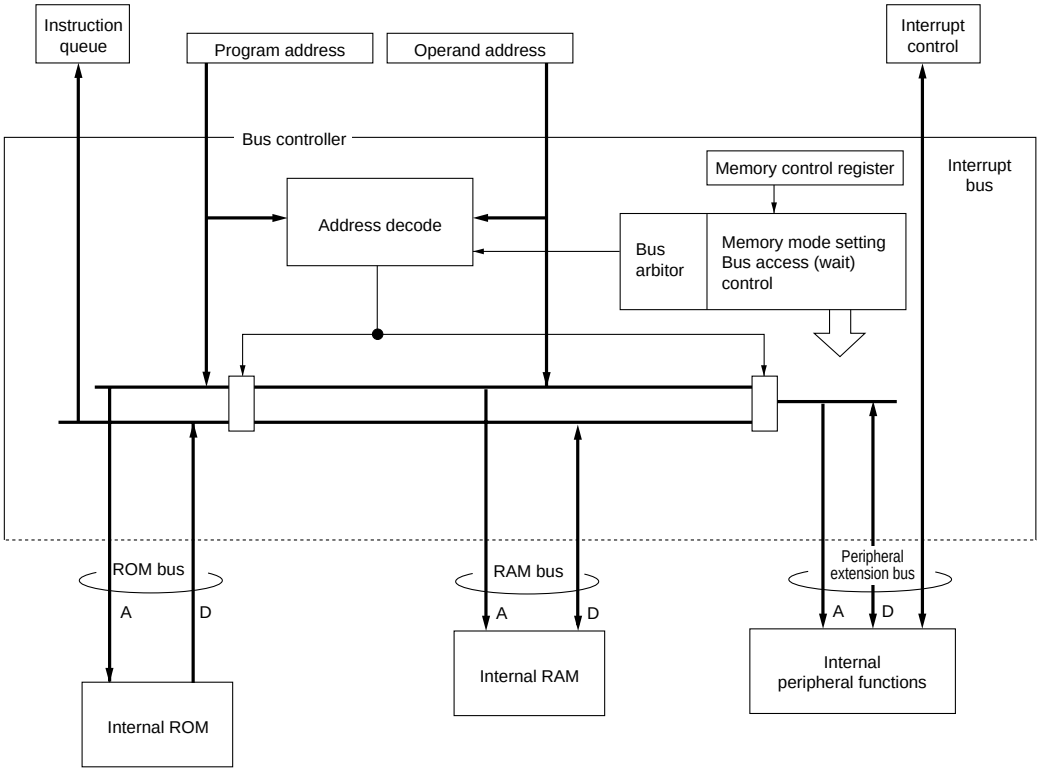


Figure 2-3-1 Functional Block Diagram of the Bus Controller

2-3-2 Control Registers

Bus interface is controlled by the memory control register (MEMCTR).

■Memory Control Register (MEMCTR)

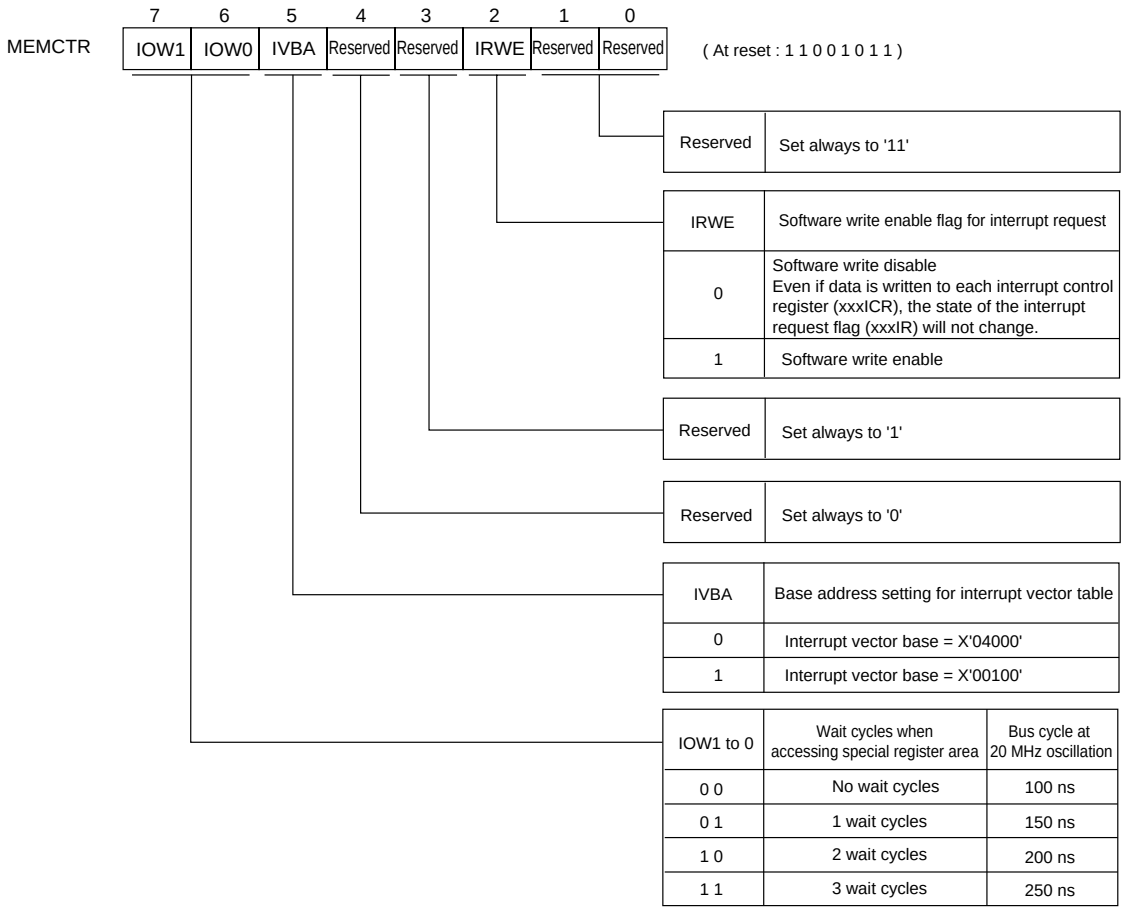


Figure 2-3-2 Memory Control Register (MEMCTR: x'3F01' R/W)

The IOW1-IOW0 wait settings affect accesses to the special registers located at the addresses x'3F00'-x'3FFF'. After reset, MEMCTR specifies the fixed wait cycle mode with three wait cycles. Wait setting of IOW is a function, which CPU supports for special use, for example, when special function register or I/O is expanded to external. For this LSI, wait cycle setting is not always necessary. Select "no-wait cycle" for high performance system construction.

2-4 Standby Function

2-4-1 Overview

This LSI has two sets of system clock oscillator (high speed oscillation, low speed oscillation) for two CPU operating modes (NORMAL and SLOW), each with two standby modes (HALT and STOP). Power consumption can be decreased with using those modes.

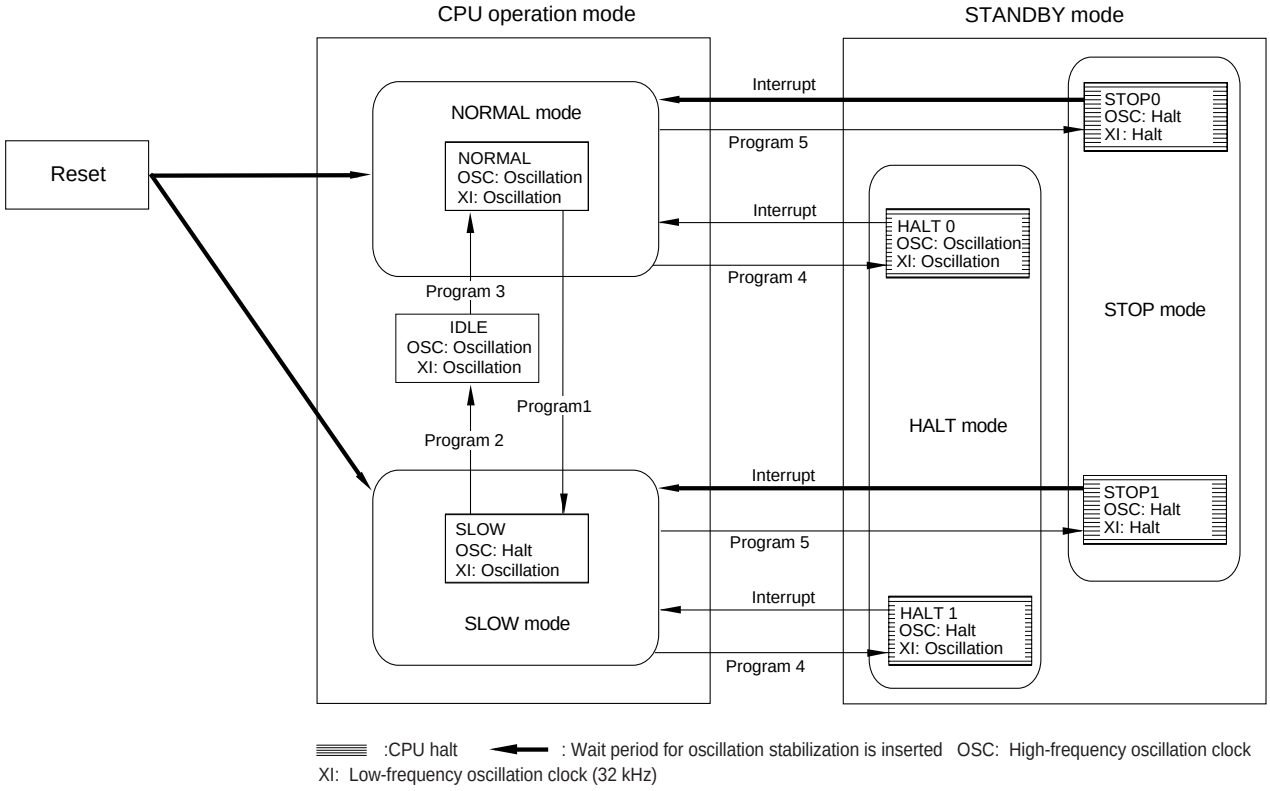


Figure 2-4-1 Transition Between Operation Modes

> Only 48-pin TQFP package type is activated at low speed oscillation(XI). 48-pin SDIP and 44-pin QFP package type are activated only at high speed oscillation (OSC).

■HALT Modes (HALT0, HALT1)

– The CPU stops operating. But both of the oscillators remain operational in HALT0 and only the high-frequency oscillator stops operating in HALT1.
– An interrupt returns the CPU to the previous CPU operating mode that is, to NORMAL from HALT0 or to SLOW from HALT1.

■STOP Modes (STOP0, STOP1)

– The CPU and both of the oscillators stop operating.
– An interrupt restarts the oscillators and, after allowing time for them to stabilize, returns the CPU to the previous CPU operating mode - that is, to NORMAL from STOP0 or to SLOW from STOP1.

■SLOW Mode

– This mode executes the software using the low-frequency clock. Since the high-frequency oscillator is turned off, the device consumes less power while executing the software.

■IDLE Mode

– This mode allows time for the high-frequency oscillator to stabilize when the software is changing from SLOW to NORMAL mode.

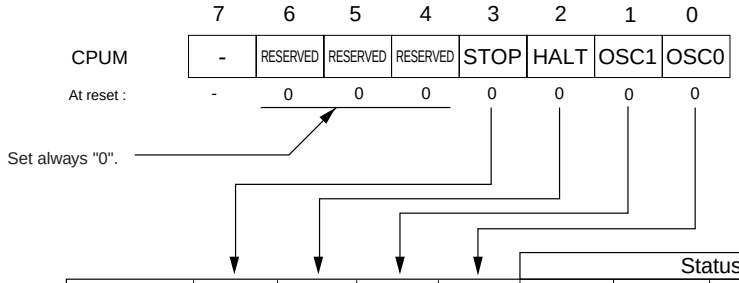
To reduce power dissipation in STOP and HALT modes, it is necessary to check the stability of both the output current from pins and port level of input pins. For output pins, the output level should match the external level or direction control should be changed to input mode. For input pins, the external level should be fixed.

This LSI has two system clock oscillation circuits. OSC is for high-frequency operation (NORMAL mode) and XI is for low-frequency operation (SLOW mode). Transition between NORMAL and SLOW modes or to standby mode is controlled by the CPU mode control register (CPUM). Reset and interrupts are the return factors from standby mode. A wait period is inserted for oscillation stabilization at reset and when returning from STOP mode, but not when returning from HALT mode. High/low-frequency oscillation mode is automatically returned to the same state as existed before entering standby mode.

To stabilize the synchronization at the moment of switching clock speed between high speed oscillation (fosc) and low speed oscillation (fx), fosc should be set to 2.5 times or higher frequency than fx.

2-4-2 CPU Mode Control Register

Transition from one mode to another mode is controlled by the CPU mode control register (CPUM).



Operation mode	STOP	HALT	OSC1	OSC0	Status: OSC1 /OSC2	Status: XI/XO	Status: System clock (fs)	Status: CPU
NORMAL	0	0	0	0	Oscillation	Oscillation	fosc/2	Operating
IDLE	0	0	0	1	Oscillation	Oscillation	fx/4	Operating
SLOW	0	0	1	1	Halt	Oscillation	fx/4	Operating
HALT0	0	1	0	0	Oscillation	Oscillation	fosc/2	Halt
HALT1	0	1	1	1	Halt	Oscillation	fx/4	Halt
STOP0	1	0	0	0	Halt	Halt	Halt	Halt
STOP1	1	0	1	1	Halt	Halt	Halt	Halt

Figure 2-4-2 Operating Mode and Clock Oscillation (CPUM : x'3F00', R/W)

The procedure for transition from NORMAL to HALT or STOP mode is given below.

(1) If the return factor is a maskable interrupt, set the MIE flag in the PSW to "1" and set the interrupt mask (IM) to a level permitting acceptance of the interrupt.
(2) Clear the interrupt request flag (xxxIR) in the maskable interrupt control register (xxxICR) , set the interrupt enable flag (xxxIE) for the return factor, and set the IE flag in the PSW.
(3) Set CPUM to HALT or STOP mode.

Set the IRWE flag of the memory control register (MEMCTR) to clear interrupt request flag by software.

The system clock (fs) is fosc/2 at NORMAL mode, and fx/4 at SLOW mode.

2-4-3 Transition between SLOW and NORMAL

This LSI has two CPU operating modes, NORMAL and SLOW. Transition from SLOW to NORMAL requires passing through IDLE mode.

A sample program for transition from NORMAL to SLOW mode is given below.

```
Program 1
        MOV   x'3', D0          ; Set SLOW mode.
        MOV   D0, (CPUM)
```

Transition from NORMAL to SLOW mode, when the low-frequency clock has fully stabilized, can be done by writing to the CPU mode control register. In this case, transition through IDLE is not needed.

For transition from SLOW to NORMAL mode, the program must maintain the idle state until high-frequency clock oscillation is fully stable. In IDLE mode, the CPU operates on the low-frequency clock.

For transition from SLOW to NORMAL, oscillation stabilization waiting time is required same as that after reset. Software must count that time.
We recommend selecting the oscillation stabilization time after consulting with oscillator manufacturers.

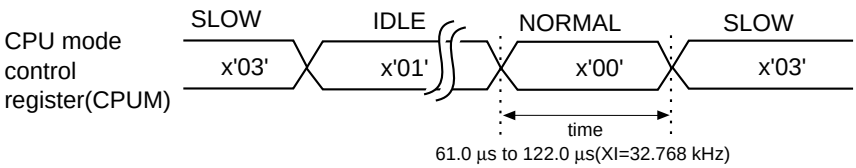
Sample program for transition from SLOW to NORMAL mode is given below.

```
Program 2
                MOV         x'01', D0           ; Set IDLE mode.
                MOV         D0, (CPUM)
```

```
Program 3
        MOV   x'0B', D0     ; A loop to keep approx. 6.7 ms with low-frequency clock (32 kHz)
LOOP    ADD   -1, D0        ; operation when changed to high-frequency clock (20 MHz).
        BNE   LOOP          ;
        SUB   D0, D0        ;
        MOV   D0, (CPUM)    ;  Set NORMAL mode.
```

Refer the following cautions to initiate the program on the transition to SLOW mode in case where the execution time at NORMAL mode is too short.

After the transition to NORMAL mode from SLOW mode, if the mode is returned to SLOW again during 2 to 4 cycles of the low speed oscillation clock, the short pulse can be generated in the system of the clock causing errors.



61.0 µs to 122.0 µs(XI=32.768 kHz)

If the mode will be switched to SLOW again, the execution time of NORMAL mode should be not in this duration.

The following (1) or (2) should be executed on the program by the software.

(1) When the execution time at NORMAL is above that duration.

The following program should be inserted to make the waiting time for more than 4 cycles of low speed oscillation clock, before the transition from NORMAL to SLOW.

```
Program for waiting time
        MOV   WAIT_CONST, D0
LOOP    NOP
        NOP
        NOP
        ADD   -1, D0
        BNE   LOOP
```

High speed oscillation clock [MHz]	Setting value of WAIT_CONST (decimal)
17	195
18	206
19	218
20	229

low speed oscillation clock = 32.768 kHz

(2) When the execution time at NORMAL is above that duration, also its possibility will become clear at IDLE.

Set the program for switching to SLOW mode, not to NORMAL mode from IDLE.

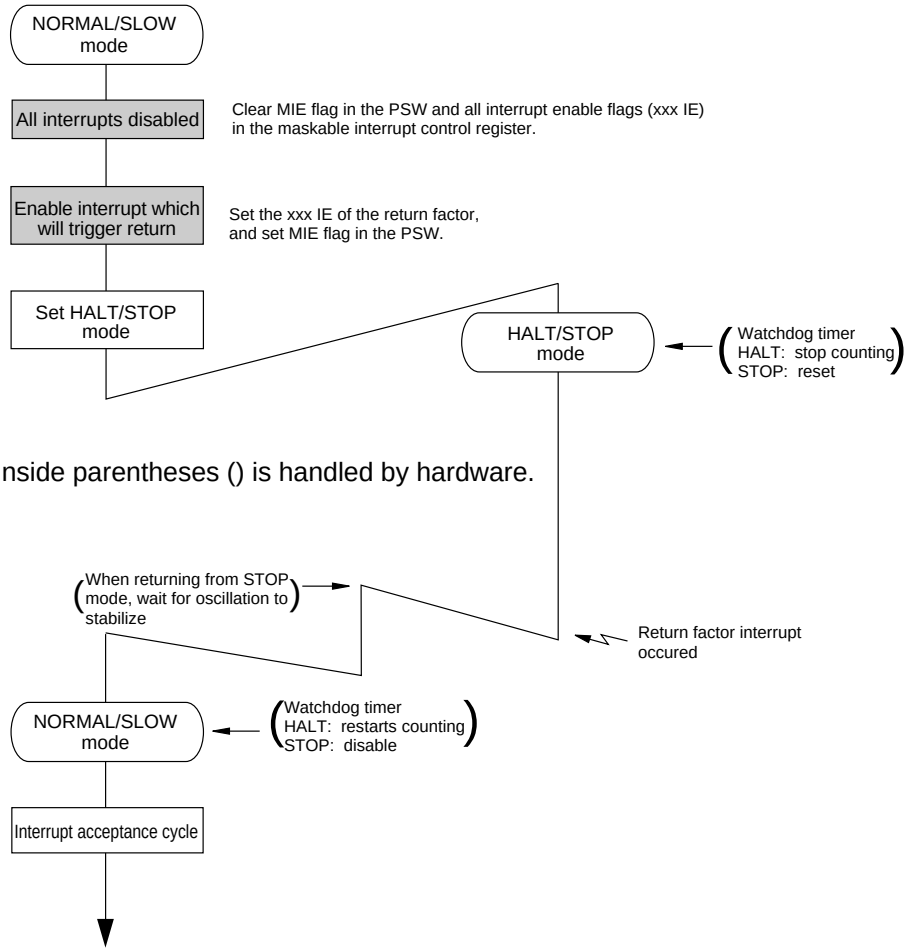
2-4-4 Transition to STANDBY Modes

The program initiates transitions from a CPU operating mode to the corresponding STANDBY (HALT/STOP) modes by specifying the new mode in the CPU mode control register (CPUM). Interrupts initiate the return to the former CPU operating mode.

Before initiating a transition to a STANDBY mode, however, the program must

(1) Set the maskable interrupt enable flag (MIE) in the processor status word (PSW) to '0' to disable all maskable interrupts temporarily.

(2) Set the interrupt enable flags (xxxIE) in the interrupt control registers (xxxICR) to '1' or '0' to specify which interrupts do and do not initiate the return from the STANDBY mode. Set MIE '1' to enable those maskable interrupts.



Processing inside parentheses () is handled by hardware.

Figure 2-4-3 Transition to/from STANDBY Mode

> If the interrupt is enabled but interrupt priority level of the interrupt to be used is not equal to or higher than the mask level in PSW before transition to HALT or STOP mode, it is impossible to return to CPU operation mode by maskable interrupt.

■Transition to HALT modes

The system transfers from NORMAL mode to HALT0 mode, and from SLOW mode to HALT1 mode. The CPU stops operating, but the oscillators remain operational. There are two ways to leave a HALT mode: a reset or an interrupt. A reset produces a normal reset; an interrupt, an immediate return to the CPU state prior to the transition to the HALT mode. The watchdog timer, if enabled, resumes counting.

Program 4

```
        MOV     x'4',  D0      ; Set HALT0 mode.
        MOV     D0,  (CPUM)
        NOP                     ; After written in CPUM, some NOP
        NOP                     ; instructions (three or less) are
        NOP                     ; executed.
```

Program 5

```
        MOV     x'7',  D0      ; Set HALT1 mode.
        MOV     D0,  (CPUM)
        NOP                     ; After written in CPUM, some NOP
        NOP                     ; instructions (three or less) are
        NOP                     ; executed.
```

■Transition to STOP mode

The system transfers from NORMAL mode to STOP0 mode, and from SLOW mode to STOP1 mode. In both cases, oscillation and the CPU are both halted. There are two ways to leave a STOP mode: a reset or an interrupt.

Program 6

```
        MOV     x'8',  D0      ; Set STOP0 mode
        MOV     D0,  (CPUM)
        NOP                     ; After written in CPUM, some NOP
        NOP                     ; instructions (three or less) are
        NOP                     ; executed.
```

Program 7

```
        MOV     x'B',  D0      ; Set STOP1 mode
        MOV     D0,  (CPUM)
        NOP                     ; After written in CPUM, some NOP
        NOP                     ; instructions (three or less) are
        NOP                     ; executed.
```

Right after the instruction of the transition to HALT, STOP mode, NOP instruction should be inserted 3 times.

Do not set the system to enter the stop mode when instructions are executed in the RAM area.

2-5 Reset

2-5-1 Reset operation

The CPU contents are reset and registers are initialized when the NRST pin (P27) is pulled to low.

■Initiating a Reset

There are two methods to initiate a reset.

(1) Drive the NRST pin low.
NRST pin should be held "low" for more than OSC 4 clock cycles (200 ns at a 20 MHz).

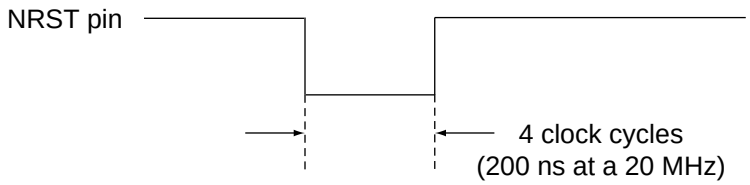


Figure 2-5-1 Minimum Reset Pulse Width

(2) Setting the P2OUT7 flag of the P2OUT register to "0" outputs low level at P27 (NRST) pin. And transferring to reset by program (software reset) can be executed. If the internal LSI is reset and register is initiated, the P2OUT7 flag becomes "1" and reset is released.
[☞ Chapter 4. 4-4-2 Registers]

When NRST pin is connected to low power voltage, use the circuit that provides low level pulses with sufficient time during sudden disconnection. And reset can be generated even if NRST pin is held "low" for less than OSC 4 clock cycles, take notice of noise.

■Sequence at Reset

(1) When reset pin comes to high level from low level, the internal 14-bit counter (It can be used as watchdog timer, too.) starts its operation by system clock. The period that starts its count from its overflow is called oscillation stabilization wait time.

(2) During reset, internal register and special function register are initialized.

(3) After oscillation stabilization wait time, internal reset is released and program starts from the address written at address x'04000' at interrupt vector table.

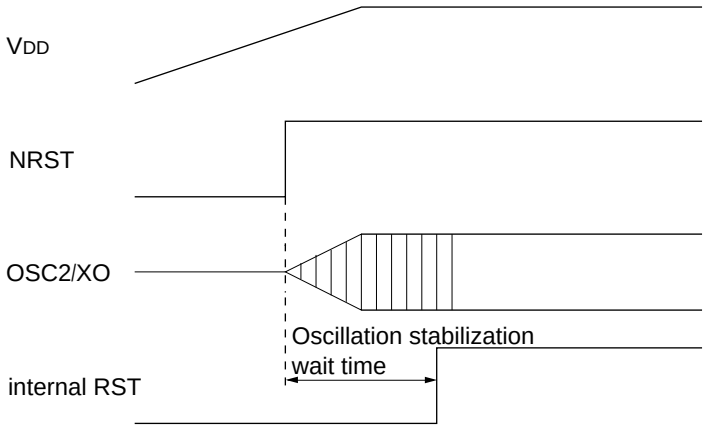


Figure 2-5-2 Reset Released Sequence

On this LSI, the oscillation is stopped during the NRST pin (p27) is low level.

2-5-2 Oscillation Stabilization Wait time

Oscillation stabilization wait time is the required time for oscillation to stabilize from halt condition. Oscillation stabilization wait time is automatically inserted at reset release and at recovering from STOP mode. At recovering from STOP mode the oscillation stabilization wait time control register (DLYCTR) is set to select the oscillation stabilization wait time. At releasing from reset, oscillation stabilization wait time is fixed.

The timer that counts oscillation stabilization wait time is also used as a watchdog timer at anytime except at reset release and at recovering from STOP mode. Watchdog timer is initiated at reset and at STOP mode and starts counting from the initialize value (x'0000') when system clock (fs) is as clock source. After oscillation stabilization wait time, it continues counting as a watchdog timer. [☞ Chapter 8 Watchdog timer]

■Block Diagram of Oscillation Stabilization Wait Time (watchdog timer)

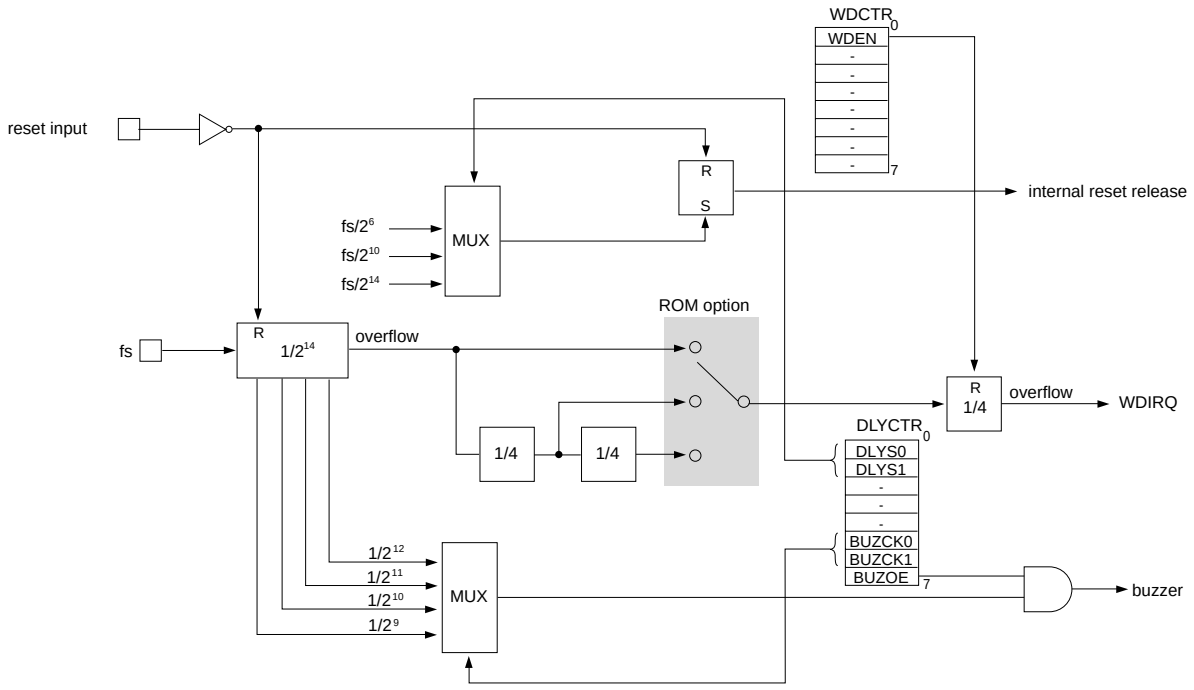
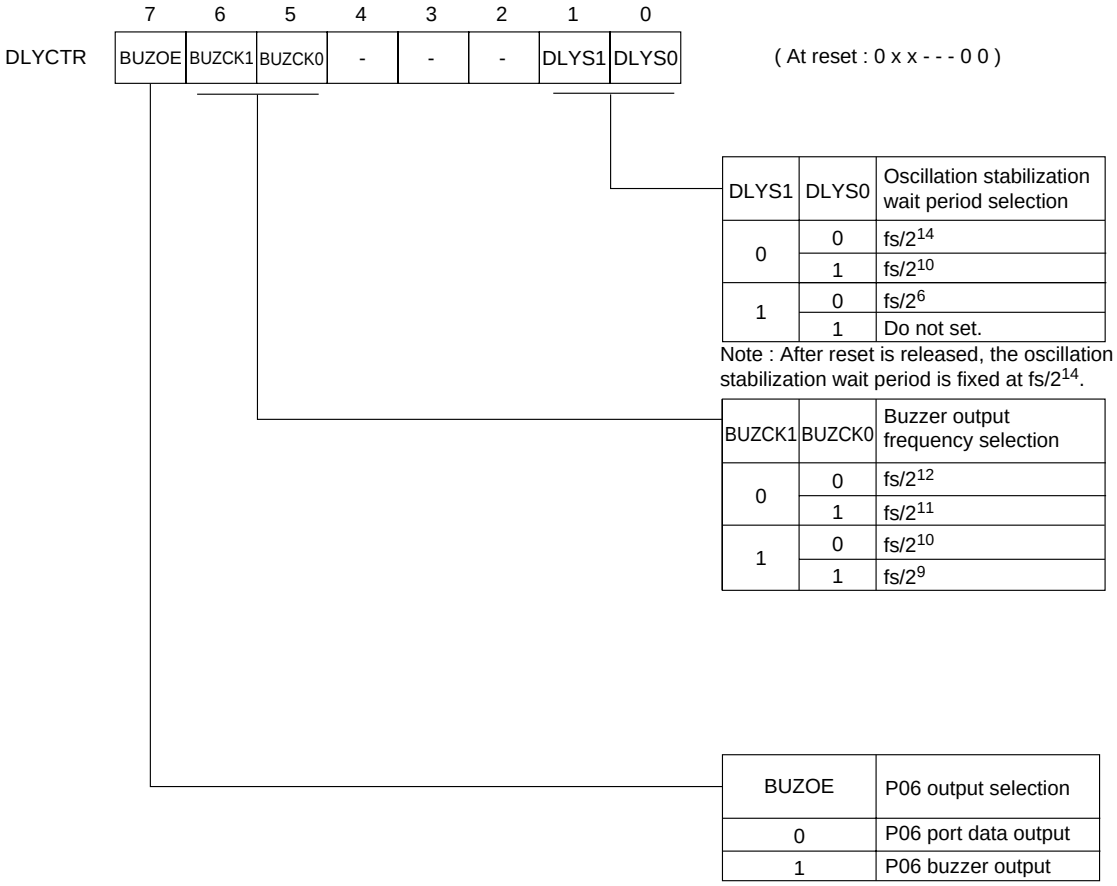


Figure 2-5-3 Block Diagram of Oscillation Stabilization Wait Time (watchdog timer)

■Oscillation Stabilization Wait Time Control Register



DLYS1	DLYS0	Oscillation stabilization wait period selection
0	0	$fs/2^{14}$
	1	$fs/2^{10}$
1	0	$fs/2^{6}$
	1	Do not set.

Note : After reset is released, the oscillation stabilization wait period is fixed at $fs/2^{14}$.

BUZCK1	BUZCK0	Buzzer output frequency selection
0	0	$fs/2^{12}$
	1	$fs/2^{11}$
1	0	$fs/2^{10}$
	1	$fs/2^{9}$

BUZOE	P06 output selection
0	P06 port data output
1	P06 buzzer output

Figure 2-5-4 Oscillation Stabilization Wait Time Control Register (DLYCTR : x'03F03', R/W)

■Control the Oscillation Stabilization Wait Time

At recovering from STOP mode, the bit 1-0 (DLYS1, DLYS0) of the oscillation stabilization wait time control register can be set to select the oscillation stabilization wait time from 2^{14}, 2^{10}, 2^{6} x system clock. The DLYCTR register is also used for controlling of buzzer functions. [☞ Chapter 9 Buzzer]

At releasing from reset, the oscillation stabilization wait time is fixed to "2^{14} x system clock". System clock is determined by the CPU mode control register (CPUM).

Table 2-5-1 Oscillation Stabilization Wait Time

DLYS1	DLYS0	period	Oscillation stabilization wait time (at fosc = 20 MHz)
0	0	2^{14} x Systemclock	1.6384 ms
0	1	2^{10}x Systemclock	102.4 µs
1	0	2^{6} x Systemclock	6.4 µs
1	1	Do not set.	

Chapter 3 Interrupts

3-1 Overview

This LSI speeds up interrupt response with circuitry that automatically loads the branch address to the corresponding interrupt service routine from an interrupt vector table : reset, non-maskable interrupts (NMI), 8 maskable peripheral interrupts, and 4*1 external interrupts.

For interrupts other than reset, the interrupt processing sequence consists of interrupt request, interrupt acceptance, and hardware processing. After the interrupt is accepted, the program counter (PC) and processor status word (PSW) and handy addressing data (HA) are saved onto the stack. And an interrupts handler ends by restoring, using the POP instruction and other means, the contents of any registers used during processing and then executing the return from interrupt (RTI) instruction to return to the point at which execution was interrupted. Max.12 machine cycles before execution, and max 11 machine cycles after execution.

Each interrupt has an interrupt control register, which controls the interrupts. Interrupt control register consists of the interrupt level field (LV1-0), interrupt enable flag (IE), and interrupt request flag (IR).

Interrupt request flag (IR) is set to "1" by an interrupt request, and cleared to "0" by the interrupt acceptance. This flag is managed by hardware, but can be rewritten by software.

Interrupt enable flag (IE) is the flag that enables interrupts in the group. There is no interrupt enable flag in non-maskable interrupt (NMI). Once this interrupt request flag is set, it is accepted without any conditions. Interrupt enable flag is set in maskable interrupt. Interrupt enable flag (IE) of each maskable interrupt is valid when the maskable interrupt enable flag (MIE flag) of PSW is "1".

Maskable interrupts have had vector numbers by hardware, but their priority can be changed by setting interrupts level field. There are three hierarchical interrupt levels. If multiple interrupts have the same priority, the one with the lowest vector number takes priority. Maskable interrupts are accepted when its level is higher than the interrupt mask level (IM1-0) of PSW. Non-maskable interrupts are always accepted, regardless of the interrupt mask level.

*1 3 external interrupts are provided to the other types except 48-pin TQFP package type.

3-1-1 Functions

Table 3-1-1 Interrupt Functions

Interrupt type	Reset (interrupt)	Non-maskable interrupt	Maskable interrupt
Vector number	0	1	2 to 16
Table address	x'04000'	x'04004'	x'04008' to x'04040'
Starting address	Address specified by vector address		
Interrupt level	-	-	Level 0 to 2 (Set by software)
Interrupt factor	External RST pin input	Errors detection, PI interrupt	External pin input Internal peripheral function
Generated operation	Direct input to CPU core	Input to CPU core from non-maskable interrupt control register (NMICR)	Input interrupt request level set in interrupt level flag (xxxLVn) of maskable interrupt control register (xxxICR) to CPU core.
Accept operation	Always accepts	Always accepts	Acceptance only by the interrupt control of the register (xxxICR) and the interrupt mask level in PSW.
Machine cycles until acceptance	12	12	12
PSW status after acceptance	All flags are cleared to "0".	The interrupt mask level flag in PSW is cleared to "00".	Values of the interrupt level flag (xxxLVn) are set to the interrupt mask level (masking all interrupt requests with the same or the lower priority).

3-1-2 Block Diagram

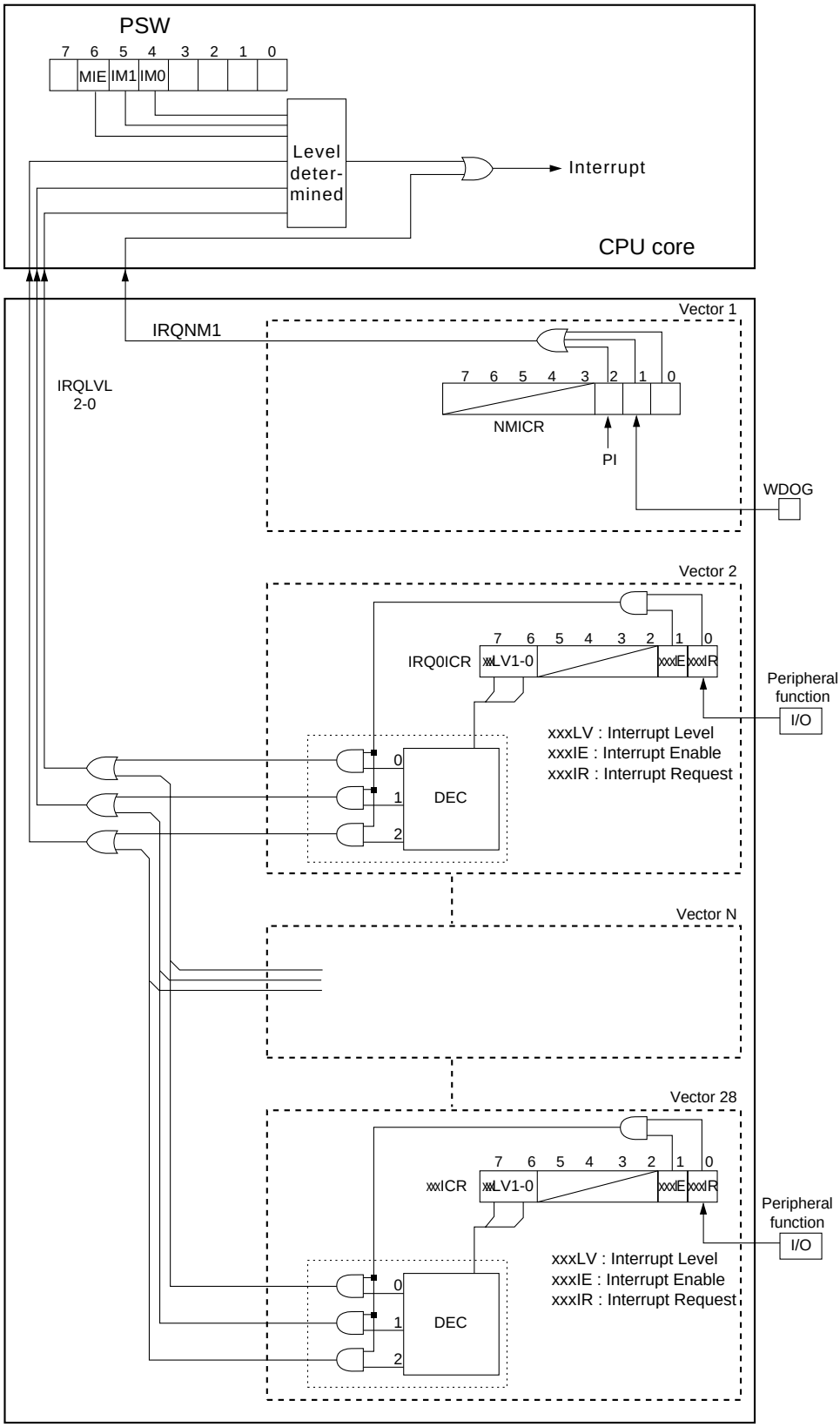


Figure 3-1-1 Interrupt Block Diagram

3-1-3 Operation

■Interrupt Processing Sequence

For interrupts other than reset, the interrupt processing sequence consists of interrupt request, interrupt acceptance, and hardware processing. The program counter (PC) and processor status word (PSW) and handy addressing data (HA) are saved onto the stack, and execution branches to the address specified by the corresponding interrupt vector.

An interrupt handler ends by restoring the contents of any registers used during processing and then executing the return from interrupt (RTI) instruction to return to the point at which execution was interrupted.

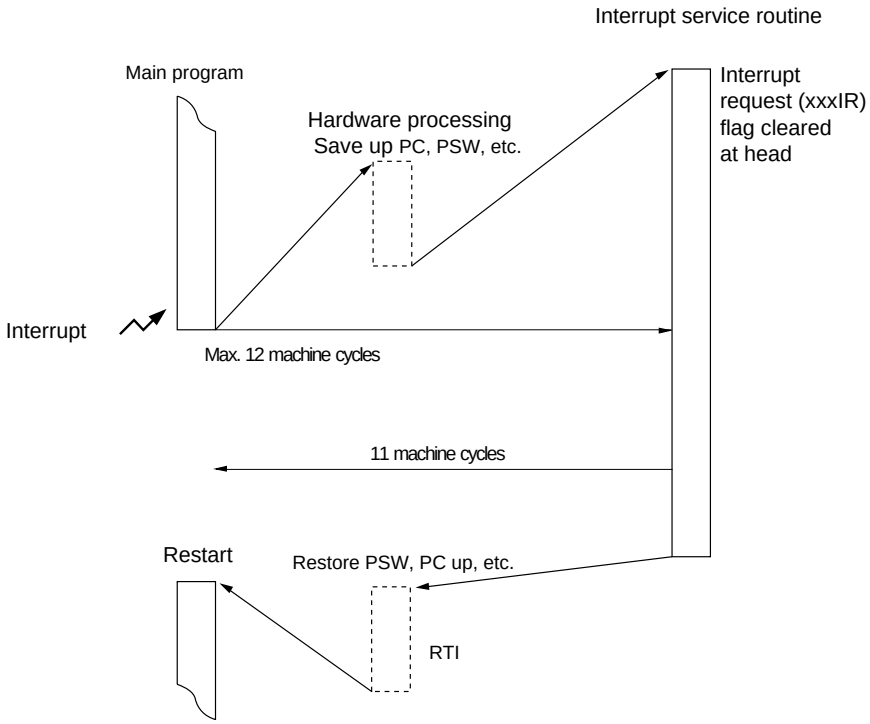


Figure 3-1-2 Interrupt Processing Sequence (maskable interrupts)

Non-maskable interrupts have priority over maskable ones.

■Interrupt Sources and Vector Addresses

Here is the list of interrupt vector address and interrupt group.

Table 3-1-2 Interrupt Vector Address and Interrupt Group

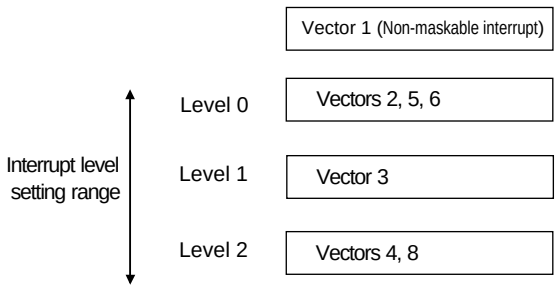
Vector Number	Vector Address	Interrupt group (Interrupt source)		Control Register (address)	
0	x'04000'	Reset	-	-	-
1	x'04004'	Non-maskable interrupt	NMI	NMICR	x'03FE1'
2	x'04008'	External interrupt 0	IRQ0	IRQ0ICR	x'03FE2'
3	x'0400C'	External interrupt 1	IRQ1	IRQ1ICR	x'03FE3'
4	x'04010'	Reserved	-	-	x'03FE4'
5	x'04014'	Reserved	-	-	x'03FE5'
6	x'04018'	Timer 2 interrupt	TM2IRQ	TM2ICR	x'03FE6'
7	x'0401C'	Time base period	TBIRQ	TBICR	x'03FE7'
8	x'04020'	Serial interface 0 interrupt	SC0IRQ	SC0ICR	x'03FE8'
9	x'04024'	Reserved	-	-	x'03FE9'
10	x'04028'	AD converter interrupt	ADIRQ	ADICR	x'03FEA'
11	x'0402C'	External interrupt 2	IRQ2	IRQ2ICR	x'03FEB'
12	x'04030'	External interrupt 3*1	IRQ3	IRQ3ICR	x'03FEC'
13	x'04034'	Reserved	-	-	x'03FED'
14	x'04038'	Timer 3 interrupt	TM3IRQ	TM3ICR	x'03FEE'
15	x'0403C'	Timer 4 interrupt	TM4IRQ	TM4ICR	x'03FEF'
16	x'04040'	Timer 5 interrupt	TM5IRQ	TM5ICR	x'03FF0'
17	x'04044'	Reserved	-	-	x'03FF1'
18	x'04048'	Reserved	-	-	x'03FF2'
19	x'0404C'	Reserved	-	-	x'03FF3'
20	x'04050'	Reserved	-	-	x'03FF4'

*1 External interrupt 3 cannot be used for the other types except 48-pin TQFP package type.

For unused interrupts and reserved interrupts, set the address the RTI instruction is described on to the corresponded address.

■Interrupt Level and Priority

On this LSI, vector numbers and interrupt control registers (except reset interrupt) are allocated to each interrupts. The interrupt level (except reset interrupt, non-maskable interrupt) can be set by software, per each interrupt group. There are three hierarchical interrupt levels. If multiple interrupts have the same priority, the one with the lowest vector number takes priority. For example, if a vector 3 set to level 1 and a vector 4 set to level 2 request interrupts simultaneously, vector 3 will be accepted.



Priority	Interrupt vector No.
1	Vector 1
2	Vector 2
3	Vector 5
4	Vector 6
5	Vector 3
6	Vector 4
7	Vector 8

Figure 3-1-3 Interrupt Priority Outline

■Determination of Interrupt Acceptance

The following is the procedure from interrupt request input to acceptance.

(1) The interrupt request flag (xxxIR) in the corresponding external interrupt control register (IRQnICR) or internal interrupt control register (xxxICR) is set to '1'.

(2) An interrupt request is input to the CPU, If the interrupt enable flag (xxxIE) in the same register is '1'.

(3) The interrupt level (IL) is set for each interrupt. The interrupt level (IL) is input to the CPU.

(4) The interrupt request is accepted, If IL has higher priority than IM and MIE is '1'.

(5) After the interrupt is accepted, the hardware resets the interrupt request flag (xxxIR) in the interrupt control register (xxxICR) to '0'.

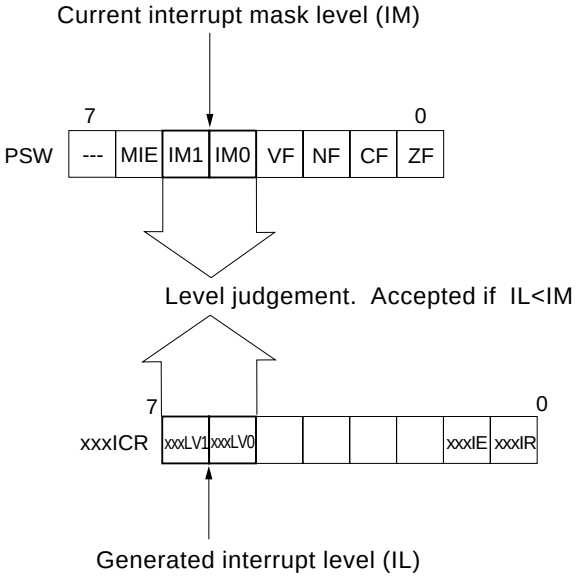


Figure 3-1-4 Determination of Interrupt Acceptance

The corresponding interrupt enable flag (xxxIE) is not cleared to "0", even if the interrupt is accepted.

When the setting is xxxLV1=1, xxxLV0=1, the interrupt is disabled regardless of the value of xxxIE, xxxIR.

MIE='0' and interrupts are disabled when:

- MIE in the PSW is reset to '0' by a program
- Reset is detected

MIE='1' and interrupts are enabled when:

- MIE in the PSW is set to '1' by a program

The interrupt mask level (IM=IM1 - IM0) in the processor status word (PSW) changes when:

- The program alters it directly,
- A reset initializes it to 0 (00b),
- The hardware accepts and thus switches to the interrupt level (IL) for a maskable interrupt.
- Execution of the RTI instruction at the end of an interrupt service routine restores the processor status word (PSW) and thus the previous interrupt mask level.

The maskable interrupt enable (MIE) flag in the processor status word (PSW) is not cleared to "0" when an interrupt is accepted.

Non-maskable interrupts have priority over maskable ones.

■Interrupt Acceptance Operation

When accepting an interrupt, this hardware saves the handy address register, the return address from the program counter, and the processor status word (PSW) to the stack and branches to the interrupt handler using the starting address in the vector table.

The following is the hardware processing sequence after interrupt acceptance.

1. The stack pointer (SP) is updated.
   (SP-6 → SP)
2. The contents of the handy address register (HA) are saved to the stack.
   Upper half of HA → (SP+5)
   Lower half of HA → (SP+4)
3. The contents of the program counter (PC), the return address, are saved to the stack.
   PC bits 18, 17, and 0 → (SP+3)
   PC bits 16-9 → (SP+2)
   PC bits 8-1 → (SP+1)
4. The contents of the PSW are saved to the stack.
   PSW → (SP)
5. The interrupt level (xxxLVn) for the interrupt is copied to the interrupt mask (IMn) in the PSW.
   Interrupt level (xxxLVn) → IMn
6. The hardware branches to the address in the vector table.

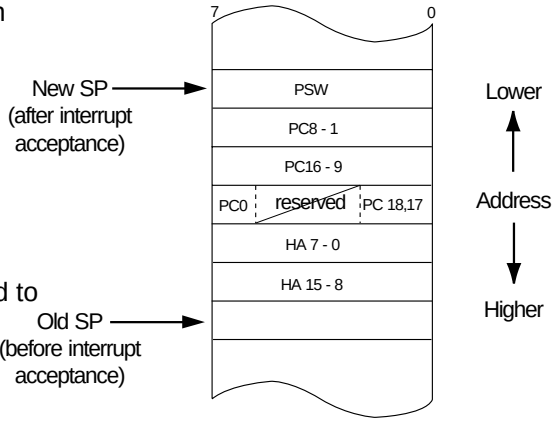


Figure 3-1-5 Stack Operation during interrupt acceptance

■Interrupt Return Operation

An interrupt handler ends by restoring, using the POP instruction and other means, the contents of any registers used during processing and then executing the return from interrupt (RTI) instruction to return to the point at which execution was interrupted.

The following is the processing sequence after the RTI instruction.

1. The contents of the PSW are restored from the stack. (SP)
2. The contents of the program counter (PC), the return address, are restored from the stack. (SP+1 to SP+3)
3. The contents of the handy address register (HA) are restored from the stack. (SP+4, SP+5)
4. The stack pointer is updated. (SP+6 → SP)
5. Execution branches to the address in the program counter.

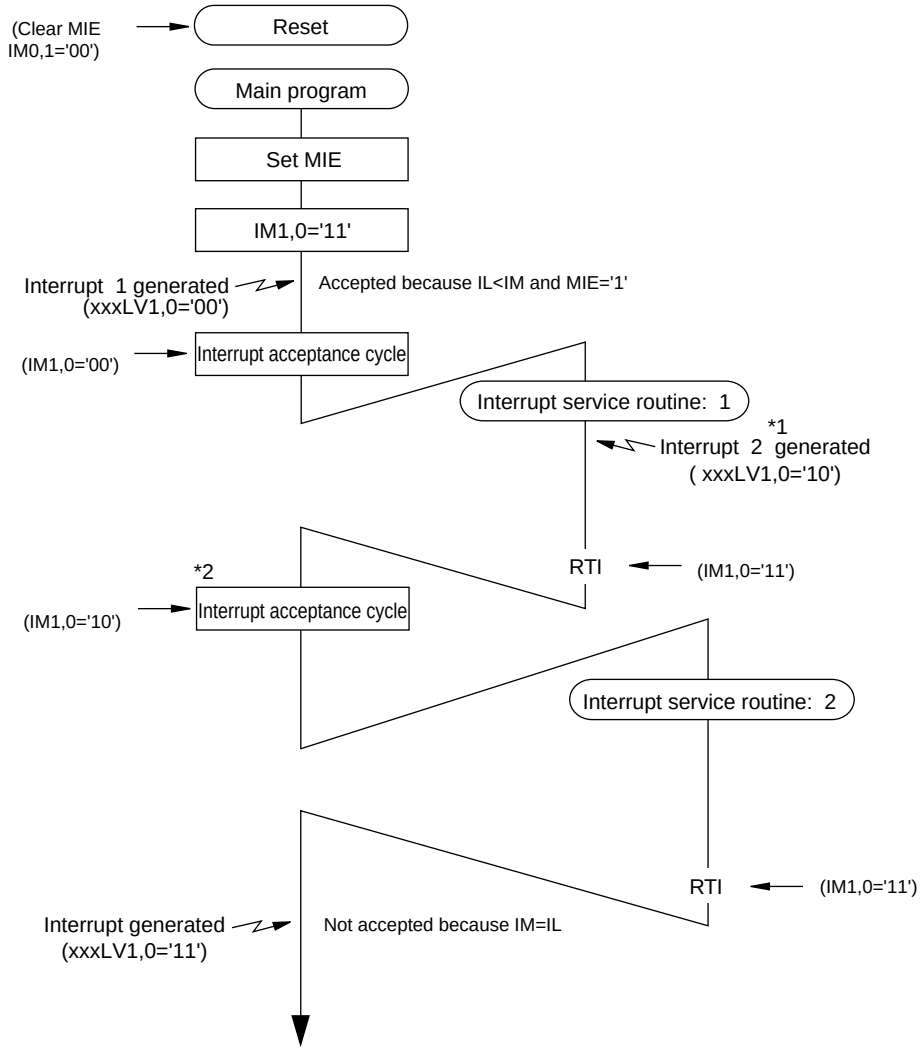
The handy address register is an internal register used by the handy addressing function. The hardware saves its contents to the stack to prevent the interrupt from interfering with operation of the function.

Registers such as data register, or address register are not saved, so that PUSH instruction should be used to save data register or address register onto the stack, if necessary.

The address bp6 to bp2, when program counter (PC) are saved to the stack, are reserved. Do not change by program.

■Maskable Interrupt

Figure 3-1-6 shows the processing flow when a second interrupt with a lower priority level (xxxLV1-xxxLV0='10') arrives during the processing of one with a higher priority level (xxxLV1-xxxLV0='00').



Parentheses ( ) indicate hardware processing.

*1 If during the processing of the first interrupt, an interrupt request with an interrupt level (IL) numerically lower than the interrupt mask (IM) arrives, it is accepted as a nested interrupt. If IL ≥ IM, however, the interrupt is not accepted.

*2 The second interrupt, postponed because its interrupt level (IL) was numerically greater than the interrupt mask (IM) for the first interrupt service routine, is accepted when the first interrupt handler returns.

Figure 3-1-6 Processing Sequence for Maskable Interrupts

■Multiplex Interrupt

When an MN101C45 series device accepts an interrupt, it automatically disables acceptance of subsequent interrupts with the same or lower priority level. When the hardware accepts an interrupt, it copies the interrupt level (xxxLVn) for the interrupt to the interrupt mask (IM) in the PSW. As a result, subsequent interrupts with the same or lower priority levels are automatically masked. Only interrupts with higher priority levels are accepted. The net result is that interrupts are normally processed in decreasing order of priority. It is, however, possible to alter this arrangement.

1. To disable interrupt nesting
   - Reset the MIE bit in the PSW to "0."
   - Raise the priority level of the interrupt mask (IM) in the PSW.
2. To enable interrupts with lower priority than the currently accepted interrupt
   - Lower the priority level of the interrupt mask (IM) in the PSW.

Multiplex interrupts are only enabled for interrupts with levels higher than the PSW interrupt mask level (IM).

It is possible to forcibly rewrite IM to accept an interrupt with a priority lower than the interrupt being processed, but be careful of stack overflow.

Do not operate the maskable interrupt control register (xxxICR) when multiple interrupts are enabled. If operation is necessary, first clear the PSW MIE flag to disable interrupts.

Figure 3-1-7 shows the processing flow for multiple interrupts (interrupt 1: xxxLV1-xxxLV0='10', and interrupt 2: xxxLV1-xxxLV0='00').

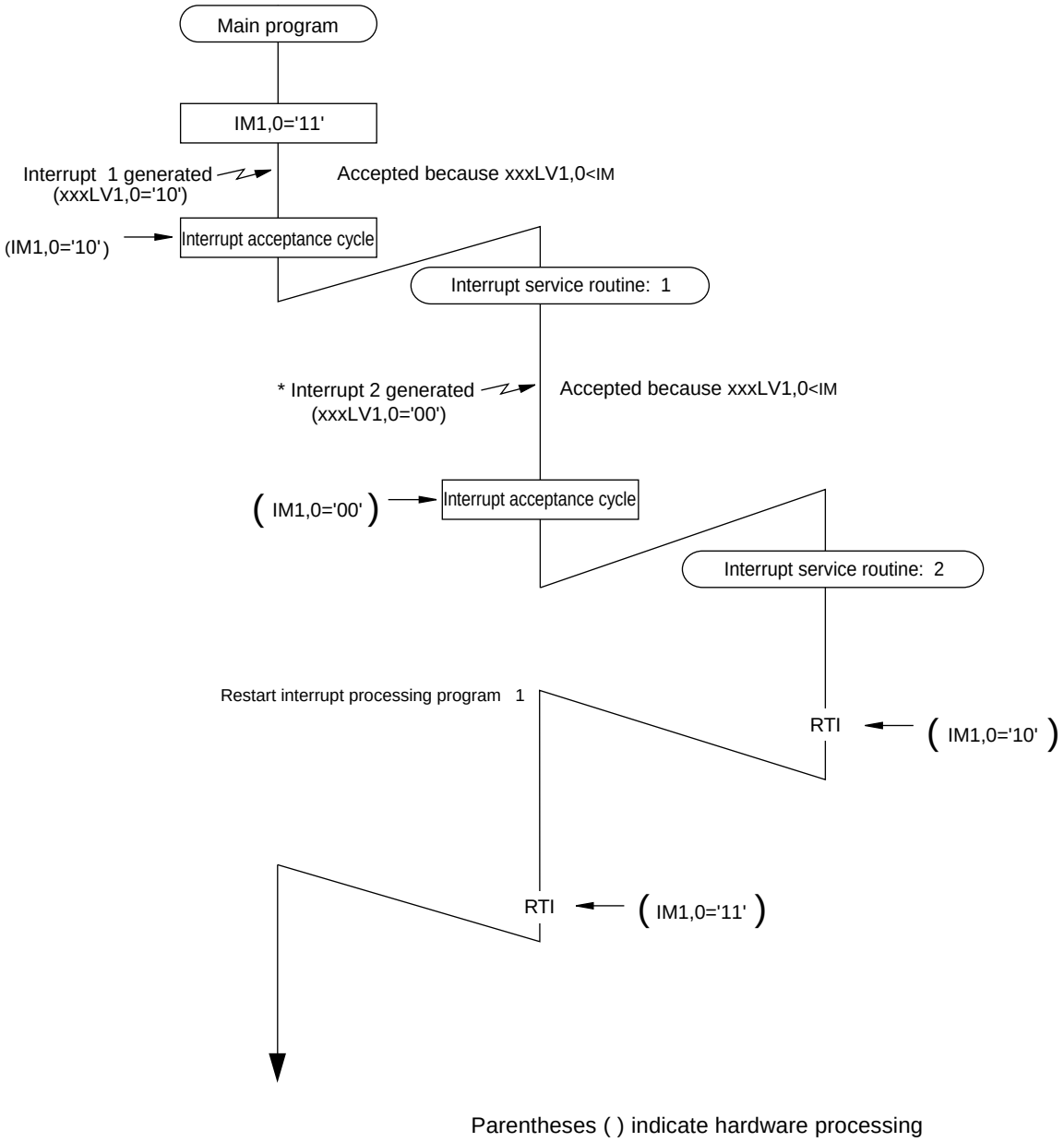


Figure 3-1-7 Processing Sequence with Multiple Interrupts Enabled

3-1-4 Interrupt Flag Setup

■ Interrupt request flag (IR) setup by the software

The interrupt request flag is operated by the hardware. That is set to "1" when any interrupt factor is generated, and cleared to "0" when the interrupt is accepted. If you want to operate it by the software, the IRWE flag of MEMCTR should be set to "1".

■ Interrupt flag setup procedure

A setup procedure of the interrupt request flag set by the hardware and the software shows as follows ;

Setup Procedure	Description
(1) Disable all maskable interrupts. PSW bp6 : MIE = 0	(1) Clear the MIE flag of PSW to disable all maskable interrupts. This is necessary, especially when the interrupt control register is changed.
(2) Select the interrupt factor.	(2) Select the interrupt factor such as interrupt edge selection, or timer interrupt cycle change.
(3) Enable the interrupt request flag to be rewritten. MEMCTR (x'3F01') bp2 : IRWE = 1	(3) Set the IRWE flag of MEMCTR to enable the interrupt request flag to be rewritten. This is necessary only when the interrupt request flag is changed by the software.
(4) Rewrite the interrupt request flag. xxxICR bp0 : xxxIR	(4) Rewrite the interrupt request flag (xxxIR) of the interrupt control register (xxxICR).
(5) Disable the interrupt request flag to be rewritten. MEMCTR (x'3F01') bp2 : IRWE = 0	(5) Clear the IRWE flag so that interrupt request flag can not be rewritten by the software.
(6) Set the interrupt level. xxxICR bp7-6 : xxxLV1-0 PSW bp5-4 : IM1-0	(6) Set the interrupt level by the xxxLV1-0 flag of the interrupt control register (xxxICR). Set the IM1-0 flag of PSW when the interrupt acceptance level of CPU should be changed.
(7) Enable the interrupt. xxxICR bp1 : xxxIE = 1	(7) Set the xxxIE flag of the interrupt control register (xxxICR) to enable the interrupt.
(8) Enable all maskable interrupts. PSW bp6 : MIE = 1	(8) Set the MIE flag of PSW to enable maskable interrupts.

3-2 Control Registers

3-2-1 Registers List

Table 3-2-1 Interrupt Control Registers

Register	Address	R/W	Functions	Page
NMICR	x'03FE1'	R/W	Non-maskable interrupt control register	III - 16
IRQ0ICR	x'03FE2'	R/W	External interrupt 0 control register	III - 17
IRQ1ICR	x'03FE3'	R/W	External interrupt 1 control register	III - 18
IRQ2ICR	x'03FEB'	R/W	External interrupt 2 control register	III - 19
IRQ3ICR*1	x'03FEC'	R/W	External interrupt 3 control register	III - 20
TM2ICR	x'03FE6'	R/W	Timer 2 interrupt control register (Timer 2 interrupt)	III - 21
TM3ICR	x'03FEE'	R/W	Timer 3 interrupt control register (Timer 3 interrupt)	III - 22
TM4ICR	x'03FEF'	R/W	Timer 4 interrupt control register (Timer 4 interrupt)	III - 23
TM5ICR	x'03FF0'	R/W	Timer 5 interrupt control register (Timer 5 interrupt)	III - 24
TBICR	x'03FE7'	R/W	Time base interrupt control register (Time base period)	III - 25
SC0ICR	x'03FE8'	R/W	Serial interface 0 interrupt control register (Serial interface 0 interrupt)	III - 26
ADICR	x'03FEA'	R/W	A/D converter interrupt control register (A/D converter interrupt)	III - 27

1* IRQ3ICR can be used only for 48-pin TQFP package type.

Writing to the interrupt control register should be done after that all maskable interrupts are set to be disabled by the MIE flag of the PSW register.

If the interrupt level flag (xxxLVn) is set to "level 3", its vector is disabled, regardless of interrupt enable flag and interrupt request flag.

3-2-2 Interrupt Control Registers

The interrupt control registers include the non-maskable interrupt control register (NMICR), the external interrupt control register (IRQnICR) and the internal interrupt control register (xxxICR).

■Non-Maskable Interrupt Control Register (NMICR address: x'03FE1')
The non-maskable interrupt control register (NMICR) stores the non maskable interrupt request. When the non-maskable interrupt request is generated, the interrupt is accepted regardless of the interrupt mask level (IMn) of PSW. The hardware then branches to the address stored at location x'04004' in the interrupt vector table. The watchdog timer overflow interrupt request flag (WDIR) is set to "1" when the watchdog timer overflows. The program interrupt request flag (PIR) is set to "1" when the undefined instruction is executed.

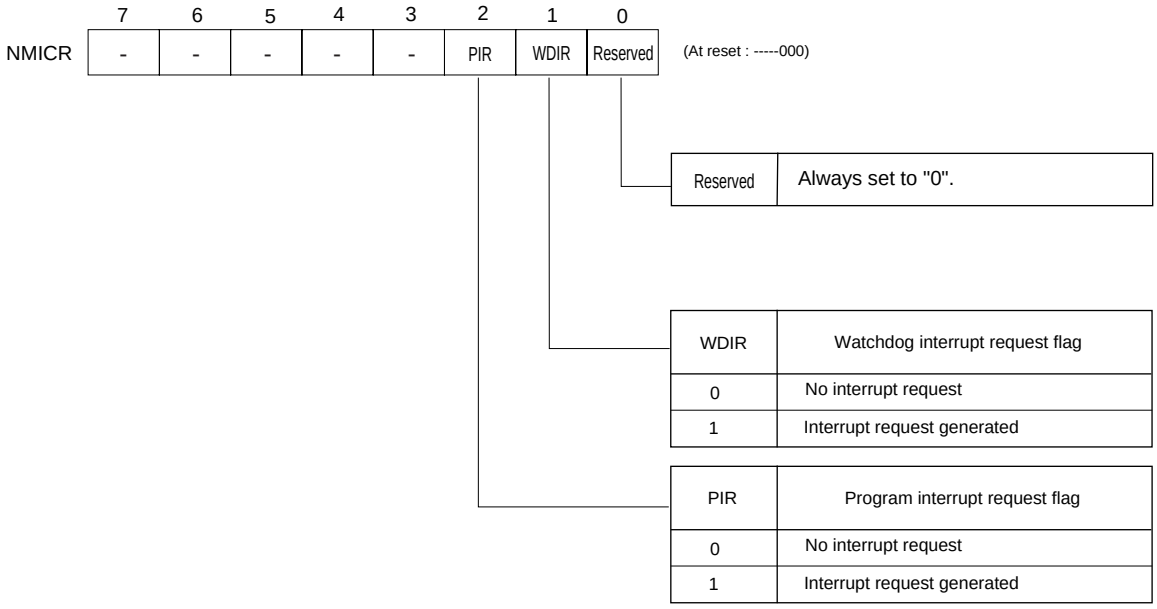


Figure 3-2-1 Non-Maskable Interrupt Control Register (NMICR:x'03FE1', R/W)

On this LSI, when undefined instruction is decoded, the program interrupt request flag (PIR) is set to "1", and the non-maskable interrupt is generated.
If the PIR flag setup is confirmed by the non-maskable interrupt service routine, the reset via the software is recommended. When software reset, the reset pin (P27) outputs "0".

Once the WDIR becomes "1" by generating of non-maskable interrupt, only the program can clear it to "0".

■External Interrupt 0 Control Register (IRQ0ICR)

The external interrupt 0 control register (IRQ0ICR) controls interrupt level of the external interrupt 0, active edge, interrupt enable and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag for external interrupt is set to level 3 (IRQ0LV1=IRQ0LV0="1"), the interrupt of its vector is disabled regardless of the external interrupt request flag and the external interrupt enable flag.

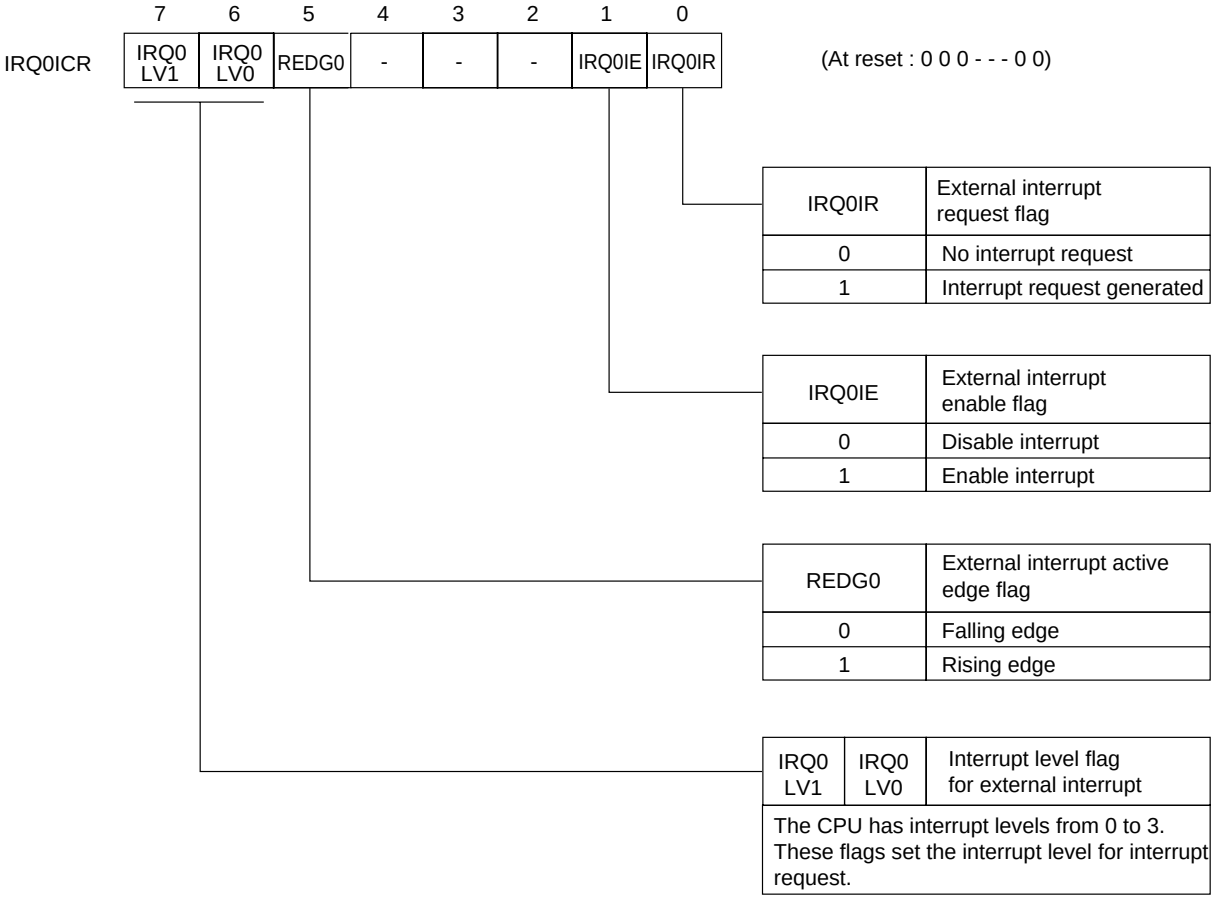


Figure 3-2-2 External Interrupt 0 Control Register (IRQ0ICR : x'03FE2', R/W)

■External Interrupt 1 Control Register (IRQ1ICR)

The external interrupt 1 control register (IRQ1ICR) controls interrupt level of external interrupt 1, active edge, interrupt enable and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag for external interrupt is set to level 3 (IRQ1LV1=IRQ1LV0="1"), the interrupt of its vector is disabled regardless of the external interrupt request flag and the external interrupt enable flag.

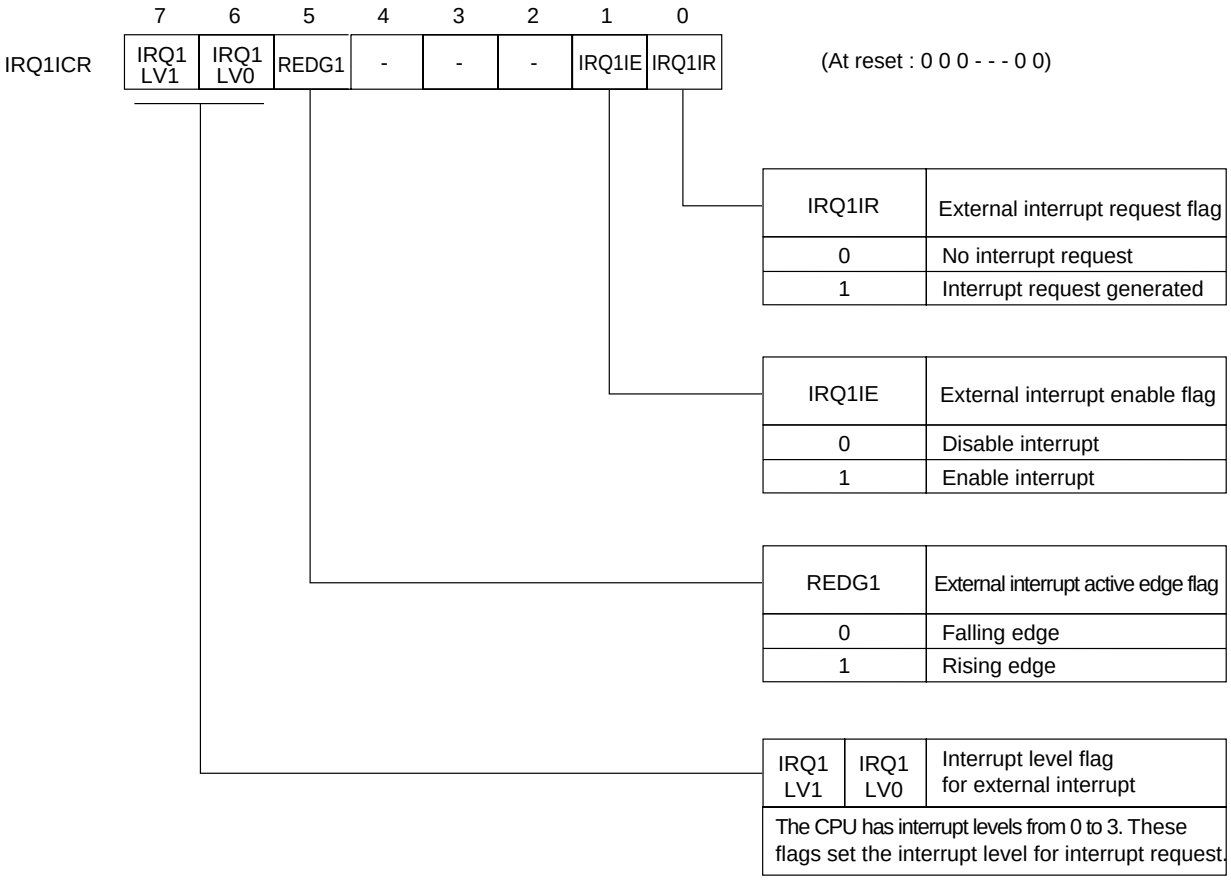


Figure 3-2-3 External Interrupt 1 Control Register (IRQ1ICR : x'03FE3', R/W)

■External Interrupt 2 Control Register (IRQ2ICR)

The external interrupt 2 control register (IRQ2ICR) controls interrupt level of external interrupt 2, active edge, interrupt enable and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag for external interrupt is set to level 3 (IRQ2LV0=IRQ2LV1="1"), the interrupt of its vector is disabled regardless of the external interrupt request flag and the external interrupt enable flag.

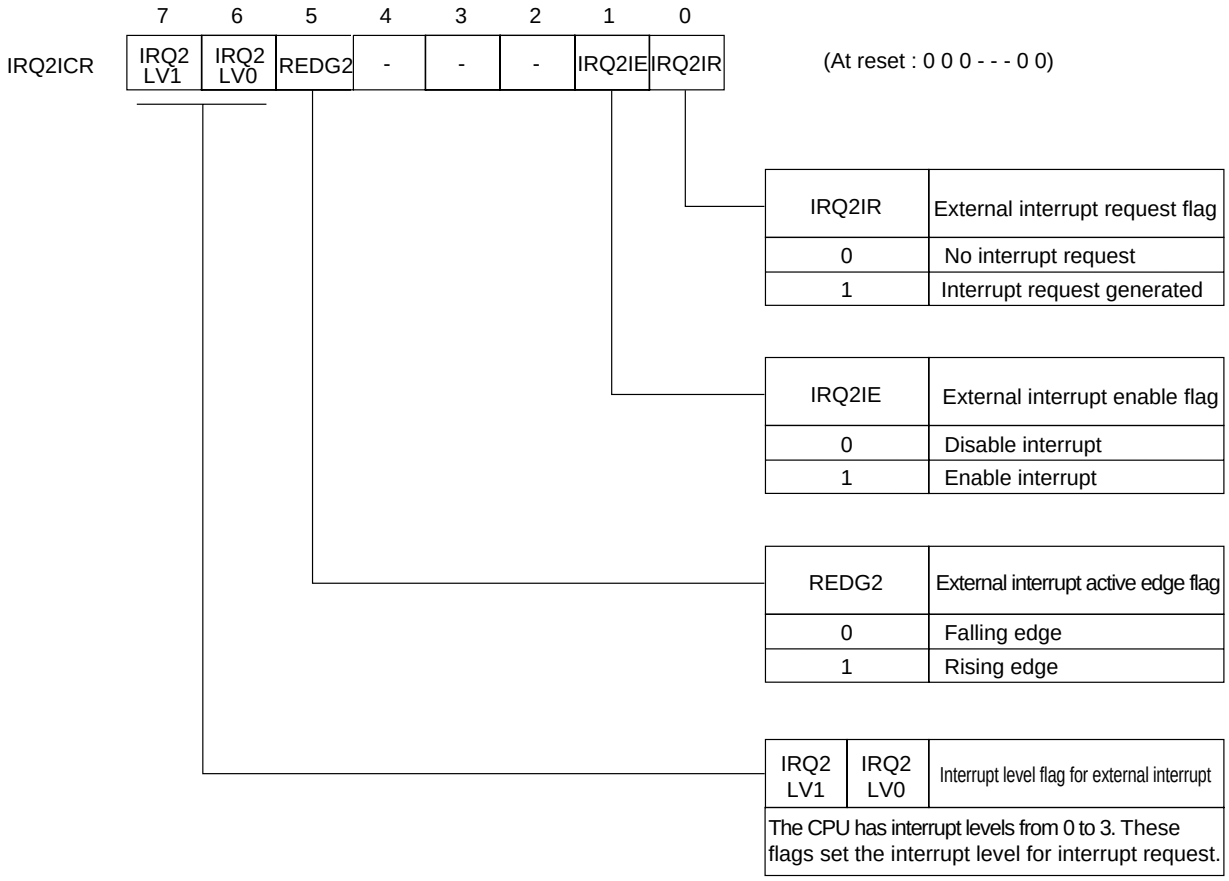


Figure 3-2-4 External Interrupt 2 Control Register (IRQ2ICR : x'03FEB', R/W)

■External Interrupt 3 Control Register (IRQ3ICR)

The external interrupt 3 control register (IRQ3ICR) controls interrupt level of external interrupt 3, active edge, interrupt enable flag and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag for external interrupt is set to level 3 (IRQ3LV1=IRQ3LV0="1"), the interrupt of its vector is disabled regardless of the external interrupt request flag and the external interrupt enable flag.

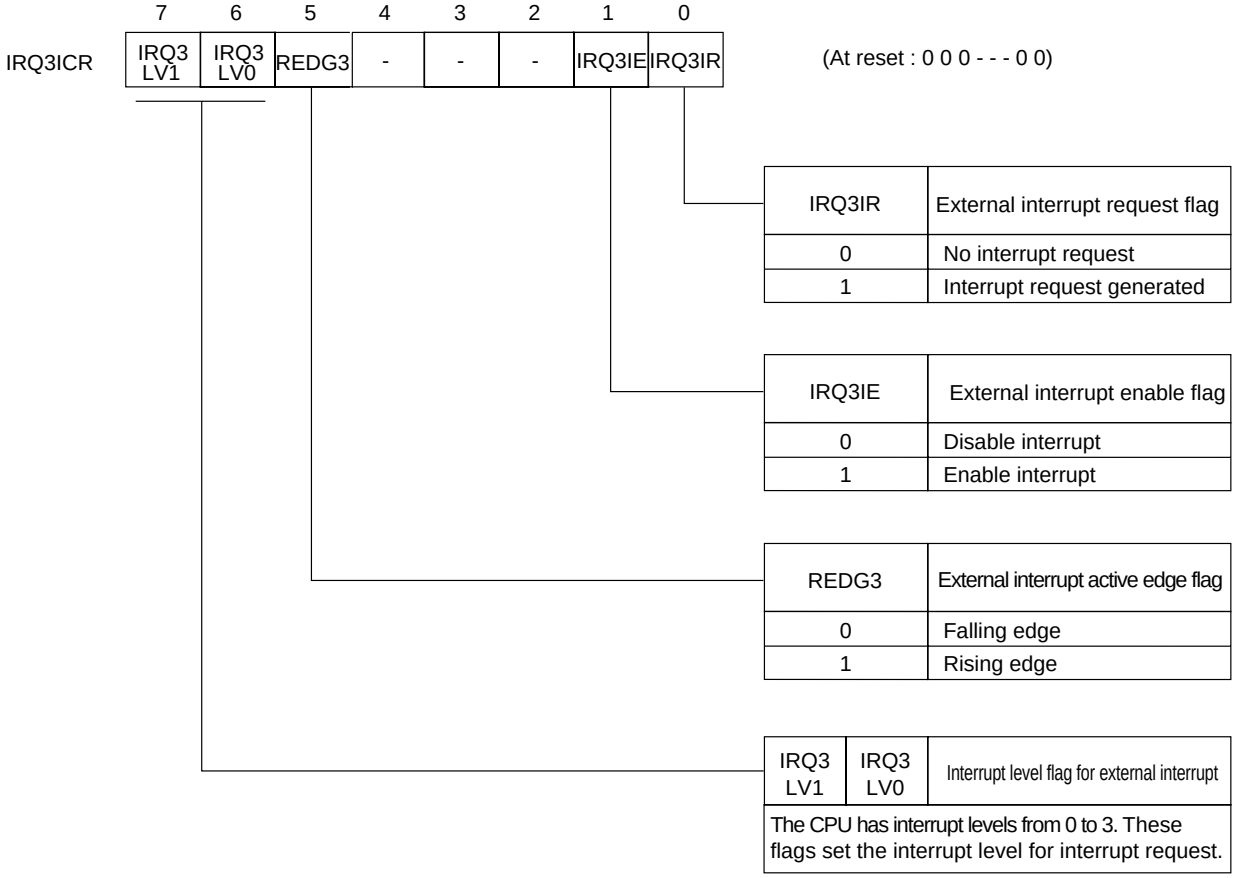


Figure 3-2-5 External Interrupt 3 Control Register (IRQ3ICR : x'03FEC', R/W)

External interrupt 3 control register (IRQ3ICR) can be used only for 48-pin TQFPpackage type.

■Timer 2 Interrupt Control Register (TM2ICR)

The timer 2 interrupt control register (TM2ICR) controls interrupt level of timer 2 interrupt, interrupt enable flag and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag is set to level 3 (TM2LV1= TM2LV0 ="1"), the interrupt of its vector is disabled regardless of the interrupt request flag and the interrupt enable flag.

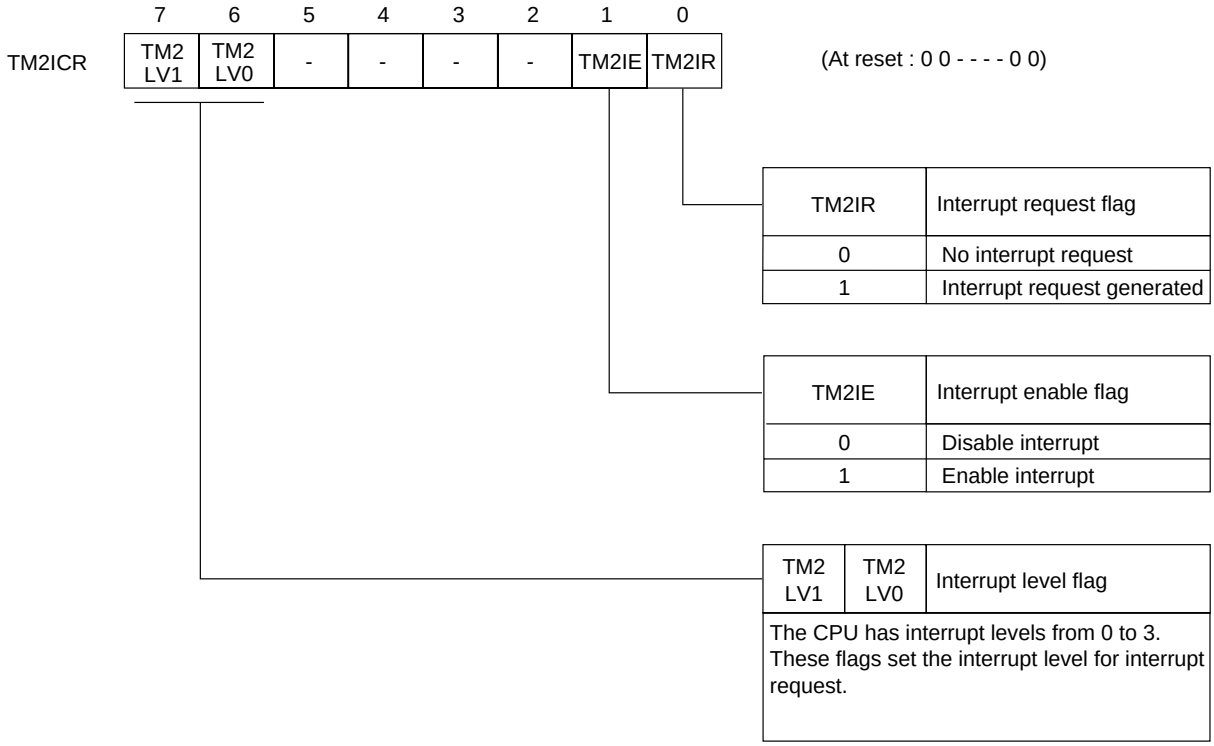


Figure 3-2-6 Timer 2 Interrupt Control Register (TM2ICR : x'03FE6', R/W)

■Timer 3 Interrupt Control Register (TM3ICR)

The timer 3 interrupt control register (TM3ICR) controls interrupt level of timer 3 interrupt, interrupt enable flag and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag is set to level 3 (TM3LV1=TM3LV0 ="1"), the interrupt of its vector is disabled regardless of the interrupt request flag and the interrupt enable flag.

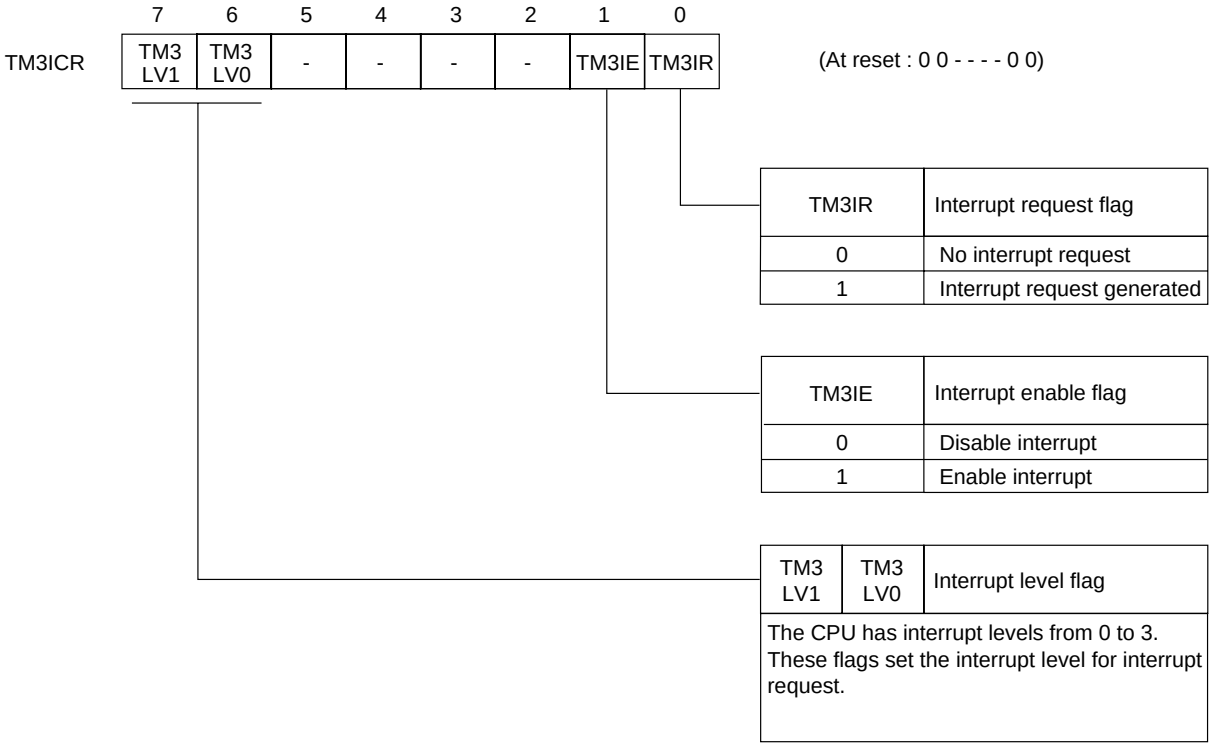


Figure 3-2-7 Timer 3 Interrupt Control Register (TM3ICR : x'03FEE', R/W)

■Timer 4 Interrupt Control Register (TM4ICR)

The timer 4 interrupt control register (TM4ICR) controls interrupt level of timer 4 interrupt, interrupt enable flag and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag is set to level 3 (TM4LV1=TM4LV0 ="1"), the interrupt of its vector is disabled regardless of the interrupt request flag and the interrupt enable flag.

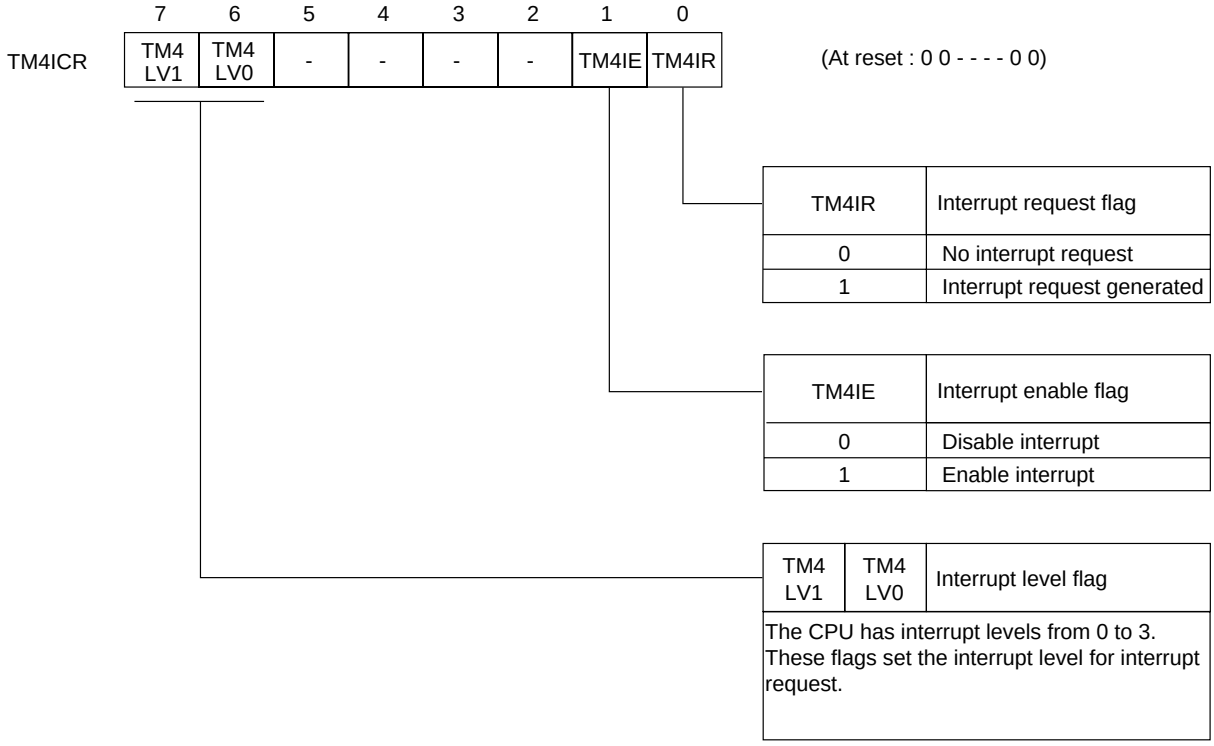


Figure 3-2-8 Timer 4 Interrupt Control Register (TM4ICR : x'03FEF', R/W)

■Timer 5 Interrupt Control Register (TM5ICR)

The timer 5 interrupt control register (TM5ICR) controls interrupt level of timer 5 interrupt, interrupt enable flag and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag is set to level 3 (TM5LV1=TM5LV0 ="1"), the interrupt of its vector is disabled regardless of the interrupt request flag and the interrupt enable flag.

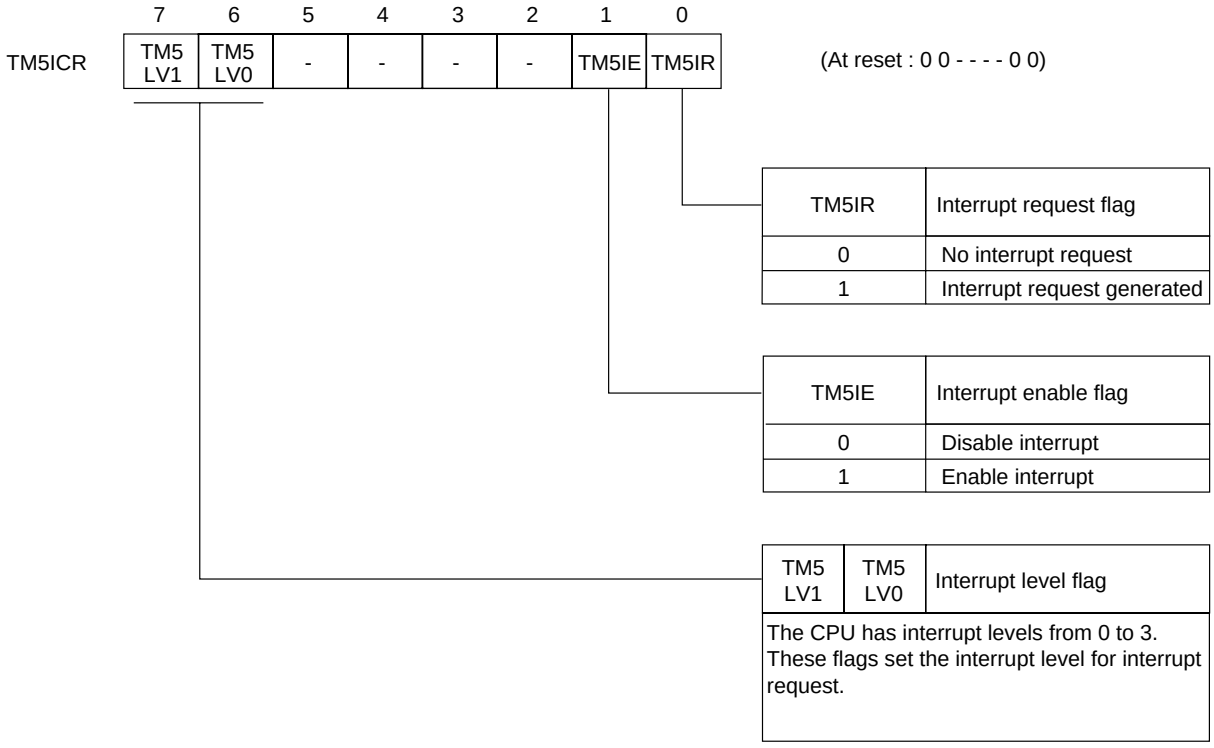


Figure 3-2-9 Timer 5 Interrupt Control Register (TM5ICR : x'03FF0', R/W)

■Time Base Interrupt Control Register (TBICR)

The time base interrupt control register (TBICR) controls interrupt level of time base interrupt, interrupt enable flag and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag is set to level 3 (TBLV1=TBLV0="1"), the interrupt of its vector is disabled regardless of the interrupt request flag and the interrupt enable flag.

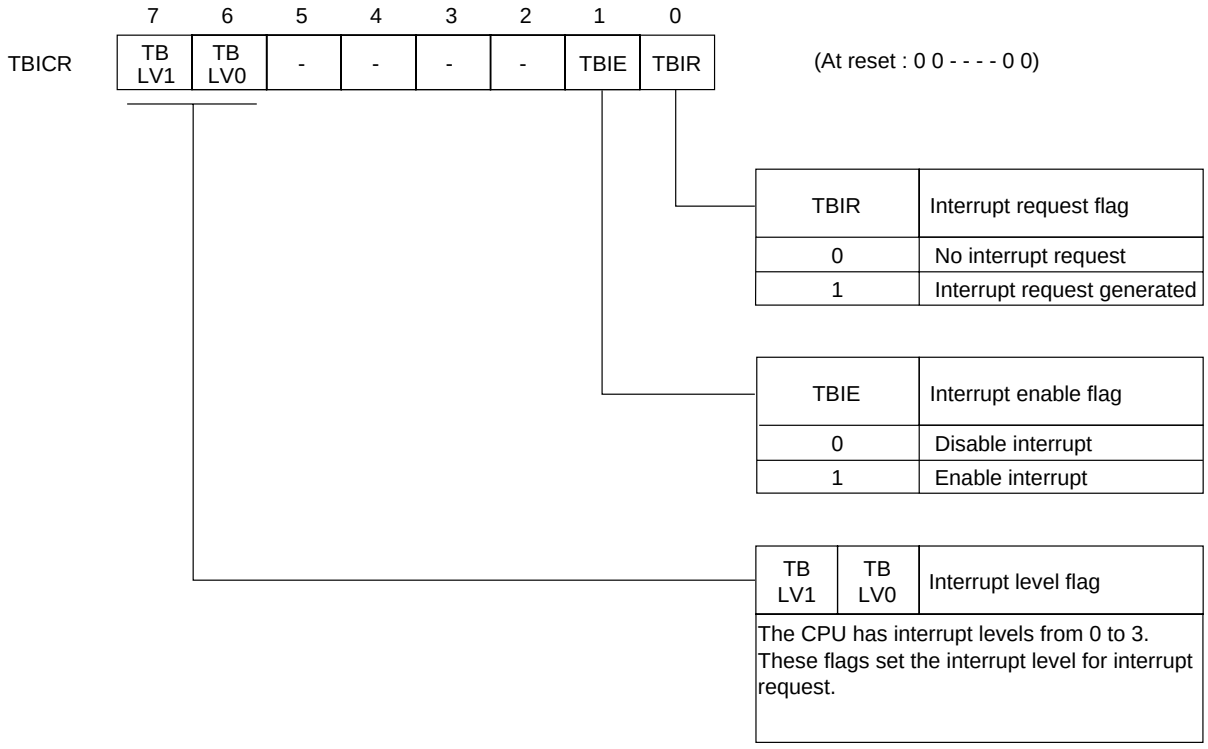


Figure 3-2-10 Time Base Interrupt Control Register (TBICR : x'03FE7', R/W)

■Serial interface 0 Interrupt Control Register (SC0ICR)

The serial interface 0 interrupt control register (SC0ICR) controls interrupt level of serial interface 0 interrupt, interrupt enable flag and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag is set to level 3 (SC0LV1=SC0LV0="1"), the interrupt of its vector is disabled regardless of the interrupt request flag and the interrupt enable flag.

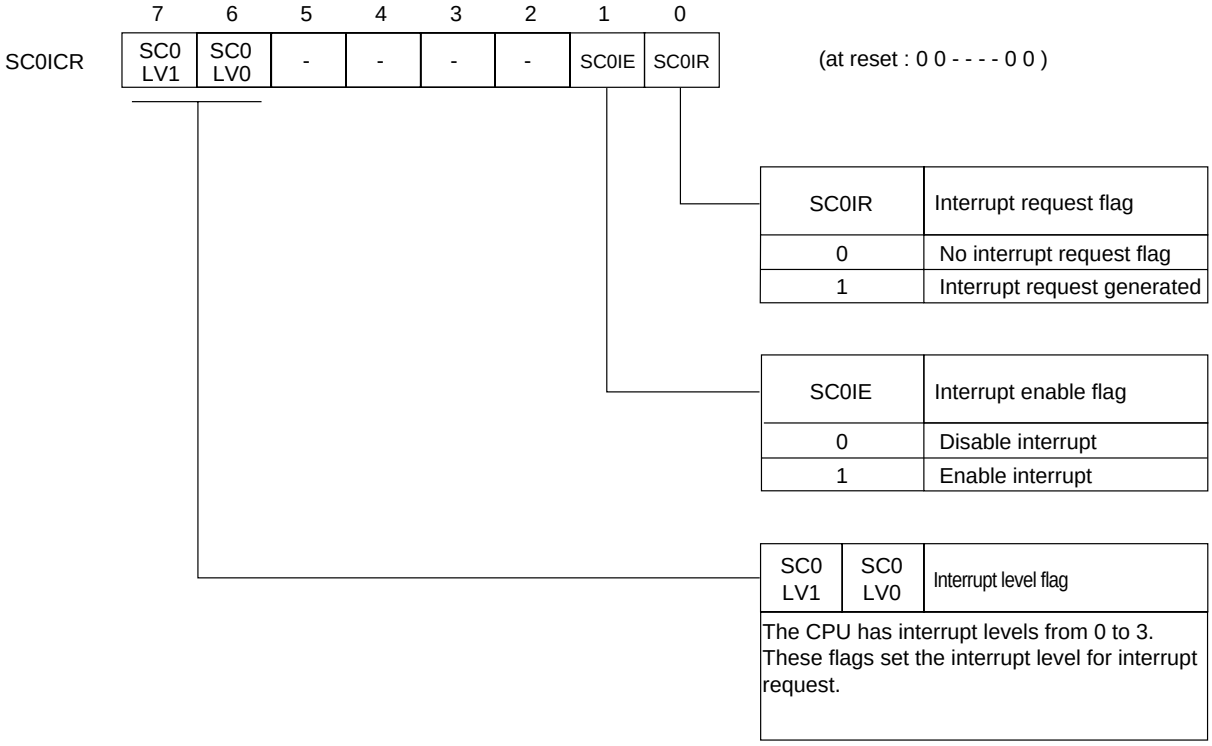


Figure 3-2-11 Serial interface 0 Interrupt Control Register (SC0ICR : x'03FE8', R/W)

■A/D Conversion Interrupt Control Register (ADICR)

The A/D conversion interrupt control register (ADICR) controls interrupt level of A/D conversion interrupt, interrupt enable flag and interrupt request. Interrupt control register should be operated when the maskable interrupt enable flag (MIE) of PSW is "0". When the interrupt level flag is set to level 3 (ADLV1=ADLV0="1"), the interrupt of its vector is disabled regardless of the interrupt request flag and the interrupt enable flag.

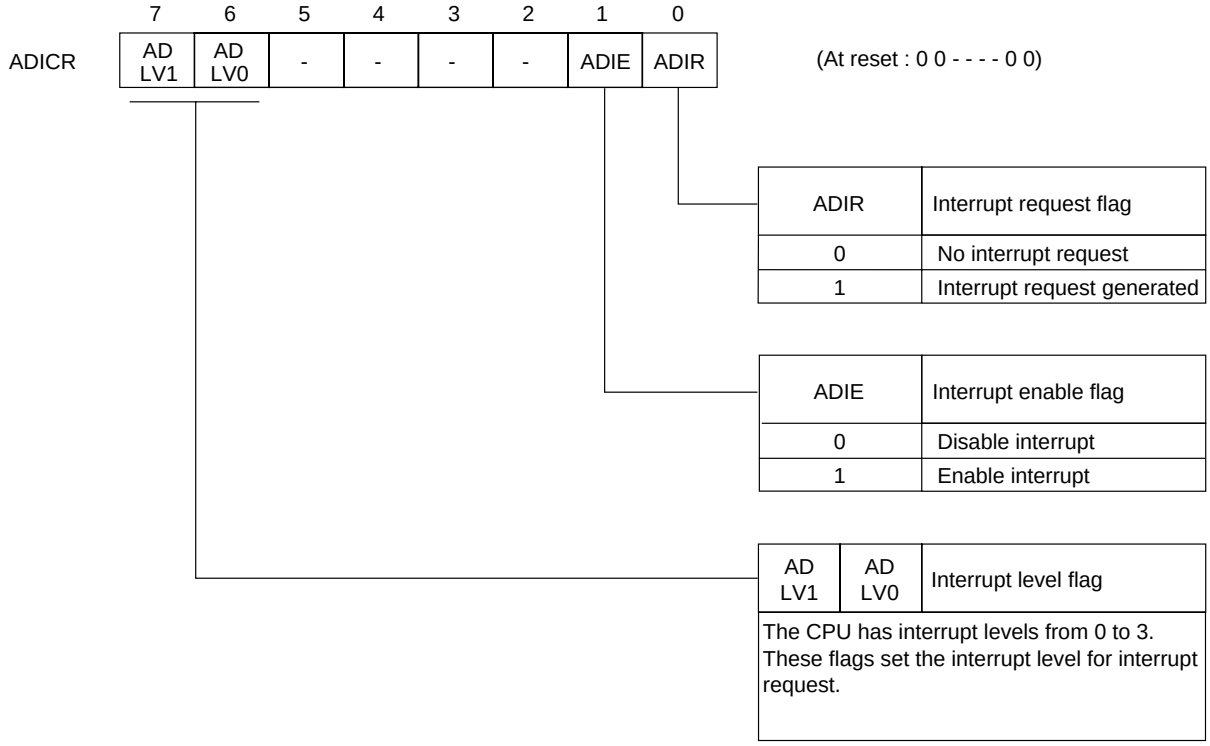


Figure 3-2-12 A/D Conversion Interrupt Control Register (ADICR : x'03FEA', R/W)

3-3 External Interrupts

There are 4*[1] external interrupts in this LSI. The circuit (external interrupt interface) for the external interrupt input signal, is built-in between the external interrupt input pin and the interrupt controller block. This external interrupt interface can manage to do with any kind of external interrupts.

3-3-1 Overview

Table 3-3-1 shows the list for functions which external interrupts 0 to 3 can be used.

Table 3-3-1 External Interrupt Functions

	External interrupt 0 (IRQ0)	External interrupt 1 (IRQ1)	External interrupt 2 (IRQ2)	External interrupt 3*[2] (IRQ3)
External interrupt input pin	P20	P21	P22	P23
Programmable active edge interrupt	√	√	√	√
Noise filter built-in	√	√	-	-
AC zero-cross detection	-	√	-	-
Capture trigger for timer 4	√	√	√	-

1* 3 external interrupts are provided to other package types except 48-pin TQFP package type.

2* External interrupt 3 (IRQ3) can be used only for 48-pin TQFP package type.

3-3-2 Block Diagram

■External Interrupt 0 Interface, External Interrupt 1 Interface, Block Diagram

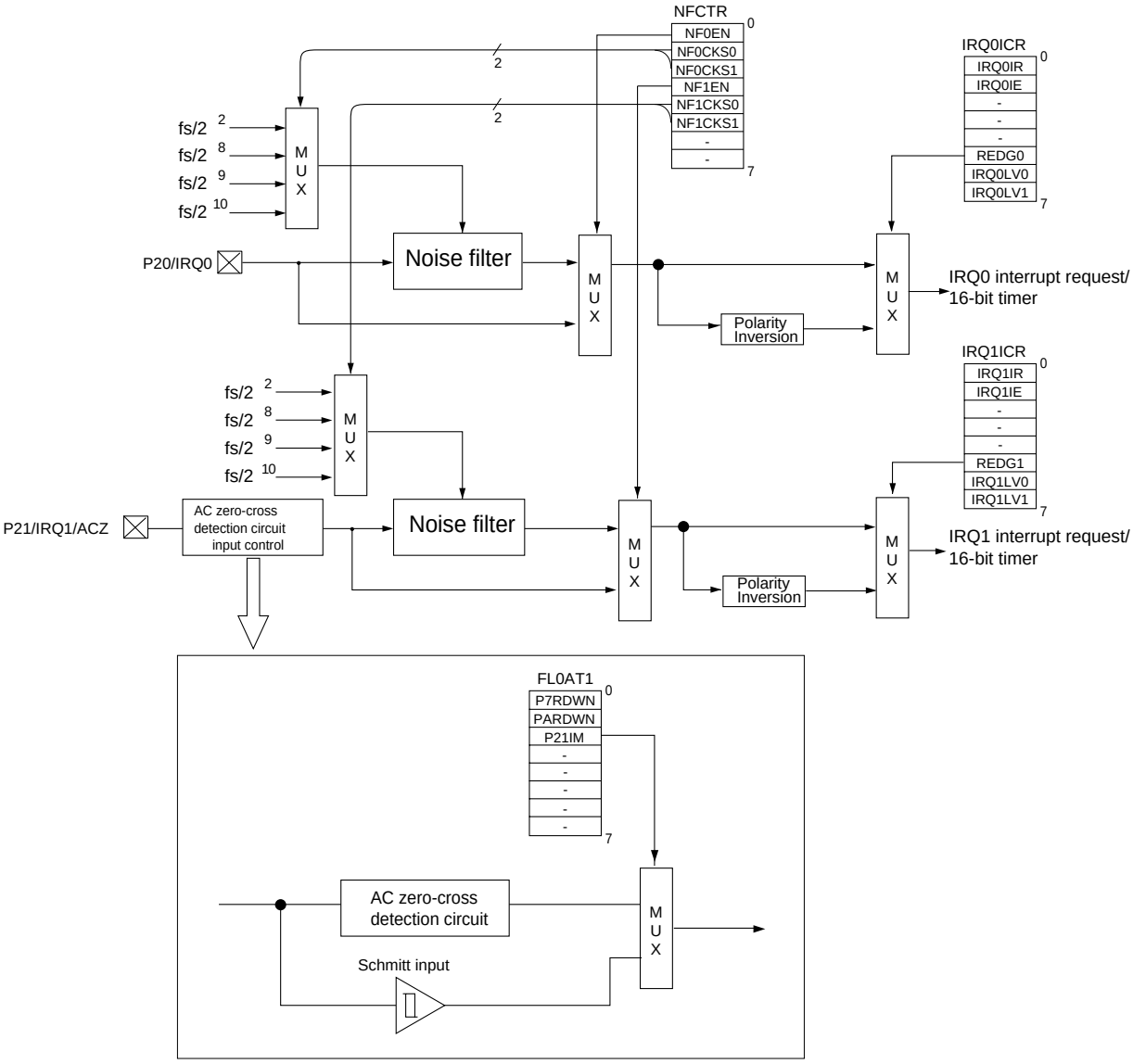
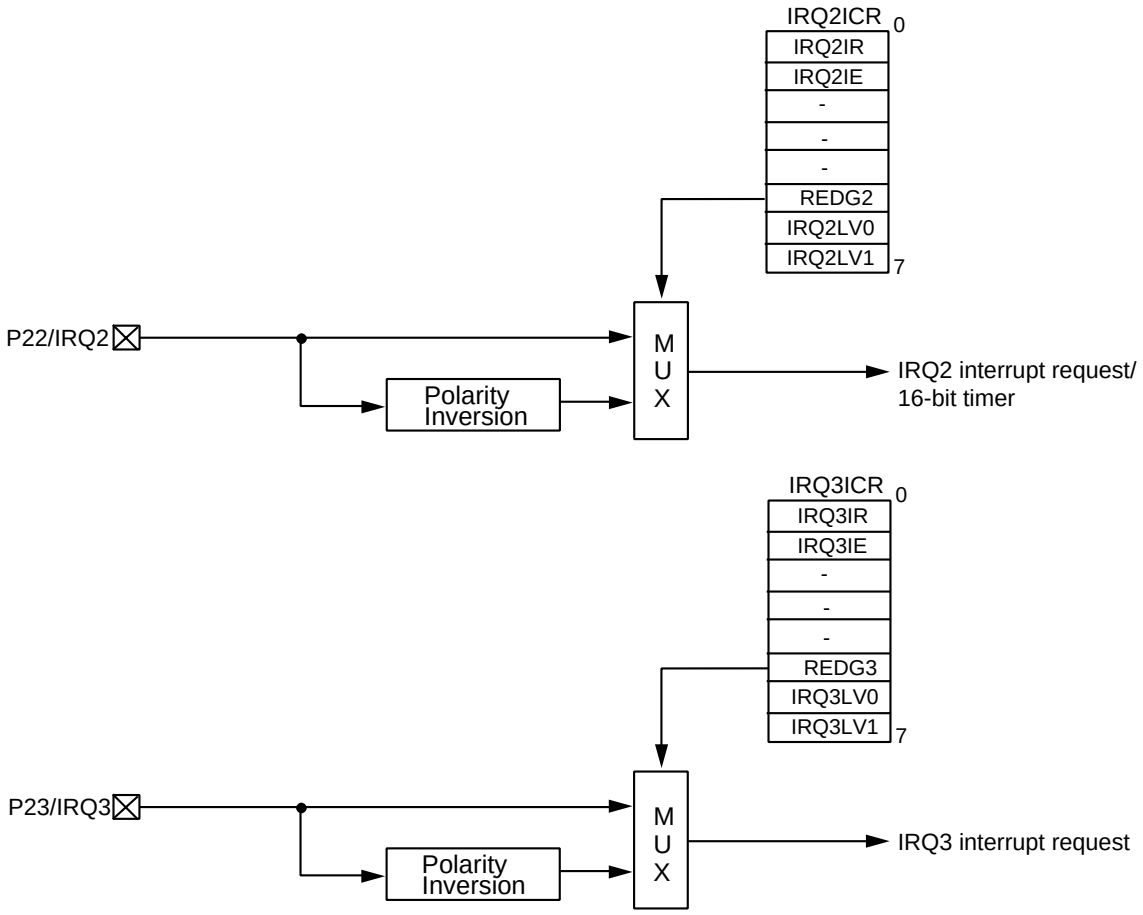


Figure 3-3-1 External Interrupt 0 Interface and External Interrupt 1 Interface Block Diagram

■External Interrupt 2 Interface and External Interrupt 3 Interface Block Diagram



1* External interrupt 3 interface can be used only for 48-pin TQFP package type.

Figure 3-3-2 External Interrupt 2 Interface, External Interrupt 3 Interface

3-3-3 Control Registers

The external interrupt input signals, which operated in each external interrupt 0 to 3 interface generate interrupt requests.

External interrupt 0 to 3 interface are controlled by the external interrupt control register (IRQnICR). And external interrupt interface 0 to 1 are controlled by the noise filter control register (NFCTR). When the external interrupt 1 is used for AC zero-cross detection, it is controlled by the pin control register 1 (FLOAT1).

Table 3-3-2 shows the list of registers, control external interrupt 0 to 3.

Table 3-3-2 External Interrupt Control Register

External Interrupt	Register	Address	R/W	Function	Page
External interrupt 0	IRQ0ICR	x'03FE2'	R/W	External interrupt 0 control register	III - 17
	NFCTR	x'03F8A'	R/W	Noise filter control register	III - 32
External interrupt 1	IRQ1ICR	x'03FE3'	R/W	External interrupt 1 control register	III - 18
	NFCTR	x'03F8A'	R/W	Noise filter control register	III - 32
	FLOAT1	x'03F4B'	R/W	Pin control register 1	III - 33
External interrupt 2	IRQ2ICR	x'03FEB'	R/W	External interrupt 2 control register	III - 19
External interrupt 3* [3]	IRQ3ICR	x'03FEC'	R/W	External interrupt 3 control register	III - 20

R/W : Readable / Writable.

*External interrupt 3 can be used only for 48-pin TQFP package type.

■Noise Filter Control Register (NFCTR)

The noise filter control register (NFCTR) sets the noise remove function to IRQ0 and IRQ1 and also selects the sampling cycle of noise remove function.

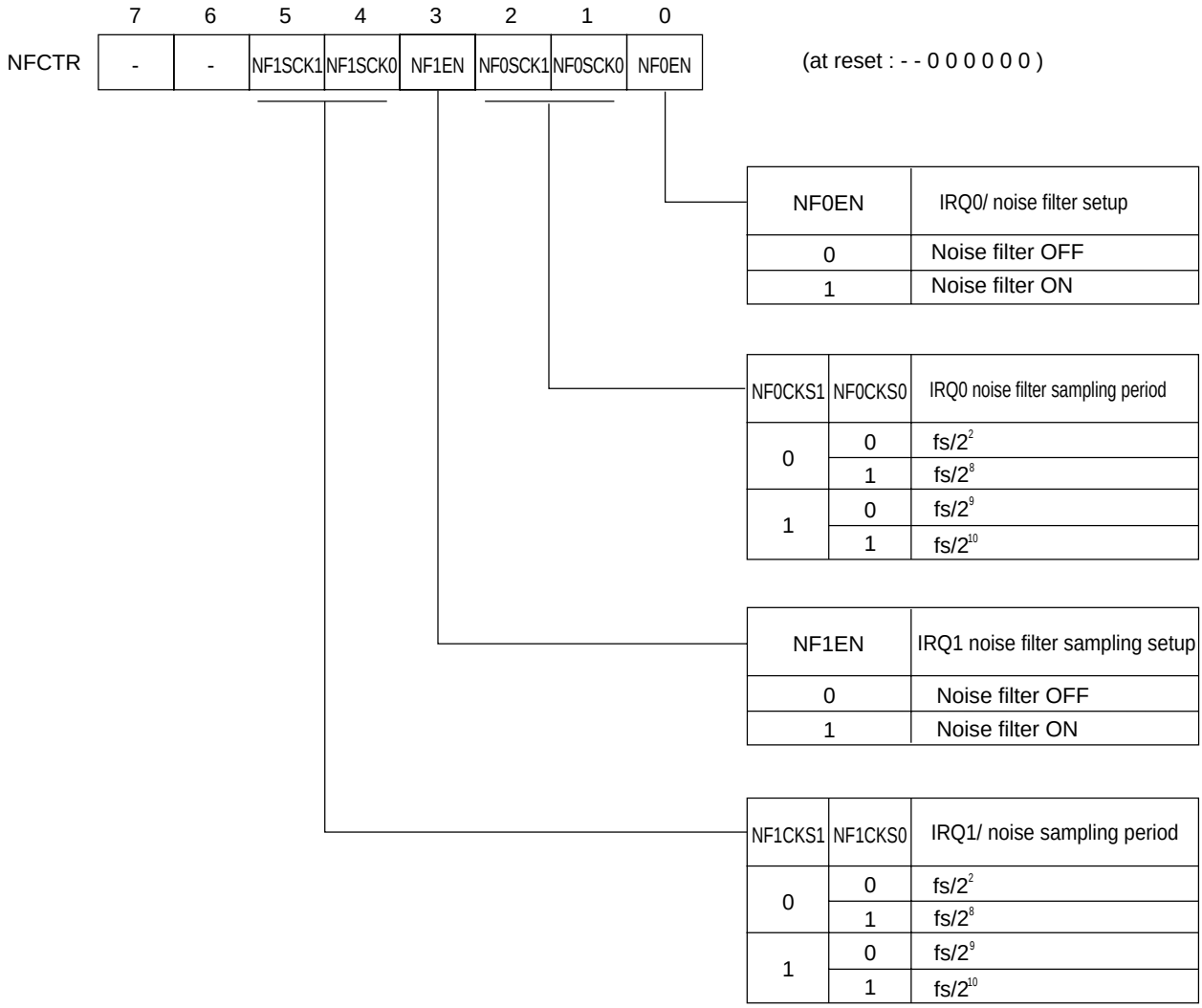


Figure 3-3-3 Noise Filter Control Register (NFCTR : x'03F8A', R/W)

■Pin Control Register 1 (FLOAT 1)

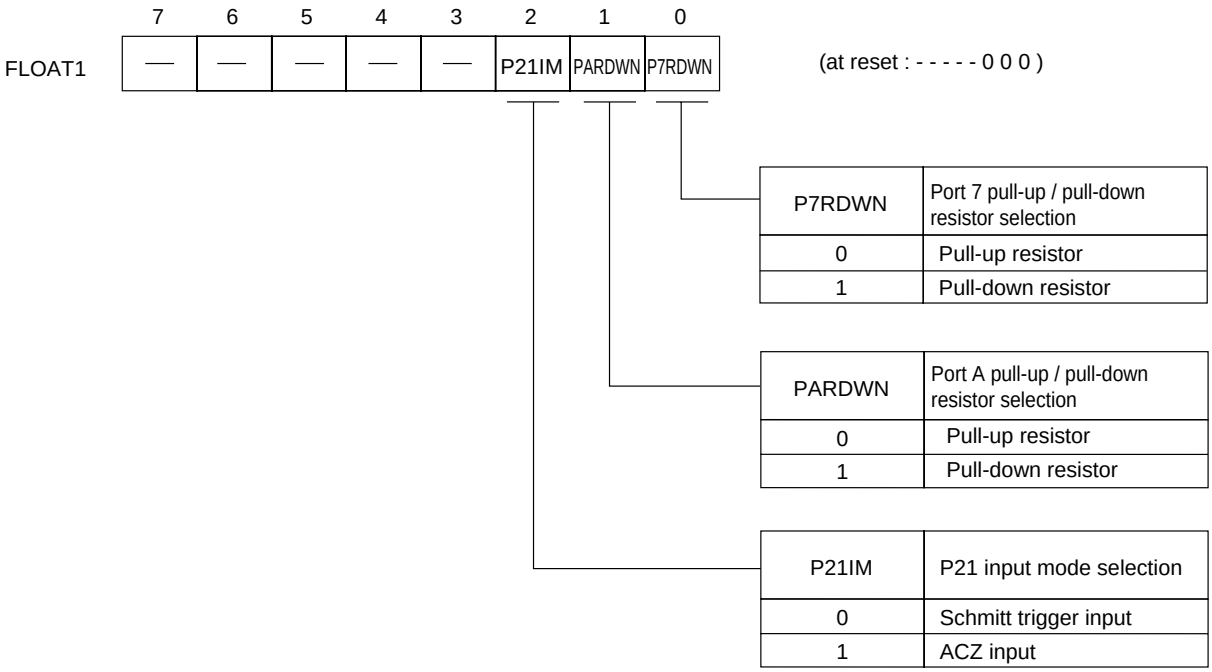


Figure 3-3-4 Pin Control Register 1 (FLOAT1 : x'03F4B', R/W)

3-3-4 Programmable Active Edge Interrupt

■Programmable Active Edge Interrupts (External interrupts 0 to 3)
Through register settings, external interrupts 0 to 3 can generate interrupt at the selected edge either rising or falling edge.

■Programmable Active Edge Interrupt Setup Example (External interrupts 0 to 3)
External interrupt 1 (IRQ1) is generated at the rising edge of the input signal from P21.
The table below provides a setup example for IRQ1.

Setup Procedure	Description
(1) Specify the interrupt active edge. IRQ1ICR (x'3FE3') bp5 : REDG1 = 1	(1) Set the REDG1 flag of the external interrupt 1 control register (IRQ1ICR) to "1" to specify the rising edge as the active edge for interrupts.
(2) Set the interrupt level. IRQ1ICR (x'3FE3') bp7-6 : IRQ1LV1-0= 10	(2) Set the interrupt priority level in the IRQ1LV1-0 flag of the IRQ1ICR register. If any interrupt request flag had already been set, clear it. [☞ Chapter 3. 3-1-4 Interrupt flag setup]
(3) Enable the interrupt. IRQ1ICR (x'3FE3') bp1 : IRQ1IE = 1	(3) Set the IRQ1IE flag of the IRQ1ICR register to "1" to enable the interrupt.

External interrupt 1 is generated at the rising edge of the input signal from P21.

The Interrupt request flag may be set to "1" at switching the interrupt edge, so specify the interrupt active edge before the interrupt permission.

If the interrupt request flag is set to "1" at the switching the interrupt edge, an interrupt is generated by setting the interrupt enable flag. Therefore, clear the interrupt request flag after the switching the interrupt edge is highly recommended.
[☞ Chapter 3. 3-1-4 Interrupt flag setup]

Pull-up the external interrupt pin in advance is also recommended.

3-3-5 Noise Filter

■Noise Filter (External interrupts 0 to1)

Noise filter reduces noise by sampling the input waveform from the external interrupt pins (IRQ0, IRQ1). Its sampling cycle can be selected from 4 types (fs/2^2, fs/2^8, fs/2^9, fs/2^{10}).

■Noise Remove Selection (External interrupts 0 to 1)

Noise remove function can be used by setting the NFnEN flag of the noise filter control register (NFCTR) to "1".

Table 3-3-3 Noise Remove Function

NFnEN	IRQ0 input (P20)	IRQ1 input (P21)
0	IRQ0 Noise filter OFF	IRQ1 Noise filter OFF
1	IRQ0 Noise filter ON	IRQ1 Noise filter ON

■Sampling Cycle Setup (External interrupts 0 and 1)

The sampling cycle of noise remove function can be set by the NFnSCK 1- 0 flag of the NFCTR register.

Table 3-3-4 Sampling Cycle / Time of Noise Remove Function

NFnCKS1	NFnCKS0	Sampling cycle	High-frequency oscillation			
			at fosc=20 MHz		at fosc=8 MHz	
0	0	fs/2^2	2.5 MHz	400 ns	1 MHz	1 µs
	1	fs/2^8	39.06 kHz	25.60 µs	15.62 kHz	64 µs
1	0	fs/2^9	19.53 kHz	51.20 µs	7.81 kHz	128 µs
	1	fs/2^{10}	9.77 kHz	102.40 µs	3.91 kHz	256 µs

■Noise Remove Function Operation (External interrupts 0 to 1)

After sampling the input signal to the external interrupt pins (IRQ0, IRQ1) by the set sampling time, if the same level comes continuously three times, that level is sent to the inside of LSI. If the same level does not come continuously three times, the previous level is sent. It means that only the signal with the width of more than " Sampling time X 3 sampling clocks " can pass through the noise filter, and other much narrower signals are removed, because those are regarded as noise.

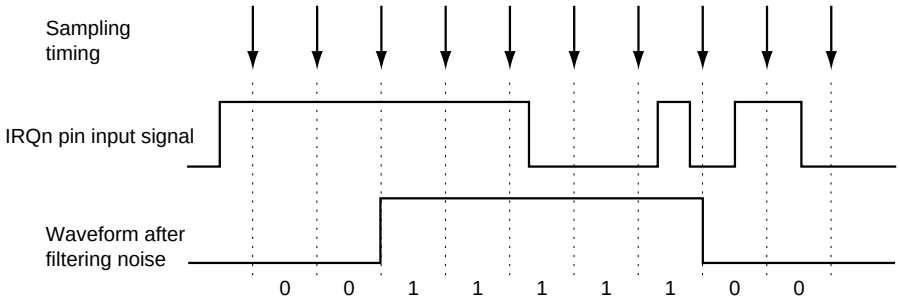


Figure 3-3-5 Noise Remove Function Operation

Noise filter can not be used at STOP mode and HALT mode.

■Noise Filter Setup Example (External interrupt 0 and 1)

Noise remove function is added to the input signal from P20 pin to generate the external interrupt 0 (IRQ0) at the rising edge. The sampling clock is set to fs/2^2, and the operation state is fosc = 20 MHz. An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Specify the interrupt active edge. IRQ0ICR (x'3FE2') bp5 : REDG0 = 1	(1) Set the REDG 0 flag of the external interrupt 0 control register (IRQ0ICR) to "1" to specify the interrupt active edge to the rising edge.
(2) Select the sampling clock. NFCTR (x'3F8A') bp2-1 : NF0CKS1-0 = 00	(2) Select the sampling clock to fs/2^2 by the NF0CKS1-0 flag of the noise filter control register (NFCTR).
(3) Set the noise filter operation. NFCTR (x'3F8A') bp0 : NF0EN = 1	(3) Set the NF0EN flag of the NFCTR register to "1" to add the noise filter operation.
(4) Set the interrupt level. IRQ0ICR (x'3FE2') bp7-6 : IRQ0LV1-0= 10	(4) Set the interrupt level by the IRQ0LV 1- 0 flag of the IRQ0ICR register. If any interrupt request flag had already been set, clear it. [☞Chapter 3 3-1-4. Interrupt flag setup]
(5) Enable the interrupt. IRQ0ICR (x'3FE2') bp1 : IRQ0IE = 1	(5) Set the IRQ0IE flag of the IRQ0ICR register to "1" to enable the interrupt.

Note : The above (2) and (3) are set at the same time.

The input signal from the P20 pin generates the external interrupt 0 at the rising edge of the signal, after passing through the noise filter.

The setup of the noise filter should be done before the interrupt is enabled.

The external interrupt pins are recommended to be pull-up in advance.

3-3-6 AC Zero-Cross Detector

This LSI has AC zero-cross detector circuit. The P21 / ACZ pin is the input pin of AC zero-cross detector circuit. AC zero-cross detector circuit output the high level when the input level is at the middle, and outputs the low level at other level.

■AC Zero-Cross Detector (External interrupt 1)
AC zero-cross detector sets the IRQ1 pin to the high level when the input signal (P21/ACZ pin) is at intermediate range. At the other level, IRQ1 pin is set to the low level. AC zero-cross can be detected by setting the P21IM flag of the pin control register (FLOAT1) to "1".

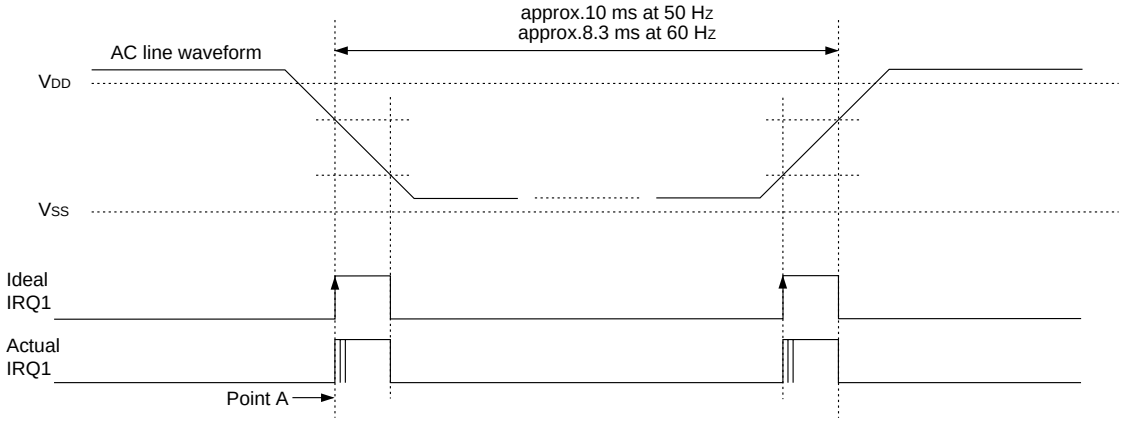


Figure 3-3-6 AC Line Waveform and IRQ1 Generation Timing

Actual IRQ1 interrupt request is generated several times at crossing the 1/2 V_{DD} of AC line waveform. So, the filtering operation by the program is necessary.

If you select the noise filter, the judgement of this program can be easier. But it can not be used for the recover when OSC is stopped at the back up mode.

■AC Zero-Cross Detector Setup Example (External interrupt 1)

AC zero-cross detector generates the external interrupt 1 (IRQ1) by using P21/ACZ pin.
The sampling clock is set to $fs/2^2$, and the noise filter is used.
An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Select the interrupt edge. IRQ1ICR (x'3FE3') bp5 : REDG1 = 1	(1) Set the REDG1 flag of the external interrupt 1 control register (IRQ1ICR) to "1" to specify the active edge of the external interrupt to "rising".
(2) Select the noise filter and its sampling clock. NFCTR (x'3F8A') bp3 : NF1EN = 1 bp5-4 : NF1CKS1-0 = 00	(2) Select the noise filter by the NF1EN, NFCKS1-0 flag of the noise filter control register (NFCTR). And select $fs/2^2$ for its sampling cycle.
(3) Select the AC zero-cross detector signal. FLOAT1 (x'3F4B') bp2 : P21IM = 1	(3) Set the P21IM flag of the pin control register 1 (FLOAT1) to "1" to select the AC zero-cross detector signal as the external interrupt 1 generation factor.
(4) Set the interrupt level. IRQ1ICR (x'3FE3') bp7-6 : IRQ1LV1-0= 10	(4) Set the interrupt level by the IRQ1LV 1-0 flag of the IRQ1ICR register. If any interrupt request flag had already been set, clear it. [☞ Chapter 3 3-1-4. Interrupt flag setup]
(5) Enable the interrupt. IRQ1ICR (x'3FE3') bp1 : IRQ1IE = 1	(5) Set the IRQ1IE flag of the IRQ1ICR register to "1" to enable the interrupt.

When the input signal level from P21/ACZ pin crosses 1/2 V_{DD}, the external interrupt 1 is generated.

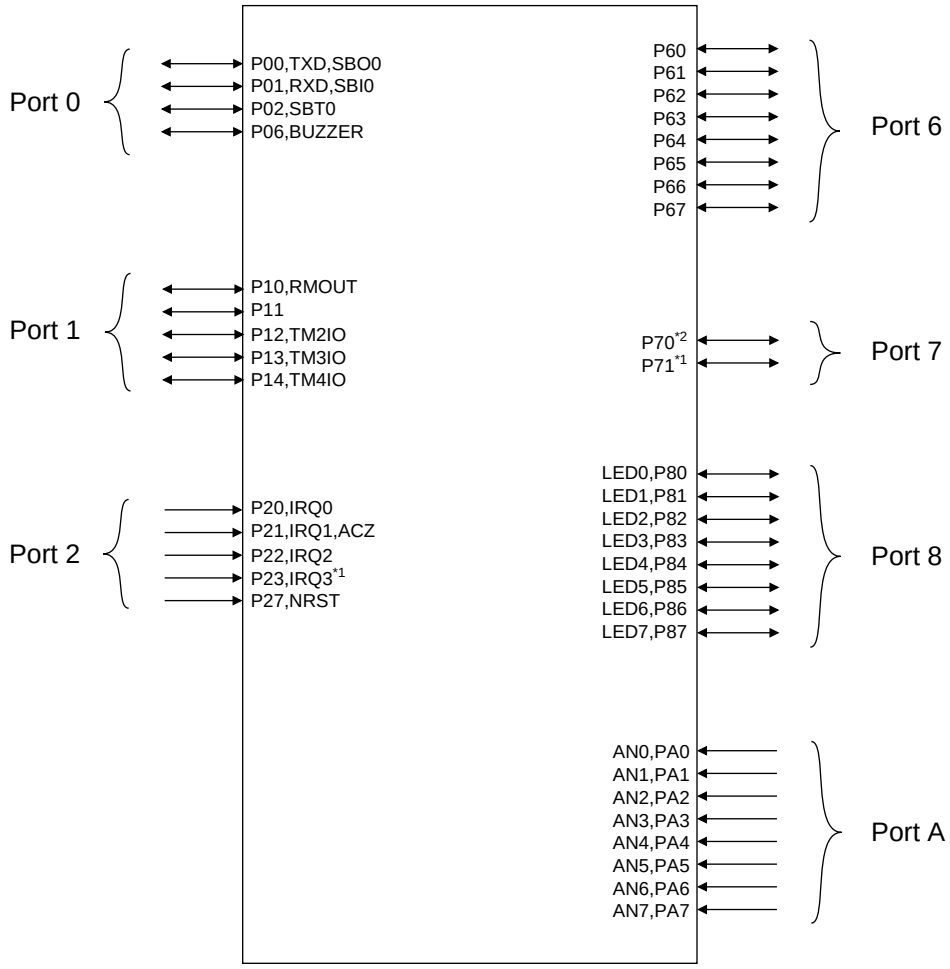
Chapter 4 I/O Ports

4

4-1 Overview

4-1-1 I/O Port Diagram

A total of 40 pins on this LSI, including those shared with special function pins, are allocated for the 7 I/O ports of ports 0 to 2, ports 6 to 8, and port A. Each I/O port is assigned to its corresponding special function register area in memory. I/O ports are operated in byte or bit units in the same way as RAM.



*1 P71 is not allocated to 42-SDIP and 44-QFP package types.

*2 P70 is not allocated to 42-SDIP package type.

Figure 4-1-1 I/O Port Functions

4-1-2 I/O Port Status at Reset

Table 4-1-1 I/O Port Status at Reset (Single chip mode)

Port Name	I/O mode	Pull-up / Pull-down resistor	I/O port, special functions
Port 0	Input mode	No pull-up resistor	I/O port
Port 1	Input mode	No pull-up resistor	I/O port
Port 2	Input mode	No pull-up resistor	I/O port
Port 6	Input mode	No pull-up resistor	I/O port
Port 7	Input mode	No pull-up / pull-down resistor	I/O port
Port 8	Input mode	No pull-up resistor	I/O port
Port A	Input mode	No pull-up / pull-down resistor	I/O port

4-1-3 Control Registers

Ports 0 to 2, ports 6 to 8, and A are controlled by the data output register (PnOUT), the data input register (PnIN), the I/O direction control register (PnDIR), the pull-up resistor control register (PnPLU) and the pull-up / pull-down resistor control resister (PnPLUD) and registers (P1OMD, PAIMD, FLOAT1) that control special function pin.

This I/O control is valid at selection of the special function, as well.

Table 4-1-2 shows the registers to control ports 0 to 2, ports 6 to 8, and A ;

Table 4-1-2 I/O Port Control Registers List

	Register	Address	R/W	Function	Page
Port 0	P0OUT	x'03F10'	R/W	Port 0 output register	Ⅳ-6
	P0IN	x'03F20'	R	Port 0 input register	Ⅳ-6
	P0DIR	x'03F30'	R/W	Port 0 direction control register	Ⅳ-6
	P0PLU	x'03F40'	R/W	Port 0 pull-up resistor control register	Ⅳ-6
Port 1	P1OUT	x'03F11'	R/W	Port 1 output register	Ⅳ-10
	P1IN	x'03F21'	R	Port 1 input register	Ⅳ-10
	P1DIR	x'03F31'	R/W	Port 1 direction control register	Ⅳ-10
	P1PLU	x'03F41'	R/W	Port 1 pull-up resistor control register	Ⅳ-10
	P1OMD	x'03F39'	R/W	Port 1 output mode register	Ⅳ-11
Port 2	P2OUT	x'03F12'	R/W	Port 2 output register	Ⅳ-15
	P2IN	x'03F22'	R	Port 2 input register	Ⅳ-15
	P2PLU	x'03F42'	R/W	Port 2 pull-up resistor control register	Ⅳ-15
Port 6	P6OUT	x'03F16'	R/W	Port 6 output register	Ⅳ-18
	P6IN	x'03F26'	R	Port 6 input register	Ⅳ-18
	P6DIR	x'03F36'	R/W	Port 6 direction control register	Ⅳ-18
	P6PLU	x'03F46'	R/W	Port 6 pull-up resistor control register	Ⅳ-18
Port 7	P7OUT	x'03F17'	R/W	Port 7 output register	Ⅳ-21
	P7IN	x'03F27'	R	Port 7 input register	Ⅳ-21
	P7DIR	x'03F37'	R/W	Port 7 direction control register	Ⅳ-21
	P7PLUD	x'03F47'	R/W	Port 7 pull-up / pull-down resistor control register	Ⅳ-21
Port 8	P8OUT	x'03F18'	R/W	Port 8 output register	Ⅳ-25
	P8IN	x'03F28'	R	Port 8 input register	Ⅳ-25
	P8DIR	x'03F38'	R/W	Port 8 direction control register	Ⅳ-25
	P8PLU	x'03F48'	R/W	Port 8 pull-up resistor control register	Ⅳ-25
Port A	PAIN	x'03F2A'	R	Port A input register	Ⅳ-28
	PAIMD	x'03F3A'	R/W	Port A input mode register	Ⅳ-28
	PAPLUD	x'03F4A'	R/W	Port A pull-up / pull-down resistor control register	Ⅳ-28
Pin control	FLOAT1	x'03F4B'	R/W	Pin control register 1	Ⅳ-22,Ⅳ-29

4-2 Port 0

4-2-1 Description

■General Port Setup
Each bit of the port 0 control I/O direction register (P0DIR) can be set individually to set pins as input or output. The control flag of the port 0 direction control register (P0DIR) should be set to "1" for output mode, and "0" for input mode.

To read input data of pin, set the control flag of the port 0 direction control register (P0DIR) to "0" and read the value of the port 0 input register (P0IN).

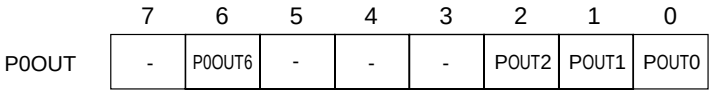
To output data to pin, set the control flag of the port 0 direction control register (P0DIR) to "1" and write the value of the port 0 output register (P0OUT).

Each pin can be set individually if pull-up resistor is added or not, by the port 0 pull-up resistor control register (P0PLU). Set the control flag of the port 0 pull-up resistor control register (P0PLU) to "1" to add pull-up resistor.
At reset, the input mode is selected and pull-up resistors are disabled (high impedance output).

■Special Function Pin Setup
P00 to P02 are used as I/O pin for serial interface 0, as well. P00 is output pin of the serial interface 0 transmission data, and UART transmission data. When the SC0SBOS flag of the serial interface 0 mode register 3 (SC0MD3) is "1", P00 is serial data output pin. P01 is the input pin of the serial interface 0 reception data, and UART reception data. When the SC0SBIS flag of the serial interface 0 mode register 3 (SC0MD3) is "1", P01 is serial data input pin. P02 is I/O pin of the serial interface 0 clock. When the SC0SBTS flag of serial interface 0 mode register 3 (SC0MD3) is "1", P02 is serial interface clock output pin.
P00 and P02 can be selected as either an push-pull output or Nch open-drain output by the SC0SBOM and the SC0SBTM of the serial interface 0 mode register 3 (SC0MD3).
[☞ Chapter 10 10-2. Control registers]

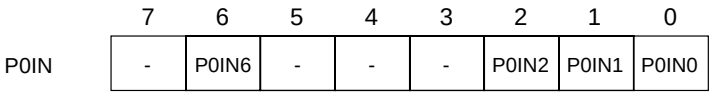
P06 is used as a buzzer output pin, as well. When the bp7 of the oscillation control register (DLYCTR) is "1", buzzer output is enabled.

4-2-2 Registers



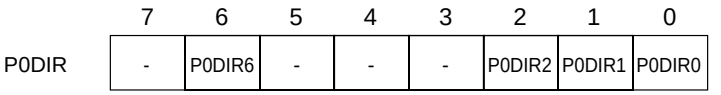
P0OUT	Output data
0	L(VSS level)
1	H(VDD level)

Port 0 output register (P0OUT : x'03F10', R/W)



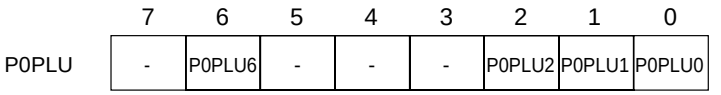
P0IN	Input data
0	Pin is low(VSS level).
1	Pin is high(VDD level).

Port 0 input register (P0IN : x'03F20', R)



P0DIR	I/O mode selection
0	Input mode
1	Output mode

Port 0 direction control register (P0DIR : x'03F30', R/W)



P0PLU	Pull-up resistor selection
0	No pull-up resistor
1	Pull-up resistor

Port 0 pull-up resistor control register (P0PLU : x'03F40', R/W)

Figure 4-2-1 Port 0 Registers

4-2-3 Block Diagram

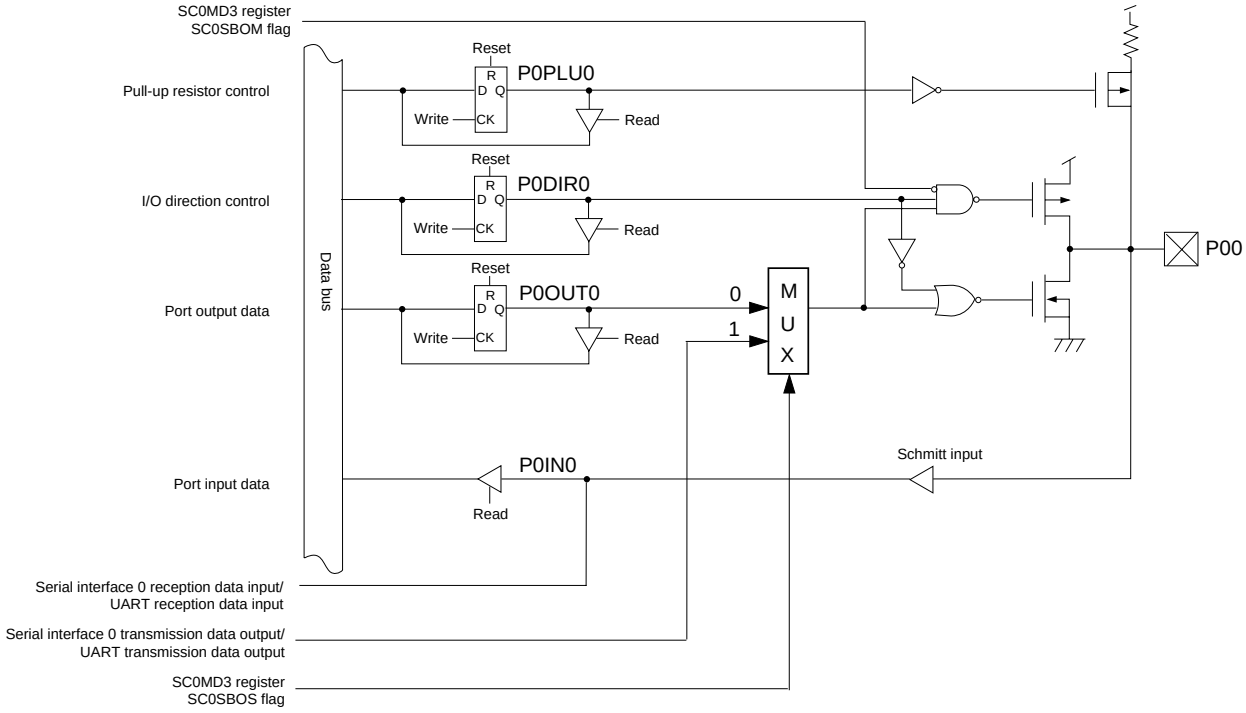


Figure 4-2-2 Block diagram (P00)

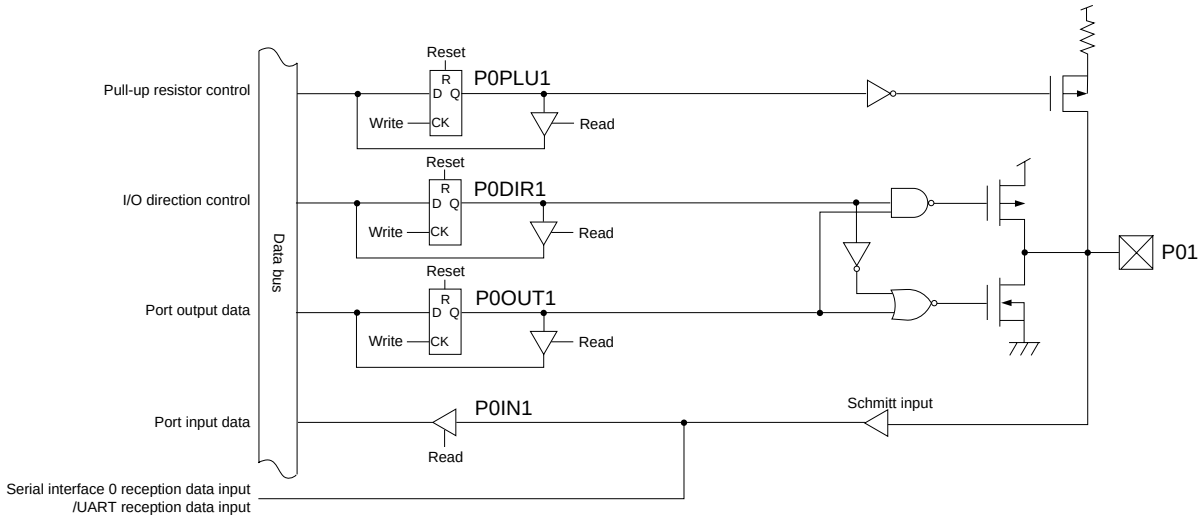


Figure 4-2-3 Block diagram (P01)

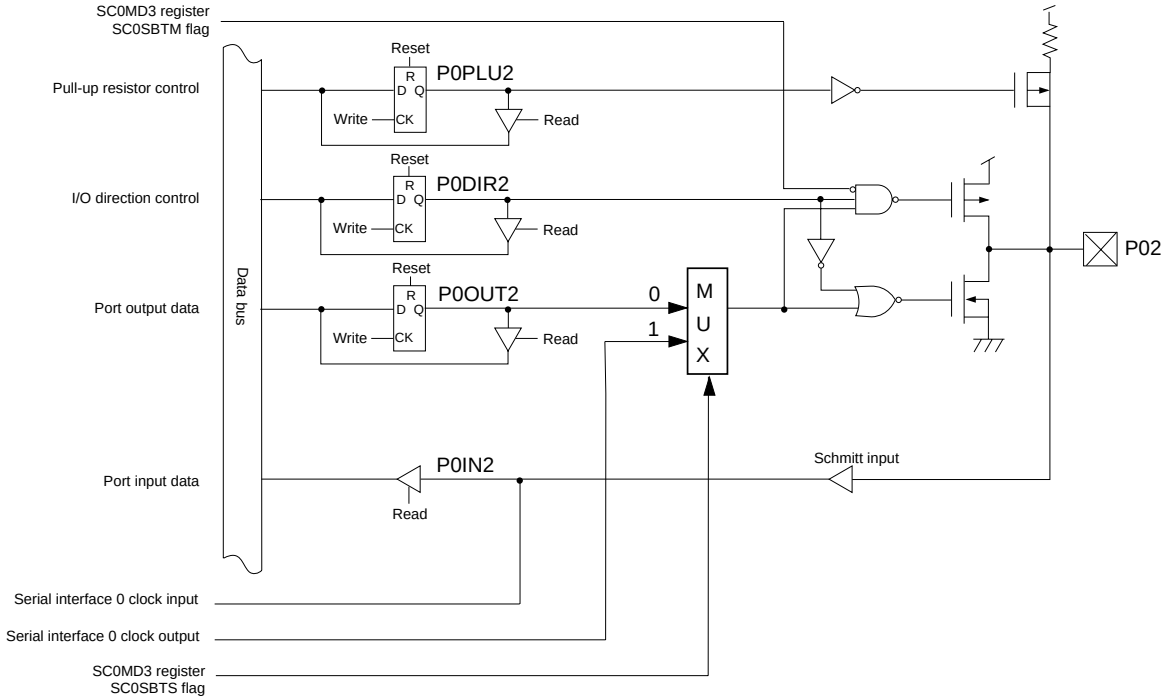


Figure 4-2-4 Block diagram (P02)

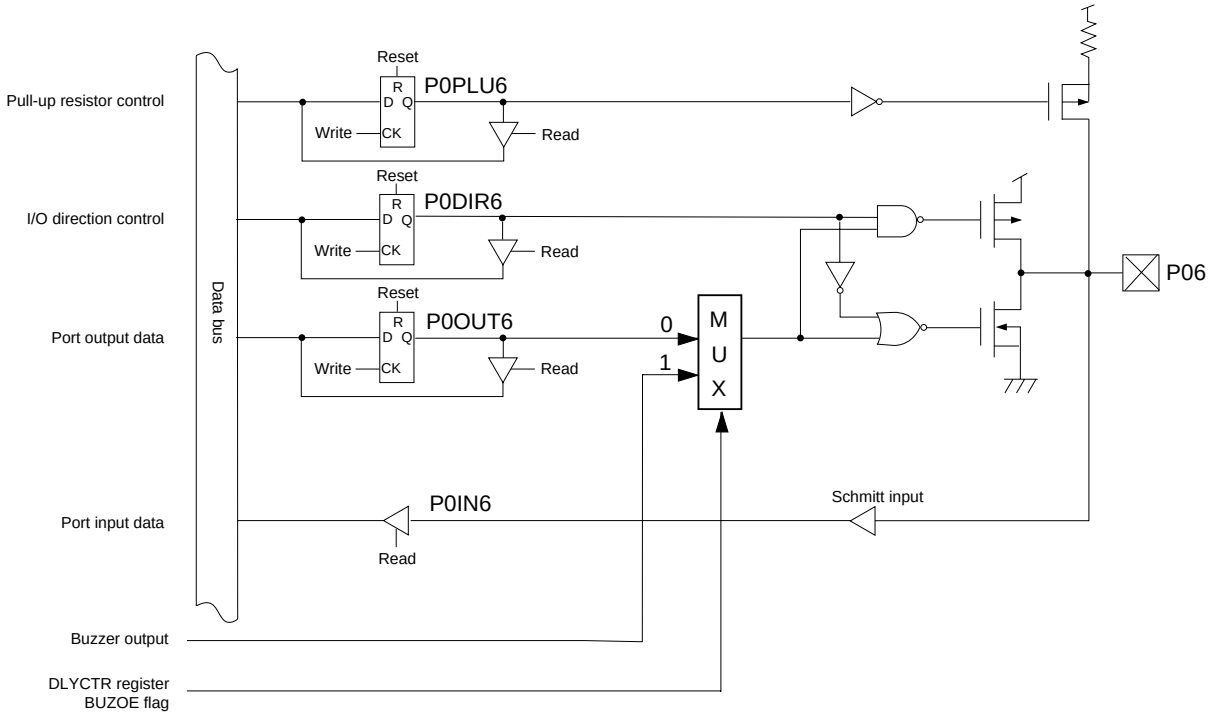


Figure 4-2-6 Block Diagram (P06)

4-3 Port 1

4-3-1 Description

■General Port Setup
Each bit of the port 1 control I/O direction register (P1DIR) can be set individually to set pins as input or output. The control flag of the port 1 direction control register (P1DIR) should be set to "1" for output mode, and "0" for input mode.

To read input data of pin, set the control flag of the port 1 direction control register (P1DIR) to "0" and read the value of the port 1 input register (P1IN).

To output data to pin, set the control flag of the port 1 direction control register (P1DIR) to "1" and write the value of the port 1 output register (P1OUT).

Each pin can be set individually if pull-up resistor is added or not, by the port 1 pull-up resistor control register (P1PLU). Set the control flag of the port 1 pull-up resistor control register (P1PLU) to "1" to add pull-up resistor.

At reset, the input mode is selected and pull-up resistors are disabled (high impedance output).

■Special Function Pin Setup
P12 to P14 are used as timer I/O pin, as well. P10 is used as remote control carrier output pin, as well. The port 1 output mode register (P1OMD) can select P12 to P14 output mode by each bit. When the port 1 output mode register (P1OMD) is "1", special function data is output, and when it is "0", they are used as general port.

4-3-2 Registers

	7	6	5	4	3	2	1	0	
P1OUT	-	-	-	P1OUT4	P1OUT3	P1OUT2	P1OUT1	P1OUT0	(At reset : - - - 0 0 0 0 0)

P1OUT	Output data
0	Low (V_{SS} level)
1	High (V_{DD} level)

Port 1 output register (P1OUT : x'03F11', R/W)

	7	6	5	4	3	2	1	0	
P1IN	-	-	-	P1IN4	P1IN3	P1IN2	P1IN1	P1IN0	(At reset : - - - X X X X X)

P1IN	Input data
0	Pin is low(V_{SS} level).
1	Pin is high(V_{DD} level).

Port 1 input register (P1IN : x'03F21', R)

	7	6	5	4	3	2	1	0	
P1DIR	-	-	-	P1DIR4	P1DIR3	P1DIR2	P1DIR1	P1DIR0	(At reset : - - - 0 0 0 0 0)

P1DIR	I/O mode selection
0	Input mode
1	Output mode

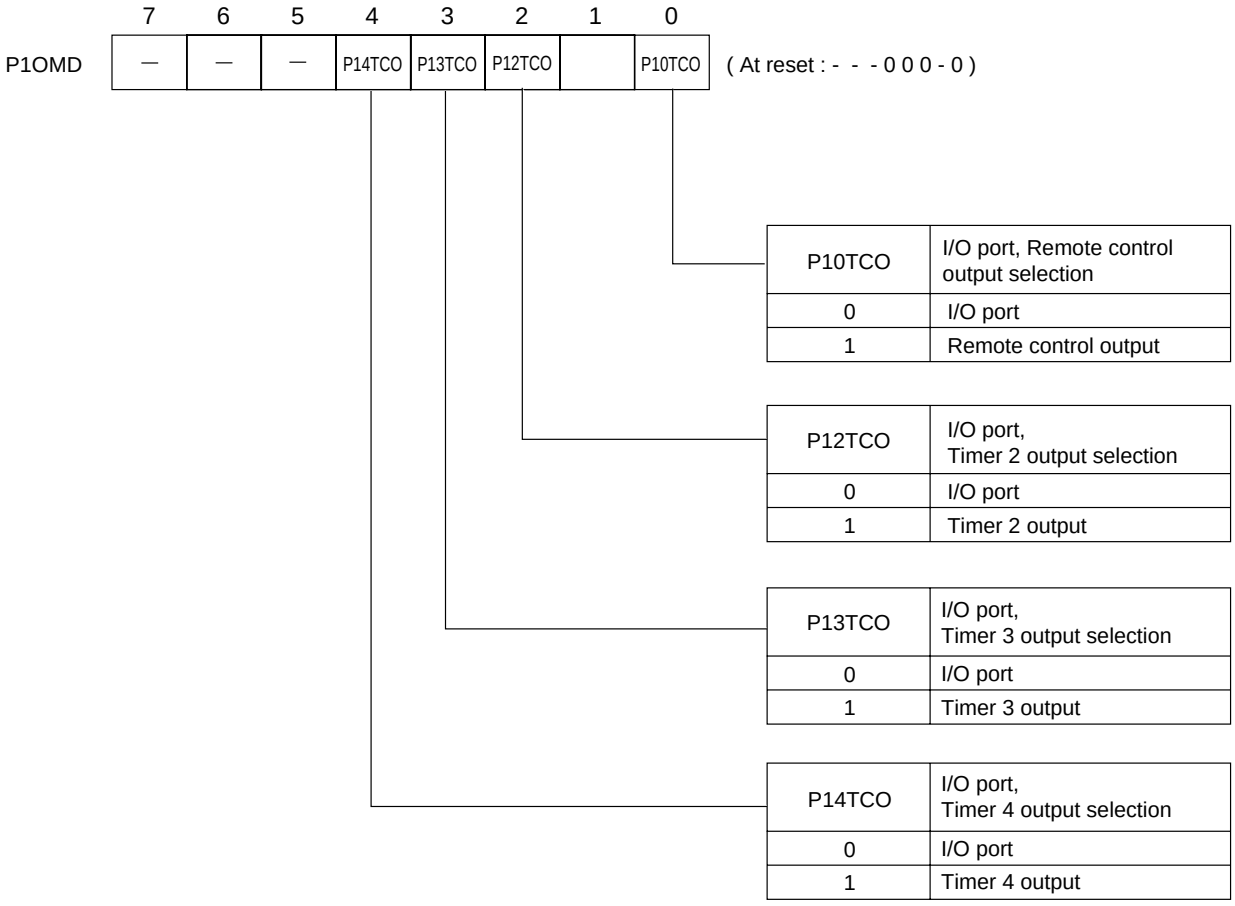
Port 1 direction control register (P1DIR : x'03F31', R/W)

	7	6	5	4	3	2	1	0	
P1PLU	-	-	-	P1PLU4	P1PLU3	P1PLU2	P1PLU1	P1PLU0	(At reset : - - - 0 0 0 0 0)

P1PLU	Pull-up resistor selection
0	No pull-up resistor
1	Pull-up resistor

Port 1 pull-up resistor control register (P1PLU : x'03F41', R/W)

Figure 4-3-1 Port 1 Registers (1/2)



Port 1 output mode register (P1OMD : x'03F39', R/W)

Figure 4-3-2 Port 1 Registers (2/2)

4-3-3 Block Diagram

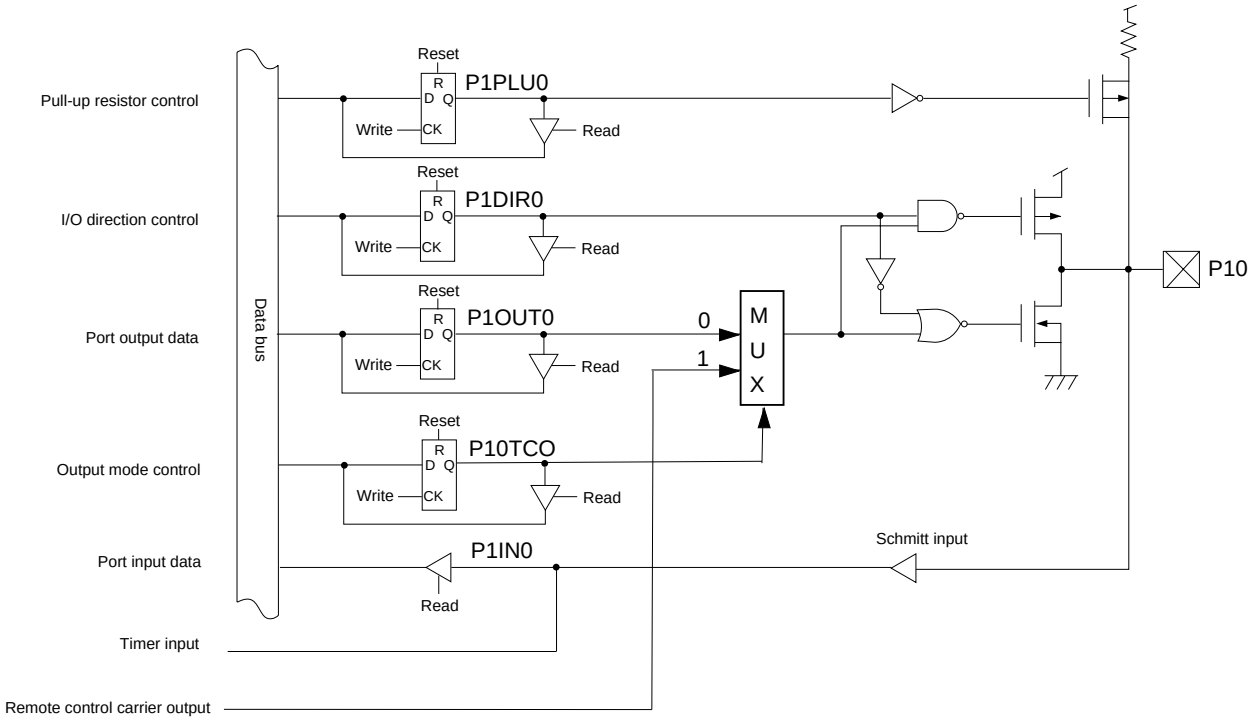


Figure 4-3-3 Block Diagram (P10)

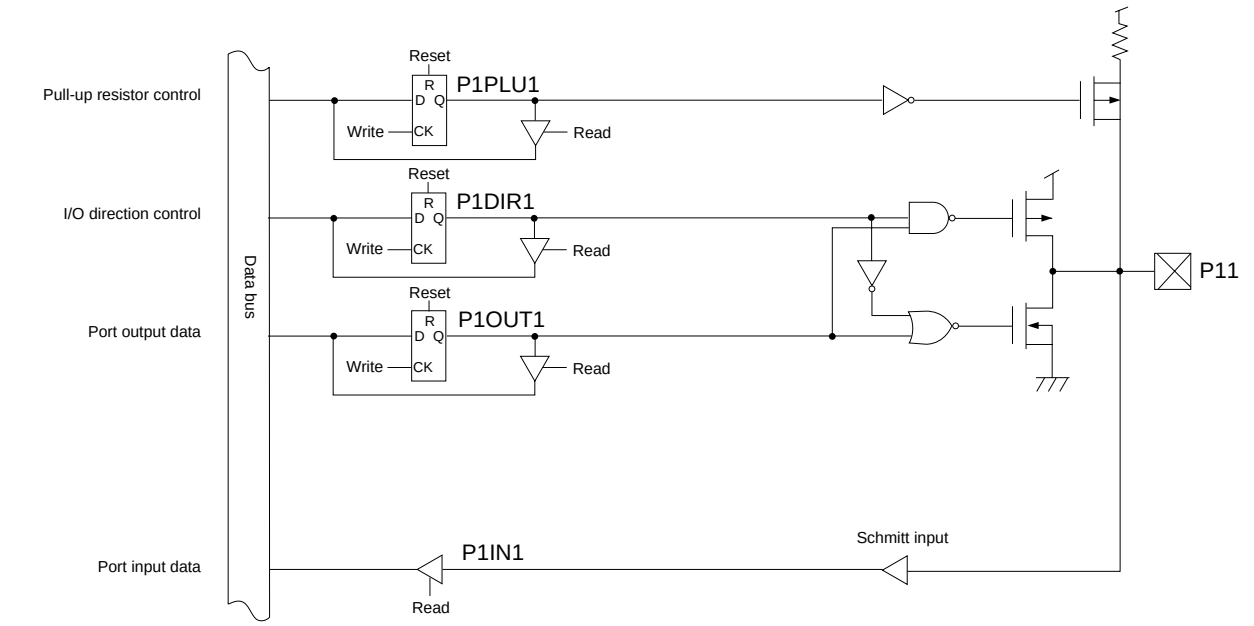


Figure 4-3-4 Block Diagram (P11)

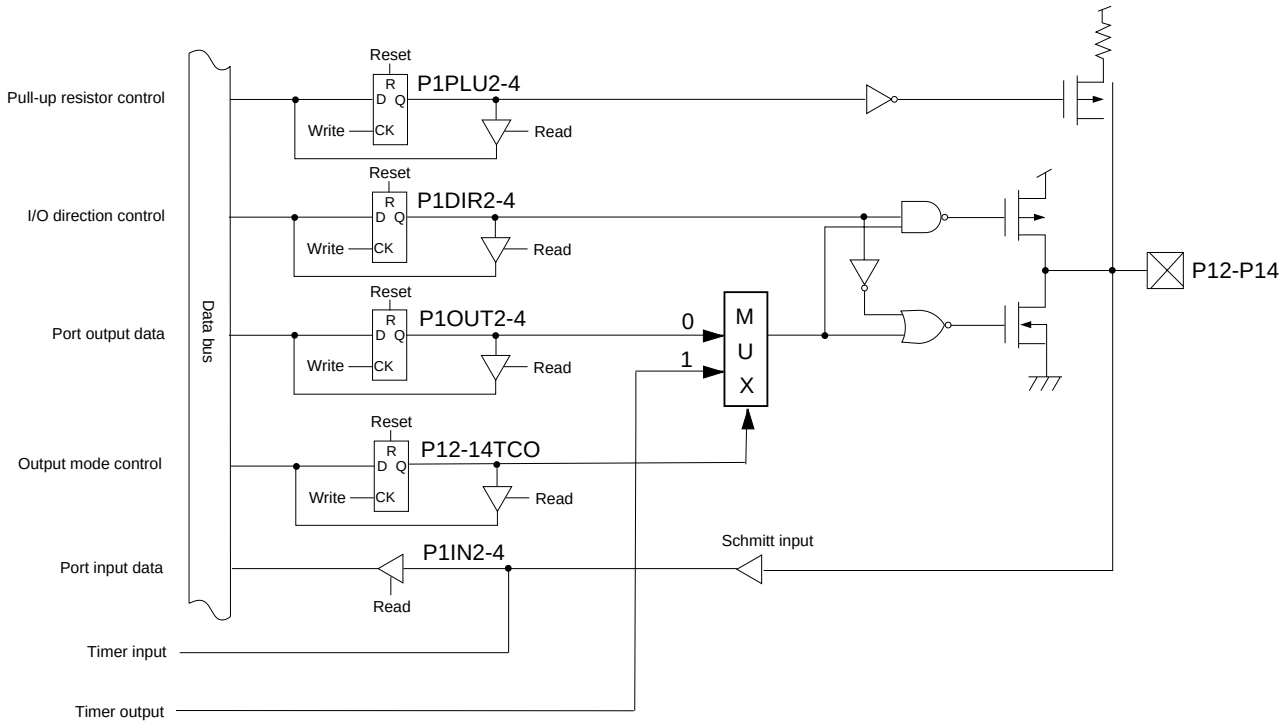


Figure 4-3-5 Block Diagram (P12, P13, P14)

4-4 Port 2

4-4-1 Description

■General Port Setup
Port 2 is input port, except P27. To read input data of pin, read out the value of the port 2 input register (P2IN).

P27 is reset pin. When the software is reset, write the bp7 of the port 2 output register (P2OUT) to "0".

Each bit can be set individually if pull-up resistor is added or not by the port 2 pull-up resistor control register (P2PLU). When the control flag of the port 2 pull-up resistor control register (P2PLU) is set to "1", pull-up resistor is added. P27 is always added pull-up resistor.

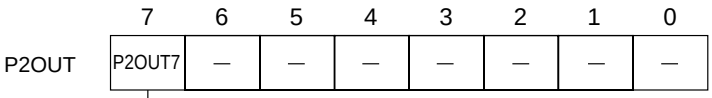
■Special Function Pin Setup
P20 to P23 are used as external interrupt pins, as well.

P21 is used as an input pin for external interrupt and AC zero-cross. To read data of AC zero-cross, set the bp2 of the pin control register (FLOAT1) to "1" and read the value of the port 2 input register (P2IN).

P23 is not allocated to package types of 42-pin SDIL and 44pin QFP .

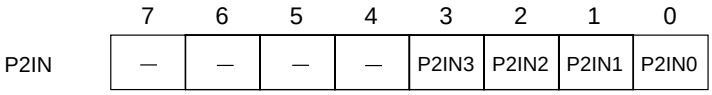
Do not add the pull-up resistors to the P23 of 42-pin SDIL and 44pin QFP package types .

4-4-2 Registers



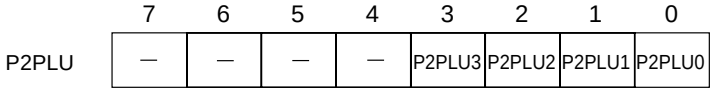
P2OUT	Output data
0	Low (VSS level)
1	High (VDD level)

Port 2 output register(P2OUT : x'03F12', R/W)



P2IN	Input data
0	Pin is Low (VSS level).
1	Pin is High (VDD level).

Port 2 input register (P2IN : x'03F22', R)



P2PLU	Pull-up resistor selection
0	No pull-up resistor
1	Pull-up resistor

Port 2 pull-up resistor control register(P2PLU : x'03F42', R/W)

Figure 4-4-1 Port 2 Registers

4-4-3 Block Diagram

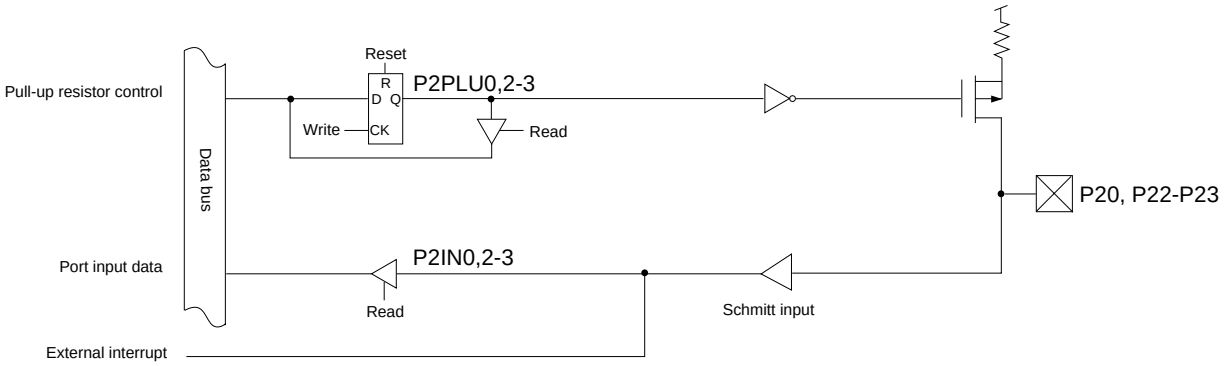


Figure 4-4-2 Block Diagram (P20, P22 to P23)

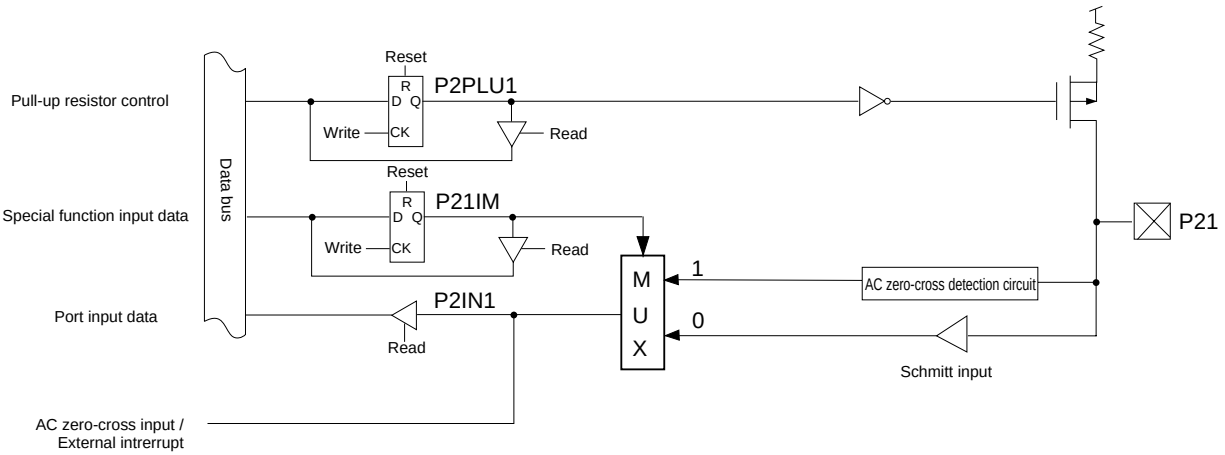
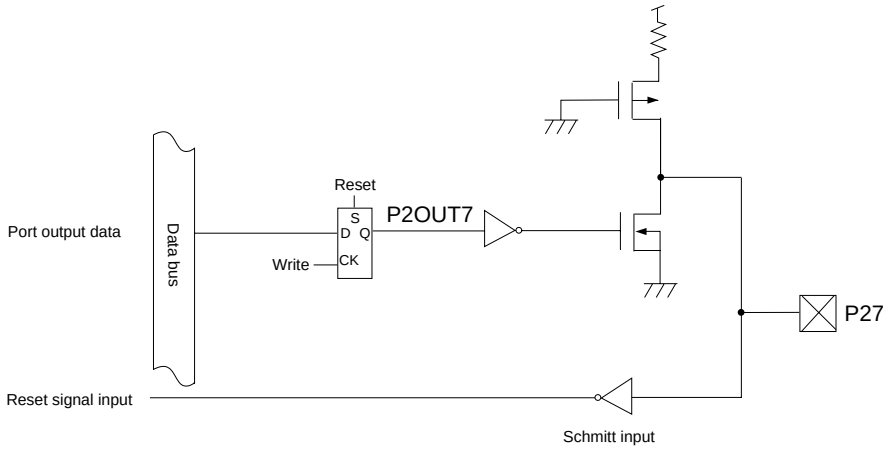


Figure 4-4-3 Block Diagram (P21)



* Pull- up resistor is always added.

Figure 4-4-4 Block Diagram (P27)

4-5 Port 6

4-5-1 Description

■General port Setup
Each bit of the port 6 control I/O direction register (P6DIR) can be set individually to set pins as input or output. The control flag of the port 6 direction control register (P6DIR) should be set to "1" for output mode, and "0" for input mode.

To read input data of pin, set the control flag of the port 6 direction control register (P6DIR) to "0" and read the value of the port 6 input register (P6IN).

To output data to pin, set the control flag of the port 6 direction control register (P6DIR) to "1" and write the value of the port 6 output register (P6OUT).

Each pin can be set individually if pull-up resistor is added or not, by the port 6 pull-up resistor control register (P6PLU). Set the control flag of the port 6 pull-up resistor control register (P6PLU) to "1" to add pull-up resistor.

At reset, the P60 to P67 input mode is selected and pull-up resistors are disabled (high impedance output). In processor mode.

4-5-2 Registers

	7	6	5	4	3	2	1	0	
P6OUT	P6OUT7	P6OUT6	P6OUT5	P6OUT4	P6OUT3	P6OUT2	P6OUT1	P6OUT0	(At reset : 0 0 0 0 0 0 0 0)

P6OUT	Output data
0	Low (V_{SS} level)
1	High (V_{DD} level)

Port 6 output register (P6OUT : x'03F16', R/W)

	7	6	5	4	3	2	1	0	
P6IN	P6IN7	P6IN6	P6IN5	P6IN4	P6IN3	P6IN2	P6IN1	P6IN0	(At reset : X X X X X X X X)

P6IN	Input data
0	Pin is Low (V_{SS} level).
1	Pin is High (V_{DD} level).

Port 6 intput register (P6IN : x'03F26', R)

	7	6	5	4	3	2	1	0	
P6DIR	P6DIR7	P6DIR6	P6DIR5	P6DIR4	P6DIR3	P6DIR2	P6DIR1	P6DIR0	(At reset : 0 0 0 0 0 0 0 0)

P6DIR	I/O mode selection
0	Input mode
1	Output mode

Port 6 direction control register (P6DIR : x'03F36', R/W)

	7	6	5	4	3	2	1	0	
P6PLU	P6PLU7	P6PLU6	P6PLU5	P6PLU4	P6PLU3	P6PLU2	P6PLU1	P6PLU0	(At reset : 0 0 0 0 0 0 0 0)

P6PLU	Pull-up resistor selection
0	No pull-up resistor
1	Pull-up resistor

Port 6 pull-up resistor control register (P6PLU : x'03F46', R/W)

Figure 4-5-1 Port 6 Registers

4-5-3 Block Diagram

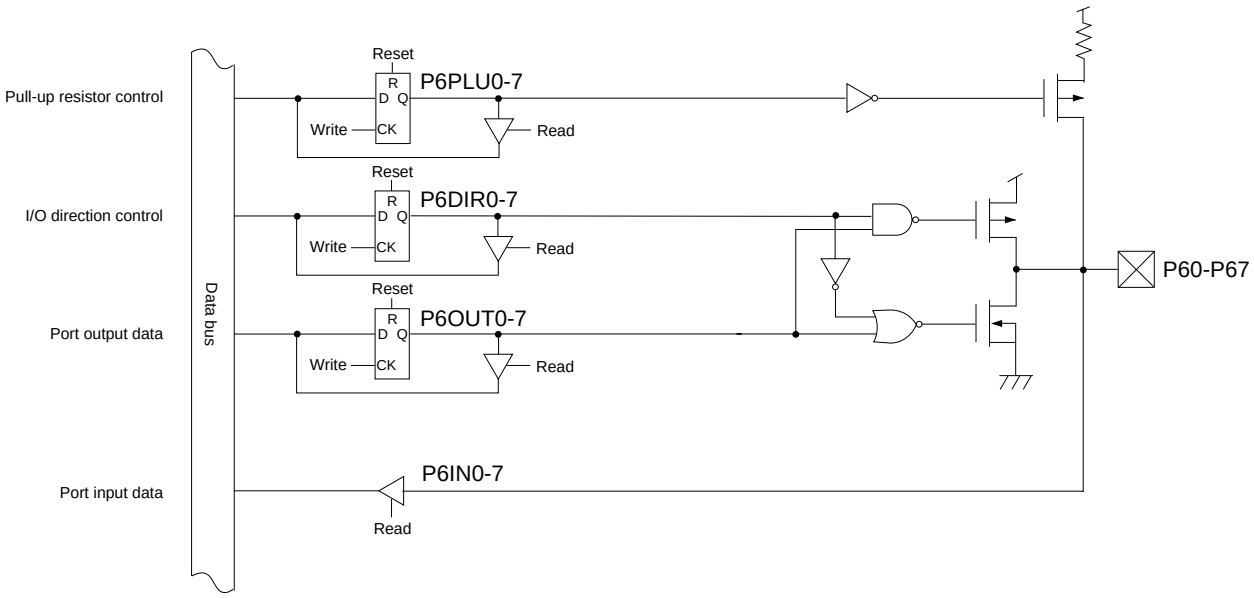


Figure 4-5-2 Block Diagram (P60 to P67)

4-6 Port 7

4-6-1 Description

■General Port Setup

Each bit of the port 7 control I/O direction register (P7DIR) can be set individually to set pins as input or output. The control flag of the port 7 direction control register (P7DIR) should be set to "1" for output mode, and "0" for input mode.

To read input data of pin, set the control flag of the port 7 direction control register (P7DIR) to "0" and read the value of the port 7 input register (P7IN).

To output data to pin, set the control flag of the port 7 direction control register (P7DIR) to "1" and write the value of the port 7 output register (P7OUT).

Each pin can be set individually if pull-up / pull-down resistor is added or not, by the port 7 pull-up / pull-down resistor control register (P7PLUD). But pull-up / pull-down cannot be mixed. Set the control flag of the port 7 pull-up / pull-down resistor control register (P7PLUD) to "1" to add pull-up or pull-down resistor. The pin control register 1 (FLOAT1) select if pull-up resistor or pull-down resistor is added. The bp0 of the pin control register 1 (FLOAT1) is set to "1" for pull-down resistor, set to "0" for pull-up resistor.

At reset, the P70 to P71 input mode is selected and pull-up resistors are disabled (high impedance output).

P70, P71 are not allocated to 42-pin SDIL package type.
P71 is not allocated to 44-pin QFP package type.

4-6-2 Registers

	7	6	5	4	3	2	1	0	
P7OUT	–	–	–	–	–	–	P7OUT1	P7OUT0	(At reset : - - - - - - 0 0)

P7OUT	Output data
0	Low (VSS level)
1	High (VDD level)

Port 7 output register (P7OUT : x'03F17', R/W)

	7	6	5	4	3	2	1	0	
P7IN	–	–	–	–	–	–	P7IN1	P7IN0	(At reset : - - - - - - X X)

P7IN	Input data
0	Pin is Low (VSS level).
1	Pin is High (VDD level).

Port 7 input register (P7IN : x'03F27', R)

	7	6	5	4	3	2	1	0	
P7DIR	–	–	–	–	–	–	P7DIR1	P7DIR0	(At reset : - - - - - - 0 0)

P7DIR	I/O mode selection
0	Input mode
1	Output mode

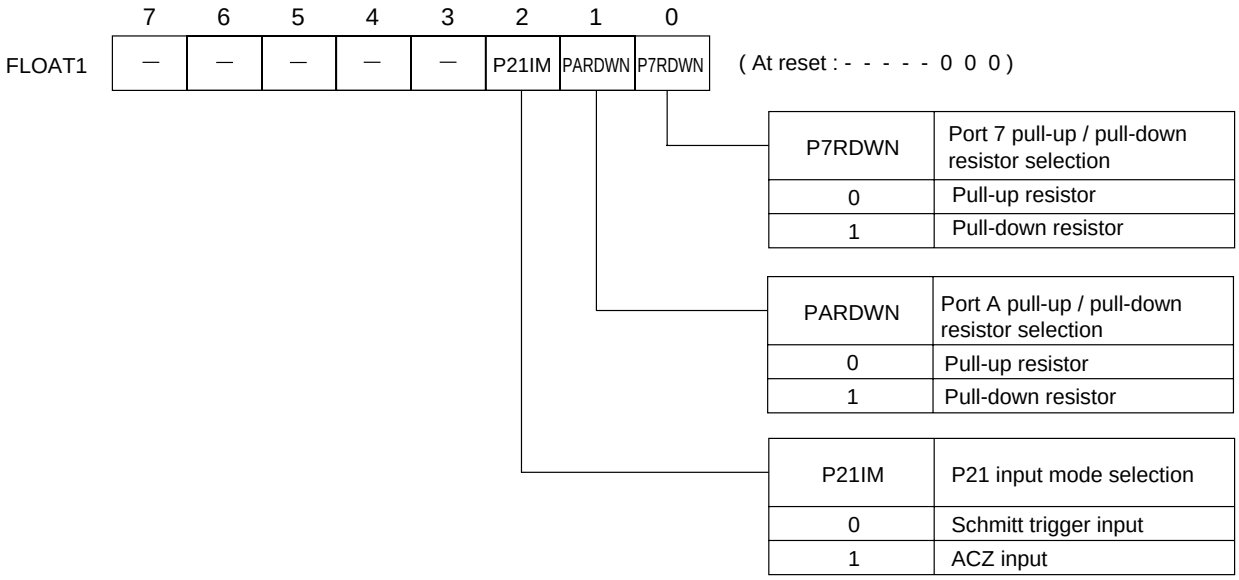
Port 7 direction control register (P7DIR : x'03F37', R/W)

	7	6	5	4	3	2	1	0	
P7PLUD	–	–	–	–	–	–	P7PLUD1	P7PLUD0	(At reset : - - - - - - 0 0)

P7PLUD	Pull-up (or Pull-down) resistor selection
0	No pull-up (or pull-down) resistor
1	Pull-up (or Pull-down) resistor

Port 7 pull-up / pull-down resistor control register (P7PLUD : x'03F47', R/W)

Figure 4-6-1 Port 7 Registers (1/2)



Pin control register 1 (FLOAT1 : X'03F4B', R/W)

Figure 4-6-2 Port 7 Registers (2/2)

4-6-3 Block Diagram

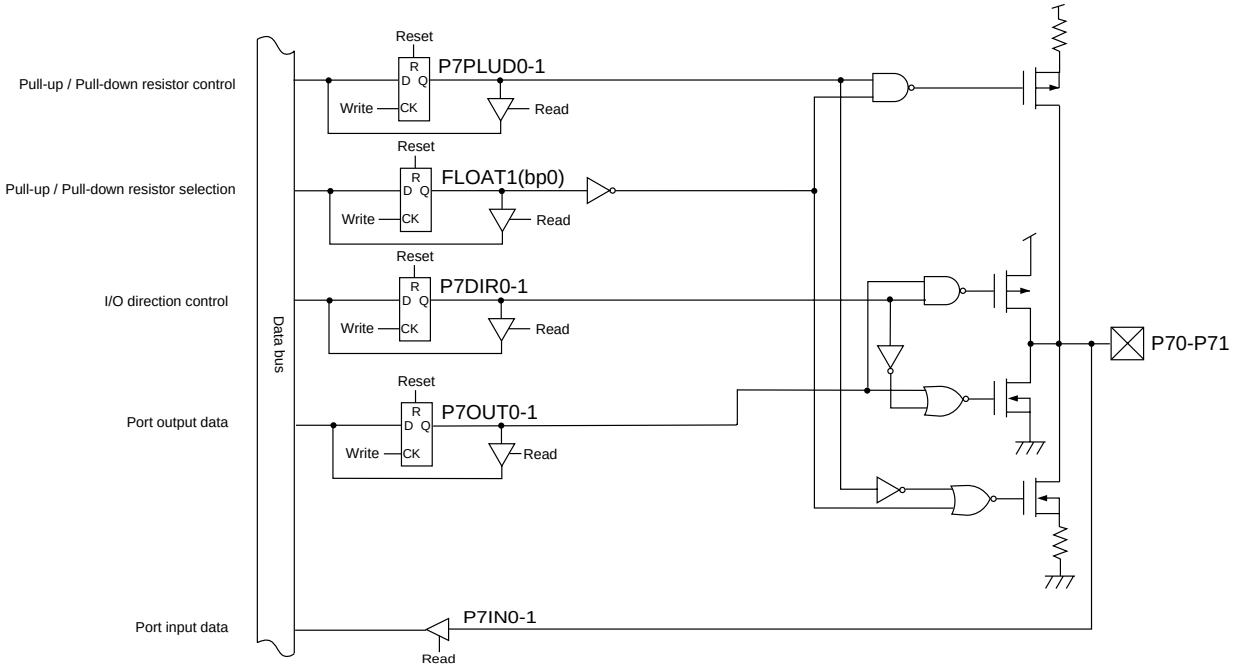


Figure 4-6-3 Block Diagram (P70 to P71)

4-7 Port 8

4-7-1 Description

■General Port Setup
Each bit of the port 8 control I/O direction register (P8DIR) can be set individually to set pins as input or output. The control flag of the port 8 direction control register (P8DIR) should be set to "1" for output mode, and "0" for input mode.

To read input data of pin, set the control flag of the port 8 direction control register (P8DIR) to "0" and read the value of the port 8 input register (P8IN).

To output data to pin, set the control flag of the port 8 direction control register (P8DIR) to "1" and write the value of the port 8 output register (P8OUT).

Each pin can be set individually if pull-up resistor is added or not, by the port 8 pull-up resistor control register (P8PLU). Set the control flag of the port 8 pull-up resistor control register (P8PLU) to "1" to add pull-up resistor.

At reset, the P80 to P87 input mode is selected and pull-up resistors are disabled (high impedance output).

■Special Function Pin Setup
P80 to P87 are used as LED driving pins, as well.

4-7-2 Registers

	7	6	5	4	3	2	1	0	
P8OUT	P8OUT7	P8OUT6	P8OUT5	P8OUT4	P8OUT3	P8OUT2	P8OUT1	P8OUT0	(At reset : 0 0 0 0 0 0 0 0)

P8OUT	Output data
0	Low (V_{SS} level)
1	High (V_{DD} level)

Port 8 output register (P8OUT : x'03F18', R/W)

	7	6	5	4	3	2	1	0	
P8IN	P8IN7	P8IN6	P8IN5	P8IN4	P8IN3	P8IN2	P8IN1	P8IN0	(At reset : X X X X X X X X)

P8IN	Input data
0	Pin is Low (V_{SS} level).
1	Pin is High (V_{DD} level).

Port 8 input register (P8IN : x'03F28', R)

	7	6	5	4	3	2	1	0	
P8DIR	P8DIR7	P8DIR6	P8DIR5	P8DIR4	P8DIR3	P8DIR2	P8DIR1	P8DIR0	(At reset : 0 0 0 0 0 0 0 0)

P8DIR	I/O mode selection
0	Input mode
1	Output mode

Port 8 direction control register (P8DIR : x'03F38', R/W)

	7	6	5	4	3	2	1	0	
P8PLU	P8PLU7	P8PLU6	P8PLU5	P8PLU4	P8PLU3	P8PLU2	P8PLU1	P8PLU0	(At reset : 0 0 0 0 0 0 0 0)

P8PLU	Pull-up resistor selection
0	No pull-up resistor
1	Pull-up resistor

Port 8 pull-up resistor control register (P8PLU : x'03F48', R/W)

Figure 4-7-1 Port 8 Registers

4-7-3 Block Diagram

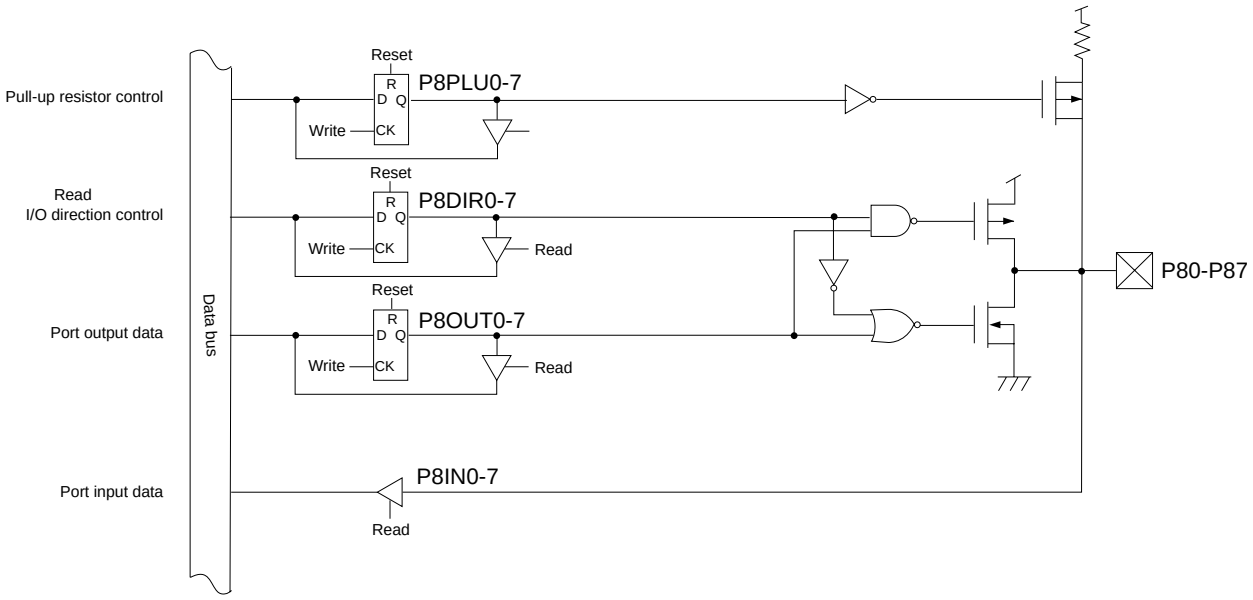


Figure 4-7-2 Block Diagram (P80 to P87)

4-8 Port A

4-8-1 Description

■General Port Setup

Port A is input port. To read input data of pin, read the value of the port A input register (PAIN).

Each pin can be set individually if pull-up / pull-down resistor is added or not, by the port A pull-up / pull-down resistor control register (PAPLUD). But pull-up / pull-down cannot be mixed. Set the control flag of the port A pull-up / pull-down resistor control register (PAPLUD) to "1" to add pull-up or pull-down resistor. The pin control register 1 (FLOAT1) select if pull-up resistor or pull-down resistor is added. The bp1 of the FLOAT1 is set to "1" for pull-down resistor, and set to "0" for pull-up resistor.

At reset, the PA0 to PA7 input mode is selected and pull-up resistors are disabled.

■Special Function Pin Setup

PA0 to PA7 are used as input pins for analog. Each bit can be set individually as an input by the port A input mode register (PAIMD). When they are used as analog input pins, set the port A input mode register (PAIMD) to "1". Then, the value of the port A input register (PAIN) is "1".

By setting the control flag of the PAIMD register to "1", the through current is not occurred when input voltage is at intermediate level.

4-8-2 Registers

	7	6	5	4	3	2	1	0	
PAIN	PAIN7	PAIN6	PAIN5	PAIN4	PAIN3	PAIN2	PAIN1	PAIN0	(At reset : X X X X X X X X)

PAIN	Input data
0	Pin is Low (V_{SS} level).
1	Pin is High (V_{DD} level).

Port A input register (PAIN : x'03F2A', R)

	7	6	5	4	3	2	1	0	
PAIMD	PAIMD7	PAIMD6	PAIMD5	PAIMD4	PAIMD3	PAIMD2	PAIMD1	PAIMD0	(At reset : 0 0 0 0 0 0 0 0)

PAIMD	I/O port, analog n input pin selection
0	I/O port
1	Analog n input pin

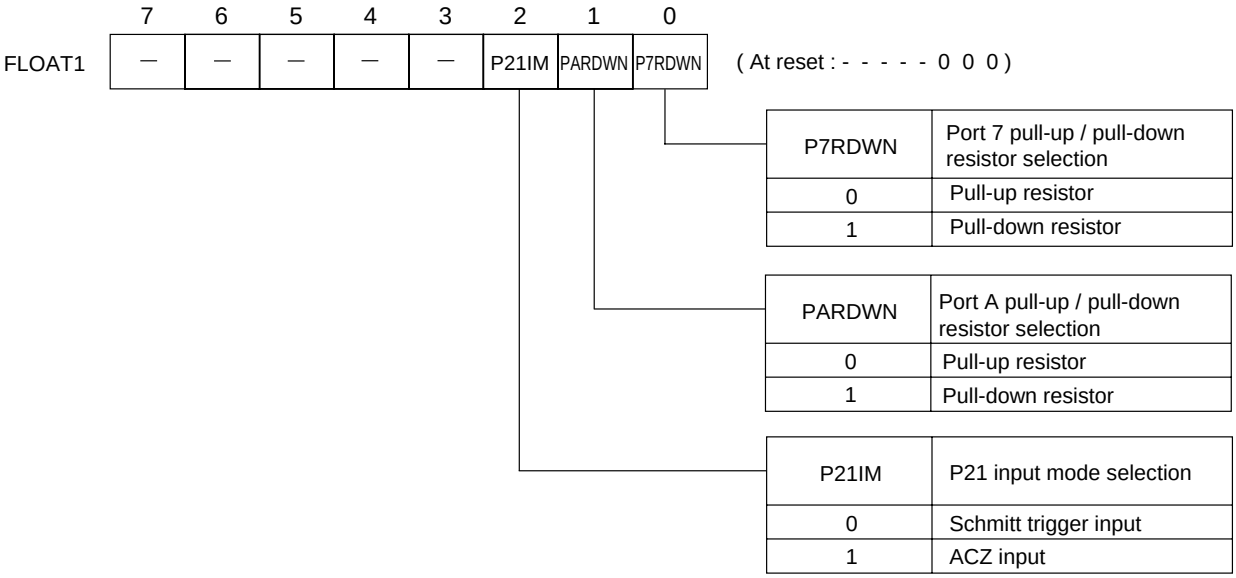
Port A input control register (PAIMD : x'03F3A', R/W)

	7	6	5	4	3	2	1	0	
PAPLUD	PAPLUD7	PAPLUD6	PAPLUD5	PAPLUD4	PAPLUD3	PAPLUD2	PAPLUD1	PAPLUD0	(At reset : 0 0 0 0 0 0 0 0)

PAPLUD	Pull-up (or Pull-down) resistor selection
0	No pull-up (or pull-down) resistor
1	Pull-up (or Pull-down) resistor

Port A pull-up / pull-down resistor control register (PAPLUD : x'03F4A', R/W)

Figure 4-8-1 Port A Registers (1/2)



Pin control register 1 (FLOAT1 : X'03F4B', R/W)

Figure 4-8-2 Port A Registers (2/2)

4-8-3 Block Diagram

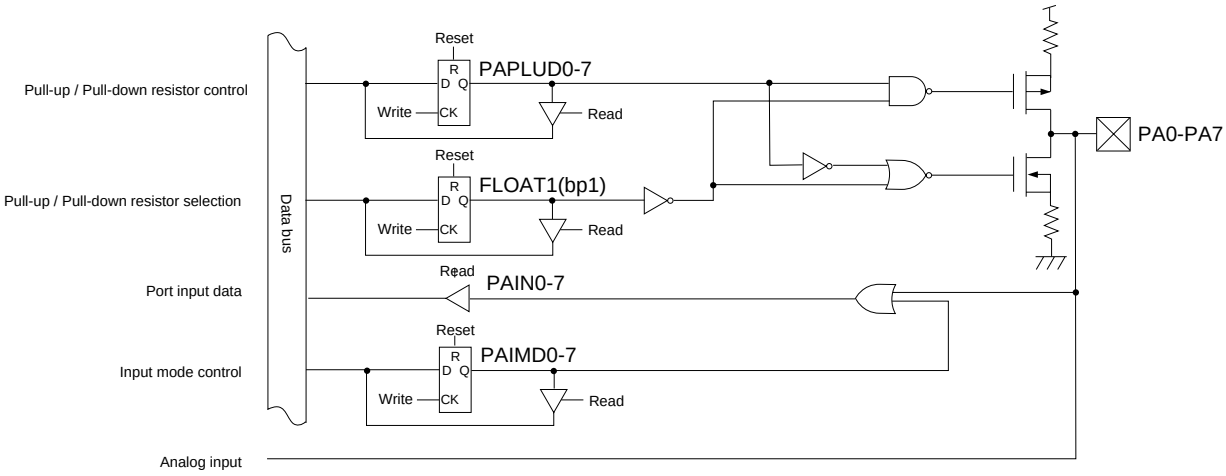


Figure 4-8-3 Block Diagram (PA0 to PA7)

Chapter 5 8-Bit Timers

5

5-1 Overview

This LSI contains one general purpose 8-bit timers (Timers 2) and one 8-bit timer (Timers 3) that can be also used as baud rate timer. Timers 2 and 3 can be used as 16-bit timers with cascade connection.

5-1-1 Functions

Table 5-1-1 shows functions of each timer.

Table 5-1-1 Timer Functions

	Timer 2 (8 bit)	Timer 3 (8 bit)	Timer 5 * (8 bit)
Interrupt source	TM2IRQ	TM3IRQ	TM5IRQ
Timer operation	√	√	√
Event count	√	√	-
Timer pulse output	√	√	-
PWM output	√	-	-
Serial transfer clock output	-	√ (SIF0)	-
Cascade connection	√		-
Remote control carrier output	-	√	-
Clock source	fs fs/4 fx TM2IO input	fosc fs/4 fs/16 TM3IO input	fosc fs/4 fx $fosc/2^{13}$ $fx/2^{13}$
fosc : Machine clock (High speed oscillation) fx : Machine clock (Low speed oscillation), not contained in the package types of 42-SDIP, 44-QFP. fs : System clock (at NORMAL mode : fs=fosc/2, at SLOW mode : fs=fx/4) - When timer 3 is used as a baud rate timer for serial interface function, it is not used as a general timer.			

* Timer 5 is described in Chapter 7.

5-1-2 Block Diagram

■Timers 2 and 3 Block Diagram

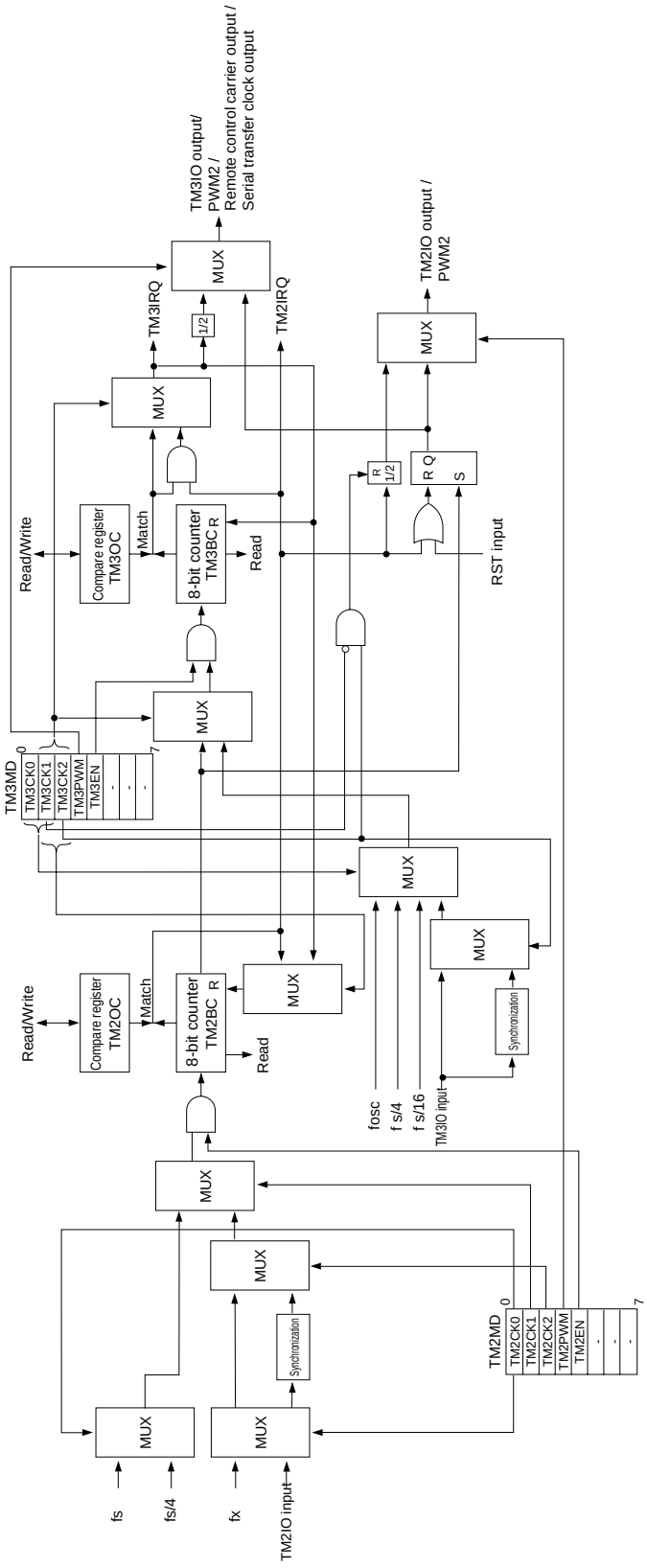


Figure 5-1-1 Timers 2 and 3 Block Diagram

■Remote Control Carrier Output Block Diagram

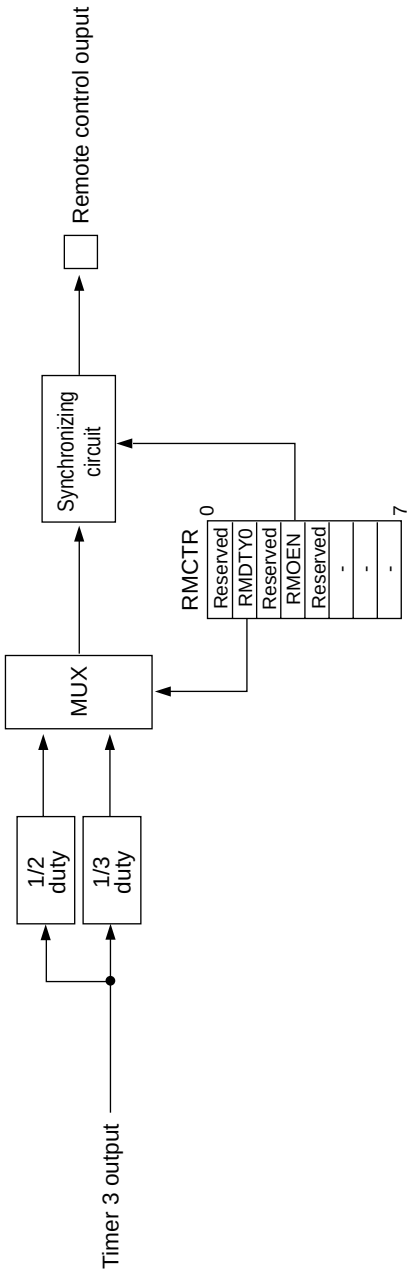


Figure 5-1-2 Remote Control Carrier Output Block Diagram

5-2 Control Registers

Timers 2 and 3 consist of the binary counter (TMnBC) and the compare register (TMnOC). And they are controlled by the mode register (TMnMD). Remote control carrier output is controlled by the remote control carrier output control register (RMCTR).

5-2-1 Registers

Table 5-2-1 shows registers that control timers 2 and 3 and remote control carrier output.

Table 5-2-1 8-bit Timer Control Registers

	Register	Address	R/W	Function	Page
Timer 2	TM2BC	x'03F62'	R	Timer 2 binary counter	Ⅴ - 6
	TM2OC	x'03F72'	R/W	Timer 2 compare register	Ⅴ - 6
	TM2MD	x'03F82'	R/W	Timer 2 mode register	Ⅴ - 7
	TM2ICR	x'03FE6'	R/W	Timer 2 interrupt control register	Ⅲ - 21
	P1OMD	x'03F39'	R/W	Port 1 output mode register	Ⅳ - 11
	P1DIR	x'03F31'	R/W	Port 1 direction control register	Ⅳ - 10
Timer 3	TM3BC	x'03F63'	R	Timer 3 binary counter	Ⅴ - 6
	TM3OC	x'03F73'	R/W	Timer 3 compare register	Ⅴ - 6
	TM3MD	x'03F83'	R/W	Timer 3 mode register	Ⅴ - 8
	TM3ICR	x'03FEE'	R/W	Timer 3 interrupt control register	Ⅲ - 22
	P1OMD	x'03F39'	R/W	Port 1 output mode register	Ⅳ - 11
	P1DIR	x'03F31'	R/W	Port 1 direction control register	Ⅳ - 10
Remote control carrier output	RMCTR	x'03F89'	R/W	Remote control carrier output control register	Ⅴ - 9

R/W : Readable / Writable
R : Readable only

5-2-2 Programmable Timer Registers

Each of timers 2 and 3 has 8-bit programmable timer registers. Programmable timer register consists of compare register and binary counter.

Compare register is 8-bit register which stores the value to be compared to binary counter.

■Timer 2 Compare Register (TM2OC)

	7	6	5	4	3	2	1	0	
TM2OC	TM2OC7	TM2OC6	TM2OC5	TM2OC4	TM2OC3	TM2OC2	TM2OC1	TM2OC0	(At reset : X X X X X X X X)

Figure 5-2-1 Timer 2 Compare Register (TM2OC : x'03F72', R/W)

■Timer 3 Compare Register (TM3OC)

	7	6	5	4	3	2	1	0	
TM3OC	TM3OC7	TM3OC6	TM3OC5	TM3OC4	TM3OC3	TM3OC2	TM3OC1	TM3OC0	(At reset : X X X X X X X X)

Figure 5-2-2 Timer 3 Compare Register (TM3OC : x'03F73', R/W)

Binary counter is 8-bit up counter. If any data is written to compare register during counting is stopped, binary counter is cleared to x'00'.

■Timer 2 Binary Counter (TM2BC)

	7	6	5	4	3	2	1	0	
TM2BC	TM2BC7	TM2BC6	TM2BC5	TM2BC4	TM2BC3	TM2BC2	TM2BC1	TM2BC0	(At reset : 0 0 0 0 0 0 0 0)

Figure 5-2-3 Timer 2 Binary Counter (TM2BC : x'03F62', R)

■Timer 3 Binary Counter (TM3BC)

	7	6	5	4	3	2	1	0	
TM3BC	TM3BC7	TM3BC6	TM3BC5	TM3BC4	TM3BC3	TM3BC2	TM3BC1	TM3BC0	(At reset : 0 0 0 0 0 0 0 0)

Figure 5-2-4 Timer 3 Binary Counter (TM3BC : x'03F63', R)

5-2-3 Timer Mode Registers

Timer mode register is readable / writable register that controls timers 2 and 3.

■Timer 2 Mode Register (TM2MD)

	7	6	5	4	3	2	1	0	
TM2MD	-	-	-	TM2EN	TM2PWM	TM2CK2	TM2CK1	TM2CK0	(At reset : - - - 0 0 X X X)

TM2CK2	TM2CK1	TM2CK0	Clock source
-	0	0	fs
		1	fs/4
0	1	0	fx
		1	TM2IO input
1		0	Synchronous fx
		1	Synchronous TM2IO input

TM2PWM	Timer 2 operation mode selection
0	Normal timer operation
1	PWM operation

TM2EN	Timer 2 count control
0	Disable the count
1	Enable the count

Figure 5-2-5 Timer 2 Mode Register (TM2MD : x'03F82', R/W)

■Timer 3 Mode Register (TM3MD)

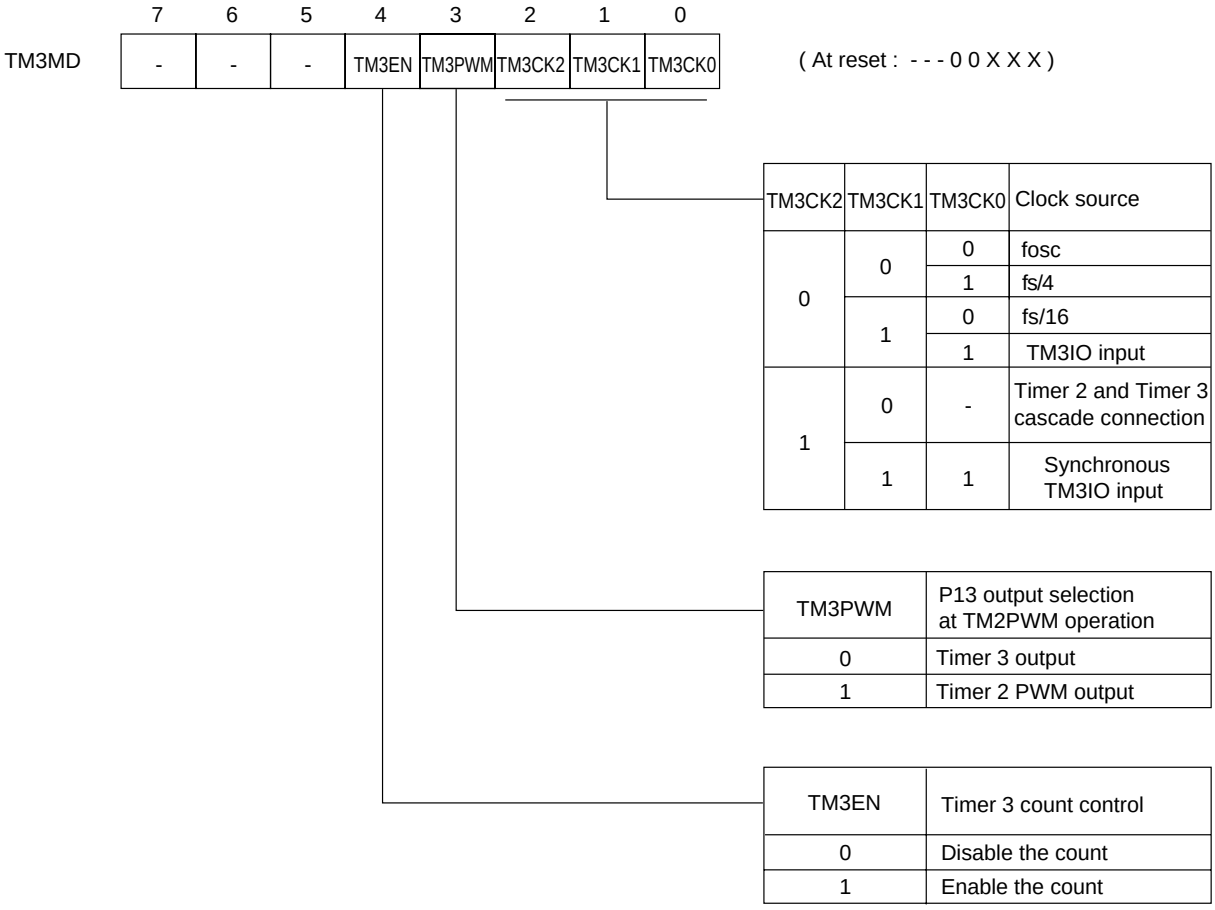


Figure 5-2-6 Timer 3 Mode Register (TM3MD : x'03F83', R/W)

■Remote Control Carrier Output Control Register (RMCTR)

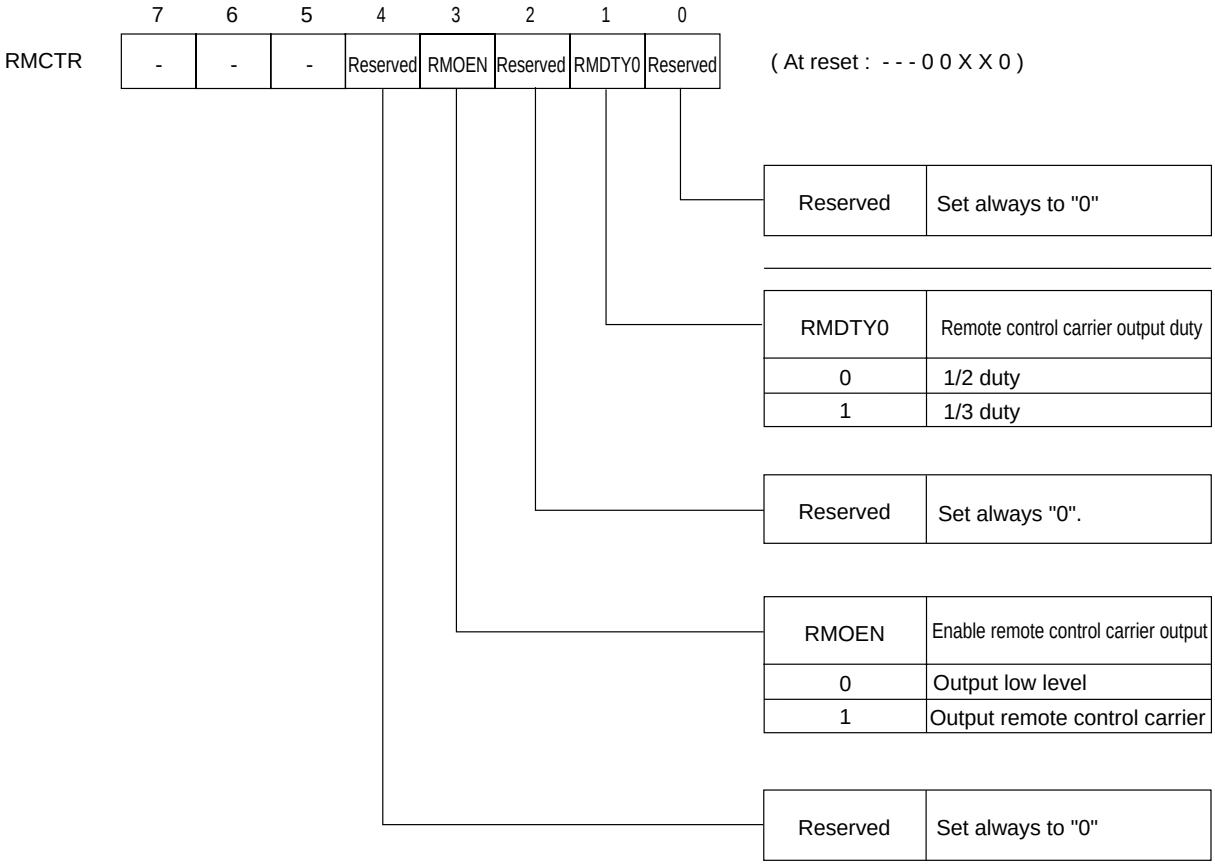


Figure 5-2-7 Remote Control Carrier Output Control Register (RMCTR : x'03F89', R/W)

5-3 8-Bit Timer Count

5-3-1 Operation

The timer operation can constantly generate interrupts.

■8-Bit Timer Operation (Timers 2 and 3)
The generation cycle of timer interrupts is set by the clock source selection and the setting value of the compare register (TMnOC), in advance. If the binary counter (TMnBC) reaches the setting value of the compare register, an interrupt is generated at the next count clock, then binary counter is cleared and counting is restarted from x'00'.
Table 5-3-1 shows clock source that can be selected.

Table 5-3-1 Clock Source (Timers 2 and 3) at Timer Operation

Clock source	1 count time	Timer 2 (8 Bit)	Timer 3 (8 Bit)
fosc	50 ns	-	√
fs	100 ns	√	-
fs/4	400 ns	√	√
fs/16	1.6 µs	-	√
fx	30.5 µs	√	-
Notes : as fosc = 20 MHz fx = 32.768 kHz fs = fosc/2 = 10 MHz			

■Count Timing of Timer Operation (Timers 2 and 3)

Binary counter counts up with selected clock source as a count clock.

The basic operation of the whole function of 8-bit timer is as follows ;

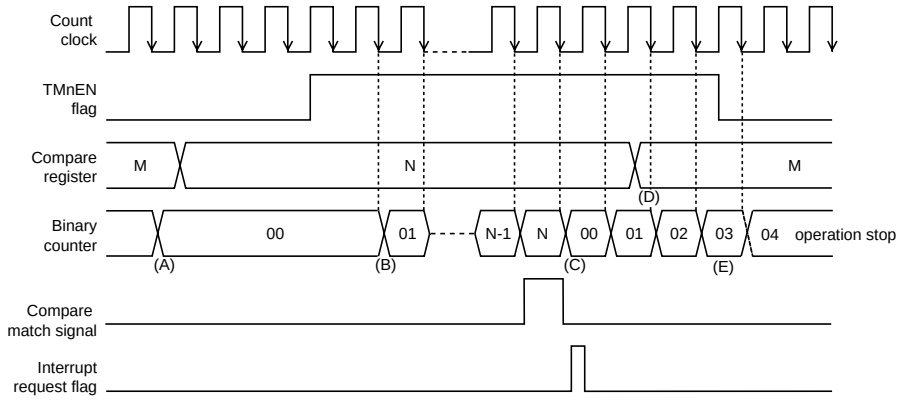


Figure 5-3-1 Count Timing of Timer Operation (Timers 2 and 3)

(A) If the value is written to the compare register during the TMnEN flag is "0", the binary counter is cleared to x'00', at the writing cycle.

(B) If the TMnEN flag is "1", the binary counter is started to count.
The counter starts to count up at the falling edge of the count clock.
But the binary counter doesn't count up at the first falling of the count edge.

(C) If the binary counter reaches the value of the compare register, the interrupt request flag is set at the next count clock, then the binary counter is cleared to x'00' and the counting is restarted.

(D) Even if the compare register is rewritten during the TMnEN flag is "1", the binary counter is not changed.

(E) If the TMnEN flag is "0", the binary counter is stopped after 1 count up.

When the binary counter reaches the value in the compare register, the interrupt request flag is set and the binary counter is cleared, at the next count clock. So, set the compare register as : Compare register setting = (count till the interrupt request - 1)

If the compare register is set the smaller than the binary counter during the count operation, the binary counter counts up to the overflow, at first.

If the interrupt is enabled, the timer interrupt request flag should be cleared before timer operation is started.

Even if the TMnEN flag of the timer is cleared during operation, it does not stop until the next count clock. Therefore, during max. 1 count clock after the TMnEM is cleared, the binary counter cannot be initialized.

5-3-2 Setup Example

■Timer Operation Setup Example (Timers 2 and 3)

Timer function can be set by using timer 2 that generates the constant interrupt. By selecting fs/4 (at fosc = 20 MHz) as a clock source, interrupt is generated every 250 clock cycles (100 µs).

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM2MD (x'3F82') bp4 :TM2EN = 0	(1) Set the TM2EN flag of the timer 2 mode register (TM2MD) to "0" to stop the counting of timer 2.
(2) Select the normal timer operation. TM2MD (x'3F82') bp3 :TM2PWM = 0	(2) Set the TM2PWM flag of the TM2MD register to "0" to select the normal timer operation.
(3) Select the count clock source. TM2MD (x'3F82') bp2-0 :TM2CK2-0 = 001	(3) Select fs/4 to the clock source by the TM2CK2-0 flag of the TM2MD register.
(4) Set the cycle of the interrupt generation. TM2OC (x'3F72') = x'F9'	(4) Set the value of the interrupt generation cycle to the timer 2 compare register (TM2OC). The cycle is 250, so that the setting value is set to 249 (x'F9'). At that time, the timer 2 binary counter (TM2BC) is initialized to x'00'.
(5) Set the interrupt level. TM2ICR (x'3FE6') bp7-6 :TM2LV1-0 = 10	(5) Set the interrupt level by the TM2LV1-0 flag of the timer 2 interrupt control register (TM2ICR). If any interrupt request flag had already been set, clear it. [☞ Chapter 3 3-1-4. Interrupt flag setting]
(6) Enable the interrupt. TM2ICR (x'3FE6') bp1 :TM2IE = 1	(6) Set the TM2IE flag of the TM2ICR register to "1" to enable the interrupt.

Setup Procedure	Description
(7) Start the timer operation. TM2MD (x'3F82') bp4 :TM2EN = 1	(7) Set the TM2EN flag of the TM2MD register to "1" to start the timer 2.

The TM2BC starts to count up from 'x00'. When the TM2BC reaches the setting value of the TM2OC register, the timer 2 interrupt request flag is set at the next count clock, then the value of the TM2BC becomes x'00' and restart to count up.

When the TMnEN flag of the TMnMD register is changed at the same time to other bit, binary counter may count up by the switching operation.

The initial value of the TM3CK2-0 in the TM3MD register is indefinite.
When timer 2 / timer 3 is used independently, set any mode except cascade connection.

If fx is selected as the count clock source in timer 2, when the binary counter is read at operation, uncertain value on counting up may be read. To prevent this, select the synchronous fx as the count clock source. In this case, the timer 2 counter counts up in synchronization with system clock, therefore the correct value is always read.
But, if the synchronous fx is selected as the count clock source, CPU mode cannot return from STOP/HALT mode.

5-4 8-Bit Event Count

5-4-1 Operation

Event count operation has 2 types ; TMnIO input and synchronous TMnIO input can be selected as the count clock.

■8-Bit Event Count Operation

Event count means that the binary counter (TMnBC) counts the input signal from external to the TMnIO pin. If the value of the binary counter reaches the setting value of the compare register (TMnOC), interrupts can be generated at the next count clock.

Table 5-4-1 Event Count Input Clock

	Timer 2	Timer 3
Event input	TM2IO input (P12)	TM3IO input (P13)
	Synchronous TM2IO input	Synchronous TM3IO input

■Count Timing of TMnIO Input (Timers 2 and 3)

When TMnIO input is selected, TMnIO input signal is directly input to the count clock of the timer n. The binary counter counts up at the falling edge of the TMnIO input signal.

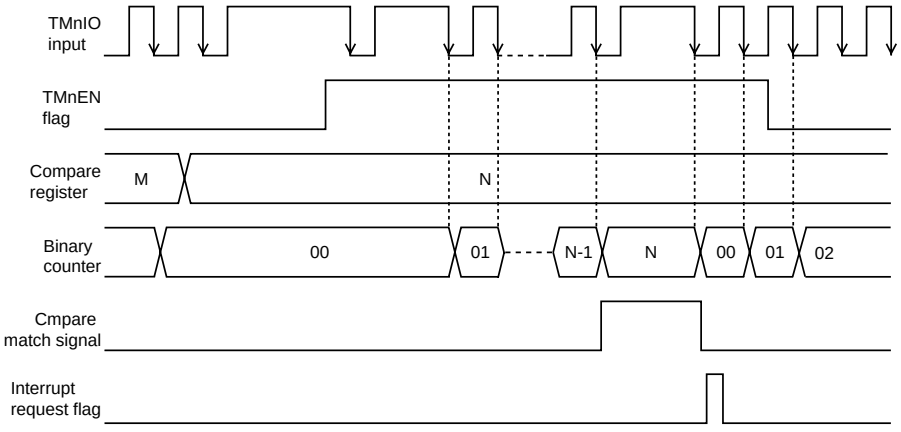


Figure 5-4-1 Count Timing of TMnIO Input (Timers 2 and 3)

When the TMnIO input is selected for count clock source and the value of the timer n binary counter is read during operation, incorrect value at count up may be read. To prevent this, use the event count by synchronous TMnIO input, as the following page.

■Count Timing of Synchronous TMnIO Input (Timers 2 and 3)

If the synchronous TMnIO input is selected, the synchronizing circuit output signal is input to the timer n count clock. The synchronizing circuit output signal is changed at the falling edge of the system clock after the TMnIO input signal is changed.

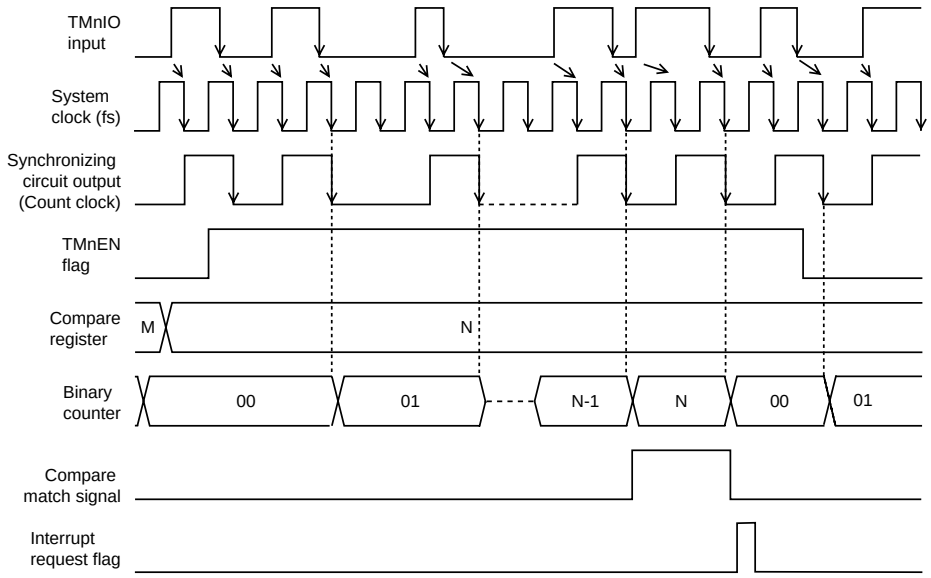


Figure 5-4-2 Count Timing of Synchronous TMnIO Input (Timers 2 and 3)

When the synchronous TMnIO input is selected as the count clock source, the timer n counter counts up in synchronization with system clock, therefore the correct value is always read.

But, if the synchronous TMnIO is selected as the count clock source, CPU mode cannot return from STOP/HALT mode.

5-4-2 Setup Example

■Event Count Setup Example (Timers 2 and 3)

If the falling edge of the TM2IO input pin signal is detected 5 times with using timer 2, an interrupt is generated.

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM2MD (x'3F82') bp4 :TM2EN = 0	(1) Set the TM2EN flag of the timer 2 mode register (TM2MD) to "0" to stop timer 2 counting.
(2) Set the special function pin to input. P1DIR (x'3F31') bp2 :P1DIR2 = 0	(2) Set the P1DIR2 flag of the port 1 direction control register (P1DIR) to "0" to set P12 pin to input mode. If needed, add the pull up resistor. [☞ Chapter 4. I/O Port Function]
(3) Select the normal timer operation. TM2MD (x'3F82') bp3 :TM2PWM = 0	(3) Set the TM2PWM flag of the TM2MD register to "0" to select the normal timer operation.
(4) Select the count clock source. TM2MD (x'3F82') bp2-0 :TM2CK2-0 = 011	(4) Select the clock source to TM2IO input by the TM2CK2-0 flag of the TM2MD register.
(5) Set the interrupt generation cycle. TM2OC (x'3F72') = x'04'	(5) Set the timer 2 compare register (TM2OC) the interrupt generation cycle. Counting is 5, so the setting value should be 4. At that time, the timer 2 binary counter (TM2BC) is initialized to x'00'.
(6) Set the interrupt level. TM2ICR (x'3FE6') bp7-6 :TM2LV1-0 = 10	(6) Set the interrupt level by the TM2LV1-0 flag of the timer 2 interrupt control register (TM2ICR). If any interrupt request flag had already been set, clear it. [☞ Chapter 3 3-1-4. Interrupt Flag Setup]

Setup Procedure	Description
(7) Enable the interrupt. TM2ICR (x'3FE6') bp1 :TM2IE = 1	(7) Set the TM2IE flag of the TM2ICR register to "1" to enable the interrupt.
(8) Start the event counting. TM2MD (x'3F82') bp4 :TM2EN = 1	(8) Set the TM2EN flag of the TM2MD register to start timer 2.

Every time TM2BC detects the falling edge of TM2IO input, TM2BC counts up from 'x00'. When TM2BC reaches the setting value of theTM2OC register, the timer 2 interrupt request flag is set at the next count clock, then the value of TM2BC becomes x'00' and counting up is restarted.

5-5 8-Bit Timer Pulse Output

5-5-1 Operation

The TMnIO pin can output a pulse signal with any cycle.

■Operation of Timer Pulse Output (Timers 2 and 3)
The timers can output 2 x cycle signal, compared to the setting value in the compare register (TMnOC). Output pins are as follows ;

Table 5-5-1 Timer Pulse Output Pins

	Timer 2	Timer 3
Pulse output pin	TM2IO output (P12)	TM3IO output (P13)

■Count Timing of Timer Pulse Output (Timers 2 and 3)

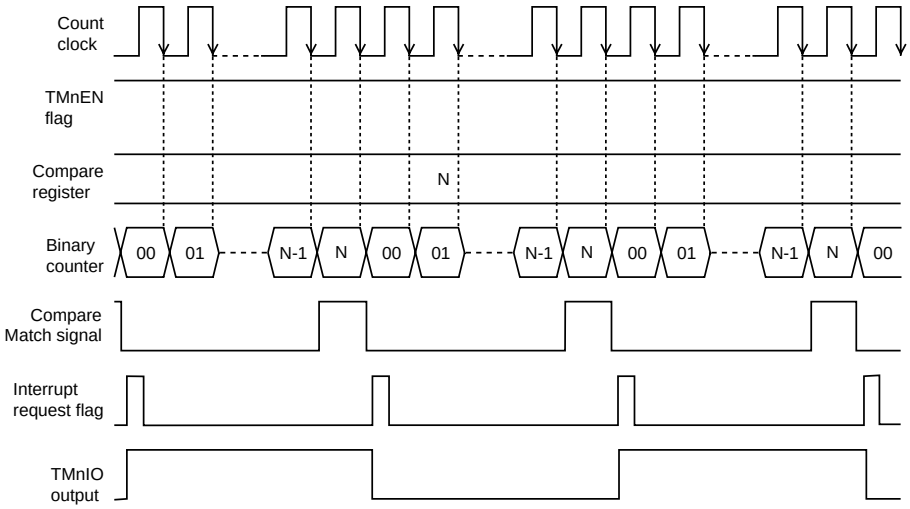


Figure 5-5-1 Count Timing of Timer Pulse Output (Timers 2 and 3)

The TMnIO pin outputs 2 x cycle, compared to the value in the compare register. If the binary counter reaches the compare register, and the binary counter is cleared to x'00', TMnIO output is inverted.

5-5-2 Setup Example

■Timer Pulse Output Setup Example (Timers 2 and 3)

TM3IO pin outputs 50 kHz pulse by using timer 3. For this, select fosc as clock source, and set a 1/2 cycle (100 kHz) for the timer 3 compare register (at fosc=20 MHz).

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM3MD (x'3F83') bp4 :TM3EN = 0	(1) Set the TM3EN flag of the timer 3 mode register (TM3MD) to "0" to stop timer 3 counting.
(2) Set the special function pin to the output mode. P1OMD (x'3F39') bp3 :P13TC0 = 1 P1DIR (x'3F31') bp3 :P1DIR3 = 1	(2) Set the P13TC0 flag of the port 1 output mode register (P1OMD) to "1" to set P13 the special function pin. Set the P1DIR3 flag of the port 1 direction control register (P1DIR) to "1" to set output mode. If needed, add pull-up resister. [☞ Chapter 4. I/O Ports]
(3) Select the normal timer operation. TM3MD (x'3F83') bp3 :TM3PWM = 0	(3) Set the TM3PWM flag of the TM3MD register to "0" to select the normal timer operation.
(4) Select the count clock source. TM3MD (x'3F83') bp2-0 :TM3CK2-0 = 000	(4) Select fosc for the clock source by the TM3CK2-0 flag of the TM3MD register.
(5) Set the timer pulse output cycle. TM3OC (x'3F73') = x'C7'	(5) Set the timer 3 compare register (TM3OC) to the 1/2 of the timer pulse output cycle. The setting value should be 200-1=199(x'C7'), because 100 kHz is divided by 20 MHz. At that time, the timer 3 binary counter (TM3BC) is initialized to x'00'.
(6) Start the timer operation. TM3MD (x'3F83') bp4 :TM3EN = 1	(6) Set the TM3EN flag of the TM3MD register to "1" to start timer 3.

TM3BC counts up from x'00'. If TM3BC reaches the setting value of the TM3OC register, then TM3BC is cleared to x'00', TM3IO output signal is inverted and TM3BC restarts to count up from x'00'.

When port 1 is used as pulse output pin, the settings of the port 1 direction control register (P1DIR) and the port 1 pull-up register (P1PLU) need to be set to "1".

Set the compare register value as follows,

$$\text{The compare register value} = \frac{\text{The timer pulse output cycle}}{\text{The count clock cycle X 2}} - 1$$

The initial value of timer output and the initialization (low level)

	Initial value (after reset release)	To initialize (Set to low level)	Program example
Timer 2	Low level	After timers 2 and 3 are set to cascade connection, the setting should be the original.	mov x'04', (TM3MD) bclr (TM3MD), 2
Timer 3	indefinite	After P13 output selection is set to the timer 2 PWM output (TM2PWM flag = 1), the setting should be back to the timer 3 output.	mov x'08', (TM3MD) bclr (TM3MD), 3

5-6 8-Bit PWM Output

The TMnIO pin outputs the PWM waveform, which is determined by the match timing for the compare register and the overflow timing of the binary counter.

5-6-1 Operation

■Operation of 8-Bit PWM Output (Timers 2)

The PWM waveform with any duty cycle is generated by setting the duty cycle of PWM "H" period to the compare register (TMnOC). The cycle is the period from the full count to the overflow of the 8-bit timer. Table 5-6-1 shows PWM output pins ;

Table 5-6-1 Output Pins of PWM Output

	Timer 2
PWM output pin	TM2IO output pin (P12) TM3IO output pin (P13)

■Count Timing of PWM Output (at normal) (Timers 2)

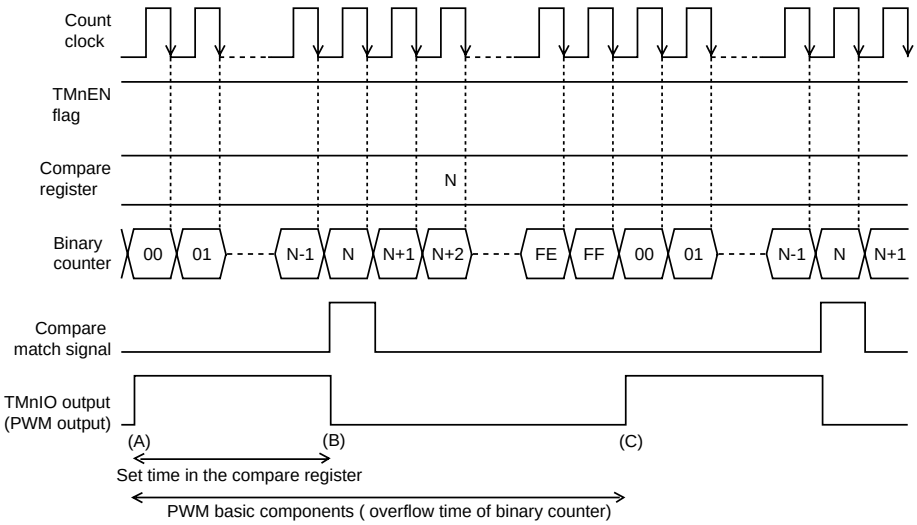


Figure 5-6-1 Count Timing of PWM Output (at Normal)

PWM source waveform,

(A) is "H" while counting up from x'00' to the value stored in the compare register.

(B) is "L" after the match to the value in the compare register, then the binary counter continues counting up till the overflow.

(C) is "H" again, if the binary counter overflows.

■Count Timing of PWM Output (when the compare register is x'00') (Timers 2)

Here is the count timing when the compare register is set to x'00' ;

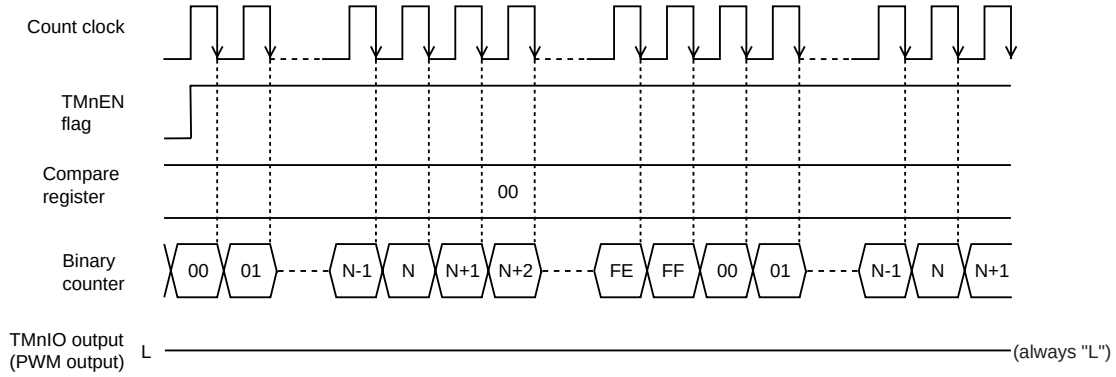


Figure 5-6-2 Count Timing of PWM Output (when compare register is x'00')

■Count Timing of PWM Output (when the compare register is x'FF') (Timers 2)

Here is the count timing when the compare register is set to x'FF' ;

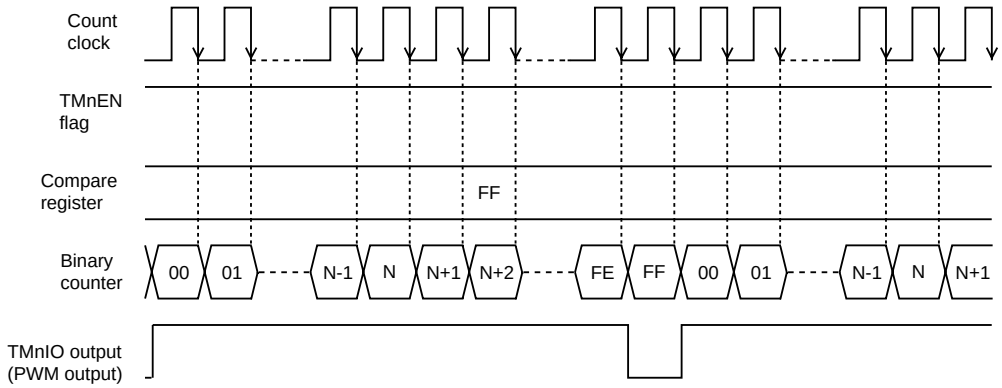


Figure 5-6-3 Count Timing of PWM Output (when compare register is x'FF')

5-6-2 Setup Example

■PWM Output Setup Example (Timers 2)

The 1/4 duty cycle PWM output waveform is output from the TM2IO output pin at 2 kHz by using timer 2 (at fosc=4.19 MHz). Cycle period of PWM output waveform is decided by the overflow of the binary counter. "H" period of the PWM output waveform is decided by the setting value of the compare register. An example setup procedure, with a description of each step is shown below.

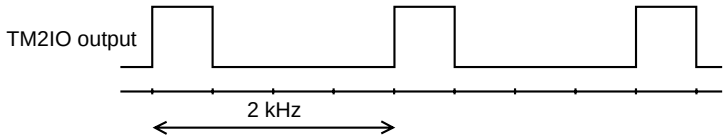


Figure 5-6-4 Output Waveform of TM2IO Output Pin

Setup Procedure	Description
(1) Stop the counter. TM2MD (x'3F82') bp4 :TM2EN = 0	(1) Set the TM2EN flag of the timer 2 mode register (TM2MD) to "0" to stop the timer 2 counting.
(2) Set the special function pin to the output mode. P1OMD (x'3F39') bp2 :P12TC0 = 1 P1DIR (x'3F31') bp0 :P1DIR2 = 1	(2) Set the P12TC0 flag of the port 1 output mode register (P10MD) to "1" to set P12 pin to the special function pin. Set the P1DIR2 flag of the port 1 direction control register (P1DIR) to "1" for the output mode. If needed, add pull up resistor. [☞ Chapter 4. I/O Ports]
(3) Select the PWM operation. TM2MD (x'3F82') bp3 :TM2PWM = 1	(3) Set the TM2PWM flag of the TM2MD register to "1" to select the PWM operation.
(4) Select the count clock source. TM2MD (x'3F82') bp2-0 :TM2CK2-0 = 001	(4) Select "fs/4" for the clock source by the TM2CK2-0 flag of the TM2MD register.

Setup Procedure	Description
(5) Set the period of PWM "H" output. TM2OC (x'3F72') = x'40'	(5) Set the "H" period of PWM output to the timer 2 compare register (TM2OC). The setting value is set to 256 / 4 = 64 (x'40'), because it should be the 1/4 duty of the full count (256). At that time, the timer 2 binary counter (TM2BC) is initialized to x'00'.
(6) Start the timer operation. TM2MD (x'3F82') bp4 :TM2EN = 1	(6) Set the TM2EN flag of the TM2MD register to "1" to operate timer 2.

TM2BC counts up from x'00'. PWM source waveform outputs "H" till TM2BC reaches the setting value of the TM2OC register, and outputs "L" after that. Then, TM2BC continues counting up, and PWM source waveform outputs "H" again, once overflow happens, and TM2BC restarts counting up from x'00'.

If the timer 2 PWM output is selected by setting the TM3PWM flag of the TM3MD register to "1", the TM3IO pin outputs the timer 2 PWM output, too.

When port 1 is used as PWM output pin, the settings of the P1DIR register and the P1PLU register need to be set to "1".

5-7 Serial Interface Transfer Clock Output

5-7-1 Operation

Serial interface transfer clock can be created by using the timer output signal.

■Serial Interface Transfer Clock Operation by 8-Bit Timer (Timer 3)
Timer 3 output can be used as a transfer clock source for serial interface 0.

Table 5-7-1 Timer for Serial Interface Transfer Clock

Serial transfer clock	Timer 3
Serial interface 0	√

■Timing of Serial Interface Transfer Clock (Timer 3)

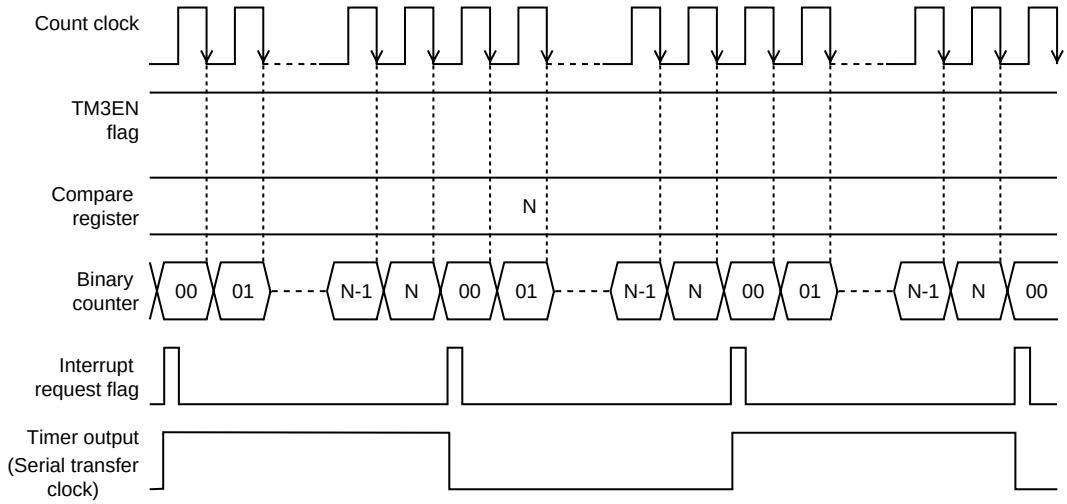


Figure 5-7-1 Timing of Serial Interface Transfer Clock (Timer 3)

The timer pulse output is used as the clock source of the serial interface. And its frequency is 1/2 of the set frequency in the timer compare register.
The count timing is same to the timing of timer operation. For the baud rate calculation and the serial interface setup, refer to chapter 10. Serial Interface 0.

5-7-2 Setup Example

■Serial Interface Transfer Clock Setup Example (Timer 3)

How to create a transfer clock for half duplex UART (serial interface 0) using with timer 3 is shown below. The baud rate is selected to be 300 bps, the source clock of timer 3 is selected to be fs/4 (at fosc=8 MHz).

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM3MD (x'3F83') bp4 :TM3EN = 0	(1) Set the TM3EN flag of the timer 3 mode register (TM3MD) to "0" to stop timer 3 counting.
(2) Select the normal timer operation. TM3MD (x'3F83') bp3 :TM3PWM = 0	(2) Set the TM3PWM flag of the TM3MD register to "0" to select the normal timer operation.
(3) Select the count clock source. TM3MD (x'3F83') bp2-0 :TM4CK2-0 = 001	(3) Select the clock source to fs/4 by the TM3CK2-0 flag of the TM3MD register.
(4) Set the baud rate. TM3OC (x'3F73') = x'CF'	(4) Set the timer 3 compare register (TM3OC) to the value that baud rate comes to 300 bps. [☞ Chapter 10. Table 10-3-18] At that time, the timer 3 binary counter (TM3BC) is initialized to x'00'.
(5) Start the timer operation TM3MD (x'3F83') bp4 :TM3EN = 1	(5) Set the TM3EN flag of the TM3MD register to "1" to start timer 3.

TM3BC counts up from x'00'. Timer 3 output is the clock of the serial interface 0 at transmission and reception.

For the compare register setup value and the serial interface operation setup, refer to chapter 10. Serial Interface 0.

5-8 Cascade Connection

5-8-1 Operation

Cascading timer 2 and 3 form a 16-bit timer.

■8-Bit Timer Cascade Connection Operation (Timer 2 + Timer 3)
Timer 2 and timer 3 are combined to be a 16-bit timer. Cascading timer is operated at clock source of timer 2 which are lower 8 bits.

Table 5-8-1 Timer Functions at Cascade Connection

	Timer 2 + Timer 3 (16 Bit)
Interrupt source	TM3IRQ
Timer operation	√
Event count	√ (TM2IO input)
Timer pulse output	√ (TM3IO output)
PWM output	-
Serial interface transfer clock output	√ (TM3IO output)
Remote control carrier output	√
Clock source	fs fs/4 fx TM2IO input
fosc : Machine clock (High speed oscillation) fx : Machine clock (Low speed oscillation) fs : System clock (at NORMAL mode : fs=fosc/2, at SLOW mode : fs=fx/4)	

At cascade connection, the binary counter and the compare register are operated as a 16 bit register. At operation, set the TMnEN flag of the upper and lower 8-bit timers to "1" to be operated.
Also, the clock source is the one which is selected in the lower 8-bit timer.
Other setup and count timing is the same to the 8-bit timer at independently operation.

When timer 2 and timer 3 are used in cascade connection, timer 3 interrupt request flag is used. Disable the timer 2 interrupt. Timer pulse output of timer 2 is "L" fixed output.

At the cascade connection, if the binary counter should be cleared by rewriting the compare register, the TMnEN flags of the lower and upper 8 bits timers mode registers should be set to "0" to stop the counting, then rewrite the compare register.
Also, set the (TM3OC + TM2OC) register by the 16-bit access instruction.

5-8-2 Setup Example

■Cascade Connection Timer Setup Example (Timer 2 + Timer 3)

Setting example of timer function that an interrupt is constantly generated by cascade connection of timer 2 and timer 3, as a 16-bit timer is shown. An interrupt is generated in every 2500 cycles (1 ms) by selecting source clock to fs/4 (fosc=20 MHz).

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM2MD (x'3F82') bp4 :TM2EN = 0 TM3MD (x'3F83') bp4 :TM3EN = 0	(1) Set the TM2EN flag of the timer 2 mode register (TM2MD) to "0", the TM3EN flag of the timer 3 mode register (TM3MD) to "0" to stop timer 2 and timer 3 counting.
(2) Select the normal operation of lower timer . TM2MD (x'3F82') bp3 :TM2PWM = 0	(2) Set both of the TM2PWM flag of the TM2MD register to "0" to select the normal operation of timer 2.
(3) Set the cascade connection. TM3MD (x'3F83') bp2-0 :TM3CK2-0 = 100	(3) Connect timer 2 and timer 3 in cascade connection by the TM3CK2-0 flag of the TM3MD register.
(4) Select the count clock source. TM2MD (x'3F82') bp2-0 :TM2CK2-0 = 001	(4) Set the clock source to fs/4 by the TM2CK2-0 flag of the TM2MD register.
(5) Set the interrupt generation cycle TMnOC(x'3F71', x'3F72')=x'09C3'	(5) Set the timer 2 compare register + timer 3 compare register (TM3OC + TM2OC) to the interrupt generation cycle (x'09C3' : 2500 cycles - 1). At that time, timer 3 binary counter + timer 2 binary counter (TM3BC + TM2BC) are initialized to x'0000'.
(6) Disable the lower timer interrupt. TM2ICR (x'3FE6') bp1 :TM2IE = 0	(6) Set the TM2IE flag of the timer 2 interrupt control register (TM2ICR) to "0" to disable the interrupt.

Setup Procedure	Description
(7) Set the level of the upper timer interrupt. TM3ICR (x'3FE7') bp7-6 :TM3LV1-0 = 10	(7) Set the interrupt level by the TM3LV1-0 flag of the timer 3 interrupt control register (TM3ICR). If any interrupt request flag had already been set, clear it.
(8) Enable the upper timer interrupt. TM3ICR (x'3FE7') bp1 :TM3IE = 1	(8) Set the TM3IE flag of the TM3ICR register to "1" to enable the interrupt. [☞ Chapter 3 3-1-4. Interrupt Flag Setup]
(9) Start the upper timer operation. TM3MD (x'3F83') bp4 :TM3EN = 1	(9) Set the TM3EN flag of the TM3MD register to "1" to start timer 3.
(10) Start the lower timer operation. TM2MD (x'3F82') bp4 :TM2EN = 1	(10) Set the TM2EN flag of the TM2MD register to "1" to start timer 2.

TM3BC + TM2BC counts up from x'0000' as a 16-bit timer. When TM3BC + TM2BC reaches the set value of TM3OC + TM2OC register, the timer 3 interrupt request flag is set to "1" at the next count clock, and the value of TM3BC + TM2BC becomes x'0000' and counting up is restarted.

Use a 16-bit access instruction to set the (TM3OC + TM2OC) register.

If the lower timer starts to operate before the upper timer does, the first overflow signal of the lower timer may be invalid. To prevent this, start the upper timer operation before the lower timer operation.

5-9 Remote Control Carrier Output

5-9-1 Operation

Carrier pulse for remote control can be generated.

■Operation of Remote Control Carrier Output (Timer 3)
Remote control carrier pulse is based on output signal of timer 3. Duty cycle is selected from 1/2, 1/3. RMOUT (P10) outputs remote control carrier output signal.

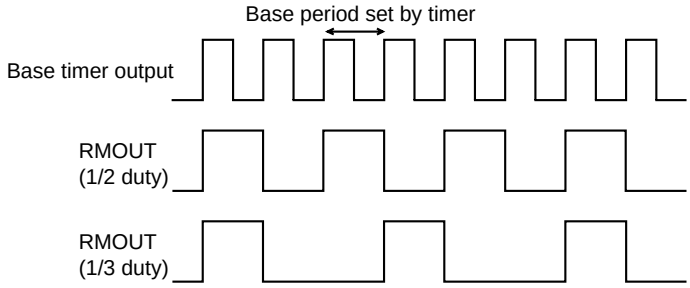


Figure 5-9-1 Duty Cycle of Remote Control Carrier Output Signal

■Count Timing of Remote Control Carrier Output (Timer 3)

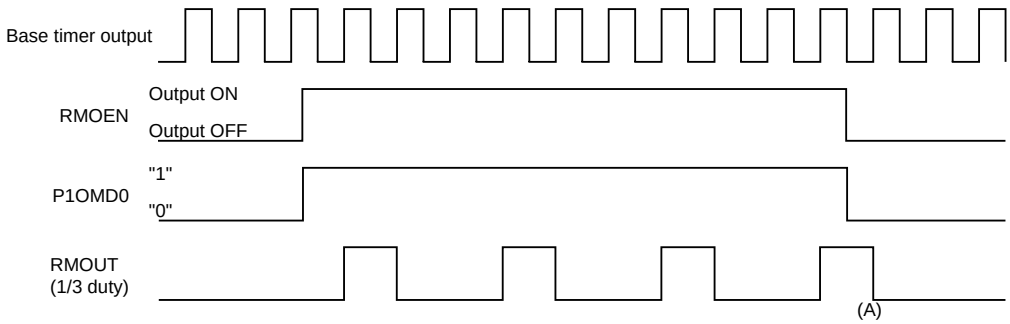


Figure 5-9-2 Count Timing of Remote Control Carrier Output Function (Timer 3)

(A) Even if the RMOEN flag is off when the carrier output is high, the carrier waveform is held by the synchronizing circuit.

When the RMOEN flag is switched to on, set the P10TCO flag of the P1OMD register to "1". When it is switched to off, set it to "0".

When the RMOEN flag is changed, do not change the base cycle and its duty at the same time. If they are changed at the same time, the carrier wave form is not output properly.

5-9-2 Setup Example

■Remote Control Carrier Output Setup Example (Timer 3)
Here is the setting example that the RMOUT pin outputs the 1/3 duty carrier pulse signal with "H" period of 36.7 kHz, by using timer 0. The source clock of timer 0 is set to fosc (at 8 MHz).
An example setup procedure, with a description of each step is shown below.

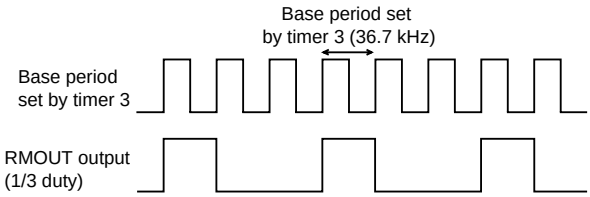


Figure 5-9-3 Output Wave Form of RMOUT Output Pin

Setup Procedure	Description
(1) Disable the remote control carrier output. RMCTR (x'3F89') bp3 : RMOEN = 0	(1) Set the RMOEN flag of the remote control carrier output control register (RMCTR) to "0" to disable the remote control carrier output.
(2) Select the carrier output duty. RMCTR (x'3F89') bp1 : RMDTY0 = 1	(2) Set the RMDTY0 flag of the RMCTR register to "1" to select 1/3 duty.
(3) Stop the counter. TM3MD (x'3F83') bp4 : TM3EN = 0	(3) Set the TM3EN flag of the timer 3 mode register (TM3MD) to stop the timer 3 counting.
(4) Set the remote control carrier output of the special function pin. P1OUT (x'3F11') bp0 : P1OUT0 = 0 P1OMD (x'3F39') bp0 : P1OTC0 = 1 P1DIR (x'3F31') bp0 : P1DIR0 = 1	(4) Set the P1OUT0 flag of the port 1 output register (P1OUT) to "0" to set the output data of P10 pin to "0. Set the P1OTC0 flag of the port 1 output mode register (P1OMD) to "1" to set P10 pin as a special function pin. Set the P1DIR0 flag of the port 1 direction control register (P1DIR) to "1" for output mode.
(5) Select the normal timer operation. TM3MD (x'3F83') bp3 : TM3PWM = 0	(5) Set the TM3PWM flag of the TM3MD register to "0" to select normal timer operation.

Setup Procedure	Description
(6) Select the count clock source. TM3MD (x'3F83') bp2-0 : TM3CK2-0 = 000	(6) Select fosc to clock source by the TM3CK2-0 flag of the TM3MD register.
(7) Set the base cycle of remote control carrier. TM3OC (x'3F73') = x'6C'	(7) Set the base cycle of remote control carrier by writing x'6C' to the timer 3 compare register (TM3OC). The set value should be (8 MHz/ 73.4 kHz) - 1 = 108(x'6C') 8 MHz is divided to be 73.4 kHz, 2 times 36.7 kHz.
(8) Start the timer operation. TM3MD (x'3F83') bp4 : TM3EN = 1	(8) Set the TM3EN flag of the TM3MD register to "1" to stop the timer 3 counting.
(9) Enable the remote control carrier output. RMCTR (x'3F89') bp3 : RMOEN = 1	(9) Set the RMOEN flag of the RMCTR register to "1" to enable the remote control carrier output.

TM3BC counts up from x'00'. Timer 3 outputs the base cycle pulse set in TM3OC. Then, the 1/3 duty remote control carrier pulse signal is output. If the RMOEN flag of the RMCTR register is set to "0", the remote control carrier pulse signal output is stopped.

Chapter 6 16-Bit Timer

6

6-1 Overview

This LSI contains a general-purpose 16-bit timer (Timer 4).

6-1-1 Functions

Table 6-1-1 shows the functions of timer 4 can use.

Table 6-1-1 16-Bit Timer Functions

	Timer 4 (16-bit timer)
Interrupt source	TM4IRQ
Timer operation	√
Event count	√
Timer pulse output	√
PWM output (Added Pulse Type)	√
Capture function	√
Clock source	fosc fs/4 fs/16 TM4IO input
fosc : Machine clock (High speed oscillation) fs : System clock (at NORMAL mode : fs=fosc/2, at SLOW mode : fs=fx/4)	

6-1-2 Block Diagram

■Timer 4 Block Diagram

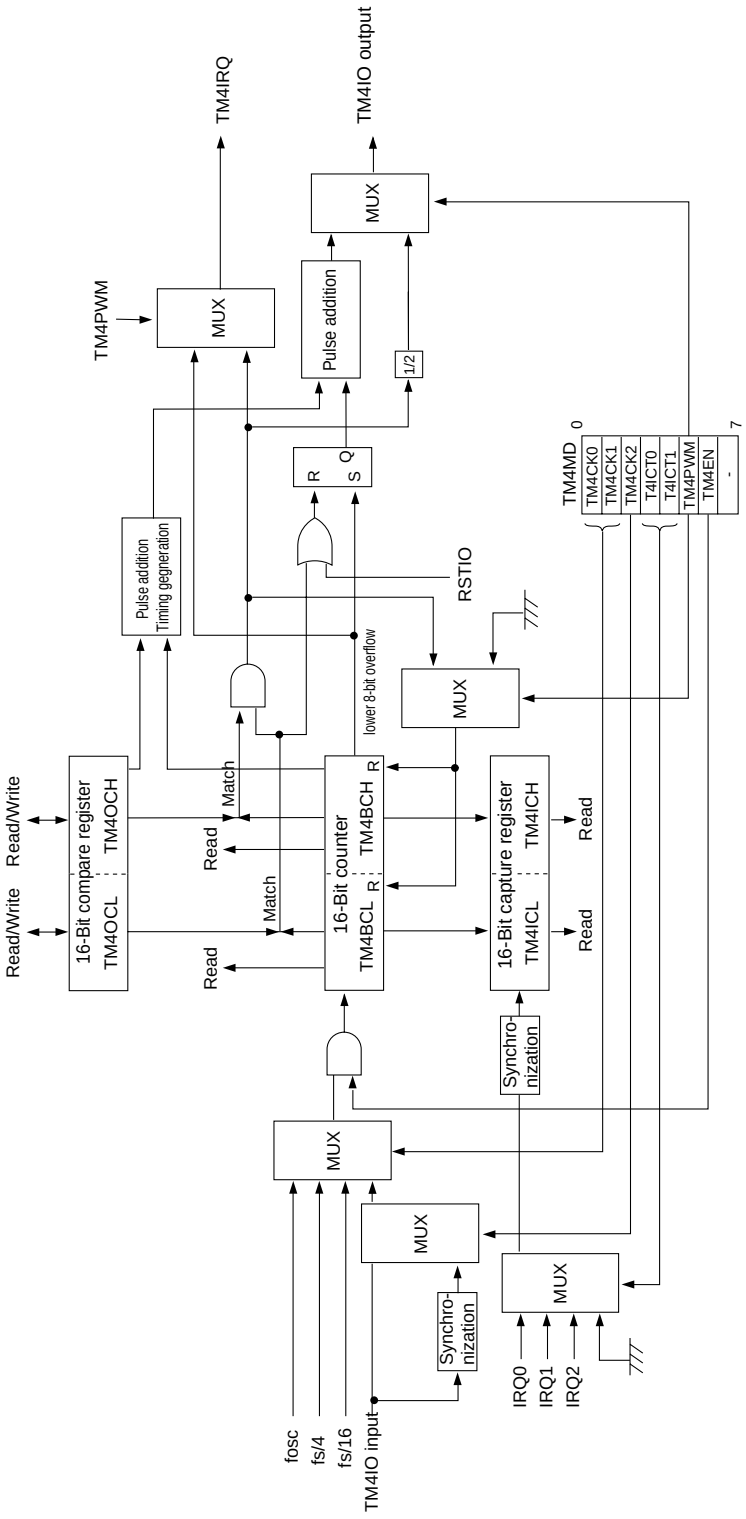


Figure 6-1-1 Timer 4 Block Diagram

6-2 Control Registers

Timer 4 contains the binary counter (TM4BCL/TM4BCH), the compare register (TM4OCL/TM4OCH) and input capture register (TM4ICL/TM4ICH). The timer 4 mode register (TM4MD) controls timer 4.

6-2-1 Registers

Table 6-2-1 shows the registers that control timer 4.

Table 6-2-1 16-Bit Timer Control Registers

	Register	Address	R/W	Function	Page
Timer 4	TM4BCL	x'03F64'	R	Timer 4 binary counter (lower 8 bits)	VI - 5
	TM4BCH	x'03F65'	R	Timer 4 binary counter (upper 8 bits)	VI - 5
	TM4OCL	x'03F74'	R/W	Timer 4 compare register (lower 8 bits)	VI - 5
	TM4OCH	x'03F75'	R/W	Timer 4 compare register (upper 8 bits)	VI - 5
	TM4ICL	x'03F66'	R	Timer 4 input capture regsiter (lower 8 bits)	VI - 6
	TM4ICH	x'03F67'	R	Timer 4 input capture register (upper 8 bits)	VI - 6
	TM4MD	x'03F84'	R/W	Timer 4 mode register	VI - 7
	TM4ICR	x'03FEF'	R/W	Timer 4 interrupt register (timer 4 compare match)	III - 23
	P1OMD	x'03F39'	R/W	Port 1 output mode register	IV - 11
	P1DIR	x'03F31'	R/W	Port 1 direction control register	IV - 10

R/W : Readable/Writable
R : Readable only

6-2-2 Programmable Timer Registers

Timer 4 has a 16-bit programmable timer register. It contains a compare register, a binary counter and a capture register. Each register has 2 sets of 8-bit register. Operate by 16-bit access.

Compare register is a 16-bit register stores the value that compared to binary counter.

■Timer 4 Compare Register (TM4OC)

	7	6	5	4	3	2	1	0	
TM4OCL	TM4OCL7	TM4OCL6	TM4OCL5	TM4OCL4	TM4OCL3	TM4OCL2	TM4OCL1	TM4OCL0	(At reset : X X X X X X X X)

Figure 6-2-1 Timer 4 Compare Register Lower 8 bits (TM4OCL : x'03F74', R/W)

	7	6	5	4	3	2	1	0	
TM4OCH	TM4OCH7	TM4OCH6	TM4OCH5	TM4OCH4	TM4OCH3	TM4OCH2	TM4OCH1	TM4OCH0	(At reset : X X X X X X X X)

Figure 6-2-2 Timer 4 Compare Register Upper 8 bits (TM4OCH : x'03F75', R/W)

Binary counter is a 16-bit up counter. If any data is written to a compare register during counting is stopped, the binary counter is cleared to x'0000'.

■Timer 4 Binary Counter (TM4BC)

	7	6	5	4	3	2	1	0	
TM4BCL	TM4BCL7	TM4BCL6	TM4BCL5	TM4BCL4	TM4BCL3	TM4BCL2	TM4BCL1	TM4BCL0	(at reset : 0 0 0 0 0 0 0 0)

Figure 6-2-3 Timer 4 Binary Counter Lower 8 bits (TM4BCL : x'03F64', R)

	7	6	5	4	3	2	1	0	
TM4BCH	TM4BCH7	TM4BCH6	TM4BCH5	TM4BCH4	TM4BCH3	TM4BCH2	TM4BCH1	TM4BCH0	(at reset : 0 0 0 0 0 0 0 0)

Figure 6-2-4 Timer 4 Binary Counter Upper 8 bits (TM4BCH : x'03F65', R)

Input capture register is a register that holds the value loaded from a binary counter by capture trigger. Capture trigger is generated by an input signal from an external interrupt pin (Directly writing to the register by program is disable.).

■Timer 4 Input Capture Register (TM4IC)

	7	6	5	4	3	2	1	0	
TM4ICL	TM4ICL7	TM4ICL6	TM4ICL5	TM4ICL4	TM4ICL3	TM4ICL2	TM4ICL1	TM4ICL0	(At reset : X X X X X X X X)

Figure 6-2-5 Timer 4 Input Capture Register Lower 8 bits (TM4ICL : x'03F66', R)

	7	6	5	4	3	2	1	0	
TM4ICH	TM4ICH7	TM4ICH6	TM4ICH5	TM4ICH4	TM4ICH3	TM4ICH2	TM4ICH1	TM4ICH0	(At reset : X X X X X X X X)

Figure 6-2-6 Timer 4 Input Capture Register Upper 8 bits (TM4ICH : x'03F67', R)

6-2-3 Timer Mode Registers

This is a readable / writable register that controls timer 4.

■Timer 4 Mode Register (TM4MD)

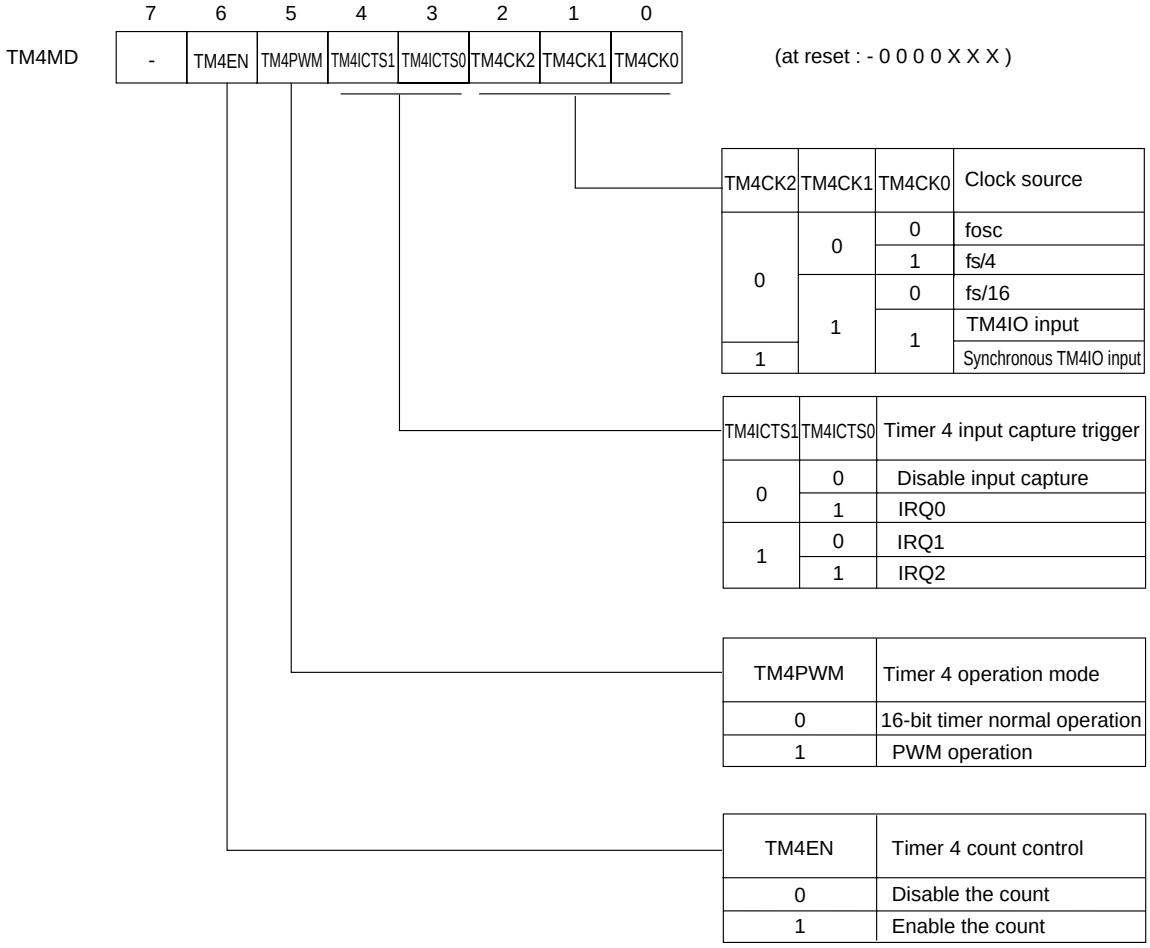


Figure 6-2-7 Timer 4 Mode Register (TM4MD : x'03F84', R/W)

6-3 16-Bit Timer Count

6-3-1 Operation

Timer operation can constantly generate interrupt.

■16-Bit Timer Operation (Timer 4)
The generation cycle of an timer interrupt is set by the clock source selection and the set value of the compare register (TM4OC), in advance. When the binary counter (TM4BC) reaches the set value of the compare register, the timer 4 interrupt request flag is set to "1" at the next count clock, the binary counter (TM4BC) is cleared to x'0000' and the counting up is restarted from x'0000'.

When the CPU reads the 16-bit binary counter (TM4BC), the read data is treated as 8-bits unit data, even if it is a 16-bit MOVW instruction. As a result, the CPU will read the data incorrectly if a carry from the lower 8 bits to the upper 8 bits occurs during counting.

Table 6-3-1 shows the clock source that can be selected.

Table 6-3-1 Clock Source at Timer Operation (Timer 4)

Clock source	1 count time
fosc	50 ns
fs/4	400 ns
fs/16	1.6 µs
as fosc = 20 MHz, fs = fosc/2 = 10 MHz	

■Count Timing of Timer Operation (Timer 4)

The binary counter counts up with the selected clock source as the count clock.

The basic operation of the whole function of 16-bit timer is as follows ;

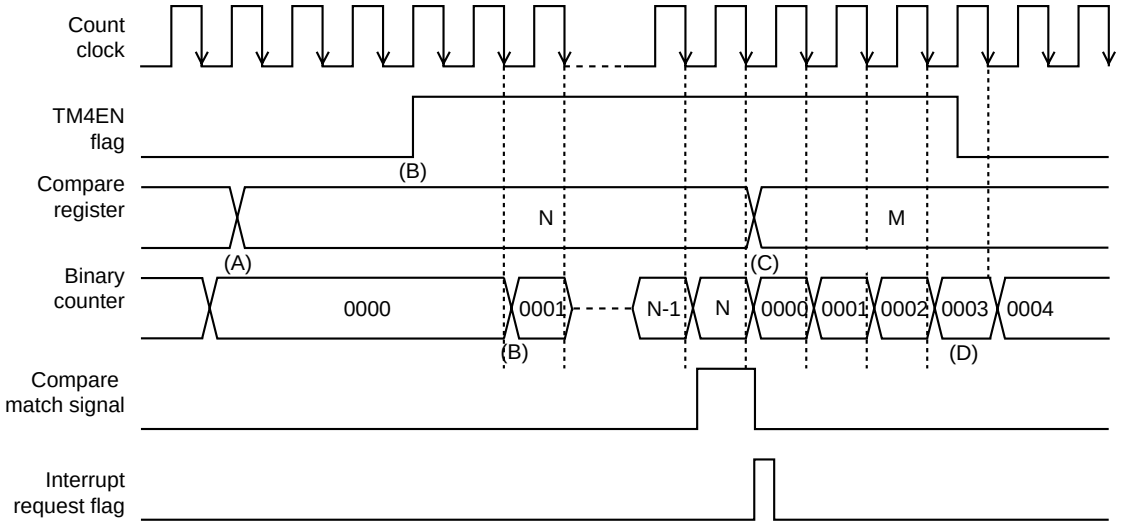


Figure 6-3-1 Count Timing of Timer Operation (Timer 4)

(A) Set the value to the timer 4 compare register (TM4OC).

(B) If the TM4EN flag is "1", the binary counter starts counting from x'0000'.
The counting is happened at the falling edge of the count clock.
But the binary counter doesn't count up at the first falling edge of the count clock.

(C) If the binary counter reaches the value of the compare register, the interrupt request flag is set at the next count clock, and the binary counter is cleared to x'0000' to restart counting up.

(D) If the TM4EN flag is "0", the binary counter is stopped after 1 counting up.

When the binary counter reaches the value in the compare register, the interrupt request flag is set and the binary counter is cleared, at the next count clock. So, set the compare register as : Compare register setting = (count till the interrupt request - 1)

If the interrupt is enabled, the timer interrupt request flag should be cleared before timer operation is started.

If the smaller value than that of the binary counter (TM4BC) is set to the compare register (TM4OC), the binary counter counts up to the overflow, at first.

Even if the TM4EN flag of the timer 4 is cleared during operation, it does not stop until the next count clock. Therefore, during max. 1 count clock after the TM4EN is cleared, the binary counter cannot be initialized.

6-3-2 Setup Example

■Timer Operation Setup Example (Timer 4)

Timer 4 generates an interrupt constantly for timer function. Fosc (fosc=20 MHz at operation) is selected as a clock source to generate an interrupt every 1000 cycles (50 µs).

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM4MD (x'3F84') bp6 : TM4EN = 0	(1) Set the TM4EN flag of the timer 4 mode register (TM4MD) to "0" to stop timer 4 counting.
(2) Select the normal timer operation. TM4MD (x'3F84') bp5 : TM4PWM = 1	(2) Set the TM4PWM flag of the TM4MD register to "0" to select the normal timer operation.
(3) Select the count clock source. TM4MD (x'3F84') bp2-0 : TM4CK2-0 = 000	(3) Select fosc as a clock source by the TM4CK2-0 flag of the TM4MD register.
(4) Set the interrupt generation cycle. TM4OC (x'3F75', x'3F74')=x'03E7	(4) Set the interrupt generation cycle to the timer 4 compare register (TM4OC). The cycle is 1000. The set value should be 1000-1=999(x'03E7').
(5) Set the interrupt level. TM4ICR (x'3FEF') bp7-6 : TM4LV1-0 = 10	(5) Set the interrupt level by the TM4LV1-0 flag of the timer 4 interrupt control register (TM4ICR). If any interrupt request flag had already been set, clear it. [☞ Chapter 3 3-1-4. Interrupt Flag Setup]
(6) Enable the interrupt. TM4ICR (x'3FEF') bp1 : TM4IE = 1	(6) Set the TM4IE flag of the TM4ICR register to "1" to enable the interrupt.
(7) Start the timer operation. TM4MD (x'3F84') bp6 : TM4EN = 1	(7) Set the TM4EN flag of the TM4MD register to "1" to start timer 4.

TM4BC counts up from x'0000'. When TM4BC reaches the set value of the TM4OC register, the timer 4 interrupt request flag is set to "1" at the next count clock and the TM4BC becomes x'0000' and counts up, again.

When the TM4EN flag of the TM4MD register is changed at the same time to other bit, binary counter may count up by the switching operation.

If the value of the TM4OCH and TM4OCL register are rewritten when the timer 4 is stopped, the timer 4 binary counter becomes x'0000'.
But, even if the TM4EN flag of the operating timer is cleared to "0", it doesn't stop until the count edge of the next clock. Therefore, during max. 1 count clock after the TM4EN is cleared, the binary counter cannot be initialized.

6-4 16-Bit Event Count

6-4-1 Operation

Event count operation has 2 types ; TM4IO input and synchronous TM4IO input can be selected as the count clock.

■16-Bit Event Count Operation (Timer 4)
Event count means that the binary counter (TM4BC) counts the input signal from external to the TM4IO pin. If the value of the binary counter reaches the setting value of the compare register (TM4OC), interrupts can be generated at the next count clock.

Table 6-4-1 Event Count Input Clock Source

	Timer 4
Event input	TM4IO input (P14)
	Synchronous TM4IO input

■Count Timing of TM4IO Input (Timer 4)
When TM4IO input is selected, TM4IO input signal is directly input to the count clock of the timer 4. The binary counter counts up at the falling edge of the TM4IO input signal.

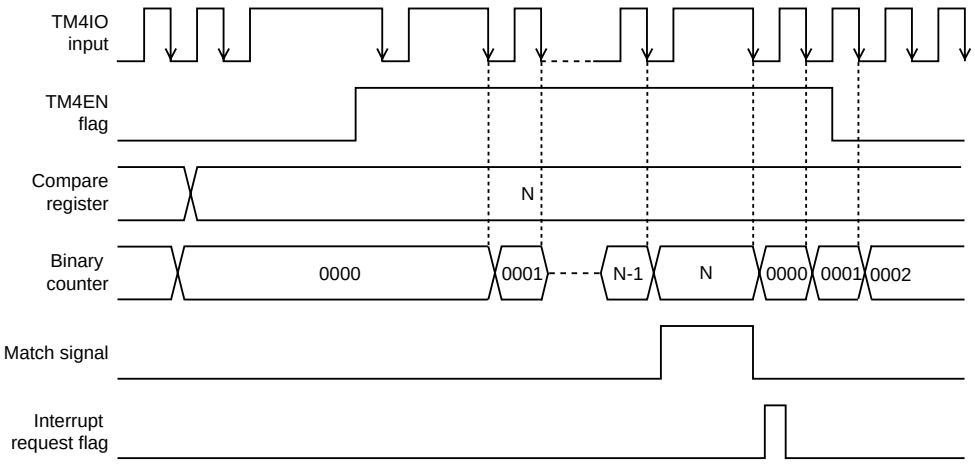


Figure 6-4-1 Count Timing TM4IO Input (Timer 4)

If the binary counter is read at operation, incorrect data at counting up may be read. To prevent this, use the event count by the synchronous TM4IO input as the following page.

■Count Timing of Synchronous TM4IO Input (Timer 4)

If the synchronous TM4IO input is selected, the synchronizing circuit output signal is input to the count clock. The synchronizing circuit output signal is changed at the falling edge of the system clock after the TM4IO input signal is changed. The binary counter counts up at the falling edge of the synchronizing circuit output signal or the synchronizing circuit output signal that passed through the divide-by circuit.

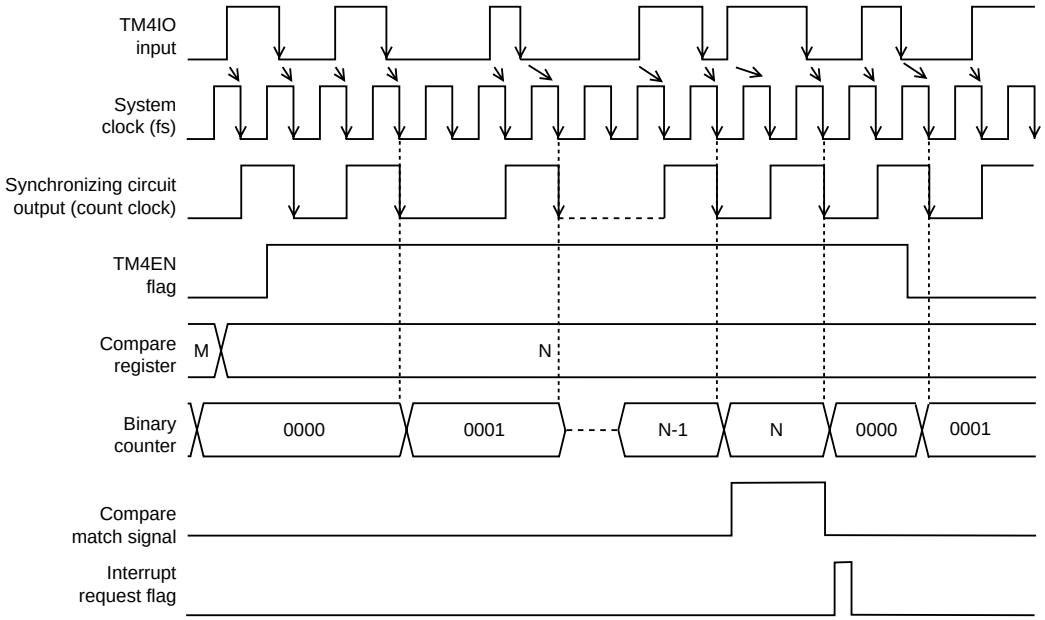


Figure 6-4-2 Count Timing of Synchronous TM4IO Input (Timer 4)

When the synchronous TM4IO input is selected as the count clock source, the timer 4 counter counts up in synchronization with system clock, therefore the correct value is always read.

But, if the synchronous TM4IO is selected as the count clock source, CPU mode cannot return from STOP/HALT mode.

6-4-2 Setup Example

■Event Count Setup Example (Timer 4)

If the falling edge of the TM4IO input pin signal is detected 5 times using timer 4, an interrupt is generated.

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM4MD (x'3F84') bp6 : TM4EN = 0	(1) Set the TM4EN flag of the timer 4 mode register (TM4MD) to "0" to stop timer 4 counting.
(2) Select the normal timer operation. TM4MD (x'3F84') bp5 : TM4PWM = 0	(2) Set the TM4PWM flag of the TM4MD register to "0" to select the normal timer operation.
(3) Set the special function pin to input mode. P1DIR (x'3F31') bp4 : P1DIR4 = 0	(3) Set the P1DIR4 flag of the port 1 direction control register (P1DIR) to "0" to set P14 pin to input mode. If needed, pull up resistor should be added. [☞ Chapter 4 I/O Ports]
(4) Select the count clock source. TM4MD (x'3F84') bp2-0 : TM4CK2-0 = 011	(4) Select the TM4IO input as a clock source by the TM4CK2-0 flag of the TM4MD register.
(5) Set the interrupt generation cycle. TM4OC (x'3F75', x'3F74')=x'0004'	(5) Set the interrupt generation cycle to the timer 4 compare register (TM4OC). The set value should be 4, because the counting is 5 times.
(6) Set the interrupt level. TM4ICR (x'3FEF') bp7-6 :TM4LV1-0 = 10	(6) Set the interrupt level by the TM4LV1-0 flag of the timer 4 interrupt control register (TM4ICR). If any interrupt request flag had already been set, clear it. [☞ Chapter 3 3-1-4. Interrupt Flag Setup]

Setup Procedure	Description
(7) Enable the interrupt. TM4ICR (x'3FEF') bp1 : TM4IE = 1	(7) Set the TM4IE flag of the TM4ICR register to "1" to enable interrupt.
(8) Start the event count. TM4MD (x'3F84') bp6 : TM4EN = 1	(8) Set the TM4EN flag of the TM4MD register to "1" to start timer 4.

Every time TM4BC detects the falling edge of TM4IO input, TM4BC counts up from 'x0000'. When TM4BC reaches the setting value of theTM4OC register, the timer 4 interrupt request flag is set at the next count clock, then the value of TM4BC becomes x'0000' and counting up is restarted.

6-5 16-Bit Timer Pulse Output

6-5-1 Operation

TM4IO pin can output a pulse signal with any frequency.

■Operation of 16-Bit Timer Pulse Output (Timer 4)
The timers can output 2 x cycle signal, compared to the setting value in the compare register (TM4OC). Output pins are as follows ;

Table 6-5-1 Timer Pulse Output Pin

	Timer 4
Pulse output pin	TM4IO output (P14)

■Count Timing of Timer Pulse Output (Timer 4)

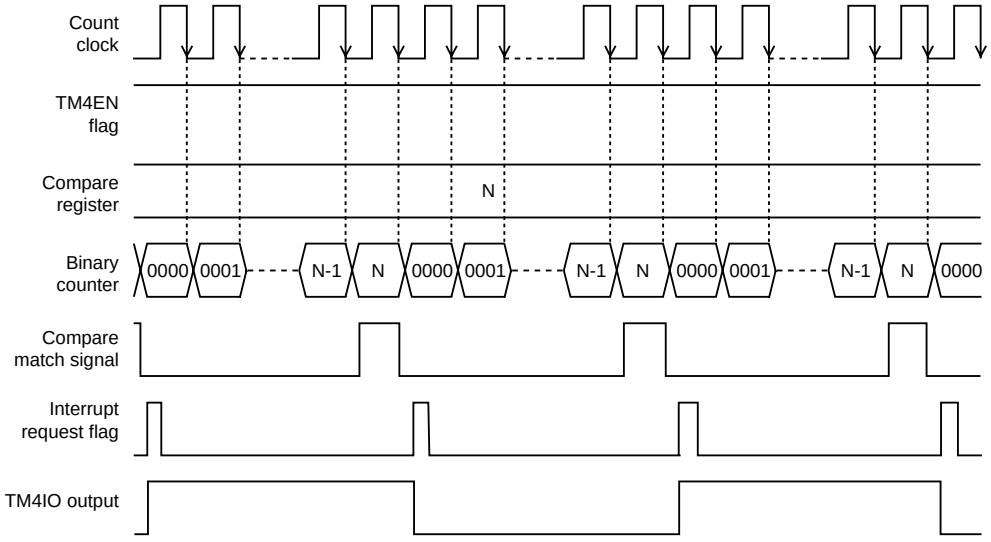


Figure 6-5-1 Count Timing of Timer Pulse Output (Timer 4)

The TM4IO pin outputs 2 x cycle, compared to the value in the compare register. If the binary counter reaches the compare register, and the binary counter is cleared to x'0000', TM4IO output (timer output) is inverted. The inversion of the timer output is changed at the rising edge of the count clock. This is happened to form the waveform inside to correct the output cycle.

In the initial state after releasing reset, the timer pulse output is low output.

6-5-2 Setup Example

■Timer Pulse Output Setup Example (Timer 4)

TM4IO pin outputs 50 kHz pulse by using timer 4. For this, select fosc as clock source, and set a 1/2 cycle (100 kHz) for the timer 4 compare register (at fosc=20 MHz).

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM4MD (x'3F84') bp6 : TM4EN = 0	(1) Set the TM4EN flag of the timer 4 mode register (TM4MD) to "0" to stop timer 4 counting.
(2) Set the special function pin to output mode. P1OMD (x'3F39') bp4 : P14TCO = 1 P1DIR (x'3F31') bp4 : P1DIR4 = 1	(2) Set the P14TCO flag of the port 1 output mode register (P1OMD) to "1" to set P14 pin as the special function pin. Set the P1DIR4 flag of the port 1 direction control register (P1DIR) to "1" to set output mode. If needed, pull-up resister should be added. [☞ Chapter 4 I/O Ports]
(3) Select the normal timer operation. TM4MD (x'3F84') bp5 : TM4PWM = 0	(3) Set the TM4PWM flag of the timer 4 mode register (TM4MD) to "0" to select the normal timer operation.
(4) Select the count clock source. TM4MD (x'3F84') bp2-0 : TM4CK2-0 = 000	(4) Select fosc as a clock source by the TM4CK1-0 flag of the TM4MD register.
(5) Set the timer pulse output cycle. TM4OC (X'3F75', X'3F74')=x'00C7'	(5) Set the 1/2 frequency of the timer pulse output cycle to the timer 4 compare register (TM4OC). To be 100 kHz by a divided 20 MHz, set as follows ; 200 - 1 = 199 (x'C7')
(6) Start the timer operation. TM4MD (x'3F84') bp6 : TM4EN = 1	(6) Set the TM4EN flag of the TM4MD register to "1" to start timer 4.

TM4BC counts up from x'0000'. If TM4BC reaches the set value of the TM4OC register and TM4BC is cleared to x'0000', the signal of the TM4IO output is inverted and TM4BC counts up from x'0000', again.

Set the compare register value as follows,

$$\text{The compare register value} = \frac{\text{The timer pulse output cycle}}{\text{The count clock cycle X 2}} - 1$$

6-6 Added Pulse Type 16-Bit PWM Output

6-6-1 Operation

In the added pulse method 16-bit PWM output, a 1-bit output is appended to the basic component of the 8-bit PWM output, and the output is from TM4IO. Precise 16-bit control is possible based on the number of PWM repetitions (256 times) to which this bit is appended.

■Added Pulse Type 16-Bit PWM Output (Timer 4)
The lower 8 bits of the compare register (TM4OCL) set the duty ("H" period) of the basic PWM waveform and the upper 8 bits of the compare register (TC4OCH) set the added pulse position. The cycle of the basic PWM waveform is the period of the full count overflow in the lower 8 bits of the binary counter (TM4BCL). Table 6-6-1 shows the PWM output pin.

Table 6-6-1 PWM Output Pin

	Timer 4
PWM output pin	TM4IO output pin (P14)

■Added Pulse Type PWM Output (Timer 4)

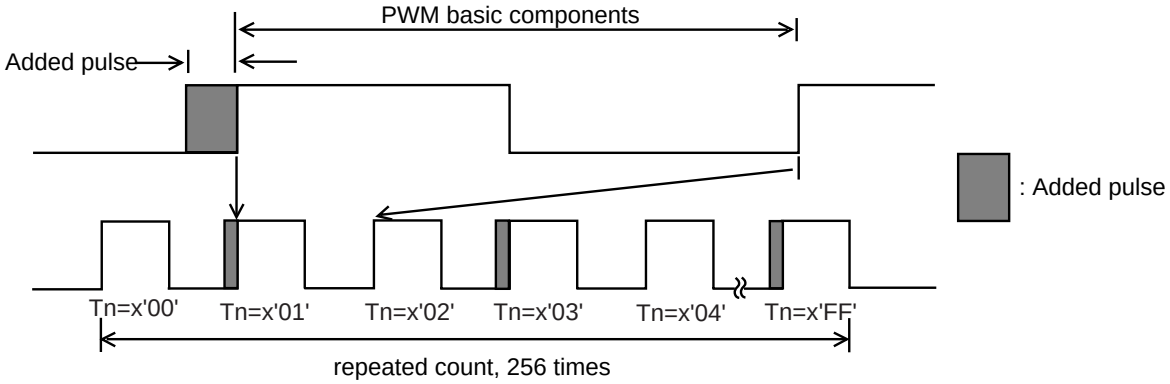


Figure 6-6-1 Added Pulse Type PWM Output

Set the P1DIR register and the P1PLU register, when the P14 pin is used as a PWM output pin.

For PWM operation, x'FF' in TM4OCL produces the same result as x'00' : constant low level output at the PWM4 pin, not constant high. Do not set x'FF' in TM4OCL.

■Setting the Added Pulse Position

The upper 8 bits of timer 4 compare register (TM4OCH) set the position of the added pulse. If the TM4OCH register is set to x'00', an additional bit is not appended to the basic PWM component. If the TM4OCH register is set to x'FF', an additional bit is repeatedly appended to the 255 basic PWM components during the cycle. The relation between the value set in the TM4OCH register and the position of the added pulse is shown in the table below.

In the TM4OCH register, the position of the added pulse (the value of Tn) depends which bit has "1". And the number of the setting value in TM4OCH is the number of bits to be added. For example, if x'03' is set in the TM4OCH register (set "1" in bp0 and bp1), bits are appended to pulse positions for x'01' (Tn=x'80") and x'02' (Tn=x'40', x'C0'), shown in the below table.

The setting value of TM4OCH	Position of the added pulse (the value of Tn)
0 0 0 0 0 0 0 0 (x'00')	none
0 0 0 0 0 0 0 1 (x'01')	x'80'
0 0 0 0 0 0 1 0 (x'02')	x'40',x'C0'
0 0 0 0 0 1 0 0 (x'04')	x'20',x'60',x'A0',x'E0'
0 0 0 0 1 0 0 0 (x'08')	x'10',x'30',x'50',x'70',x'90',x'B0',x'D0',x'F0'
0 0 0 1 0 0 0 0 (x'10')	x'08',x'18',x'28',x'38',x'48',x'58',- - - - - ,x'E8',x'F8'
0 0 1 0 0 0 0 0 (x'20')	x'04',x'0C',x'14',x'1C',x'24',x'2C,- - - - - ,x'F4',x'FC'
0 1 0 0 0 0 0 0 (x'40')	x'02',x'06',x'0A',x'0E',x'12',x'16,- - - - - ,x'FA',x'FE'
1 0 0 0 0 0 0 0 (x'80')	x'01',x'03',x'05',x'07',x'09',x'0B,- - - - - ,x'FD',x'FF'
(bp7) (bp0)	

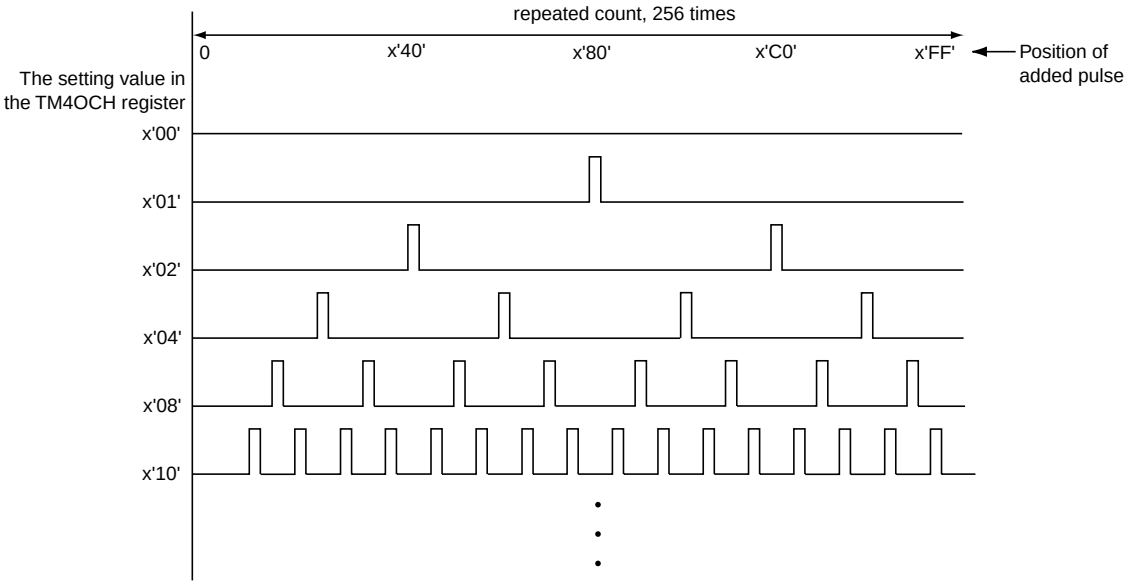


Figure 6-6-2 The Setting Value in The TM4OCH Register and The Position of The Added Pulse

6-6-2 Setup Example

■Added Pulse Type 16-Bit PWM Output Setup Example (Timer 4)

The TM4IO output pin outputs the 1/4 duty (64 :192) PWM output waveform at 78.125 kHz with timer 4. In the PWM output repetitions (256 times), the added pulse is appended 7 times and the duty becomes 65 : 191. The high frequency oscillation (fosc) is set to be operated at 20 MHz.

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Stop the counter. TM4MD (x'3F84') bp6 : TM4EN = 0	(1) Set the TM4EN flag of the timer 4 mode register (TM4MD) to "0" to stop timer 4 counting.
(2) Set the special function pin to output mode. P1OMD (x'3F39') bp4 : P14TCO = 1 P1DIR (x'3F31') bp4 : P1DIR4 = 1	(2) Set the P14TCO flag of the port 1 output mode register (P1OMD) to "1" to set the P14 pin as a special function pin. Set the P1DIR4 flag of the port 1 direction control register (P1DIR) to "1" to set output mode. If needed, pull-up resister should be added. [☞ Chapter 4 I/O Ports]
(3) Select the count clock source. TM4MD (x'3F84') bp2-0 : TM4CK2-0 = 000	(3) Select fosc as a clock source by the TM4CK2-0 flag of the TM4MD register.
(4) Set the PWM operation. TM4MD (x'3F84') bp5 : TM4PWM = 1	(4) Set the TM4PWM flag of the timer 4 mode register (TM4MD) to "1" to select the PWM operation.
(5) Set the PWM output "H" period and the location of the added pulse. TM4OC(x'3F75', x'3F74') = x'0740'	(5) Set the "H" period of the PWM output in the lower 8 bits of the timer 4 compare register (TM4OCL). To be 1/4 duty of the full count 256 of the lower 8 bits in the timer 4 binary counter (TM4BCL), the setting value should be 256 / 4 = 64 (x'40'). Also set the location of the added pulse in the upper 8 bits of the compare register. If it is set to x'07', the added pulse is appended 7 times in 256 repetitions.

Setup Procedure	Description
(6) Start the timer operation. TM4MD (x'3F84') bp6 : TM4EN = 1	(6) Set the TM4EN flag of the TM4MD register to "1" to start timer 4.

TM4BCL counts up from x'00'. The PWM source waveform outputs "H" until TM4BCL reaches the set value of the TM4OCL register, then, after the match it outputs "L". After that, TM4BCL continues to count up, once a overflow happens, the PWM source waveform outputs "H" again, and TM4BCL counts up from x'00', again.
From the above setting, the basic PWM waveform becomes 64 : 192. And the TM4OCH is set to x'07', in the PWM output repetitions (256 times), the added pulse is appended 7 times and the duty becomes 65 : 191.

For PWM operation, x'FF' in TM4OCL produces the same result as x'00' : constant low level output at the PWM4 pin, not constant high. Do not set x'FF' in TM4OCL.

Use a 16-bit access instruction to set the TM4OCH, TM4OCL register.

6-7 16-Bit Timer Capture

6-7-1 Operation

The value of a binary counter is stored to register at the timing of the external interrupt input signal.

■Capture Operation with External Interrupt Signal as a Trigger (Timer 4)
Capture trigger of input capture function is generated at the external interrupt signal that passed through the external interrupt interface block. The capture trigger is selected by the timer 4 mode register (TM4MD) and the external interrupt control register (IRQ0ICR, IRQ1ICR, IRQ2ICR).
Here are the capture trigger to be selected and the interrupt flag setup.

Table 6-7-1 Capture Trigger

Capture trigger source	Timer 4 mode register	External interrupt n control register (IRQnICR)	Interrupt starting edge of external interrupt n
	T4ICTS1-0	REDGn (bp5)	
Disable input capture	00	-	-
IRQ0 falling edge	01(IRQ0)	0	IRQ0 falling edge
IRQ0 rising edge	01(IRQ0)	1	IRQ0 rising edge
IRQ1 falling edge	10(IRQ1)	0	IRQ1 falling edge
IRQ1 rising edge	10(IRQ1)	1	IRQ1 rising edge
IRQ2 falling edge	11(IRQ2)	0	IRQ2 falling edge
IRQ2 rising edge	11(IRQ2)	1	IRQ2 rising edge

An interrupt request and a capture trigger are generated at switching the active edge of an external interrupt by program, when the setup is as follows ;

(1) at switching the active edge from the falling to the rising, when the interrupt pin is "H" level.
(2) at switching the active edge from the rising to the falling, when the interrupt pin is "L" level.

Operate the interrupt flag with regard to the noise influence on the program.
[☞ Chapter 3 3-3-4. Programmable Active Edge Interrupt]

■Capture Count Timing at Falling Edges of External Interrupt Signal is selected as a Trigger (Timer 4)

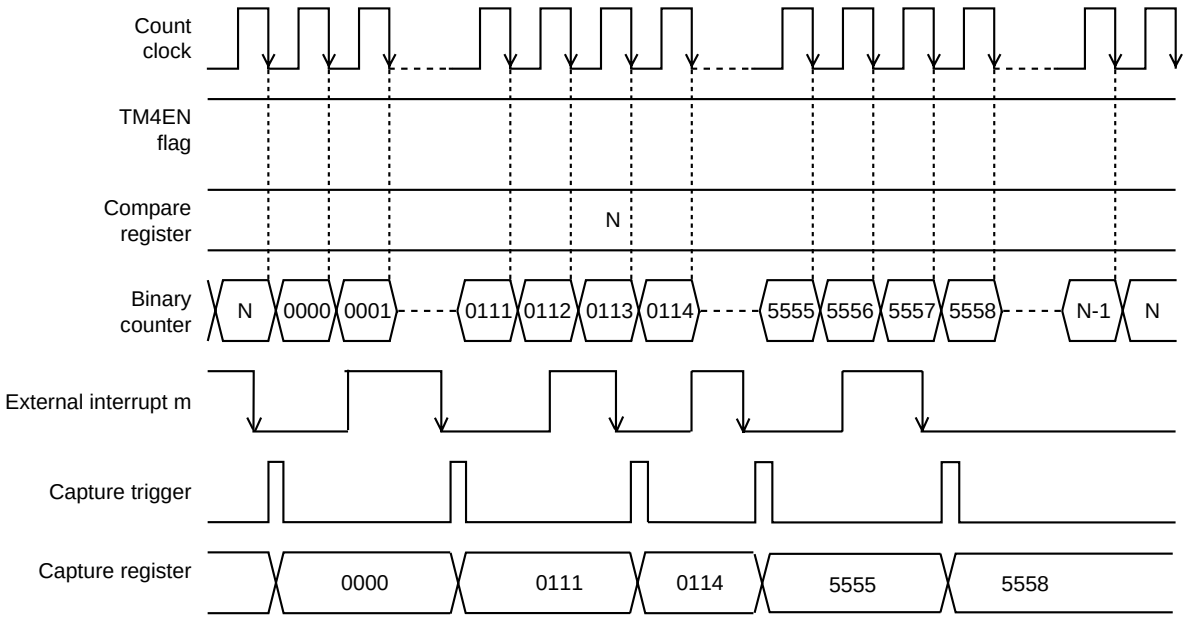


Figure 6-7-1 Capture Count Timing at an External Interrupt Signal is selected as a Trigger (Timer 4)

A capture trigger is generated at the falling edges of the external interrupt m input signal. At the same timing, the value of a binary counter is stored to the input capture register. A capture trigger is generated only at the edge that is specified as a capture trigger source. The other count timing is same to the count timing of the timer operation.

When the binary counter is used as a free counter that counts x'0000' to x'FFFF', set the compare register to x'FFFF'.

If a capture trigger is generated before the value of the input capture register is read, the value of the input capture register can be rewritten.

6-7-2 Setup Example

■Capture Function Setup Example (Timer 4)
Pulse width measurement is enabled by storing the value of the binary counter to the capture register at the interrupt generation edge of the external interrupt 0 input signal with timer 4. The interrupt generation edge is specified to be the rising edge.
An example setup procedure, with a description of each step is shown below.

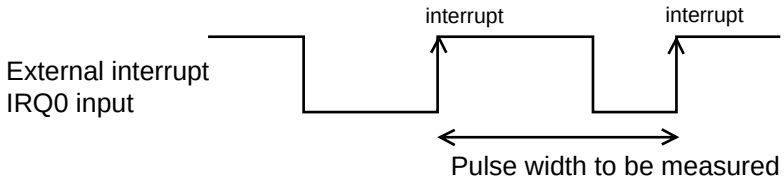


Figure 6-7-2 Pulse Width Measurement of External Interrupt 0

Setup Procedure	Description
(1) Stop the counter. TM4MD (x'3F84') bp6 : TM4EN = 0	(1) Set the TM4EN flag of the timer 4 mode register (TM4MD) to "0" to stop timer 4 counting.
(2) Select the count clock source. TM4MD (x'3F84') bp2-0 : TM4CK2-0 = 000	(2) Select fosc as clock source by the TM4CK2-0 flag of the TM4MD register.
(3) Select the capture trigger generation interrupt source. TM4MD (x'3F84') bp4-3 : T4ICTS1-0 = 01	(3) Select the external interrupt 0 (IRQ0) input as a generation source of capture trigger by the T4ICTS1-0 flag of the TM4MD register.
(4) Select the interrupt generation active edge. IRQ0ICR (x'3FE2') bp5 : REDG0 = 1	(4) Set the REDG0 flag of the external interrupt 0 control register (IRQ0ICR) to "1" to select the rising edge as the interrupt generation active edge.
(5) Select the normal timer operation. TM4MD (x'3F84') bp5 : TM4PWM = 0	(5) Set the TM4PWM flag of the timer 4 mode register (TM4MD) to "0" to select the normal timer operation.
(6) Set the compare register. TM4OC(x'3F75',x'3F74') = x'FFFF'	(6) Set the timer 4 compare register (TM4OCH, TM4OCL) to x'FFFF'. At that time, the timer 4 binary counter (TM4BC) is initialized to x'0000'.

Setup Procedure	Description
(7) Set the interrupt level. IRQ0ICR (x'3FE2') bp7-6 : IRQ0LV1-0= 10	(7) Set the interrupt level by the IRQ0LV1-0 flag of the IRQ0ICR register. If any interrupt request flag had already been set, clear it. [☞ Chapter 3 3-1-4. Interrupt Flag Setup]
(8) Enable the interrupt. IRQ0ICR (x'3FE2') bp1 : IRQ0IE = 1	(8) Enable the interrupt by setting the IRQ0IE flag of the IRQ0ICR register to "1".
(9) Start the timer operation. TM4MD (x'3F84') bp6 : TM4EN = 1	(9) Set the TM4EN flag of the TM4MD register to "1" to start timer 4.

TM4BC counts up from x'0000'. At the timing of the rising edge of the external interrupt 0 input signal, the value of TM4BC is stored to the TM4IC register.
At the above (7), (8), the IRQ0 interrupt is enabled, but input capture is available even if an interrupt is disabled. However, if an interrupt is enabled, the pulse width between rising edges of the external interrupt input signal can be measured by reading the value of TM4IC register by the interrupt service routine, and by calculating the margin of the capture values (the values of the TM4IC register).

Chapter 7 Time Base Timer / 8-Bit Free-running Timer

7-1 Overview

This LSI has a time base timer and a 8-bit free-running timer (timer 5).
Time base timer is a 13-bit timer counter. These timers stop the timer counting only at standby mode (STOP mode).

7-1-1 Functions

Table 7-1-1 shows the clock sources and the interrupt generation cycles that timer 5 and time base timer can select.

Table 7-1-1 Clock Source and Generation Cycle

	Time base timer	Timer 5 (8-Bit free-running timer)
Timer operation	√	√
Interrupt source	TBIRQ	TM5IRQ
Clock source	fosc fx	fosc fs/4 fx fosc X $1/2^{13}$ (*1) fx X $1/2^{13}$ (*2)
Interrupt generation cycle	fosc X $1/2^{7}$ (*1) fosc X $1/2^{8}$ (*1) fosc X $1/2^{9}$ (*1) fosc X $1/2^{10}$ (*1) fosc X $1/2^{13}$ (*1) fx X $1/2^{7}$ (*2) fx X $1/2^{8}$ (*2) fx X $1/2^{9}$ (*2) fx X $1/2^{10}$ (*2) fx X $1/2^{13}$ (*2)	The interrupt generation cycle is decided by the any value written to TM5OC.
fosc : Machine clock (High speed oscillation) fx : Machine clock (Low speed oscillation), not provided to the package types of 42-SDIP and 44-QFP. fs : System clock (at NORMAL mode : fs = fosc / 2, at SLOW mode : fs = fx / 4) - *1 can be used as a clock source of time base timer at 'fosc'. - *2 can be used as a clock source of time base timer at 'fx'. - Time base timer and timer 5 cannot stop timer counting.		

7-1-2 Block Diagram

■Timer 5, Time Base Timer Block Diagram

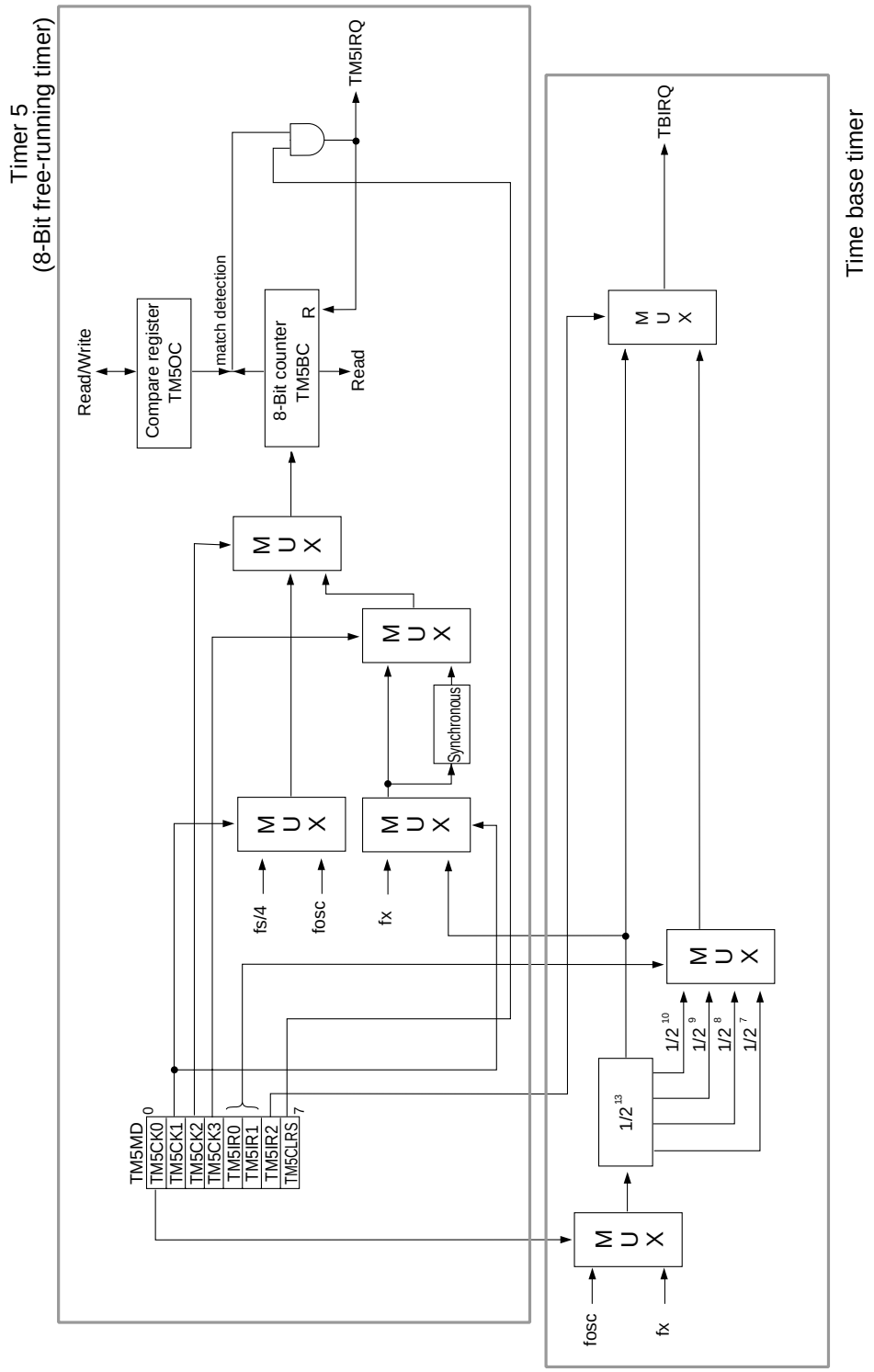


Figure 7-1-1 Block Diagram (Timer 5, Time Base Timer)

7-2 Control Registers

Timer 5 consists of binary counter (TM5BC), compare register (TM5OC), and is controlled by mode register (TM5MD). Time base timer is controlled by mode register (TM5MD), too.

7-2-1 Control Registers

Table 7-2-1 shows the registers that control timer 5, time base timer.

Table 7-2-1 Control Registers

	Register	Address	R/W	Function	Page
Timer 5	TM5BC	x'03F68'	R	Timer 5 binary counter	VII - 5
	TM5OC	x'03F78'	R/W	Timer 5 compare register	VII - 5
	TM5MD	x'03F88'	R/W	Timer 5 mode register	VII - 6
	TM5ICR	x'03FF0'	R/W	Timer 5 interrupt control register	III - 24
Timer base timer	TM5MD	x'03F88'	R/W	Timer 5 mode register	VII - 6
	TBICR	x'03FE7'	R/W	Time base interrupt control register	III - 25

R/W : Readable / Writable
R : Readable only

7-2-2 Programmable Timer Registers

Timer 5 is a 8-bit programmable counter.
Programmable counter consists of compare register (TM5OC) and binary counter (TM5BC).

Binary counter is a 8-bit up counter. When the TM5CLRS flag of the timer 5 mode register (TM5MD) is "0" and the interrupt cycle data is written to the compare register (TM5OC), the timer 5 binary counter (TM5BC) is cleared to x'00'.

■Timer 5 Binary Counter (TM5BC)

	7	6	5	4	3	2	1	0	
TM5BC	TM5BC7	TM5BC6	TM5BC5	TM5BC4	TM5BC3	TM5BC2	TM5BC1	TM5BC0	(at reset : 0 0 0 0 0 0 0 0)

Figure 7-2-1 Timer 5 Binary Counter (TM5BC : x'03F68', R)

■Timer 5 Compare Register (TM5OC)

	7	6	5	4	3	2	1	0	
TM5OC	TM5OC7	TM5OC6	TM5OC5	TM5OC4	TM5OC3	TM5OC2	TM5OC1	TM5OC0	(at reset : X X X X X X X X)

Figure 7-2-2 Timer 5 Compare Register (TM5OC : x'03F78', R/W)

7-2-3 Timer Mode Registers

This is a readable / writable register that controls timer 5 and time base timer.

■Timer 5 Mode Register (TM5MD)

	7	6	5	4	3	2	1	0
TM5MD	TM5CLRS	TM5IR2	TM5IR1	TM5IR0	TM5CK3	TM5CK2	TM5CK1	TM5CK0

(At reset : 0 X X X X X X 0)

TM5CKS0	Time base timer clock source
0	fosc
1	fx

TM5CK3	TM5CK2	TM5CK1	Timer 5 clock source
-	0	0	fosc
		1	fs/4
0	1	0	fx
		1	Output of time base timer
1		0	Synchronous fx
		1	Synchronous output of time base timer

TM5IR2	TM5IR1	TM5IR0	Time base timer interrupt cycle selection
0	0	0	Time base selection clock x $1/2^{7}$
		1	Time base selection clock x $1/2^{8}$
	1	0	Time base selection clock x $1/2^{9}$
		1	Time base selection clock x $1/2^{10}$
1	X	X	Time base selection clock x $1/2^{13}$

TM5CLRS	Timer 5 binary counter clear selection
0	Enable the initialization of TM5BC as TM5OC is written
1	Disable the initialization of TM5BC as TM5OC is written

* TM5IRQ is disabled when TM5CLRS = 0,
TM5IRQ is enabled when TM5CLRS = 1.

Figure 7-2-3 Timer 5 Mode Register (TM5MD : x'03F88', R/W)

7-3 8-Bit Free-running Timer

7-3-1 Operation

■8-Bit Free-running Timer (Timer 5)

The generation cycle of timer interrupts is set by the clock source selection and the setting value of the compare register (TM5OC), in advance. If the binary counter (TM5BC) reaches the setting value of the compare register, an interrupt is generated at the next count clock, then binary counter is cleared and counting is restarted from x'00'.

Table 7-3-1 shows clock source that can be selected.

Table 7-3-1 Clock Source at Timer Operation (Timer 5)

Clock source	One count time
fosc	50 ns
fs/4	400 ns
fx	30.5 µs
fosc X 1/2 ^{13}	409.6 µs
fx X 1/2 ^{13}	250 ms
fosc = 20(MHz) fx = 32.768(kHz) calculated as fs = fosc/2 = 10 MHz	

Timer 5 cannot stop its timer counting except at standby mode (STOP mode).

■8-bit Free-running Timer as a 1 minute-timer, a 1 second-timer

Table 7-3-2 shows the clock source selection and the TM5OC register setup, when a 8-bit free-running timer is used as a 1 minute-timer, a 1 second-timer.

Table 7-3-2 1 minute-timer, 1 second-timer Setup (Timer 5)

Interrupt Generation Cycle	Clock Source	TM5OC Register
1 min	fx x $1/2^{13}$	X'EF'
1 s	fx x $1/2^{10}$	X'1F'
	fx x $1/2^{13}$	X'03'
fx = 32.768(kHz)		

When the 1 minute-timer (1 min.) is set on Table 7-3-2, the bp1 waveform frequency (cycle) of the TM5BC register is 1 Hz (1 s). So, that can be used for adjusting the seconds.

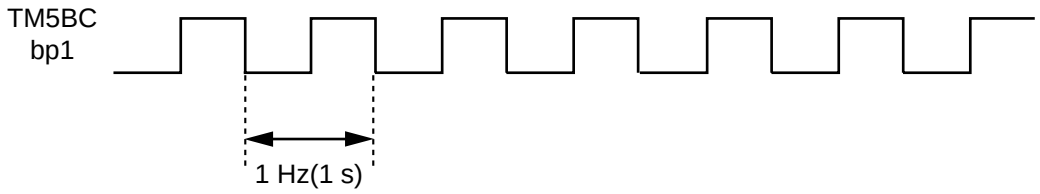


Figure 7-3-1 Waveform of TM5BC Register bp1 (Timer 5)

■Count Timing of Timer Operation (Timer 5)

Binary counter counts up with the selected clock source as a count clock.

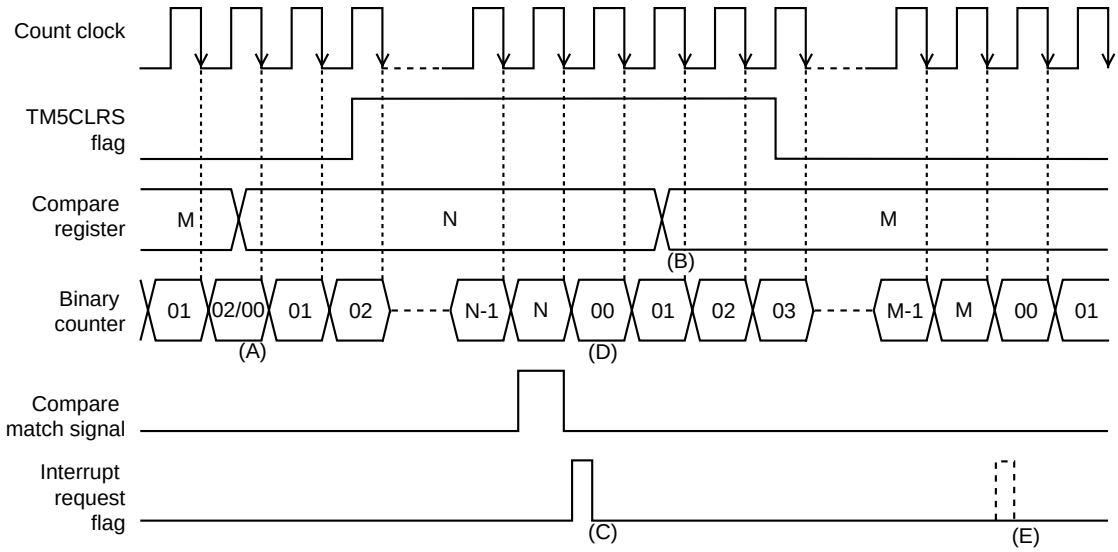


Figure 7-3-2 Count Timing of Timer Operation (Timer 5)

(A) When any data is written to the compare register as the TM5CLRS flag is "0", the binary counter is cleared to x'00'.

(B) Even if any data is written to the compare register as the TM5CLRS flag is "1", the binary counter is not changed.

(C) When the binary counter reaches the value of the compare register as the TM5CLRS flag is "1", an interrupt request flag is set at the next count clock.

(D) When an interrupt request flag is set, the binary counter is cleared to x'00' and restarts the counting.

(E) Even if the binary counter reaches the value of the compare register as the TM5CLRS flag is "0", no interrupt request flag is set.

When the binary counter reaches the value in the compare register, the interrupt request flag is set and the binary counter is cleared, at the next count clock. So, set the compare register as : Compare register setting = (count till the interrupt request - 1)

If fx is selected as the count clock source in timer 5, when the binary counter is read at operation, uncertain value on counting up may be read. To prevent this, select the synchronous fx as the count clock source.
But, if the synchronous fx is selected as the count clock source, CPU mode cannot return from STOP/HALT mode.

If the compare register is set the smaller value than the binary counter's during the count operation, the binary counter counts up to the overflow, at first.

7-3-2 Setup Example

■Timer Operation Setup (Timer 5)

Timer 5 generates an interrupt constantly for timer function. fs/4 (fosc=20 MHz) is selected as a clock source to generate an interrupt every 250 dividing (100 µs).

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Enable the binary counter initialization. TM5MD (x'3F88') bp7 : TM5CLRS = 0	(1) Set the TM5LRS flag of the timer 5 mode register (TM5MD) to "0". At that time, the initialization of the timer 5 binary counter (TM5BC) is enabled.
(2) Select the clock source. TM5MD (x'3F88') bp3-1 : TM5CK3-1 = 001	(2) Clock source can be selected by the TM5CK3-1 flag of the TM5MD register. Actually, fs/4 is selected.
(3) Set the interrupt generation cycle. TM5OC (X'3F78') = x'F9'	(3) Set the interrupt generation cycle to the timer 5 compare register (TM5OC). At that timer, TM5BC is initialized to x'00'.
(4) Enable the interrupt request generation. TM5MD (x'3F88') bp7 : TM5CLRS = 1	(4) Set the TM5CLRS flag of the TM5MD register to "1" to enable the interrupt request generation.
(5) Set the interrupt level. TM5ICR (x'3FF0') bp7-6 : TM5LV1-0 = 01	(5) Set the interrupt level by the TM5LV1-0 flag of the timer 5 interrupt control register (TM5ICR). If any interrupt request flag had already been set, clear it. [☞ Chapter 3 3-1-4. Interrupt Flag Setup]
(6) Enable the interrupt. TM5ICR (x'3FF0') bp1 : TM5IE = 1	(6) Set the TM5IE flag of the TM5ICR register to "1" to enable the interrupt.

* the above steps (1), (2) can be set at once.

As TM5OC is set, TM5BC is initialized to x'00' to count up.
When TM5BC matches TM5OC, the timer 5 interrupt request flag is set at the next count clock and TM5BC is cleared to x'00' to restart counting.

If the interrupt is enabled, the timer 5 interrupt request flag should be cleared before timer 5 operation is started.

If the TM5CLRS flag of the TM5MD register is set to "0", TM5BC can be initialized in every rewriting of TM5OC register, but in that state the timer 5 interrupt is disabled. If the timer 5 interrupt should be enabled, set the TM5CLRS flag to "1" after rewriting the TM5OC register.

On the timer 5 clock source selection, either the time base timer output or the time base timer synchronous output is selected, the clock setup of time base timer is necessary.

7-4 Time Base Timer

7-4-1 Operation

■Time Base Timer (Time Base Timer)

The Interrupt is constantly generated.

Table 7-4-1 shows the interrupt generation cycle in combination with the clock source ;

Table 7-4-1 Time Base Timer Interrupt Generation Cycle

Selected clock source	Interrupt generation cycle	
fosc (= 20 MHz)	fosc X $1/2^7$	6.4 µs
	fosc X $1/2^8$	12.8 µs
	fosc X $1/2^9$	25.6 µs
	fosc X $1/2^{10}$	51.2 µs
	fosc X $1/2^{13}$	409.6 µs
fosc (= 8.39 MHz)	fosc X $1/2^7$	15.2 µs
	fosc X $1/2^8$	30.5 µs
	fosc X $1/2^9$	61.0 µs
	fosc X $1/2^{10}$	122.0 µs
	fosc X $1/2^{13}$	976.4 µs
fx (= 32.768 kHz)	fx X $1/2^7$	3.9 ms
	fx X $1/2^8$	7.8 ms
	fx X $1/2^9$	15.6 ms
	fx X $1/2^{10}$	31.2 ms
	fx X $1/2^{13}$	250 ms

■Count Timing of Timer Operation (Time Base Timer)

The counter counts up with the selected clock source as a count clock.

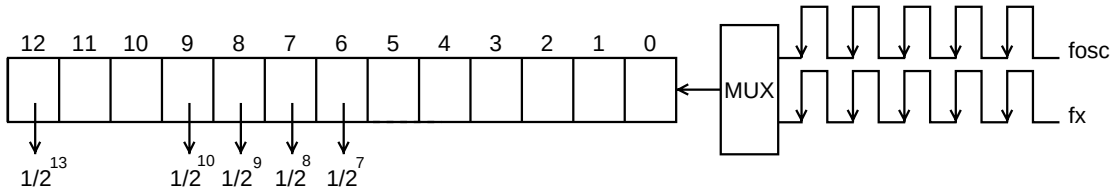


Figure 7-4-1 Count Timing of Timer Operation (Time Base Timer)

When the selected interrupt cycle has passed, the interrupt request flag of the time base interrupt control register (TBICR) is set to "1".

An interrupt may be generated at switching of the clock source. Enable interrupt after switching the clock source.

Time base timer cannot stop the operation.

13-bit counter of time base timer can be initialized only at reset.

This LSI has built-in time base timer for digital clock. For example, if fx (= 32.768 kHz) is selected as clock source, interrupt request flag is set by 13-bit counter par 250 ms.
However, the 13-bit counter can be initialized only at reset. Therefore, the first interrupt request flag is not always set after 250 ms.
Depending on counting condition, the first interrupt request flag is generated after 0 ms (minimum) to 250 ms (maximum). So, digital clock may gain 250 ms (maximum).

How to keep a error to a minimum, on setting for digital clock.
When fx (= 32.768 kHz) is set as clock source, and the time base timer is used as digital clock ;
- Select fosc as clock source.
  ↓
- Generate interrupt.
  ↓
- During interrupt service routine, change clock source to fx, and initialize a digital clock.

7-4-2 Setup Example

■Timer Operation Setup (Time Base Timer)

Time base timer generates an interrupt constantly in the selected interrupt cycle. The interrupt generation cycle is as fosc × $1/2^{13}$ (as 0.976 ms : fosc = 8.39 MHz) for generation interrupts.

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Select the clock source. TM5MD (x'3F88') bp0 : TM5CK0 = 0	(1) Select fosc as a clock source by the TM5CK0 flag of the timer 5 mode register (TM5MD).
(2) Select the interrupt generation cycle. TM5MD (x'3F88') bp6-4 : TM5IR2-0 = 100	(2) Select the selected clock × $1/2^{13}$ as an interrupt generation cycle by the TM5IR2-0 flag of the TM5MD register.
(3) Set the interrupt level. TBICR (x'3FE7') bp7-6 : TBLV1-0 = 01	(3) Set the interrupt level by the TBLV1-0 flag of the time base interrupt control register (TBICR). If any interrupt request flag had already been set, clear it.
(4) Enable the interrupt. TBICR (x'3FE7') bp1 : TBIE = 1	(4) Set the TBIE flag of the TBICR register to "1" to enable the interrupt. [☞ Chapter 3 3-1-4. Interrupt Flag Setup]

* the above steps (1), (2) can be set at once.

When the selected interrupt generation cycle has passed, the interrupt request flag of the time base interrupt control register (TBICR) is set to "1".

Chapter 8 Watchdog Timer

8-1 Overview

This LSI has a watchdog timer. This timer is used to detect software processing errors. It is controlled by the watchdog timer control register (WDCTR). And, once an overflow of watchdog timer is generated, a watchdog interrupt (WDIRQ) is generated. If the watchdog interrupt is generated twice, consecutively, it is regarded to be an indication that the software cannot execute in the intended sequence; thus, a system reset is initiated by the hardware (Reset pin outputs low level.).

8-1-1 Block Diagram

■Watchdog Timer Block Diagram

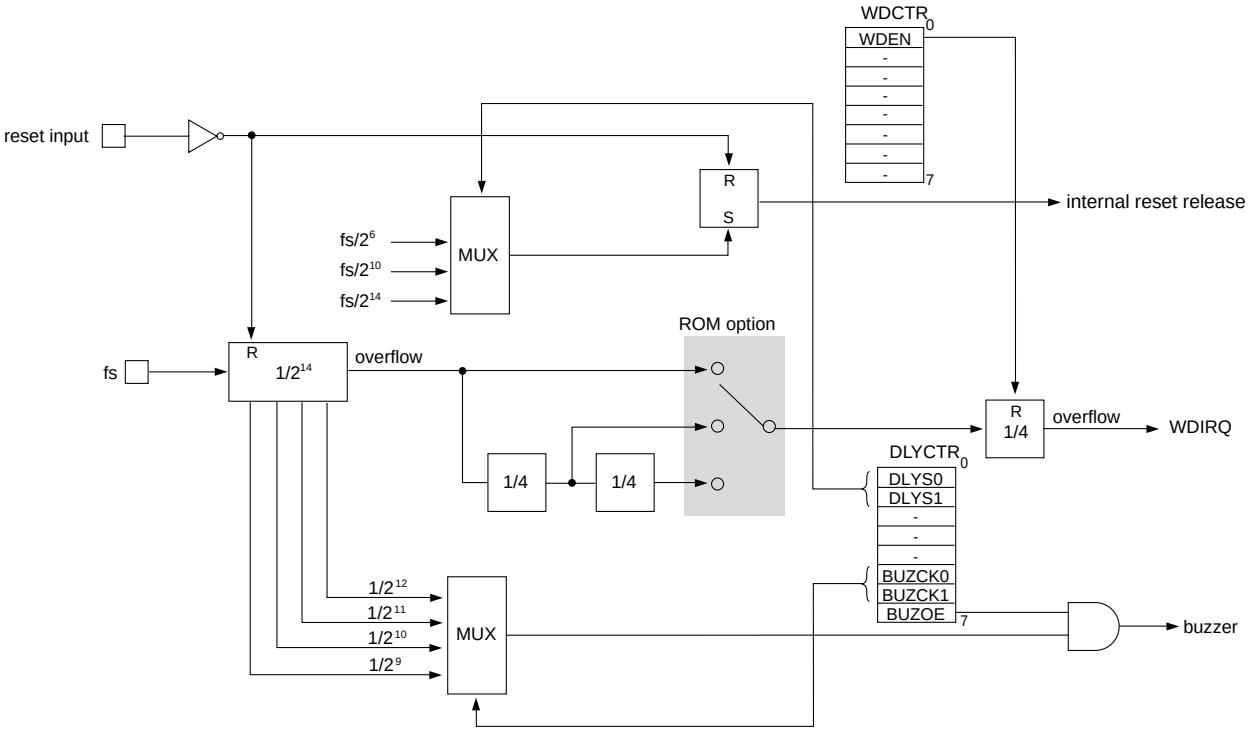


Figure 8-1-1 Block Diagram (Watchdog Timer)

The watchdog timer is also used as a timer to count the oscillation stabilization wait time. This is used as a watchdog timer except at recovering from STOP mode and at reset releasing.
The watchdog timer is initialized at reset or at STOP mode, and counts system clock (fs) as a clock source from the initial value (x'0000'). The oscillation stabilization wait time is set by the oscillation stabilization control register (DLYCTR). After the oscillation stabilization wait, counting is continued as a watchdog timer.

[☞ Chapter 2 2-5. Reset]

8-2 Control Registers

The watchdog timer is controlled by the watchdog timer control register (WDCTR). And the cycle of the watchdog timer period is set in ROM option.

[☞ Chapter 1 1-6-1. Rom option]

■Watchdog Timer Control Register (WDCTR)

	7	6	5	4	3	2	1	0	
WDCTR	-	-	-	-	-	-	-	WDEN	(at reset : - - - - - - - 0)

WDEN	Watchdog timer
0	Watchdog timer is cleared/disabled.
1	Watchdog timer is enabled.

Figure 8-2-1 Watchdog Timer Control Register (WDCTR : x'03F02', R/W)

8-3 Operation

8-3-1 Operation

The watchdog timer counts system clock (fs) as a clock source. If the watchdog timer overflows, the watchdog interrupt (WDIRQ) is generated as an non-maskable interrupt (NMI). At reset, the watchdog timer is stopped. The watchdog timer control register (WDCTR) sets if the watchdog timer is enabled or disabled.

If the watchdog interrupt (WDIRQ) is generated twice consecutively, it is regarded to be an indication that the software cannot execute in the intended sequence; thus, a system reset is initiated by the hardware (Reset pin outputs low level.) .

■Usage of Watchdog Timer
When the watchdog timer is used, constant clear in program is necessary to prevent an overflow of the watchdog timer. As a result of the software failure, the software cannot execute in the intended sequence, thus the watchdog timer overflows and error is detected. After error is detected, the watchdog timer interrupt (WDIRQ) is generated as non-maskable interrupt (NMI).

Programming of the watchdog timer is generally done in the last step of its programming.

■How to Clear Watchdog Timer
The upper 2 bits of the watchdog timer can be cleared by setting the WDEN flag of the watchdog timer control register (WDCTR) to "0".

The upper 2 bits of the watchdog timer are cleared when the WDEN flag of the watchdog timer control register (WDCTR) is set to "0". Therefore, depending on the clear timing the watchdog timer may be reset at 1/4 x (watchdog timer frequency). If the WDEN flag is to be repeatedly cleared and set at regular intervals, those operations should be performed within 1/4 of the watchdog timer frequency.

■Watchdog Timer Period

The watchdog timer period is decided by the system clock (fs) and ROM option.

[☞ Chapter 1 1-6-1. Rom option]

If the watchdog timer is not cleared till the set period of watchdog timer, that is regarded as an error and the watchdog interrupt (WDIRQ) of the non-maskable interrupt (NMI) is generated.

Table 8-3-1 Watchdog Timer Period

WDSEL2	WDSEL1	Watchdog timer period
0	0	2^{16} X system clock
0	1	2^{18} X system clock
1	X	2^{20} X system clock

System clock is decided by the CPU mode control register (CPUM).

The watchdog timer period is generally decided from the execution time for main routine of program. That should be set the longer period than the value of the execution time for main routine divided by natural number (1, 2, , ,). And insert the instruction of the watchdog timer clear to the main routine as that value makes the same cycle.

If the watchdog timer interrupt service routine does not respond to a watchdog timer interrupt for resetting the chip, the hardware responds to the next one by pulling the RESET pin low to reset the chip.

■Watchdog Timer and CPU Mode

The relation between this watchdog timer and CPU mode features are as follows ;

(1) In NORMAL, IDLE, SLOW mode, the system clock is counted.
(2) The counting is continued regardless of switching at NORMAL, IDLE, SLOW mode.
(3) In HALT mode, the watchdog timer is not stopped.
(4) In STOP mode, the watchdog timer is cleared automatically by hardware.
(5) In STOP mode, the watchdog interrupt cannot be generated.
(6) After releasing reset or recovering from STOP, the counting is executed for the duration of the oscillation stabilization wait time.

On HALT mode, the watchdog timer count won't stop. If it should be stopped, set the WDEN flag of the watchdog timer control register (WDCTR) to "0" to stop the watchdog timer operation, before transition to HALT mode.

When CPU mode is switched to STOP mode during the watchdog timer operation, the operation does not stop after it operates as a counter for oscillation stabilization waiting at recover. If the watchdog timer need not to detect errors, set the WDEN flag of the watchdog timer control register (WDCTR) to "0" to stop the watchdog timer, before CPU mode is switched to STOP mode.

8-3-2 Setup Example

The watchdog timer detects errors. On the following example, the watchdog timer period is set to $2^{18} \times$ system clock in ROM option.
An example setup procedure, with a description of each step is shown below.

■Initial Setup Program (Watchdog Timer Initial Setup Example)

Setup Procedure	Description
(1) Start the watchdog timer operation. WDCTR (x'03F02') bp0 : WDEN = 1	(1) Set the WDEN flag of the WDCTR register to start the watchdog timer operation.

■Main Routine Program (Watchdog Timer Constant Clear Setup Example)

Setup Procedure	Description
(1) Set the constant watchdog timer clear. BCLR (WDCTR) WDEN (bp0 : WDEN = 0) BSET (WDCTR) WDEN (bp0 : WDEN = 1)	(1) Clear the watchdog timer under the 1/4 cycle of $2^{18} \times$ system clock. The watchdog timer clear should be inserted in the main routine, with the same cycle, and to be the set cycle. Operate the watchdog timer again, after it is stopped (Upper 2 bits of the counter are cleared).

The upper 2 bits of the watchdog timer are cleared when the WDEN flag of the watchdog timer control register (WDCTR) is set to "0". Therefore, depending on the clear timing the watchdog timer may be reset at 1/4 x (watchdog timer frequency). If the WDEN flag is to be repeatedly cleared and set at regular intervals, those operations should be performed within 1/4 of the watchdog timer frequency.

■Interrupt Service Routine Setup

Setup Procedure	Description
(1) Set the watchdog interrupt service routine. NMICR (x'03FE1') TBNZ (NMICR) WDIR, WDPRO	(1) If the watchdog timer overflows, the non maskable interrupt is generated. Confirm that the WDIR flag of the non maskable interrupt control register (NMICR) is "1" on the interrupt service routine and manage the suitable execution.

Proper operation right before the WDOG interrupt is not guaranteed. Therefore, if the WDOG interrupt is generated, initialize the system.

Chapter 9 Buzzer

9-1 Overview

This LSI has a buzzer. It can output the square wave having a frequency $1/2^9$ to $1/2^{12}$ of the system clock (fs) from P06/BUZZER pin.

9-1-1 Block Diagram

■Buzzer Block Diagram

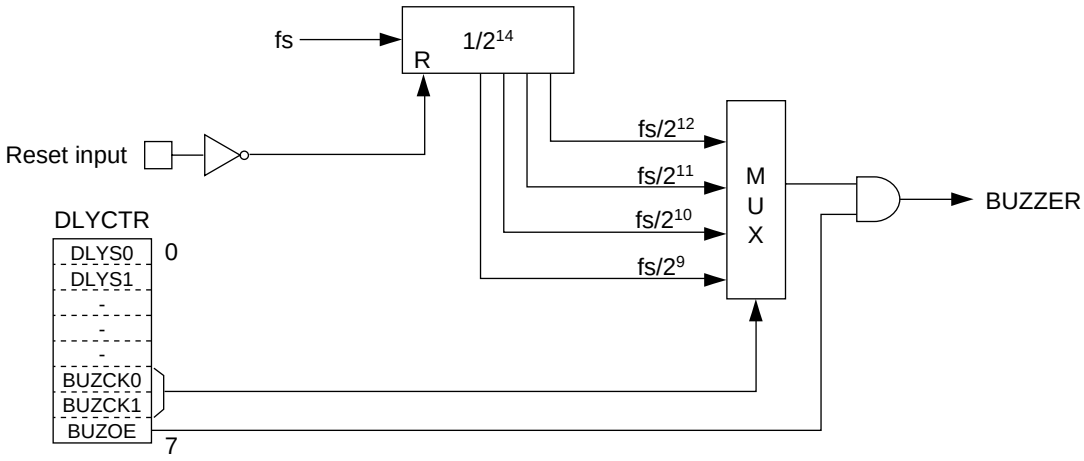


Figure 9-1-1 Block Diagram (Buzzer)

9-2 Control Register

■Oscillation Stabilization Wait Time Control Register

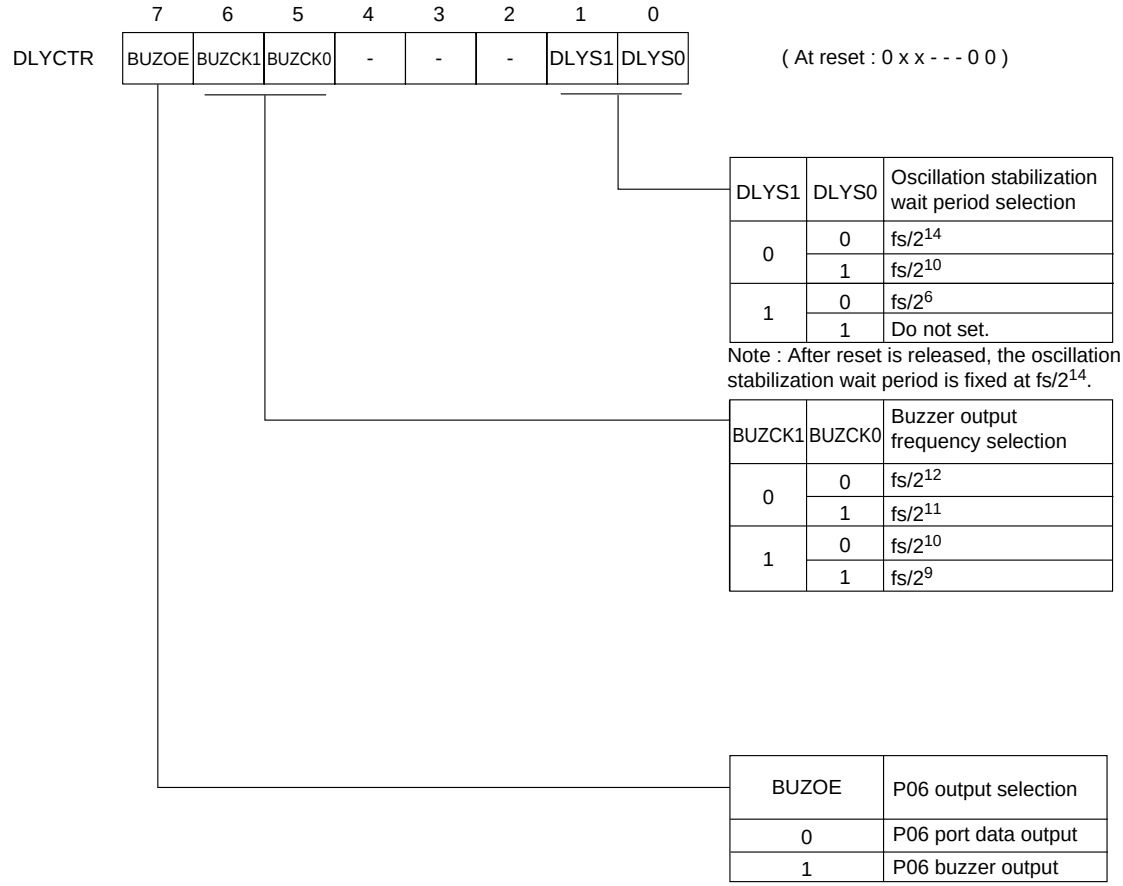


Figure 9-2-1 Oscillation Stabilization Wait Timer Control Register (DLYCTR : x'03F03', R/W)

9-3 Operation

9-3-1 Operation

■Buzzer

Buzzer outputs the square wave having a frequency $1/2^9$ to $1/2^{12}$ of the system clock (fs). The BUZCK 1, 0 flag of the oscillation stabilization wait control register (DLYCTR) set the frequency of buzzer output. The BUZOE flag of the oscillation stabilization wait control register (DLYCTR) sets buzzer output ON / OFF.

■Buzzer Output Frequency

The frequency of buzzer output is decided by the frequency of the system clock (fs) and the bit 6, 5 (BUZCK1, BUZCK0) of the oscillation stabilization wait control register (DLYCTR). Table 9-3-1 shows the buzzer output frequency.

Table 9-3-1 Buzzer Output Frequency

fosc	fs	BUZCK1	BUZCK0	Buzzer output frequency
20 MHz	10 MHz	0	0	2.44 kHz
		0	1	4.88 kHz
8.39 MHz	4.19 MHz	0	1	2.05 kHz
		1	0	4.10 kHz
2 MHz	1 MHz	1	1	1.95 kHz

9-3-2 Setup Example

Buzzer outputs the square wave of 2 kHz from P06 pin. It is used 8.39 MHz as the high oscillation clock (fosc).
An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Set the buzzer frequency. DLYCTR (x'3F03') bp6-5 : BUZCK1-0 = 01	(1) Set the BUZCK1-0 flag of the oscillation stabilization wait control register (DLYCTR) to "01" to select $fs/2^{11}$ to the buzzer frequency. When the high oscillation clock fosc is 8.39 MHz, the buzzer output frequency is 2 kHz.
(2) Set P06 pin. P0OUT (x'3F10') bp6 : P0OUT6 = 0 P0DIR (x'3F30') bp6 : P0DIR6 = 1	(2) Set the output data P0OUT6 of P06 pin to "0", and set the direction control P0DIR6 of P06 pin to "1" to select output mode. P06 pin outputs low level.
(3) Buzzer output ON. DLYCTR (x'3F03') bp7 : BUZOE = 1	(3) Set the BUZOE flag of the oscillation stabilization wait control register (DLYCTR) to "1" to output the square wave of the buzzer output frequency set by P06 pin.
(4) Buzzer output OFF. DLYCTR (x'3F03') bp7 : BUZOE = 0	(4) Set the BUZOE flag of the oscillation stabilization wait control register (DLYCTR) to "0" to clear, and P06 pin outputs low level.

Chapter 10 Serial Interface 0

10-1 Overview

This LSI contains a serial interface 0 that can be used for both communication types of clock synchronous and UART (Half-duplex).

10-1-1 Functions

Table 10-1-1 shows functions of serial interface 0.

Table 10-1-1 Serial Interface 0 Functions

Communication style	clock synchronous	UART (half-duplex)
Interrupt	SC0IRQ	SC0IRQ
Used pins	SBO0,SBI0,SBT0	TXD,RXD
3 channels type	√	-
2 channels type	√ (SBO0,SBT0)	√
1 channel type	-	√ (TXD)
Specification of transfer bit count / Frame selection	1 to 8 bits	7 bits + 1 stop 7 bits + 2 stops 8 bits + 1 stop 8 bits + 2 stops
Selection of parity bit	-	√
Parity bit control	-	0 parity 1 parity odd parity even parity
Selection of start condition	√	no selection Start bit is always added.
Specification of the first transfer bit	√	√
Specification of input edge / output edge	√	-
Internal clock 1/8 dividing	√	only 1/8 dividing is available
Clock source	fs/2 fs/4 fs/16 Timer 3 output External clock	fs/2 fs/4 fs/16 Timer 3 output
Maximum transfer rate	5.0 MHz	625 kbps
fosc : Machine clock (High speed oscillation) fs : System clock (at NORMAL mode : fs=fosc/2, at SLOW mode : fs=fx/4) When the transmission and reception are operated at the same time at master communication of the clock synchronous, select "no start condition".-		

Set fs/2 as maximum frequency for external clock.

10-1-2 Block Diagram

■Serial Interface 0 Block Diagram

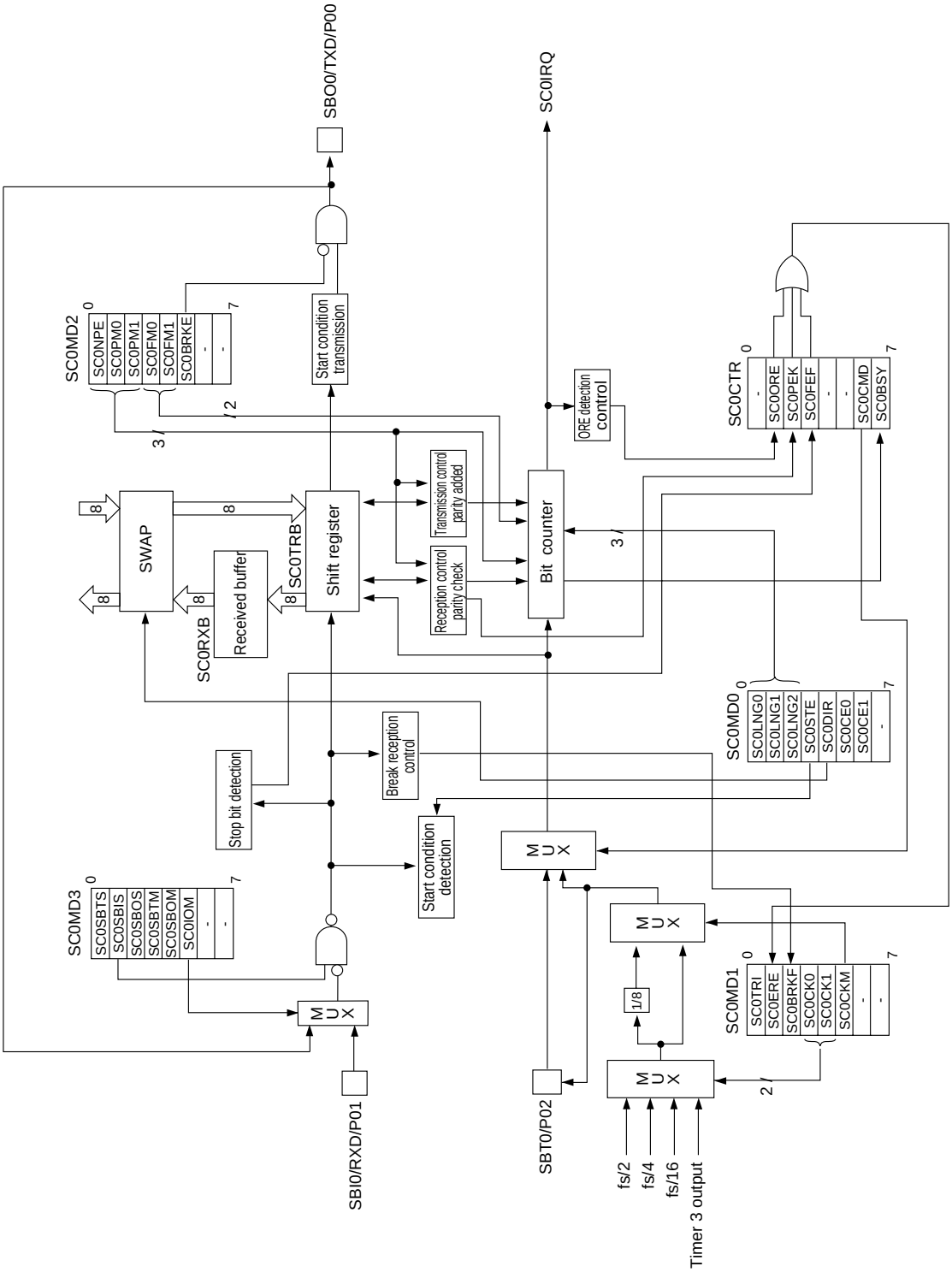


Figure 10-1-1 Serial Interface 0 Block Diagram

10-2 Control Registers

10-2-1 Registers

Table 10-2-1 shows registers to control serial interface 0.

Table 10-2-1 Serial Interface 0 Control Registers

	Register	Address	R/W	Function	Page
Serial interface 0	SC0MD0	x'03F50'	R/W	Serial interface 0 mode register 0	X - 6
	SC0MD1	x'03F51'	R/W	Serial interface 0 mode register 1	X - 7
	SC0MD2	x'03F52'	R/W	Serial interface 0 mode register 2	X - 8
	SC0MD3	x'03F53'	R/W	Serial interface 0 mode register 3	X - 9
	SC0CTR	x'03F54'	R/W	Serial interface 0 control register	X - 10
	SC0TRB	x'03F55'	R/W	Serial interface 0 transmission / reception shift register	X - 5
	SC0RXB	x'03F56'	R	Serial interface 0 reception data buffer	X - 5

R/W : Readable / Writable

R : Readable only

10-2-2 Data Buffer Registers

Serial Interface 0 has a 8-bit shift register to shift the transmission and reception data and a 8-bit data buffer register for reception.

■Serial Interface 0 Transmission/Reception Shift Register (SC0TRB)

	7	6	5	4	3	2	1	0	
SC0TRB	SC0TRB7	SC0TRB6	SC0TRB5	SC0TRB4	SC0TRB3	SC0TRB2	SC0TRB1	SC0TRB0	(at reset : X X X X X X X X)

Figure 10-2-1 Serial Interface 0 Transmission/Reception Shift Register (SC0TRB : x'03F55', R/W)

■Serial Interface 0 Received Data Buffer (SC0RXB)

	7	6	5	4	3	2	1	0	
SC0RXB	SC0RXB7	SC0RXB6	SC0RXB5	SC0RXB4	SC0RXB3	SC0RXB2	SC0RXB1	SC0RXB0	(at reset : X X X X X X X X)

Figure 10-2-2 Serial Interface 0 Reception Data Buffer (SC0RXB : x'03F56', R)

10-2-3 Mode Registers / Control Registers

■Serial Interface 0 Mode Register 0 (SC0MD0)

	7	6	5	4	3	2	1	0
SC0MD0	-	SC0CE0	SC0CE1	SC0DIR	SC0STE	SC0LNG2	SC0LNG1	SC0LNG0

(at reset : - 0 0 X X 0 0 0)

SC0LNG2	SC0LNG1	SC0LNG0	Synchronous serial transfer bit count
0	0	0	8 bits
		1	7 bits
	1	0	6 bits
		1	5 bits
1	0	0	4 bits
		1	3 bits
	1	0	2 bits
		1	1 bit

SC0STE	Synchronous serial data transfer start condition selection
0	Disable start condition
1	Enable start condition

SC0DIR	First bit to be transferred
0	MSB first
1	LSB first

SC0CE0	SC0CE1	Reception data input edge	Transmission data output edge
0	0	rising	falling
	1	falling	rising
1	0	falling	falling
	1	rising	rising

Figure 10-2-3 Serial Interface 0 Mode Register 0 (SC0MD0 : x'03F50', R/W)

■Serial Interface 0 Mode Register 1 (SC0MD1)

The SC0TRI, SC0ERE, and SC0BRKF flags are only readable .

	7	6	5	4	3	2	1	0	
SC0MD1	-	-	SC0CKM	SC0CK1	SC0CK0	SC0BRKF	SC0ERE	SC0TRI	(at reset : - - X 0 0 0 0 0)

SC0TRI	Transmission / Reception interrupt request flag
0	Transmission interrupt request
1	Reception interrupt request

SC0ERE	Error monitor
0	No error
1	Error

SC0BRKF	Break status receive monitor
0	Data
1	Break

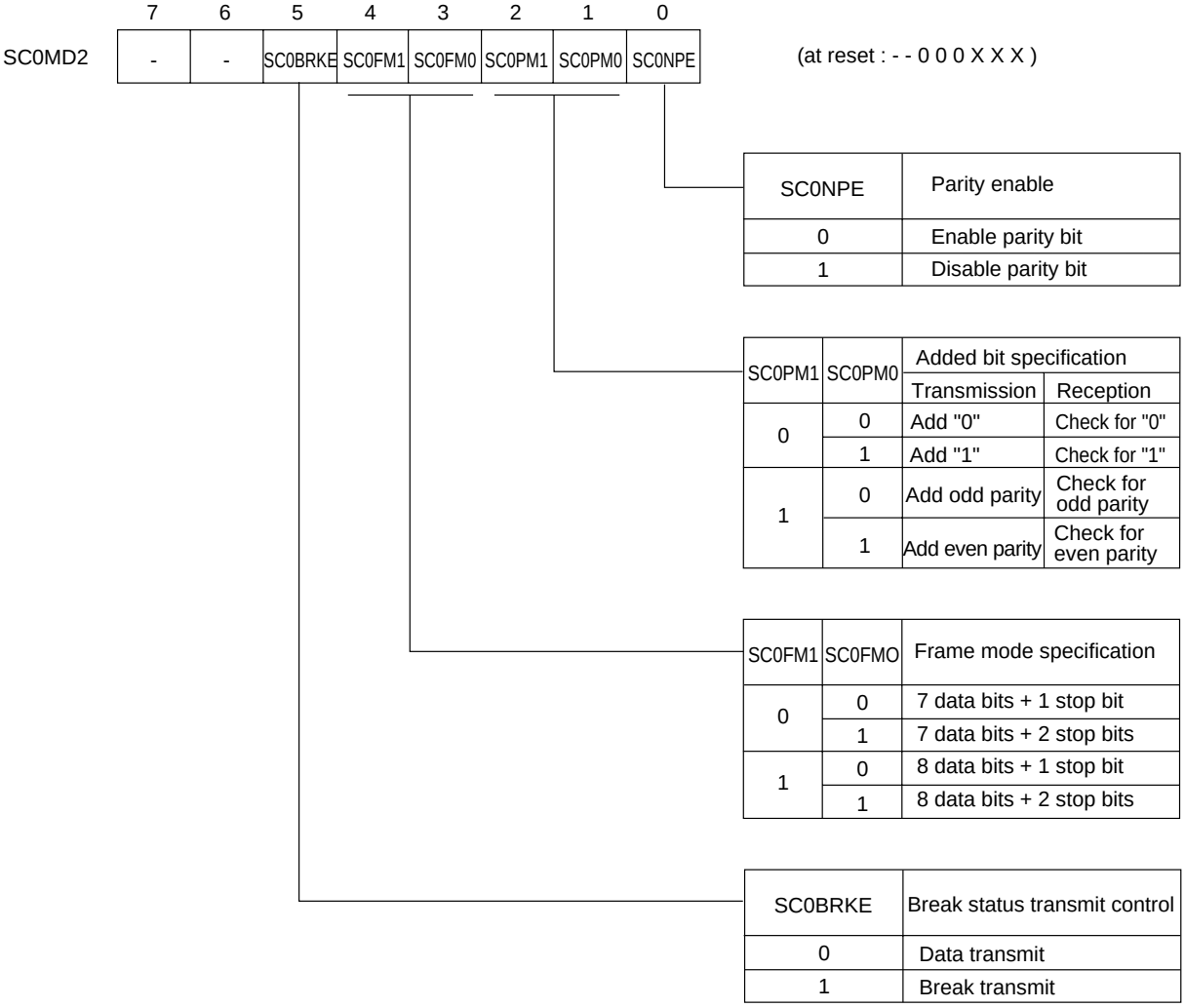
SC0CK1	SC0CK0	Clcok source
0	0	fs/2
	1	fs/4
1	0	fs/16
	1	Timer 3 output

SC0CKM	1/8 dividing of transfer clock selection
0	Do not divide by 8
1	Divide by 8

Clock source can be selected as an external clock by setting the SBT0 pin to input mode. At UART mode (SC0CMD=1),the SC0CKM is fixed to "1".

Figure 10-2-4 Serial Interface 0 Mode Register 1 (SC0MD1 : x'03F51', R/W)

■Serial Interface 0 Mode Register 2 (SC0MD2)



SC0NPE	Parity enable
0	Enable parity bit
1	Disable parity bit

SC0PM1	SC0PM0	Added bit specification	
		Transmission	Reception
0	0	Add "0"	Check for "0"
	1	Add "1"	Check for "1"
1	0	Add odd parity	Check for odd parity
	1	Add even parity	Check for even parity

SC0FM1	SC0FMO	Frame mode specification
0	0	7 data bits + 1 stop bit
	1	7 data bits + 2 stop bits
1	0	8 data bits + 1 stop bit
	1	8 data bits + 2 stop bits

SC0BRKE	Break status transmit control
0	Data transmit
1	Break transmit

Figure 10-2-5 Serial Interface 0 Mode Register 2 (SC0MD2 : x'03F52', R/W)

■Serial Interface 0 Mode Register 3 (SC0MD3)

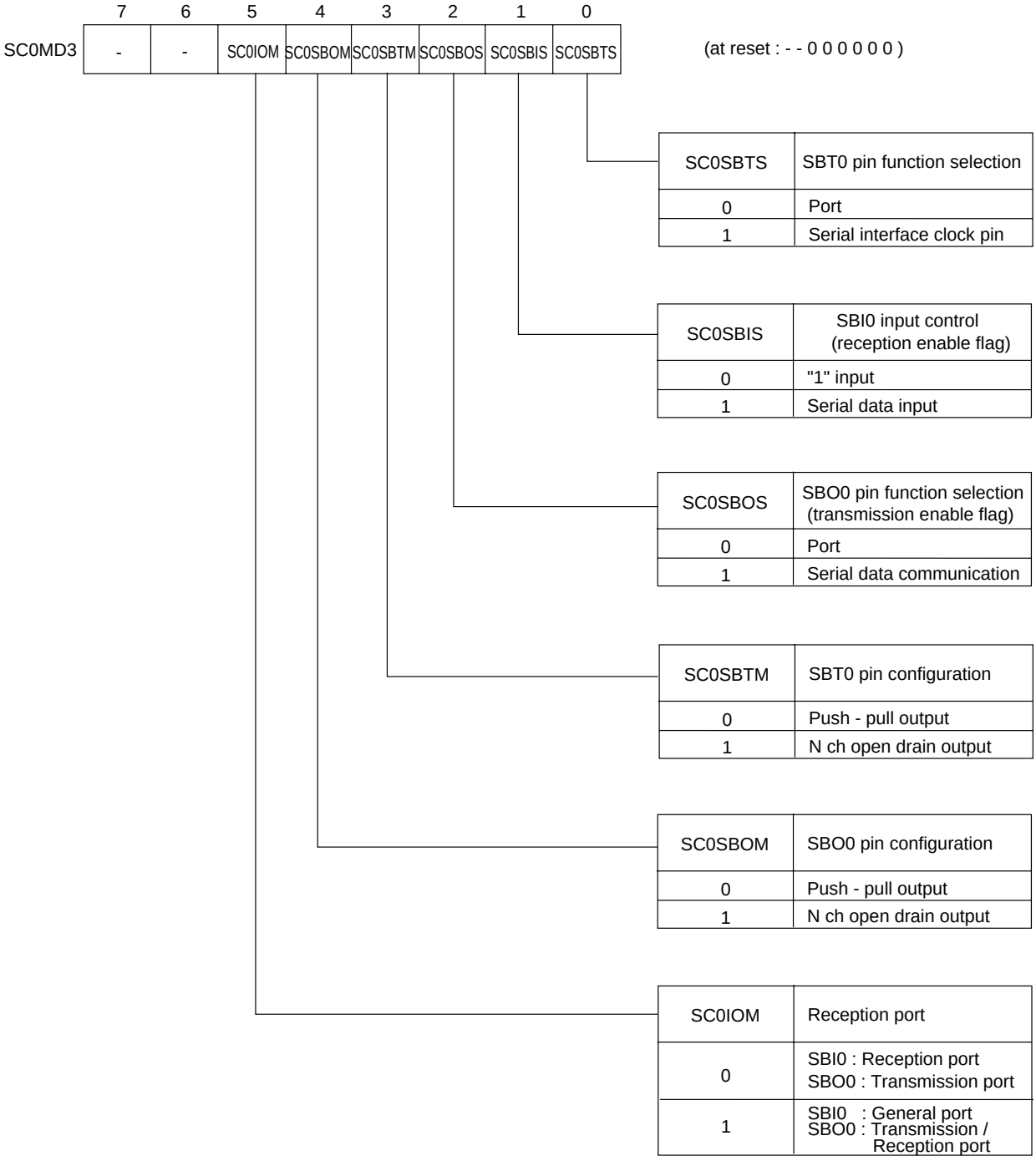


Figure 10-2-6 Serial Interface 0 Mode Register 3 (SC0MD3 : x'03F53', R/W)

■Serial Interface 0 Control Register (SC0CTR)

The SC0ORE, SC0PEK, SC0FEF,and SC0BSY flags are only readable.

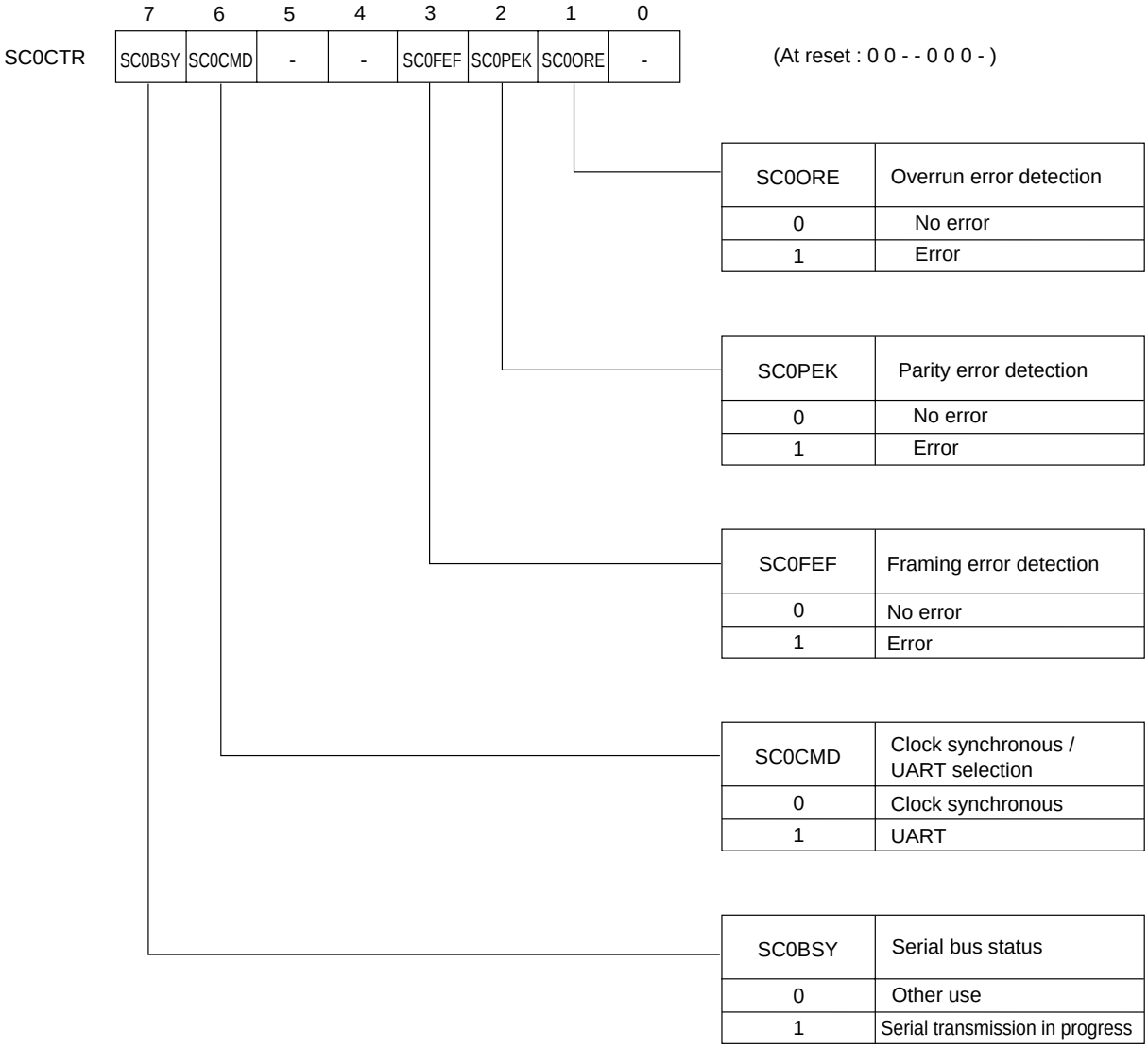


Figure 10-2-7 Serial Interface 0 Control Register (SC0CTR : x'03F54', R/W)

10-3 Operation

Serial Interface 0 can be used for both clock synchronous and half-duplex UART.

10-3-1 Clock Synchronous Serial Interface

■Selection of Clock Synchronous Serial Interface

When the serial interface 0 is used as clock synchronous serial interface, set the SC0CMD flag of the serial interface control register (SC0CTR) to "0".

■Activation Factor for Communication

Table 10-3-1 shows activation factors for communication. At master, the transfer clock is generated by setting data to the transmission / reception shift register SC0TRB, or by receiving a start condition. At slave, input an external clock, or input an external clock after a start condition is input.

Table 10-3-1 Synchronous Serial Interface Activation Factor

Operation mode			Activation factor	Sequence communication
Transmission	at master	Enable start condition	Writing data to serial buffer	√
		Disable start condition	Writing data to serial buffer	√
	at slave	Enable start condition	Clock reception *	√
		Disable start condition	Clock reception	√
Reception	at master	Enable start condition	Start condition reception	√
		Disable start condition	Writing data to serial buffer	—
	at slave	Enable start condition	Start condition reception	√
		Disable start condition	Clock reception	√

* Start condition is output by writing the transmission data to the transmission / reception shift register SC0TRB when the SC0SBOS flag of the serial interface 0 mode register 3 (SC0MD3) is set to "1". Then, the transmission is started by the slave clock.

When synchronous serial interface is used for master clock reception, it is necessary to write dummy data to the transmission / reception shift register (SC0TRB) for starting master clock. Automatic sequence reception with automatic data transfer can not be used, because it is necessary to write dummy data to serial interface buffer and to read reception data per a frame reception.

Cautions for master clock reception by the synchronous serial interface 0

On the product with serial interface 1 or serial interface 2, master clock reception by synchronous serial interface 1, 2 is started by setting the SCxSBTS of the serial interface mode register (SCxMDx) to "1", then, setting the SCxSBIS to "1" and writing dummy data to the transmission / reception shift register (SCxTRB).

But, by the above setting, this serial interface 0 cannot output the master clock, so that the reception is not started.
Therefore, the following setup by the software is necessary.

<By software>
When synchronous serial interface 0 is used for master clock reception, it is necessary to set the SC0SBTS flag of the serial interface 0 mode register 3 (SC0MD3) to "1", then, set the SC0SBIS flag to "1" and set the SC0SBOS flag to "1".
At last, the master clock is output by the writing dummy data to the transmission / reception shift register (SC0TRB), then, the reception is started.

Program example for master clock reception by the synchronous serial interface 0

SC0SBTS	← 1	
SC0SBIS, SC0SBOS	← 1, 1	
SC0TRB	← X'xx'	(dummy data is written, reception is started)

The SBO0 pin cannot be used as general output port by setting the SC0SBOS flag to "1". But it can be used as general input port by setting the bp0 of the port 0 direction control register (P0DIR) to "0".

Serial data communication of serial interface 0 can be available by setting the SC0SBIS flag or the SC0SBOS flag of the SC0MD3 register to "1". The SC0SBIS flag or the SC0SBOS flag should be set to "1" after all conditions are set.

On the master communication of the clock synchronous, set the SC0SBTS flag to "1" before the SC0SBOS flag or the SC0SBIS flag of the SC0MD3 register is set to "1". But, at the slave communication, the SC0SBTS flag needs not to be set to "1".

■Transfer Bit Count

The transfer bit count is selected from 1 bit to 8 bits. Set it by the SC0LNG2 to 0 flag of the SC0MD0 register (at reset : 000).

The SC0LNG2 to 0 flags change at the opposite edge of the transmission data output edge.

After the transfer has completed, the transfer bit count in the SC0LNG2 to 0 flags of the SC0MD0 register is changed. Except in an 8-bit transfer, reset the transfer bit count at the time of the next transmission.

When the SC0SBOS flag or the SC0SBIS flag of the SC0MD3 register to "1" and the SC0CE1 to 0 flags of the SC0MD0 register are changed, the transfer bit count in the SC0LNG2 to 0 flags of the SC0MD0 register may be incremented.

■Start Condition

The SC0STE flag of the SC0MD0 register sets if a start condition is enabled or not. If a start condition is enabled and input, a bit counter is cleared to start the communication. The start condition, if the SC0CE1 flag of the SC0MD0 register is set to "0", is regarded when a data line (SBI0 pin (with 3 channels) or SBO0 pin (with 2 channels) is changed from "H" to "L" as a clock line (SBT0 pin) is "H". Also, the start condition, if the SC0CE1 flag is set to "1", is regarded when a data line (SBI0 pin (with 3 channels) or SBO0 pin (with 2 channels) is changed from "H" to "L" as a clock line (SBT0 pin) is "L".
When the reception and the transmission should be operated at the same time, disable start condition for proper operation.

Enabling the start condition drives the SBO0 pin high level for a fixed time interval (1/2 the clock source cycle) after the transmission has completed. If the start condition is disabled, the SBO0 pin will remain at the level of the last data bit.

If the start condition is enabled, the SC0LNG2 to 0 flags of the SC0MD0 register will be cleared when the start condition is received. In this case, the receive bit count is fixed at 8 bits.

On the master communication of the clock synchronous, if start condition is enabled, the reception and the transmission should not be operated at the same time. The clock may be continued to output after the communication has completed.

■First Transfer Bit

The SC0DIR flag of the SC0MD0 register can set the first transfer bit. MSB first or LSB first can be selected.

■Transmission Data

Set the transmission data to the transmission / reception shift register (SC0TRB).

When switching from transmission to reception, set the SC0SBOS flag of the SC0MD0 register to "0" and then set the SC0SBIS flag to "1". Do not change both of these flags at the same time.

When switching from reception to transmission, set the SC0SBIS flag of the SC0MD0 register to "0" and then set the SC0SBOS flag to "1". Do not change both of these flags at the same time.

■Tranfer Bit Count and First Transfer Bit

On transmission, when the transfer bit is 1 bit to 7 bits, the data storing method to the transmission / reception shift register SC0TRB is different, depending on the first transfer bit selection. At MSB first, use the upper bits of SC0TRB. When there are 6 bits to be transferred, as shown on figure 10-3-1-1, if data "A" to "F" are stored to bp2 to bp7 of SC0TRB, the transmission is started from "F" to "A". At LSB first, use the lower bits on the program. When there are 6 bits to be transferred, as shown on figure 10-3-1-2, if data "A" to "F" are stored to bp0 to bp5 on the program, the transmission is started from "A" to "F", because their order is changed in the SWAP circuit.

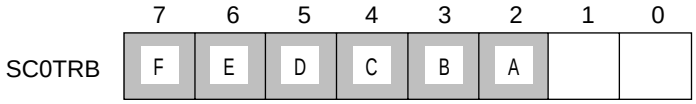


Figure 10-3-1-1 Transfer Bit Count and First Transfer Bit (starting with MSB)

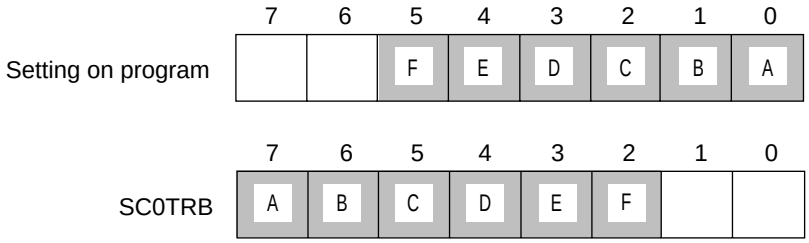


Figure 10-3-1-2 Transfer Bit Count and First Transfer Bit (starting with LSB)

■Received Data Buffer

The received data buffer SC0RXB is the sub-buffer that pushed the received data in the internal shift register. After the communication complete interrupt SC0IRQ is generated, data stored in the transmission / reception shift register is stored to the received data buffer SC0RXB automatically. SC0RXB can store data up to 1 byte. SC0RXB is rewritten in every communication complete, so read data of SC0RXB till the next receive complete. And before the next data reception is started, the same data to the SC0RXB can be read, even if the SC0TRB is reading.

When the SC0SBIS flag of the SC0MD3 register is set to "serial interface input", the SC0TRI flag of the SC0MD1 register is set to "1" at the same time SC0IRQ is generated. SC0TRI is cleared to "0" when the next reception has completed.

■Receive Bit Count and First Transfer Bit

On reception, when the transfer bit count is 1 bit to 7 bits, the data reading method from the received data buffer SC0RXB is different depending on the first transfer bit selection. At MSB first, data are read from the lower bits of SC0RXB. When there are 6 bits to be transferred, as shown on figure 10-3-2-1, if data "F" to "A" are stored to bp0 to bp5 of SC0RXB. Also, data are read as the same way. At LSB first, data are read from the upper bits of SC0RXB. When there are 6 bits to be transferred, as shown on figure 10-3-2-2, if data "A" to "F" are stored to bp0 to bp5 of SC0RXB. But their order is changed in the SWAP circuit, and reading is started from the upper bits.

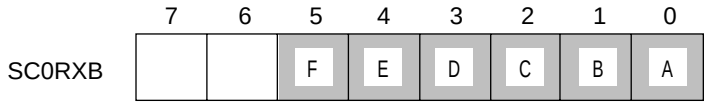


Figure 10-3-2-1 Receive Bit Count and Transfer First Bit (starting with MSB bit)

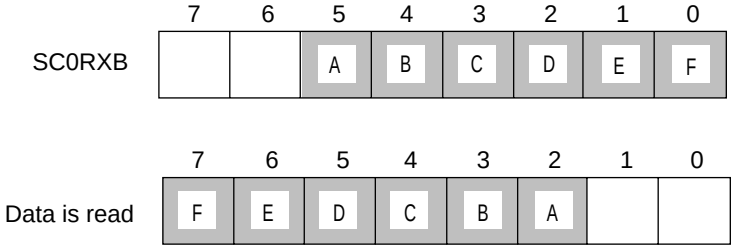
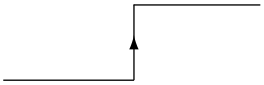
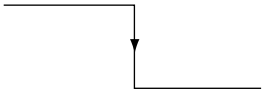
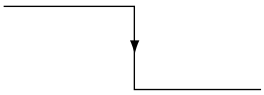
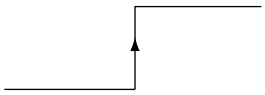
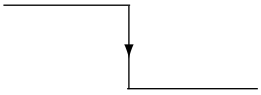
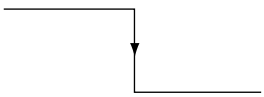
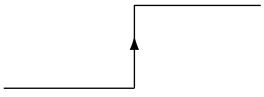
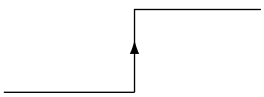


Figure 10-3-2-2 Receive Bit Count and Transfer First Bit (starting with LSB bit)

■Input Edge / Output Edge Setup

The SC0CE1 to 0 flag of the SC0MD0 register set an output edge of the transmission data, an input edge of the reception data. As the SC0CE1 flag = "0", the transmission data is output at the falling edge, and as "1", output at the rising edge. As SC0CE0="0", the reception data is stored at the inversion edge to the output edge of transmission data, and as "1", stored at the same edge.

Table 10-3-2 Input Edge and Output Edge of Transmission Reception Data

SC0CE0	SC0CE1	Reception data input edge	Transmission data output edge
0	0		
0	1		
1	0		
1	1		

■Clock Setup

The clock source can be selected from the internal clock or the external clock. Here is the internal clock source that can be set by the SC0CK1 to 0 register of the SC0MD1 register. Also, the internal clock can be divided by 8, by setting the SC0CKM flag of the SC0MD1 register to "1".

Table 10-3-3 Synchronous Serial Interface Internal Clock Source

	Serial interface 0
Clock source (internal clock)	fs/2
	fs/4
	fs/16
	Timer 3 output

■Data Input Pin Setup

3 channels type (clock pin (SBT0 pin), data output pin (SBO0 pin), data input pin (SBI0 pin)) or 2 channels type (clock pin (SBT0 pin), data I/O pin (SBO0 pin)) can be selected as the communication. SBI0 pin can be used for only serial data input. SBO0 pin can be used for serial data input or output. The SC0IOM flag of the SC0MD3 register can select if the serial data is input from SBI0 pin or SBO0 pin. When "data input from SBO0 pin" is selected to set the 2 channels type, the P0DIR0 flag of the P0DIR register controls direction of SBO0 pin to switch transmission / reception. At that time, SBI0 pin is free to be used as a general port.

At reception, if SC0IOM of the SC0MD3 register is set to "1" and "serial data input from SBO0" is selected, SBI0 pin is used as a general port.

■BUSY Flag

When the activation factor is generated, shown in table 10-3-1, and the serial interface communication is started, the BUSY flag SC0BSY of the SC0CTR register is set to "1". That is cleared to "0" when the communication complete interrupt SC0IRQ is generated.

■Other Control Flag Setup

Table 10-3-4 shows flags that are not used at clock synchronous communication. So, they need not to be set or monitored.

Table 10-3-4 Other Control Flag

Register	Flag	Detail
SC0MD1	SC0BRKF	Brake status reception monitor
	SC0ERE	Error monitor
SC0MD2	SC0NPE	Parity is enabled
	SC0PM1 to 0	Added bit specification
	SC0FM1 to 0	Frame mode specification
	SC0BRKE	Brake status transmission control
SC0CTR	SC0ORE	Overrun error detection
	SC0PEK	Parity error detection
	SC0FEF	Frame error detection

■Transmission Timing

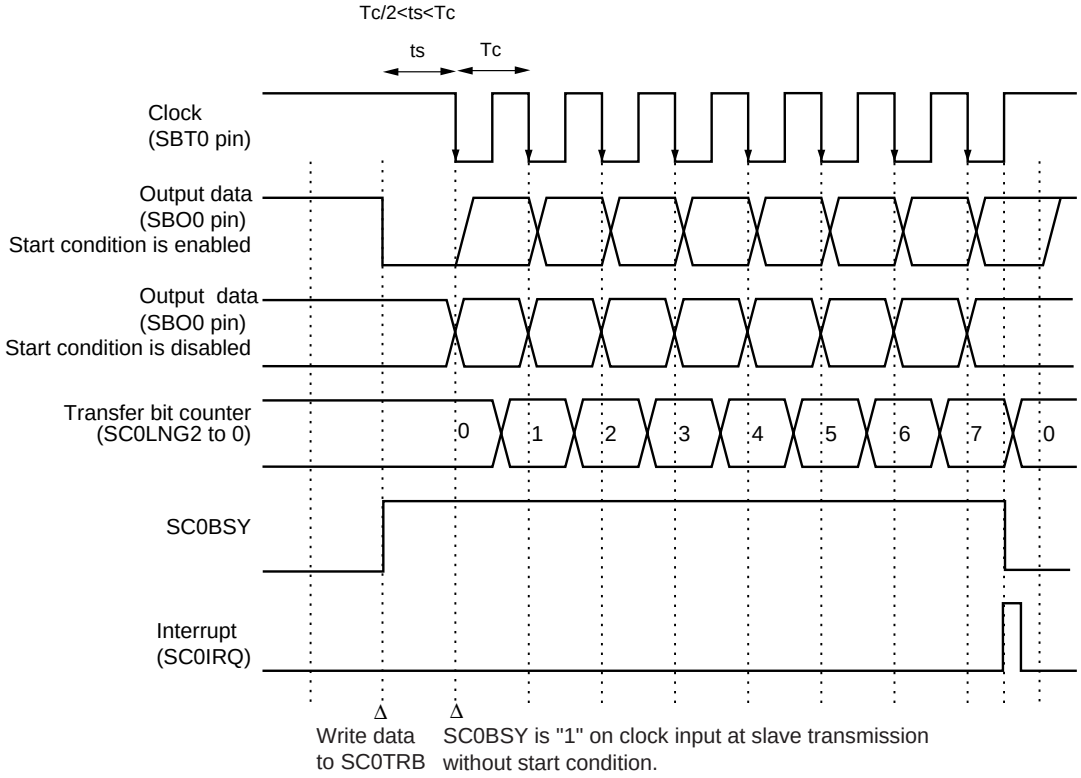


Figure 10-3-3 Transmission Timing (falling edge)

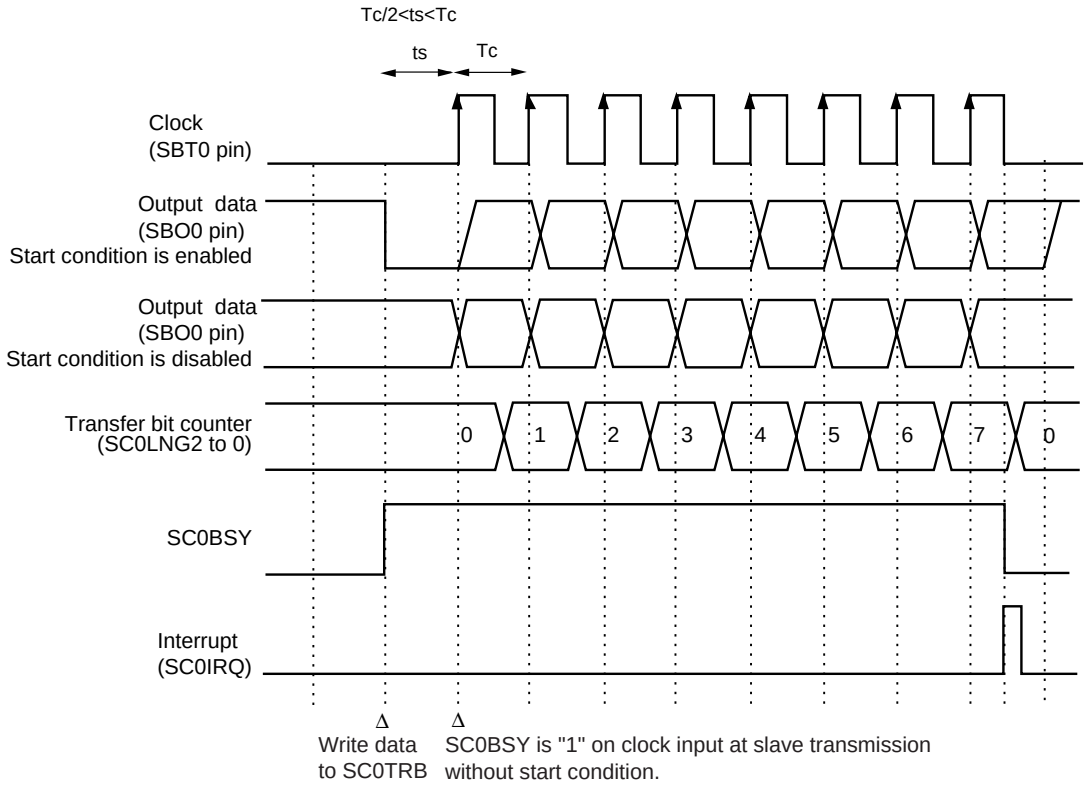


Figure 10-3-4 Transmission Timing (rising edge)

■Reception Timing

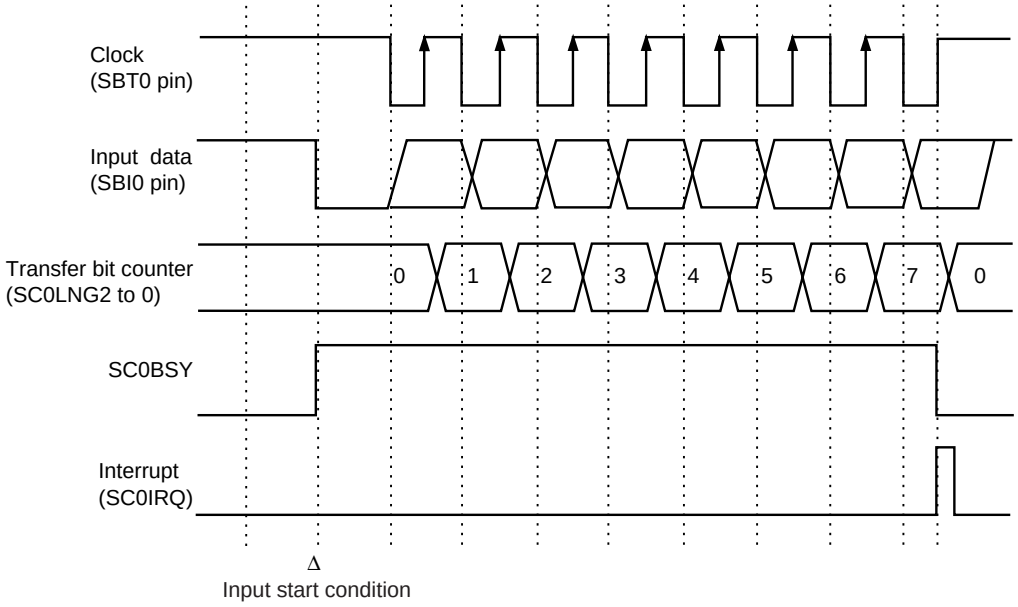


Figure 10-3-5 Reception Timing (rising edge, start condition is enabled)

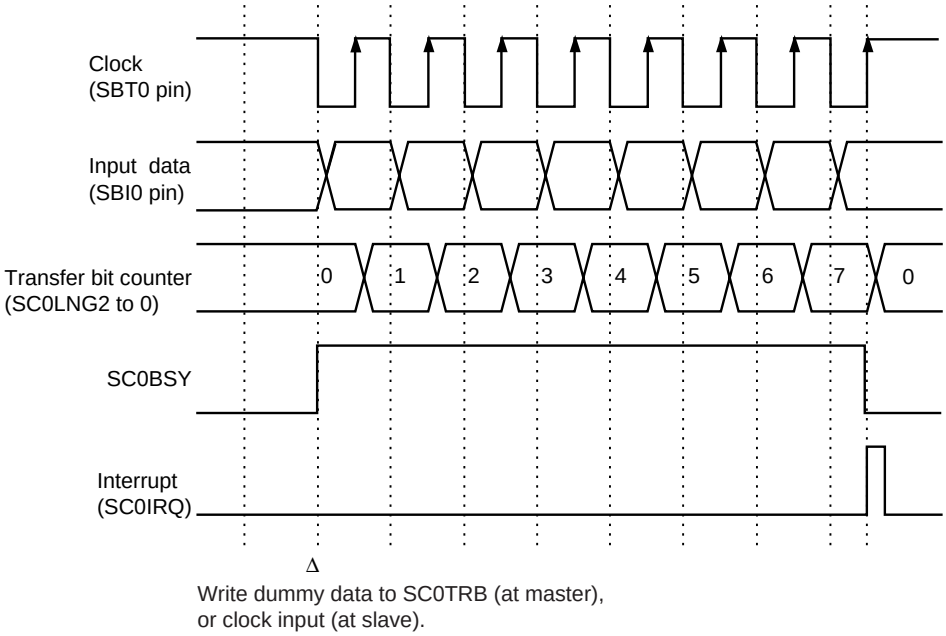


Figure 10-3-6 Reception Timing (rising edge, start condition is disabled)

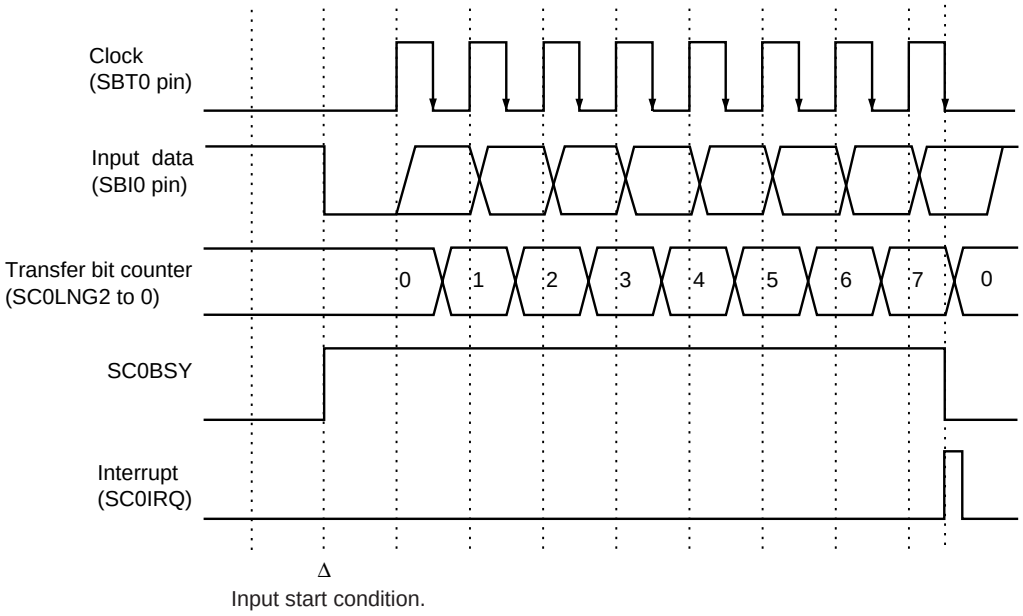


Figure 10-3-7 Reception Timing (falling edge, start condition is enabled)

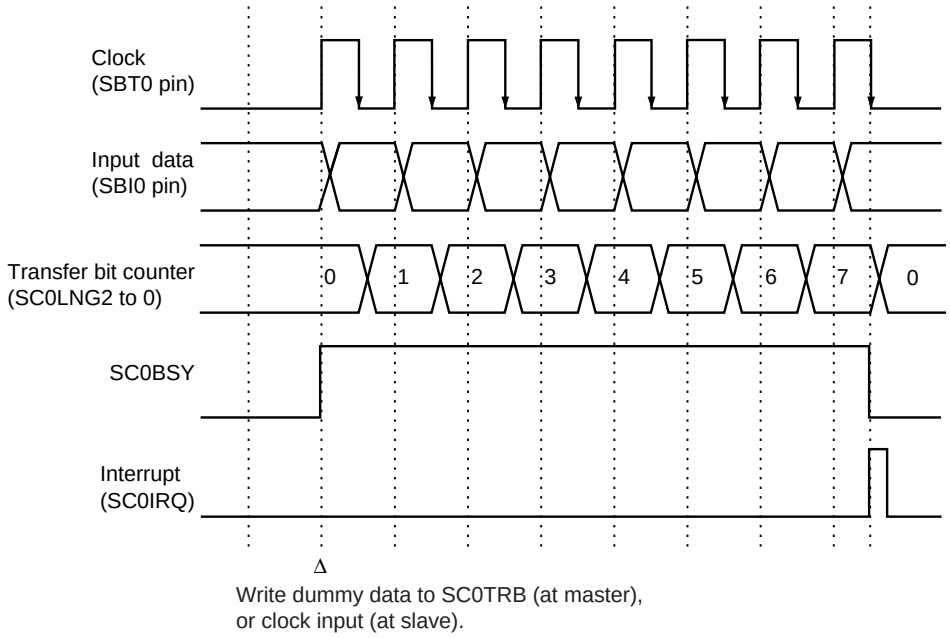


Figure 10-3-8 Reception Timing (falling edge, start condition is disabled)

■Transmission / Reception Simultaneous Timing

When transmission and reception are operated at the same time, set the SC0CE0 to 1 flag of the SC0MD0 register to "00" or "01". Data is received at the opposite edge of the transmission clock, so that the reception clock should be the opposite edge of the transmission clock from the other side.

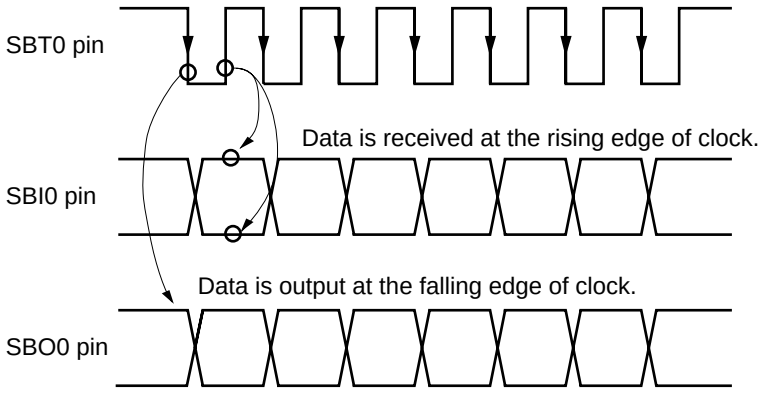


Figure 10-3-9 Transmission / Reception Timing
(Reception : rising edge, Transmission : falling edge)
(SC0CE0 = 0, SC0CE1 = 0)

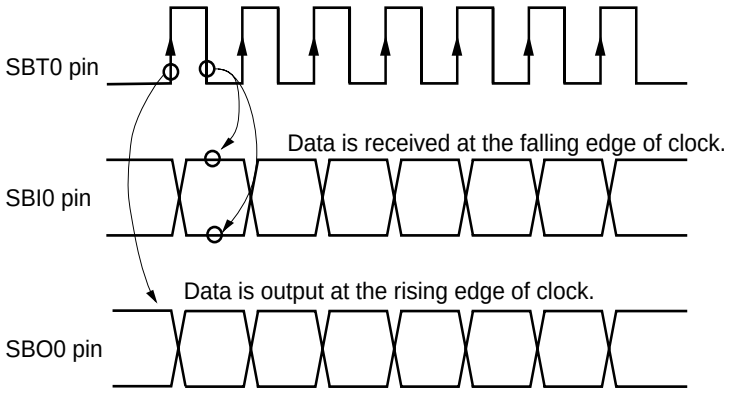


Figure 10-3-10 Transmission / Reception Timing
(Reception : falling edge, Transmission : rising edge)
(SC0CE0 = 0, SC0CE1 = 1)

■Pins Setup (3 channels, at transmission)

Table 10-3-5 shows the setup for synchronous serial interface pin with 3 channels (SBO0 pin, SBI0 pin, SBT0 pin) at transmission.

Table 10-3-5 Setup for Synchronous Serial Interface Pin (3 channels, at transmission)

Setup item	Data output pin	Data input pin	Clock I/O pin	
	SBO0 pin	SBI0 pin	SBT0 pin	
			Internal clock (master communication)	External clock (slave communication)
Pin	P00	P01	P02	
SBI0 / SBO0 pin	SBI0 / SBO0 independent		-	
	SC0MD3(SC0IOM)			
Function	Serial data output	"1" input	Serial clock I/O	Port
	SC0MD3(SC0SBOS)	SC0MD3(SC0SBIS)	SC0MD3(SC0SBTS)	
Style	Push-pull / Nch open-drain	-	Push-pull / Nch open-drain	Push-pull / Nch open-drain
	SC0OMD3(SC0SBOM)		SC0MD3(SC0SBTM)	
I/O	Output mode	-	Output mode	Input mode
	P0DIR(P0DIR0)		P0DIR(P0DIR2)	
Pull-up	Added / Not added	-	Added / Not added	Added / Not added
	P0PLU(P0PLU0)		P0PLU(P0PLU2)	

■Pins Setup (3 channels, at reception)

Table 10-3-6 shows the setup for synchronous serial interface pin with 3 channels (SBO0 pin, SBI0 pin, SBT0 pin at reception).

Table 10-3-6 Setup for Synchronous Serial Interface Pin (3 channels, at reception)

Setup item	Data output pin	Data input pin	Clock I/O pin	
	SBO0 pin	SBI0 pin	SBT0 pin	
			Internal clock (master communication)	External clock (slave communication)
Pin	P00	P01	P02	
SBI0 / SBO0 pin	SBI0 / SBO0 independent		-	
	SC0MD3(SC0IOM)			
Function	Port	Serial data input	Serial clock I/O	Port
	SC0MD3(SC0SBOS)	SC0MD3(SC0SBIS)	SC0MD3(SC0SBTS)	
Style	-	-	Push-pull / Nch open-drain	Push-pull / Nch open-drain
			SC0MD3(SC0SBTM)	
I/O	-	Input mode	Output mode	Input mode
		P0DIR(P0DIR1)	P0DIR(P0DIR2)	
Pull-up	-	Added / Not added	Added / Not added	Added / Not added
		P0PLU(P0PLU1)	P0PLU(P0PLU2)	

■Pins Setup (3 channels, at transmission / reception)

Table 10-3-7 shows the setup for synchronous serial interface pin with 3 lines (SBO0 pin, SBI0 pin, SBT0 pin) at transmission / reception.

Table 10-3-7 Setup for Synchronous Serial Interface Pin (3 channels, at transmission / reception)

Setup item	Data output pin	Data input pin	Clock I/O pin	
	SBO0 pin	SBI0 pin	SBT0 pin	
			Internal clock (master communication)	External clock (slave communication)
Pin	P00	P01	P02	
SBI0 / SBO0 pin	SBI0 / SBO0 independent		-	
	SC0MD3(SC0IOM)			
Function	Serial data output	Serial data input	Serial clock I/O	Port
	SC0MD3(SC0SBOS)	SC0MD3(SC0SBIS)	SC0MD3(SC0SBTS)	
Style	Push-pull / Nch open-drain	-	Push-pull / Nch open-drain	Push-pull / Nch open-drain
	SC0MD3(SC0SBOM)		SC0MD3(SC0SBTM)	
I/O	Output mode	Input mode	Output mode	Input mode
	P0DIR(P0DIR0)	P0DIR(P0DIR1)	P0DIR(P0DIR2)	
Pull-up	Added / Not added	Added / Not added	Added / Not added	Added / Not added
	P0PLU(P0PLU0)	P0PLU(P0PLU1)	P0PLU(P0PLU2)	

■Pins Setup (2 channels, at transmission)

Table 10-3-8 shows the setup for synchronous serial interface pin with 2 channels (SBO0 pin, SBT0 pin) at transmission. SBI0 pin can be used as a general port.

Table 10-3-8 Setup for Synchronous Serial Interface Pin (2 channels, at transmission)

Setup item	Data I/O pin	Serial unused pin	Clock I/O pin	
	SBO0 pin	SBI0 pin	SBT1 pin	
			Internal clock (master communication)	External clock (slave communication)
Pin	P00	P01	P02	
SBI0 / SBO0 pin	SBI0 / SBO0 connected		-	
	SC0MD3(SC0IOM)			
Function	Serial data output	"1" input	Serial clock I/O	Port
	SC0MD3(SC0SBOS)	SC0MD3(SC0SBIS)	SC0MD3(SC0SBTS)	
Style	Push-pull / Nch open-drain	-	Push-pull / Nch open-drain	Push-pull / Nch open-drain
	SC0MD3(SC0SBOM)		SC0MD3(SC0SBTM)	
I/O	Output mode	-	Output mode	Input mode
	P0DIR(P0DIR0)		P0DIR(P0DIR2)	
Pull-up	Added / Not added	-	Added / Not added	Added / Not added
	P0PLU(P0PLU0)		P0PLU(P0PLU2)	

■Pins Setup (2 channels, at reception)

Table 10-3-9 shows the setup for synchronous serial interface pin with 2 channels (SBO0 pin, SBT0 pin) at reception. SBI0 pin can be used as a general port.

Table 10-3-9 Setup for Synchronous Serial Interface Pin (2 channels, at reception)

<table>
<tr><td rowspan="3">Setup item</td><td>Data I/O pin</td><td>Serial unused pin</td><td colspan="2">Clock I/O pin</td></tr>
<tr><td rowspan="2">SBO0 pin</td><td rowspan="2">SBI0 pin</td><td colspan="2">SBT0 pin</td></tr>
<tr><td>Internal clock
(master communication)</td><td>External clock
(slave communication)</td></tr>
<tr><td>Pin</td><td>P00</td><td>P01</td><td colspan="2">P02</td></tr>
<tr><td rowspan="2">SBI0 / SBO0 pin</td><td colspan="2">SBI0 / SBO0 connected</td><td colspan="2" rowspan="2">-</td></tr>
<tr><td colspan="2">SC0MD3(SC0IOM)</td></tr>
<tr><td rowspan="2">Function</td><td>Port</td><td>Serial data input</td><td>Serial clock I/O</td><td>Port</td></tr>
<tr><td>SC0MD3
(SC0SBOS)</td><td>SC0MD3
(SC0SBIS)</td><td colspan="2">SC0MD3(SC0SBTS)</td></tr>
<tr><td rowspan="2">Stype</td><td rowspan="2">-</td><td rowspan="2">-</td><td>Push-pull /
Nch open-drain</td><td>Push-pull /
Nch open-drain</td></tr>
<tr><td colspan="2">SC0MD3(SC0SBTM)</td></tr>
<tr><td rowspan="2">I/O</td><td>Input mode</td><td rowspan="2">-</td><td>Output mode</td><td>Input mode</td></tr>
<tr><td>P0DIR(P0DIR0)</td><td colspan="2">P0DIR(P0DIR2)</td></tr>
<tr><td rowspan="2">Pull-up</td><td>Added / Not added</td><td rowspan="2">-</td><td>Added / Not added</td><td>Added / Not added</td></tr>
<tr><td>P0PLU(P0PLU0)</td><td colspan="2">P0PLU(P0PLU2)</td></tr>
</table>

10-3-2 Setup Example

■Transmission / Reception Setup Example

The setup example for clock synchronous serial interface communication with serial interface 0 is shown. Table 10-3-10 shows the conditions at transmission / reception.

Table 10-3-10 Setup Examples for Synchronous Serial Interface Transmission / Reception

Setup item	set to		Setup item	set to
SBI0 / SBO0 pin	Independent (with 3 channels)		Clock source	fs/2
Transfer bit count	8 bits		Clock source 1/8 dividing	not divided by 8
Start condition	none		SBT0 / SBO0 pin style	Nch open-drain
First transfer bit	MSB		SBT0 pin pull-up resistor	Not added
Input clock edge	falling edge		SBO0 pin pull-up resistor	Not added
			SBI0 pin pull-up resistor	Added
Output clock edge	rising edge		Serial 0 communication complete interrupt	Enable
Clock	Internal clock (master communication)			

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Select the clock synchronous serial interface. SC0CTR (x'3F54') bp6 : SC0CMD = 0	(1) Set the SC0CMD flag of the serial interface 0 control register (SC0CTR) to "0" to select the clock synchronous serial interface.
(2) Set the SC0MD0 register. Select the transfer bit count SC0MD0 (x'3F50') bp2-0 : SC0LNG2-0 = 000	(2) Set the SC0LNG2-0 flag of the serial interface 0 mode register 0 (SC0MD0) to "000" to set the transfer bit to 8 bits.
Select the start condition. SC0MD0 (x'3F50') bp3 : SC0STE = 0	Set the SC0STE flag of the SC0MD0 register to "0" to disable start condition.
Select the first bit to be transferred. SC0MD0 (x'3F50') bp4 : SC0DIR = 0	Set the SC0DIR flag of the SC0MD0 register to "0" to set MSB as a transfer first bit.
Select the transfer edge. SC0MD0 (x'3F50') bp6 : SC0CE0 = 0 bp5 : SC0CE1 = 1	Set the SC0CE0, 1 flag of the SC0MD0 register to "0, 1" to set the transmission data output edge "rising" and the received data input edge "falling".

Setup Procedure	Description
(3) Select the clock source. SC0MD1 (x'3F51') bp4-3 : SC0CK1-0 = 00 bp5 : SC0CKM = 0	(3) Set the SC0CK1-0 flag of the SC0MD1 register to "00" to select the clock source "fs/2". Set the SC0CKM flag to "0" to select not to divide the clock source by 1/8.
(4) Select the transfer clock. SC0MD3 (x'3F53') bp0 : SC0BTS = 1	(4) Set the SC0SBTS flag of the SC0MD3 register to "1" to set the SBT0 pin to serial interface clock I/O pin. The communication is used with the internal clock (master communication).
(5) Control the pin type. SC0MD3 (x'3F53') bp4-3 : SC0SBOM, SC0SBTM = 11 bp5 : SC0IOM = 0 P0PLU (x'3F40') bp2-0 : P0PLU2-0 = 010	(5) Set the SC0SBOM, SC0SBTM flag of the SC0MD3 register to "11" to select the SBO0/ SBT0 pin to "N-ch open drain". Set the SC0IOM flag to "0" to set "input serial data from the SBI0 pin". Set the POPLU2-0 flag of the POPLU register to "010" to select "add pull-up resistor" only to the SBI0 pin.
(6) Control the pin direction. P0DIR (x'3F30') bp2-0 : P0DIR2-0 = 101	(6) Set the P0DIR2-0 flag of the port 0 pin direction control register (P0DIR) to "101" to set P00 and P02 to output mode and to set P01 to input mode.
(7) Control the pin function. SC0MD3 (x'3F53') bp2 : SC0SBOS = 1 bp1 : SC0SBIS = 1	(7) Set the SC0SBOS, SC0SBIS flag of the SC0MD3 register to "1" to set SBO0 pin "serial data output", SBI0 pin "serial data input".
(8) Set the interrupt level. SC0ICR (x'3FF8') bp7-6 : SC0LV1-0 = 10	(8) Set the interrupt level by the SC0LV1-0 flag of the serial interface 0 interrupt control register (SC0ICR).
(9) Enable the interrupt. SC0ICR (x'3FF8') bp1 : SC0IE = 1	(9) Set the SC0IE flag of the SC0ICR register to "1" to enable interrupts. If the interrupt request flag (SC0IR of the SC0ICR register) had already been set, clear SC0IR before an interrupt is enabled. [☞ Chapter 3 3-1-4. Interrupt Flag Setup]

Setup Procedure	Description
(10) Start serial interface transmission. Transmission data→SC0TRB(x'3F55') Reception data→input to SBI0 pin.	(10) Set the transmission data to the serial interface 0 transmission / reception shift register (SC0TRB). Then, an internal clock is generated to start transmission / reception. After the transmission has finished, serial interface 0 interrupt SC0IRQ is generated.

Note : In (2), each settings can be set at once.

When only reception with 3 channels is operated, set SC0SBOS of the SC0MD3 register to "0" and select a port. The SBO0 pin can be used as a general port.

When SBO0 / SBI0 pin are connected for communication with 2 lines, the SBO0 pin inputs / outputs serial data. The port direction control register P0DIR switches input / output. At reception, set SC0SBIS of the SC0MD3 register to "1", always, to select "serial data input". The SBI0 pin can be used as a general port.

If the SC0IOM flag of the SC0MD3 register is set to "1", the SBI0 pin can be used as port. When the SBO0 pin is input mode, reception is operated, and when it is output mode, transmission is operated.

When the register except the SC0TRB is written or rewritten, set the SC0SBOS, SC0SBIS flag to "0".

When the internal clock is used as clock source, write dummy data to the SC0TRB register after setting the SC0SBIS flag and the SC0SBOS flag of the SC0MD3 register to "1". Even if the reception is operated again, write dummy data to the SC0TRB register.

10-3-3 Half-duplex UART Serial Interface

Serial interface 0 can be used for half-duplex UART communication. Table 10-3-11 shows UART serial interface functions.

Table 10-3-11 UART Serial Interface Functions

Communication style	UART(Half-duplex)
Interrupt	SC0IRQ(transmission, reception)
Used pins	TXD(output, input) RXD(input)
First transfer bit	MSB/LSB
Parity bit selection	√
Parity bit control	0 parity 1 parity odd parity even parity
Frame selection	7 bits + 1 stop 7 bits + 2 stops 8 bits + 1 stop 8 bits + 2 stops
Maximum transfer rate	625 kbps

■Selection of Half-duplex UART Serial Interface

When the serial interface 0 is used as half-duplex UART serial interface, set the SC0CMD flag of the serial interface 0 control register (SC0CTR) to "1".

■Activation Factor for Communication

At transmission, if any data is written to the transmission / reception shift register SC0TRB, a start bit (Data is changed from "H" to "L") is generated to start transfer. At reception, if a start bit (Data is changed from "H" to "L") is received, communication is started. At reception, if the data length of "L" is longer than 0.5 bit, that can be regarded as a start bit.

■Transmission

Data transfer is automatically started by writing data to the transmission / reception shift register SC0TRB after setting the SC0SBOS flag of the SC0MD3 register to "1". During transmission, reception and start bit input are disabled.

■Reception

When the SC0SBIS flag of the SC0MD3 register is set to "1" and a start bit is received, reception is started after the transfer bit counter is set as frame mode is specified. During reception, transmission is disabled.

■Transfer Bit Count Setup

The transfer bit count is automatically set after the frame mode is specified by the SC0FM1 to 0 flag of the SC0MD2 register. If the SC0CMD flag of the SC0CTR register is set to "1", and UART communication is selected, the synchronous serial data transfer bit count selection flag SC0LNG2 to 0 of the SC0MD0 register is automatically set.

■Input Edge / Output Edge Setup

The SC0CE 1 to 0 flag of the SC0MD0 register set an output edge of the transmission data, an input edge of the received data. At UART communication, not the transfer clock being needed, but the SC0CE1-0 flag should be set to decide the timing of the data transmission / reception in this serial interface. At UART communication, generally, set the SC0CE1-0 flag to "00", the transmission data output edge to "falling", and the reception data input edge to "rising". Refer to table 10-3-2 (X-16) for Input Edge / Output Edge Setup detail.

■Data Input Pin Setup

The communication mode can be selected from with 2 channels (data output pin (TXD pin), data input pin (RXD pin)), or with 1 channel (data I/O pin (TXD pin)). The RXD pin can be used only for serial data input. The TXD pin can be used for serial data input or output. The SC0IOM flag of the SC0MD3 register can specify which pin, RXD or TXD to input the serial data. "Data input from TXD pin" is selected to be with 1 channel communication. At switching transmission / reception, TXD pin's direction should be controlled by the P0DIR0 flag of the P0DIR register. At that time, the RXD pin is not used, so that it can be used as a general port.

■Frame Mode and Parity Check Setup

Figure 10-3-11 shows the data format at UART communication.

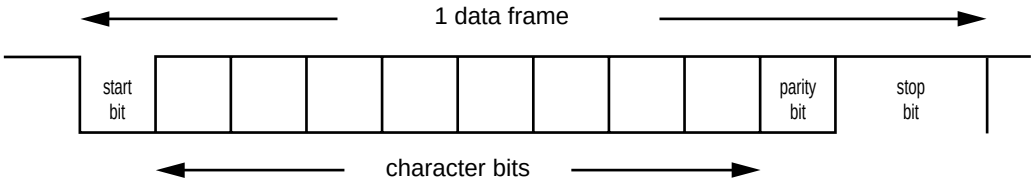


Figure 10-3-11 UART Serial Interface Transmission / Reception Data Format

The transmission / reception data consists of start bit, character bit, parity bit and stop bit. Table 10-3-12 shows its kinds to be set.

Table 10-3-12 UART Serial Interface Transmission / Reception Data

Start bit	1 bit (must be 'L')
Character bit	7, 8 bits
Parity bit	fixed to 0, fixed to 1, even, odd, none
Stop bit	1, 2 bits (noramally 'H')

The SC0FM1 to 0 flag of the SC0MD2 register sets the frame mode. Table 10-3-13 is shown the UART serial interface frame mode setting. If the SC0CMD flag of the SC0CTR register is set to "1", and UART communication is selected, the SC0LNG2 to 0 flag of the SC0MD0 register is automatically set.

Table 10-3-13 UART Serial Interface Frame Mode

SC0MD2 register		Frame mode
SC0FM1	SC0FM0	
0	0	Character bit 7 bits + Stop bit 1 bit
0	1	Character bit 7 bits + Stop bit 2 bits
1	0	Character bit 8 bits + Stop bit 1 bit
1	1	Character bit 8 bits + Stop bit 2 bits

Parity bit is to detect wrong bits with transmission / reception data.
Table 10-3-14 shows kinds of parity bit. The SC0NPE, SC0PM1 to 0 flag of the SC0MD2 register set parity bit.

Table 10-3-14 Parity Bit of UART Serial Interface

SC0MD2 register			Parity bit	Setup
SC0NPE	SC0PM1	SC0PM0		
0	0	0	fixed to 0	Set parity bit to "0".
0	0	1	fixed to 1	Set parity bit to "1".
0	1	0	odd parity	Control the total number of "1" of parity bit and character bit should be odd.
0	1	1	even parity	Control the total number of "1" of parity bit and character bit should be even.
1	-	-	none	Do not add parity bit.

■Break Status Transmission Control Setup
The SC0BRKE flag of the SC0MD2 register generates the break status. If SC0BRKE is set to "1" to select the break transmission, all bits from start bits to stop bits transfer "0".

■Reception Error
At reception , there are 3 types of error ; overrun error, parity error and framing error. Reception error can be determined by the SC0ORE, SC0PEK and SC0FEF flag of the SC0CTR register. Even one of those errors is detected, the SC0ERE flag of the SC0MD1 register is set to "1". The reception error flag is renewed at generation of the reception complete interrupt SC0IRQ. The judgement of the received error flag should be operated until the next communication has finished. The communication operation does not have any effect on those error flags. Table 10-3-15 shows the list of reception error source.

Table 10-3-15 Reception Error Source of UART Serial Interface

Flag	Error	Error source	
SC0ORE	Overrun error	Next data is received before reading the receive buffer.	
SC0PEK	Parity error	at fixed to 0	when parity bit is "1"
		at fixed to 1	when parity bit is "0"
		odd parity	The total of "1" of parity bit and character bit is even.
		even parity	The total of "1" of parity bit and character bit is odd.
SC0FEF	Framing error	Stop bit ('H') is not detected.	

■Judgement of Break Status Reception

Reception at break status can be judged. If all received data from start bit to stop bit is "0", the SC0BRKF flag of the SC0MD1 register is set and regard the break status. The SC0BRKF flag is set at generation of the reception complete interrupt SC0IRQ.

■Selection of Start Condition

The SC0STE flag of the SC0MD0 register is originally to select start condition of the synchronous serial data communication. When serial interface 0 is used as half-duplex UART serial interface, set the SC0STE flag always to "0" to prevent the following errors.

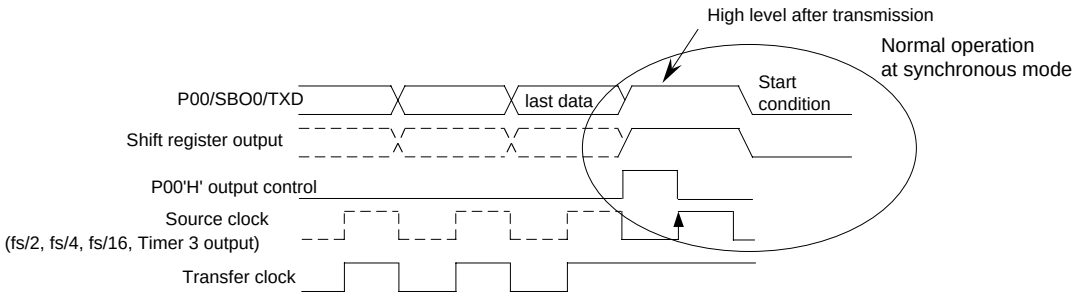
< Caution >

At UART communication, set the SC0STE flag of the SC0MD register to "0".

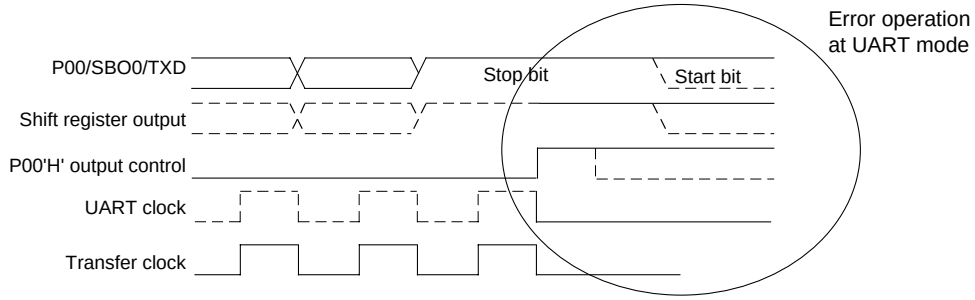
< Error >

At UART transmission, when the SC0STE flag is "1", start bit becomes "H" at the 2nd transmission and after.

[At synchronous serial data transmission (as the SC0STE flag = 1)]



[At UART transmission (as the SC0STE flag = 1)]



■Other Control Flags

The following flags need not to be set at UART communication.

Table 10-3-16 Other Control Flags

Register	Flag	Detail
SC0MD0	SC0LNG2 to 0	Selection ot the transfer bit count (automatically set)
SC0MD1	SC0CKM	Selection of the 1/8 division (automatically set)
SC0MD3	SC0SBTS	Selection of the SBT pin's function
	SC0SBTM	Selection of the SBT pin's style

The following items are the same to clock synchronous serial interface.
Reference as follows ;

■First Transfer Bit Setup

Refer to : X-13

■Transfer Bit Count and First Transfer Bit

Refer to : X-15

■Received Data Buffer

Refer to : X-15

■Receive Bit Count and First Transfer Bit

Refer to : X-15

■BUSY Flag Operation

Refer to : X-18

■Transmission Timing

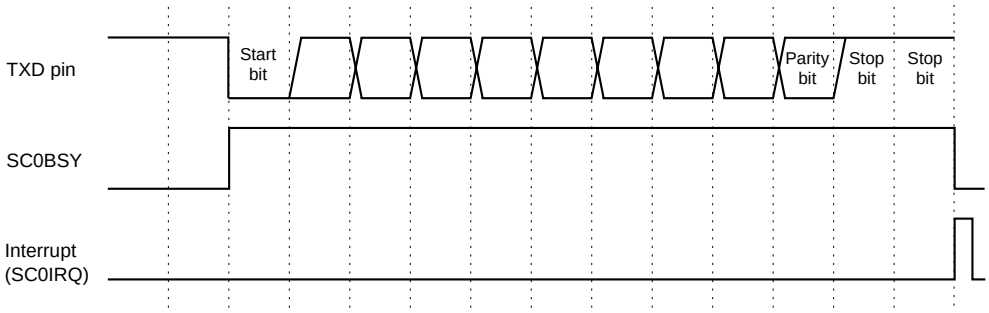


Figure 10-3-12 Transmission Timing (parity bit is enabled)

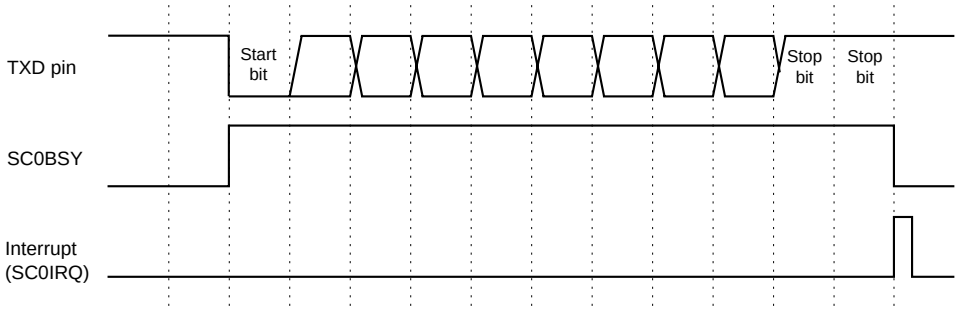


Figure 10-3-13 Transmission Timing (parity bit is disabled)

■Reception Timing

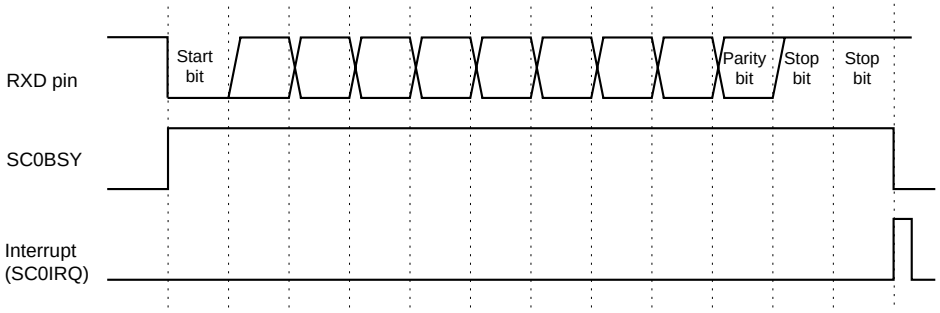


Figure 10-3-14 Reception Timing (parity bit is enabled)

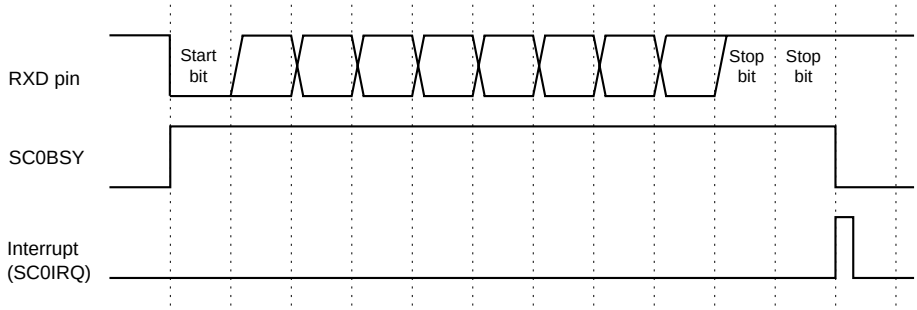
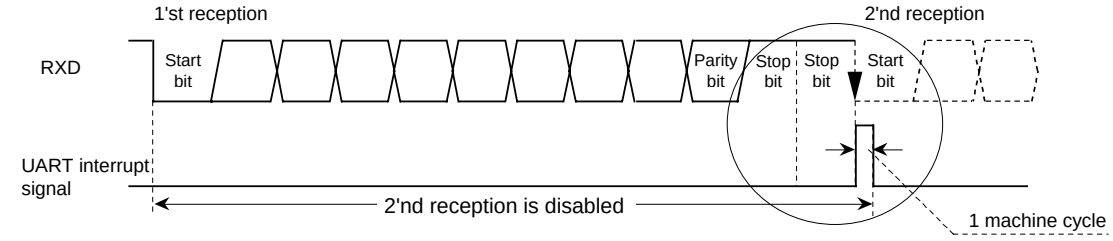


Figure 10-3-15 Reception Timing (parity bit is disabled)

■Sequence Communication



On the above sequence communication, this UART cannot regard start bit when the "H" period of the interrupt signal generated inside at reception complete and the falling edge of start bit input from the RXD pin are happened at the same time (1 machine cycle).
Therefore, from the 2nd reception, the operation cannot be properly executed.

To prevent this, the reception interrupt signal and the falling edge of the start bit should not be happened at the same time.
There are 2 ways to solve it.

Method 1 (by stop bit)
Set the stop bit at the transmission side to "2 bits", and set the stop bit at the reception side to "1 bit".
(For parity bit, set the same to both sides of the reception and transmission.)

Method 2 (by parity bit)
Set the transmission parity bit to "always 1", and set the reception parity bit to "none".
(For stop bit, set the same to both sides of the reception and transmission. At the reception, parity bit is regarded as one of stop bit.)

This error can be prevented if one of the above methods can be enabled.
Both methods do not depend on the combination of the oscillation frequency and the baud rate timer setup.

■Transfer Rate

Baud rate timer (timer 3) can set any transfer rate.

Table 10-3-17 shows the setup example of the transfer rate. For detail of the baud rate timer setup, refer to chapter 5. 5-7 serial interface transfer clock output operation.

Table 10-3-17 UART Serial Interface Transfer Rate Setup Register

Setup	Register	Page
Serial 0 clock source (timer 3 output)	SC0MD1	X - 7
Timer 3 clock source	TM3MD	V - 8
Timer 3 compare register	TM3OC	V - 6

Timer 3 compare register is set as follows ;

overflow cycle = (set value of compare register + 1) x timer clock cycle

baud rate = 1 / (overflow cycle x 2 x 8) ("8" means that clock source is divided by 8)

Therefore,

set value of compare register = timer clock frequency / (baud rate x 2 x 8) - 1

For example, if baud rate should be 300 bps at timer 3 clock source fs/4 (fosc = 8 MHz, fs = fosc/2), set value should be as follows ;

Set value of compare register = $(8 \times 10^6 / 2 / 4) / (300 \times 2 \times 8) - 1$

= 207

= x'CF'

Timer 3 clock source and the set values of timer 3 compare register at the standard transfer rate are shown on the following page.

At UART communication, "clock source is divided by 8" is selected, regardless of the setup for the SC0CKM flag of the SC0MD1 register.

Table 10-3-18 UART Serial Interface Transfer Rate and Timer 3 Compare Register (decimal)

fosc (MHz)	Clock source (timer 3)	Transfer Rate (bps)											
		300		1200		2400		4800		9600		19200	
		Set value	Calculated Value	Set value	Calculated Value	Set value	Calculated Value	Set value	Calculated Value	Set value	Calculated Value	Set value	Calculated Value
4.00	fosc	-	-	207	1202	103	2403	51	4807	25	9615	12	19230
	fs/4	103	300	-	-	-	-	-	-	-	-	-	-
	fs/16	-	-	-	-	-	-	-	-	-	-	-	-
4.19	fosc	-	-	217	1201	108	2402	54	4762	26	9699	-	-
	fs/4	108	300	-	-	-	-	-	-	-	-	-	-
	fs/16	-	-	-		-	-	-	-	-	-	-	-
8.00	fosc	-	-	-	-	207	2404	103	4807	51	9615	25	19230
	fs/4	207	300	51	1201	-	-	-	-	-	-	-	-
	fs/16	-	-	-	-	-	-	-	-	-	-	-	-
8.38	fosc	-	-	-	-	217	2403	108	4805	54	9523	26	19398
	fs/4	217	300	54	1190	-	-	-	-	-	-	-	-
	fs/16	-	-	-	-	-	-	-	-	-	-	-	-
12.00	fosc	-	-	-	-	-	-	155	1808	77	9615	38	19230
	fs/4	-	-	77	1202	38	2403	-	-	-	-	-	-
	fs/16	77	300	-	-	-	-	-	-	-	-	-	-
16.00	fosc	-	-	-	-	-	-	207	4808	103	9615	51	19230
	fs/4	-	-	103	1202	51	2404	-	-	-	-	-	-
	fs/16	103	300	-	-	-	-	-	-	-	-	-	-
16.76	fosc	-	-	-	-	-	-	217	4805	108	9610	54	19045
	fs/4	-	-	108	1201	54	2381	-	-	-	-	-	-
	fs/16	108	300	-	-	-	-	-	-	-	-	-	-
20.00	fosc	-	-	-	-	-	-	-	-	129	9615	64	19231
	fs/4	-	-	129	1202	64	2404	32	4735	-	-	-	-
	fs/16	129	300	-	-	-	-	-	-	-	-	-	-

■Pin Setup (1, 2 channels, at transmission)

Table 10-3-19 shows the pins setup at UART serial interface transmission. The pins setup is common to the TXD pin, RXD pin, regardless of those pins are independent / connected. The RXD pin can be used as general port (P01).

Table 10-3-19 UART Serial Interface Pin Setup (1, 2 channels, at transmission)

Setup item	Data output pin	Data input pin
	TXD pin	RXD pin
Pin	P00	P01
TXD / RXD pins	TXD / RXD pins are connected or independent	
	SC0MD3(SC0IOM)	
Function	Serial data output	"1" input
	SC0MD3(SC0SBOS)	SC0MD3(SC0SBIS)
Style	Push-pull / Nch open-drain	-
	SC0MD3(SC0SBOM)	
I/O	Output mode	-
	P0DIR(P0DIR0)	
Pul-up	Added / Not added	-
	P0PLU(P0PLU0)	

■Pin Setup (2 channels, at reception)

Table 10-3-20 shows the pins setup at UART serial interface reception with 2 channels (TXD pin, RXD pin). The TXD pin can be used as general port (P00).

Table 10-3-20 UART Serial Interface Pin Setup (2 channels, at reception)

Setup item	Data output pin	Data input pin
	TXD pin	RXD pin
Pin	P00	P01
TXD / RXD pin	TXD / RXD pins are independent	
	SC0MD3(SC0IOM)	
Function	port	serial data input
	SC0MD3(SC0SBOS)	SC0MD3(SC0SBIS)
Style	-	-
I/O	-	input mode
	-	P0DIR(P0DIR1)
Pull-up	-	added / not added
		P0PLU(P0PLU1)

■Pin Setup (1 channel, at reception)

Table 10-3-21 shows the pin setup at UART serial interface reception with 1 channel (TXD pin). The RXD pin can be used as general port (P01).

Table 10-3-21 UART Serial Interface Pin Setup (1 channel, at reception)

Setup item	Data output pin	Serial unused pin
	TXD pin	RXD pin
Pin	P00	P01
TXD / RXD pin	TXD / RXD pins are connected	
	SC0MD3(SC0IOM)	
Function	Port	Serial data input
	SC0MD3(SC0SBOS)	SC0MD3(SC0SBIS)
Style	-	-
I/O	Input mode	-
	P0DIR(P0DIR0)	-
Pull-up	added / not added	-
	P0PLU(P0PLU0)	

10-3-4 Setup Example

■Transmission Setup

The setup example at UART transmission with serial interface 0 is shown.

Table 10-3-22 shows the conditions at transmission.

Table 10-3-22 UART Interface Transmission Setup

Setup item	set to
TXD / RXD pin	connected (with 1 channel)
Frame mode specification	8 bits + 2 stop bits
First transfer bit	MSB
Clock source	timer 3 output
TXD pin type	Nch open-drain
Pull-up resistor of TXD pin	not added
Parity bit add / check	"0"add / check
Serial interface 0 interrupt	Enable.

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Select the UART communication. SC0CTR (x'3F54') bp6 : SC0CMD = 1	(1) Set the SC0CMD flag of the SC0CTR register to "1" to select the UART communication.
(2) Select the first bit to be transferred. SC0MD0 (x'3F50') bp4 : SC0DIR = 0	(2) Select MSB as first transfer bit by the SC0DIR flag of the SC0MD0 register.
(3) Select the start condition. SC0MD0 (x'3F50') bp3 : SC0STE = 0	(3) Set the SC0STE flag of the SC0MD0 register to disable start condition. [☞ X-33 ■Selection of Start Condition]
(4) Select the clock source. SC0MD1 (x'3F51') bp4-3 : SC0CK1-0 = 11	(4) Set the SC0CK1-0 flag to select timer 3 output as a clock source.
(5) Select the parity bit. SC0MD2 (x'3F52') bp0 : SC0NPE = 0 bp2-1 : SC0PM1-0 = 00	(5) Set the SC0NPE flag of the SC0MD2 register to select "parity is enabled", and set the SC0PM1-0 flag to select "0 added".

Setup Procedure	Description
(6) Specify the flame mode. SC0MD2 (x'3F52') bp4-3 : SC0FM1-0 = 11	(6) Set the SC0FM1-0 flag of the SC0MD2 register to "11" to select 8 bits data + 2 stop bits at the frame mode.
(7) Control the output data. SC0MD2 (x'3F52') bp5 : SC0BRKE = 0	(7) Set the SC0BRKE flag of the SC0MD2 register to "0" to select serial data transmission.
(8) Select the pin type. SC0MD3 (x'3F53') bp4 : SC0SBOM = 1 P0PLU (x'3F40') bp0 : P0PLU0 = 0	(8) Set the SC0SBOM flag of the SC0MD3 register to "1" to select N-ch open drain for the TXD pin. Set the P0PLU0 flag of the P0PLU register to "0" not to add pull-up resistor.
(9) Select the reception mode. SC0MD3 (x'3F53') bp5 : SC0IOM = 1	(9) Set the SC0IOM flag of the SC0MD3 register to "1" to set the SBO0 to transmission / reception port.
(10) Control the pin direction. P0DIR (x'3F30') bp0 : P0DIR0 = 1	(10) Set the P0DIR0 flag of the P0DIR register to "1" to set P00 to output mode.
(11) Select the interrupt level. SC0ICR (x'03FE8') bp7-6 : SC0LV1-0 = 10	(11) Select the interrupt level by the SC0LV1-0 flag of the serial interface 0 interrupt control register (SC0ICR).
(12) Enable the interrupt. SC0ICR (x'3FE8') bp1 : SC0IE = 1	(12) Set the SC0IE flag of the SC0ICR register to "1" to enable the interrupt request. If any interrupt request flag had already been set, clear it. [☞ Chapter 3. 3-1-4 Interrupt Flag Setup]
(13) Set the baud rate timer.	(13) Set the baud rate timer by the TM3MD register, TM3OC register. And set the TM3EN flag to "1" to operate timer 3. [☞ Chapter 5. 5-7 Serial interface transfer clock output]
(14) Set the serial interface communication. SC0MD3 (x'3F53') bp2 : SC0SBOS = 1	(14) Set the SC0SBOS flag of the SC0MD3 register to "1" to set the serial interface communication.
(15) Start the serial interface communication. SC0TRB (x'3F55')	(15) Set the transfer data to the SC0TRB register. And the serial interface communication is started.

Only timer 3 can be used as a baud rate timer.
For baud rate setup, refer to Chapter 5. 5-7 Serial Interface Transfer Clock Output.

Serial interface 0 is operated by setting the SC0SBOS flag or the SC0SBIS flag of the SC0MD3 register to "1".
The SC0SBOS flag or the SC0SBIS flag should be set after all conditions are set.
After that, at transmission, the communication is started by writing data to the SC0TRB.

When a register except the SC0TRB is written / rewritten, set the SC0SBOS, the SC0SBIS flag to "0", in advance.

When the TXD / RXD pin are connected for communication with 1 channel, the TXD pin inputs / outputs serial data. The port direction control register P0DIR should be set, for switching input / output. The RXD pin can be used as a general port.

When the serial interface port is enabled, if the SC0CE1-0 flag of the SC0MD0 register is switched, the transfer bit count may be changed. If it is used as half-duplex UART serial interface, setting the SC0CE1-0 flag fixed to "00" is recommended.

After transmission has completed, the TXD pin is "H" level.

If the frame mode is set by the SC0FM flag of the SC0MD2 register, the SC0LNG2-0 flag of the SC0MD0 register is automatically set.

After the transfer has completed, the transfer bit count in the SC0LNG2-0 flag of the SC0MD0 register is automatically set.

At UART transmission, set the SC0SBOS flag of the SC0MD3 register to "1", and set the SC0SBIS flag to "0". Setting both of flags to "1" is disabled.

■Reception Setup

The setup example at UART reception with serial interface 0 is shown.

Table 10-3-23 shows the conditions at reception.

Table 10-3-23 UART Interface Transmission Reception Setup

Setup item	set to
TXD / RXD pin	connected (with 1 channel)
Frame mode specification	8 bits + 2 stop bits
First transfer bit	MSB
Clock source	timer 3
TXD pin type	Nch open-drain
Pull-up resistor of TXD pin	added
Parity bit add / check	"0"add / check
Serial 0 interface interrupt	Enable.

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Select the UART communication. SC0CTR (x'3F54') bp6 : SC0CMD = 1	(1) Set the SC0CMD flag of the SC0CTR register to "1" to select the UART communication.
(2) Select the first bit to be transferred. SC0MD0 (x'3F50') bp4 : SC0DIR = 0	(2) Select MSB as first transfer bit by the SC0DIR flag of the SC0MD0 register.
(3) Select the start condition. SC0MD0 (x'3F50') bp3 : SC0STE = 0	(3) Set the SC0STE flag of the SC0MD0 register to disable start condition. [☞ X-33 ■Selection of Start Condition]
(4) Select the clock source. SC0MD1 (x'3F51') bp4-3 : SC0CK1-0 = 11	(4) Set the SC0CK1-0 flag of the SC0MD1 register to select timer 3 output as a clock source.
(5) Select the parity bit. SC0MD2 (x'3F52') bp0 : SC0NPE = 0 bp2-1 : SC0PM1-0 = 00	(5) Set the SC0NPE flag of the SC0MD2 register to select "parity is enabled", and set the SC0PM1-0 flag to select "0 checked".
(6) Specify the frame mode. SC0MD2 (x'3F52') bp4-3 : SC0FM1-0 = 11	(6) Set the SC0FM1-0 flag of the SC0MD2 register to "11" to select 8 bits data + 2 stop bits at the frame mode.
(7) Select the reception mode. SC0MD3 (x'3F53') bp5 : SC0IOM = 1	(7) Set the SC0IOM flag of the SC0MD3 register to "1" to set the SBO0 to transmission / reception port.

Setup Procedure	Description
(8) Control the pin direction. P0DIR (x'3F30') bp0 : P0DIR0 = 0	(8) Set the P0DIR0 flag of the P0DIR register to "0" to set the TXD pin to input mode.
(9) Add pull-up resistor to the TXD pin. P0PLU (x'3F40') bp0 : P0PLU0 = 1	(9) Set the P0PLU0 flag of the P0PLU register to add pull-up resistor to the TXD pin.
(10) Select the interrupt level. SC0ICR (x'03FE8') bp7-6 : SC0LV1-0 = 10	(10) Select the interrupt level by the SC0LV1-0 flag of the serial interface 0 interrupt control register (SC0ICR).
(11) Enable the interrupt. SC0ICR (x'3FE8') bp1 : SC0IE = 1	(11) Set the SC0IE flag of the SC0ICR register to "1" to enable the interrupt request. If any interrupt request flag had already been set, clear it. [☞ Chapter 3. 3-1-4 Interrupt Flag Setup]
(12) Set the baud rate timer.	(12) Set the baud rate timer by the TM3MD register, TM3OC register. And set the TM3EN flag to "1" to operate timer 3.
(13) Set the serial interface communication. SC0MD3 (x'3F53') bp1 : SC0SBIS = 1	(13) Set the SC0SBIS flag of the SC0MD3 register to "1" to set the serial interface communication.
(14) Start the serial interface reception. Received data → Input to TXD	(14) After start bit is received by inputting serial interface data from the TXD pin, the received data is stored to the serial interface transmission / reception shift register (SC0TRB). When the reception has completed, the serial interface 0 interrupt (SC0IRQ) is generated, then, the received data is stored to the received buffer (SC0RXB).

When the TXD / RXD pin are connected for communication with 1 channel, the TXD pin inputs / outputs serial data. The port direction control register P0DIR should be set, for switching input / output. At reception, the SC0SBIS flag of the SC0MD3 register should be set to "1" and select "serial interface data input". The RXD pin can be used as a general port.

Only timer 3 can be used as a baud rate timer.
For baud rate setup, refer to Chapter 5. 5-7 Serial Interface Transfer Clock Output.

Serial interface 0 is operated by setting the SC0SBOS flag or the SC0SBIS flag of the SC0MD3 register to "1".
The SC0SBOS flag or the SC0SBIS flag should be set after all conditions are set.
After that, at reception, the communication is started by receiving start bit.

When a register except the SC0TRB is written / rewritten, set the SC0SBOS, the SC0SBIS flag of the SC0MD3 register to "0", in advance.

When the TXD / RXD pin are connected for communication with 1 channel, the TXD pin inputs / outputs serial data. The port direction control register P0DIR should be set, for switching input / output. The RXD pin can be used as a general port.

When the serial interface port is enabled, if the SC0CE1-0 flag of the SC0MD0 register is switched, the transfer bit count may be changed. If it is used as half-duplex UART serial interface, setting the SC0CE1-0 flag fixed to "00" is recommended.

After reception has completed, the TXD pin is "H" level.

If the frame mode is set by the SC0FM flag of the SC0MD2 register, the SC0LNG2-0 flag of the SC0MD0 register is automatically set.

After the transfer has completed, the transfer bit count in the SC0LNG2-0 flag of the SC0MD0 register is automatically set.

At UART reception, set the SC0SBIS flag of the SC0MD3 register to "1", and set the SC0SBOS flag to "0". Setting both of flags to "1" is disabled.

Chapter 11 A/D Converter

11

11-1 Overview

This LSI has an A/D converter with 10 bits resolution. That has a built-in sample hold circuit, and its analog input can be switched in channel 0 to 7 (AN0 to AN7) by software. As A/D converter is stopped, the power consumption can be reduced by a built-in ladder resistance.

11-1-1 Functions

Table 11-1-1 shows the A/D converter functions.

Table 11-1-1 A/D Converter Functions

A/D input pins	8 pins
Pins	AN7 to AN0
Interrupt	ADIRQ
Resolution	10 bits
Conversion time (min.)	9.6 μs (as T_{AD} =800 ns)
Input range	V_{DD} to V_{SS}
Power consumption	Built-in ladder resistance (ON/OFF)

11-1-2 Block Diagram

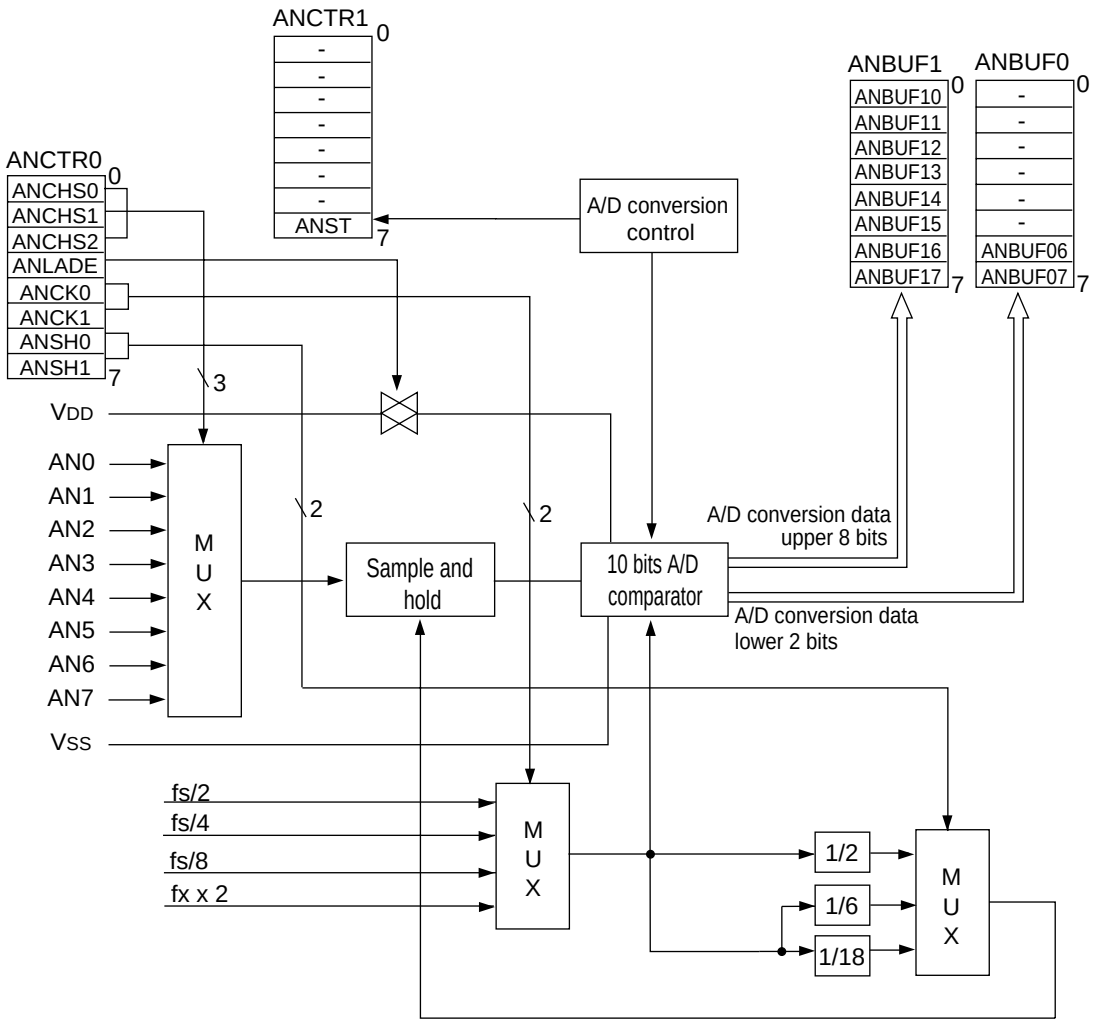


Figure 11-1-1 A/D Converter Block Diagram

11-2 Control Registers

A/D converter consists of the control register (ANCTRn) and the data storage buffer (ANBUFn).

11-2-1 Registers

Table 11-2-1 shows the registers used to control A/D converter.

Table 11-2-1 A/D Converter Control Registers

Register	Address	R/W	Function	Page
ANCTR0	x'03F90'	R/W	A/D converter control register 0	XI - 5
ANCTR1	x'03F91'	R/W	A/D converter control register 1	XI - 6
ANBUF0	x'03F92'	R	A/D buffer 0	XI - 7
ANBUF1	x'03F93'	R	A/D buffer 1	XI - 7
ADICR	x'03FEA'	R/W	A/D converter interrupt control register	III - 27
PAIMD	x'03F3A'	R/W	Port A input mode register	IV - 28
PAPLUD	x'03F4A'	R/W	Port A pull-up/pull-down resistance control register	IV - 28

R/W : Readable/Writable
R : Readable only

11-2-2 Control Registers

■A/D Converter Control Register 0 (ANCTR0)

	7	6	5	4	3	2	1	0
ANCTR0	ANSH1	ANSH0	ANCK1	ANCK0	ANLADE	ANCHS2	ANCHS1	ANCHS0

(At reset : X X X X 0 X X X)

ANCHS2	ANCHS1	ANCHS0	Analog input selection
0	0	0	AN0
		1	AN1
	1	0	AN2
		1	AN3
1	0	0	AN4
		1	AN5
	1	0	AN6
		1	AN7

ANLADE	A/D ladder resistance control
0	A/D ladder resistance OFF
1	A/D ladder resistance ON

ANCK1	ANCK0	A/D conversion clock (ftad=1/TAD)
0	0	fs/2
	1	fs/4
1	0	fs/8
	1	fx x 2

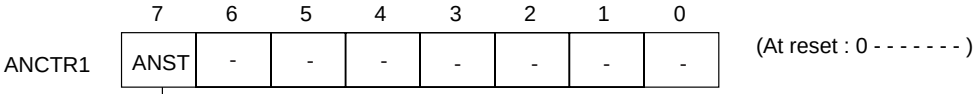
* as 800 ns < T_{AD} ≤ 15.26 μs

ANSH1	ANSH0	Sample and hold time
0	0	T_{AD} x 2
	1	T_{AD} x 6
1	0	T_{AD} x 18
	1	Not to use

* Sampling and holding time is decided by the input impedance at analog input.
T_{AD} means the cycle for A/D conversion clock.

Figure 11-2-1 A/D Converter Control Register 0 (ANCTR0 : x'03F90', R/W)

■A/D Converter Control Register 1 (ANCTR1)



ANST	A/D conversion status
0	A/D conversion is completed, stopped.
1	A/D conversion is started, in progress.

Figure 11-2-2 A/D Converter Control Register 1 (ANCTR1 : x'03F91', R/W)

11-2-3 A/D Buffers

They are reading only registers that stores result of A/D conversion.

■A/D Buffer 0 (ANBUF0)

The lower 2 bits from the result of A/D conversion are stored to this register.

	7	6	5	4	3	2	1	0	
ANBUF0	ANBUF07	ANBUF06	-	-	-	-	-	-	(at reset : X X - - - - - -)

Figure 11-2-3 A/D Buffer 0 (ANBUF0 : x'03F92', R)

■A/D Buffer 1 (ANBUF1)

The upper 8 bits from the result of A/D conversion are stored to this register.

	7	6	5	4	3	2	1	0	
ANBUF1	ANBUF17	ANBUF16	ANBUF15	ANBUF14	ANBUF13	ANBUF12	ANBUF11	ANBUF10	(at reset : X X X X X X X X)

Figure 11-2-4 A/D Buffer 1 (ANBUF1 : x'03F93', R)

11-3 Operation

Here is a description of A/D converter circuit setup procedure.

(1) Set the analog pins.
Set the analog input pin, set in (2), to "special function pin" by the port A input mode register (PAIMD).
*** Setup for the port A input mode register should be done before analog voltage is put to pins.**

(2) Select the analog input pin.
Select the analog input pin from AN7 to AN0 (PA7 to PA0) by the ANCHS2 to ANCHS0 flag of the A/D converter control register 0 (ANCTR0).

(3) Select the A/D converter clock.
Select the A/D converter clock by the ANCK1, ANCK0 flag of the A/D converter control register 0 (ANCTR0).
The converter clock (TAD) should not be under 800 ns with any resonator.

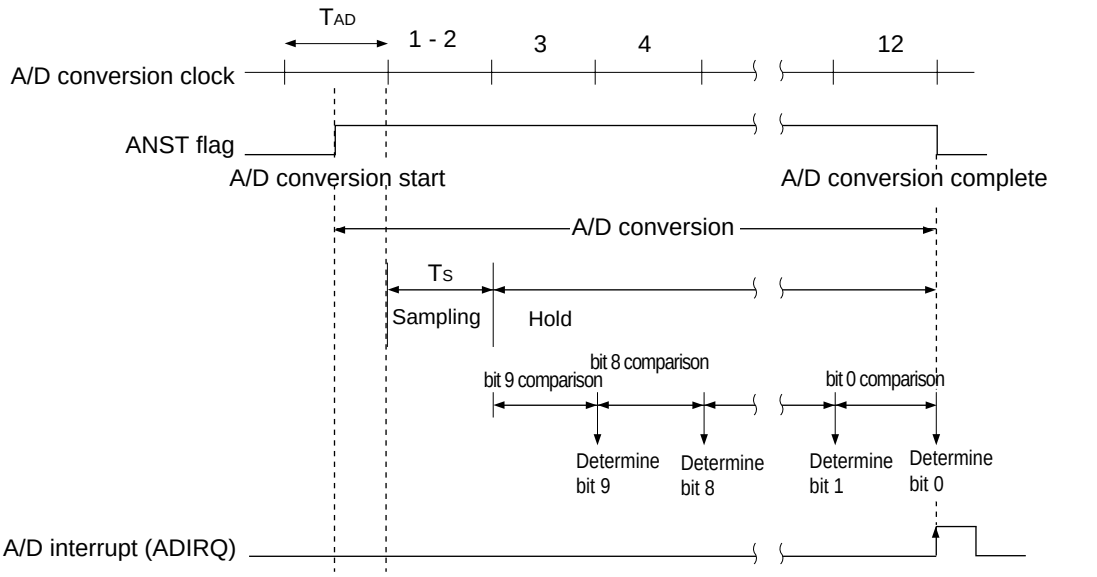
(4) Set the sample hold time.
Set the sample hold time by the ANSH1, ANSH0 flag of the A/D converter control register 0 (ANCTR0). The sample hold time should be based on analog input impedance.

(5) Set the A/D ladder resistance.
Set the ANLADE flag of the A/D converter control register 0 (ANCTR0) to "1", and a current flow through the ladder resistance and A/D converter goes into the waiting.
*** (2) to (5) are not in order. (3), (4) and (5) can be operated simultaneously.**

(6) Start the A/D conversion.
Set the ANST flag of the A/D converter control register 1 (ANCTR1) to "1" to start A/D converter.

(7) A/D conversion
Each bit of the A/D buffer 0, 1 is generated after being sampled during sample and hold time set in (3).
Each bit is generated in sequence from MSB to LSB.

(8) Complete the A/D conversion.
When A/D conversion has finished, the ANST flag is cleared to "0", and the result of the conversion is stored to the A/D buffer (ANBUF0, 1). At the same time, the A/D complete interrupt request (ADIRQ) is generated.



* This example is as sampling and hold time is TAD x 2.

Figure 11-3-1 Operation of A/D Conversion

To read the value of the A/D conversion, A/D conversion should be done several times to prevent noise error by confirming the match of level by program, or by using the average value.

11-3-1 Setup

■Input Pins of A/D Converter Setup

Input pins for A/D converter is selected by the ANCH2 to 0 flag of the ANCTR0 register.

Table 11-3-1 Input Pins of A/D Converter Setup

ANCHS2	ANCHS1	ANCHS0	A/D pin
0	0	0	AN0 pin
		1	AN1 pin
	1	0	AN2 pin
		1	AN3 pin
1	0	0	AN4 pin
		1	AN5 pin
	1	0	AN6 pin
		1	AN7 pin

■Clock of A/D Converter Setup

The A/D converter clock is set by the ANCK1 to 0 flag of the ANCTR0 register. Set the A/D converter clock (TAD) more than 800 ns and less than 15.26 µs. Table 11-3-2 shows the machine clock (fosc, fx, fs) and the A/D converter clock (TAD). (calculated as fs = fosc/2, fx/4)

Table 11-3-2 A/D Conversion Clock and A/D Conversion Cycle

ANCK1	ANCK0	A/D conversion clock	A/D conversion cycle (TAD)		
			at oscillation for high speed		at oscillation for low speed
			at fosc=20 MHz	at fosc=8.38 MHz	at fx=32.768 kHz
0	0	fs/2	200.00 ns (unusable)	477.33 ns (unusable)	244.14 µs (unusable)
	1	fs/4	400.00ns (unusable)	954.65ns	488.28 µs (unusable)
1	0	fs/8	800.00 ns	1.91 µs	976.56 µs (unusable)
	1	fx x 2	15.26 µs	15.26 µs	15.26 µs

■Sampling Time (Ts) of A/D Converter Setup

The sampling time of A/D converter is set by the ANSH1 to 0 flag of the ANCTR0 register. The sampling time of A/D converter depends on external circuit, so set the right value by analog input impedance.

Table 11-3-3 Sampling Time of A/D Conversion and A/D Conversion Time

ANSH1	ANSH0	Sampling time (Ts)	A/D conversion time			
			at TAD=800 ns	at TAD=954.65 ns	at TAD=1.91 µs	at TAD=15.26 µs
0	0	TAD x 2	9.60 µs	11.46 µs	22.92 µs	183.12 µs
	1	TAD x 6	12.80 µs	15.27 µs	30.56 µs	244.16 µs
1	0	TAD x 18	22.40 µs	26.73 µs	53.48 µs	427.28 µs
	1	Reserved	-	-	-	-

■Built-in Ladder Resistor Control

The ANLADE flag of the ANCTR0 register is set to "1" to send a current to the ladder resistance for A/D conversion. As A/D converter is stopped, the ANLADE flag of the ANCTR0 register is set to "0" to save the power consumption.

Table 11-3-4 A/D Ladder Resistor Control

ANLADE	A/D ladder resistance control
0	A/D ladder resistance OFF (A/D conversion stopped)
1	A/D ladder resistance ON (A/D conversion stopped)

■A/D Conversion Starting Setup

A/D conversion starting is set by the ANST flag of the ANCTR1 register. The ANST flag of the ANCTR1 register is set to "1" to start A/D conversion. Also, the ANST flag of the ANCTR1 register is set to "1" during A/D conversion, then cleared to "0" as the A/D conversion complete interrupt is generated.

Table 11-3-5 A/D Conversion Starting

ANST	A/D conversion status
1	A/D conversion started or in progress.
0	A/D conversion completed or stopped.

11-3-2 Setup Example

■A/D Converter Setup Example by Registers

A/D conversion is started by setting registers. The analog input pins are set to AN0, the converter clock is set to fs/4, and the sampling hold time is set to TAD x 6. Then, A/D conversion complete interrupt is generated.

An example setup procedure, with a description of each step is shown below.

Setup Procedure	Description
(1) Set the analog input pin. PAIMD (x'3F3A') bp0 : PAIMD0 = 1 PAPLUD (x'3F4A') bp0 : PAPLUD0 = 0	(1) Set the analog input pin, set in (2), to the special function pin by the port A input mode register (PAIMD). Also, set no pull-up/pull-down resistance by the port A pull-up/pull-down resistance control register (PAPLUD).
(2) Select the analog input pin. ANCTR0 (x'3F90') bp2-0 : ANCHS2-0 = 000	(2) Set the AN0 (PA0) to the analog input pin by setting the ANCHS2-0 flag of the A/D converter control register 0 (ANCTR0) to "000".
(3) Select the A/D converter clock. ANCTR0 (x'3F90') bp5-4 : ANCK1-0 = 01	(3) Set the fs/4 to the A/D converter clock by setting the ANCK1, ANCK0 flag of the A/D converter control register 0 (ANCTR0) to "01".
(4) Set the sample and hold time. ANCTR0 (x'3F90') bp7-6 : ANSH1-0 = 01	(4) Set the TAD x 6 to the sample and hold time by setting the ANSH1, ANSH0 flag of the A/D converter control register 0 (ANCTR0) to "01".
(5) Set the interrupt level. ADICR (x'3FEA') bp7-6 : ADLV1-0 = 00	(5) Set the interrupt level by the ADLV1-0 flag of the A/D conversion complete interrupt control register (ADICR). If any interrupt request flag had already been set, clear it. [☞ Chapter 3. 3-1-4 Interrupt Flag Setting]
(6) Enable the interrupt. ADICR (x'3FEA') bp1 : ADIE = 1	(6) Enable the interrupt by setting the ADIE flag of the ADICR register to "1".
(7) Set the A/D ladder resistance. ANCTR0 (x'3F90') bp3 : ANLADE = 1	(7) Set the ANLADE flag of the A/D converter control register 0 (ANCTR0) to "1" to send a current to the ladder resistance for the A/D conversion.

Setup Procedure	Description
(8) Start the A/D conversion. ANCTR1 (x'3F91') bp7 : ANST = 1	(8) Set the ANST flag of the A/D converter control register 1 (ANCTR1) to "1" to start the A/D conversion.
(9) Complete the A/D conversion. ANBUF0 (x'3F92') ANBUF1 (x'3F93')	(9) When the A/D conversion has finished, the A/D conversion complete interrupt is generated and the ANST flag of the A/D converter control register 1 (ANCTR1) is cleared to "0". The result of the conversion is stored to the A/D converter buffer (ANBUF0, 1).

Note : The above (2) to (4) can be set at once.

Start the A/D conversion after the current flowing through the ladder resistors stabilizes. The wait time should be decided by the calculated time from the ladder resistance (max. 80 kΩ) and the external bypass capacitor connected between V_{REF+} and V_{REF-}.

11-3-3 Cautions

Since A/D conversion can be damaged by noise easily, antinoise measures should be taken.

■Antinoise transaction
For A/D input (analog input pin), add condenser near the Vss pins of micro controller.

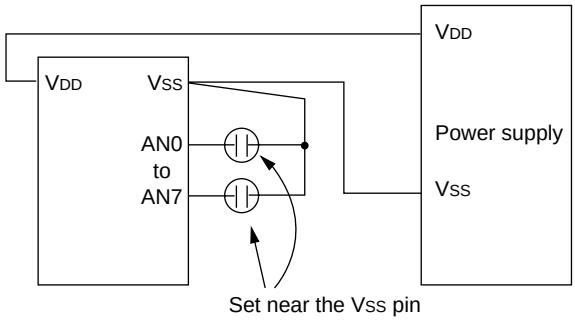
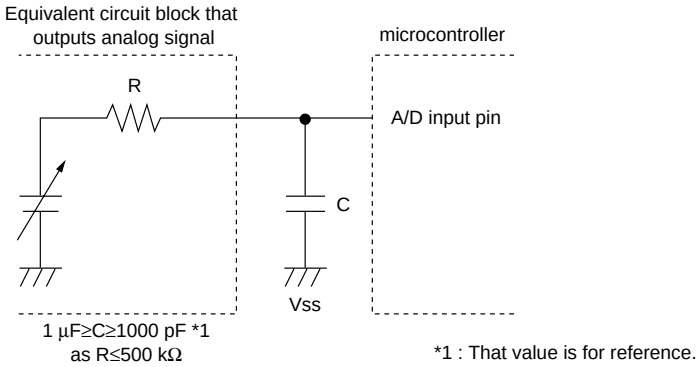


Figure 11-3-2 A/D Converter Recommended Example 1

For high precision of A/D conversion, the following cautions on A/D converter should be kept.

1. The input impedance R of A/D input pin should be under 500 kΩ[*1], and the external capacitor C (more than 1000 pF, under 1 μF)[*1].
2. The A/D conversion frequency should be set with consideration of R, C time constant.
3. At the A/D conversion, if the input level of micro controller is changed, or the peripheral added circuit is switched to ON/OFF, the A/D conversion may work wrongly, because the analog input pins and power pins does not fix. At the check of the setup, confirm the wave form of analog input pins.



Recommend Connection with A/D Converter

Chapter 12 Appendices

12-1 EPROM Version

12-1-1 Overview

EPROM version is microcomputer which was replaced the mask ROM of the MN101C457 with an electronically programmable EPROM. There are MN101CP427DP/BF/HP and PX-AP101C42-SDC/FBC for MN101C457.

The MN101CP427DP, the MN101CP427BF and MN101C427HP are sealed in plastic. Once data is written to the internal EPROM, it cannot be erased. The PX-AP101C42-SDC and PX-AP101C42-FBC are sealed in a ceramic package with a window. Written data can be erased by exposing the physical chip to intense ultraviolet radiation. We offer the 42-pin shrink DIL package, the 44-pin flat package and the 48-pin flat package of plastic packages, and the 42-pin shrink DIL package and 44-pin flat package of ceramic packages.

Setting the EPROM version to EPROM mode, functions as a microcomputer are halted, and the internal EPROM can be programmed. For EPROM mode pin connection, refer to figure 12-1-2, 12-1-3 and 12-1-4. Programming Adapter Connection.

The specification for writing to the internal EPROM are the same as for a general-purpose 256 K-bit EPROM (V_{PP}=12.5 V, tpw=1 ms). Therefore, by using a dedicated programming adapter (supplied by Panasonic) which can convert the 42 (44, 48) pin of EPROM version to 28 pin, having the same configuration as a normal EPROM, a general-purpose ROM writer can be used to perform read and write operations.

The EPROM Version is described on the following items :

- Cautions on use of the internal EPROM
- Erasing Data in Windowed Package (PX-AP101C42-SDC/FBC)
- Differences between mask ROM version and EPROM version
- Writing to the Microcomputer with internal EPROM
- Cautions on handling a ROM writer
- Programming Adapter Connection
- Option bit

12-1-2 Cautions on Use

EPROM Version differs from the MN101C457 Mask ROM Version in some of its electrical characteristics. The user should be aware of the following cautions :

(1) To prevent data from being erased by ultraviolet light after a program is written, affix seals impermeable to UV rays to the glass sections at the top and side sections of the CPU. (PX-AP101C42-FBC, PX-AP101C42-SDC)

(2) Because of device characteristics of the MN101CP42xxx, a writing test cannot be performed on all bits.Therefore, the reliability of data writing may not be 100% ensured.

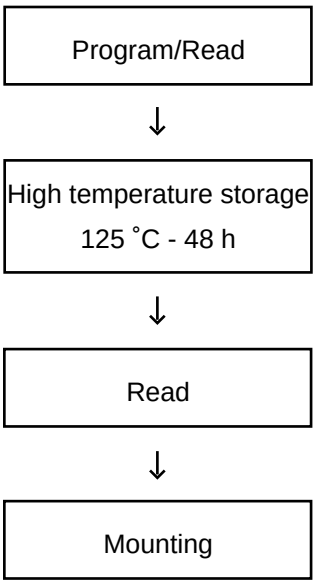
(3) When a program is being written, be sure that V_{DD} power supply (6 V) is connected before applying the V_{PP} power supply (12.5 V). Disconnect the V_{PP} supply before disconnecting the V_{DD} supply.

(4) V_{PP} should never exceed 13.5 V including overshoot.

(5) If a device is removed while a V_{PP} of +12.5 V is applied, device reliability may be damaged.

(6) At NCE=V_{IL}, do not change Vpp from V_{IL} to +12.5 V or from +12.5 V to V_{IL}.

(7) After a program is written, screening at a high temperature storage before mounting is recom mended.



12-1-3 Erasing Data in Windowed Package (PX-AP101C42-FBC/SDC)

To erase data of an internal EPROM with windowed packaging ("0" → "1"), UV light at 253.7 nm is used to irradiate the chip through a permeable cover.

The recommended exposure is 10 W·s/cm^2. This coverage can be achieved by using a commercial UV lamp positioned 2 to 3 cm above the package for 14 - 20 minutes (when the illumination intensity of the package surface is 12000 μW/cm^2). Remove any filters attached to the lamp. With a mirrored reflector plate to the lamp, illumination intensity will increase 1.4 to 1.8 times, and decrease the erasure time.

If the window becomes dirty with oil, adhesive, etc., UV light permeability will get worse, causing the erasure time to increase. If this happens, clean with alcohol or another solvent that will not harm the package. The above recommended exposure has enough leeway, with several times as much as it takes to erase all the bits. It is based on the reliable data over all temperature and voltage. The lump and the level of illumination should be regularly checked and well controlled.

Data in internal EPROM with windowed packaging is erased by applying a light that the wavelength is shorter than 400 nm. Fluorescent lamp and sunlight are not able to erase data as much as UV light of 253.7 nm is, but those light sources are also able to erase data more or less. To expose those light sources for a long while can damage its system. To prevent this, cover the window with an opaque label.

If the wavelength is longer than 400 nm to 500 nm, data can not be erased. However, because of typical semiconductor characteristics, the circuit may malfunction if the chip is exposed to an extremely high illumination intensity. The chip will operate normally if this exposure is stopped. However, for areas where it is continuous, take necessary precautions against the light that the wavelength is longer than 400 nm.

12-1-4 Differences between Mask ROM version and EPROM version

The differences between the 8-bit microcomputer MN101C457 (Mask ROM version) and MN101CP427 are as follows ;

Table 12-1-1 Differences between Mask ROM version and internal EPROM version

	MN101C457 (Mask ROM version)	MN101CP427 (EPROM version)
Operating voltage	2.0 V to 5.5 V (0.477 µs / at 4.19 MHz) 2.0 V to 5.5 V (125 µs / at 32 kHz)	2.7 V to 5.5 V(0.477 µs / at 4.19 MHz) 2.7 V to 5.5 V (125 µs / at 32 kHz)
Pin DC Characteristics	Output current, input current and input judge level are the same.	
Option bits (Settings for operating mode after reset and watchdog timer frequency) [☞ Chapter 1 1-6. Option]	ROM option	EPROM option
	Data for ROM option setting is used as option data.	Data for EPROM option setting is used as option data.
Oscillation characteristics	The combination of oscillator and each version should be estimated to match when EPROM version is changed to Mask ROM version for mass production.	
Noise characteristics	EMC check should be done on each version when EPROM version is changed to Mask ROM version for mass production.	

There are no other functional differences.

12-1-5 Writing to Microcomputer with Internal EPROM

The device type that set by each ROM writer should be selected the mode for writing 256 K-bit EPROM. Set the writing voltage to 12.5 V.

■Mounting the device in the programming adapter and the position of the No.1 pin.

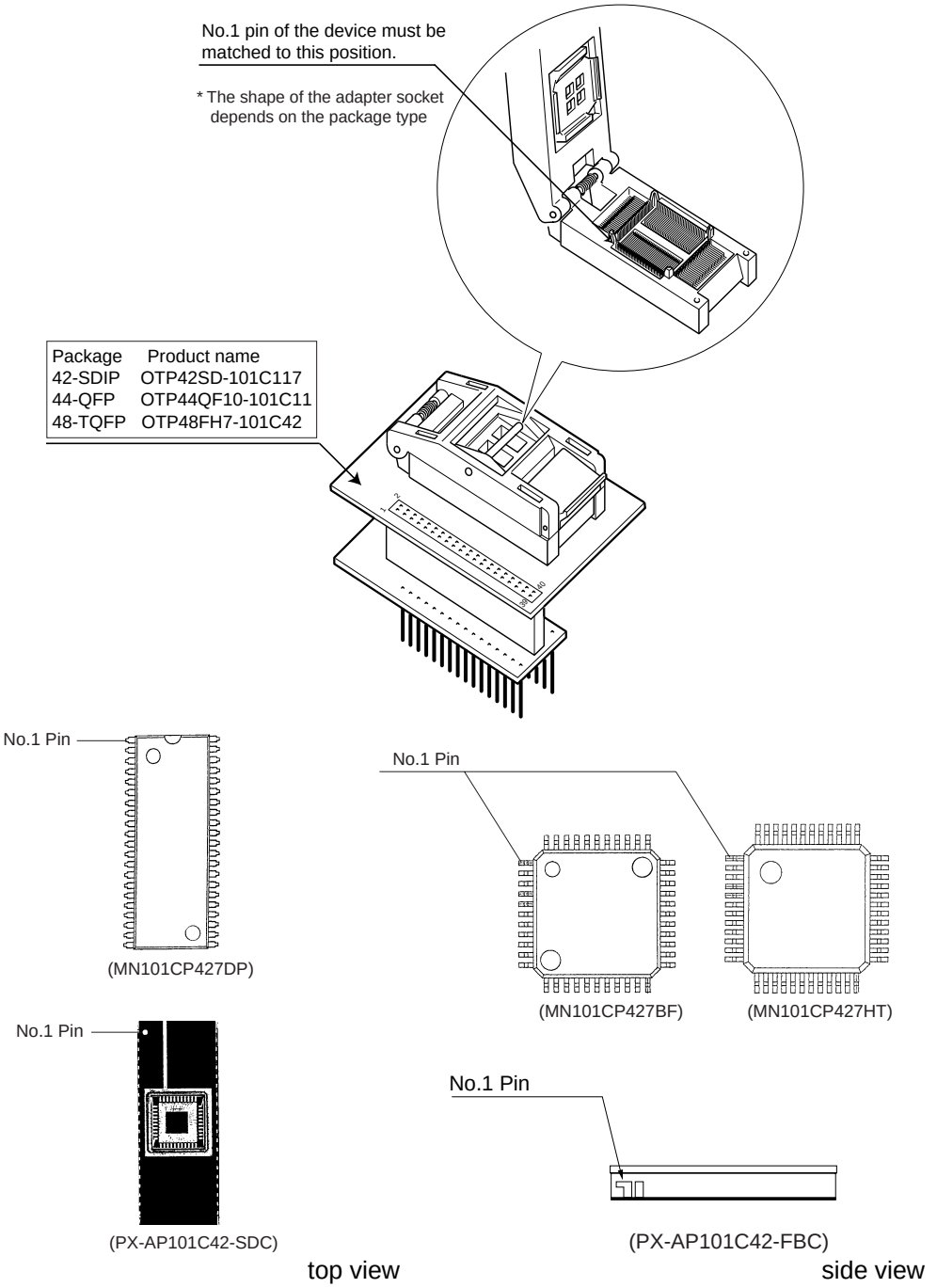


Figure 12-1-1 Mounting a Device in Programming Adapter and the Position of No.1 Pin

■ROM Writer Setup

The device types should be set up as listed below.

Table 12-1-2 Setup for Device Type

Equip. name	Vendor	Device type	Remarks
Pecker30	Aval Data	Hitachi 27C256	
		Mitsubishi 27C256	
1890A	Minato Electronics	Hitachi 27C256	
		Mitsubishi 27C256	
2900	Data I/O	Hitachi 27C256	Do not run ID check.
		Mitsubishi 27C256	
ChipLab	Data I/O	Hitachi 27C256	Do not run ID check and pin connection inspection.
		Mitsubishi 27C256	

The above table is based on the standard samples.

Please contact the nearest semiconductor design center (Refer to the sales office table attached at the end of the manual), when you use the other equipment.

12-1-6 Cautions on Operation of ROM Writer

■Cautions on Handling the ROM writer

(1) The V_{PP} programming voltage for the EPROM versions is 12.5 V.
Programming with a 21 V ROM writer can lead to damage. The ROM writer specifications must match those for standard 256 K-bit EPROM : V_{PP}=12.5 V ; tpw=1 ms.

(2) Make sure that the socket adapter matches the ROM writer socket and that the chip is correctly mounted in the socket adapter. Faulty connections can damage the chip.

(3) After clearing all memory of the ROM writer, load the program to the ROM writer.

(4) After confirming the device type, write the loaded program in (3) to this LSI address, from x'4000' to the final address of the internal ROM.

(5) There is the same address for ROM option setting, even on EPROM version.
[☞ Chapter 12 1-8. Option Bit]

The internal ROM space of this LSI is from x'4000'.
[☞ Chapter 2 2-2. Memory Space]

This writer has no internal ID codes of "Silicon Signature" and "Intelligent Identifier" of the auto-device selection command of ROM writer. If the auto-device selection command is to be executed for this writer, the device is likely damaged. Therefore, never use this command.

■When the writing is disabled

When the writing is disabled, check the following points.

(1) Check that the device is mounted correctly on the socket (pin bending, connection failure).

(2) Check that the erase check result is no problem.

(3) Check that the adapter type is identical to the device name.

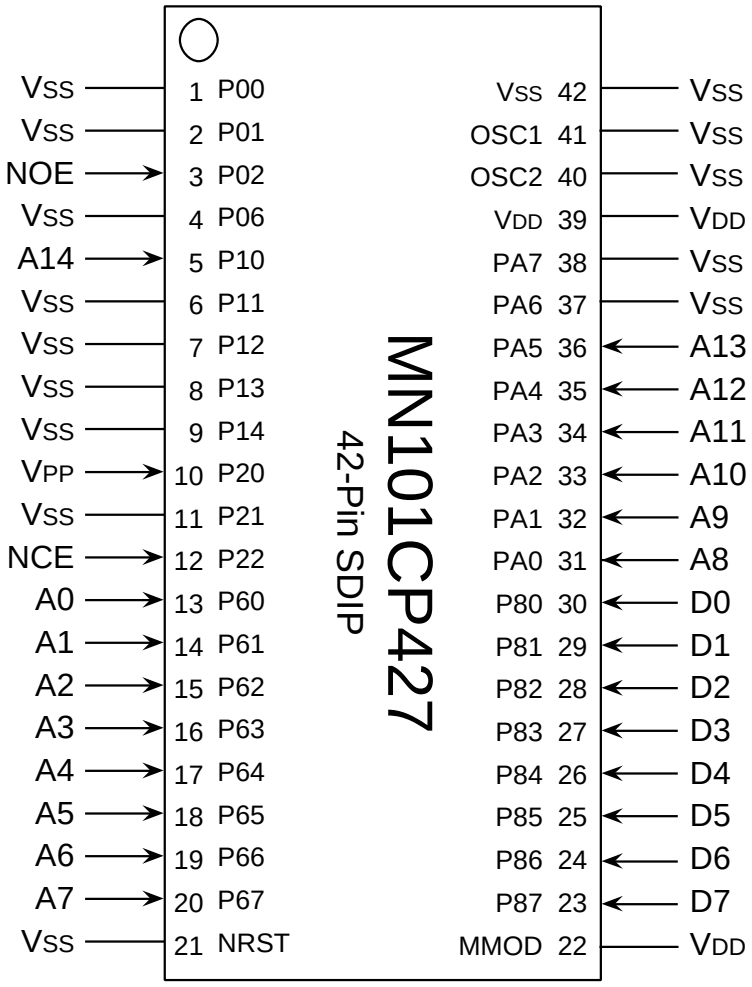
(4) Check that the writing mode is set correctly.

(5) Check that the data is correctly transferred to the ROM writer.

(6) Recheck the check points (1) to (5) provided on the above paragraph of 'Cautions on Handling the ROM writer'.

Please contact the nearest semiconductor design center (See the attached sales office table.), when the writing is disabled even after the above check points are confirmed and the device is replaced with another one.

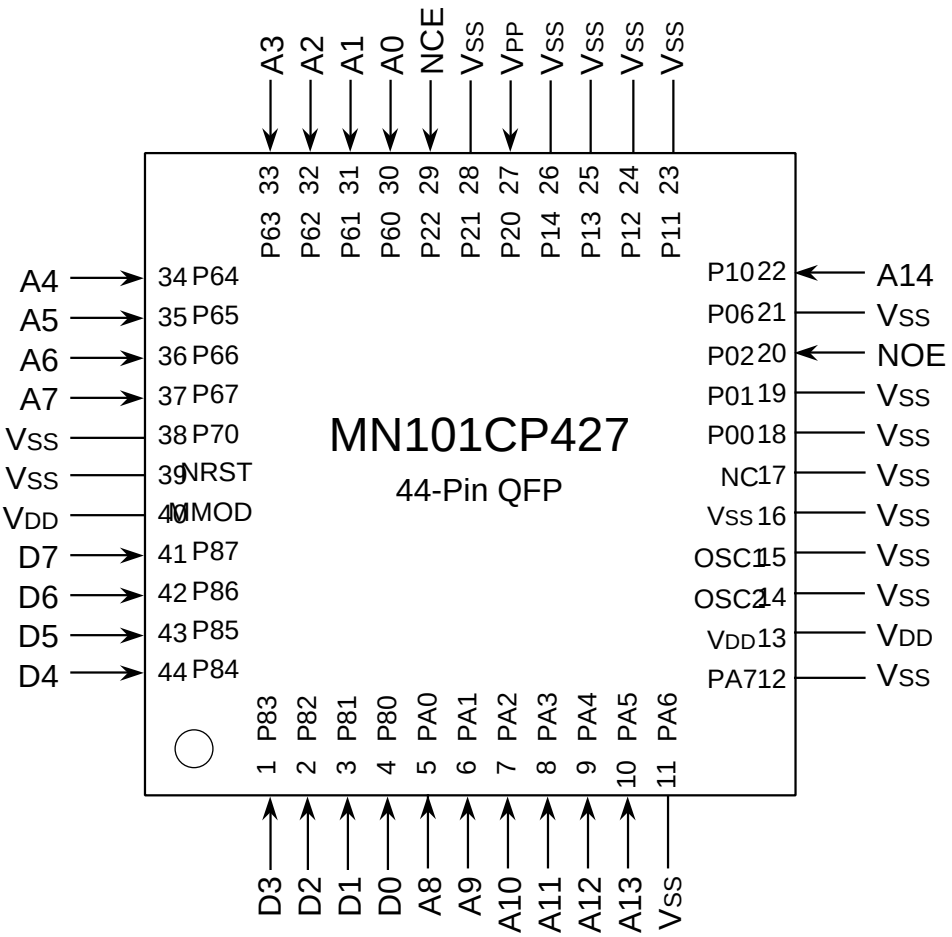
12-1-7 Programming Adapter Connection



Package code : SDIP042-P-0600

Figure 12-1-2 MN101CP427-DP(DC) EPROM Programming Adapter Connection

Refer to the pin connection drawing of the 256-K bit EPROM (27C256).



Package code : QFP044-P-1010
Pin pitch : 0.8 mm

Figure 12-1-3 MN101CP427-BL(BC) EPROM Programming Adapter Connection

Refer to the pin connection drawing of the 256-K bit EPROM (27C256).

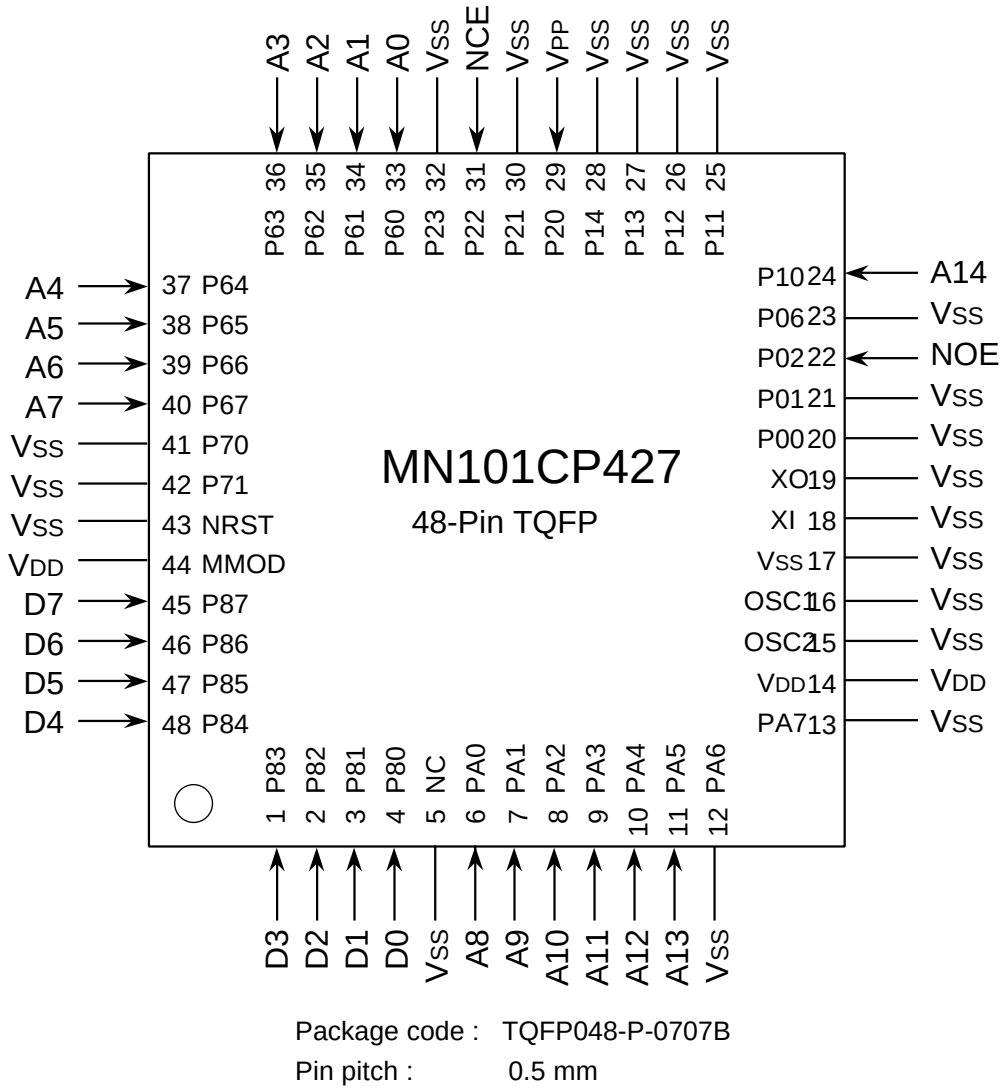


Figure 12-1-4 MN101CP427-HT EPROM Programming Adapter Connection

Refer to the pin connection drawing of the 256-K bit EPROM (27C256).

12-1-8 Option Bit

MN101CP427 has EPROM option address to specify the watchdog timer frequency, to select the package and to disenable the watchdog timer during the operation.

■EPROM Option Bits

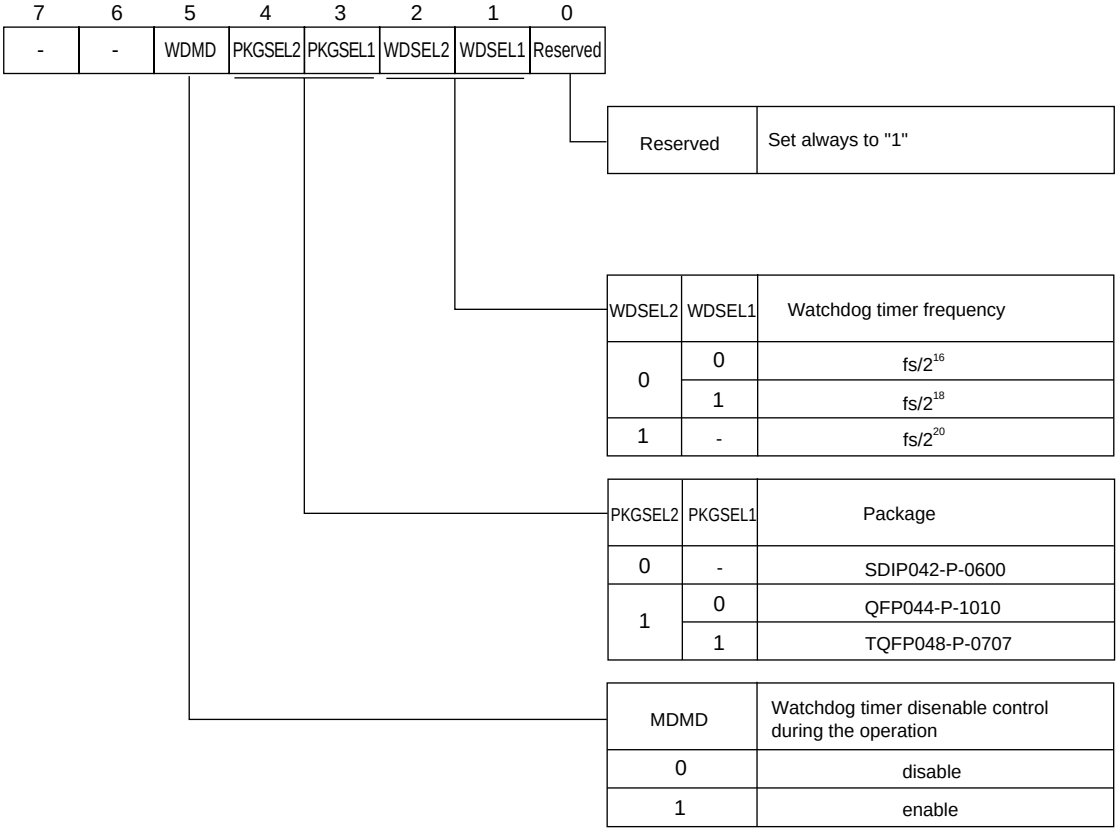


Figure 12-1-5 EPROM Option Bits

Model	EPROM option address
MN101CP427	x'07FFF'

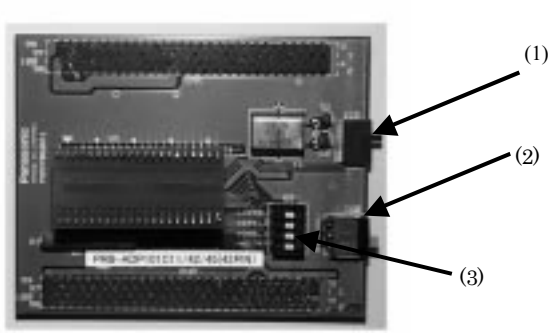
When the WDMD (bp5) is set to "0" and once the watchdog timer is started, the operation cannot be stopped.

12-2 Probe Switches

12-2-1 PRB-ADP101C11/42/45(42PIN) Probe Switches

Adapter boards differ depending upon the models. This adapter board can be used for only 101C11, 101C42 and 101C45(42 PIN).
Use this adapter board with EV board, PRB-EV101C15. Improper matching may cause any damage to the ICE. The switches that the adapter board provides for configuring the probe are described below.

Adapter Board Layout



(1)S2 (Oscillator control) : Set this switch to its USR position to drive the in-circuit emulator with the oscillator built into the target board. If there is no oscillator on the target board, set this switch to the ICE position to use the oscillator built into the probe.

(2)S1 (Power supply control)
: Set this switch to its USR position to use the power supply from the target board. If there is no oscillator on the target board , set this switch to the ICE position to use the 5 V power supply from the in-circuit emulator.
attention: To use A/D converter with power supply below 5 V, set this switch to its USR position. (Reference voltage is 5 V)

(3)Function control DIP switches
: Each model has different setting of DIPSW as described below.

(LCDSEL)
ON : For models which use LCD function.
OFF : For models which use LED function.

(WDSEL1, WDSEL2) Switches for watchdog timer frequency

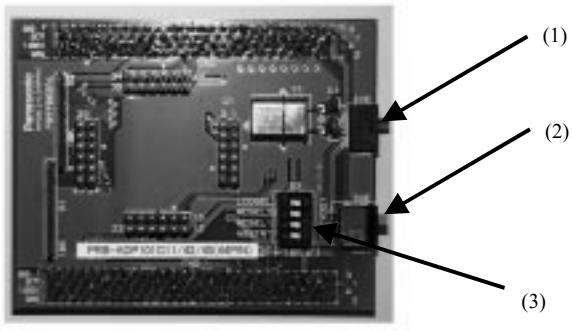
Pin's setting		Watchdog timer frequency
WDSEL1	WDSEL2	
OFF	OFF	fosc/2^{16}
ON	OFF	fosc/2^{18}
Don't care	ON	fosc/2^{20}

$\overline{\text{NSSTRT}}$ Switch for oscillation control at reset released.
ON : Start with the low speed (XI) oscillation (Do not switch on at 101C45).
OFF : Start with the high speed (OSC) oscillation.

12-2-2 PRB-ADP101C11/42/45(44PIN) Probe Switches

Adapter boards differ depending upon the models. This adapter board can be used for only 101C11, 101C42 and 101C45(44 PIN).
Use this adapter board with EV board, PRB-EV101C15. Improper matching may cause any damage to the ICE. The switches that the adapter board provides for configuring the probe are described below.

Adapter Board Layout



(1)S2 (Oscillator control) : Set this switch to its USR position to drive the in-circuit emulator with the oscillator built into the target board. If there is no oscillator on the target board, set this switch to the ICE position to use the oscillator built into the probe.

(2)S1 (Power supply control)
: Set this switch to its USR position to use the power supply from the target board. If there is no oscillator on the target board, set this switch to the ICE position to use the 5 V power supply from the in-circuit emulator.
attention: To use A/D converter with power supply below 5 V, set this switch to its USR position. (Reference voltage is 5 V)

(3)Function control DIP switches
: Each model has different setting of DIPSW as described below.

(LCDSEL)
ON : For models which use LCD function.
OFF : For models which use LED function.

(WDSEL1, WDSEL2) Switches for watchdog timer frequency

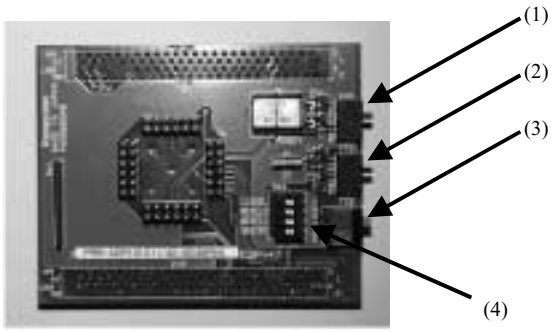
Pin's setting		Watchdog timer frequency
WDSEL1	WDSEL2	
OFF	OFF	fosc/2^{16}
ON	OFF	fosc/2^{18}
Don't care	ON	fosc/2^{20}

($\overline{\text{NSSTRT}}$) Switch for oscillation control at reset released.
ON : Start with the low speed (XI) oscillation (Do not switch on at 101C45).
OFF : Start with the high speed (OSC) oscillation.

12-2-3 PRB-ADP101C11/42/45(48PIN) Probe Switches

Adapter boards differ depending upon the models. This adapter board can be used for only 101C11, 101C42 and 101C45(48 PIN).
Use this adapter board with EV board, PRB-EV101C15. Improper matching may cause any damage to the ICE. The switches that the adapter board provides for configuring the probe are described below.

Adapter Board Layout



(1)SW1 (OSC control) : Set this switch to its USR position to drive the in-circuit emulator with the crystal oscillator 1 built into the target board. If there is no oscillator on the target board, set this switch to the ICE position to use the oscillator built into the probe.

(2)SW2 (XI control) : Set this switch to its USR position to drive the in-circuit emulator with the crystal oscillator 2 built into the target board. If there is no oscillator on the target board, set this switch to the ICE position to use the oscillator built into the probe.

(3)SW3 (Power supply control)
: Set this switch to its USR position to use the power supply from the target board. If there is no oscillator on the target board, set this switch to the ICE position to use the 5 V power supply from the in-circuit emulator.

attention: To use A/D converter with power supply below 5 V, set this switch to its USR position. (Reference voltage is 5 V)

(4)Function control DIP switches
: Each model has different setting of DIPSW as described below.

(LCDSEL)
ON : For models which use LCD function.
OFF : For models which use LED function.

(WDSEL1, WDSEL2) Switches for watchdog timer frequency

Pin's setting		Watchdog timer frequency
WDSEL1	WDSEL2	
OFF	OFF	fosc/2^{16}
ON	OFF	fosc/2^{18}
Don't care	ON	fosc/2^{20}

$\overline{\text{(NSSTRT)}}$ Switch for oscillation control at reset released.
ON : Start with the low speed (XI) oscillation (Do not switch on at 101C45).
OFF : Start with the high speed (OSC) oscillation.

12-3 Special Function Registers List

Address	Register	Bit Symbol / Initial Value / Description								Page
		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
X'3F00'	CPUM	-	Reserved	Reserved	Reserved	STOP	HALT	OSC1	OSC0	II - 19
		-	0	0	0	0	0	0	0	
			Set always "0".	Set always "0".	Set always "0".	STOP transition request	HALT transition request	Oscillation Control		
X'3F01'	MEMCTR	IOW1	IOW0	IVBA	Reserved	Reserved	IRWE	Reserved	Reserved	II - 16
		1	1	0	0	1	0	1	1	
		I/O Wait Setup		Interrupt Vector Address	Set always "0".	Set always "1".	Interrupt request flag	Set always "11".		
X'3F02'	WDCTR	-	-	-	-	-	-	-	WDEN	VIII - 3
		-	-	-	-	-	-	-	0	
									WDT Activation	
X'3F03'	DLYCTR	BUZOE	BUZCK1	BUZCK0	-	-	-	DLYS1	DLYS0	II - 27 IX - 3
		0	x	x	-	-	-	0	0	
		Enable Buzzer Output	Buzzer Output Frequency Setup					Oscillation Stabilization Wait Cycle Setup		
X'3F10'	P0OUT	-	P0OUT6	-	-	-	P0OUT2	P0OUT1	P0OUT0	IV - 6
		-	0	-	-	-	0	0	0	
			Port 0 output data				Port 0 output data			
X'3F11'	P1OUT	-	-	-	P1OUT4	P1OUT3	P1OUT2	P1OUT1	P1OUT0	IV - 10
		-	-	-	0	0	0	0	0	
					Port 1 Output Data					
X'3F12'	P2OUT	P2OUT7	-	-	-	-	-	-	-	IV - 15
		1	-	-	-	-	-	-	-	
		Port 2 output data								
X'3F16'	P6OUT	P6OUT7	P6OUT6	P6OUT5	P6OUT4	P6OUT3	P6OUT2	P6OUT1	P6OUT0	IV - 18
		0	0	0	0	0	0	0	0	
		Port 6 Output Data								
X'3F17'	P7OUT	-	-	-	-	-	-	P7OUT1	P7OUT0	IV - 21
		0	0	0	0	0	0	0	0	
								Port 7 Output Data		
X'3F18'	P8OUT	P8OUT7	P8OUT6	P8OUT5	P8OUT4	P8OUT3	P8OUT2	P8OUT1	P8OUT0	IV - 25
		0	0	0	0	0	0	0	0	
		Port 8 Output Data								
X'3F20'	P0IN	-	P0IN6	-	-	-	P0IN2	P0IN1	P0IN0	IV - 6
		-	x	-	-	-	x	x	x	
			Port 0 Input Data				Port 0 Input Data			
X'3F21'	P1IN	-	-	-	P1IN4	P1IN3	P1IN2	P1IN1	P1IN0	IV - 10
		-	-	-	x	x	x	x	x	
					Port 1 Input Data					
X'3F22'	P2IN	-	-	-	-	P2IN3	P2IN2	P2IN1	P2IN0	IV - 15
		-	-	-	-	x	x	x	x	
						Port 2 Input Data				

Note) x : Initial value is unstable. - : No data

Address	Register	Bit Symbol / Initial Value / Description								Page
		Bit 7	Bit 7	Bit 7	Bit 7	Bit 7	Bit 7	Bit 7	Bit 7	
X'3F26'	P6IN	P6IN7	P6IN6	P6IN5	P6IN4	P6IN3	P6IN2	P6IN1	P6IN0	IV - 18
		x	x	x	x	x	x	x	x	
		Port 6 Output Data								
X'3F27'	P7IN	-	-	-	-	-	-	P7IN1	P7IN0	IV - 21
		-	-	-	-	-	-	x	x	
								Port 7 Input Data		
X'3F28'	P8IN	P8IN7	P8IN6	P8IN5	P8IN4	P8IN3	P8IN2	P8IN1	P8IN0	IV - 25
		x	x	x	x	x	x	x	x	
		Port 8 Input Data								
X'3F2A'	PAIN	PAIN7	PAIN6	PAIN5	PAIN4	PAIN3	PAIN2	PAIN1	PAIN0	IV - 28
		x	x	x	x	x	x	x	x	
		Port A Input Data								
X'3F30'	P0DIR	-	-	-	-	-	P0DIR2	P0DIR1	P0DIR0	IV - 6
		-	-	-	-	-	0	0	0	
							Port 0 I/O Direction Control			
X'3F31'	P1DIR	-	-	-	P1DIR4	P1DIR3	P1DIR2	P1DIR1	P1DIR0	IV - 10
		-	-	-	0	0	0	0	0	
					Port 1 I/O Direction Control					
X'3F36'	P6DIR	P6DIR7	P6DIR6	P6DIR5	P6DIR4	P6DIR3	P6DIR2	P6DIR1	P6DIR0	IV - 18
		0	0	0	0	0	0	0	0	
		Port 6 I/O Direction Control								
X'3F37'	P7DIR	-	-	-	-	-	-	P7DIR1	P7DIR0	IV - 21
		-	-	-	-	-	-	0	0	
								Port 7 I/O Direction Control		
X'3F38'	P8DIR	P8DIR7	P8DIR6	P8DIR5	P8DIR4	P8DIR3	P8DIR2	P8DIR1	P8DIR0	IV - 25
		0	0	0	0	0	0	0	0	
		Port 8 I/O Direction Control								
X'3F39'	P1OMD	-	-	-	P14TCO	P13TCO	P12TCO	-	P10TCO	IV - 11
		-	-	-	0	0	0	-	0	
					I/O Port / Special function pin control				I/O Port / Special function pin cntrol	
X'3F3A'	PAIMD	PAIMD7	PAIMD6	PAIMD5	PAIMD4	PAIMD3	PAIMD2	PAIMD1	PAIMD0	IV - 28
		0	0	0	0	0	0	0	0	
		I/O Port / Special function pin control								
X'3F40'	P0PLU	-	P0PLU6	-	-	-	P0PLU2	P0PLU1	P0PLU0	IV - 6
		-	0	-	-	-	0	0	0	
			Port 0 pull-up register ON/OFF control				Port 0 pull-up register ON/OFF control			
X'3F41'	P1PLU	-	-	-	P1PLU4	P1PLU3	P1PLU2	P1PLU1	P1PLU0	IV - 10
		-	-	-	0	0	0	0	0	
					Port 1 pull-up register ON/OFF control					
X'3F42'	P2PLU	-	-	-	-	P2PLU3	P2PLU2	P2PLU1	P2PLU0	IV - 15
		-	-	-	-	0	0	0	0	
						Port 2 pull-up register ON/OFF control				

Note) x : Inicial value is unstable .- : No data

Address	Register	Bit Symbol / Initial Value / Description								Page
		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
X'3F46'	P6PLU	P6PLU7	P6PLU6	P6PLU5	P6PLU4	P6PLU3	P6PLU2	P6PLU1	P6PLU0	IV - 18
		0	0	0	0	0	0	0	0	
		Port 6 pull-up resister ON /OFF control								
X'3F47'	P7PLUD	-	-	-	-	-	-	P7PLUD1	P7PLUD0	IV - 21
		-	-	-	-	-	-	0	0	
								Port 7 pull-up / pull-down resister ON /OFF control		
X'3F48'	P8PLU	P8PLU7	P8PLU6	P8PLU5	P8PLU4	P8PLU3	P8PLU2	P8PLU1	P8PLU0	IV - 25
		0	0	0	0	0	0	0	0	
		Port 8 pull-up resister ON /OFF control								
X'3F4A'	PAPLUD	PAPLUD7	PAPLUD6	PAPLUD5	PAPLUD4	PAPLUD3	PAPLUD2	PAPLUD1	PAPLUD0	IV - 28
		0	0	0	0	0	0	0	0	
		Port A pull-up / pull-down resister ON /OFF control								
X'3F4B'	FLOAT1	-	-	-	-	-	P21IM	PARDWN	P7RDWN	III - 33 IV - 22,29
		-	-	-	-	-	0	0	0	
							P21 input mode selection	Port A pull-up pull-down selection	Port 7 pull-up pull-down selection	
X'3F50'	SC0MD0	-	SC0CE0	SC0CE1	SC0DIR	SC0STE	SC0LNG2	SC0LNG1	SC0LNG0	X - 6
		-	0	0	x	x	0	0	0	
			Reception data input edge / Transmission data output edge		First bit to be transferred	Synchronous serial data transfer start condition	Synchronous serial transfer bit count			
X'3F51'	SC0MD1	-	-	SC0CKM	SC0CK1	SC0CK0	SC0BRKF	SC0ERE	SC0TRI	X - 7
		-	-	x	0	0	0	0	0	
				1/8 dividing of transfer clock	Clock source		Brake status receive monitor	Error monitor	Transmission/ Reception interrupt request flag	
X'3F52'	SC0MD2	-	-	SC0BRKE	SC0FM1	SC0FM0	SC0PM1	SC0PM0	SC0NPE	X - 8
		-	-	0	0	0	x	x	x	
				Brake status transmit control	Frame mode specification		Added bit specification		Parity enable	
X'3F53'	SC0MD3	-	-	SC0IMO	SC0SBOM	SC0SBTM	SC0SBOS	SC0SBIS	SC0SBTS	X - 9
		-	-	0	0	0	0	0	0	
				SBI0/SBO0 pin connection	SBO0 pin configuration	SBT0 pin configuration	SBO0 pin function	SBI0 input control	SBT0 pin function	
X'3F54'	SC0CTR	SC0BSY	SC0CMD	-	-	SC0FEF	SC0PEK	SC0ORE	-	X - 10
		0	0	-	-	0	0	0	-	
		Serial bus status	Clcok synchronous/ UART			Framing error detection	Parity error detection	Overrun error detection		
X'3F55'	SC0TRB	SC0TRB7	SC0TRB6	SC0TRB5	SC0TRB4	SC0TRB3	SC0TRB2	SC0TRB1	SC0TRB0	X - 5
		x	x	x	x	x	x	x	x	
		Serial interface 0 transmission/reception shift register								
X'3F56'	SC0RXB	SC0RXB7	SC0RXB6	SC0RXB5	SC0RXB4	SC0RXB3	SC0RXB2	SC0RXB1	SC0RXB0	X - 5
		x	x	x	x	x	x	x	x	
		Serial interface 0 reception data buffer								
X'3F62'	TM2BC	TM2BC7	TM2BC6	TM2BC5	TM2BC4	TM2BC3	TM2BC2	TM2BC1	TM2BC0	V - 6
		0	0	0	0	0	0	0	0	
		Timer 2 binary counter								
X'3F63'	TM3BC	TM3BC7	TM3BC6	TM3BC5	TM3BC4	TM3BC3	TM3BC2	TM3BC1	TM3BC0	V - 6
		-	-	-	0	0	0	0	0	
		Timer 3 binary counter								

Note) x : Initial value is unstable. - : No data

Address	Register	Bit Symbol / Initial Value / Description								Page
		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
X'3F64'	TM4BCL	TM4BCL7	TM4BCL6	TM4BCL5	TM4BCL4	TM4BCL3	TM4BCL2	TM4BCL1	TM4BCL0	VI - 5
		0	0	0	0	0	0	0	0	
		Timer 4 binary counter (lower 8 bits)								
X'3F65'	TM4BCH	TM4BCH7	TM4BCH6	TM4BCH5	TM4BCH4	TM4BCH3	TM4BCH2	TM4BCH1	TM4BCH0	VI - 5
		0	0	0	0	0	0	0	0	
		Timer 4 binary counter (upper 8 bits)								
X'3F66'	TM4ICL	TM4ICL7	TM4ICL6	TM4ICL5	TM4ICL4	TM4ICL3	TM4ICL2	TM4ICL1	TM4ICL0	VI - 6
		x	x	x	x	x	x	x	x	
		Timer 4 input capture register (lower 8 bits)								
X'3F67'	TM4ICH	TM4ICH7	TM4ICH6	TM4ICH5	TM4ICH4	TM4ICH3	TM4ICH2	TM4ICH1	TM4ICH0	VI - 6
		x	x	x	x	x	x	x	0	
		Timer 4 input capture register (upper 8 bits)								
X'3F68'	TM5BC	TM5BC7	TM5BC6	TM5BC5	TM5BC4	TM5BC3	TM5BC2	TM5BC1	TM5BC0	VII - 5
		0	0	0	0	0	0	0	0	
		Timer 5 binary counter								
X'3F72'	TM2OC	TM2OC7	TM2OC6	TM2OC5	TM2OC4	TM2OC3	TM2OC2	TM2OC1	TM2OC0	V - 6
		x	x	x	x	x	x	x	x	
		Timer 2 compare register								
X'3F73'	TM3OC	TM3OC7	TM3OC6	TM3OC5	TM3OC4	TM3OC3	TM3OC2	TM3OC1	TM3OC0	V - 6
		x	x	x	x	x	x	x	x	
		Timer 3 compare register								
X'3F74'	TM4OCL	TM4OCL7	TM4OCL6	TM4OCL5	TM4OCL4	TM4OCL3	TM4OCL2	TM4OCL1	TM4OCL0	VI - 5
		x	x	x	x	x	x	x	x	
		Timer 4 compare register (lower 8 bits)								
X'3F75'	TM4OCH	TM4OCH7	TM4OCH6	TM4OCH5	TM4OCH4	TM4OCH3	TM4OCH2	TM4OCH1	TM4OCH0	VI - 5
		x	x	x	x	x	x	x	x	
		Timer 4 compare register (upper 8 bits)								
X'3F78'	TM5OC	TM5OC7	TM5OC6	TM5OC5	TM5OC4	TM5OC3	TM5OC2	TM5OC1	TM5OC0	VII - 5
		x	x	x	x	x	x	x	x	
		Timer 5 compare register								
X'3F82'	TM2MD	-	-	-	TM2EN	TM2PWM	TM2CK2	TM2CK1	TM2CK0	V - 7
		-	-	-	0	0	x	x	x	
					Timer 2 count control	Timer 2 operation mode	Clock source			
X'3F83'	TM3MD	-	-	-	TM3EN	TM3PWM	TM3CK2	TM3CK1	TM3CK0	V - 8
		-	-	-	0	0	x	x	x	
					Timer 3 count control	P13 output at TM2PWM operation	Clock source			
X'3F84'	TM4MD	-	TM4EN	TM4PWM	T4ICTS1	T4ICTS0	TM4CK2	TM4CK1	TM4CK0	VI - 7
		-	0	0	0	0	x	x	x	
			Timer 4 count control	Timer 4 operation mode	TM4 input capture trigger		Clock source			
X'3F88'	TM5MD	TM5CLRS	TM5IR2	TM5IR1	TM5IR0	TM5CK3	TM5CK2	TM5CK1	TM5CK0	VII - 6
		0	x	x	x	x	x	x	0	
		TM5 binary counter clear	Time base timer interrupt cycle			Timer 5 clock source			Time base timer clock source	

Note) x : Initial value is unstable. - : No data

Address	Register	Bit Symbol / Initial Value / Description								Page
		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
X'3F89'	RMCTR	-	-	-	Reserved	RMOEN	Reserved	RMDTY0	Reserved	V - 9
		-	-	-	0	0	x	x	0	
					Set always "0".	Enable remote control carrier output	Set always "0".	Remote control carrier output duty	Set always "0".	
X'3F8A'	NFCTR	-	-	NF1CKS1	NF1CKS0	NF1EN	NF0CKS1	NF0CKS0	NF0EN	III - 32
		-	-	0	0	0	0	0	0	
				IRQ1 noise filter sampling period		IRQ1 noise filter setup	IRQ0 noise filter sampling period		IRQ0 noise filter setup	
X'3F90'	ANCTR0	ANSH1	ANSH0	ANCK1	ANCK0	ANLADE	ANCHS2	ANCHS1	ANCHS0	XI - 5
		x	x	x	x	0	x	x	x	
		A/D sample and hold time		A/D conversion clock		A/D ladder resistance control	Analog input selection			
X'3F91'	ANCTR1	ANST	-	-	-	-	-	-	-	XI - 6
		0	-	-	-	-	-	-	-	
		A/D conversion status								
X'3F92'	ANBUF0	ANBUF07	ANBUF06	-	-	-	-	-	-	XI - 7
		x	x	-	-	-	-	-	-	
		A/D buffer 0 (lower 2 bits)								
X'3F93'	ANBUF1	ANBUF17	ANBUF16	ANBUF15	ANBUF14	ANBUF13	ANBUF12	ANBUF11	ANBUF10	XI - 7
		x	x	x	x	x	x	x	x	
		A/D buffer 1 (upper 8 bits)								
X'3FE0'	Can not use	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	-	-	
X'3FE1'	NMICR	-	-	-	-	-	PIR	WDIR	Reserved	III - 16
		-	-	-	-	-	0	0	0	
							Program interrupt request	Watchdog interrupt request	Set always "0".	
X'3FE2'	IRQ0ICR	IRQ0LV1	IRQ0LV0	REDG0	-	-	-	IRQ0IE	IRQ0IR	III - 17
		0	0	0	-	-	-	0	0	
		IRQ0 interrupt level		IRQ0 interrupt active edge				IRQ0 interrupt enable	IRQ0 interrupt request	
X'3FE3'	IRQ1ICR	IRQ1LV1	IRQ1LV0	REDG1	-	-	-	IRQ1IE	IRQ1IR	III - 18
		0	0	0	-	-	-	0	0	
		IRQ1 interrupt level		IRQ1 interrupt active edge				IRQ1 interrupt enable	IRQ1 interrupt request	
X'3FE6'	TM2ICR	TM2LV1	TM2LV0	-	-	-	-	TM2IE	TM2IR	III - 21
		0	0	-	-	-	-	0	0	
		TM2 interrupt level						TM2 interrupt enable	TM2 interrupt request	
X'3FE7'	TBICR	TBLV1	TBLV0	-	-	-	-	TBIE	TBR	III - 25
		0	0	-	-	-	-	0	0	
		TB interrupt level						TB interrupt enable	TB interrupt request	
X'3FE8'	SC0ICR	SC0LV1	SC0LV0	-	-	-	-	SC0IE	SC0IR	III - 26
		0	0	-	-	-	-	0	0	
		SC0 interrupt level						SC0 interrupt enable	SC0 interrupt request	
X'3FEA'	ADICR	ADLV1	ADLV0	-	-	-	-	ADIE	ADIR	III - 27
		0	0	-	-	-	-	0	0	
		AD interrupt level						AD interrupt enable	AD interrupt request	

Note) x : Initial value is unstable. - : No data-

Address	Register	Bit Symbol / Initial Value / Description								Page
		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
X'3FEB'	IRQ2ICR	IRQ2LV1	IRQ2LV0	REDG2	-	-	-	IRQ2IE	IRQ2IR	III - 19
		0	0	0	-	-	-	0	0	
		IRQ2 interrupt level		IRQ2 interrupt active edge				IRQ2 interrupt enable	IRQ2 interrupt request	
X'3FEC'	IRQ3ICR *	IRQ3LV1	IRQ3LV0	REDG3	-	-	-	IRQ3IE	IRQ3IR	III - 20
		0	0	0	-	-	-	0	0	
		IRQ3 interrupt level		IRQ3 interrupt active edge				IRQ3 interrupt enable	IRQ3 interrupt request	
X'3FEE'	TM3ICR	TM3LV1	TM3LV0	-	-	-	-	TM3IE	TM3IR	III - 22
		0	0	-	-	-	-	0	0	
		TM3 interrupt level						TM3 interrupt enable	TM3 interrupt request	
X'3FEF'	TM4ICR	TM4LV1	TM4LV0	-	-	-	-	TM4IE	TM4IR	III - 23
		0	0	-	-	-	-	0	0	
		TM4 interrupt level						TM4 interrupt enable	TM4i nterrupt request	
X'3FF0'	TM5ICR	TM5LV1	TM5LV0	-	-	-	-	TM5IE	TM5IR	III - 24
		0	0	-	-	-	-	0	0	
		TM5 interrupt level						TM5 interrupt enable	TM5 interrupt request	

Note) x : Initial value is unstable. - : No data

* Can be used only for 48-pin TQFP package type

12-4 Instruction Set

MN101C SERIES INSTRUCTION SET

Group	Mnemonic	Operation	Flag VF	Flag NF	Flag CF	Flag ZF	Code Size	Cycle	Re-peat	Machine Code Ext.	1	2	3	4	5	6	7	8	9	10	11	Notes	Page
Data Move Instructions																							
MOV	MOV Dn,Dm	Dn→Dm	--	--	--	--	2	1			1010	DnDm											25
	MOV imm8,Dm	imm8→Dm	--	--	--	--	4	2			1010	DmDm	<#8.	...>									25
	MOV Dn,PSW	Dn→PSW	●	●	●	●	3	3		0010	1001	01Dn											26
	MOV PSW,Dm	PSW→Dm	--	--	--	--	3	2		0010	0001	01Dm											26
	MOV (An),Dm	mem8(An)→Dm	--	--	--	--	2	2			0100	1ADm											27
	MOV (d8,An),Dm	mem8(d8+An)→Dm	--	--	--	--	4	2			0110	1ADm	<d8.	...>								*1	27
	MOV (d16,An),Dm	mem8(d16+An)→Dm	--	--	--	--	7	4		0010	0110	1ADm	<d16	....	....	...>							28
	MOV (d4,SP),Dm	mem8(d4+SP)→Dm	--	--	--	--	3	2			0110	01Dm	<d4>									*2	28
	MOV (d8,SP),Dm	mem8(d8+SP)→Dm	--	--	--	--	5	3		0010	0110	01Dm	<d8.	...>								*3	29
	MOV (d16,SP),Dm	mem8(d16+SP)→Dm	--	--	--	--	7	4		0010	0110	00Dm	<d16	....	....	...>							29
	MOV (io8),Dm	mem8(IOTOP+io8)→Dm	--	--	--	--	4	2			0110	00Dm	<io8	...>									30
	MOV (abs8),Dm	mem8(abs8)→Dm	--	--	--	--	4	2			0100	01Dm	<abs	8..>									30
	MOV (abs12),Dm	mem8(abs12)→Dm	--	--	--	--	5	2			0100	00Dm	<abs	12..	...>								31
	MOV (abs16),Dm	mem8(abs16)→Dm	--	--	--	--	7	4		0010	1100	00Dm	<abs	16..	....	...>							31
	MOV Dn,(Am)	Dn→mem8(Am)	--	--	--	--	2	2			0101	1aDn											32
	MOV Dn,(d8,Am)	Dn→mem8(d8+Am)	--	--	--	--	4	2			0111	1aDn	<d8.	...>								*1	32
	MOV Dn,(d16,Am)	Dn→mem8(d16+Am)	--	--	--	--	7	4		0010	0111	1aDn	<d16	....	....	...>							33
	MOV Dn,(d4,SP)	Dn→mem8(d4+SP)	--	--	--	--	3	2			0111	01Dn	<d4>									*2	33
	MOV Dn,(d8,SP)	Dn→mem8(d8+SP)	--	--	--	--	5	3		0010	0111	01Dn	<d8.	...>								*3	34
	MOV Dn,(d16,SP)	Dn→mem8(d16+SP)	--	--	--	--	7	4		0010	0111	00Dn	<d16	....	....	...>							34
	MOV Dn,(io8)	Dn→mem8(IOTOP+io8)	--	--	--	--	4	2			0111	00Dn	<io8	...>									35
	MOV Dn,(abs8)	Dn→mem8(abs8)	--	--	--	--	4	2			0101	01Dn	<abs	8..>									35
	MOV Dn,(abs12)	Dn→mem8(abs12)	--	--	--	--	5	2			0101	00Dn	<abs	12..	...>								36
	MOV Dn,(abs16)	Dn→mem8(abs16)	--	--	--	--	7	4		0010	1101	00Dn	<abs	16..	....	...>							36
	MOV imm8,(io8)	imm8→mem8(IOTOP+io8)	--	--	--	--	6	3			0000	0010	<io8	...>	<#8.	...>							37
	MOV imm8,(abs8)	imm8→mem8(abs8)	--	--	--	--	6	3			0001	0100	<abs	8..>	<#8.	...>							37
	MOV imm8,(abs12)	imm8→mem8(abs12)	--	--	--	--	7	3			0001	0101	<abs	12..	...>	<#8.	...>						38
	MOV imm8,(abs16)	imm8→mem8(abs16)	--	--	--	--	9	5		0011	1101	1001	<abs	16..	....	...>	<#8.	...>					38
	MOV Dn,(HA)	Dn→mem8(HA)	--	--	--	--	2	2			1101	00Dn											39
MOVW	MOVW (An),DWm	mem16(An)→DWm	--	--	--	--	2	3			1110	00Ad											40
	MOVW (An),Am	mem16(An)→Am	--	--	--	--	3	4		0010	1110	10Aa										*4	40
	MOVW (d4,SP),DWm	mem16(d4+SP)→DWm	--	--	--	--	3	3			1110	011d	<d4>									*2	41
	MOVW (d4,SP),Am	mem16(d4+SP)→Am	--	--	--	--	3	3			1110	010a	<d4>									*2	41
	MOVW (d8,SP),DWm	mem16(d8+SP)→DWm	--	--	--	--	5	4		0010	1110	011d	<d8.	...>								*3	42
	MOVW (d8,SP),Am	mem16(d8+SP)→Am	--	--	--	--	5	4		0010	1110	010a	<d8.	...>								*3	42
	MOVW (d16,SP),DWm	mem16(d16+SP)→DWm	--	--	--	--	7	5		0010	1110	001d	<d16	....	....	...>							43
	MOVW (d16,SP),Am	mem16(d16+SP)→Am	--	--	--	--	7	5		0010	1110	000a	<d16	....	....	...>							43
	MOVW (abs8),DWm	mem16(abs8)→DWm	--	--	--	--	4	3			1100	011d	<abs	8..>									44
	MOVW (abs8),Am	mem16(abs8)→Am	--	--	--	--	4	3			1100	010a	<abs	8..>									44
	MOVW (abs16),DWm	mem16(abs16)→DWm	--	--	--	--	7	5		0010	1100	011d	<abs	16..	....	...>							45
	MOVW (abs16),Am	mem16(abs16)→Am	--	--	--	--	7	5		0010	1100	010a	<abs	16..	....	...>							45
	MOVW DWn,(Am)	DWn→mem16(Am)	--	--	--	--	2	3			1111	00aD											46
	MOVW An,(Am)	An→mem16(Am)	--	--	--	--	3	4		0010	1111	10aA										*4	46
	MOVW DWn,(d4,SP)	DWn→mem16(d4+SP)	--	--	--	--	3	3			1111	011D	<d4>									*2	47
	MOVW An,(d4,SP)	An→mem16(d4+SP)	--	--	--	--	3	3			1111	010A	<d4>									*2	47
	MOVW DWn,(d8,SP)	DWn→mem16(d8+SP)	--	--	--	--	5	4		0010	1111	011D	<d8.	...>								*3	48
	MOVW An,(d8,SP)	An→mem16(d8+SP)	--	--	--	--	5	4		0010	1111	010A	<d8.	...>								*3	48
	MOVW DWn,(d16,SP)	DWn→mem16(d16+SP)	--	--	--	--	7	5		0010	1111	001D	<d16	....	....	...>							49
	MOVW An,(d16,SP)	An→mem16(d16+SP)	--	--	--	--	7	5		0010	1111	000A	<d16	....	....	...>							49
	MOVW DWn,(abs8)	DWn→mem16(abs8)	--	--	--	--	4	3			1101	011D	<abs	8..>									50
	MOVW An,(abs8)	An→mem16(abs8)	--	--	--	--	4	3			1101	010A	<abs	8..>									50
	MOVW DWn,(abs16)	DWn→mem16(abs16)	--	--	--	--	7	5		0010	1101	011D	<abs	16..	....	...>							51
	MOVW An,(abs16)	An→mem16(abs16)	--	--	--	--	7	5		0010	1101	010A	<abs	16..	....	...>							51
	MOVW DWn,(HA)	DWn→mem16(HA)	--	--	--	--	2	3			1001	010D											52
	MOVW An,(HA)	An→mem16(HA)	--	--	--	--	2	3			1001	011A											52
	MOVW imm8,DWm	sign(imm8)→DWm	--	--	--	--	4	2			0000	110d	<#8.	...>								*5	53
	MOVW imm8,Am	zero(imm8)→Am	--	--	--	--	4	2			0000	111a	<#8.	...>								*6	53
	MOVW imm16,DWm	imm16→DWm	--	--	--	--	6	3			1100	111d	<#16	....	....	...>							54

NOTE: Pages for the MN101C Series Instruction Manual

*1 d8 sign-extension
*2 d4 zero-extension
*3 d8 zero-extension
*4 A=An, a=Am
*5 #8 sign-extension
*6 #8 zero-extension

MN101C SERIES INSTRUCTION SET

Group	Mnemonic	Operation	Flag VF	Flag NF	Flag CF	Flag ZF	Code Size	Cycle	Re-peat	extension / Machine Code 1 2 3 4 5 6 7 8 9 10 11	Notes	Page
	MOVW imm16,Am	imm16→Am	--	--	--	--	6	3		1101 111a <#16 ....>		54
	MOVW SP,Am	SP→Am	--	--	--	--	3	3		0010 0000 100a		55
	MOVW An,SP	An→SP	--	--	--	--	3	3		0010 0000 101A		55
	MOVW DWn,DWm	DWn→DWm	--	--	--	--	3	3		0010 1000 00Dd	*1	56
	MOVW DWn,Am	DWn→Am	--	--	--	--	3	3		0010 0100 11Da		56
	MOVW An,DWm	An→DWm	--	--	--	--	3	3		0010 1100 11Ad		57
	MOVW An,Am	An→Am	--	--	--	--	3	3		0010 0000 00Aa	*2	57
PUSH	PUSH Dn	SP-1→SP,Dn→mem8(SP)	--	--	--	--	2	3		1111 10Dn		58
	PUSH An	SP-2→SP,An→mem16(SP)	--	--	--	--	2	5		0001 011A		58
POP	POP Dn	mem8(SP)→Dn,SP+1→SP	--	--	--	--	2	3		1110 10Dn		59
	POP An	mem16(SP)→An,SP+2→SP	--	--	--	--	2	4		0000 011A		59
EXT	EXT Dn,DWm	sign(Dn)→DWm	--	--	--	--	3	3		0010 1001 000d	*3	60
Arithmetic manupulation instructions												
ADD	ADD Dn,Dm	Dm+Dn→Dm	●	●	●	●	3	2		0011 0011 DnDm		61
	ADD imm4,Dm	Dm+sign(imm4)→Dm	●	●	●	●	3	2		1000 00Dm <#4>	*6	61
	ADD imm8,Dm	Dm+imm8→Dm	●	●	●	●	4	2		0000 10Dm <#8. ...>		62
ADDC	ADDC Dn,Dm	Dm+Dn+CF→Dm	●	●	●	●	3	2	○	0011 1011 DnDm		63
ADDW	ADDW DWn,DWm	DWm+DWn→DWm	●	●	●	●	3	3	○	0010 0101 00Dd	*1	64
	ADDW DWn,Am	Am+DWn→Am	●	●	●	●	3	3	○	0010 0101 10Da		64
	ADDW imm4,Am	Am+sign(imm4)→Am	●	●	●	●	3	2		1110 110a <#4>	*6	65
	ADDW imm8,Am	Am+sign(imm8)→Am	●	●	●	●	5	3		0010 1110 110a <#8. ...>	*7	65
	ADDW imm16,Am	Am+imm16→Am	●	●	●	●	7	4		0010 0101 011a <#16 ....>		66
	ADDW imm4,SP	SP+sign(imm4)→SP	--	--	--	--	3	2		1111 1101 <#4>	*6	66
	ADDW imm8,SP	SP+sign(imm8)→SP	--	--	--	--	4	2		1111 1100 <#8. ...>	*7	67
	ADDW imm16,SP	SP+imm16→SP	--	--	--	--	7	4		0010 1111 1100 <#16 ....>		67
	ADDW imm16,DWm	DWm+imm16→DWm	●	●	●	●	7	4		0010 0101 010d <#16 ....>		68
ADDUW	ADDUW Dn,Am	Am+zero(Dn)→Am	●	●	●	●	3	3	○	0010 1000 1aDn	*8	69
ADDSW	ADDSW Dn,Am	Am+sign(Dn)→Am	●	●	●	●	3	3	○	0010 1001 1aDn		70
SUB	SUB Dn,Dm(when Dn≠Dm)	Dm-Dn→Dm	●	●	●	●	3	2	○	0010 1010 DnDm		71
	SUB Dn,Dn	Dn-Dn→Dn	0	0	0	1	2	1		1000 01Dn		71
	SUB imm8,Dm	Dm-imm8→Dm	●	●	●	●	5	3		0010 1010 DmDm <#8. ...>		72
SUBC	SUBC Dn,Dm	Dm-Dn-CF→Dm	●	●	●	●	3	2	○	0010 1011 DnDm		73
SUBW	SUBW DWn,DWm	DWm-DWn→DWm	●	●	●	●	3	3		0010 0100 00Dd	*1	74
	SUBW DWn,Am	Am-DWn→Am	●	●	●	●	3	3		0010 0100 10Da		74
	SUBW imm16,DWm	DWm-imm16→DWm	●	●	●	●	7	4		0010 0100 010d <#16 ....>		75
	SUBW imm16,Am	Am-imm16→Am	●	●	●	●	7	4		0010 0100 011a <#16 ....>		75
MULU	MULU Dn,Dm	Dm*Dn→DWk	0	●	●	●	3	8		0010 1111 111D	*4	76
DIVU	DIVU Dn,DWm	DWm/Dn→DWm-l...DWm-h	●	●	●	●	3	9		0010 1110 111d	*5	77
CMP	CMP Dn,Dm	Dm-Dn...PSW	●	●	●	●	3	2		0011 0010 DnDm		78
	CMP imm8,Dm	Dm-imm8...PSW	●	●	●	●	4	2		1100 00Dm <#8. ...>		78
	CMP imm8,(abs8)	mem8(abs8)-imm8...PSW	●	●	●	●	6	3		0000 0100 <abs 8..> <#8. ...>		79
	CMP imm8,(abs12)	mem8(abs12)-imm8...PSW	●	●	●	●	7	3		0000 0101 <abs 12.. ...> <#8. ...>		79
	CMP imm8,(abs16)	mem8(abs16)-imm8...PSW	●	●	●	●	9	5		0011 1101 1000 <abs 16.. ....> <#8. ...>		80
CMPW	CMPW DWn,DWm	DWm-DWn...PSW	●	●	●	●	3	3		0010 1000 01Dd	*1	81
	CMPW DWn,Am	Am-DWn...PSW	●	●	●	●	3	3		0010 0101 11Da		81
	CMPW An,Am	Am-An...PSW	●	●	●	●	3	3		0010 0000 01Aa	*2	82
	CMPW imm16,DWm	DWm-imm16...PSW	●	●	●	●	6	3		1100 110d <#16 ....>		82
	CMPW imm16,Am	Am-imm16...PSW	●	●	●	●	6	3		1101 110a <#16 ....>		83
Logical manipulation instructions												
AND	AND Dn,Dm	Dm&Dn→Dm	0	●	0	●	3	2		0011 0111 DnDm		84
	AND imm8,Dm	Dm&imm8→Dm	0	●	0	●	4	2		0001 11Dm <#8. ...>		84
	AND imm8,PSW	PSW&imm8→PSW	●	●	●	●	5	3		0010 1001 0010 <#8. ...>		85
OR	OR Dn,Dm	DmIDn→Dm	0	●	0	●	3	2		0011 0110 DnDm		86
	OR imm8,Dm	DmIimm8→Dm	0	●	0	●	4	2		0001 10Dm <#8. ...>		86
	OR imm8,PSW	PSWIimm8→PSW	●	●	●	●	5	3		0010 1001 0011 <#8. ...>		87
XOR	XOR Dn,Dm	Dm^Dn→Dm	0	●	0	●	3	2		0011 1010 DnDm	*9	88
	XOR imm8,Dm	Dm^imm8→Dm	0	●	0	●	5	3		0011 1010 DmDm <#8. ...>		88

NOTE: Pages for MN101C Series Instruction Manual

*1 D=DWn, d=DWm
*2 A=An, a=Am
*3 d=DWm
*4 D=DWk
*5 D=DWm
*6 #4 sign-extension
*7 #8 sign-extension
*8 Dn zero extension
*9 m=n/

MN101C SERIES INSTRUCTION SET

Group	Mnemonic	Operation	Flag VF	Flag NF	Flag CF	Flag ZF	Code Size	Cycle	Re-peat	Extension	Machine Code 1	2	3	4	5	6	7	8	9	10	11	Notes	Page
NOT	NOT Dn	¯Dn→Dn	0	●	0	●	3	2			0010	0010	10Dn										89
ASR	ASR Dn	Dn.msb→temp,Dn.lsb→CF Dn>>1→Dn,temp→Dn.msb	0	--	●	●	3	2	○		0010	0011	10Dn										90
LSR	LSR Dn	Dn.lsb→CF,Dn>>1→Dn 0→Dn.msb	0	0	●	●	3	2	○		0010	0011	11Dn										91
ROR	ROR Dn	Dn.lsb→temp,Dn>>1→Dn CF→Dn.msb,temp→CF	0	●	●	●	3	2	○		0010	0010	11Dn										92
Bit manipulation instructions																							
BSET	BSET (io8)bp	mem8(IOTOP+io8)&bpdata...PSW 1→mem8(IOTOP+io8)bp	0	●	0	●	5	5			0011	1000	0bp.	<io8	...>								93
	BSET (abs8)bp	mem8(abs8)&bpdata...PSW 1→mem8(abs8)bp	0	●	0	●	4	4				1011	0bp.	<abs	8..>								93
	BSET (abs16)bp	mem8(abs16)&bpdata...PSW 1→mem8(abs16)bp	0	●	0	●	7	6			0011	1100	0bp.	<abs	16..	....	...>						94
BCLR	BCLR (io8)bp	mem8(IOTOP+io8)&bpdata...PSW 0→mem8(IOTOP+io8)bp	0	●	0	●	5	5			0011	1000	1bp.	<io8	...>								95
	BCLR (abs8)bp	mem8(abs8)&bpdata...PSW 0→mem8(abs8)bp	0	●	0	●	4	4				1011	1bp.	<abs	8..>								95
	BCLR (abs16)bp	mem8(abs16)&bpdata...PSW 0→mem8(abs16)bp	0	●	0	●	7	6			0011	1100	1bp.	<abs	16..	....	...>						96
BTST	BTST imm8,Dm	Dm&imm8...PSW	0	●	0	●	5	3			0010	0000	11Dm	<#8.	...>								97
	BTST (abs16)bp	mem8(abs16)&bpdata...PSW	0	●	0	●	7	5			0011	1101	0bp.	<abs	16..	....	...>						97
Branch instructions																							
Bcc	BEQ label	if(ZF=1), PC+3+d4(label)+H→PC if(ZF=0), PC+3→PC	--	--	--	--	3	2/3				1001	000H	<d4>								*1	98
	BEQ label	if(ZF=1), PC+4+d7(label)+H→PC if(ZF=0), PC+4→PC	--	--	--	--	4	2/3				1000	1010	<d7.	...H							*2	98
	BEQ label	if(ZF=1), PC+5+d11(label)+H→PC if(ZF=0), PC+5→PC	--	--	--	--	5	2/3				1001	1010	<d11	....	...H						*3	99
	BNE label	if(ZF=0), PC+3+d4(label)+H→PC if(ZF=1), PC+3→PC	--	--	--	--	3	2/3				1001	001H	<d4>								1	100
	BNE label	if(ZF=0), PC+4+d7(label)+H→PC if(ZF=1), PC+4→PC	--	--	--	--	4	2/3				1000	1011	<d7.	...H							*2	100
	BNE label	if(ZF=0), PC+5+d11(label)+H→PC if(ZF=1), PC+5→PC	--	--	--	--	5	2/3				1001	1011	<d11	....	...H						*3	101
	BGE label	if((VF^NF)=0),PC+4+d7(label)+H→PC if((VF^NF)=1),PC+4→PC	--	--	--	--	4	2/3				1000	1000	<d7.	...H							*2	102
	BGE label	if((VF^NF)=0),PC+5+d11(label)+H→PC if((VF^NF)=1),PC+5→PC	--	--	--	--	5	2/3				1001	1000	<d11	....	...H						*3	102
	BCC label	if(CF=0),PC+4+d7(label)+H→PC if(CF=1), PC+4→PC	--	--	--	--	4	2/3				1000	1100	<d7.	...H							*2	103
	BCC label	if(CF=0), PC+5+d11(label)+H→PC if(CF=1), PC+5→PC	--	--	--	--	5	2/3				1001	1100	<d11	....	...H						*3	103
	BCS label	if(CF=1),PC+4+d7(label)+H→PC if(CF=0), PC+4→PC	--	--	--	--	4	2/3				1000	1101	<d7.	...H							*2	104
	BCS label	if(CF=1), PC+5+d11(label)+H→PC if(CF=0), PC+5→PC	--	--	--	--	5	2/3				1001	1101	<d11	....	...H						*3	104
	BLT label	if((VF^NF)=1),PC+4+d7(label)+H→PC if((VF^NF)=0),PC+4→PC	--	--	--	--	4	2/3				1000	1110	<d7.	...H							*2	105
	BLT label	if((VF^NF)=1),PC+5+d11(label)+H→PC if((VF^NF)=0),PC+5→PC	--	--	--	--	5	2/3				1001	1110	<d11	....	...H						*3	105
	BLE label	if((VF^NF)|ZF=1),PC+4+d7(label)+H→PC if((VF^NF)|ZF=0),PC+4→PC	--	--	--	--	4	2/3				1000	1111	<d7.	...H							*2	106
	BLE label	if((VF^NF)|ZF=1),PC+5+d11(label)+H→PC if((VF^NF)|ZF=0),PC+5→PC	--	--	--	--	5	2/3				1001	1111	<d11	....	...H						*3	106
	BGT label	if((VF^NF)|ZF=0),PC+5+d7(label)+H→PC if((VF^NF)|ZF=1),PC+5→PC	--	--	--	--	5	3/4			0010	0010	0001	<d7.	...H							*2	107

NOTE: Pages for MN101C Series Instruction Manual

*1 d4 sign-extension
*2 d7 sign-extension
*3 d11 sign-extension

MN101C SERIES INSTRUCTION SET

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Bcc	BGT label	if((VF^NF)|ZF=0),PC+6+d11(label)+H→PC if((VF^NF)|ZF=1),PC+6→PC	--	--	--	--	6	3/4			0010	0011	0001	<d11	....	...H						*3	107
	BHI label	if(CFIZF=0),PC+5+d7(label)+H→PC if(CFIZF=1), PC+5→PC	--	--	--	--	5	3/4			0010	0010	0010	<d7.	...H							*2	108
	BHI label	if(CFIZF=0),PC+6+d11(label)+H→PC if(CFIZF=1), PC+6→PC	--	--	--	--	6	3/4			0010	0011	0010	<d11	....	...H						*3	108
	BLS label	if(CFIZF=1),PC+5+d7(label)+H→PC if(CFIZF=0), PC+5→PC	--	--	--	--	5	3/4			0010	0010	0011	<d7.	...H							*2	109
	BLS label	if(CFIZF=1),PC+6+d11(label)+H→PC if(CFIZF=0), PC+6→PC	--	--	--	--	6	3/4			0010	0011	0011	<d11	....	...H						*3	109
	BNC label	if(NF=0),PC+5+d7(label)+H→PC if(NF=1),PC+5→PC	--	--	--	--	5	3/4			0010	0010	0100	<d7.	...H							*2	110
	BNC label	if(NF=0),PC+6+d11(label)+H→PC if(NF=1),PC+6→PC	--	--	--	--	6	3/4			0010	0011	0100	<d11	....	...H						*3	110
	BNS label	if(NF=1),PC+5+d7(label)+H→PC if(NF=0),PC+5→PC	--	--	--	--	5	3/4			0010	0010	0101	<d7.	...H							*2	111
	BNS label	if(NF=1),PC+6+d11(label)+H→PC if(NF=0),PC+6→PC	--	--	--	--	6	3/4			0010	0011	0101	<d11	....	...H						*3	111
	BVC label	if(VF=0),PC+5+d7(label)+H→PC if(VF=1),PC+5→PC	--	--	--	--	5	3/4			0010	0010	0110	<d7.	...H							*2	112
	BVC label	if(VF=0),PC+6+d11(label)+H→PC if(VF=1),PC+6→PC	--	--	--	--	6	3/4			0010	0011	0110	<d11	....	...H						*3	112
	BVS label	if(VF=1),PC+5+d7(label)+H→PC if(VF=0),PC+5→PC	--	--	--	--	5	3/4			0010	0010	0111	<d7.	...H							*2	113
	BVS label	if(VF=1),PC+6+d11(label)+H→PC if(VF=0),PC+6→PC	--	--	--	--	6	3/4			0010	0011	0111	<d11	....	...H						*3	113
	BRA label	PC+3+d4(label)+H→PC	--	--	--	--	3	3			1110	111H	<d4>									*1	114
	BRA label	PC+4+d7(label)+H→PC	--	--	--	--	4	3			1000	1001	<d7.	...H								*2	114
	BRA label	PC+5+d11(label)+H→PC	--	--	--	--	5	3			1001	1001	<d11	....	...H							*3	115
CBEQ	CBEQ imm8,Dm,label	if(Dm=imm8),PC+6+d7(label)+H→PC if(Dm≠imm8),PC+6→PC	●	●	●	●	6	3/4			1100	10Dm	<#8.	...>	<d7.	...H						*2	116
	CBEQ imm8,Dm,label	if(Dm=imm8),PC+8+d11(label)+H→PC if(Dm≠imm8),PC+8→PC	●	●	●	●	8	4/5			0010	1100	10Dm	<#8.	...>	<d11	....	...H				*3	116
	CBEQ imm8,(abs8),label	if(mem8(abs8)=imm8),PC+9+d7(label)+H→PC if(mem8(abs8)≠imm8),PC+9→PC	●	●	●	●	9	6/7			0010	1101	1100	<abs	8..>	<#8.	...>	<d7.	...H			*2	117
	CBEQ imm8,(abs8),label	if(mem8(abs8)=imm8),PC+10+d11(label)+H→PC if(mem8(abs8)≠imm8),PC+10→PC	●	●	●	●	10	6/7			0010	1101	1101	<abs	8..>	<#8.	...>	<d11	....	...H		*3	117
	CBEQ imm8,(abs16),label	if(mem8(abs16)=imm8),PC+11+d7(label)+H→PC if(mem8(abs16)≠imm8),PC+11→PC	●	●	●	●	11	7/8			0011	1101	1100	<abs	16..	....	...>	<#8.	...>	<d7.	...H	*2	118
	CBEQ imm8,(abs16),label	if(mem8(abs16)=imm8),PC+12+d11(label)+H→PC if(mem8(abs16)≠imm8),PC+12→PC	●	●	●	●	12	7/8			0011	1101	1101	<abs	16..	....	...>	<#8.	...>	<d11	....H	*3	118
CBNE	CBNE imm8,Dm,label	if(Dm≠imm8),PC+6+d7(label)+H→PC if(Dm=imm8),PC+6→PC	●	●	●	●	6	3/4			1101	10Dm	<#8.	...>	<d7.	..H>						*2	119
	CBNE imm8,Dm,label	if(Dm≠imm8),PC+8+d11(label)+H→PC if(Dm=imm8),PC+8→PC	●	●	●	●	8	4/5			0010	1101	10Dm	<#8.	...>	<d11	....	...H				*3	119
	CBNE imm8,(abs8),label	if(mem8(abs8)≠imm8),PC+9+d7(label)+H→PC if(mem8(abs8)=imm8),PC+9→PC	●	●	●	●	9	6/7			0010	1101	1110	<abs	8..>	<#8.	...>	<d7.	...H			*2	120
	CBNE imm8,(abs8),label	if(mem8(abs8)≠imm8),PC+10+d11(label)+H→PC if(mem8(abs8)=imm8),PC+10→PC	●	●	●	●	10	6/7			0010	1101	1111	<abs	8..>	<#8.	...>	<d11	....	...H		*3	120
	CBNE imm8,(abs16),label	if(mem8(abs16)≠imm8),PC+11+d7(label)+H→PC if(mem8(abs16)=imm8),PC+11→PC	●	●	●	●	11	7/8			0011	1101	1110	<abs	16..	....	...>	<#8.	...>	<d7.	...H	*2	121
	CBNE imm8,(abs16),label	if(mem8(abs16)≠imm8),PC+12+d11(label)+H→PC if(mem8(abs16)=imm8),PC+12→PC	●	●	●	●	12	7/8			0011	1101	1111	<abs	16..	....	...>	<#8.	...>	<d11	....H	*3	121
TBZ	TBZ (abs8)bp,label	if(mem8(abs8)bp=0),PC+7+d7(label)+H→PC if(mem8(abs8)bp=1),PC+7→PC	0	●	0	●	7	6/7			0011	0000	0bp.	<abs	8..>	<d7.	...H					*2	122
	TBZ (abs8)bp,label	if(mem8(abs8)bp=0),PC+8+d11(label)+H→PC if(mem8(abs8)bp=1),PC+8→PC	0	●	0	●	8	6/7			0011	0000	1bp.	<abs	8..>	<d11	....	...H				*3	122

*1 d4 sign-extension
*2 d7 sign-extension
*3 d11 sign-extension

MN101C SERIES INSTRUCTION SET

Group	Mnemonic	Operation	Flag VF	Flag NF	Flag CF	Flag ZF	Code Size	Cycle	Re-peat	Extension	Machine Code 1	2	3	4	5	6	7	8	9	10	11	Notes	Page
TBZ	TBZ (io8)bp,label	if(mem8(IOTOP+io8)bp=0),PC+7+d7(label)+H→PC if(mem8(IOTOP+io8)bp=1),PC+7→PC	0	●	0	●	7	6/7			0011	0100	0bp.	<io8	...>	<d7.	...H					*1	123
	TBZ (io8)bp,label	if(mem8(IOTOP+io8)bp=0),PC+8+d11(label)+H→PC if(mem8(IOTOP+io8)bp=1),PC+8→PC	0	●	0	●	8	6/7			0011	0100	1bp.	<io8	...>	<d11	....	...H				*2	123
	TBZ (abs16)bp,label	if(mem8(abs16)bp=0),PC+9+d7(label)+H→PC if(mem8(abs16)bp=1),PC+9→PC	0	●	0	●	9	7/8			0011	1110	0bp.	<abs	16..	....	...>	<d7.	...H			*1	124
	TBZ (abs16)bp,label	if(mem8(abs16)bp=0),PC+10+d11(label)+H→PC if(mem8(abs16)bp=1),PC+10→PC	0	●	0	●	10	7/8			0011	1110	1bp.	<abs	16..	....	...>	<d11	....	...H		*2	124
TBNZ	TBNZ (abs8)bp,label	if(mem8(abs8)bp=1),PC+7+d7(label)+H→PC if(mem8(abs8)bp=0),PC+7→PC	0	●	0	●	7	6/7			0011	0001	0bp.	<abs	8..>	<d7.	...H					*1	125
	TBNZ (abs8)bp,label	if(mem8(abs8)bp=1),PC+8+d11(label)+H→PC if(mem8(abs8)bp=0),PC+8→PC	0	●	0	●	8	6/7			0011	0001	1bp.	<abs	8..>	<d11	....	...H				*2	125
	TBNZ (io8)bp,label	if(mem8(io)bp=1),PC+7+d7(label)+H→PC if(mem8(io)bp=0),PC+7→PC	0	●	0	●	7	6/7			0011	0101	0bp.	<io8	...>	<d7.	...H					*1	126
	TBNZ (io8)bp,label	if(mem8(io)bp=1),PC+8+d11(label)+H→PC if(mem8(io)bp=0),PC+8→PC	0	●	0	●	8	6/7			0011	0101	1bp.	<io8	...>	<d11	....	...H				*2	126
	TBNZ (abs16)bp,label	if(mem8(abs16)bp=1),PC+9+d7(label)+H→PC if(mem8(abs16)bp=0),PC+9→PC	0	●	0	●	9	7/8			0011	1111	0bp.	<abs	16..	....	...>	<d7.	...H			*1	127
	TBNZ (abs16)bp,label	if(mem8(abs16)bp=1),PC+10+d11(label)+H→PC if(mem8(abs16)bp=0),PC+10→PC	0	●	0	●	10	7/8			0011	1111	1bp.	<abs	16..	....	...>	<d11	....	...H		*2	127
JMP	JMP (An)	0→PC.17-16,An→PC.15-0,0→PC.H	---	---	---	---	3	4			0010	0001	00A0										128
	JMP label	abs18(label)+H→PC	---	---	---	---	7	5			0011	1001	0aaH	<abs	18.b	p15~	0..>					*5	128
JSR	JSR (An)	SP-3→SP,(PC+3).bp7-0→mem8(SP) (PC+3).bp15-8→mem8(SP+1) (PC+3).H→mem8(SP+2).bp7, 0→mem8(SP+2).bp6-2, (PC+3).bp17-16→mem8(SP+2).bp1-0 0→PC.bp17-16 An→PC.bp15-0,0→PC.H	---	---	---	---	3	7			0010	0001	00A1										129
	JSR label	SP-3→SP,(PC+5).bp7-0→mem8(SP) (PC+5).bp15-8→mem8(SP+1) (PC+5).H→mem8(SP+2).bp7, 0→mem8(SP+2).bp6-2, (PC+5).bp17-16→mem8(SP+2).bp1-0 PC+5+d12(label)+H→PC	---	---	---	---	5	6			0001	000H	<d12	....	...>							*3	129
	JSR label	SP-3→SP,(PC+6).bp7-0→mem8(SP) (PC+6).bp15-8→mem8(SP+1) (PC+6).H→mem8(SP+2).bp7, 0→mem8(SP+2).bp6-2, (PC+6).bp17-16→mem8(SP+2).bp1-0 PC+6+d16(label)+H→PC	---	---	---	---	6	7			0001	001H	<d16	....	....	...>						*4	130
	JSR label	SP-3→SP,(PC+7).bp7-0→mem8(SP) (PC+7).bp15-8→mem8(SP+1) (PC+7).H→mem8(SP+2).bp7, 0→mem8(SP+2).bp6-2, (PC+7).bp17-16→mem8(SP+2).bp1-0 abs18(label)+H→PC	---	---	---	---	7	8			0011	1001	1aaH	<abs	18.b	p15~	0..>					*5	130
	JSRV (tbl4)	SP-3→SP,(PC+3).bp7-0→mem8(SP) (PC+3).bp15-8→mem8(SP+1) (PC+3).H→mem8(SP+2).bp7 0→mem8(SP+2).bp6-2, (PC+3).bp17-16→mem8(SP+2).bp1-0 mem8(x'004080+tbl4<<2)→PC.bp7-0 mem8(x'004080+tbl4<<2+1)→PC.bp15-8 mem8(x'004080+tbl4<<2+2).bp7→PC.H mem8(x'004080+tbl4<<2+2).bp1-0→ PC.bp17-16	---	---	---	---	3	9			1111	1110	<t4>										131
NOP	NOP	PC+2→PC	---	---	---	---	2	1	○		0000	0000											132

NOTE: Pages for MN101C Series Instruction Manual.

*1 d7 sign-extension
*2 d11 sign-extension
*3 d12 sign-extension
*4 d16 sign-extension
*5 aa=abs18.17 - 16

MN101C SERIES INSTRUCTION SET

Group	Mnemonic	Operation	Flag VF	Flag NF	Flag CF	Flag ZF	Code Size	Cycle	Re-peat	Extension	Machine Code 1	2	3	4	5	6	7	8	9	10	11	Notes	Page
RTS	RTS	mem8(SP)→(PC).bp7-0 mem8(SP+1)→(PC).bp15-8 mem8(SP+2).bp7→(PC).H mem8(SP+2).bp1-0→(PC).bp17-16 SP+3→SP	---	---	---	---	2	7			0000 0001												133
RTI	RTI	mem8(SP)→PSW mem8(SP+1)→(PC).bp7-0 mem8(SP+2)→(PC).bp15-8 mem8(SP+3).bp7→(PC).H mem8(SP+3).bp1-0→(PC).bp17-16 mem8(SP+4)→HA-l mem8(SP+5)→HA-h SP+6→SP	●	●	●	●	2	11			0000 0011												134
Contorl instructions																							
REP	REP imm3	imm3-1→RPC	---	---	---	---	3	2			0010 0001 1rep											*1	135

NOTE: Pages for MN101C Series Instruction Manual. *1 no repeat whn imm3=0, (rep: imm3-1)

Other than the instruction of MN101C Series,the assembler of this Series has the following instructions as macro instructions.
The assembler will interpret the macro instructions below as the assembler instructions.

macro instructions	replaced instructions	remarks
INC Dn	ADD 1,Dn	
DEC Dn	ADD -1,Dn	
INC An	ADDW 1,An	
DEC An	ADDW -1,An	
INC2 An	ADDW 2,An	
DEC2 An	ADDW -2,An	
CLR Dn	SUB Dn,Dm	n=m
ASL D	ADD Dn,Dm	n=m
ROL Dn	ADDC Dn,Dm	n=m
NEG Dn	NOT Dn ADD 1,Dn	
NOPL	MOVW DWn,DWm	n=m
MOV (SP),Dn	MOV (0,SP),Dn	
MOV Dn,(SP)	MOV Dn,(0,SP)	
MOVW (SP),DWn	MOVW (0,SP),DWn	
MOVW DWn,(SP)	MOVW DWn,(0,SP)	
MOVW (SP),An	MOVW (0,SP),An	
MOVW An,(SP)	MOVW An,(0,SP)	

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12-5 Instruction Map

MN101C SERIES INSTRUCTION MAP

1st nibble\2nd nibble

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NOP	RTS	MOV #8,(io8)	RTI	CMP #8,(abs8)/(abs12)		POP An		ADD #8,Dm				MOVW #8,DWm		MOVW #8,Am	
1	JSR d12(label)		JSR d16(label)		MOV #8,(abs8)/(abs12)		PUSH An		OR #8,Dm				AND #8,Dm			
2	When the exension code is b'oo10'															
3	When the extension code is b'0011'															
4	MOV (abs12),Dm				MOV (abs8),Dm				MOV (An),Dm							
5	MOV Dn,(abs12)				MOV Dn,(abs8)				MOV Dn,(Am)							
6	MOV (io8),Dm				MOV (d4,SP),Dm				MOV (d8,An),Dm							
7	MOV Dn,(io8)				MOV Dn,(d4,SP)				MOV Dn,(d8,Am)							
8	ADD #4,Dm				SUB Dn,Dn				BGE d7	BRA d7	BEQ d7	BNE d7	BCC d7	BCS d7	BLT d7	BLE d7
9	BEQ d4		BNE d4		MOVW DWn,(HA)		MOVW An,(HA)		BGE d11	BRA d11	BEQ d11	BNE d11	BCC d11	BCS d11	BLT d11	BLE d11
A	MOV Dn,Dm / MOV #8,Dm															
B	BSET (abs8)bp								BCLR (abs8)bp							
C	CMP #8,Dm				MOVW (abs8),Am		MOVW (abs8),DWm		CBEQ #8,Dm,d7				CMPW #16,DWm		MOVW #16,DWm	
D	MOV Dn,(HA)				MOVW An,(abs8)		MOVW DWn,(abs8)		CBNE #8,Dm,d7				CMPW #16,Am		MOVW #16,Am	
E	MOVW (An),DWm				MOVW (d4,SP),Am		MOVW (d4,SP),DWm		POP Dn				ADDW #4,Am		BRA d4	
F	MOVW DWn,(Am)				MOVW An,(d4,SP)		MOVW DWn,(d4,SP)		PUSH Dn				ADDW #8,SP	ADDW #4,SP	JSRV (tbl4)	

Extension code: b'0010'

2nd nible\ 3rd nibble

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	MOVW An,Am				CMPW An,Am				MOVW SP,Am		MOVW An,SP		BTST #8,Dm			
1	JMP (A0)	JSR (A0)	JMP (A1)	JSR (A1)	MOV PSW,Dm				REP #3							
2		BGT d7	BHI d7	BLS d7	BNC d7	BNS d7	BVC d7	BVS d7	NOT Dn				ROR Dn			
3		BGT d11	BHI d11	BLS d11	BNC d11	BNS d11	BVC d11	BVS d11	ASR Dn				LSR Dn			
4	SUBW DWn,DWm				SUBW #16,DWm		SUBW #16,Am		SUBW DWn,Am				MOVW DWn,Am			
5	ADDW DWn,DWm				ADDW #16,DWm		ADDW #16,Am		ADDW DWn,Am				CMPW DWn,Am			
6	MOV (d16,SP),Dm				MOV (d8,SP),Dm				MOV (d16,An),Dm							
7	MOV Dn,(d16,SP)				MOV Dn,(d8,SP)				MOV Dn,(d16,Am)							
8	MOVW DWn,DWm (NOPL @n=m)				CMPW DWn,DWm				ADDUW Dn,Am							
9	EXT Dn,DWm		AND #8,PSW	OR #8,PSW	MOV Dn,PSW				ADDSW Dn,Am							
A	SUB Dn,Dm / SUB #8,Dm															
B	SUBC Dn,Dm															
C	MOV (abs16),Dm				MOVW (abs16),Am		MOVW (abs16),DWm		CBEQ #8,Dm,d12				MOVW An,DWm			
D	MOV Dn,(abs16)				MOVW An,(abs16)		MOVW DWn,(abs16)		CBNE #8,Dm,d12				CBEQ #8,(abs8),d7/d11		CBNE #8,(abs8),d7/d11	
E	MOVW (d16,SP),Am		MOVW (d16,SP),DWm		MOVW (d8,SP),Am		MOVW (d8,SP),DWm		MOVW (An),Am				ADDW #8,Am		DIVU	
F	MOVW An,(d16,SP)		MOVW DWn,(d16,SP)		MOVW An,(d8,SP)		MOVW DWn,(d8,SP)		MOVW An,(Am)				ADDW #16,SP		MULU	

Extension code: b'0011'

2nd nibble\ 3rd nibble	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	TBZ (abs8)bp,d7								TBZ (abs8)bp,d11							
1	TBNZ (abs8)bp,d7								TBNZ (abs8)bp,d11							
2	CMP Dn,Dm															
3	ADD Dn,Dm															
4	TBZ (io8)bp,d7								TBZ (io8)bp,d11							
5	TBNZ (io8)bp,d7								TBNZ (io8)bp,d11							
6	OR Dn,Dm															
7	AND Dn,Dm															
8	BSET (io8)bp								BCLR (io8)bp							
9	JMP abs18(label)								JSR abs18(label)							
A	XOR Dn,Dm / XOR #8,Dm															
B	ADDC Dn,Dm															
C	BSET (abs16)bp								BCLR (abs16)bp							
D	BTST (abs16)bp								cmp #8,(abs16)	mov #8,(abs16)			CBEQ #8,(abs16),d7/11		CBNE #8,(abs16),d7/11	
E	TBZ (abs16)bp,d7								TBZ (abs16)bp,d11							
F	TBNZ (abs16)bp,d7								TBNZ (abs16)bp,d11							

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