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April 1st, 2010
Renesas Electronics Corporation

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3803 Group (Spec.L)

SINGLE-CHIP 8-BIT CMOS MICROCOMPUTER

REJ03B0212-0101

Rev.1.01

Jan 25, 2008

DESCRIPTION

The 3803 group (Spec.L) is the 8-bit microcomputer based on the 740 family core technology.

The 3803 group (Spec.L) is designed for household products, office automation equipment, and controlling systems that require analog signal processing, including the A/D converter and D/A converters.

FEATURES

- Basic machine-language instructions 71
- Minimum instruction execution time 0.24 μ s
(at 16.8 MHz oscillation frequency)
- Memory size
 - Mask ROM/Flash memory 60 K bytes
 - RAM 2048 bytes
- Programmable input/output ports 56
- Software pull-up resistors Built-in
- Interrupts
 - 21 sources, 16 vectors.....
 - (external 8, internal 12, software 1)
- Timers 16-bit \times 1
8-bit \times 4
(with 8-bit prescaler)
- Serial interface 8-bit \times 2 (UART or Clock-synchronized)
8-bit \times 1 (Clock-synchronized)
- PWM 8-bit \times 1 (with 8-bit prescaler)
- A/D converter 10-bit \times 16 channels
(8-bit reading enabled)
- D/A converter 8-bit \times 2 channels
- Watchdog timer 16-bit \times 1
- LED direct drive port 8
- Clock generating circuit Built-in 2 circuits
(connect to external ceramic resonator or quartz-crystal oscillator)
- Power source voltage (Mask ROM version)
 - [In high-speed mode]
 - At 16.8 MHz oscillation frequency4.5 to 5.5 V
 - At 12.5 MHz oscillation frequency4.0 to 5.5 V
 - At 8.4 MHz oscillation frequency2.7 to 5.5 V
 - At 4.2 MHz oscillation frequency2.2 to 5.5 V
 - At 2.1 MHz oscillation frequency2.0 to 5.5 V
 - [In middle-speed mode]
 - At 16.8 MHz oscillation frequency4.5 to 5.5 V
 - At 12.5 MHz oscillation frequency2.7 to 5.5 V
 - At 8.4 MHz oscillation frequency2.2 to 5.5 V
 - At 6.3 MHz oscillation frequency1.8 to 5.5 V
 - [In low-speed mode]
 - At 32 kHz oscillation frequency1.8 to 5.5 V

- Power source voltage (Flash memory version)
 - [In high-speed mode]
 - At 16.8 MHz oscillation frequency4.5 to 5.5 V
 - At 12.5 MHz oscillation frequency4.0 to 5.5 V
 - At 8.4 MHz oscillation frequency2.7 to 5.5 V
 - [In middle-speed mode]
 - At 16.8 MHz oscillation frequency4.5 to 5.5 V
 - At 12.5 MHz oscillation frequency2.7 to 5.5 V
 - [In low-speed mode]
 - At 32 kHz oscillation frequency.....2.7 to 5.5 V
- Power dissipation (Mask ROM version)
 - In high-speed mode 40 mW (typ.)
(at 16.8 MHz oscillation frequency, at 5 V power source voltage)
 - In low-speed mode 45 μ W (typ.)
(at 32 kHz oscillation frequency, at 3 V power source voltage)
- Power dissipation (Flash memory version)
 - In high-speed mode 27.5 mW (typ.)
(at 16.8 MHz oscillation frequency, at 5 V power source voltage)
 - In low-speed mode 1200 μ W (typ.)
(at 32 kHz oscillation frequency, at 3 V power source voltage)
- Operating temperature range -20 to 85 °C
- Packages
 - SP.....PRDP0064BA-A (64P4B) (64-pin 750 mil SDIP)
 - HPPLQP0064KB-A (64P6Q-A) (64-pin 10 \times 10 mm LQFP)
 - KPPLQP0064GA-A (64P6U-A) (64-pin 14 \times 14 mm LQFP)
 - WGPTLG0064JA-A (64F0G) (64-pin 6 \times 6 mm FLGA)

<Flash memory mode>

- Power source voltage $V_{CC} = 2.7$ to 5.5 V
- Program/Erase voltage $V_{CC} = 2.7$ to 5.5 V
- Programming method Programming in unit of byte
- Erasing method Block erasing
- Program/Erase control by software command
- Number of times for programming/erasing 100

<Notes>

The flash memory version cannot be used for application embedded in the MCU card.

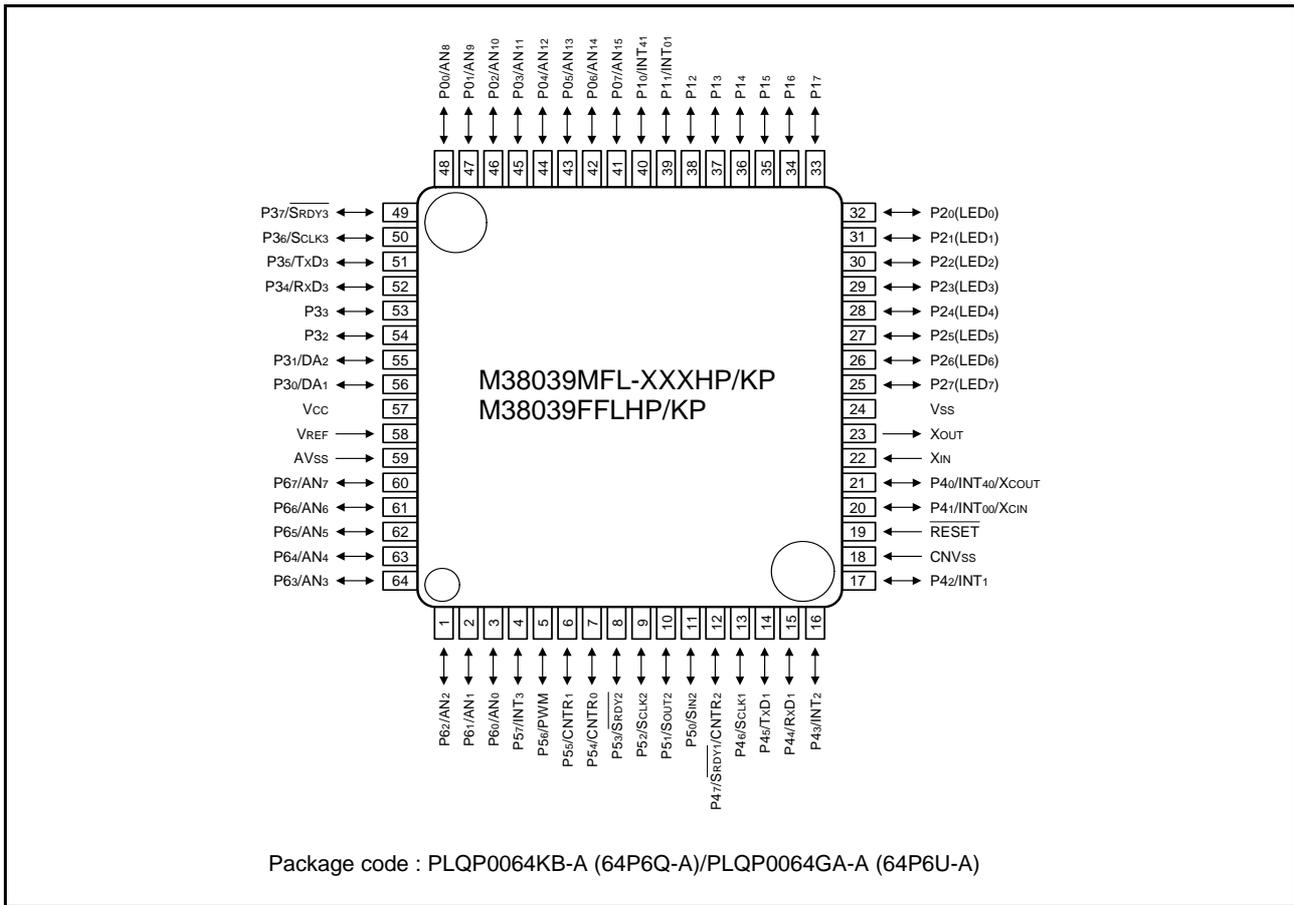


Fig 1. Pin configuration (Top view) PLQP0064KB-A (64P6Q-A)/PLQP0064GA-A (64P6U-A)

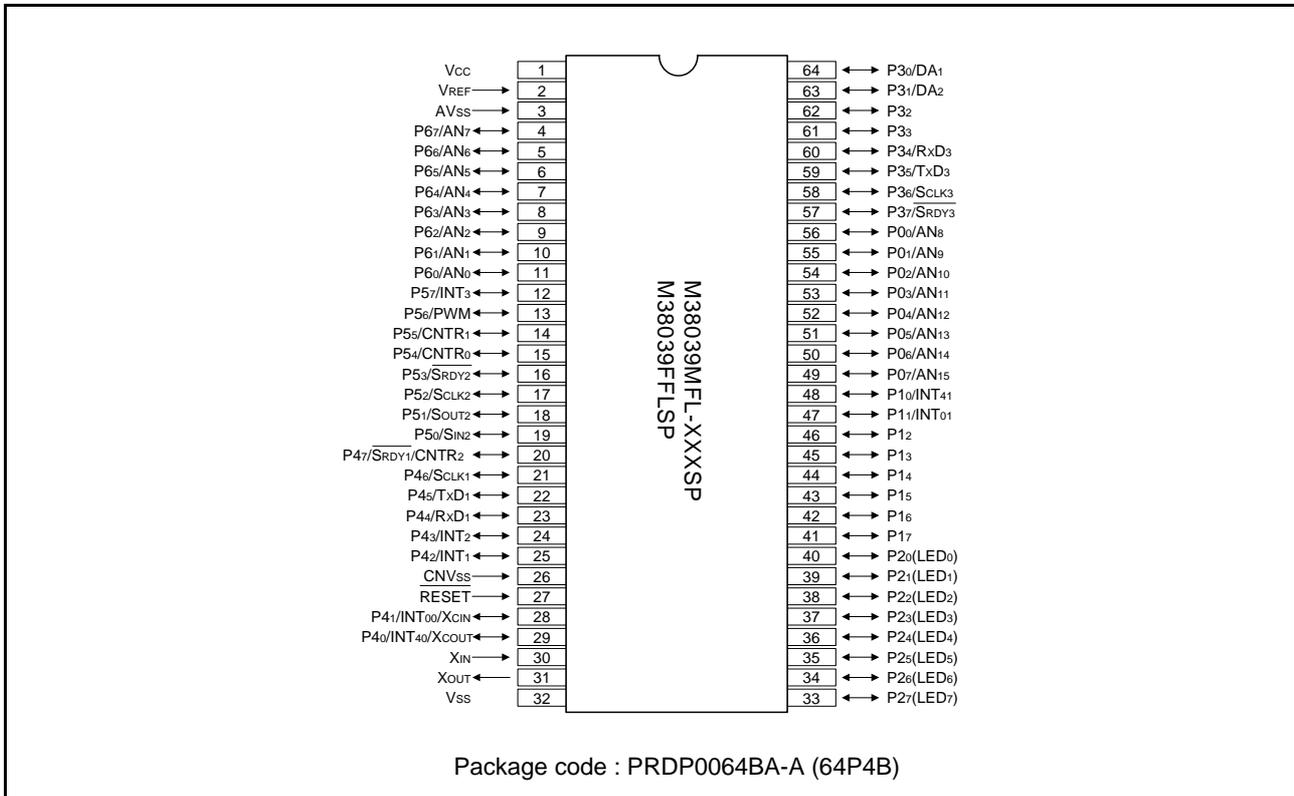


Fig 2. Pin configuration (Top view) (PRDP0064BA-A (64P4B))

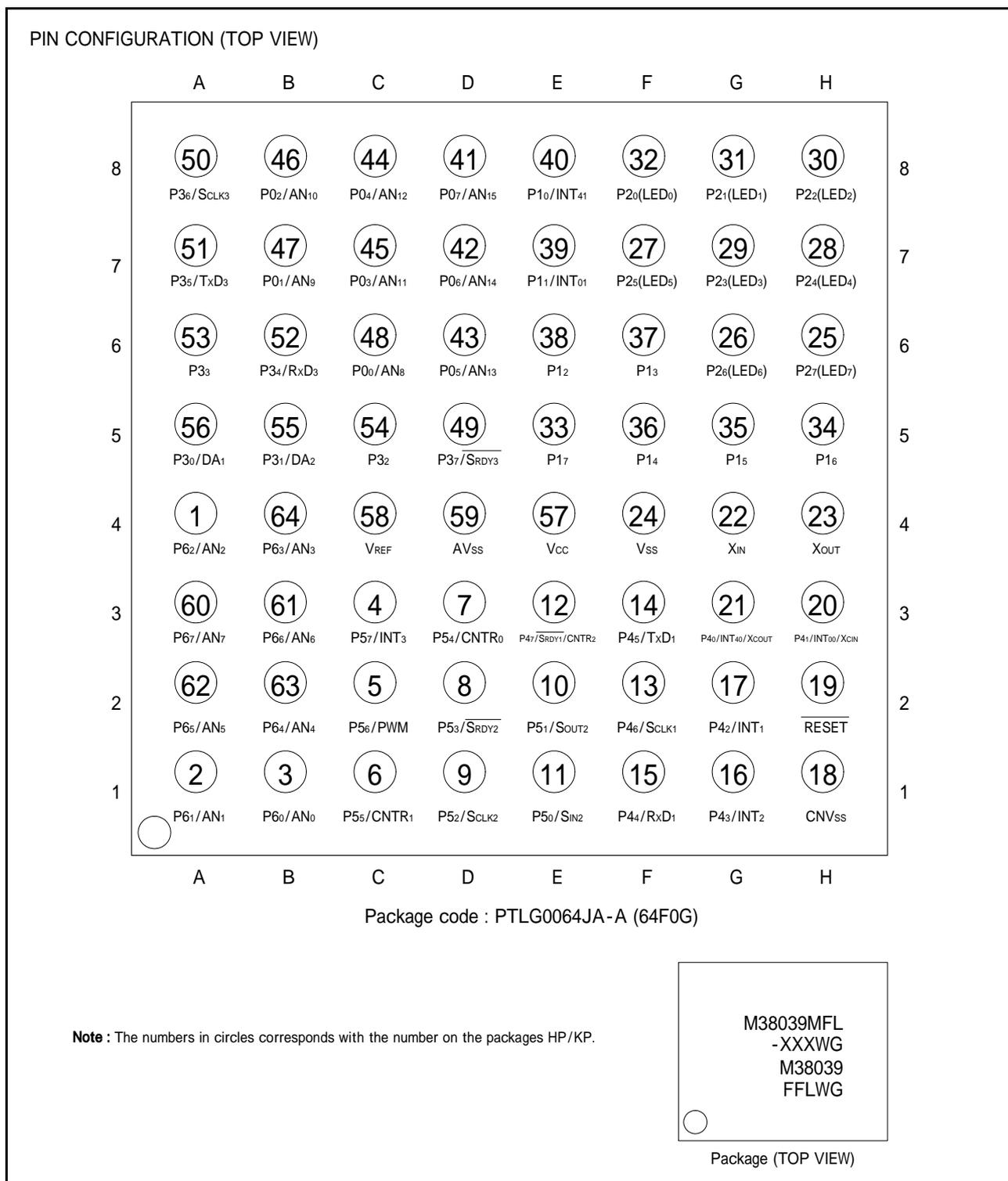


Fig 3. Pin configuration (Top view) (PTLG0064JA-A (64F0G))

Table 1 Performance overview

Parameter			Function	
Number of basic instructions			71	
Minimum instruction execution time			0.24 μ s (Oscillation frequency 16.8 MHz)	
Oscillation frequency			Oscillation frequency 16.8 MHz(Maximum)	
Memory sizes	Mask ROM version	ROM	60 Kbytes	
		RAM	2048 bytes	
	Flash memory version	ROM	60 Kbytes	
		RAM	2048 bytes	
I/O port	P0-P6		56 pins	
Software pull-up resistors			Built-in	
Interrupt			21 sources, 16 vectors (8 external, 12 internal, 1 software)	
Timer			8-bit \times 4 (with 8-bit prescaler), 16-bit \times 1	
Serial interface			8-bit \times 2 (UART or Clock-synchronized) 8-bit \times 1 (Clock-synchronized)	
PWM			8-bit \times 1 (with 8-bit prescaler)	
A/D converter			10-bit \times 16 channels (8-bit reading enabled)	
D/A converter			8-bit \times 2 channels	
Watchdog timer			16-bit \times 1	
LED direct drive port			8 (average current: 15 mA, peak current: 30 mA, total current: 90 mA)	
Clock generating circuits			Built-in 2 circuits (connect to external ceramic rasonator or quartz-crystal oscillator)	
Power source voltage	In high-speed mode	At 16.8 MHz	Mask ROM version	4.5 to 5.5 V
			Flash memory version	
		At 12.5 MHz	Mask ROM version	4.0 to 5.5 V
			Flash memory version	
		At 8.4 MHz	Mask ROM version	2.7 to 5.5 V
	Flash memory version			
	At 4.2 MHz	Mask ROM version	2.2 to 5.5 V	
		Mask ROM version		
	At 2.1 MHz	Mask ROM version	2.0 to 5.5 V	
		Mask ROM version		
	In middle-speed mode	At 16.8 MHz	Mask ROM version	4.5 to 5.5 V
			Flash memory version	
		At 12.5 MHz	Mask ROM version	2.7 to 5.5 V
			Flash memory version	
At 8.4 MHz		Mask ROM version	2.2 to 5.5 V	
	Mask ROM version			
At 6.3 MHz	Mask ROM version	1.8 to 5.5 V		
	Mask ROM version			
In low-speed mode	At 32 MHz	Mask ROM version	1.8 to 5.5 V	
		Flash memory version		2.7 to 5.5 V
Power dissipation	In high-speed mode	Mask ROM version	40 mW	
		Flash memory version	27.5 mW	
	In low-speed mode	Mask ROM version	45 μ W	
		Flash memory version	1200 μ W	
Input/Output characteristics	Input/Output withstand voltage		Vcc	
	Output current		10 mA	
Operating temperature range			-20 to 85 $^{\circ}$ C	
Device structure			CMOS silicon gate	
Package			64-pin plastic molded SDIP/LQFP/FLGA	

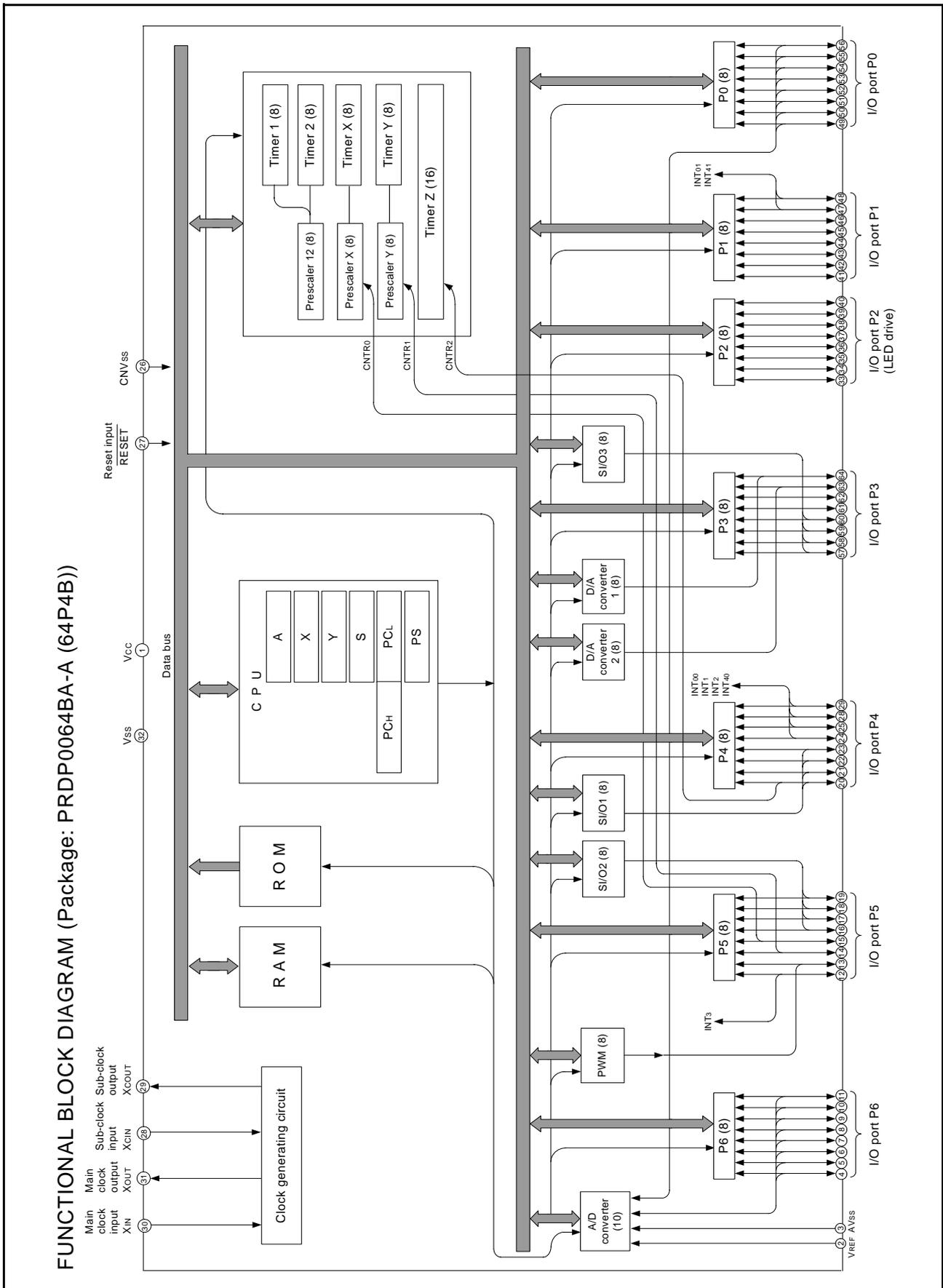


Fig 4. Functional block diagram

PIN DESCRIPTION

Table 2 Pin description

Pin	Name	Functions	
			Function except a port function
Vcc, Vss	Power source	<ul style="list-style-type: none"> Apply voltage of 1.8 V – 5.5 V to Vcc, and 0 V to Vss. In the flash memory version, apply voltage of 2.7 V – 5.5 V to Vcc. 	
CNVss	CNVss input	<ul style="list-style-type: none"> This pin controls the operation mode of the chip. Normally connected to Vss. 	
VREF	Reference voltage	<ul style="list-style-type: none"> Reference voltage input pin for A/D and D/A converters. 	
AVss	Analog power source	<ul style="list-style-type: none"> Analog power source input pin for A/D and D/A converters. Connect to Vss. 	
RESET	Reset input	<ul style="list-style-type: none"> Reset input pin for active "L". 	
XIN	Main clock input	<ul style="list-style-type: none"> Input and output pins for the clock generating circuit. Connect a ceramic resonator or quartz-crystal oscillator between the XIN and XOUT pins to set the oscillation frequency. 	
XOUT	Main clock output	<ul style="list-style-type: none"> When an external clock is used, connect the clock source to the XIN pin and leave the XOUT pin open. 	
P00/AN8– P07/AN15	I/O port P0	<ul style="list-style-type: none"> 8-bit CMOS I/O port. I/O direction register allows each pin to be individually programmed as either input or output. CMOS compatible input level. CMOS 3-state output structure. Pull-up control is enabled in a bit unit. 	<ul style="list-style-type: none"> A/D converter input pin
P10/INT41 P11/INT01	I/O port P1		<ul style="list-style-type: none"> Interrupt input pin
P12–P17			
P20(LED0)- P27(LED7)	I/O port P2	<ul style="list-style-type: none"> P20 – P27 (8 bits) are enabled to output large current for LED drive. 	
P30/DA1 P31/DA2	I/O port P3	<ul style="list-style-type: none"> 8-bit CMOS I/O port. I/O direction register allows each pin to be individually programmed as either input or output. CMOS compatible input level. P30, P31, P34 – P37 are CMOS 3-state output structure. P32, P33 are N-channel open-drain output structure. Pull-up control of P30, P31, P34 – P37 is enabled in a bit unit. 	<ul style="list-style-type: none"> D/A converter input pin
P32, P33			
P34/RxD3 P35/TxD3 P36/SCLK3 P37/SRDY3			<ul style="list-style-type: none"> Serial I/O3 function pin
P40/INT40/XCOUT P41/INT00/XCIN	I/O port P4	<ul style="list-style-type: none"> 8-bit CMOS I/O port. I/O direction register allows each pin to be individually programmed as either input or output. CMOS compatible input level. CMOS 3-state output structure. Pull-up control is enabled in a bit unit. 	<ul style="list-style-type: none"> Interrupt input pin Sub-clock generating I/O pin (resonator connected)
P42/INT1 P43/INT2			<ul style="list-style-type: none"> Interrupt input pin
P44/RxD1 P45/TxD1 P46/SCLK1			<ul style="list-style-type: none"> Serial I/O1 function pin
P47/SRDY1/CNTR2			<ul style="list-style-type: none"> Serial I/O1, timer Z function pin
			<ul style="list-style-type: none"> Serial I/O2 function pin
P50/SIN2 P51/SOUT2 P52/SCLK2 P53/SRDY2	I/O port P5		
P54/CNTR0			<ul style="list-style-type: none"> Timer X function pin
P55/CNTR1			<ul style="list-style-type: none"> Timer Y function pin
P56/PWM			<ul style="list-style-type: none"> PWM output pin
P57/INT3			<ul style="list-style-type: none"> Interrupt input pin
P60/AN0– P67/AN7			I/O port P6

PART NUMBERING

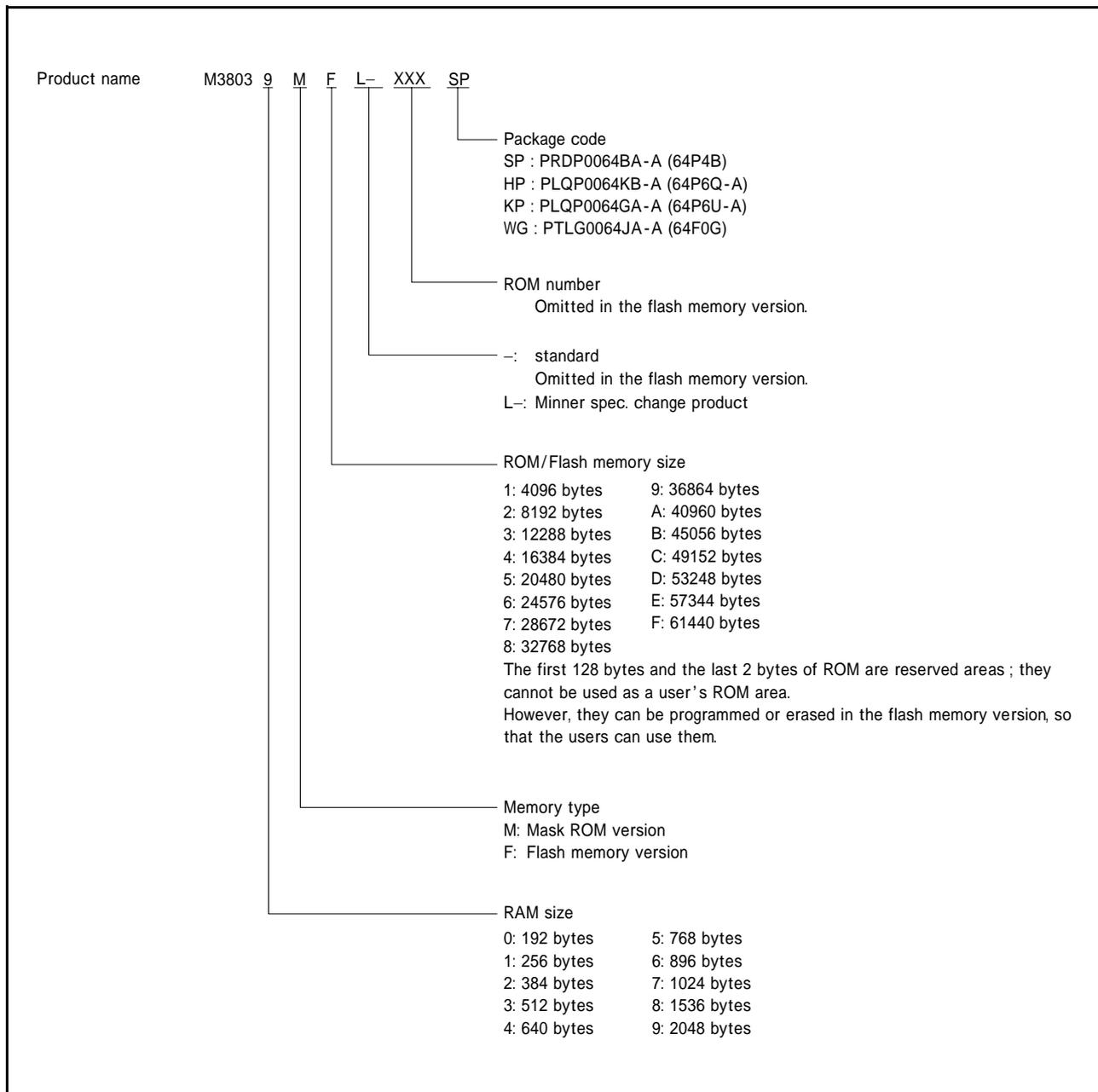


Fig 5. Part numbering

GROUP EXPANSION

Renesas plans to expand the 3803 group (Spec.L) as follows.

Memory Size

- Flash memory size60 Kbytes
- Mask ROM size60 Kbytes
- RAM size 2048 bytes

Packages

- PRDP0064BA-A (64P4B)
.....64-pin shrink plastic-molded DIP
- PLQP0064KB-A (64P6Q-A)
.....0.5 mm-pitch plastic molded LQFP
- PLQP0064GA-A (64P6U-A)
.....0.8 mm-pitch plastic molded LQFP
- PTLG0064JA-A (64F0G)
.....0.65 mm-pitch plastic molded FLGA

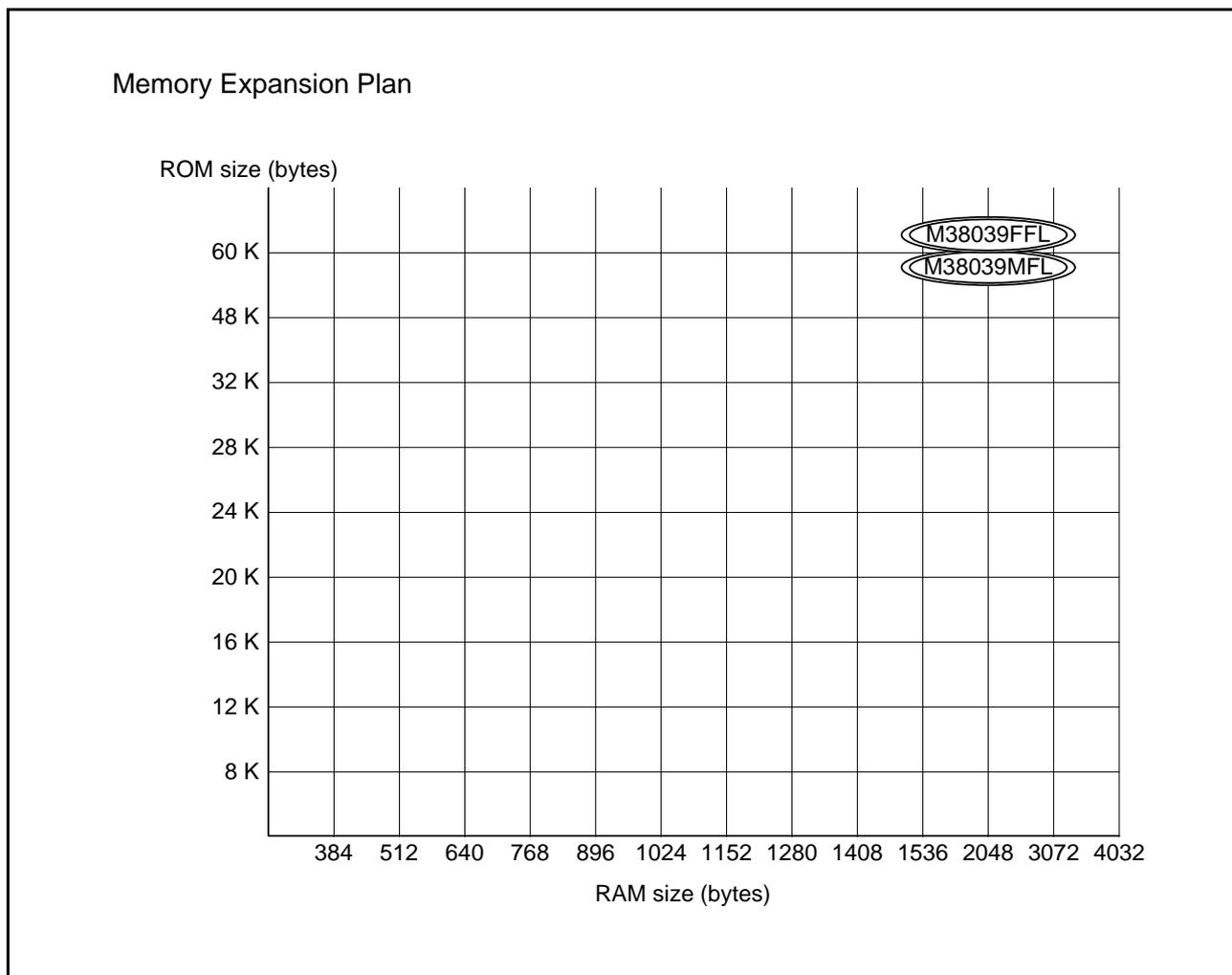


Fig 6. Memory expansion plan

Table 3 Support products

Part No.	ROM size (bytes) ROM size for User in ()	RAM size (bytes)	Package	Remarks
M38039MFL-XXXSP	61440 (61310)	2048	PRDP0064BA-A (64P4B)	Mask ROM version
M38039MFL-XXXHP			PLQP0064KB-A (64P6Q-A)	
M38039MFL-XXXKP			PLQP0064GA-A (64P6U-A)	
M38039MFL-XXXWG			PTLG0064JA-A (64F0G)	
M38039FFLSP	57344+4096 (NOTE)	2048	PRDP0064BA-A (64P4B)	Flash memory version Vcc = 2.7 to 5.5 V
M38039FFLHP			PLQP0064KB-A (64P6Q-A)	
M38039FFLKP			PLQP0064GA-A (64P6U-A)	
M38039FFLWG			PTLG0064JA-A (64F0G)	

NOTE:

1. ROM size includes the ID code area.

FUNCTIONAL DESCRIPTION**CENTRAL PROCESSING UNIT (CPU)**

The 3803 group (Spec.L) uses the standard 740 Family instruction set. Refer to the table of 740 Family addressing modes and machine instructions or the 740 Family Software Manual for details on the instruction set.

Machine-resident 740 Family instructions are as follows:

- The FST and SLW instructions cannot be used.
- The STP, WIT, MUL, and DIV instructions can be used.

[Accumulator (A)]

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

[Index Register X (X)]

The index register X is an 8-bit register. In the index addressing modes, the value of the OPERAND is added to the contents of register X and specifies the real address.

[Index Register Y (Y)]

The index register Y is an 8-bit register. In partial instruction, the value of the OPERAND is added to the contents of register Y and specifies the real address.

[Stack Pointer (S)]

The stack pointer is an 8-bit register used during subroutine calls and interrupts. This register indicates start address of stored area (stack) for storing registers during subroutine calls and interrupts.

The low-order 8 bits of the stack address are determined by the contents of the stack pointer. The high-order 8 bits of the stack address are determined by the stack page selection bit. If the stack page selection bit is "0", the high-order 8 bits becomes "0016". If the stack page selection bit is "1", the high-order 8 bits becomes "0116".

The operations of pushing register contents onto the stack and popping them from the stack are shown in Figure 8.

Store registers other than those described in Figure 7 with program when the user needs them during interrupts or subroutine calls (see Table 4).

[Program Counter (PC)]

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

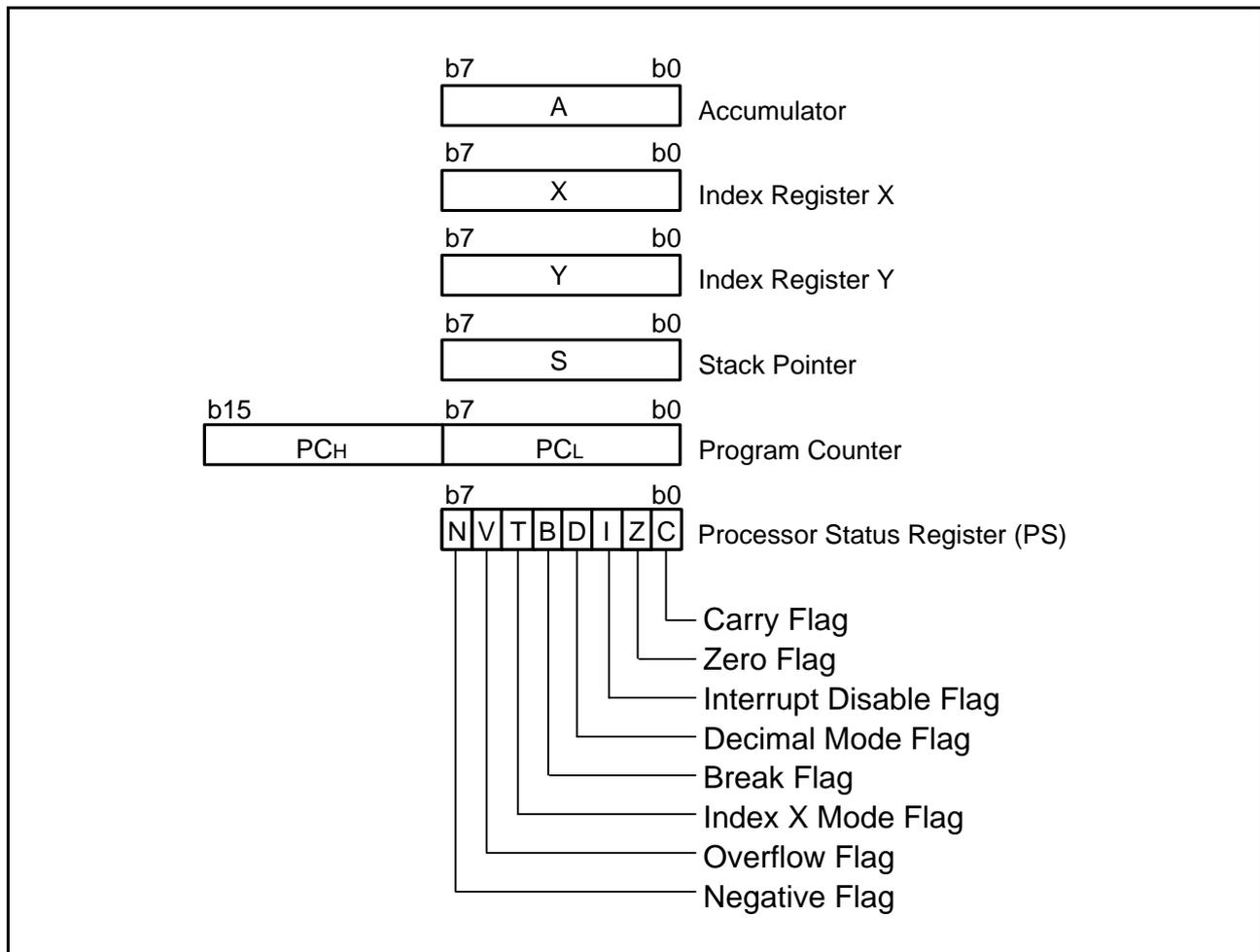


Fig 7. 740 Family CPU register structure

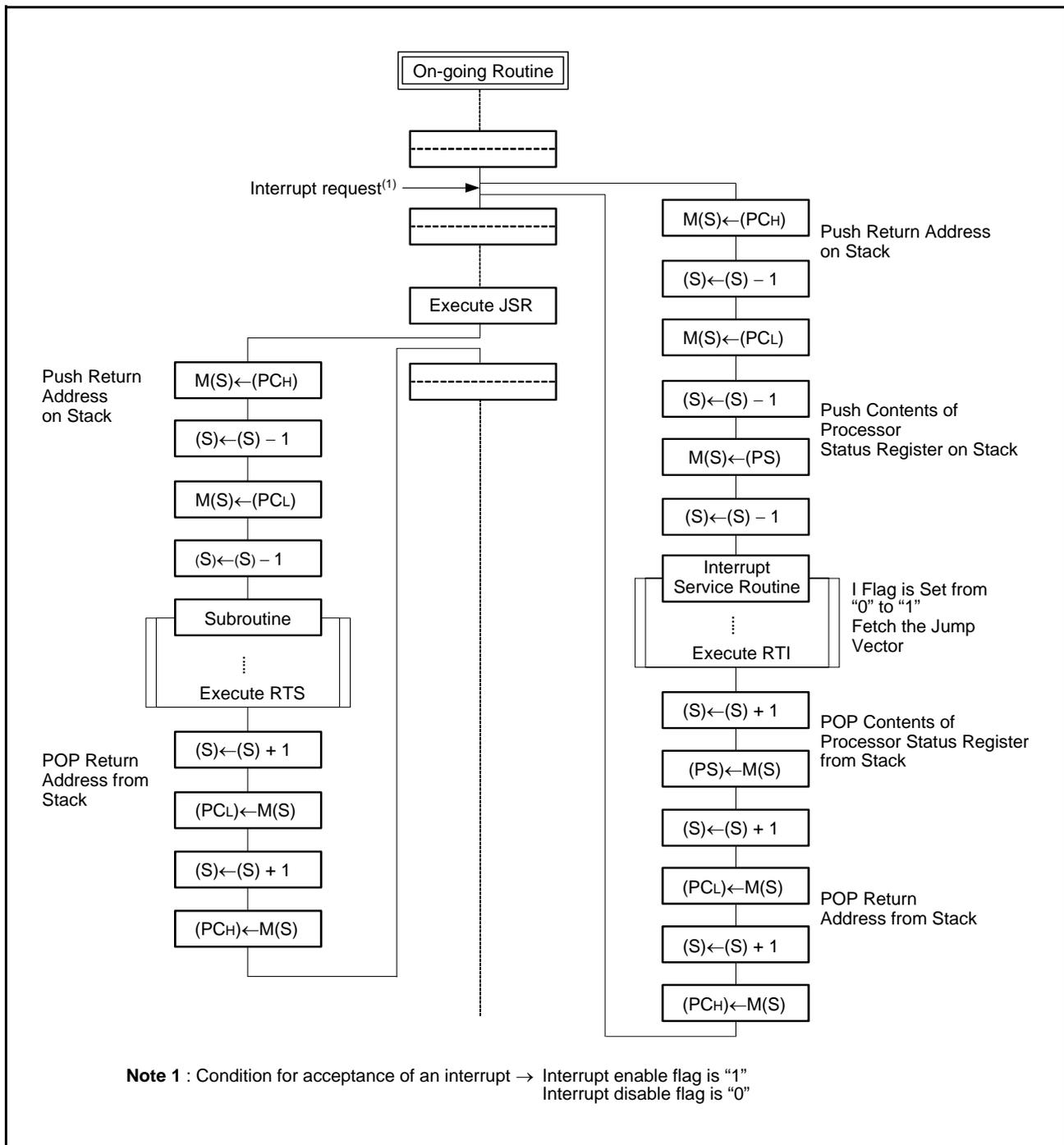


Fig 8. Register push and pop at interrupt generation and subroutine call

Table 4 Push and pop instructions of accumulator or processor status register

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

[Processor status register (PS)]

The processor status register is an 8-bit register consisting of 5 flags which indicate the status of the processor after an arithmetic operation and 3 flags which decide MCU operation. Branch operations can be performed by testing the Carry (C) flag, Zero (Z) flag, Overflow (V) flag, or the Negative (N) flag. In decimal mode, the Z, V, N flags are not valid.

Bit 0: Carry flag (C)

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

Bit 1: Zero flag (Z)

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

Bit 2: Interrupt disable flag (I)

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

Bit 3: Decimal mode flag (D)

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

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

Bit 4: Break flag (B)

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

Bit 5: Index X mode flag (T)

When the T flag is "0", arithmetic operations are performed between accumulator and memory. When the T flag is "1", direct arithmetic operations and direct data transfers are enabled between memory locations.

Bit 6: Overflow flag (V)

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

Bit 7: Negative flag (N)

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

Table 5 Set and clear instructions of each bit of processor status register

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

[CPU Mode Register (CPUM)] 003B16

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

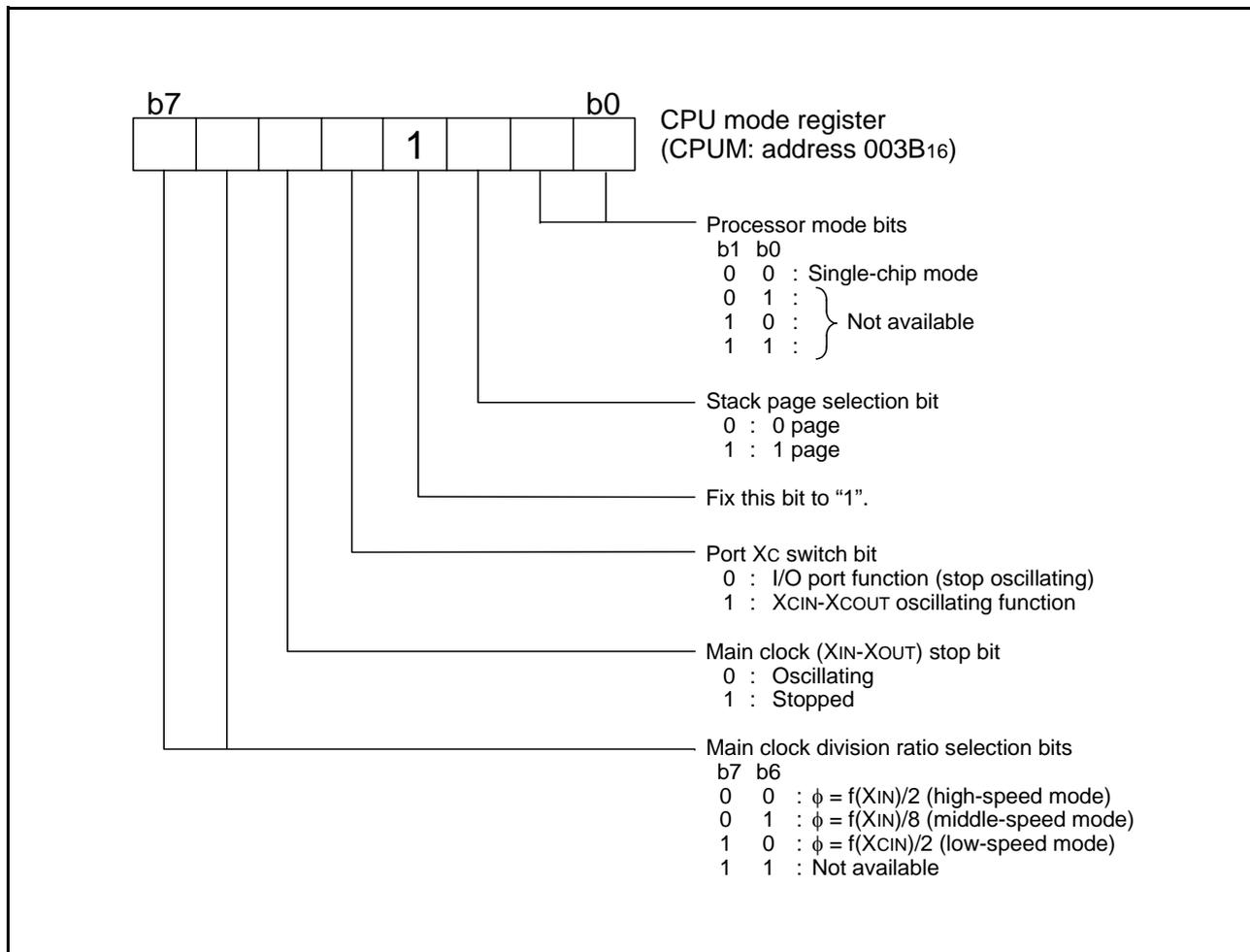


Fig 9. Structure of CPU mode register

MISRG**(1) Bit 0 of address 0010₁₆: Oscillation stabilizing time set after STP instruction released bit**

When the MCU stops the clock oscillation by the STP instruction and the STP instruction has been released by an external interrupt source, usually, the fixed values of Timer 1 and Prescaler 12 (Timer 1 = 01₁₆, Prescaler 12 = FF₁₆) are automatically reloaded in order for the oscillation to stabilize. The user can inhibit the automatic setting by setting "1" to bit 0 of MISRG (address 0010₁₆).

However, by setting this bit to "1", the previous values, set just before the STP instruction was executed, will remain in Timer 1 and Prescaler 12. Therefore, you will need to set an appropriate value to each register, in accordance with the oscillation stabilizing time, before executing the STP instruction.

Figure 10 shows the structure of MISRG.

(2) Bits 1, 2, 3 of address 0010₁₆: Middle-speed Mode Automatic Switch Function

In order to switch the clock mode of an MCU which has a sub-clock, the following procedure is necessary:

set CPU mode register (003B₁₆) --> start main clock oscillation
--> wait for oscillation stabilization --> switch to middle-speed mode (or high-speed mode).

However, the 3803 group (Spec.L) has the built-in function which automatically switches from low to middle-speed mode by program.

• Middle-speed mode automatic switch by program

The middle-speed mode can also be automatically switched by program while operating in low-speed mode. By setting the middle-speed automatic switch start bit (bit 3) of MISRG (address 0010₁₆) to "1" in the condition that the middle-speed mode automatic switch set bit is "1" while operating in low-speed mode, the MCU will automatically switch to middle-speed mode. In this case, the oscillation stabilizing time of the main clock can be selected by the middle-speed automatic switch wait time set bit (bit 2) of MISRG (address 0010₁₆).

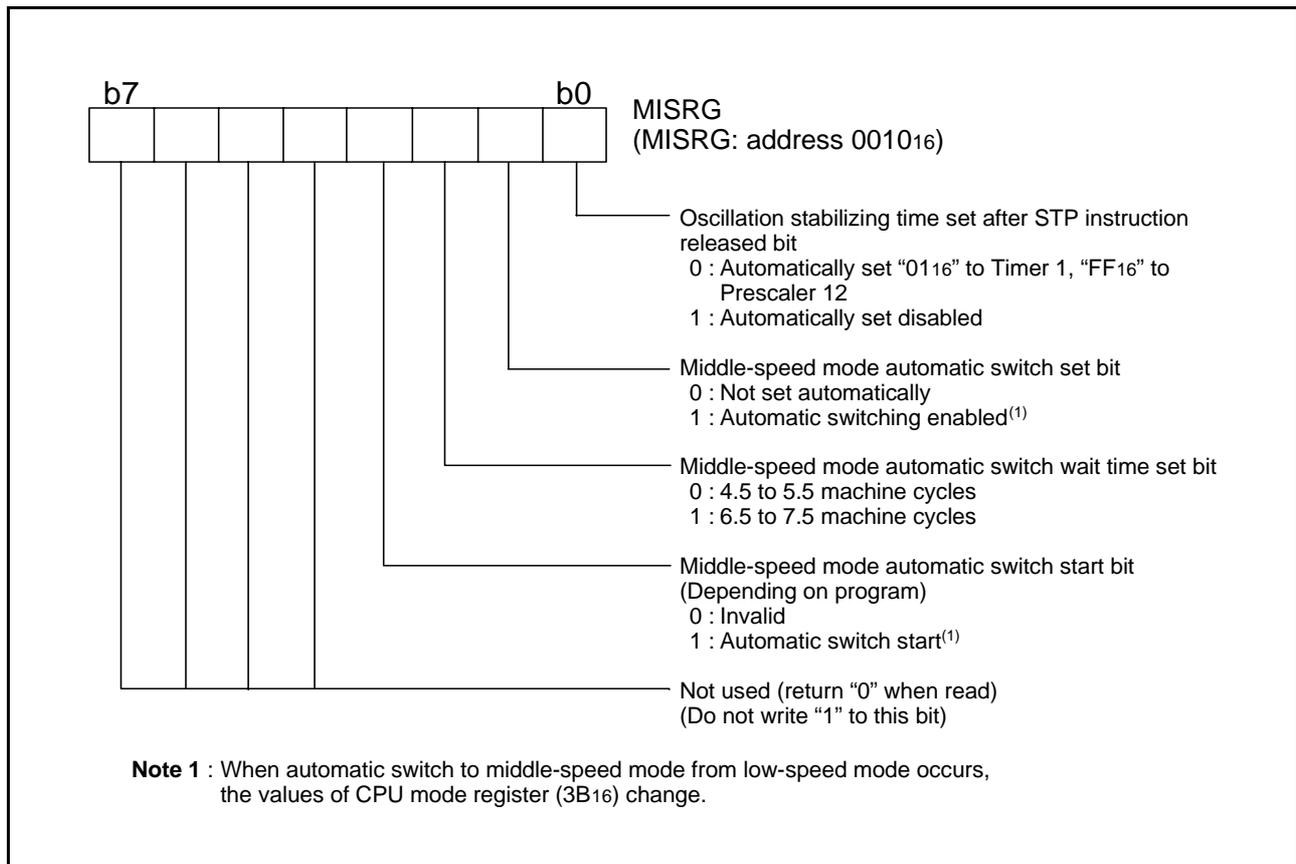


Fig 10. Structure of MISRG

MEMORY

• **Special Function Register (SFR) Area**

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

• **RAM**

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

• **ROM**

The first 128 bytes and the last 2 bytes of ROM are reserved for device testing and the rest is a user area for storing programs. The reserved ROM area can program/erase in the flash memory version.

• **Interrupt Vector Area**

The interrupt vector area contains reset and interrupt vectors.

• **Zero Page**

Access to this area with only 2 bytes is possible in the zero page addressing mode.

• **Special Page**

Access to this area with only 2 bytes is possible in the special page addressing mode.

<Note>

Since the contents of RAM are undefined at reset, be sure to set an initial value before use.

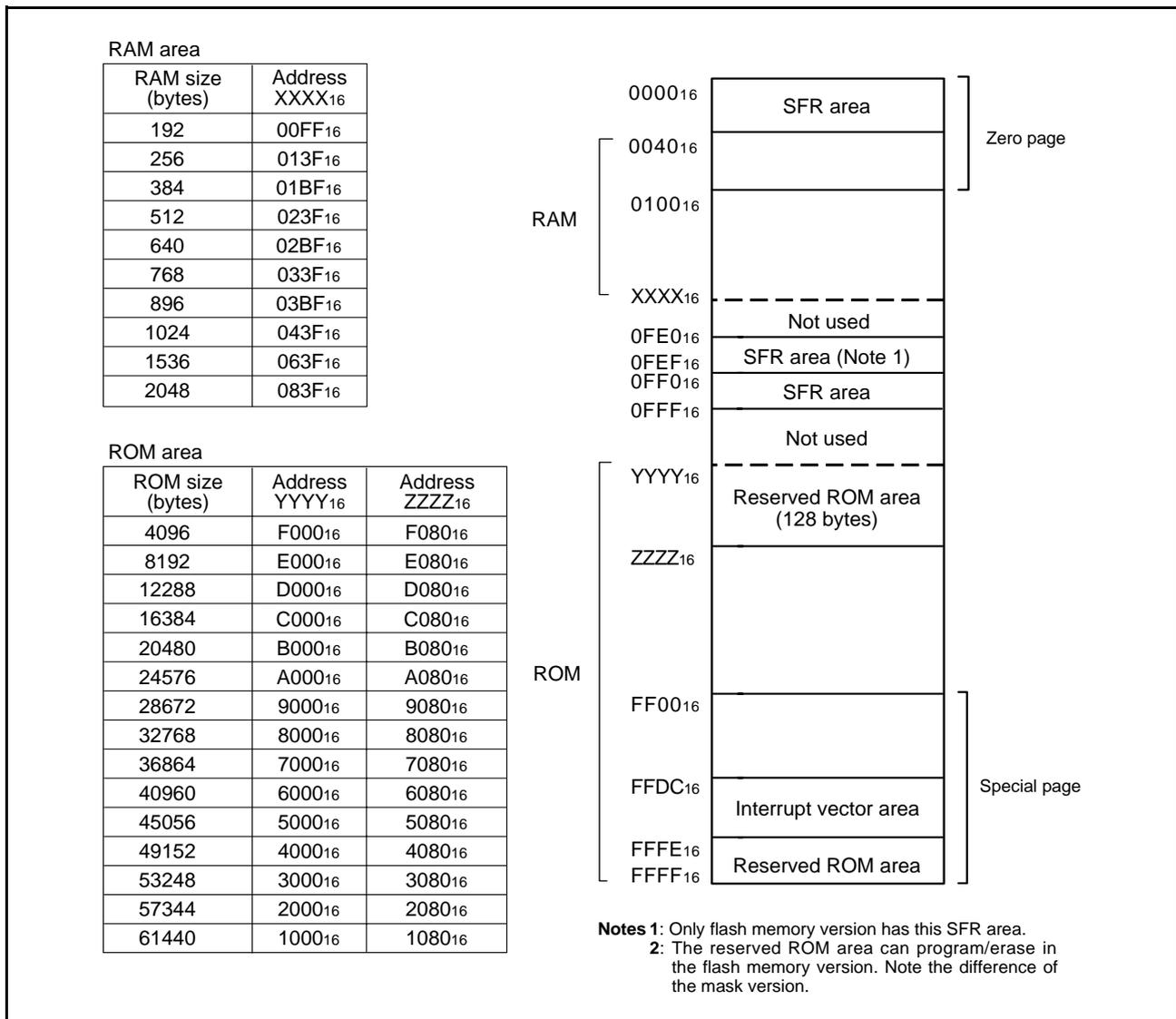


Fig 11. Memory map diagram

0000 ₁₆	Port P0 (P0)	0020 ₁₆	Prescaler 12 (PRE12)
0001 ₁₆	Port P0 direction register (P0D)	0021 ₁₆	Timer 1 (T1)
0002 ₁₆	Port P1 (P1)	0022 ₁₆	Timer 2 (T2)
0003 ₁₆	Port P1 direction register (P1D)	0023 ₁₆	Timer XY mode register (TM)
0004 ₁₆	Port P2 (P2)	0024 ₁₆	Prescaler X (PREX)
0005 ₁₆	Port P2 direction register (P2D)	0025 ₁₆	Timer X (TX)
0006 ₁₆	Port P3 (P3)	0026 ₁₆	Prescaler Y (PREY)
0007 ₁₆	Port P3 direction register (P3D)	0027 ₁₆	Timer Y (TY)
0008 ₁₆	Port P4 (P4)	0028 ₁₆	Timer Z low-order (TZL)
0009 ₁₆	Port P4 direction register (P4D)	0029 ₁₆	Timer Z high-order (TZH)
000A ₁₆	Port P5 (P5)	002A ₁₆	Timer Z mode register (TZM)
000B ₁₆	Port P5 direction register (P5D)	002B ₁₆	PWM control register (PWMCN)
000C ₁₆	Port P6 (P6)	002C ₁₆	PWM prescaler (PREPWM)
000D ₁₆	Port P6 direction register (P6D)	002D ₁₆	PWM register (PWM)
000E ₁₆	Timer 12, X count source selection register (T12XCSS)	002E ₁₆	
000F ₁₆	Timer Y, Z count source selection register (TYZCSS)	002F ₁₆	Baud rate generator 3 (BRG3)
0010 ₁₆	MISRG	0030 ₁₆	Transmit/Receive buffer register 3 (TB3/RB3)
0011 ₁₆	Reserved (Note 1)	0031 ₁₆	Serial I/O3 status register (SIO3STS)
0012 ₁₆	Reserved (Note 1)	0032 ₁₆	Serial I/O3 control register (SIO3CON)
0013 ₁₆	Reserved (Note 1)	0033 ₁₆	UART3 control register (UART3CON)
0014 ₁₆	Reserved (Note 1)	0034 ₁₆	AD/DA control register (ADCON)
0015 ₁₆	Reserved (Note 1)	0035 ₁₆	AD conversion register 1 (AD1)
0016 ₁₆	Reserved (Note 1)	0036 ₁₆	DA1 conversion register (DA1)
0017 ₁₆	Reserved (Note 1)	0037 ₁₆	DA2 conversion register (DA2)
0018 ₁₆	Transmit/Receive buffer register 1 (TB1/RB1)	0038 ₁₆	AD conversion register 2 (AD2)
0019 ₁₆	Serial I/O1 status register (SIO1STS)	0039 ₁₆	Interrupt source selection register (INTSEL)
001A ₁₆	Serial I/O1 control register (SIO1CON)	003A ₁₆	Interrupt edge selection register (INTEDGE)
001B ₁₆	UART1 control register (UART1CON)	003B ₁₆	CPU mode register (CPUM)
001C ₁₆	Baud rate generator (BRG1)	003C ₁₆	Interrupt request register 1 (IREQ1)
001D ₁₆	Serial I/O2 control register (SIO2CON)	003D ₁₆	Interrupt request register 2 (IREQ2)
001E ₁₆	Watchdog timer control register (WDTCON)	003E ₁₆	Interrupt control register 1 (ICON1)
001F ₁₆	Serial I/O2 register (SIO2)	003F ₁₆	Interrupt control register 2 (ICON2)
0FE0 ₁₆	Flash memory control register 0 (FMCR0)	0FF0 ₁₆	Port P0 pull-up control register (PULL0)
0FE1 ₁₆	Flash memory control register 1 (FMCR1)	0FF1 ₁₆	Port P1 pull-up control register (PULL1)
0FE2 ₁₆	Flash memory control register 2 (FMCR2)	0FF2 ₁₆	Port P2 pull-up control register (PULL2)
0FE3 ₁₆	Reserved (Note 1)	0FF3 ₁₆	Port P3 pull-up control register (PULL3)
0FE4 ₁₆	Reserved (Note 1)	0FF4 ₁₆	Port P4 pull-up control register (PULL4)
0FE5 ₁₆	Reserved (Note 1)	0FF5 ₁₆	Port P5 pull-up control register (PULL5)
0FE6 ₁₆	Reserved (Note 1)	0FF6 ₁₆	Port P6 pull-up control register (PULL6)
0FE7 ₁₆	Reserved (Note 1)		
0FE8 ₁₆	Reserved (Note 1)		
0FE9 ₁₆	Reserved (Note 1)		
0FEA ₁₆	Reserved (Note 1)		
0FEB ₁₆	Reserved (Note 1)		
0FEC ₁₆	Reserved (Note 1)		
0FED ₁₆	Reserved (Note 1)		
0FEE ₁₆	Reserved (Note 1)		
0FEF ₁₆	Reserved (Note 1)		

Notes:
1: Do not write any data to these addresses, because these are reserved area.
2: Do not access to the SFR area including nothing.

Fig 12. Memory map of special function register (SFR)

I/O PORTS

The I/O ports have direction registers which determine the input/output direction of each individual pin. Each bit in a direction register corresponds to one pin, and each pin can be set to be input port or output port.

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

If data is read from a pin which is set to output, the value of the port output latch is read, not the value of the pin itself. Pins set to

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

By setting the port P0 pull-up control register (address 0FF016) to the port P6 pull-up control register (address 0FF616) ports can control pull-up with a program. However, the contents of these registers do not affect ports programmed as the output ports.

Table 6 I/O port function

Pin	Name	Input/Output	I/O Structure	Non-Port Function	Related SFRs	Ref. No.	
P00/AN8–P07/AN15	Port P0	Input/output, individual bits	CMOS compatible input level CMOS 3-state output	A/D converter input	AD/DA control register	(1)	
P10/INT ₄₁ P11/INT ₀₁	Port P1			External interrupt input	Interrupt edge selection register	(2)	
P12–P17						(3)	
P20(LED ₀)– P27(LED ₇)	Port P2						
P30/DA ₁ P31/DA ₂	Port P3			D/A converter output	AD/DA control register	(4)	
P32, P33				CMOS compatible input level N-channel open-drain output		(5)	
P34/RxD ₃ P35/TxD ₃ P36/SCLK ₃ P37/SRDY ₃	Port P4			CMOS compatible input level CMOS 3-state output	Serial I/O3 function I/O	Serial I/O3 control register UART3 control register	(6) (7) (8) (9)
P40/INT ₄₀ /XCOUT P41/INT ₀₀ /XCIN				External interrupt input Sub-clock generating circuit	Interrupt edge selection register CPU mode register	(10) (11)	
P42/INT ₁ P43/INT ₂				External interrupt input	Interrupt edge selection register	(2)	
P44/RxD ₁ P45/TxD ₁ P46/SCLK ₁				Serial I/O1 function I/O	Serial I/O1 control register UART1 control register	(6) (7) (8)	
P47/SRDY ₁ /CNTR ₂		Serial I/O1 function I/O Timer Z function I/O	Serial I/O1 control register Timer Z mode register	(12)			
P50/SIN ₂ P51/SOUT ₂ P52/SCLK ₂ P53/SRDY ₂		Port P5	Serial I/O2 function I/O	Serial I/O2 control register	(13) (14) (15) (16)		
P54/CNTR ₀ P55/CNTR ₁			Timer X, Y function I/O	Timer XY mode register	(17)		
P56/PWM			PWM output	PWM control register	(18)		
P57/INT ₃			External interrupt input	Interrupt edge selection register	(2)		
P60/AN ₀ –P67/AN ₇		Port P6		A/D converter input	AD/DA control register	(1)	

NOTES:

1. Refer to the applicable sections how to use double-function ports as function I/O ports.
2. Make sure that the input level at each pin is either 0 V or V_{CC} during execution of the STP instruction.
When an input level is at an intermediate potential, a current will flow from V_{CC} to V_{SS} through the input-stage gate.

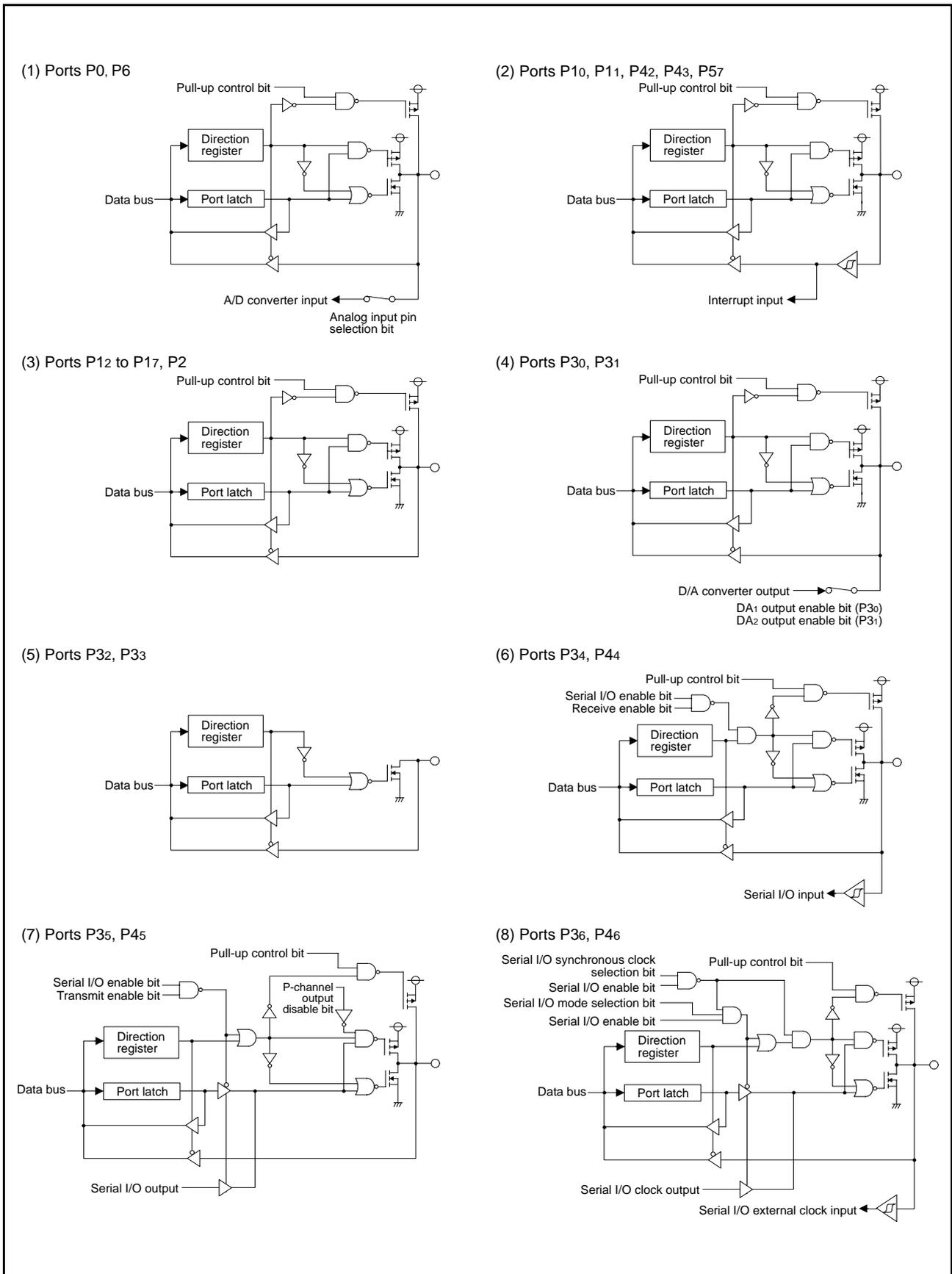


Fig 13. Port block diagram (1)

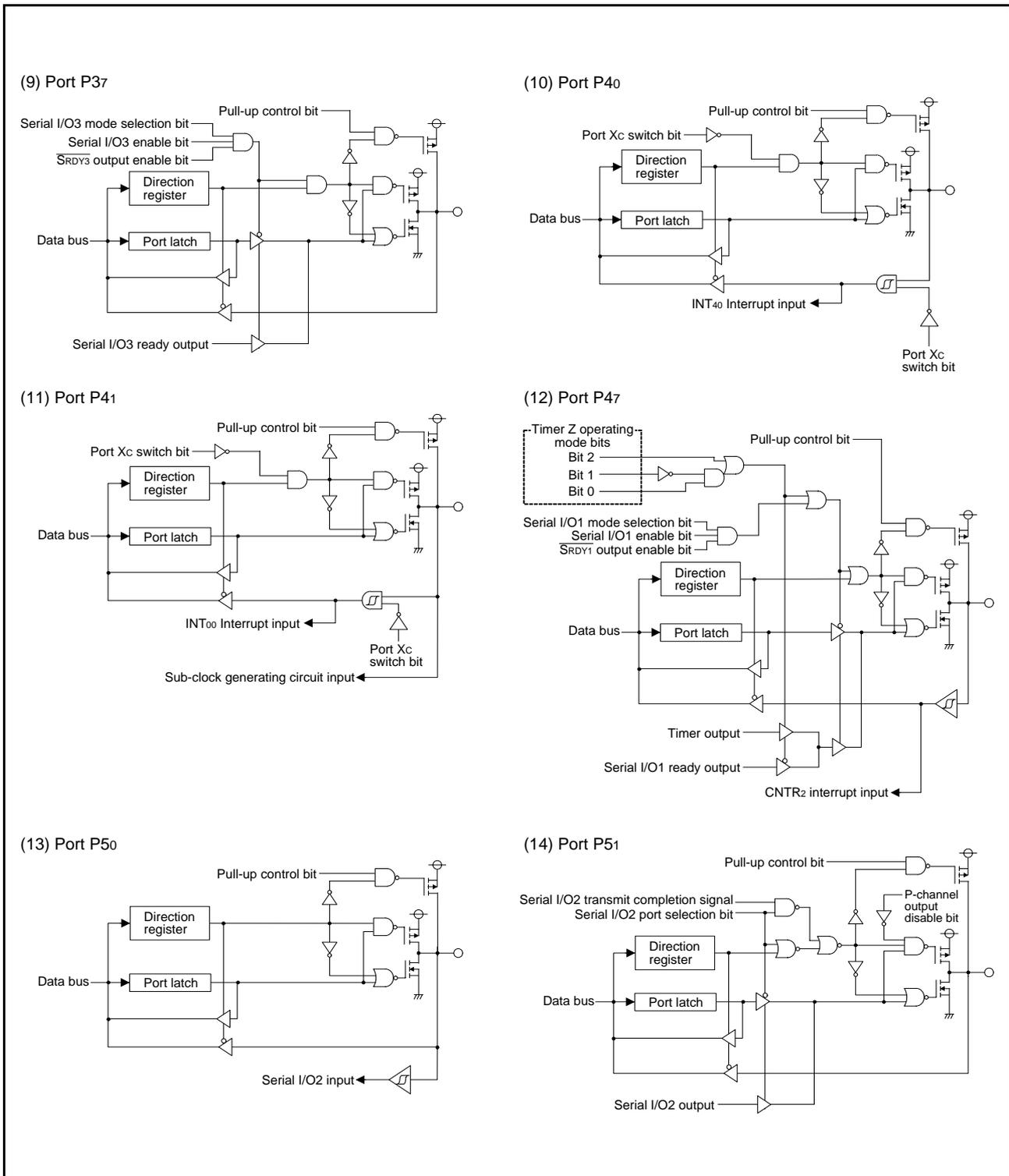


Fig 14. Port block diagram (2)

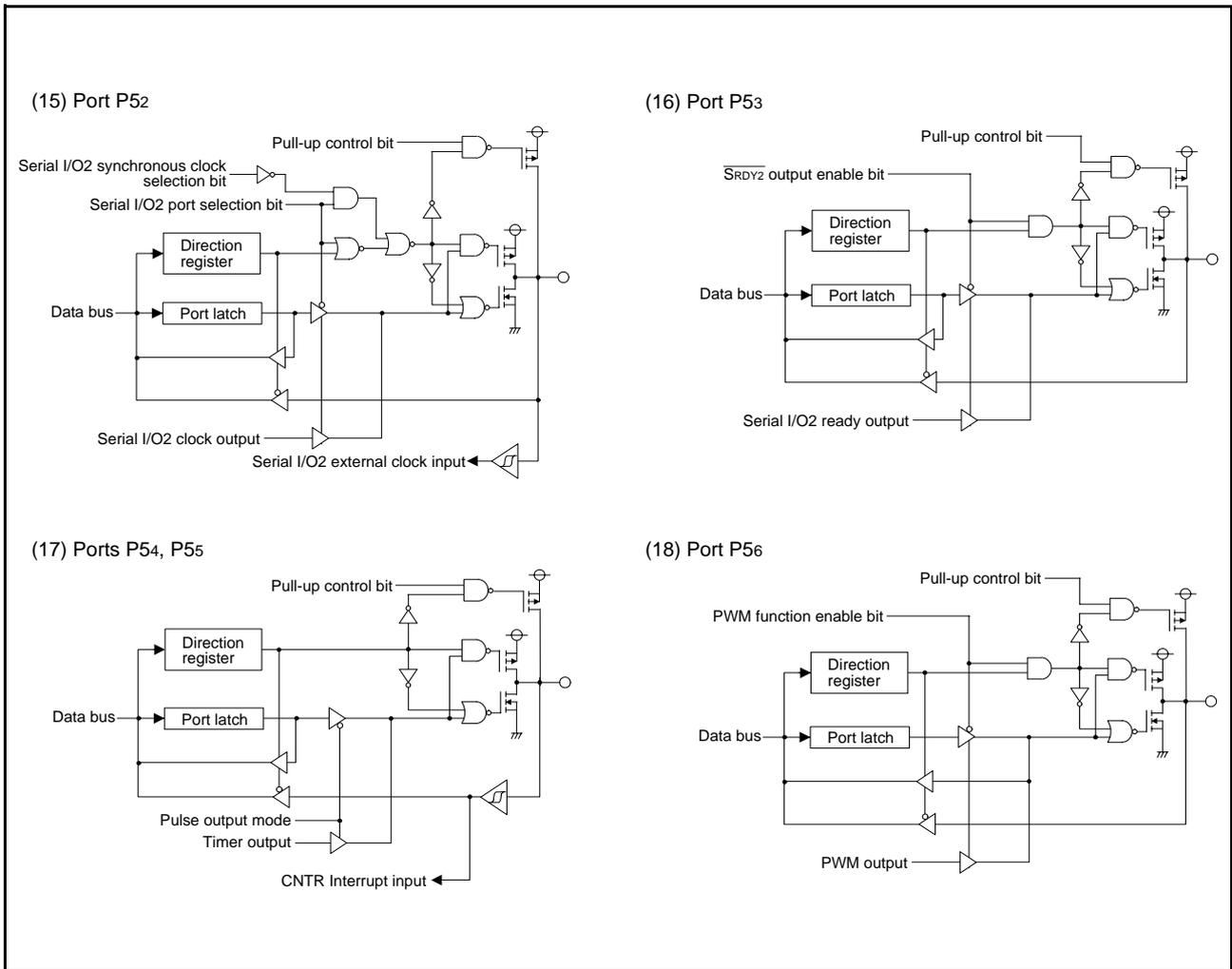


Fig 15. Port block diagram (3)

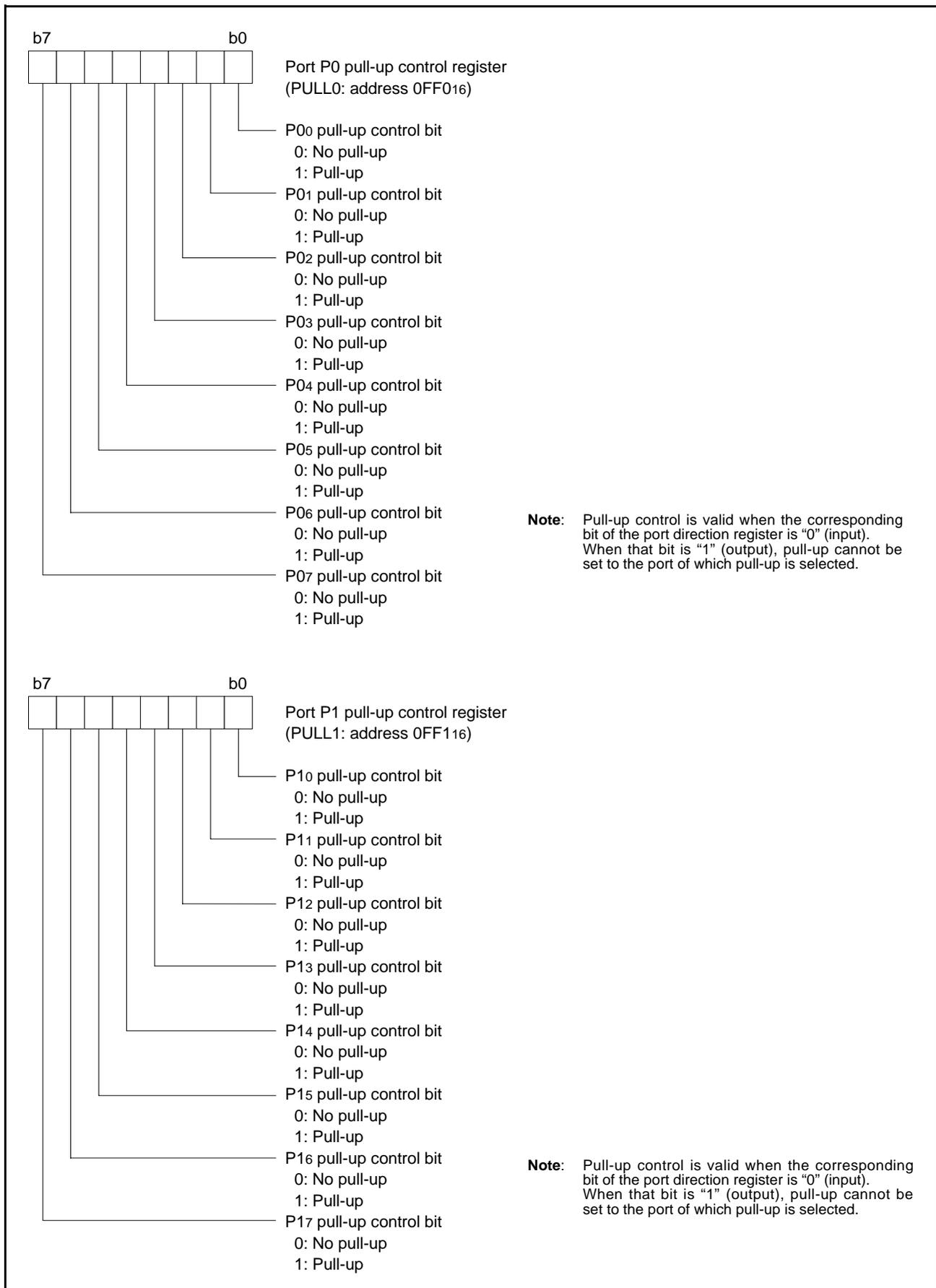


Fig 16. Structure of port pull-up control register (1)

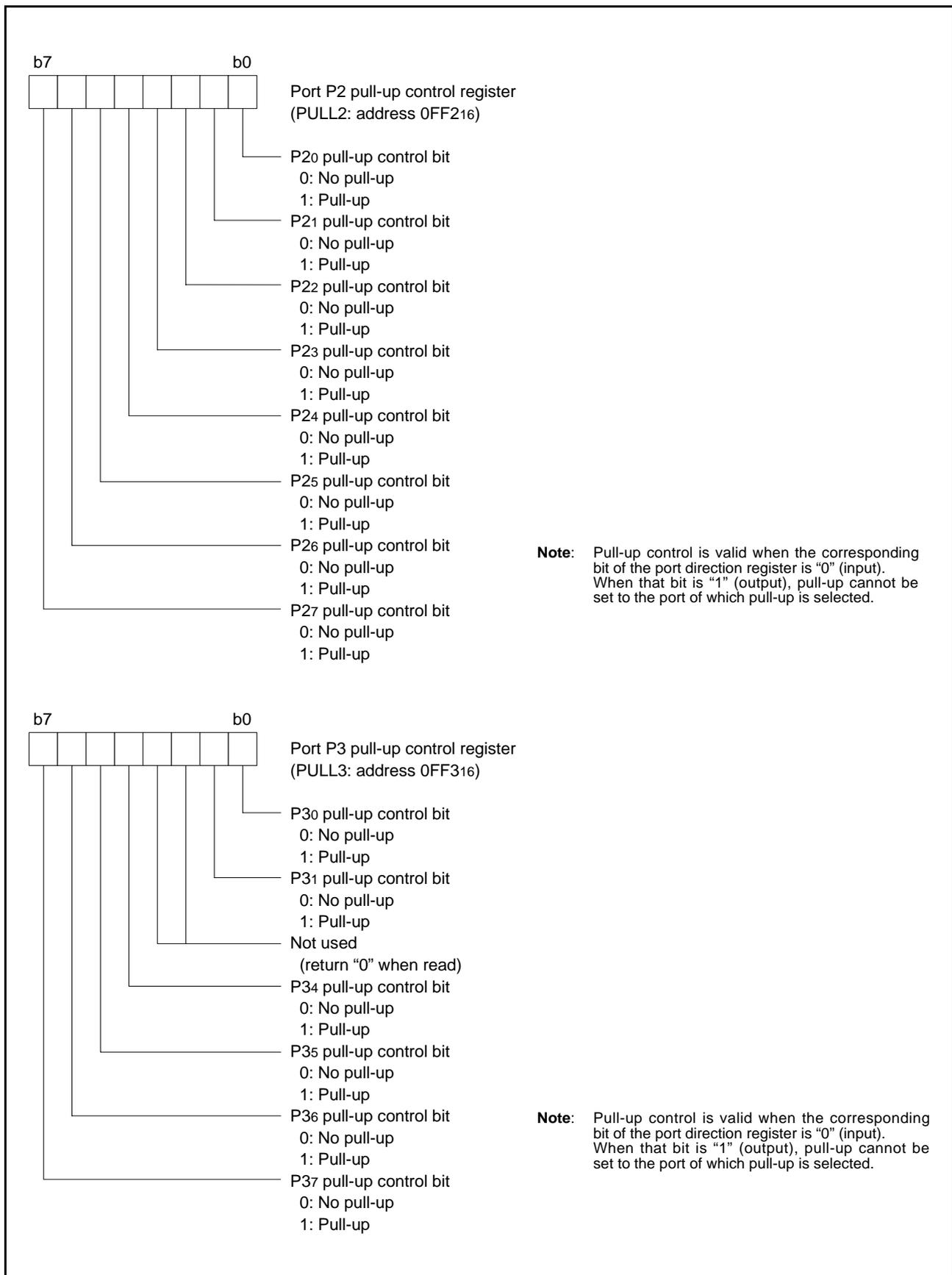


Fig 17. Structure of port pull-up control register (2)

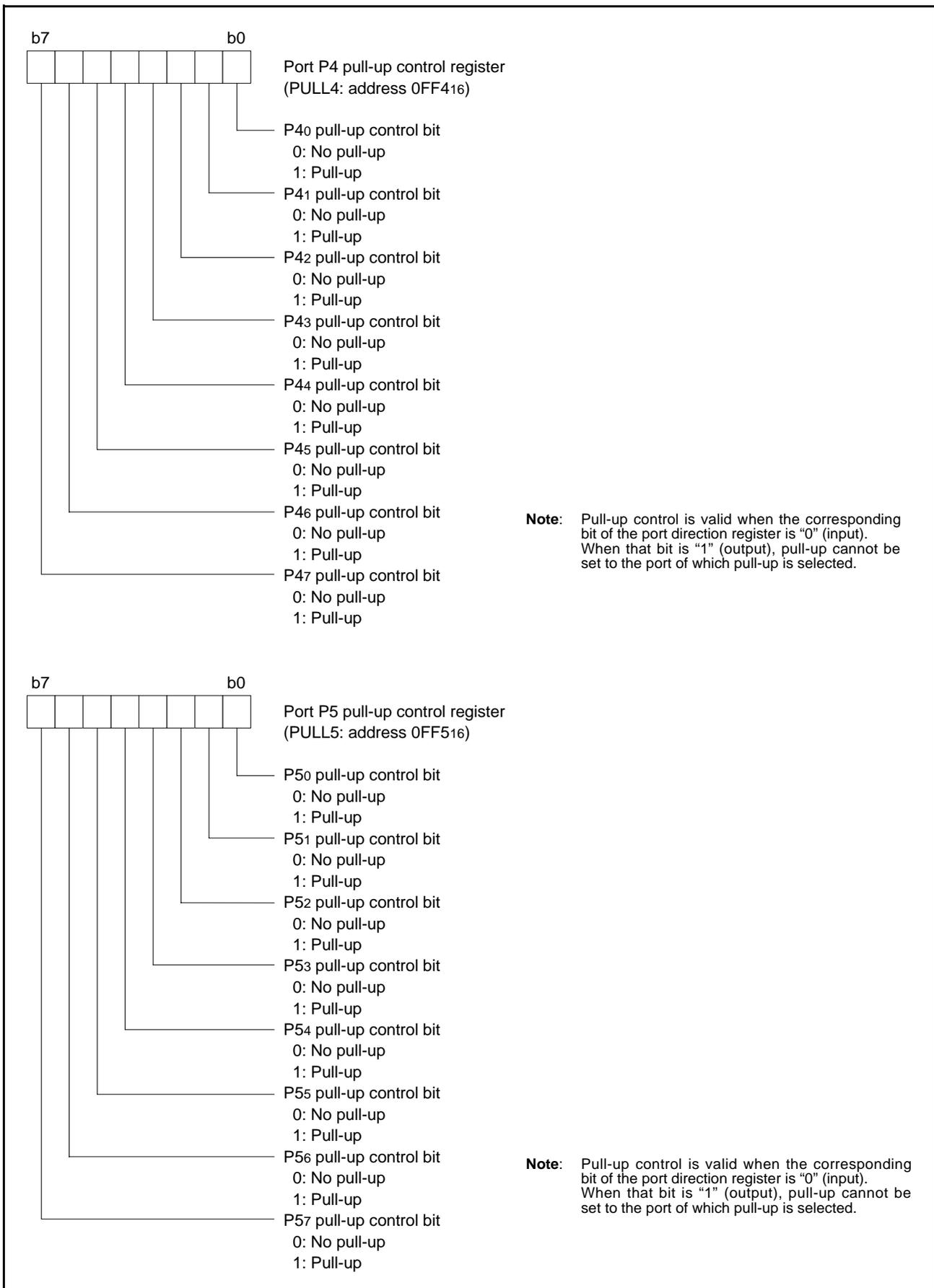


Fig 18. Structure of port pull-up control register (3)

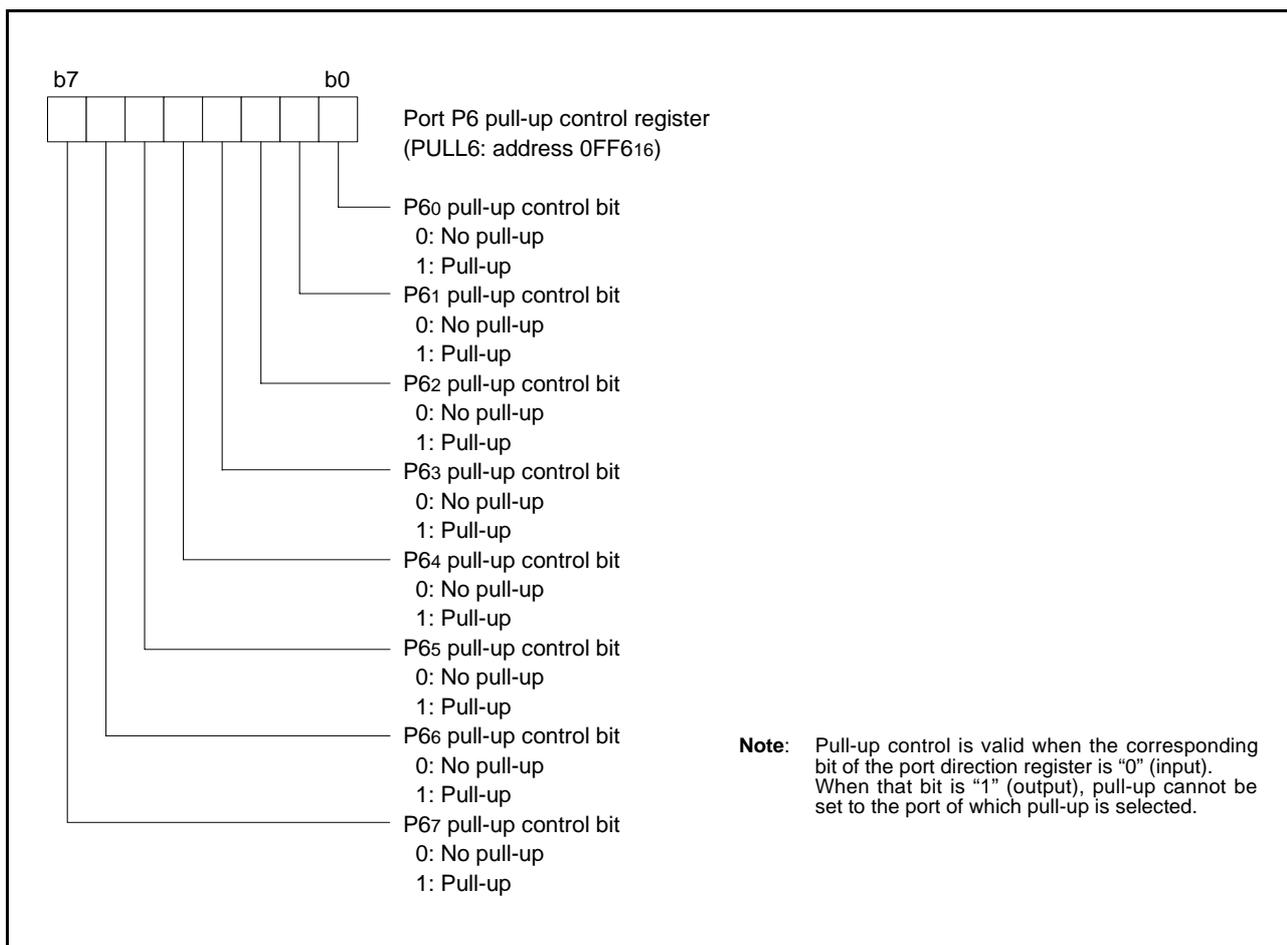


Fig 19. Structure of port pull-up control register (4)

Termination of unused pins

• Termination of common pins

I/O ports: Select an input port or an output port and follow each processing method.

In addition, it is recommended that related registers be overwritten periodically to prevent malfunctions, etc.

Output ports: Open.

Input ports: If the input level become unstable, through current flow to an input circuit, and the power supply current may increase.

Especially, when expecting low consumption current (at STP or WIT instruction execution etc.), pull-up or pull-down input ports to prevent through current (builtin resistor can be used).

We recommend processing unused pins through a resistor which can secure $I_{OH(ave)}$ or $I_{OL(ave)}$.

Because, when an I/O port or a pin which have an output function is selected as an input port, it may operate as an output port by incorrect operation etc.

Table 7 Termination of unused pins

Pins	Termination
P0, P1, P2, P3, P4, P5, P6	<ul style="list-style-type: none"> • Set to the input mode and connect each to Vcc or Vss through a resistor of 1 kΩ to 10 kΩ. • Set to the output mode and open at "L" or "H" output state.
VREF	Connect to Vcc or Vss (GND).
AVss	Connect to Vcc or Vss (GND).
XOUT	Open (only when using external clock)

INTERRUPTS

The 3803 group (Spec.L) interrupts are vector interrupts with a fixed priority scheme, and generated by 16 sources among 21 sources: 8 external, 12 internal, and 1 software.

The interrupt sources, vector addresses⁽¹⁾, and interrupt priority are shown in Table 8.

Each interrupt except the BRK instruction interrupt has the interrupt request bit and the interrupt enable bit. These bits and the interrupt disable flag (I flag) control the acceptance of interrupt requests. Figure 20 shows an interrupt control diagram.

An interrupt requests is accepted when all of the following conditions are satisfied:

- Interrupt disable flag.....“0”
- Interrupt request bit.....“1”
- Interrupt enable bit.....“1”

Though the interrupt priority is determined by hardware, priority processing can be performed by software using the above bits and flag.

Table 8 Interrupt vector addresses and priority

Interrupt Source	Priority	Vector Addresses ⁽¹⁾		Interrupt Request Generating Conditions	Remarks
		High	Low		
Reset ⁽²⁾	1	FFFD ₁₆	FFFC ₁₆	At reset	Non-maskable
INT ₀	2	FFFB ₁₆	FFFA ₁₆	At detection of either rising or falling edge of INT ₀ input	External interrupt (active edge selectable)
Timer Z				At timer Z underflow	
INT ₁	3	FFF9 ₁₆	FFF8 ₁₆	At detection of either rising or falling edge of INT ₁ input	External interrupt (active edge selectable)
Serial I/O1 reception	4	FFF7 ₁₆	FFF6 ₁₆	At completion of serial I/O1 data reception	Valid when serial I/O1 is selected
Serial I/O1 transmission	5	FFF5 ₁₆	FFF4 ₁₆	At completion of serial I/O1 transmission shift or when transmission buffer is empty	Valid when serial I/O1 is selected
Timer X	6	FFF3 ₁₆	FFF2 ₁₆	At timer X underflow	
Timer Y	7	FFF1 ₁₆	FFF0 ₁₆	At timer Y underflow	
Timer 1	8	FFE _F 1 ₁₆	FFE _E 1 ₁₆	At timer 1 underflow	STP release timer underflow
Timer 2	9	FFE _D 1 ₁₆	FFE _C 1 ₁₆	At timer 2 underflow	
CNTR ₀	10	FFE _B 1 ₁₆	FFE _A 1 ₁₆	At detection of either rising or falling edge of CNTR ₀ input	External interrupt (active edge selectable)
CNTR ₁				At detection of either rising or falling edge of CNTR ₁ input	
Serial I/O3 reception	11	FFE ₉ 1 ₁₆	FFE ₈ 1 ₁₆	At completion of serial I/O3 data reception	Valid when serial I/O3 is selected
Serial I/O2				At completion of serial I/O2 data transmission or reception	
Timer Z	12	FFE ₇ 1 ₁₆	FFE ₆ 1 ₁₆	At timer Z underflow	Valid when serial I/O2 is selected
INT ₂				At detection of either rising or falling edge of INT ₂ input	
INT ₃	13	FFE ₅ 1 ₁₆	FFE ₄ 1 ₁₆	At detection of either rising or falling edge of INT ₃ input	External interrupt (active edge selectable)
INT ₄	14	FFE ₃ 1 ₁₆	FFE ₂ 1 ₁₆	At detection of either rising or falling edge of INT ₄ input	External interrupt (active edge selectable)
CNTR ₂				At detection of either rising or falling edge of CNTR ₂ input	
A/D conversion	15	FFE ₁ 1 ₁₆	FFE ₀ 1 ₁₆	At completion of A/D conversion	External interrupt (active edge selectable)
Serial I/O3 transmission				At completion of serial I/O3 transmission shift or when transmission buffer is empty	
BRK instruction	16	FFD _F 1 ₁₆	FFD _E 1 ₁₆	At BRK instruction execution	Non-maskable software interrupt

NOTES:

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

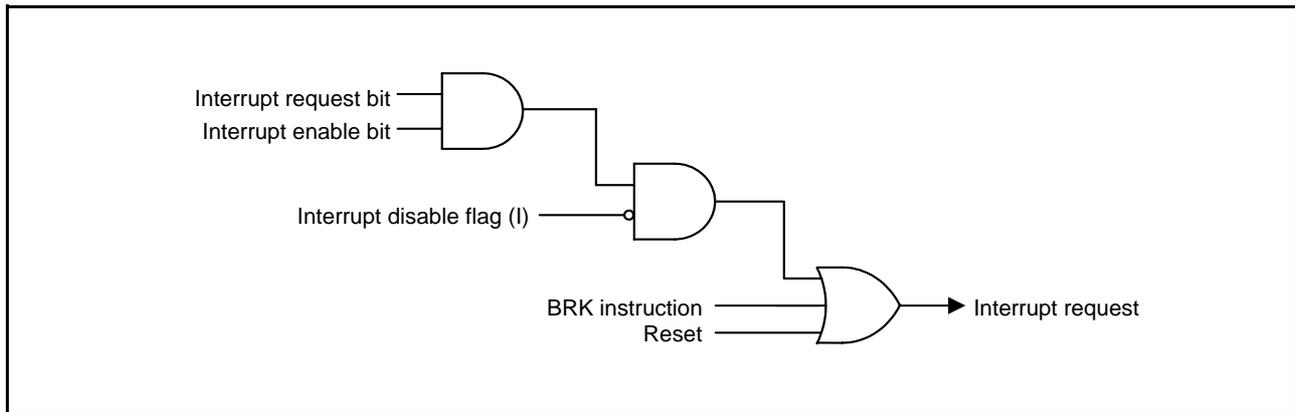


Fig 20. Interrupt control diagram

• Interrupt Disable Flag

The interrupt disable flag is assigned to bit 2 of the processor status register. This flag controls the acceptance of all interrupt requests except for the BRK instruction. When this flag is set to “1”, the acceptance of interrupt requests is disabled. When it is set to “0”, acceptance of interrupt requests is enabled. This flag is set to “1” with the SET instruction and set to “0” with the CLI instruction.

When an interrupt request is accepted, the contents of the processor status register are pushed onto the stack while the interrupt disable flag remains set to “0”. Subsequently, this flag is automatically set to “1” and multiple interrupts are disabled. To use multiple interrupts, set this flag to “0” with the CLI instruction within the interrupt processing routine.

The contents of the processor status register are popped off the stack with the RTI instruction.

• Interrupt Request Bits

Once an interrupt request is generated, the corresponding interrupt request bit is set to “1” and remains “1” until the request is accepted. When the request is accepted, this bit is automatically set to “0”.

Each interrupt request bit can be set to “0”, but cannot be set to “1”, by software.

• Interrupt Enable Bits

The interrupt enable bits control the acceptance of the corresponding interrupt requests. When an interrupt enable bit is set to “0”, the acceptance of the corresponding interrupt request is disabled. If an interrupt request occurs in this condition, the corresponding interrupt request bit is set to “1”, but the interrupt request is not accepted. When an interrupt enable bit is set to “1”, acceptance of the corresponding interrupt request is enabled. Each interrupt enable bit can be set to “0” or “1” by software.

The interrupt enable bit for an unused interrupt should be set to “0”.

• Interrupt Source Selection

Any of the following combinations can be selected by the interrupt source selection register (003916).

1. INT0 or timer Z
2. CNTR1 or Serial I/O3 reception
3. Serial I/O2 or timer Z
4. INT4 or CNTR2
5. A/D conversion or serial I/O3 transmission

• External Interrupt Pin Selection

For external interrupts INT0 and INT4, the INT0, INT4 interrupt switch bit in the interrupt edge selection register (bit 6 of address 003A16) can be used to select INT00 and INT40 pin input or INT01 and INT41 pin input.

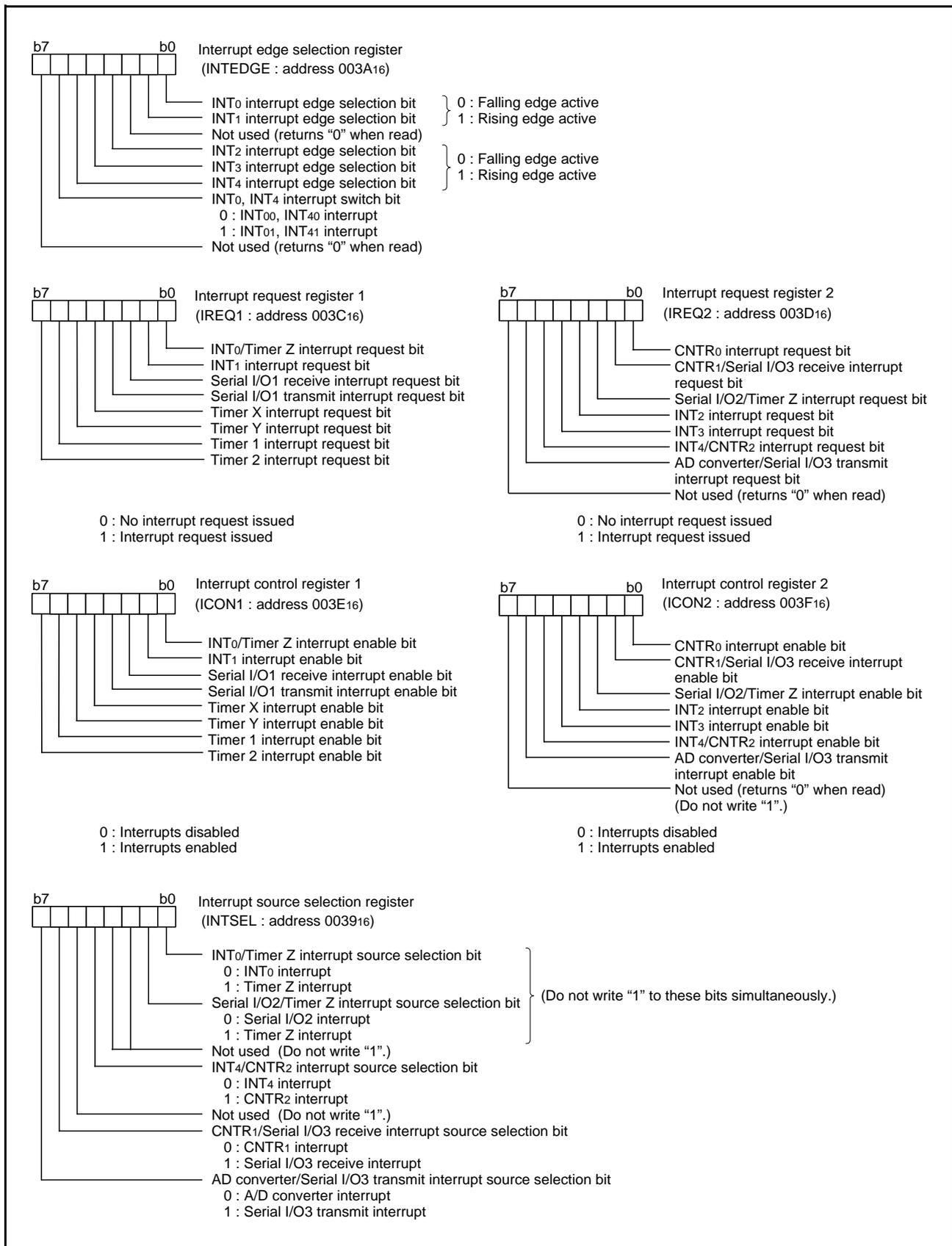


Fig 21. Structure of interrupt-related registers

• Interrupt Request Generation, Acceptance, and Handling

Interrupts have the following three phases.

- (i) **Interrupt Request Generation**
An interrupt request is generated by an interrupt source (external interrupt signal input, timer underflow, etc.) and the corresponding request bit is set to “1”.
- (ii) **Interrupt Request Acceptance**
Based on the interrupt acceptance timing in each instruction cycle, the interrupt control circuit determines acceptance conditions (interrupt request bit, interrupt enable bit, and interrupt disable flag) and interrupt priority levels for accepting interrupt requests. When two or more interrupt requests are generated simultaneously, the highest priority interrupt is accepted. The value of interrupt request bit for an unaccepted interrupt remains the same and acceptance is determined at the next interrupt acceptance timing point.
- (iii) **Handling of Accepted Interrupt Request**
The accepted interrupt request is processed.

Figure 22 shows the time up to execution in the interrupt processing routine, and Figure 23 shows the interrupt sequence. Figure 24 shows the timing of interrupt request generation, interrupt request bit, and interrupt request acceptance.

• Interrupt Handling Execution

When interrupt handling is executed, the following operations are performed automatically.

- (1) Once the currently executing instruction is completed, an interrupt request is accepted.
- (2) The contents of the program counters and the processor status register at this point are pushed onto the stack area in order from 1 to 3.
 - 1. High-order bits of program counter (PCH)
 - 2. Low-order bits of program counter (PCL)
 - 3. Processor status register (PS)
- (3) Concurrently with the push operation, the jump address of the corresponding interrupt (the start address of the interrupt processing routine) is transferred from the interrupt vector to the program counter.
- (4) The interrupt request bit for the corresponding interrupt is set to “0”. Also, the interrupt disable flag is set to “1” and multiple interrupts are disabled.
- (5) The interrupt routine is executed.
- (6) When the RTI instruction is executed, the contents of the registers pushed onto the stack area are popped off in the order from 3 to 1. Then, the routine that was before running interrupt processing resumes.

As described above, it is necessary to set the stack pointer and the jump address in the vector area corresponding to each interrupt to execute the interrupt processing routine.

<Notes>

The interrupt request bit may be set to “1” in the following cases.

- When setting the external interrupt active edge
Related registers: Interrupt edge selection register (address 003A16)
Timer XY mode register (address 002316)
Timer Z mode register (address 002A16)
- When switching the interrupt sources of an interrupt vector address where two or more interrupt sources are assigned
Related registers: Interrupt source selection register (address 003916)

If it is not necessary to generate an interrupt synchronized with these settings, take the following sequence.

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

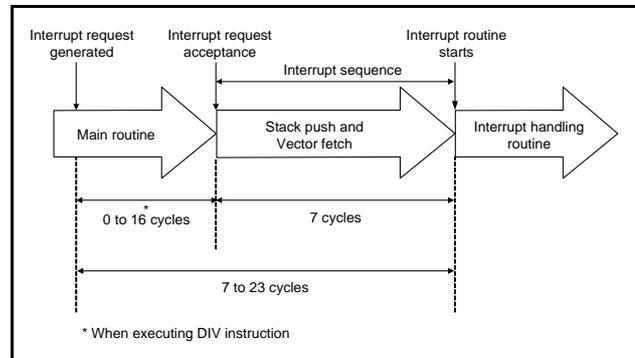


Fig 22. Time up to execution in interrupt routine

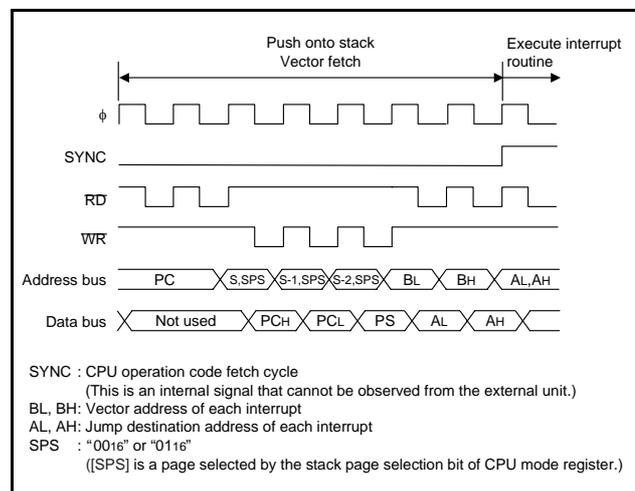


Fig 23. Interrupt sequence

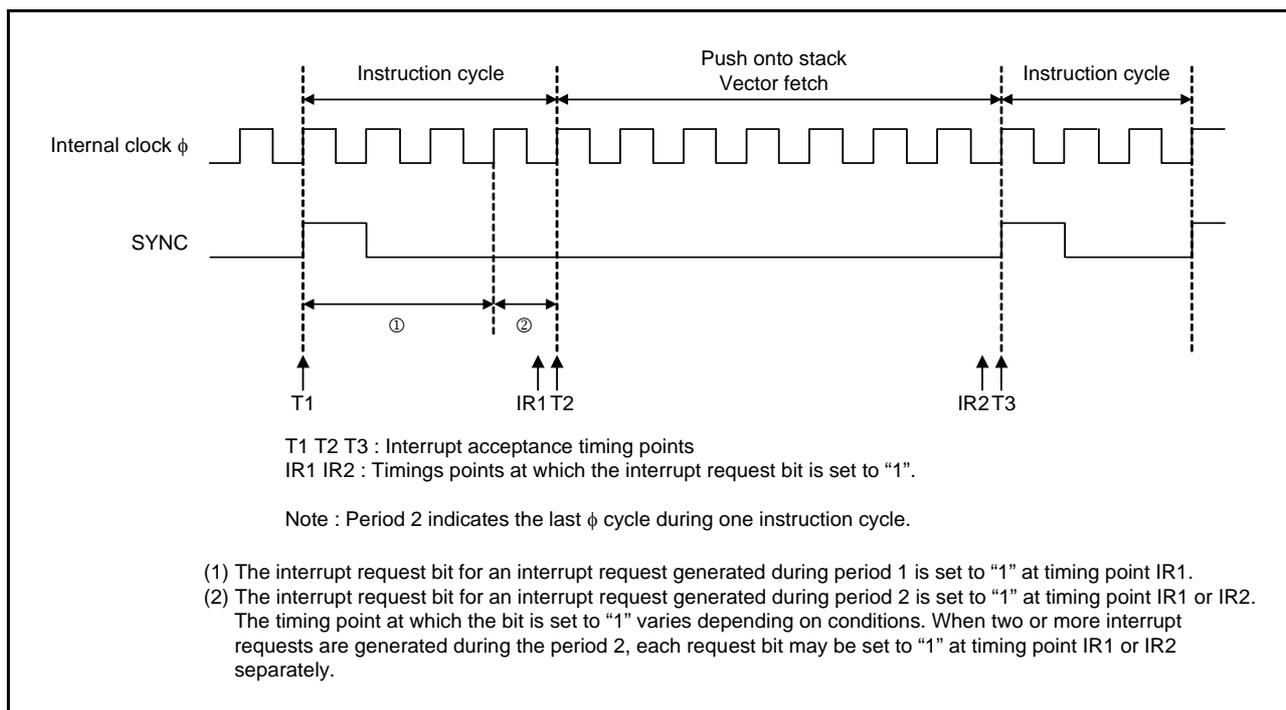


Fig 24. Timing of interrupt request generation, interrupt request bit, and interrupt acceptance

TIMERS

• 8-bit Timers

The 3803 group (Spec.L) has four 8-bit timers: timer 1, timer 2, timer X, and timer Y.

The timer 1 and timer 2 use one prescaler in common, and the timer X and timer Y use each prescaler. Those are 8-bit prescalers. Each of the timers and prescalers has a timer latch or a prescaler latch.

The division ratio of each timer or prescaler is given by $1/(n + 1)$, where n is the value in the corresponding timer or prescaler latch. All timers are down-counters. When the timer reaches "00₁₆", an underflow occurs at the next count pulse and the contents of the corresponding timer latch are reloaded into the timer and the count is continued. When the timer underflows, the interrupt request bit corresponding to that timer is set to "1".

• Timer divider

The divider count source is switched by the main clock division ratio selection bits of CPU mode register (bits 7 and 6 at address 003B₁₆). When these bits are "00" (high-speed mode) or "01" (middle-speed mode), XIN is selected. When these bits are "10" (low-speed mode), XCIN is selected.

• Prescaler 12

The prescaler 12 counts the output of the timer divider. The count source is selected by the timer 12, X count source selection register among 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512, 1/1024 of $f(XIN)$ or $f(XCIN)$.

• Timer 1 and Timer 2

The timer 1 and timer 2 counts the output of prescaler 12 and periodically set the interrupt request bit.

• Prescaler X and prescaler Y

The prescaler X and prescaler Y count the output of the timer divider or $f(XCIN)$. The count source is selected by the timer 12, X count source selection register (address 000E₁₆) and the timer Y, Z count source selection register (address 000F₁₆) among 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512, and 1/1024 of $f(XIN)$ or $f(XCIN)$; and $f(XCIN)$.

• Timer X and Timer Y

The timer X and timer Y can each select one of four operating modes by setting the timer XY mode register (address 0023₁₆).

(1) Timer mode

• Mode selection

This mode can be selected by setting "00" to the timer X operating mode bits (bits 1 and 0) and the timer Y operating mode bits (bits 5 and 4) of the timer XY mode register (address 0023₁₆).

• Explanation of operation

The timer count operation is started by setting "0" to the timer X count stop bit (bit 3) and the timer Y count stop bit (bit 7) of the timer XY mode register (address 0023₁₆).

When the timer reaches "00₁₆", an underflow occurs at the next count pulse and the contents of timer latch are reloaded into the timer and the count is continued.

(2) Pulse Output Mode

• Mode selection

This mode can be selected by setting "01" to the timer X operating mode bits (bits 1 and 0) and the timer Y operating mode bits (bits 5 and 4) of the timer XY mode register (address 0023₁₆).

• Explanation of operation

The operation is the same as the timer mode's. Moreover the pulse which is inverted each time the timer underflows is output from CNTR0/CNTR1 pin. Regardless of the timer counting or not the output of CNTR0/CNTR1 pin is initialized to the level of specified by their active edge switch bits when writing to the timer. When the CNTR0 active edge switch bit (bit 2) and the CNTR1 active edge switch bit (bit 6) of the timer XY mode register (address 0023₁₆) is "0", the output starts with "H" level. When it is "1", the output starts with "L" level.

Switching the CNTR0 or CNTR1 active edge switch bit will reverse the output level of the corresponding CNTR0 or CNTR1 pin.

• Precautions

Set the double-function port of CNTR0/CNTR1 pin and port P54/P55 to output in this mode.

(3) Event Counter Mode

• Mode selection

This mode can be selected by setting "10" to the timer X operating mode bits (bits 1 and 0) and the timer Y operating mode bits (bits 5 and 4) of the timer XY mode register (address 0023₁₆).

• Explanation of operation

The operation is the same as the timer mode's except that the timer counts signals input from the CNTR0 or CNTR1 pin. The valid edge for the count operation depends on the CNTR0 active edge switch bit (bit 2) or the CNTR1 active edge switch bit (bit 6) of the timer XY mode register (address 0023₁₆). When it is "0", the rising edge is valid. When it is "1", the falling edge is valid.

• Precautions

Set the double-function port of CNTR0/CNTR1 pin and port P54/P55 to input in this mode.

(4) Pulse Width Measurement Mode

- Mode selection

This mode can be selected by setting “11” to the timer X operating mode bits (bits 1 and 0) and the timer Y operating mode bits (bits 5 and 4) of the timer XY mode register (address 0023₁₆).

- Explanation of operation

When the CNTR0 active edge switch bit (bit 2) or the CNTR1 active edge switch bit (bit 6) of the timer XY mode register (address 0023₁₆) is “1”, the timer counts during the term of one falling edge of CNTR0/CNTR1 pin input until the next rising edge of input (“L” term). When it is “0”, the timer counts during the term of one rising edge input until the next falling edge input (“H” term).

- Precautions

Set the double-function port of CNTR0/CNTR1 pin and port P54/P55 to input in this mode.

The count operation can be stopped by setting “1” to the timer X count stop bit (bit 3) and the timer Y count stop bit (bit 7) of the timer XY mode register (address 0023₁₆). The interrupt request bit is set to “1” each time the timer underflows.

- Precautions when switching count source

When switching the count source by the timer 12, X and Y count source selection bits, the value of timer count is altered in inconsiderable amount owing to generating of thin pulses on the count input signals.

Therefore, select the timer count source before setting the value to the prescaler and the timer.

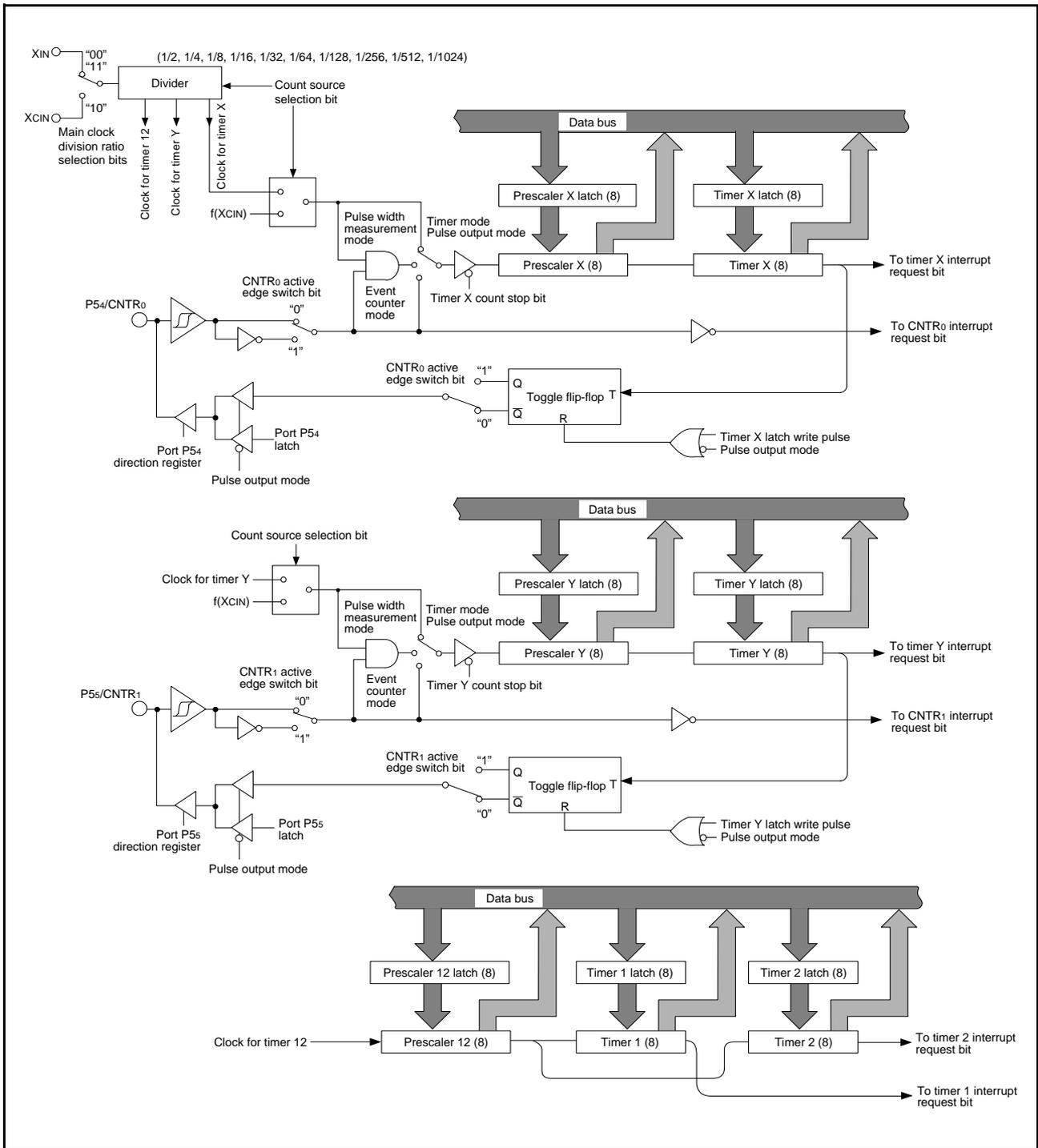


Fig 25. Block diagram of timer X, timer Y, timer 1, and timer 2

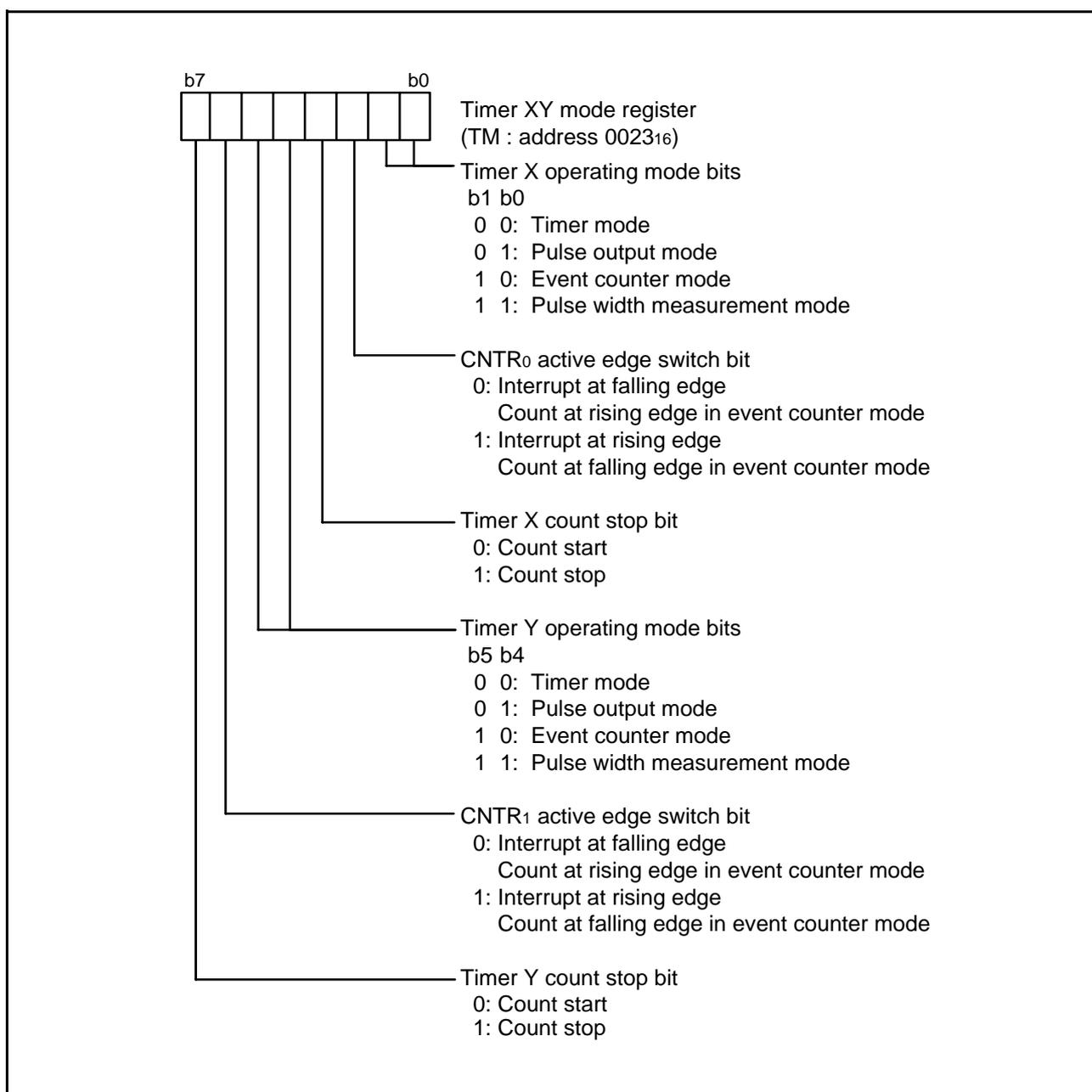


Fig 26. Structure of timer XY mode register

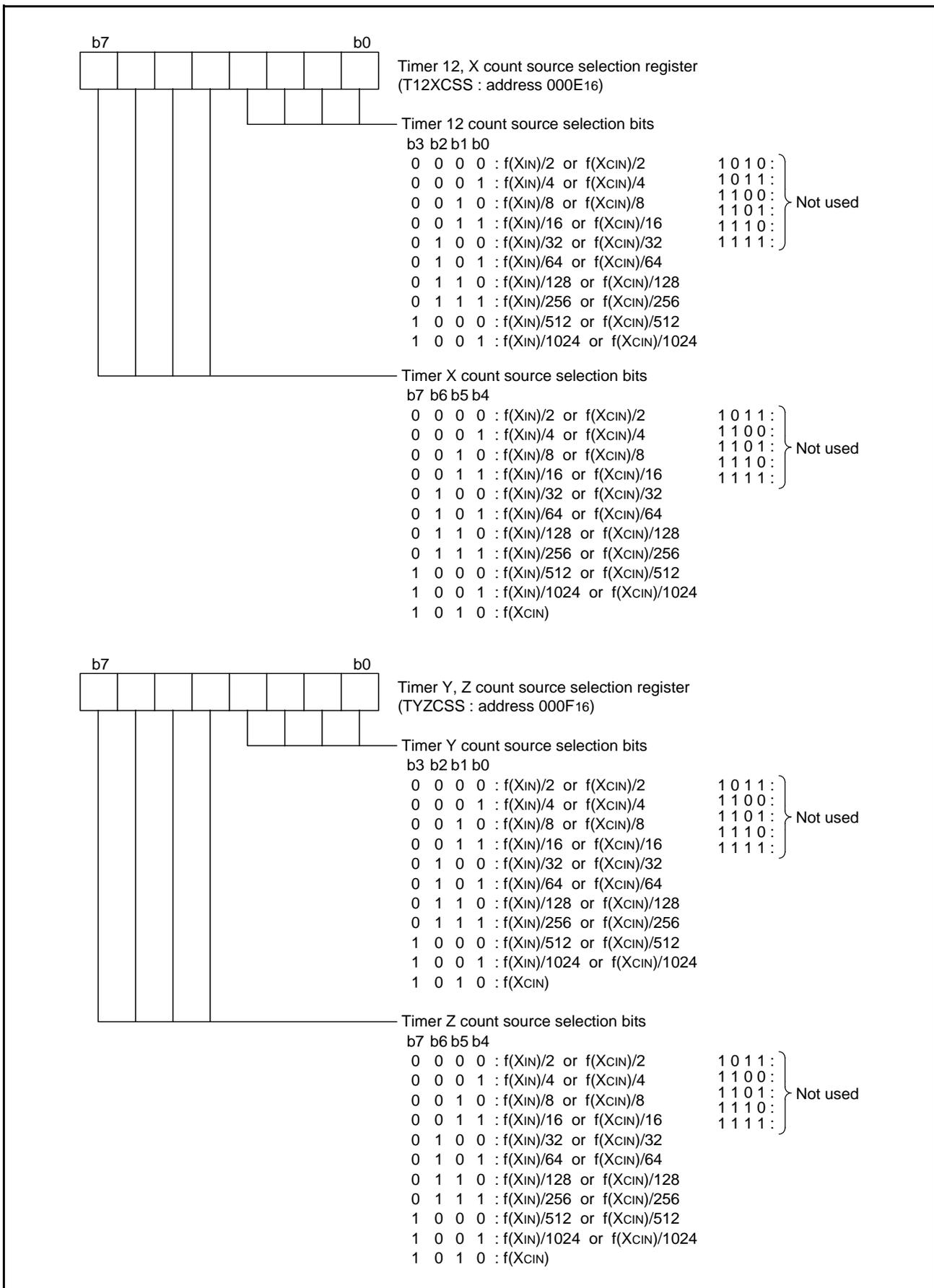


Fig 27. Structure of timer 12, X and timer Y, Z count source selection registers

• 16-bit Timer

The timer Z is a 16-bit timer. When the timer reaches “0000₁₆”, an underflow occurs at the next count pulse and the corresponding timer latch is reloaded into the timer and the count is continued. When the timer underflows, the interrupt request bit corresponding to the timer Z is set to “1”.

When reading/writing to the timer Z, perform reading/writing to both the high-order byte and the low-order byte. When reading the timer Z, read from the high-order byte first, followed by the low-order byte. Do not perform the writing to the timer Z between read operation of the high-order byte and read operation of the low-order byte. When writing to the timer Z, write to the low-order byte first, followed by the high-order byte. Do not perform the reading to the timer Z between write operation of the low-order byte and write operation of the high-order byte.

The timer Z can select the count source by the timer Z count source selection bits of timer Y, Z count source selection register (bits 7 to 4 at address 000F₁₆).

Timer Z can select one of seven operating modes by setting the timer Z mode register (address 002A₁₆).

(1) Timer mode

• Mode selection

This mode can be selected by setting “000” to the timer Z operating mode bits (bits 2 to 0) and setting “0” to the timer/event counter mode switch bit (b7) of the timer Z mode register (address 002A₁₆).

• Count source selection

In high- or middle-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of f(XIN); or f(XCIN) can be selected as the count source.

In low-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of f(XCIN); or f(XCIN) can be selected as the count source.

• Interrupt

When an underflow occurs, the INT0/timer Z interrupt request bit (bit 0) of the interrupt request register 1 (address 003C₁₆) is set to “1”.

• Explanation of operation

During timer stop, usually write data to a latch and a timer at the same time to set the timer value.

The timer count operation is started by setting “0” to the timer Z count stop bit (bit 6) of the timer Z mode register (address 002A₁₆).

When the timer reaches “0000₁₆”, an underflow occurs at the next count pulse and the contents of timer latch are reloaded into the timer and the count is continued.

When writing data to the timer during operation, the data is written only into the latch. Then the new latch value is reloaded into the timer at the next underflow.

(2) Event counter mode

• Mode selection

This mode can be selected by setting “000” to the timer Z operating mode bits (bits 2 to 0) and setting “1” to the timer/event counter mode switch bit (bit 7) of the timer Z mode register (address 002A₁₆).

The valid edge for the count operation depends on the CNTR2 active edge switch bit (bit 5) of the timer Z mode register (address 002A₁₆). When it is “0”, the rising edge is valid. When it is “1”, the falling edge is valid.

• Interrupt

The interrupt at an underflow is the same as the timer mode’s.

• Explanation of operation

The operation is the same as the timer mode’s.

Set the double-function port of CNTR2 pin and port P47 to input in this mode.

Figure 30 shows the timing chart of the timer/event counter mode.

(3) Pulse output mode

• Mode selection

This mode can be selected by setting “001” to the timer Z operating mode bits (bits 2 to 0) and setting “0” to the timer/event counter mode switch bit (b7) of the timer Z mode register (address 002A₁₆).

• Count source selection

In high- or middle-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of f(XIN); or f(XCIN) can be selected as the count source.

In low-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of f(XCIN); or f(XCIN) can be selected as the count source.

• Interrupt

The interrupt at an underflow is the same as the timer mode’s.

• Explanation of operation

The operation is the same as the timer mode’s. Moreover the pulse which is inverted each time the timer underflows is output from CNTR2 pin. When the CNTR2 active edge switch bit (bit 5) of the timer Z mode register (address 002A₁₆) is “0”, the output starts with “H” level. When it is “1”, the output starts with “L” level.

• Precautions

The double-function port of CNTR2 pin and port P47 is automatically set to the timer pulse output port in this mode.

The output from CNTR2 pin is initialized to the level depending on CNTR2 active edge switch bit by writing to the timer.

When the value of the CNTR2 active edge switch bit is changed, the output level of CNTR2 pin is inverted.

Figure 31 shows the timing chart of the pulse output mode.

(4) Pulse period measurement mode

• Mode selection

This mode can be selected by setting “010” to the timer Z operating mode bits (bits 2 to 0) and setting “0” to the timer/event counter mode switch bit (b7) of the timer Z mode register (address 002A16).

• Count source selection

In high- or middle-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of f(XIN); or f(XCIN) can be selected as the count source.

In low-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of f(XCIN); or f(XCIN) can be selected as the count source.

• Interrupt

The interrupt at an underflow is the same as the timer mode's. When the pulse period measurement is completed, the INT4/CNTR2 interrupt request bit (bit 5) of the interrupt request register 2 (address 003D16) is set to “1”.

• Explanation of operation

The cycle of the pulse which is input from the CNTR2 pin is measured. When the CNTR2 active edge switch bit (bit 5) of the timer Z mode register (address 002A16) is “0”, the timer counts during the term from one falling edge of CNTR2 pin input to the next falling edge. When it is “1”, the timer counts during the term from one rising edge input to the next rising edge input.

When the valid edge of measurement completion/start is detected, the 1's complement of the timer value is written to the timer latch and “FFFF16” is set to the timer.

Furthermore when the timer underflows, the timer Z interrupt request occurs and “FFFF16” is set to the timer. When reading the timer Z, the value of the timer latch (measured value) is read. The measured value is retained until the next measurement completion.

• Precautions

Set the double-function port of CNTR2 pin and port P47 to input in this mode.

A read-out of timer value is impossible in this mode. The timer can be written to only during timer stop (no measurement of pulse period).

Since the timer latch in this mode is specialized for the read-out of measured values, do not perform any write operation during measurement.

“FFFF16” is set to the timer when the timer underflows or when the valid edge of measurement start/completion is detected. Consequently, the timer value at start of pulse period measurement depends on the timer value just before measurement start.

Figure 32 shows the timing chart of the pulse period measurement mode.

(5) Pulse width measurement mode

• Mode selection

This mode can be selected by setting “011” to the timer Z operating mode bits (bits 2 to 0) and setting “0” to the timer/event counter mode switch bit (b7) of the timer Z mode register (address 002A16).

• Count source selection

In high- or middle-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of f(XIN); or f(XCIN) can be selected as the count source.

In low-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of f(XCIN); or f(XCIN) can be selected as the count source.

• Interrupt

The interrupt at an underflow is the same as the timer mode's. When the pulse widths measurement is completed, the INT4/CNTR2 interrupt request bit (bit 5) of the interrupt request register 2 (address 003D16) is set to “1”.

• Explanation of operation

The pulse width which is input from the CNTR2 pin is measured. When the CNTR2 active edge switch bit (bit 5) of the timer Z mode register (address 002A16) is “0”, the timer counts during the term from one rising edge input to the next falling edge input (“H” term). When it is “1”, the timer counts during the term from one falling edge of CNTR2 pin input to the next rising edge of input (“L” term).

When the valid edge of measurement completion is detected, the 1's complement of the timer value is written to the timer latch.

When the valid edge of measurement completion/start is detected, “FFFF16” is set to the timer.

When the timer Z underflows, the timer Z interrupt occurs and “FFFF16” is set to the timer Z. When reading the timer Z, the value of the timer latch (measured value) is read. The measured value is retained until the next measurement completion.

• Precautions

Set the double-function port of CNTR2 pin and port P47 to input in this mode.

A read-out of timer value is impossible in this mode. The timer can be written to only during timer stop (no measurement of pulse widths).

Since the timer latch in this mode is specialized for the read-out of measured values, do not perform any write operation during measurement.

“FFFF16” is set to the timer when the timer underflows or when the valid edge of measurement start/completion is detected. Consequently, the timer value at start of pulse width measurement depends on the timer value just before measurement start.

Figure 33 shows the timing chart of the pulse width measurement mode.

(6) Programmable waveform generating mode

• Mode selection

This mode can be selected by setting “100” to the timer Z operating mode bits (bits 2 to 0) and setting “0” to the timer/event counter mode switch bit (b7) of the timer Z mode register (address 002A16).

• Count source selection

In high- or middle-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of $f(XIN)$; or $f(XCIN)$ can be selected as the count source.

In low-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of $f(XCIN)$; or $f(XCIN)$ can be selected as the count source.

• Interrupt

The interrupt at an underflow is the same as the timer mode's.

• Explanation of operation

The operation is the same as the timer mode's. Moreover the timer outputs the data set in the output level latch (bit 4) of the timer Z mode register (address 002A16) from the CNTR2 pin each time the timer underflows.

Changing the value of the output level latch and the timer latch after an underflow makes it possible to output an optional waveform from the CNTR2 pin.

• Precautions

The double-function port of CNTR2 pin and port P47 is automatically set to the programmable waveform generating port in this mode.

Figure 34 shows the timing chart of the programmable waveform generating mode.

(7) Programmable one-shot generating mode

• Mode selection

This mode can be selected by setting “101” to the timer Z operating mode bits (bits 2 to 0) and setting “0” to the timer/event counter mode switch bit (b7) of the timer Z mode register (address 002A16).

• Count source selection

In high- or middle-speed mode, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 or 1/1024 of $f(XIN)$; or $f(XCIN)$ can be selected as the count source.

• Interrupt

The interrupt at an underflow is the same as the timer mode's.

The trigger to generate one-shot pulse can be selected by the INT1 active edge selection bit (bit 1) of the interrupt edge selection register (address 003A16). When it is “0”, the falling edge active is selected; when it is “1”, the rising edge active is selected.

When the valid edge of the INT1 pin is detected, the INT1 interrupt request bit (bit 1) of the interrupt request register 1 (address 003C16) is set to “1”.

• Explanation of operation

1. “H” one-shot pulse; Bit 5 of timer Z mode register = “0”

The output level of the CNTR2 pin is initialized to “L” at mode selection. When trigger generation (input signal to INT1 pin) is detected, “H” is output from the CNTR2 pin. When an underflow occurs, “L” is output. The “H” one-shot pulse width is set by the setting value to the timer Z register low-order and high-order. When trigger generating is detected during timer count stop, although “H” is output from the CNTR2 pin, “H” output state continues because an underflow does not occur.

2. “L” one-shot pulse; Bit 5 of timer Z mode register = “1”

The output level of the CNTR2 pin is initialized to “H” at mode selection. When trigger generation (input signal to INT1 pin) is detected, “L” is output from the CNTR2 pin. When an underflow occurs, “H” is output. The “L” one-shot pulse width is set by the setting value to the timer Z low-order and high-order. When trigger generating is detected during timer count stop, although “L” is output from the CNTR2 pin, “L” output state continues because an underflow does not occur.

• Precautions

Set the double-function port of INT1 pin and port P42 to input in this mode.

The double-function port of CNTR2 pin and port P47 is automatically set to the programmable one-shot generating port in this mode.

This mode cannot be used in low-speed mode.

If the value of the CNTR2 active edge switch bit is changed during one-shot generating enabled or generating one-shot pulse, then the output level from CNTR2 pin changes.

Figure 35 shows the timing chart of the programmable one-shot generating mode.

<Notes regarding all modes>

• Timer Z write control

Which write control can be selected by the timer Z write control bit (bit 3) of the timer Z mode register (address 002A16), writing data to both the latch and the timer at the same time or writing data only to the latch.

When the operation “writing data only to the latch” is selected, the value is set to the timer latch by writing data to the address of timer Z and the timer is updated at next underflow. After reset release, the operation “writing data to both the latch and the timer at the same time” is selected, and the value is set to both the latch and the timer at the same time by writing data to the address of timer Z.

In the case of writing data only to the latch, if writing data to the latch and an underflow are performed almost at the same time, the timer value may become undefined.

• Timer Z read control

A read-out of timer value is impossible in pulse period measurement mode and pulse width measurement mode. In the other modes, a read-out of timer value is possible regardless of count operating or stopped.

However, a read-out of timer latch value is impossible.

• Switch of interrupt active edge of CNTR2 and INT1

Each interrupt active edge depends on setting of the CNTR2 active edge switch bit and the INT1 active edge selection bit.

• Switch of count source

When switching the count source by the timer Z count source selection bits, the value of timer count is altered in inconsiderable amount owing to generating of thin pulses on the count input signals.

Therefore, select the timer count source before setting the value to the prescaler and the timer.

• Usage of CNTR2 pin as normal I/O port P47

To use the CNTR2 pin as normal I/O port P47, set timer Z operating mode bits (b2, b1, b0) of timer Z mode register (address 002A16) to “000”.

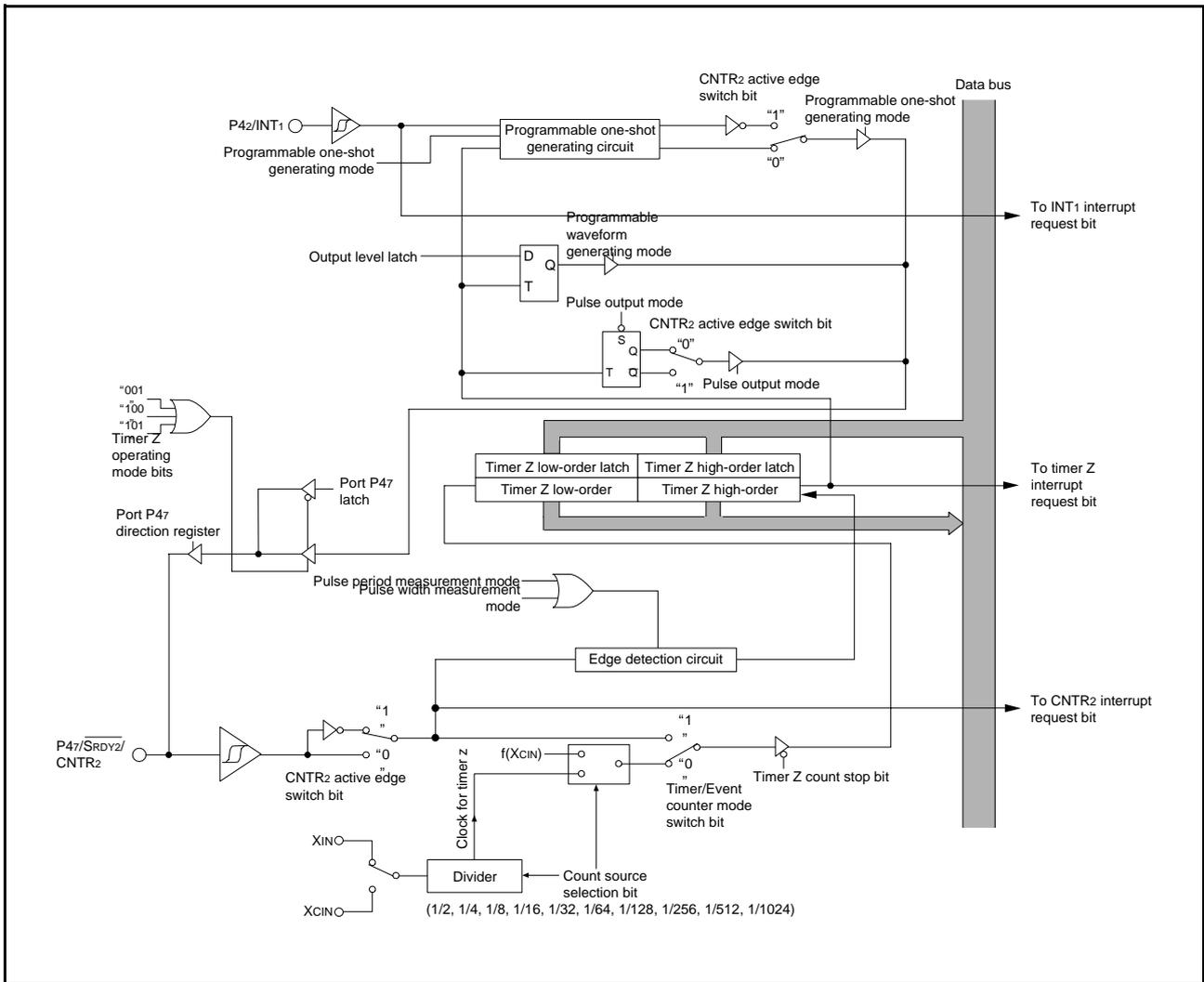


Fig 28. Block diagram of timer Z

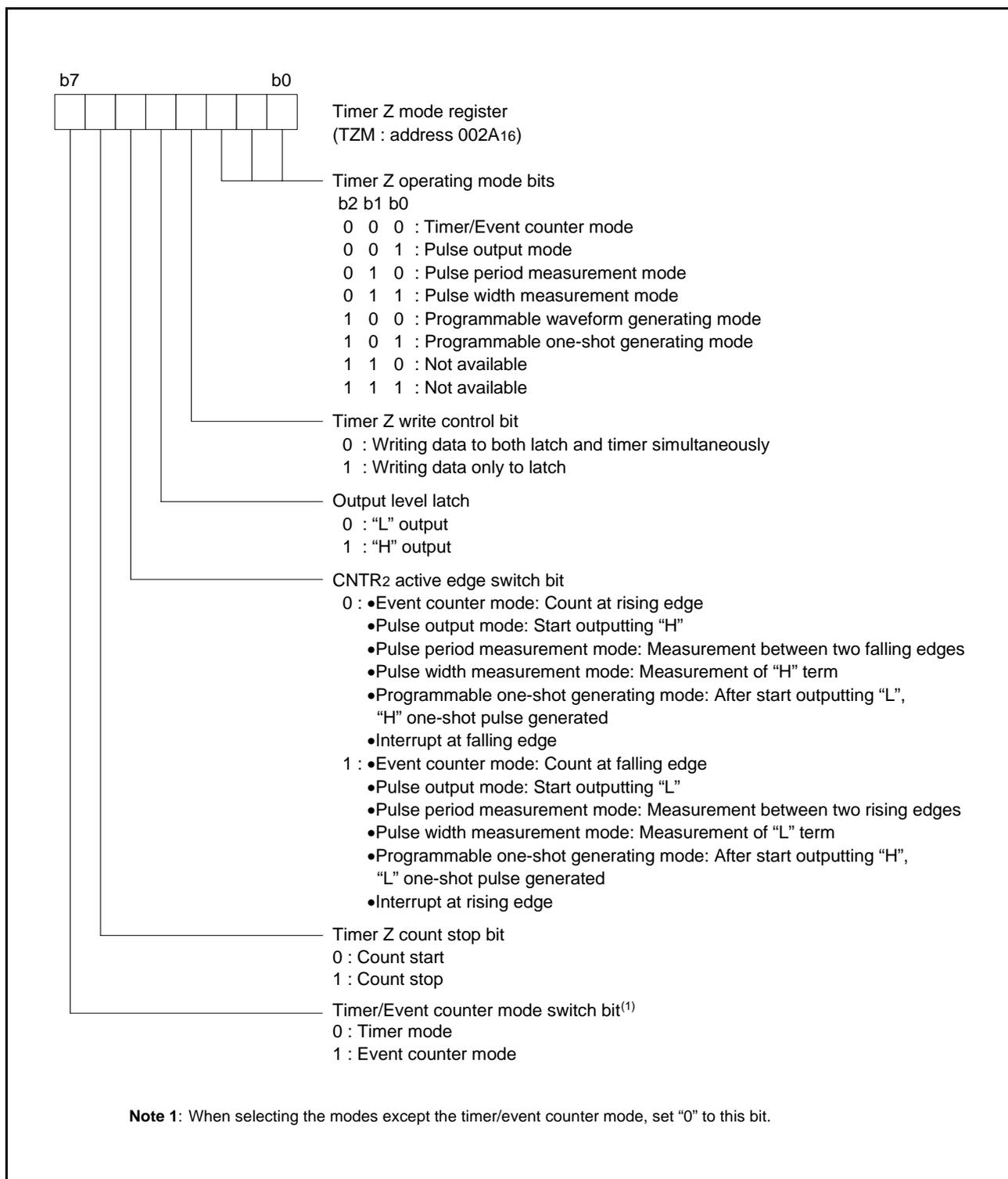


Fig 29. Structure of timer Z mode register

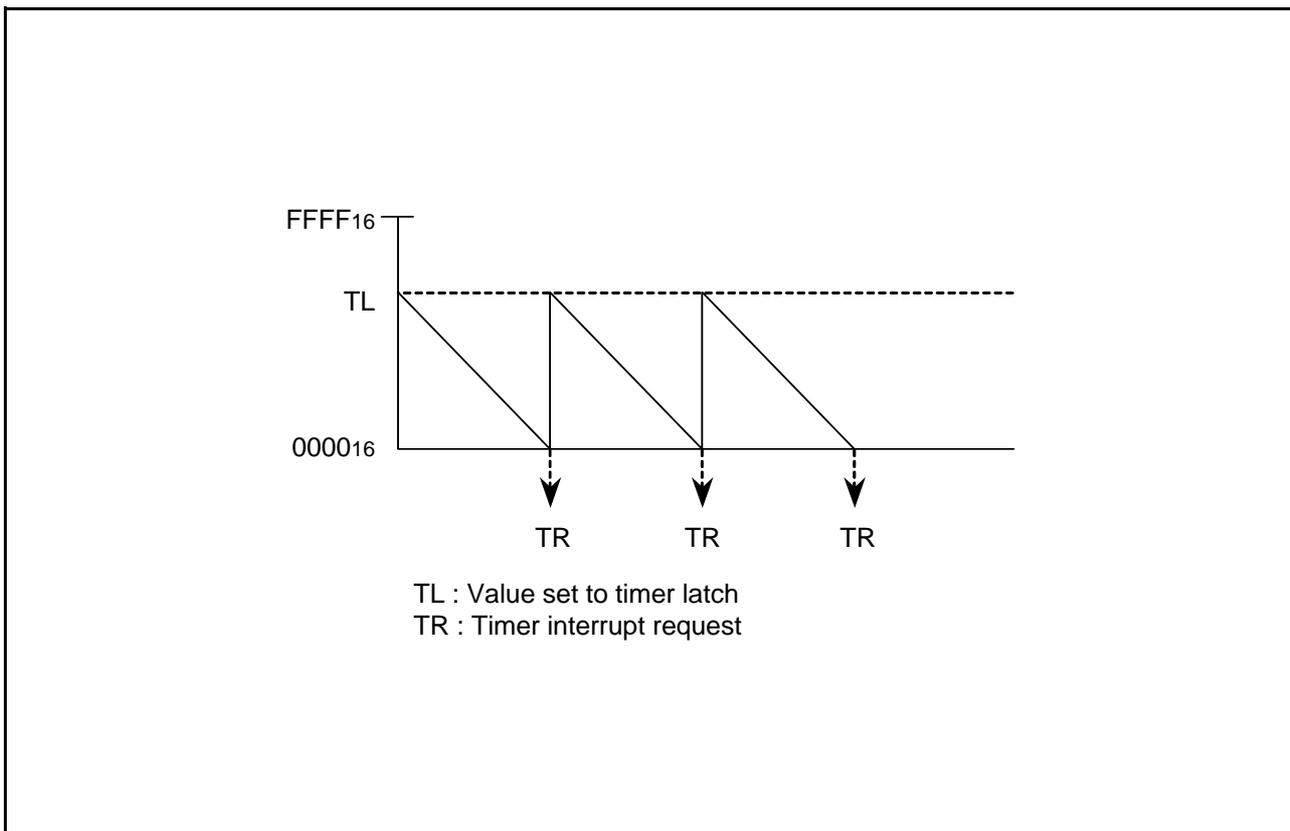


Fig 30. Timing chart of timer/event counter mode

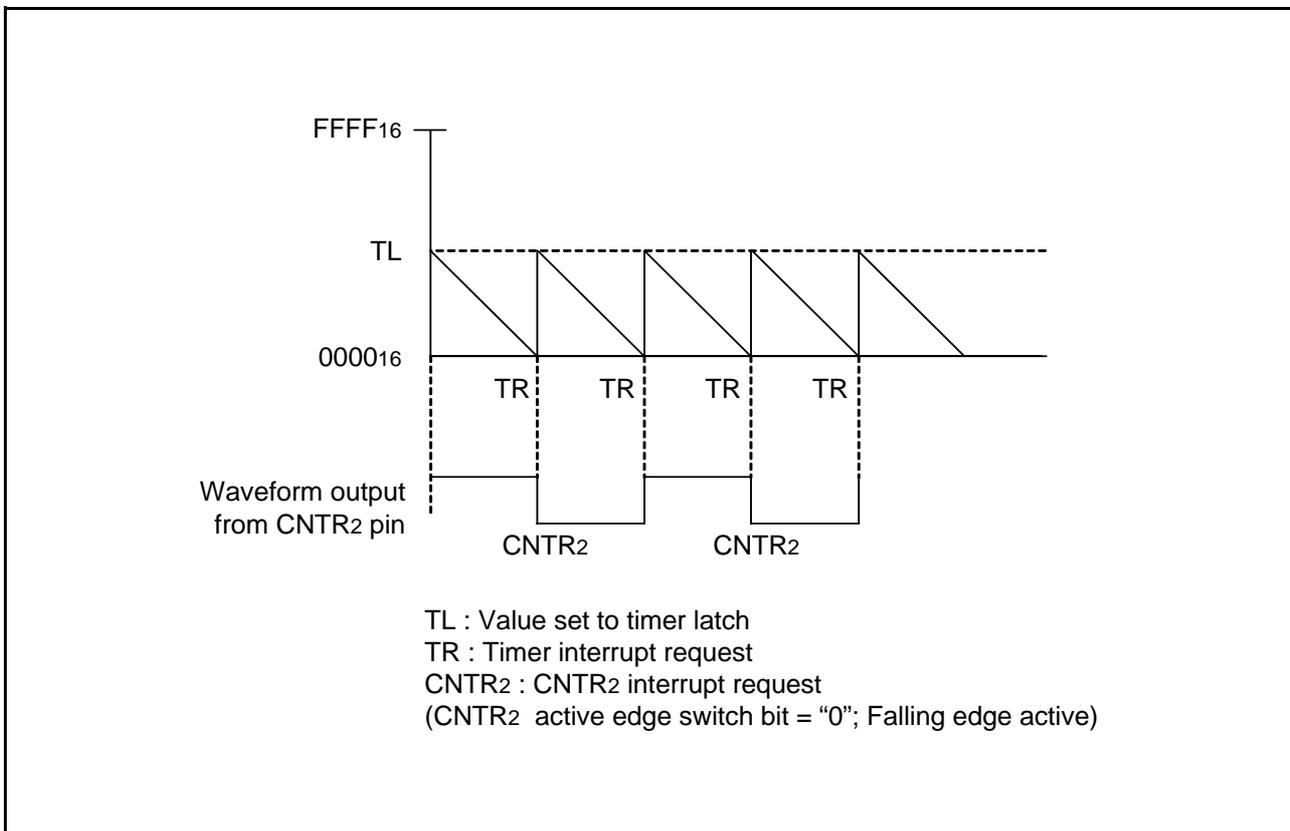


Fig 31. Timing chart of pulse output mode

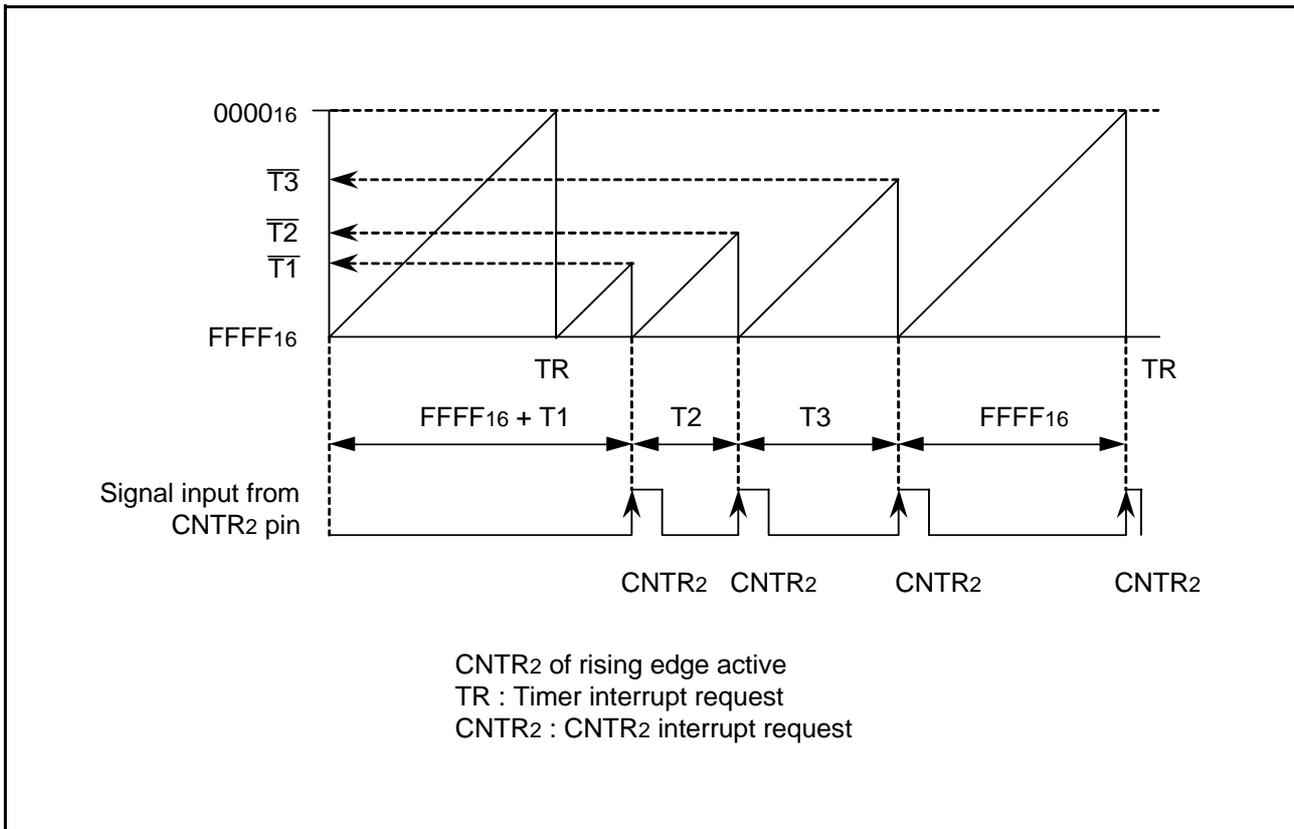


Fig 32. Timing chart of pulse period measurement mode (Measuring term between two rising edges)

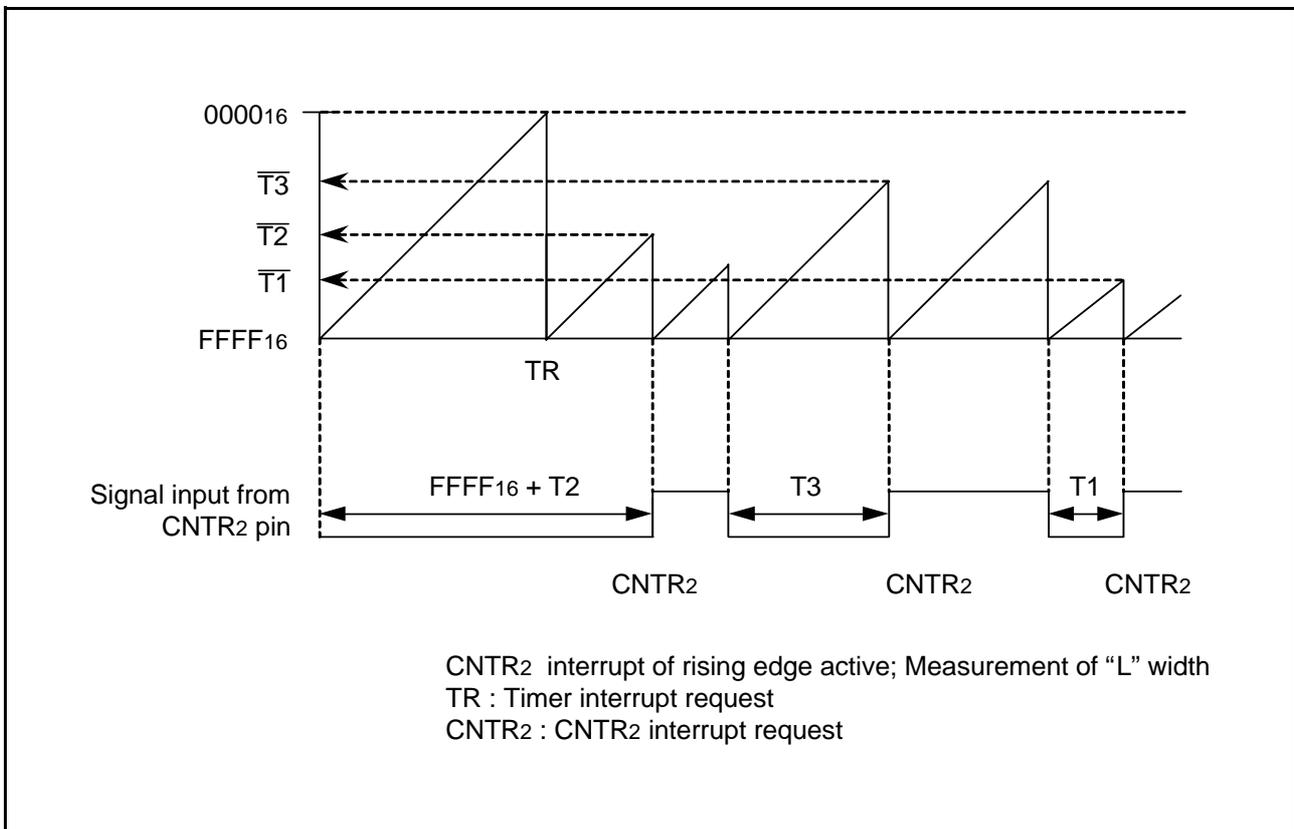


Fig 33. Timing chart of pulse width measurement mode (Measuring "L" term)

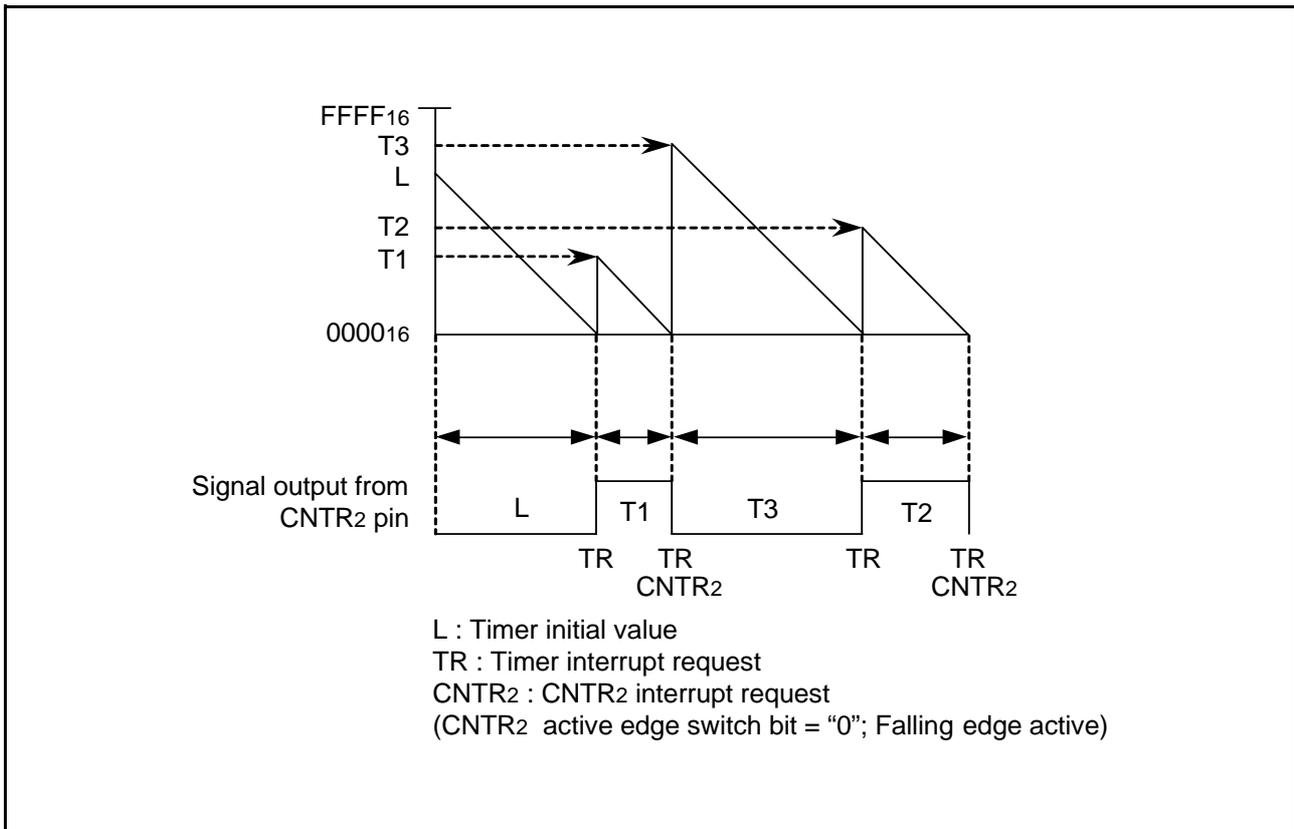


Fig 34. Timing chart of programmable waveform generating mode

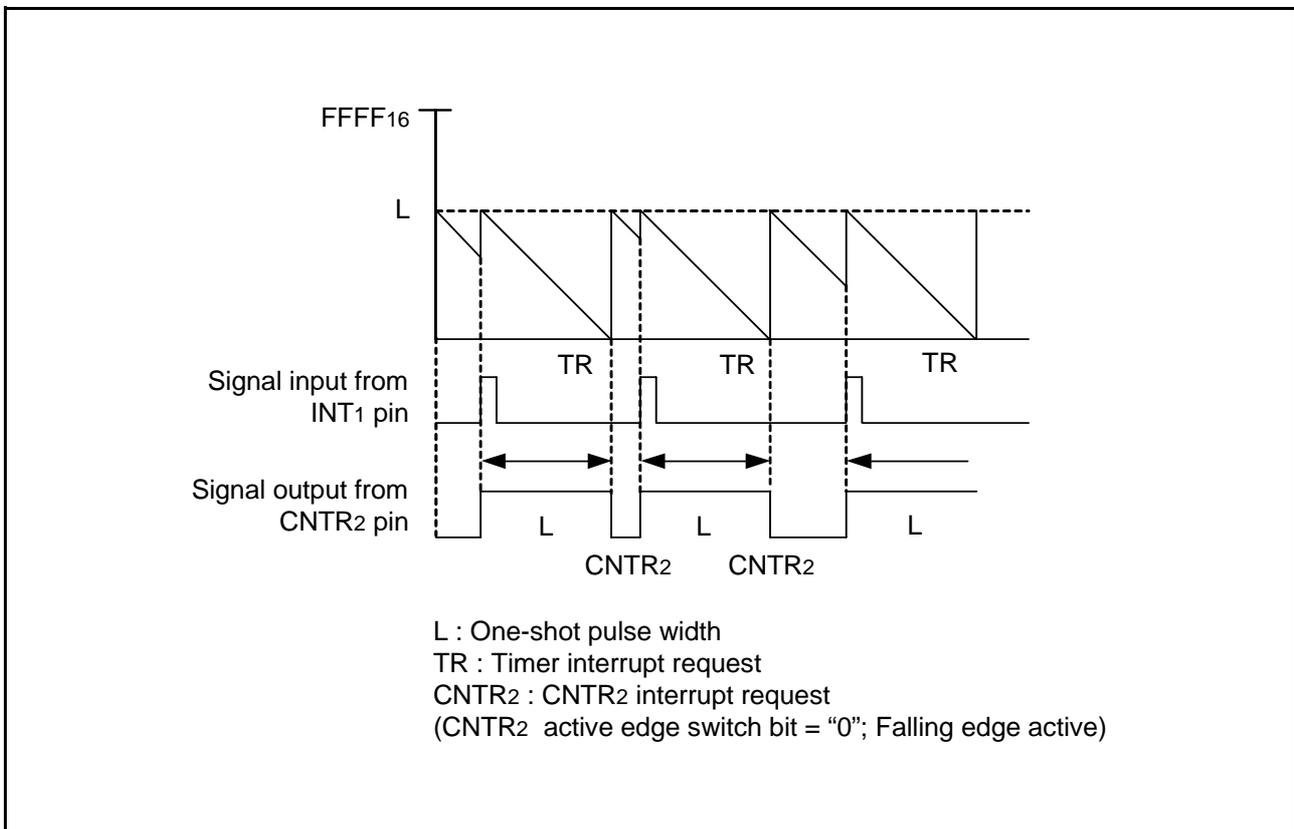


Fig 35. Timing chart of programmable one-shot generating mode ("H" one-shot pulse generating)

SERIAL INTERFACE

• Serial I/O1

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

(1) Clock Synchronous Serial I/O Mode

Clock synchronous serial I/O1 mode can be selected by setting the serial I/O1 mode selection bit of the serial I/O1 control register (bit 6 of address 001A16) to "1".

For clock synchronous serial I/O, the transmitter and the receiver must use the same clock. If an internal clock is used, transfer is started by a write signal to the transmit/receive buffer register.

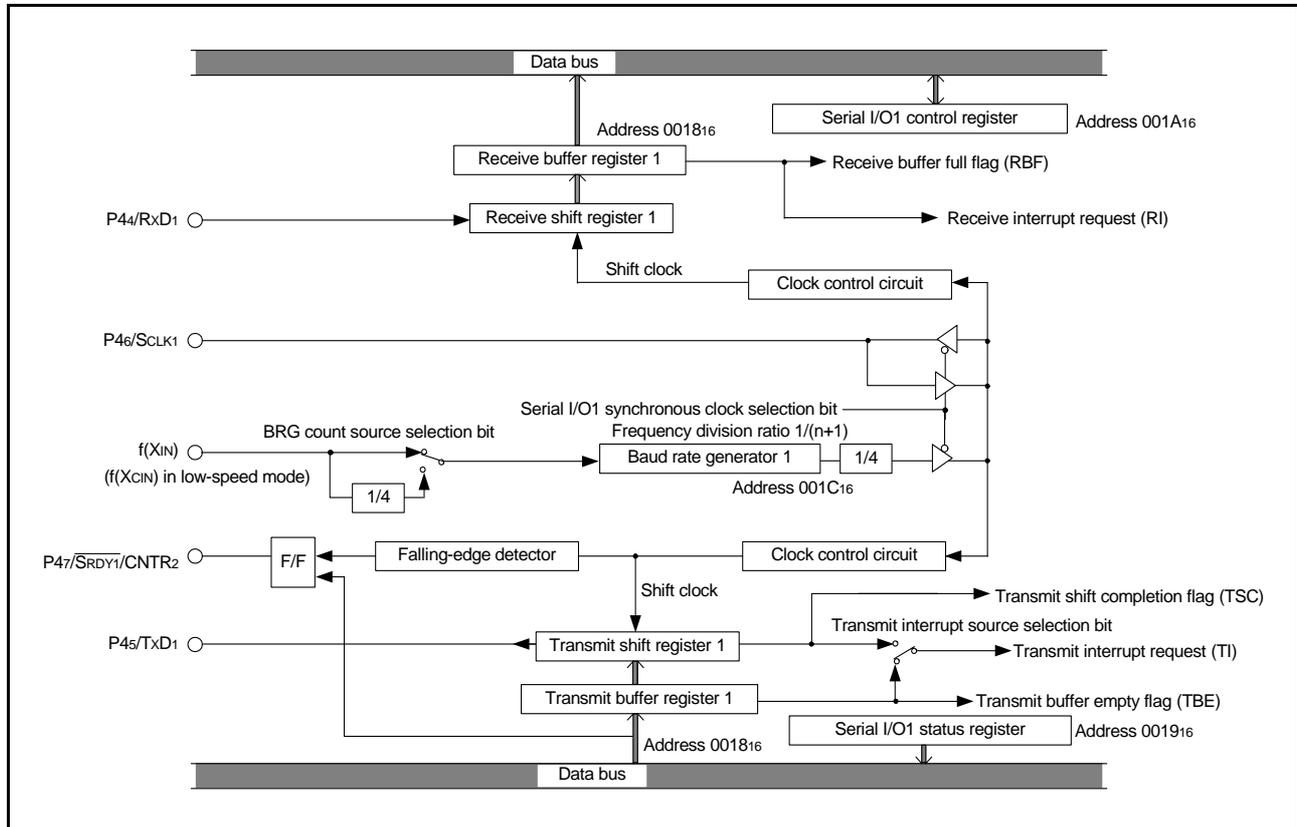


Fig 36. Block diagram of clock synchronous serial I/O1

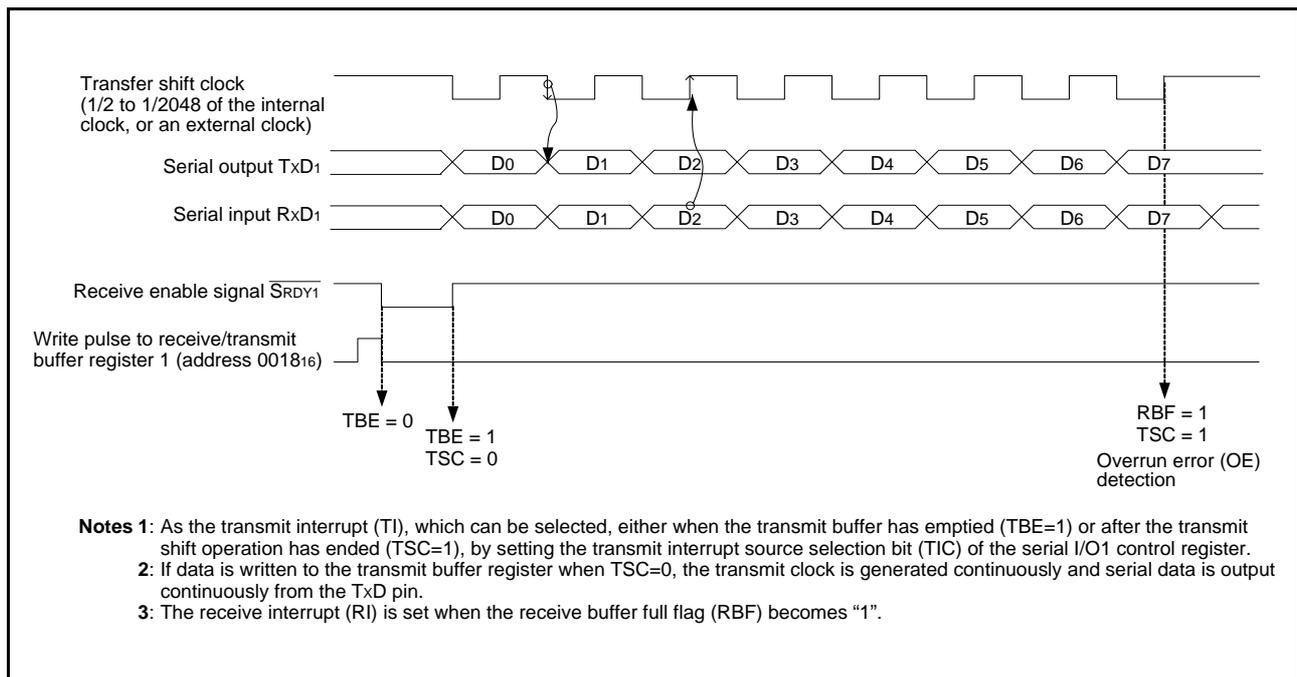


Fig 37. Operation of clock synchronous serial I/O1

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

Clock asynchronous serial I/O mode (UART) can be selected by clearing the serial I/O1 mode selection bit (b6) of the serial I/O1 control register to "0". Eight serial data transfer formats can be selected, and the transfer formats used by a transmitter and receiver must be identical.

The transmit and receive shift registers each have a buffer, but the two buffers have the same address in a memory. Since the shift register cannot be written to or read from directly, transmit data is written to the transmit buffer register, and receive data is read from the receive buffer register. The transmit buffer register can also hold the next data to be transmitted, and the receive buffer register can hold a character while the next character is being received.

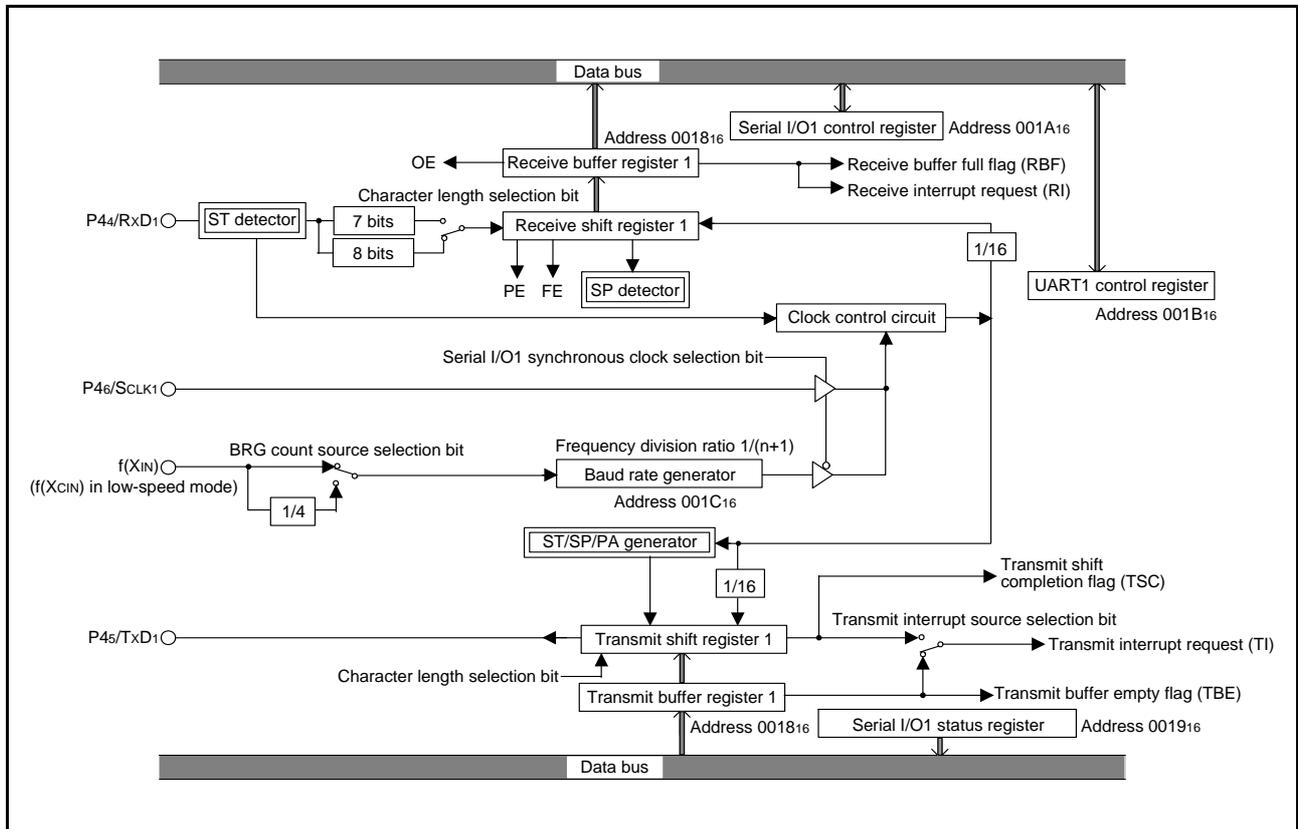


Fig 38. Block diagram of UART serial I/O1

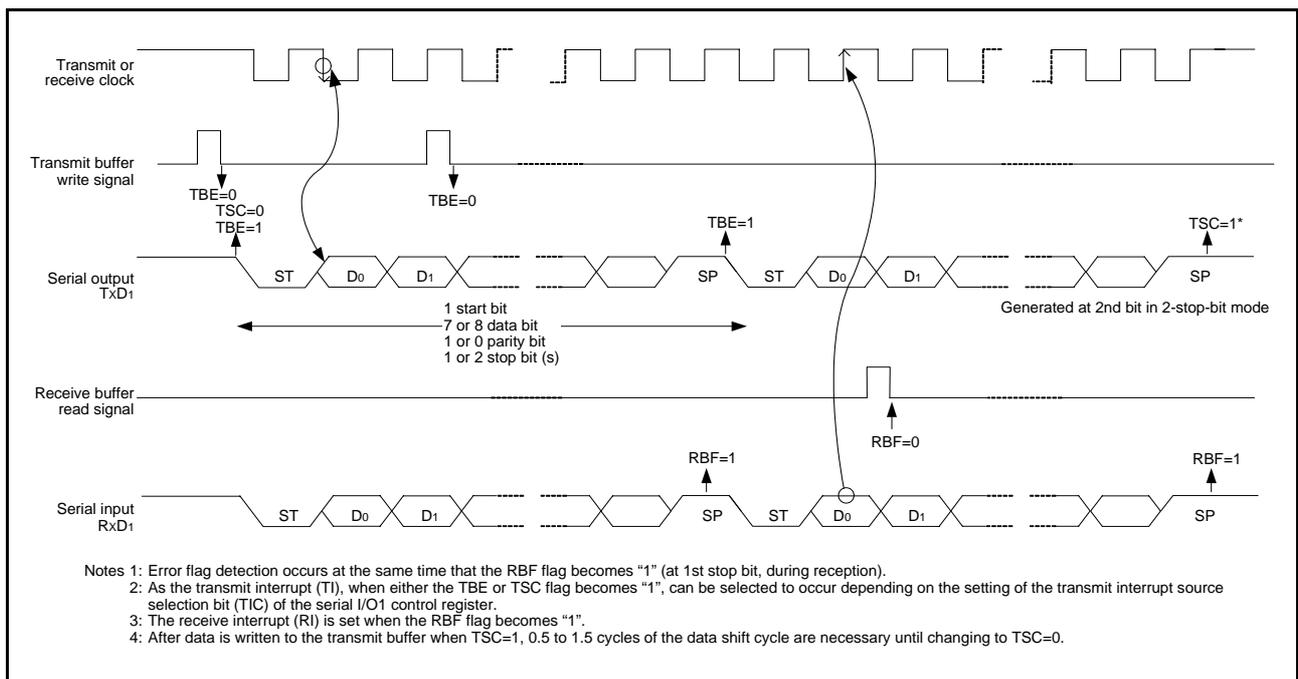


Fig 39. Operation of UART serial I/O1

[Transmit Buffer Register 1/Receive Buffer Register 1 (TB1/RB1)] 0018₁₆

The transmit buffer register 1 and the receive buffer register 1 are located at the same address. The transmit buffer is write-only and the receive buffer is read-only. If a character bit length is 7 bits, the MSB of data stored in the receive buffer is "0".

[Serial I/O1 Status Register (SIO1STS)] 0019₁₆

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

Three of the flags (bits 4 to 6) are valid only in UART mode. The receive buffer full flag (bit 1) is cleared to "0" when the receive buffer register is read.

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

Bits 0 to 6 of the serial I/O1 status register are initialized to "0" at reset, but if the transmit enable bit (bit 4) of the serial I/O1 control register has been set to "1", the transmit shift completion flag (bit 2) and the transmit buffer empty flag (bit 0) become "1".

[Serial I/O1 Control Register (SIO1CON)] 001A₁₆

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

[UART1 Control Register (UART1CON)] 001B₁₆

The UART control register consists of four control bits (bits 0 to 3) which are valid when asynchronous serial I/O is selected and set the data format of an data transfer, and one bit (bit 4) which is always valid and sets the output structure of the P45/TxD1 pin.

[Baud Rate Generator 1 (BRG1)] 001C₁₆

The baud rate generator determines the baud rate for serial transfer.

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

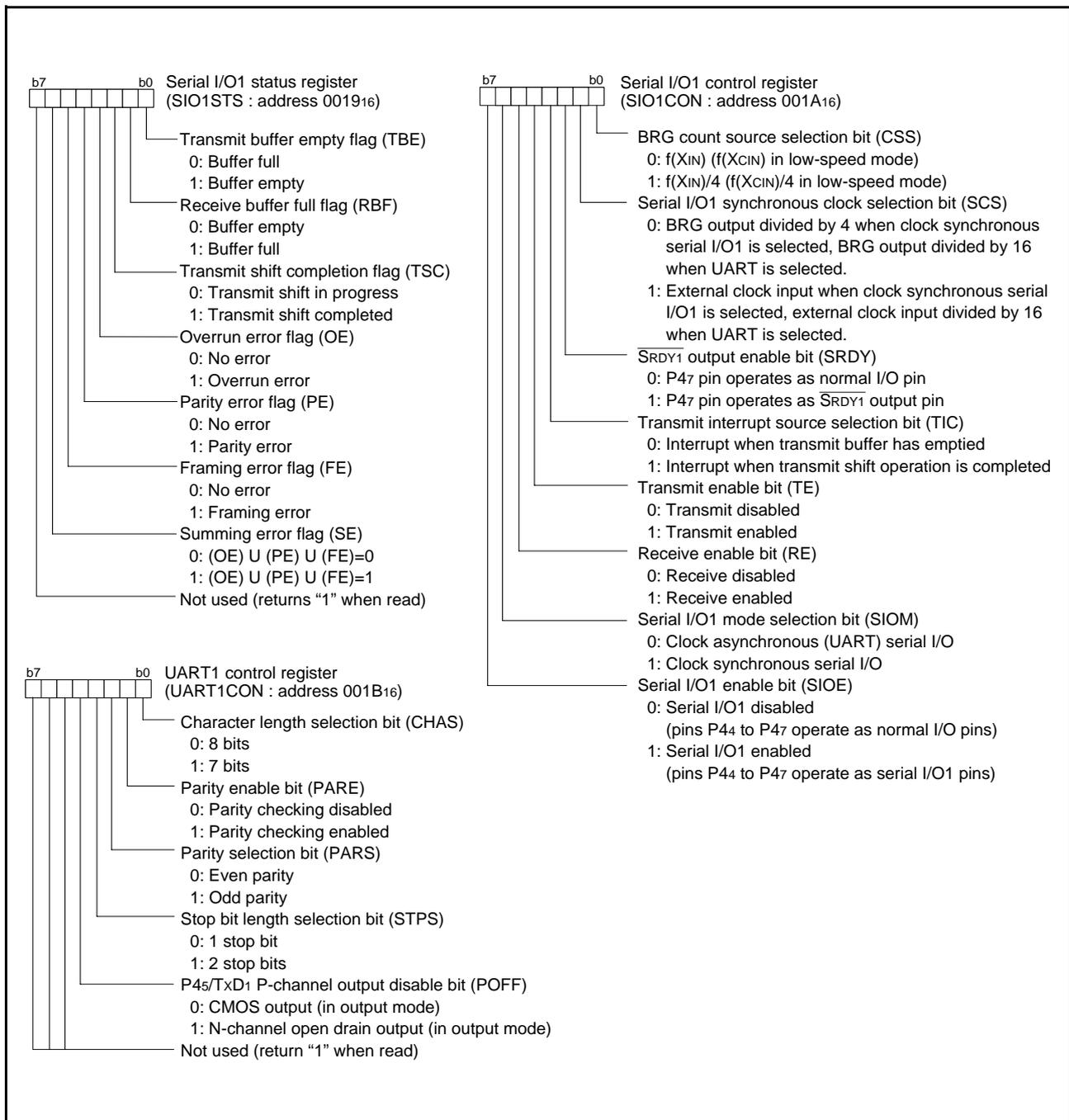


Fig 40. Structure of serial I/O1 control registers

<Notes concerning serial I/O1>

1. Notes when selecting clock synchronous serial I/O

1.1 Stop of transmission operation

• Note

Clear the serial I/O1 enable bit and the transmit enable bit to “0” (serial I/O and transmit disabled).

• Reason

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O1 enable bit is cleared to “0” (serial I/O disabled), the internal transmission is running (in this case, since pins TXD1, RXD1, SCLK1, and $\overline{\text{SRDY1}}$ function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O1 enable bit is set to “1” at this time, the data during internally shifting is output to the TXD1 pin and an operation failure occurs.

1.2 Stop of receive operation

• Note

Clear the receive enable bit to “0” (receive disabled), or clear the serial I/O1 enable bit to “0” (serial I/O disabled).

1.3 Stop of transmit/receive operation

• Note

Clear both the transmit enable bit and receive enable bit to “0” (transmit and receive disabled).

(when data is transmitted and received in the clock synchronous serial I/O mode, any one of data transmission and reception cannot be stopped.)

• Reason

In the clock synchronous serial I/O mode, the same clock is used for transmission and reception. If any one of transmission and reception is disabled, a bit error occurs because transmission and reception cannot be synchronized.

In this mode, the clock circuit of the transmission circuit also operates for data reception. Accordingly, the transmission circuit does not stop by clearing only the transmit enable bit to “0” (transmit disabled). Also, the transmission circuit is not initialized by clearing the serial I/O1 enable bit to “0” (serial I/O disabled) (refer to 1.1).

2. Notes when selecting clock asynchronous serial I/O

2.1 Stop of transmission operation

• Note

Clear the transmit enable bit to “0” (transmit disabled). The transmission operation does not stop by clearing the serial I/O1 enable bit to “0”.

• Reason

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O1 enable bit is cleared to “0” (serial I/O disabled), the internal transmission is running (in this case, since pins TXD1, RXD1, SCLK1, and $\overline{\text{SRDY1}}$ function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O1 enable bit is set to “1” at this time, the data during internally shifting is output to the TXD1 pin and an operation failure occurs.

2.2 Stop of receive operation

• Note

Clear the receive enable bit to “0” (receive disabled).

2.3 Stop of transmit/receive operation

• Note 1 (only transmission operation is stopped)

Clear the transmit enable bit to “0” (transmit disabled). The transmission operation does not stop by clearing the serial I/O1 enable bit to “0”.

• Reason

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O1 enable bit is cleared to “0” (serial I/O disabled), the internal transmission is running (in this case, since pins TXD1, RXD1, SCLK1, and $\overline{\text{SRDY1}}$ function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O1 enable bit is set to “1” at this time, the data during internally shifting is output to the TXD1 pin and an operation failure occurs.

• Note 2 (only receive operation is stopped)

Clear the receive enable bit to “0” (receive disabled).

3. $\overline{\text{SRDY1}}$ output of reception side

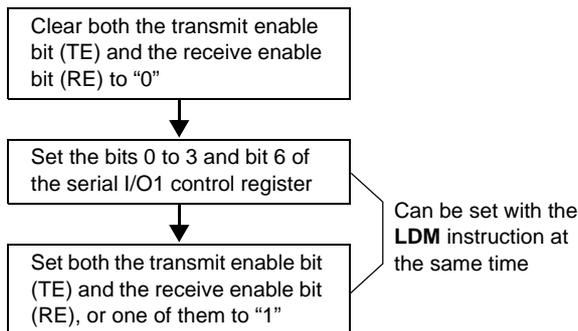
• Note

When signals are output from the $\overline{\text{SRDY1}}$ pin on the reception side by using an external clock in the clock synchronous serial I/O mode, set all of the receive enable bit, the $\overline{\text{SRDY1}}$ output enable bit, and the transmit enable bit to "1" (transmit enabled).

4. Setting serial I/O1 control register again

• Note

Set the serial I/O1 control register again after the transmission and the reception circuits are reset by clearing both the transmit enable bit and the receive enable bit to "0".



5. Data transmission control with referring to transmit shift register completion flag

• Note

After the transmit data is written to the transmit buffer register, the transmit shift register completion flag changes from "1" to "0" with a delay of 0.5 to 1.5 shift clocks. When data transmission is controlled with referring to the flag after writing the data to the transmit buffer register, note the delay.

6. Transmission control when external clock is selected

• Note

When an external clock is used as the synchronous clock for data transmission, set the transmit enable bit to "1" at "H" of the SCLK1 input level. Also, write data to the transmit buffer register at "H" of the SCLK1 input level.

7. Transmit interrupt request when transmit enable bit is set

• Note

When using the transmit interrupt, take the following sequence.

1. Set the serial I/O1 transmit interrupt enable bit to "0" (disabled).
2. Set the transmit enable bit to "1".
3. Set the serial I/O1 transmit interrupt request bit to "0" after 1 or more instruction has executed.
4. Set the serial I/O1 transmit interrupt enable bit to "1" (enabled).

• Reason

When the transmit enable bit is set to "1", the transmit buffer empty flag and the transmit shift register shift completion flag are also set to "1". Therefore, regardless of selecting which timing for the generating of transmit interrupts, the interrupt request is generated and the transmit interrupt request bit is set at this point.

• **Serial I/O2**

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

For clock synchronous serial I/O2, the transmitter and the receiver must use the same clock. If the internal clock is used, transfer is started by a write signal to the serial I/O2 register (address 001F16).

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

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

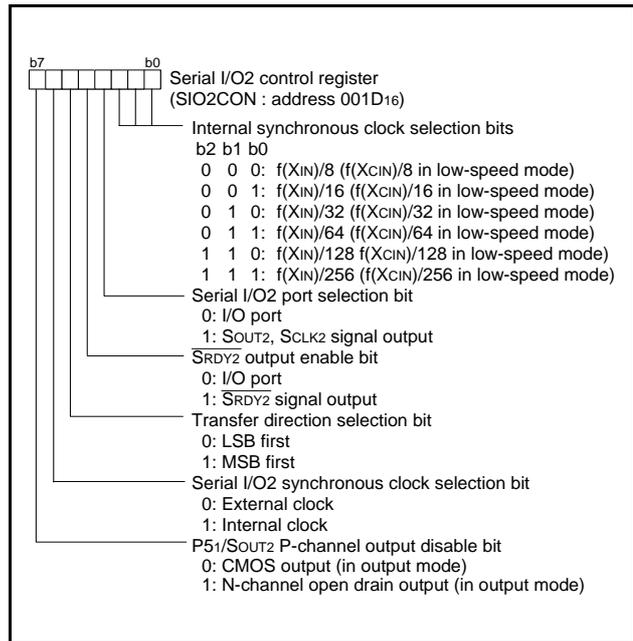


Fig 41. Structure of Serial I/O2 control register

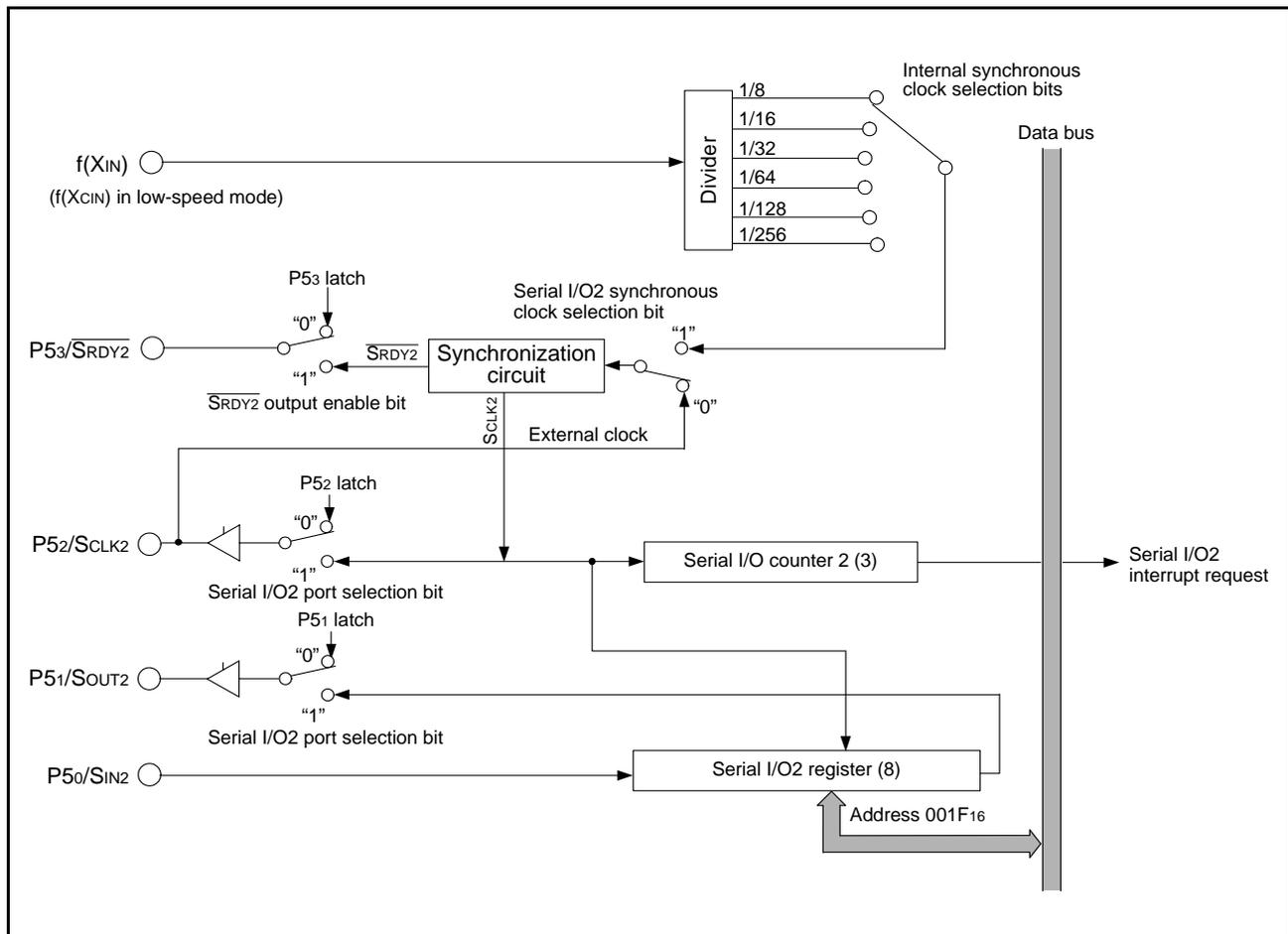


Fig 42. Block diagram of serial I/O2

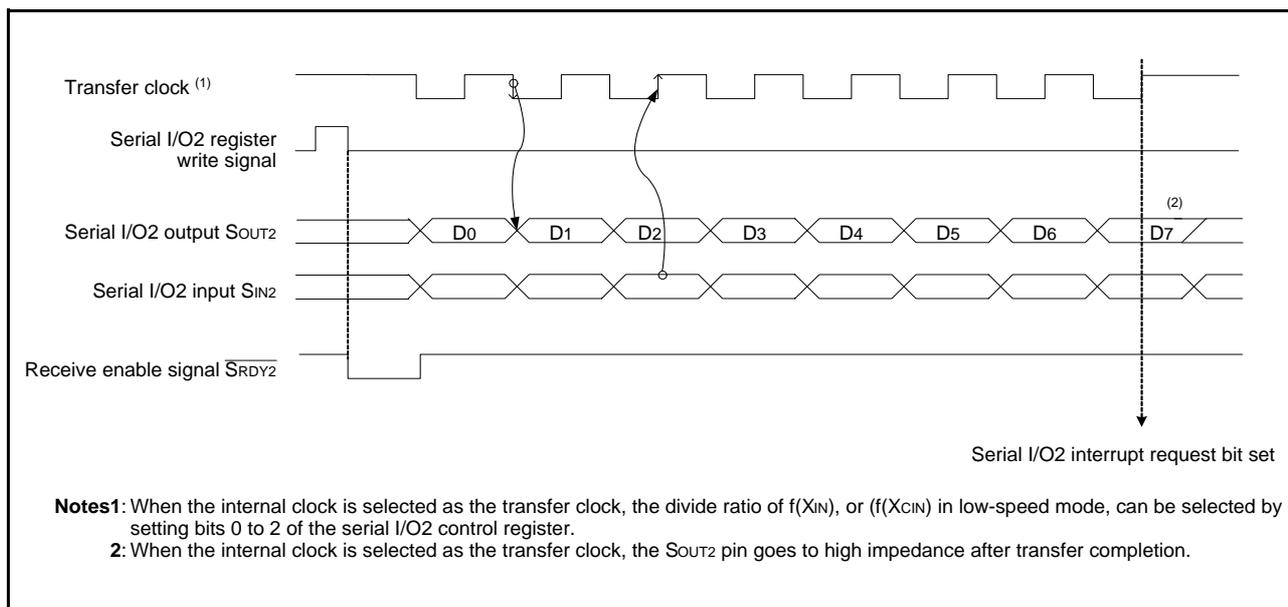


Fig 43. Timing of serial I/O2

• Serial I/O3

Serial I/O3 can be used as either clock synchronous or asynchronous (UART) serial I/O3. A dedicated timer is also provided for baud rate generation.

(1) Clock Synchronous Serial I/O Mode

Clock synchronous serial I/O3 mode can be selected by setting the serial I/O3 mode selection bit of the serial I/O3 control register (bit 6 of address 003216) to "1".

For clock synchronous serial I/O, the transmitter and the receiver must use the same clock. If an internal clock is used, transfer is started by a write signal to the transmit/receive buffer register.

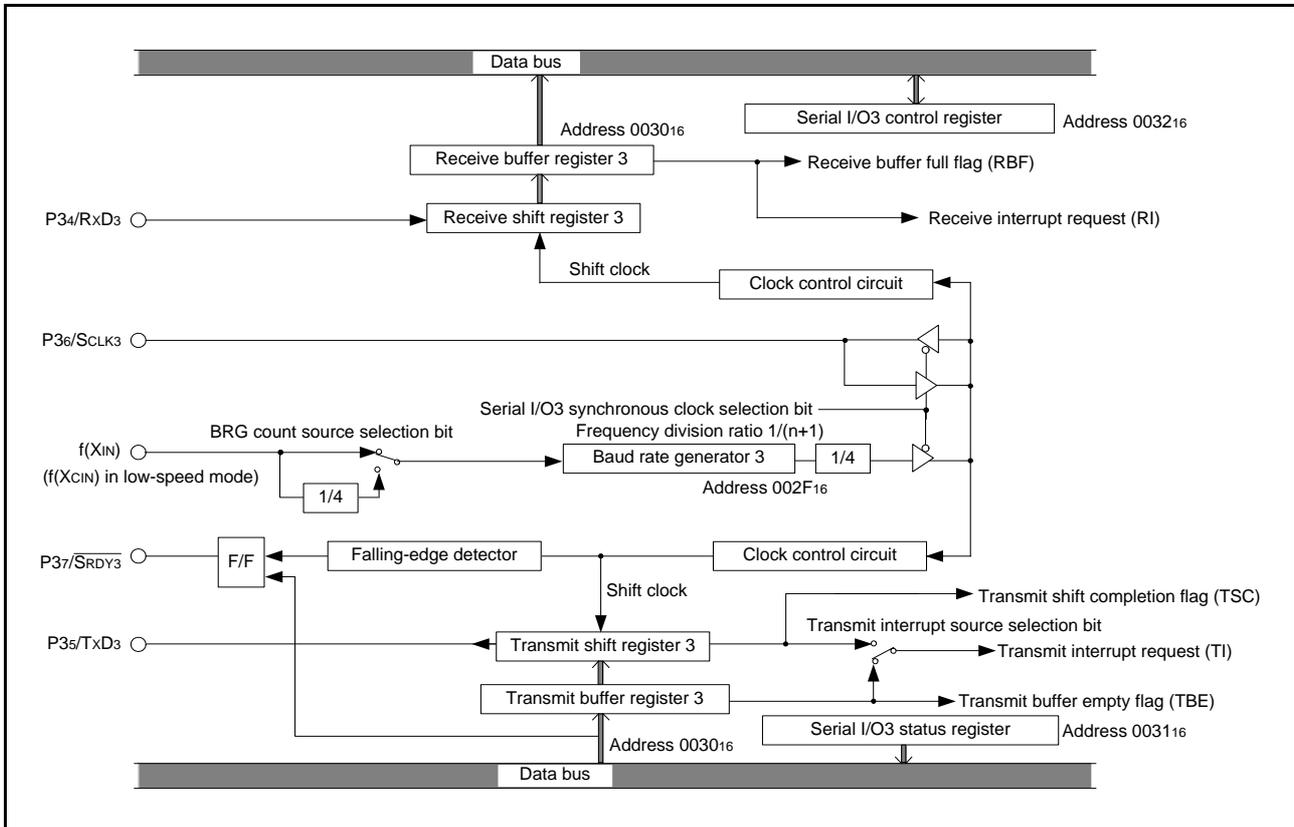


Fig 44. Block diagram of clock synchronous serial I/O3

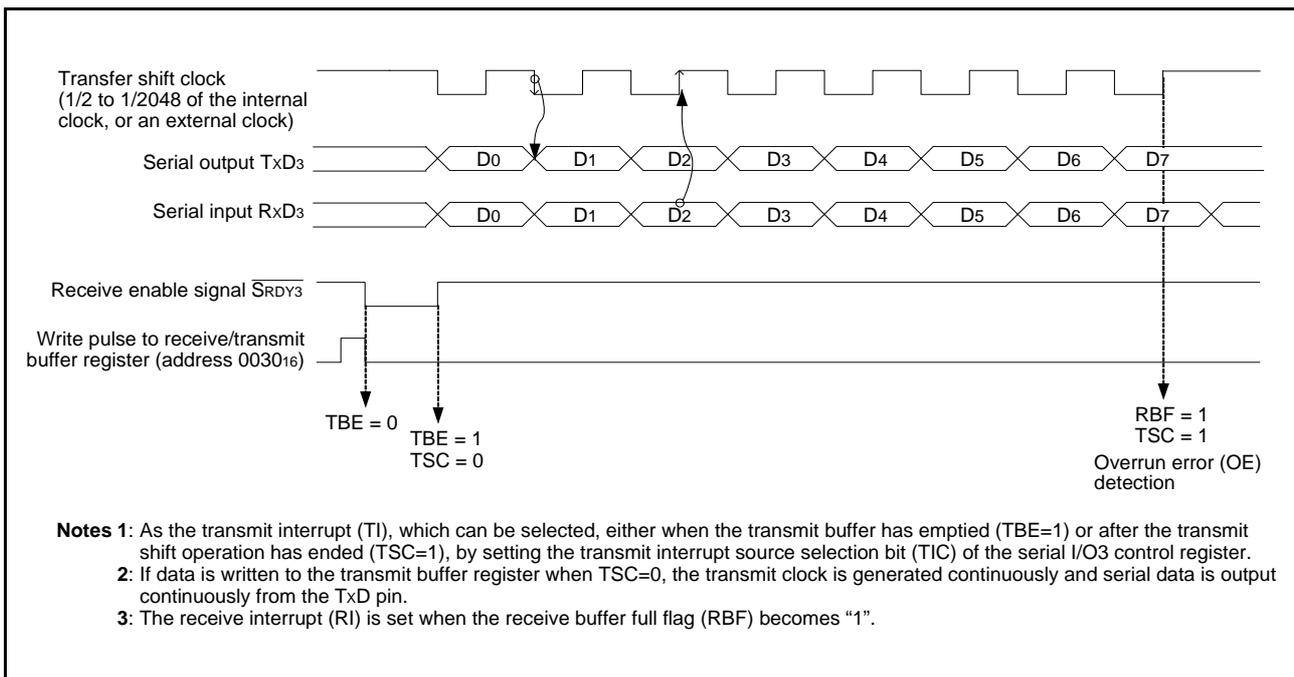


Fig 45. Operation of clock synchronous serial I/O3

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

Clock asynchronous serial I/O mode (UART) can be selected by clearing the serial I/O3 mode selection bit (b6) of the serial I/O3 control register to "0". Eight serial data transfer formats can be selected, and the transfer formats used by a transmitter and receiver must be identical.

The transmit and receive shift registers each have a buffer, but the two buffers have the same address in a memory. Since the shift register cannot be written to or read from directly, transmit data is written to the transmit buffer register, and receive data is read from the receive buffer register. The transmit buffer register can also hold the next data to be transmitted, and the receive buffer register can hold a character while the next character is being received.

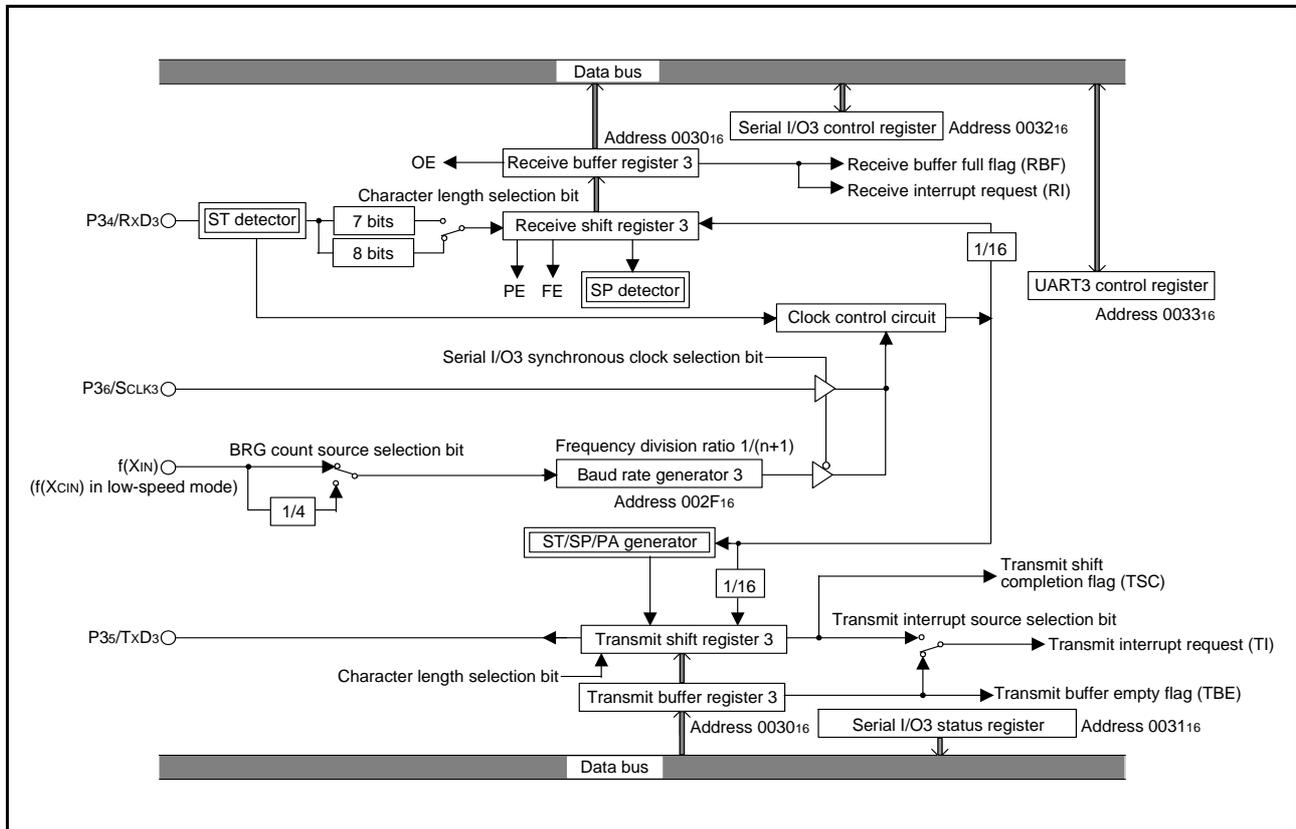


Fig 46. Block diagram of UART serial I/O3

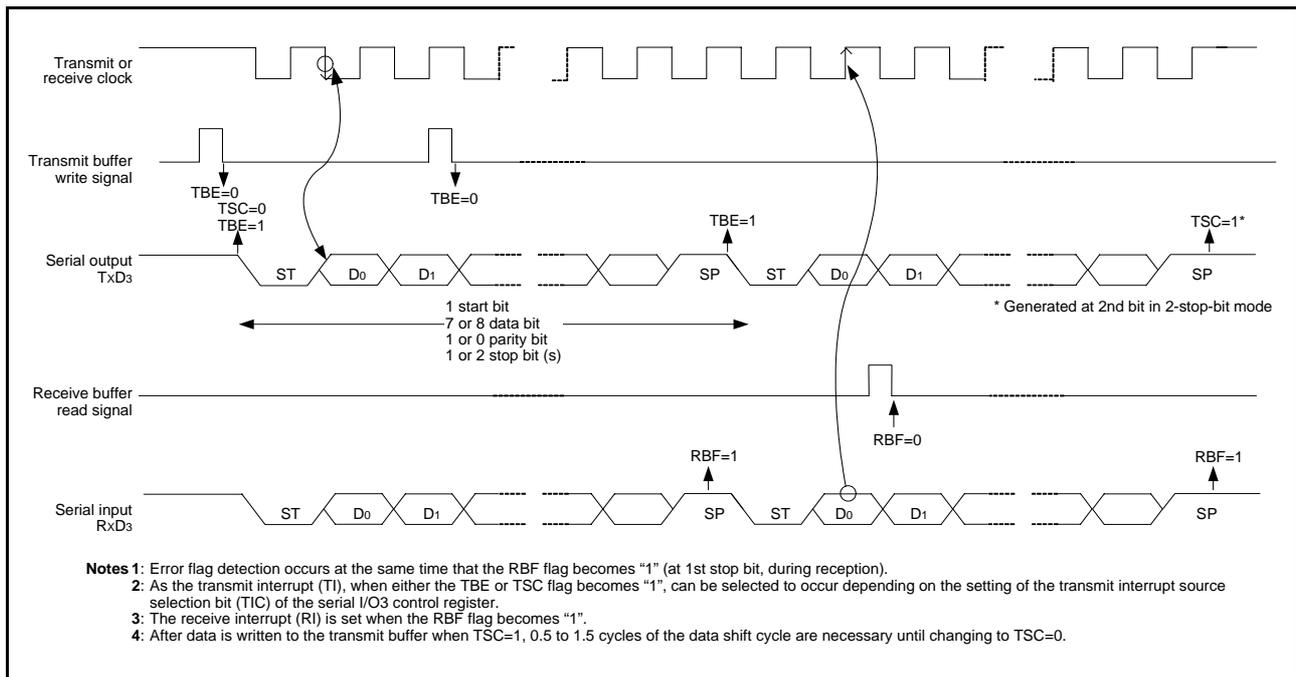


Fig 47. Operation of UART serial I/O3

[Transmit Buffer Register 3/Receive Buffer Register 3 (TB3/RB3)] 0030₁₆

The transmit buffer register 3 and the receive buffer register 3 are located at the same address. The transmit buffer is write-only and the receive buffer is read-only. If a character bit length is 7 bits, the MSB of data stored in the receive buffer is "0".

[Serial I/O3 Status Register (SIO3STS)] 0031₁₆

The read-only serial I/O3 status register consists of seven flags (bits 0 to 6) which indicate the operating status of the serial I/O3 function and various errors.

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

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

If there is an error, it is detected at the same time that data is transferred from the receive shift register to the receive buffer register, and the receive buffer full flag is set. A write to the serial I/O3 status register clears all the error flags OE, PE, FE, and SE (bit 3 to bit 6, respectively). Writing "0" to the serial I/O3 enable bit SIOE (bit 7 of the serial I/O3 control register) also clears all the status flags, including the error flags.

Bits 0 to 6 of the serial I/O3 status register are initialized to "0" at reset, but if the transmit enable bit (bit 4) of the serial I/O3 control register has been set to "1", the transmit shift completion flag (bit 2) and the transmit buffer empty flag (bit 0) become "1".

[Serial I/O3 Control Register (SIO3CON)] 0032₁₆

The serial I/O3 control register consists of eight control bits for the serial I/O3 function.

[UART3 Control Register (UART3CON)] 0033₁₆

The UART control register consists of four control bits (bits 0 to 3) which are valid when asynchronous serial I/O is selected and set the data format of an data transfer, and one bit (bit 4) which is always valid and sets the output structure of the P3₅/TXD₃ pin.

[Baud Rate Generator 3 (BRG3)] 002F₁₆

The baud rate generator determines the baud rate for serial transfer.

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

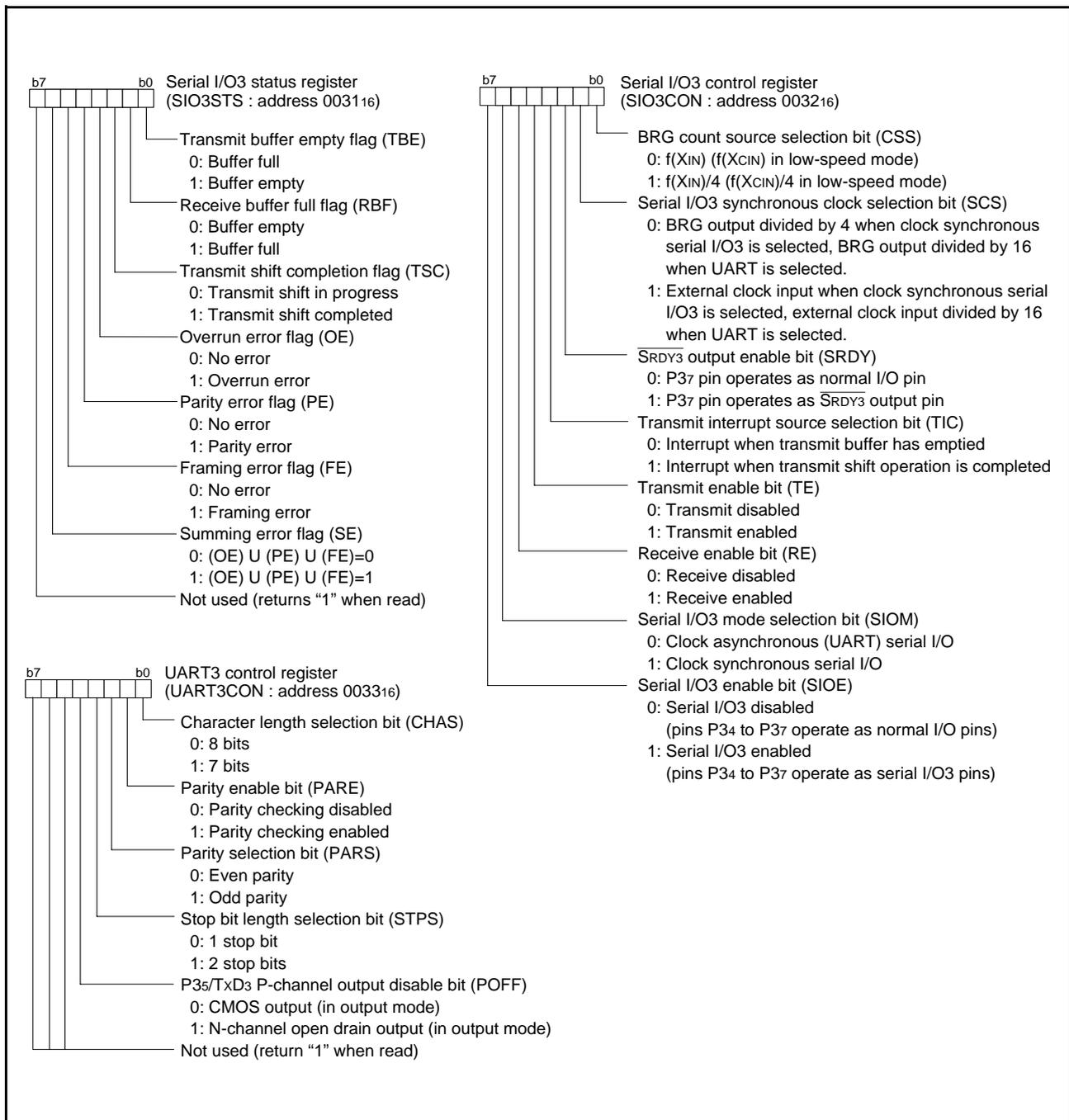


Fig 48. Structure of serial I/O3 control registers

<Notes concerning serial I/O3>

1. Notes when selecting clock synchronous serial I/O

1.1 Stop of transmission operation

• Note

Clear the serial I/O3 enable bit and the transmit enable bit to “0” (serial I/O and transmit disabled).

• Reason

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O3 enable bit is cleared to “0” (serial I/O disabled), the internal transmission is running (in this case, since pins TXD3, RXD3, SCLK3, and $\overline{\text{SRDY3}}$ function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O3 enable bit is set to “1” at this time, the data during internally shifting is output to the TXD3 pin and an operation failure occurs.

1.2 Stop of receive operation

• Note

Clear the receive enable bit to “0” (receive disabled), or clear the serial I/O3 enable bit to “0” (serial I/O disabled).

1.3 Stop of transmit/receive operation

• Note

Clear both the transmit enable bit and receive enable bit to “0” (transmit and receive disabled).

(when data is transmitted and received in the clock synchronous serial I/O mode, any one of data transmission and reception cannot be stopped.)

• Reason

In the clock synchronous serial I/O mode, the same clock is used for transmission and reception. If any one of transmission and reception is disabled, a bit error occurs because transmission and reception cannot be synchronized.

In this mode, the clock circuit of the transmission circuit also operates for data reception. Accordingly, the transmission circuit does not stop by clearing only the transmit enable bit to “0” (transmit disabled). Also, the transmission circuit is not initialized by clearing the serial I/O3 enable bit to “0” (serial I/O disabled) (refer to 1.1).

2. Notes when selecting clock asynchronous serial I/O

2.1 Stop of transmission operation

• Note

Clear the transmit enable bit to “0” (transmit disabled). The transmission operation does not stop by clearing the serial I/O3 enable bit to “0”.

• Reason

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O3 enable bit is cleared to “0” (serial I/O disabled), the internal transmission is running (in this case, since pins TXD3, RXD3, SCLK3, and $\overline{\text{SRDY3}}$ function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O3 enable bit is set to “1” at this time, the data during internally shifting is output to the TXD3 pin and an operation failure occurs.

2.2 Stop of receive operation

• Note

Clear the receive enable bit to “0” (receive disabled).

2.3 Stop of transmit/receive operation

• Note 1 (only transmission operation is stopped)

Clear the transmit enable bit to “0” (transmit disabled). The transmission operation does not stop by clearing the serial I/O3 enable bit to “0”.

• Reason

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O3 enable bit is cleared to “0” (serial I/O disabled), the internal transmission is running (in this case, since pins TXD3, RXD3, SCLK3, and $\overline{\text{SRDY3}}$ function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O3 enable bit is set to “1” at this time, the data during internally shifting is output to the TXD3 pin and an operation failure occurs.

• Note 2 (only receive operation is stopped)

Clear the receive enable bit to “0” (receive disabled).

3. $\overline{\text{SRDY3}}$ output of reception side

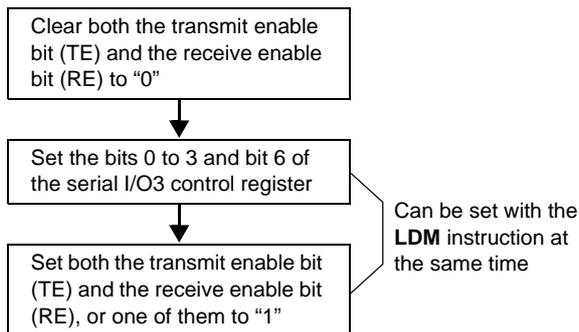
• Note

When signals are output from the $\overline{\text{SRDY3}}$ pin on the reception side by using an external clock in the clock synchronous serial I/O mode, set all of the receive enable bit, the $\overline{\text{SRDY3}}$ output enable bit, and the transmit enable bit to “1” (transmit enabled).

4. Setting serial I/O3 control register again

• Note

Set the serial I/O3 control register again after the transmission and the reception circuits are reset by clearing both the transmit enable bit and the receive enable bit to “0”.



5. Data transmission control with referring to transmit shift register completion flag

• Note

After the transmit data is written to the transmit buffer register, the transmit shift register completion flag changes from “1” to “0” with a delay of 0.5 to 1.5 shift clocks. When data transmission is controlled with referring to the flag after writing the data to the transmit buffer register, note the delay.

6. Transmission control when external clock is selected

• Note

When an external clock is used as the synchronous clock for data transmission, set the transmit enable bit to “1” at “H” of the SCLK3 input level. Also, write data to the transmit buffer register at “H” of the SCLK input level.

7. Transmit interrupt request when transmit enable bit is set

• Note

When using the transmit interrupt, take the following sequence.

1. Set the serial I/O3 transmit interrupt enable bit to “0” (disabled).
2. Set the transmit enable bit to “1”.
3. Set the serial I/O3 transmit interrupt request bit to “0” after 1 or more instruction has executed.
4. Set the serial I/O3 transmit interrupt enable bit to “1” (enabled).

• Reason

When the transmit enable bit is set to “1”, the transmit buffer empty flag and the transmit shift register shift completion flag are also set to “1”. Therefore, regardless of selecting which timing for the generating of transmit interrupts, the interrupt request is generated and the transmit interrupt request bit is set at this point.

PULSE WIDTH MODULATION (PWM)

The 3803 group (Spec.H QzROM version) has PWM functions with an 8-bit resolution, based on a signal that is the clock input X_{IN} or that clock input divided by 2 or the clock input X_{CIN} or that clock input divided by 2 in low-speed mode.

• Data Setting

The PWM output pin also functions as port P56. Set the PWM period by the PWM prescaler, and set the “H” term of output pulse by the PWM register.

If the value in the PWM prescaler is n and the value in the PWM register is m (where n = 0 to 255 and m = 0 to 255):

$$\begin{aligned} \text{PWM period} &= 255 \times (n+1) / f(\text{X}_{\text{IN}}) \\ &= 31.875 \times (n+1) \mu\text{s} \\ &\text{(when } f(\text{X}_{\text{IN}}) = 8 \text{ MHz, count source selection bit} = \text{“0”}) \end{aligned}$$

$$\begin{aligned} \text{Output pulse “H” term} &= \text{PWM period} \times m / 255 \\ &= 0.125 \times (n+1) \times m \mu\text{s} \\ &\text{(when } f(\text{X}_{\text{IN}}) = 8 \text{ MHz, count source selection bit} = \text{“0”}) \end{aligned}$$

• PWM Operation

When bit 0 (PWM enable bit) of the PWM control register is set to “1”, operation starts by initializing the PWM output circuit, and pulses are output starting at an “H”.

If the PWM register or PWM prescaler is updated during PWM output, the pulses will change in the cycle after the one in which the change was made.

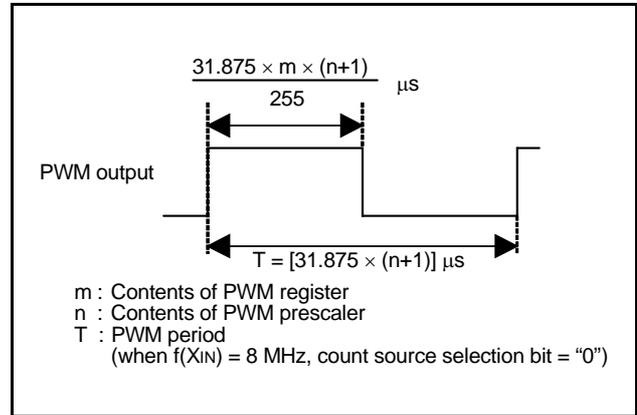


Fig 49. Timing of PWM period

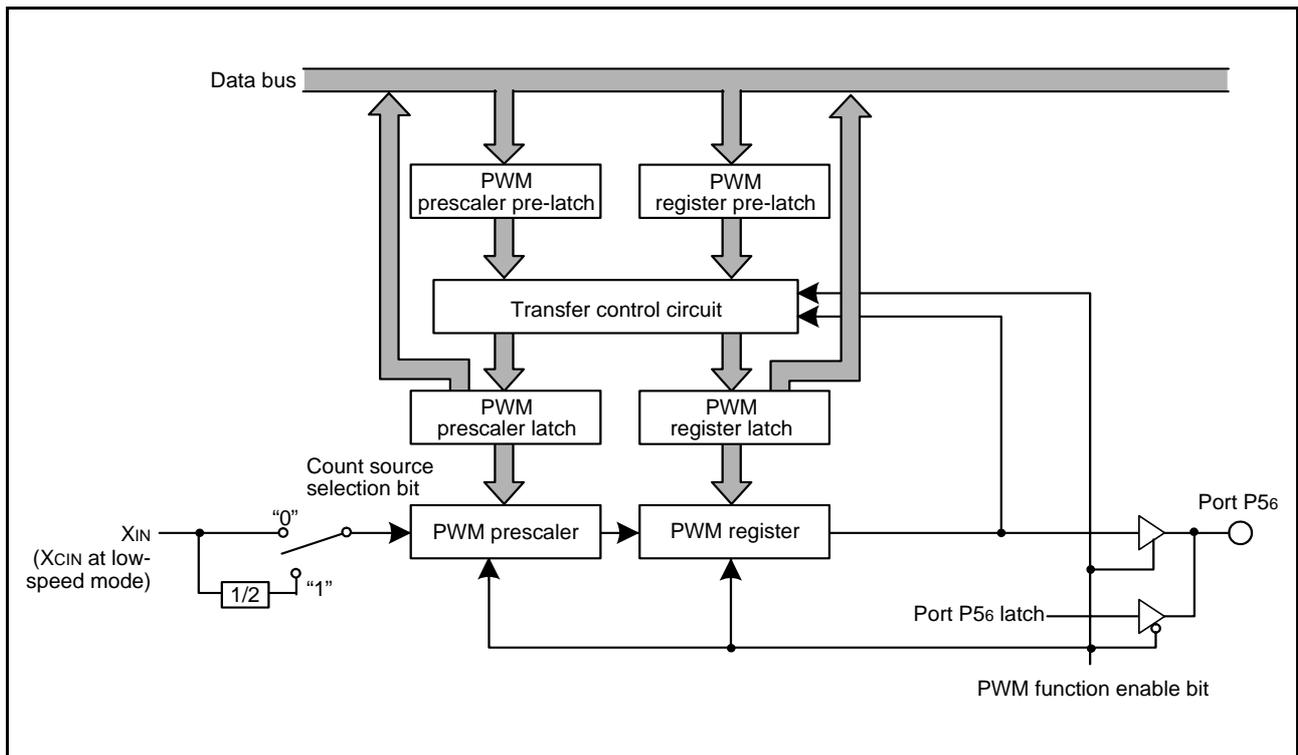


Fig 50. Block diagram of PWM function

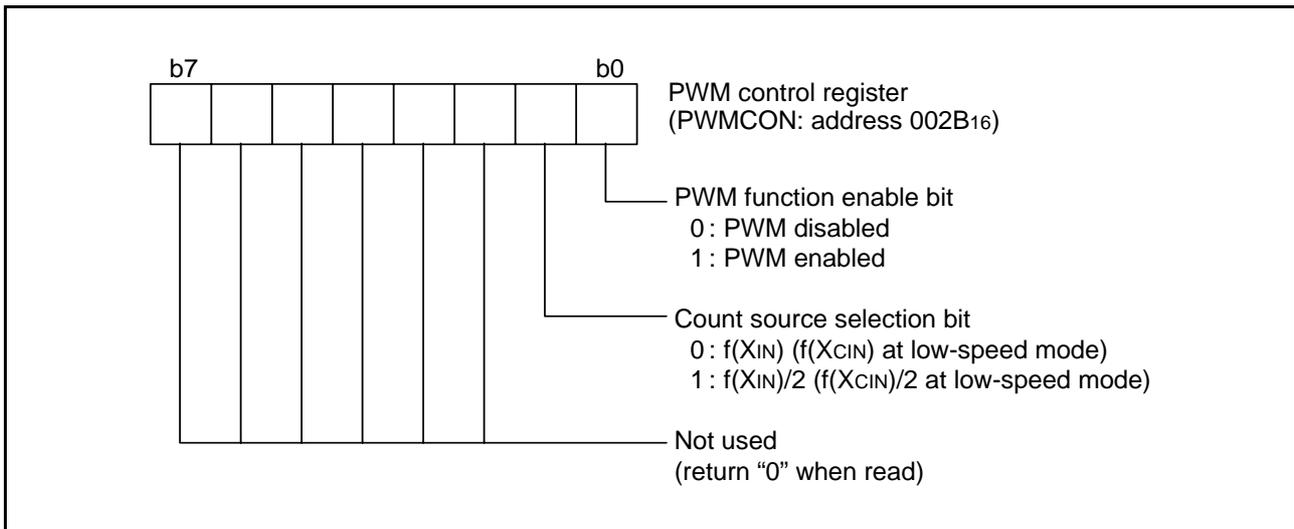


Fig 51. Structure of PWM control register

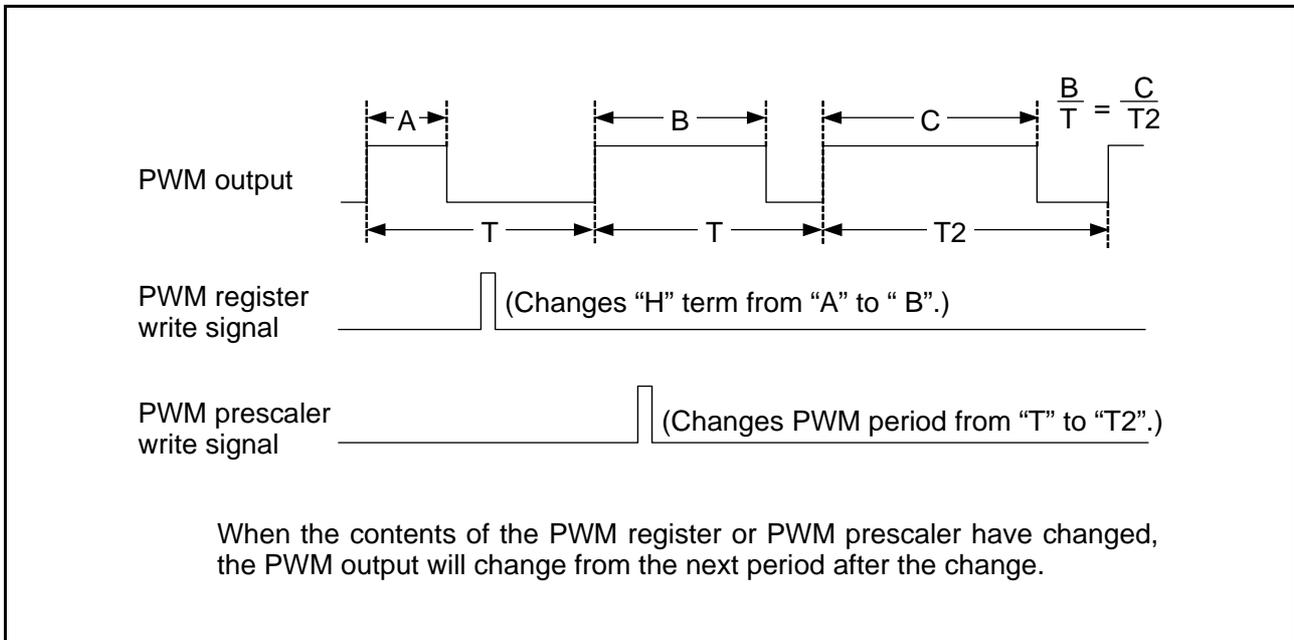


Fig 52. PWM output timing when PWM register or PWM prescaler is changed

<Notes>

The PWM starts after the PWM function enable bit is set to enable and "L" level is output from the PWM pin. The length of this "L" level output is as follows:

$$\frac{n+1}{2 \times f(X_{IN})} \text{ sec} \quad (\text{Count source selection bit} = 0, \text{ where } n \text{ is the value set in the prescaler})$$

$$\frac{n+1}{f(X_{IN})} \text{ sec} \quad (\text{Count source selection bit} = 1, \text{ where } n \text{ is the value set in the prescaler})$$

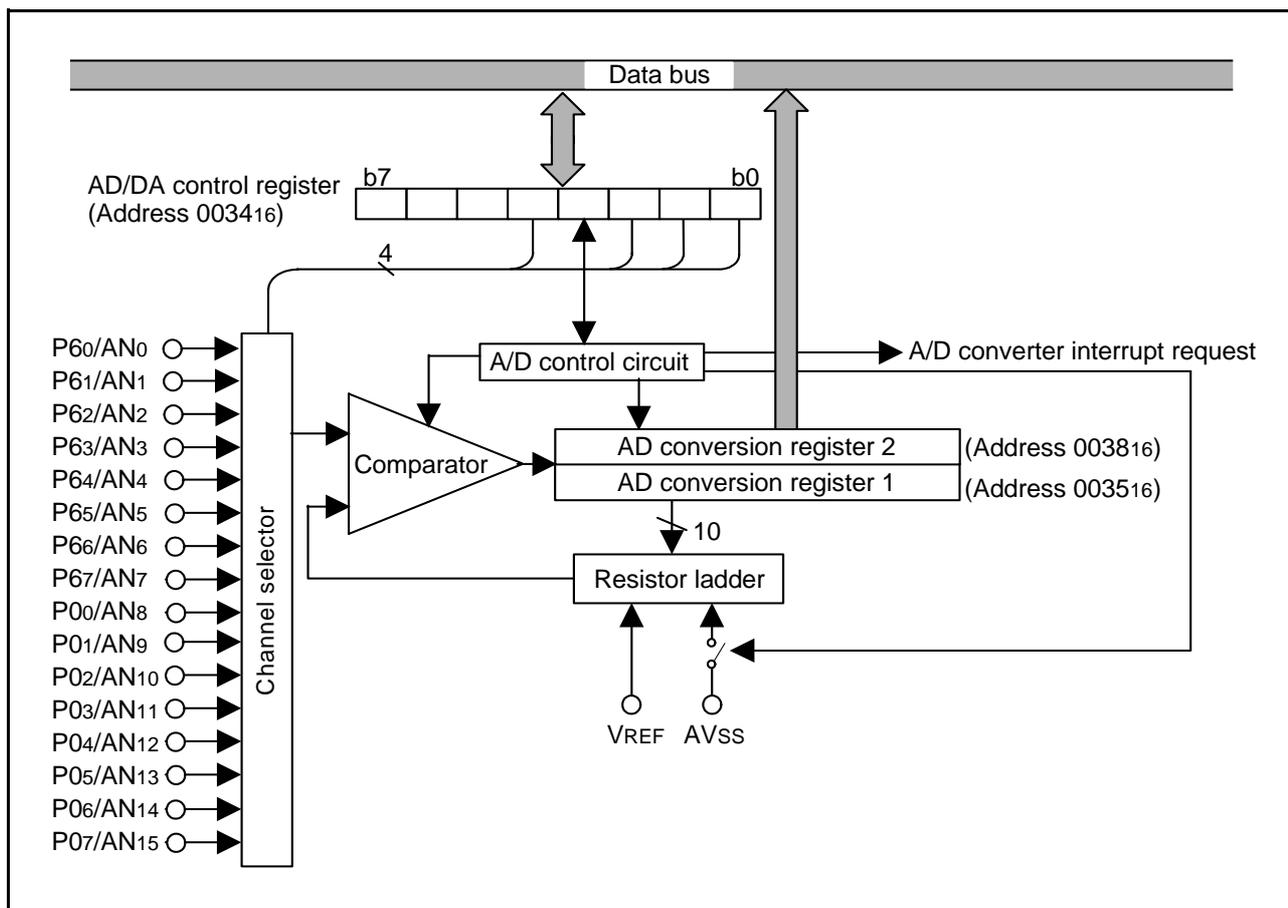


Fig 55. Block diagram of A/D converter

D/A CONVERTER

The 3803 group (Spec.L) has two internal D/A converters (DA1 and DA2) with 8-bit resolution.

The D/A conversion is performed by setting the value in each DA conversion register. The result of D/A conversion is output from the DA1 or DA2 pin by setting the DA output enable bit to "1".

When using the D/A converter, the corresponding port direction register bit (P30/DA1 or P31/DA2) must be set to "0" (input status).

The output analog voltage V is determined by the value n (decimal notation) in the DA conversion register as follows:

$$V = V_{REF} \times n/256 \quad (n = 0 \text{ to } 255)$$

Where VREF is the reference voltage.

At reset, the DA conversion registers are cleared to "0016", and the DA output enable bits are cleared to "0", and the P30/DA1 and P31/DA2 pins become high impedance.

The DA output does not have buffers. Accordingly, connect an external buffer when driving a low-impedance load.

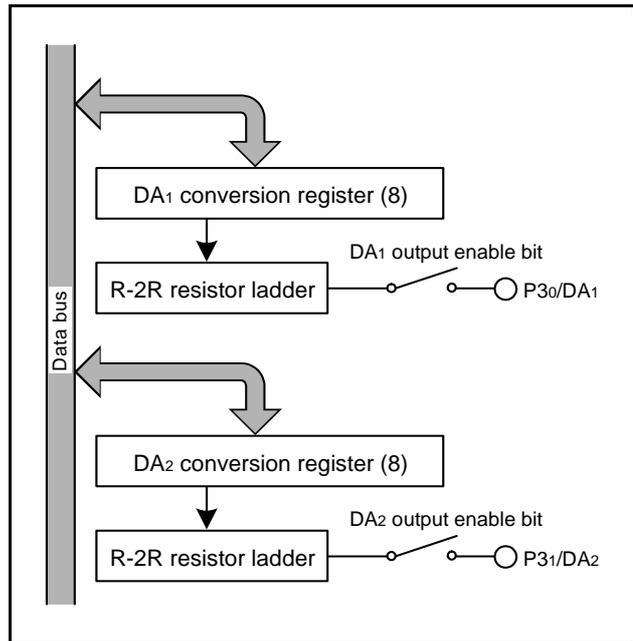


Fig 56. Block diagram of D/A converter

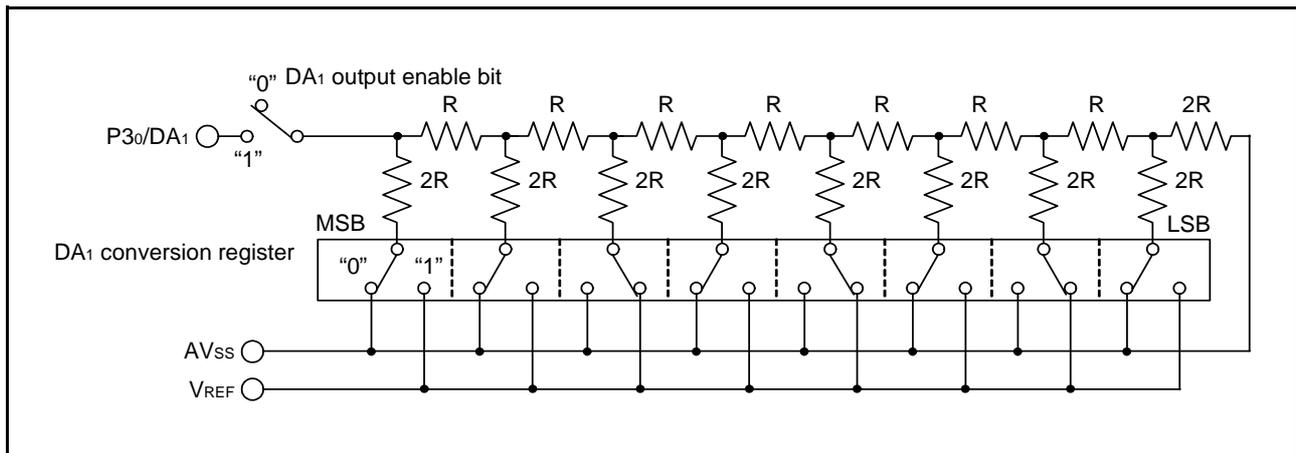


Fig 57. Equivalent connection circuit of D/A converter (DA1)

WATCHDOG TIMER

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

• Watchdog Timer Initial Value

Watchdog timer L is set to “FF16” and watchdog timer H is set to “FF16” by writing to the watchdog timer control register (address 001E16) or at a reset. Any write instruction that causes a write signal can be used, such as the STA, LDM, CLB, etc. Data can only be written to bits 6 and 7 of the watchdog timer control register. Regardless of the value written to bits 0 to 5, the above-mentioned value will be set to each timer.

Bit 6 can be written only once after releasing reset. After rewriting it is disable to write any data to this bit.

• Watchdog Timer Operations

The watchdog timer stops at reset and starts to count down by writing to the watchdog timer control register (address 001E16). An internal reset occurs at an underflow of the watchdog timer H. The reset is released after waiting for a reset release time and the program is processed from the reset vector address. Accordingly, programming is usually performed so that writing to the watchdog timer control register may be started before an

underflow. If writing to the watchdog timer control register is not performed once, the watchdog timer does not function.

• Bit 6 of Watchdog Timer Control Register

- When bit 6 of the watchdog timer control register is “0”, the MCU enters the stop mode by execution of STP instruction. Just after releasing the stop mode, the watchdog timer restarts counting(Note.). When executing the WIT instruction, the watchdog timer does not stop.
- When bit 6 is “1”, execution of STP instruction causes an internal reset. When this bit is set to “1” once, it cannot be rewritten to “0” by program. Bit 6 is “0” at reset.

The following shows the period between the write execution to the watchdog timer control register and the underflow of watchdog timer H.

Bit 7 of the watchdog timer control register is “0”:
 when XCIN = 32.768 kHz; 32 s
 when XIN = 16 MHz; 65.536 ms

Bit 7 of the watchdog timer control register is “1”:
 when XCIN = 32.768 kHz; 125 ms
 when XIN = 16 MHz; 256 μs

Note. The watchdog timer continues to count even while waiting for a

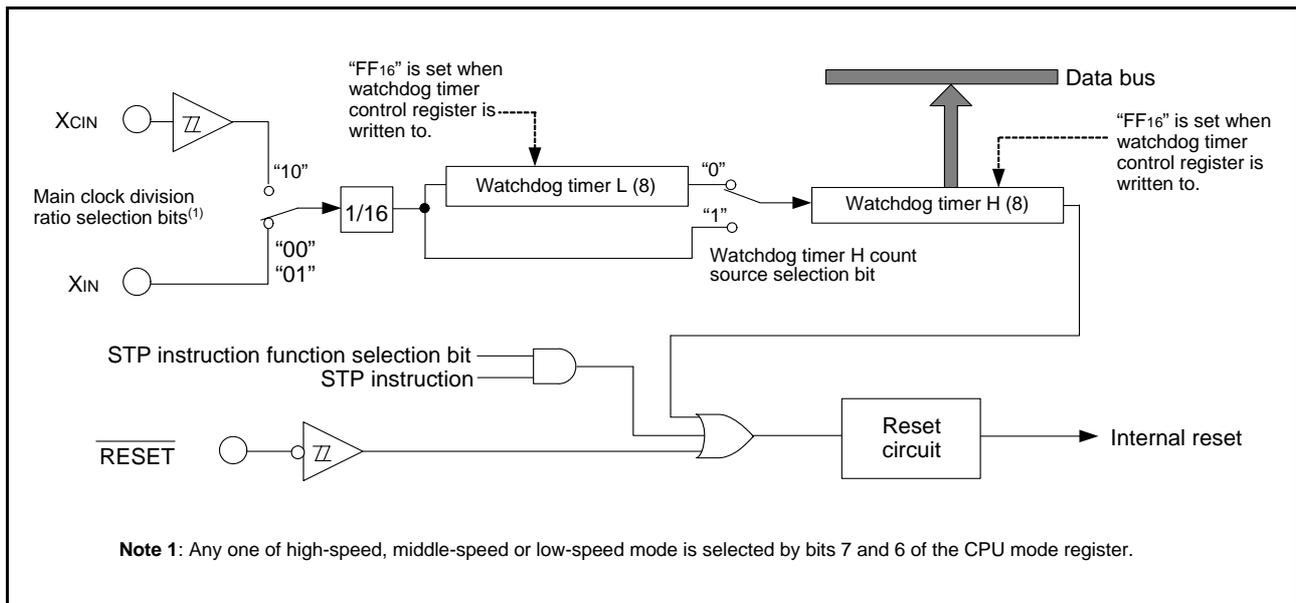


Fig 58. Block diagram of Watchdog timer

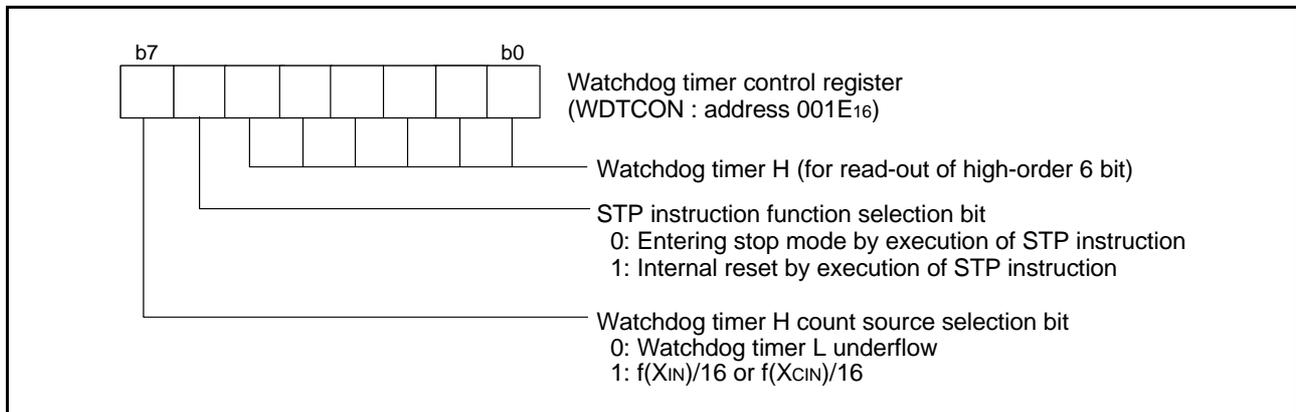


Fig 59. Structure of Watchdog timer control register

RESET CIRCUIT

To reset the microcomputer, $\overline{\text{RESET}}$ pin should be held at an “L” level for 16 cycles or more of X_{IN} . Then the $\overline{\text{RESET}}$ pin is returned to an “H” level (the power source voltage should be between 1.8 V and 5.5 V (between 2.7 V to 5.5 V for flash memory version), and the oscillation should be stable), reset is released. After the reset is completed, the program starts from the address contained in address FFFD₁₆ (high-order byte) and address FFFC₁₆ (low-order byte). Make sure that the reset input voltage for the mask ROM version is less than 0.29 V for V_{CC} of 1.8 V.

In the flash memory version, input to the $\overline{\text{RESET}}$ pin in the following procedure.

- When power source is stabilized
 - (1) Input “L” level to $\overline{\text{RESET}}$ pin.
 - (2) Input “L” level for 16 cycles or more to X_{IN} pin.
 - (3) Input “H” level to $\overline{\text{RESET}}$ pin.
- At power-on
 - (1) Input “L” level to $\overline{\text{RESET}}$ pin.
 - (2) Increase the power source voltage to 2.7 V.
 - (3) Wait for $t_d(P-R)$ until internal power source has stabilized.
 - (4) Input “L” level for 16 cycles or more to X_{IN} pin.
 - (5) Input “H” level to $\overline{\text{RESET}}$ pin.

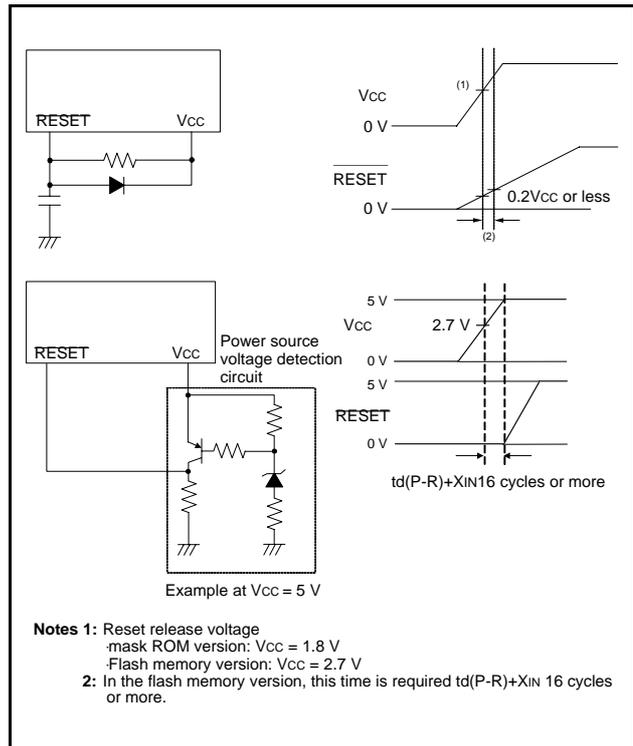


Fig 60. Reset circuit example

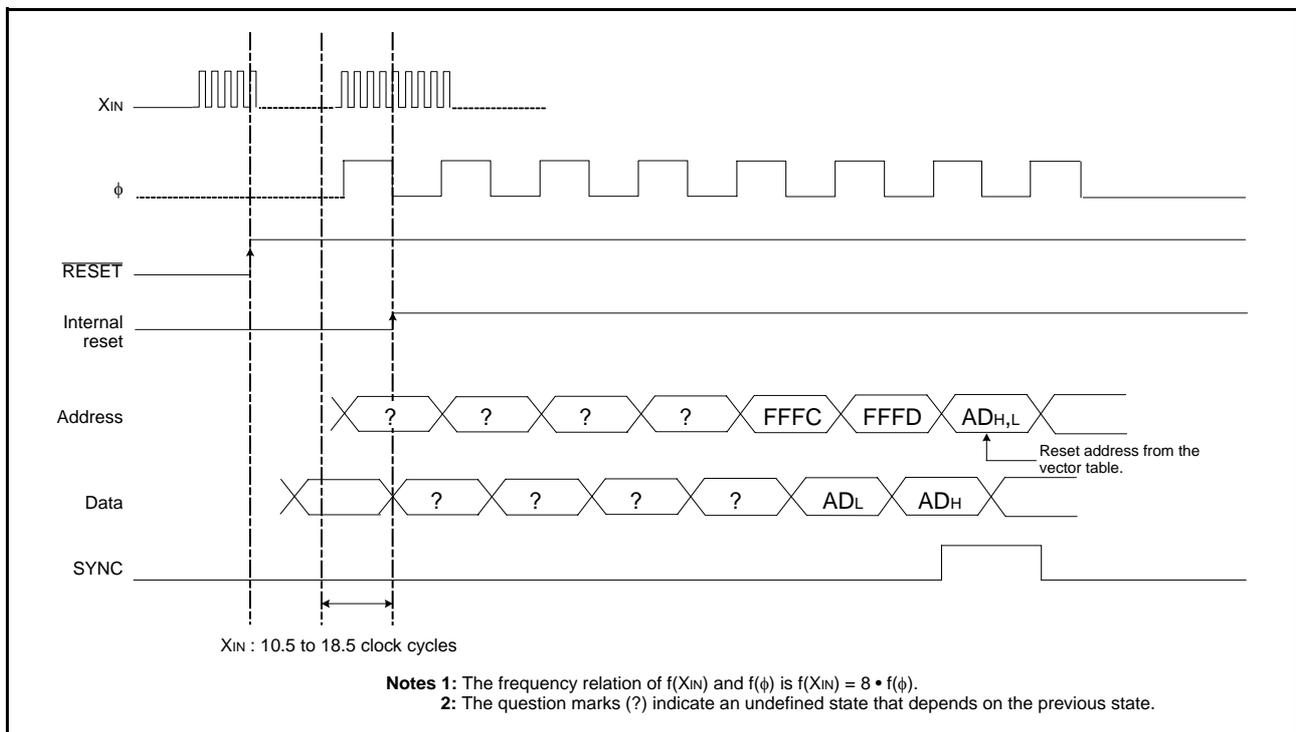


Fig 61. Reset sequence

	Address	Register contents		Address	Register contents
(1) Port P0 (P0)	0000 ₁₆	00 ₁₆	(34) Timer Z (low-order) (TZL)	0028 ₁₆	FF ₁₆
(2) Port P0 direction register (P0D)	0001 ₁₆	00 ₁₆	(35) Timer Z (high-order) (TZH)	0029 ₁₆	FF ₁₆
(3) Port P1 (P1)	0002 ₁₆	00 ₁₆	(36) Timer Z mode register (TZM)	002A ₁₆	00 ₁₆
(4) Port P1 direction register (P1D)	0003 ₁₆	00 ₁₆	(37) PWM control register (PWMCON)	002B ₁₆	00 ₁₆
(5) Port P2 (P2)	0004 ₁₆	00 ₁₆	(38) PWM prescaler (PREPWM)	002C ₁₆	X X X X X X X X
(6) Port P2 direction register (P2D)	0005 ₁₆	00 ₁₆	(39) PWM register (PWM)	002D ₁₆	X X X X X X X X
(7) Port P3 (P3)	0006 ₁₆	00 ₁₆	(40) Baud rate generator 3 (BRG3)	002F ₁₆	X X X X X X X X
(8) Port P3 direction register (P3D)	0007 ₁₆	00 ₁₆	(41) Transmit/Receive buffer register 3 (TB3/RB3)	0030 ₁₆	X X X X X X X X
(9) Port P4 (P4)	0008 ₁₆	00 ₁₆	(42) Serial I/O3 status register (SIO3STS)	0031 ₁₆	1 0 0 0 0 0 0 0
(10) Port P4 direction register (P4D)	0009 ₁₆	00 ₁₆	(43) Serial I/O3 control register (SIO3CON)	0032 ₁₆	00 ₁₆
(11) Port P5 (P5)	000A ₁₆	00 ₁₆	(44) UART3 control register (UART3CON)	0033 ₁₆	1 1 1 0 0 0 0 0
(12) Port P5 direction register (P5D)	000B ₁₆	00 ₁₆	(45) AD/DA control register (ADCON)	0034 ₁₆	0 0 0 0 0 1 0 0
(13) Port P6 (P6)	000C ₁₆	00 ₁₆	(46) AD conversion register 1 (AD1)	0035 ₁₆	X X X X X X X X
(14) Port P6 direction register (P6D)	000D ₁₆	00 ₁₆	(47) DA1 conversion register (DA1)	0036 ₁₆	00 ₁₆
(15) Timer 12, X count source selection register (T12XCSS)	000E ₁₆	0 0 1 1 0 0 1 1	(48) DA2 conversion register (DA2)	0037 ₁₆	00 ₁₆
(16) Timer Y, Z count source selection register (TYZCSS)	000F ₁₆	0 0 1 1 0 0 1 1	(49) AD conversion register 2 (AD2)	0038 ₁₆	0 0 0 0 0 0 X X
(17) MISRG	0010 ₁₆	00 ₁₆	(50) Interrupt source selection register (INTSEL)	0039 ₁₆	00 ₁₆
(18) Transmit/Receive buffer register 1 (TB1/RB1)	0018 ₁₆	X X X X X X X X	(51) Interrupt edge selection register (INTEDGE)	003A ₁₆	00 ₁₆
(19) Serial I/O1 status register (SIO1STS)	0019 ₁₆	1 0 0 0 0 0 0 0	(52) CPU mode register (CPUM)	003B ₁₆	0 1 0 0 1 0 0 0
(20) Serial I/O1 control register (SIO1CON)	001A ₁₆	00 ₁₆	(53) Interrupt request register 1 (IREQ1)	003C ₁₆	00 ₁₆
(21) UART1 control register (UART1CON)	001B ₁₆	1 1 1 0 0 0 0 0	(54) Interrupt request register 2 (IREQ2)	003D ₁₆	00 ₁₆
(22) Baud rate generator 1 (BRG1)	001C ₁₆	X X X X X X X X	(55) Interrupt control register 1 (ICON1)	003E ₁₆	00 ₁₆
(23) Serial I/O2 control register (SIO2CON)	001D ₁₆	00 ₁₆	(56) Interrupt control register 2 (ICON2)	003F ₁₆	00 ₁₆
(24) Watchdog timer control register (WDTCON)	001E ₁₆	0 0 1 1 1 1 1 1	(57) Flash memory control register 0 (FMCRO)	0FE0 ₁₆	0 0 0 0 0 0 0 1
(25) Serial I/O2 register (SIO2)	001F ₁₆	X X X X X X X X	(58) Flash memory control register 1 (FMCR1)	0FE1 ₁₆	0 1 0 0 0 0 0 0
(26) Prescaler 12 (PRE12)	0020 ₁₆	FF ₁₆	(59) Flash memory control register 2 (FMCR2)	0FE2 ₁₆	0 1 0 0 0 0 1 0
(27) Timer 1 (T1)	0021 ₁₆	01 ₁₆	(60) Port P0 pull-up control register (PULL0)	0FF0 ₁₆	00 ₁₆
(28) Timer 2 (T2)	0022 ₁₆	FF ₁₆	(61) Port P1 pull-up control register (PULL1)	0FF1 ₁₆	00 ₁₆
(29) Timer XY mode register (TM)	0023 ₁₆	00 ₁₆	(62) Port P2 pull-up control register (PULL2)	0FF2 ₁₆	00 ₁₆
(30) Prescaler X (PREX)	0024 ₁₆	FF ₁₆	(63) Port P3 pull-up control register (PULL3)	0FF3 ₁₆	00 ₁₆
(31) Timer X (TX)	0025 ₁₆	FF ₁₆	(64) Port P4 pull-up control register (PULL4)	0FF4 ₁₆	00 ₁₆
(32) Prescaler Y (PREY)	0026 ₁₆	FF ₁₆	(65) Port P5 pull-up control register (PULL5)	0FF5 ₁₆	00 ₁₆
(33) Timer Y (TY)	0027 ₁₆	FF ₁₆	(66) Port P6 pull-up control register (PULL6)	0FF6 ₁₆	00 ₁₆
			(67) Processor status register (PS)		X X X X X 1 X X
			(68) Program counter (PC _H)		FFF ₁₆ contents
				(PC _L)	FFF ₁₆ contents

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

Fig 62. Internal status at reset

CLOCK GENERATING CIRCUIT

The 3803 group (Spec.L) has two built-in oscillation circuits: main clock XIN-XOUT oscillation circuit and sub clock XCIN-XCOUT oscillation circuit. An oscillation circuit can be formed by connecting a resonator between XIN and XOUT (XCIN and XCOUT). Use the circuit constants in accordance with the resonator manufacturer's recommended values. No external resistor is needed between XIN and XOUT since a feed-back resistor exists on-chip. (An external feed-back resistor may be needed depending on conditions.) However, an external feed-back resistor is needed between XCIN and XCOUT. Immediately after power on, only the XIN oscillation circuit starts oscillating, and XCIN and XCOUT pins function as I/O ports.

• Frequency Control

(1) Middle-speed mode

The internal clock ϕ is the frequency of XIN divided by 8. After reset is released, this mode is selected.

(2) High-speed mode

The internal clock ϕ is half the frequency of XIN.

(3) Low-speed mode

The internal clock ϕ is half the frequency of XCIN.

(4) Low power dissipation mode

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

The sub-clock XCIN-XCOUT oscillating circuit can not directly input clocks that are generated externally. Accordingly, make sure to cause an external resonator to oscillate.

Oscillation Control

(1) Stop mode

If the STP instruction is executed, the internal clock ϕ stops at an "H" level, and XIN and XCIN oscillators stop. When the oscillation stabilizing time set after STP instruction released bit (bit 0 of address 001016) is "0", the prescaler 12 is set to "FF16" and timer 1 is set to "0116". When the oscillation stabilizing time set after STP instruction released bit is "1", set the sufficient time for oscillation of used oscillator to stabilize since nothing is set to the prescaler 12 and timer 1.

After STP instruction is released, the input of the prescaler 12 is connected to count source which had set at executing the STP instruction, and the output of the prescaler 12 is connected to timer 1. Oscillator restarts when an external interrupt is received, but the internal clock ϕ is not supplied to the CPU (remains at "H") until timer 1 underflows. The internal clock ϕ is supplied for the first time, when timer 1 underflows. This ensures time for the clock oscillation using the ceramic resonators to be stabilized. When the oscillator is restarted by reset, apply "L" level to the RESET pin until the oscillation is stable since a wait time will not be generated.

(2) Wait mode

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

To ensure that the interrupts will be received to release the STP or WIT state, their interrupt enable bits must be set to "1" before executing of the STP or WIT instruction.

When releasing the STP state, the prescaler 12 and timer 1 will start counting the clock XIN divided by 16. Accordingly, set the timer 1 interrupt enable bit to "0" before executing the STP instruction.

<Notes>

- If you switch the mode between middle/high-speed and low-speed, stabilize both XIN and XCIN oscillations. The sufficient time is required for the sub clock to stabilize, especially immediately after power on and at returning from stop mode. When switching the mode between middle/high-speed and low-speed, set the frequency on condition that $f(XIN) > 3 \times f(XCIN)$.
- When using the quartz-crystal oscillator of high frequency, such as 16 MHz etc., it may be necessary to select a specific oscillator with the specification demanded.
- When using the oscillation stabilizing time set after STP instruction released bit set to "1", evaluate time to stabilize oscillation of the used oscillator and set the value to the timer 1 and prescaler 12.

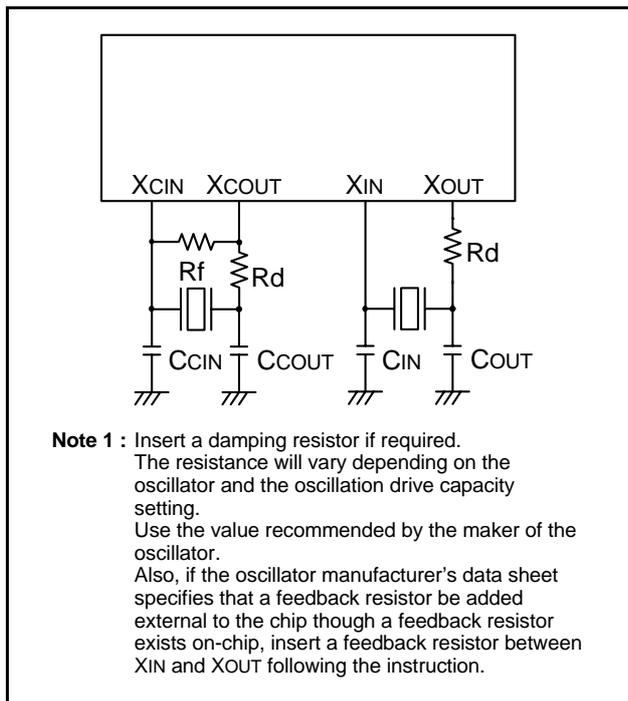


Fig 63. Ceramic resonator circuit

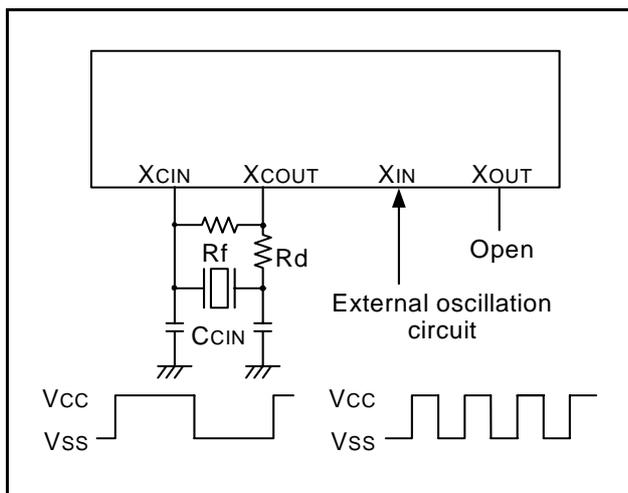


Fig 64. External clock input circuit

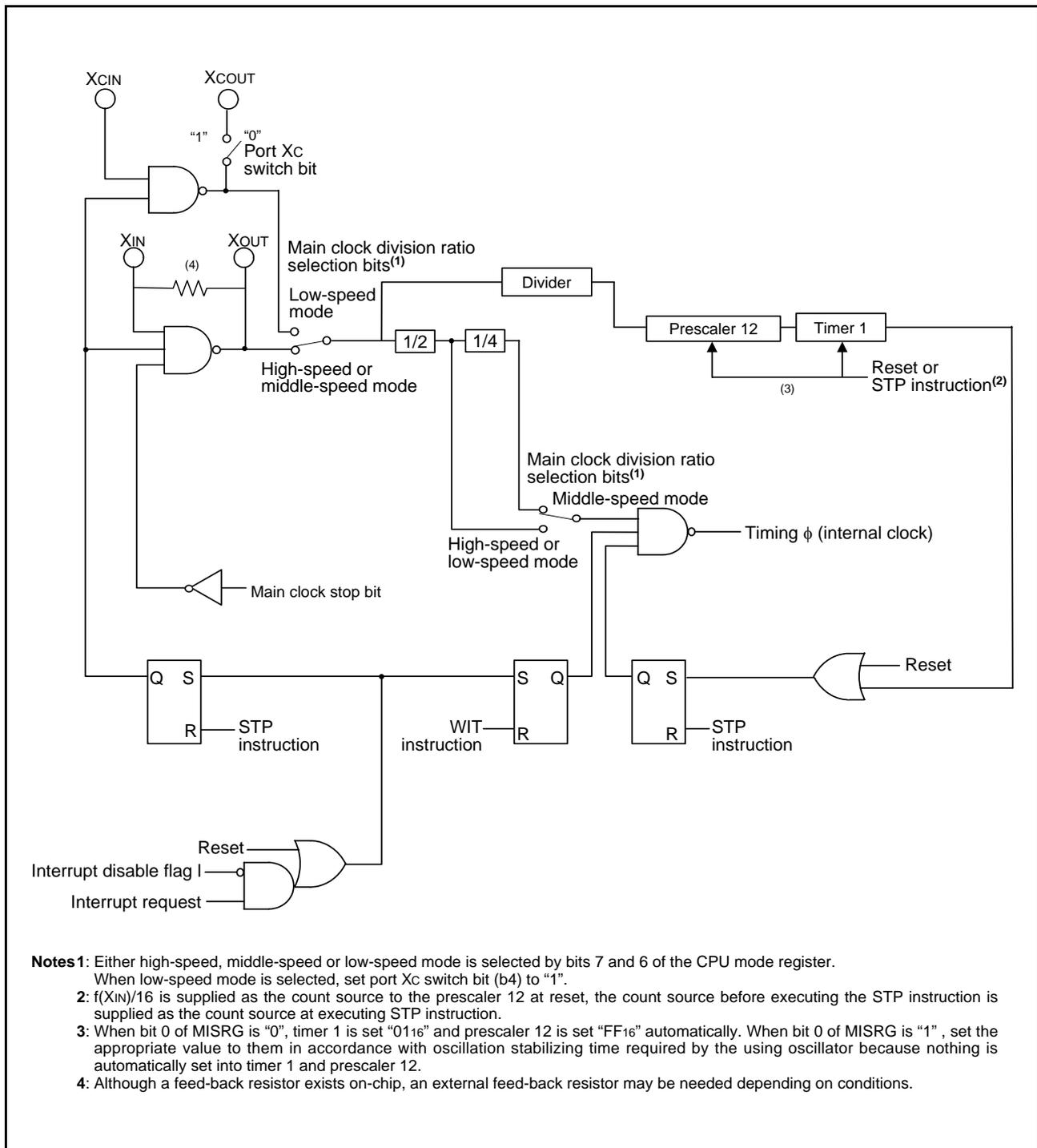


Fig 65. System clock generating circuit block diagram (Single-chip mode)

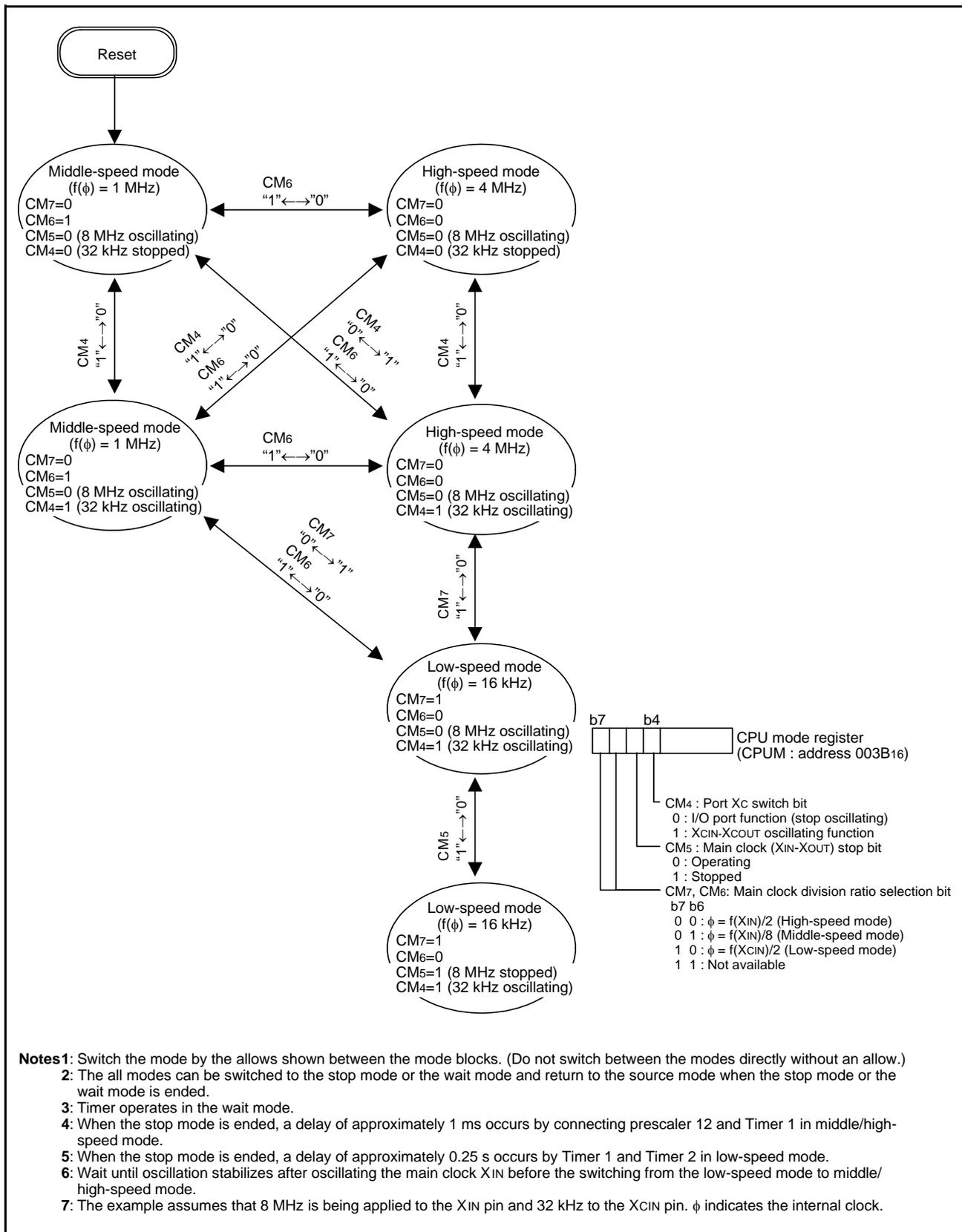


Fig 66. State transitions of system clock

FLASH MEMORY MODE

The 3803 group (Spec.L)'s flash memory version has the flash memory that can be rewritten with a single power source. For this flash memory, three flash memory modes are available in which to read, program, and erase: the parallel I/O and standard serial I/O modes in which the flash memory can be manipulated using a programmer and the CPU rewrite mode in which the flash memory can be manipulated by the Central Processing Unit (CPU).

This flash memory version has some blocks on the flash memory as shown in Figure 67 and each block can be erased.

In addition to the ordinary User ROM area to store the MCU operation control program, the flash memory has a Boot ROM area that is used to store a program to control rewriting in CPU rewrite and standard serial I/O modes. This Boot ROM area has had a standard serial I/O mode control program stored in it when shipped from the factory. However, the user can write a rewrite control program in this area that suits the user's application system. This Boot ROM area can be rewritten in only parallel I/O mode.

Summary

Table 9 lists the summary of the 3803 group (Spec.L) flash memory version.

Table 9 Summary of 3803 group (Spec.L)'s flash memory version

Item		Specifications
Power source voltage (VCC)		VCC = 2.7 to 5.5 V
Program/Erase VPP voltage (VPP)		VCC = 2.7 to 5.5 V
Flash memory mode		3 modes; Parallel I/O mode, Standard serial I/O mode, CPU rewrite mode
Erase block division	User ROM area/Data ROM area	Refer to Figure 67.
	Boot ROM area (1)	Not divided (4 Kbytes)
Program method		In units of bytes
Erase method		Block erase
Program/Erase control method		Program/Erase control by software command
Number of commands		5 commands
Number of program/Erase times		100(Max.)
ROM code protection		Available in parallel I/O mode and standard serial I/O mode

NOTE:

1. The Boot ROM area has had a standard serial I/O mode control program stored in it when shipped from the factory. This Boot ROM area can be erased and written in only parallel I/O mode.

Table 10 Electrical characteristics of flash memory (program ROM)

Symbol	Parameter	Test conditions	Limits			Unit	
			Min.	Typ.	Max.		
–	Byte programming time	VCC = 5.0 V, Topr = 25 °C	–	60	400	μs	
–	Block erase time	VCC = 5.0 V, Topr = 25 °C	(Block 1)	–	0.5	9	s
			(Block 2)	–	0.9	9	s
			(Block 3)	–	1.3	9	s
			(Block A, B)	–	0.3	9	s

NOTES:

1. VCC = AVCC = 2.7 V to 5.5 V, Topr = 0 °C to 60 °C, unless otherwise noted.
2. Definition of programming/erase count
The programming/erase count refers to the number of erase operations per block. For example, if block A is a 2 Kbyte block and 2,048 1-byte writes are performed, all to different addresses, after which block A is erased, the programming/erase count is 1. Note that for each erase operation it is not possible to perform more than one programming (write) operation to the same address (overwrites prohibited).
3. This is the number of times for which all electrical characteristics are guaranteed after a programming or erase operation. (The guarantee covers the range from 1 to maximum value.)
4. On systems where reprogramming is performed a large number of times, it is possible to reduce the effective number of overwrites by sequentially shifting the write address, so that as much of the available area of the block is used up through successive programming (write) operations before an erase operation is performed. For example, if each programming operation uses 16 bytes of space, a maximum of 128 programming operations may be performed before it becomes necessary to erase the block in order to continue. In this way the effective number of overwrites can be kept low. The effective overwrite count can be further reduced by evenly dividing operations between block A and block B. It is recommended that data be retained on the number of times each block has been erased and a limit count set.
5. If a block erase error occurs, execute the clear status register command followed by the block erase command a minimum of three times and until the erase error is no longer generated.

Boot Mode

The control program for CPU rewrite mode must be written into the User ROM or Boot ROM area in parallel I/O mode beforehand. (If the control program is written into the Boot ROM area, the standard serial I/O mode becomes unusable.) See Figure 67 for details about the Boot ROM area.

Normal microcomputer mode is entered when the microcomputer is reset with pulling CNVss pin low. In this case, the CPU starts operating using the control program in the User ROM area.

When the microcomputer is reset and the CNVss pin high after pulling the P45/TxD1 pin and CNVss pin high, the CPU starts operating (start address of program is stored into addresses FFFC16 and FFFD16) using the control program in the Boot ROM area. This mode is called the "Boot mode". Also, User ROM area can be rewritten using the control program in the Boot ROM area.

Block Address

Block addresses refer to the maximum address of each block. These addresses are used in the block erase command.

CPU Rewrite Mode

In CPU rewrite mode, the internal flash memory can be operated on (read, program, or erase) under control of the Central Processing Unit (CPU).

In CPU rewrite mode, only the User ROM area shown in Figure 67 can be rewritten; the Boot ROM area cannot be rewritten. Make sure the program and block erase commands are issued for only the User ROM area and each block area.

The control program for CPU rewrite mode can be stored in either User ROM or Boot ROM area. In the CPU rewrite mode, because the flash memory cannot be read from the CPU, the rewrite control program must be transferred to internal RAM area before it can be executed.

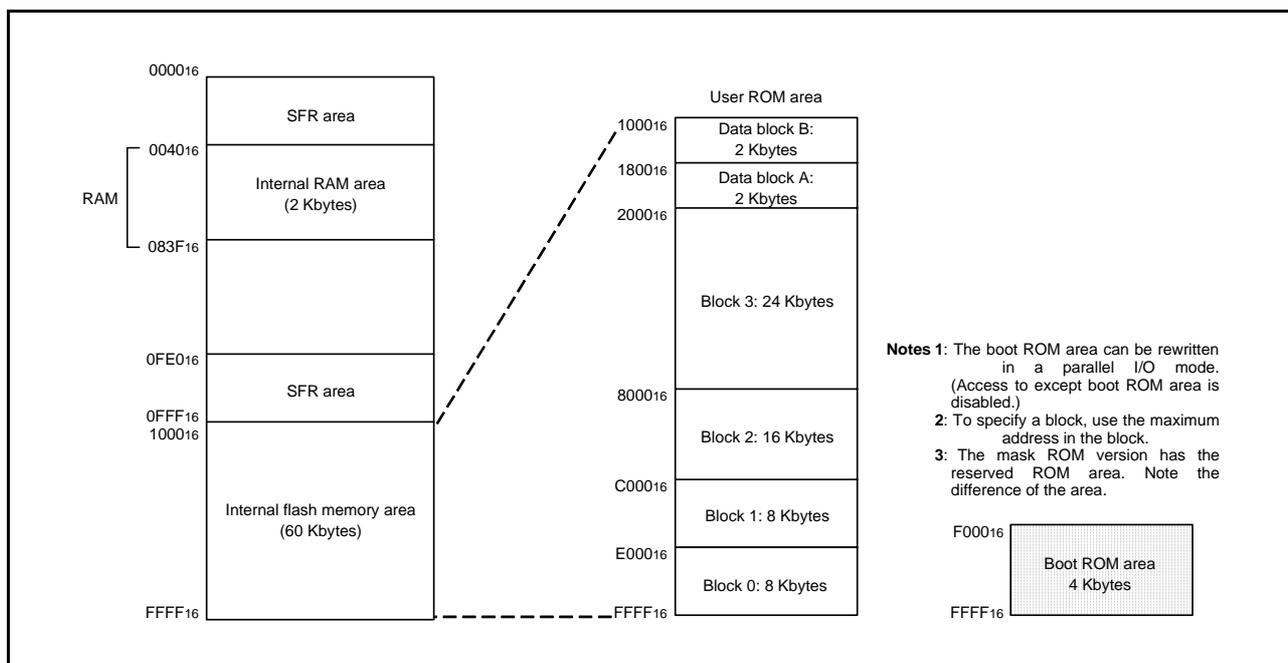


Fig 67. Block diagram of built-in flash memory

Outline Performance

CPU rewrite mode is usable in the single-chip or Boot mode. The only User ROM area can be rewritten.

In CPU rewrite mode, the CPU erases, programs and reads the internal flash memory as instructed by software commands. This rewrite control program must be transferred to internal RAM area before it can be executed.

The MCU enters CPU rewrite mode by setting "1" to the CPU rewrite mode select bit (bit 1 of address 0FE016). Then, software commands can be accepted.

Use software commands to control program and erase operations. Whether a program or erase operation has terminated normally or in error can be verified by reading the status register. Figure 68 shows the flash memory control register 0.

Bit 0 of the flash memory control register 0 is the RY/BY status flag used exclusively to read the operating status of the flash memory. During programming and erase operations, it is "0" (busy). Otherwise, it is "1" (ready).

Bit 1 of the flash memory control register 0 is the CPU rewrite mode select bit. When this bit is set to "1", the MCU enters CPU rewrite mode. And then, software commands can be accepted. In CPU rewrite mode, the CPU becomes unable to access the internal flash memory directly. Therefore, use the control program in the internal RAM for write to bit 1. To set this bit 1 to "1", it is necessary to write "0" and then write "1" in succession to bit 1. The bit can be set to "0" by only writing "0".

Bit 2 of the flash memory control register 0 is the 8 KB user block E/W enable bit. By setting combination of bit 4 of the flash memory control register 2 and this bit as shown in Table 11, E/W is disabled to user block in the CPU rewriting mode.

Bit 3 of the flash memory control register 0 is the flash memory reset bit used to reset the control circuit of internal flash memory. This bit is used when flash memory access has failed. When the CPU rewrite mode select bit is "1", setting "1" for this bit resets the control circuit. To release the reset, it is necessary to set this bit to "0".

Bit 5 of the flash memory control register 0 is the User ROM area select bit and is valid only in the boot mode. Setting this bit to "1" in the boot mode switches an accessible area from the boot ROM area to the user ROM area. To use the CPU rewrite mode in the boot mode, set this bit to "1". To rewrite bit 5, execute the useroriginal reprogramming control software transferred to the internal RAM in advance.

Bit 6 of the flash memory control register 0 is the program status flag. This bit is set to "1" when writing to flash memory is failed. When program error occurs, the block cannot be used.

Bit 7 of the flash memory control register 0 is the erase status flag.

This bit is set to "1" when erasing flash memory is failed. When erase error occurs, the block cannot be used.

Figure 69 shows the flash memory control register 1.

Bit 0 of the flash memory control register 1 is the Erase suspend enable bit. By setting this bit to "1", the erase suspend mode to suspend erase processing temporarily when block erase command is executed can be used. In order to set this bit to "1", writing "0" and "1" in succession to bit 0. In order to set this bit to "0", write "0" only to bit 0.

Bit 1 of the flash memory control register 1 is the erase suspend request bit. By setting this bit to "1" when erase suspend enable bit is "1", the erase processing is suspended.

Bit 6 of the flash memory control register 1 is the erase suspend flag. This bit is cleared to "0" at the flash erasing.

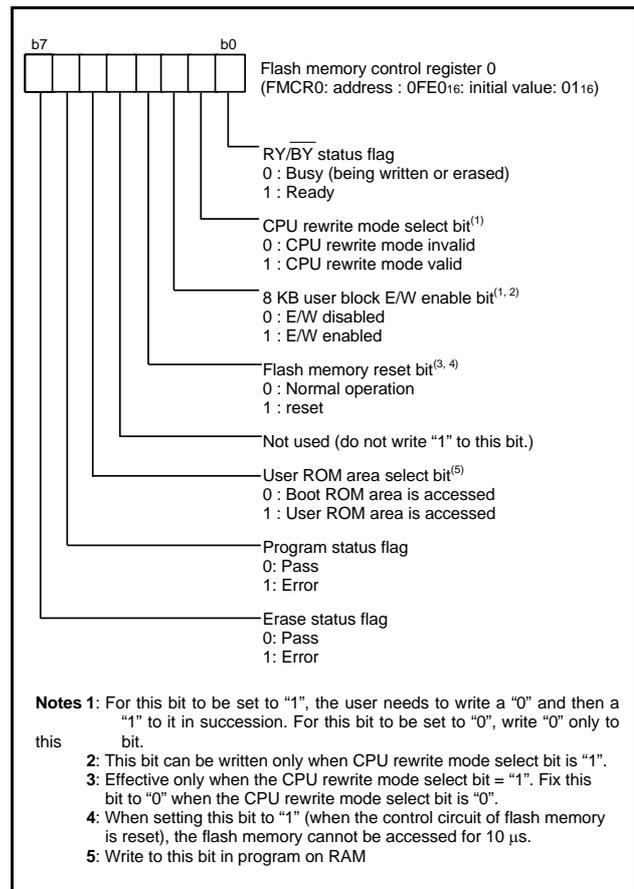


Fig 68. Structure of flash memory control register 0

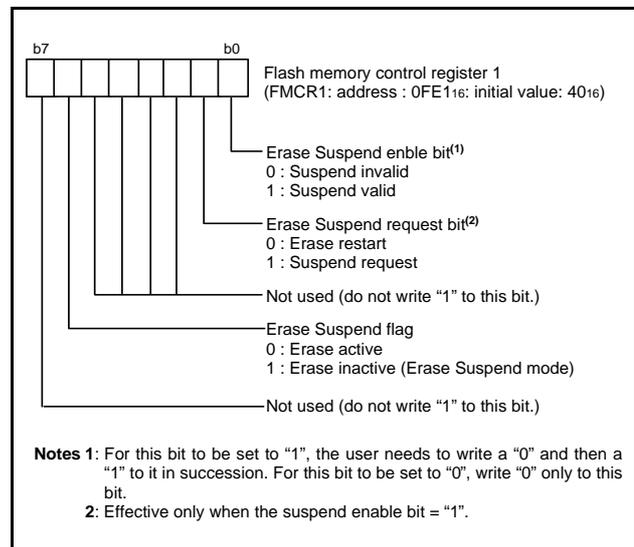


Fig 69. Structure of flash memory control register 1

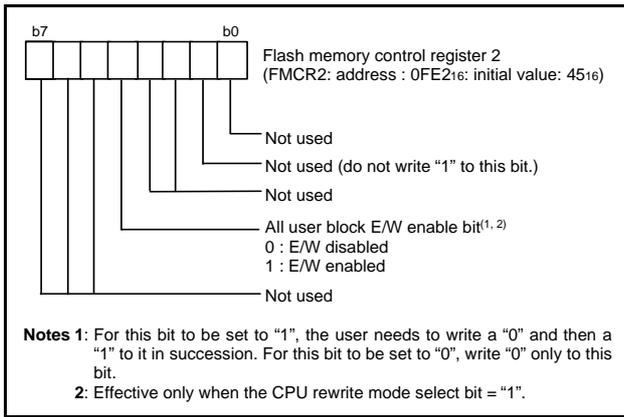


Fig 70. Structure of flash memory control register 2

Table 11 State of E/W inhibition function

All user block E/W enable bit	8 KB user block E/W enable bit	8 KB × 2 block Addresses C00016 to FFFF16	16 KB + 24 KB block Addresses 200016 to BFFF16	Data block Addresses 100016 to 1FFF16
0	0	E/W disabled	E/W disabled	E/W enabled
0	1	E/W disabled	E/W disabled	E/W enabled
1	0	E/W disabled	E/W enabled	E/W enabled
1	1	E/W enabled	E/W enabled	E/W enabled

Figure 71 shows a flowchart for setting/releasing CPU rewrite mode.

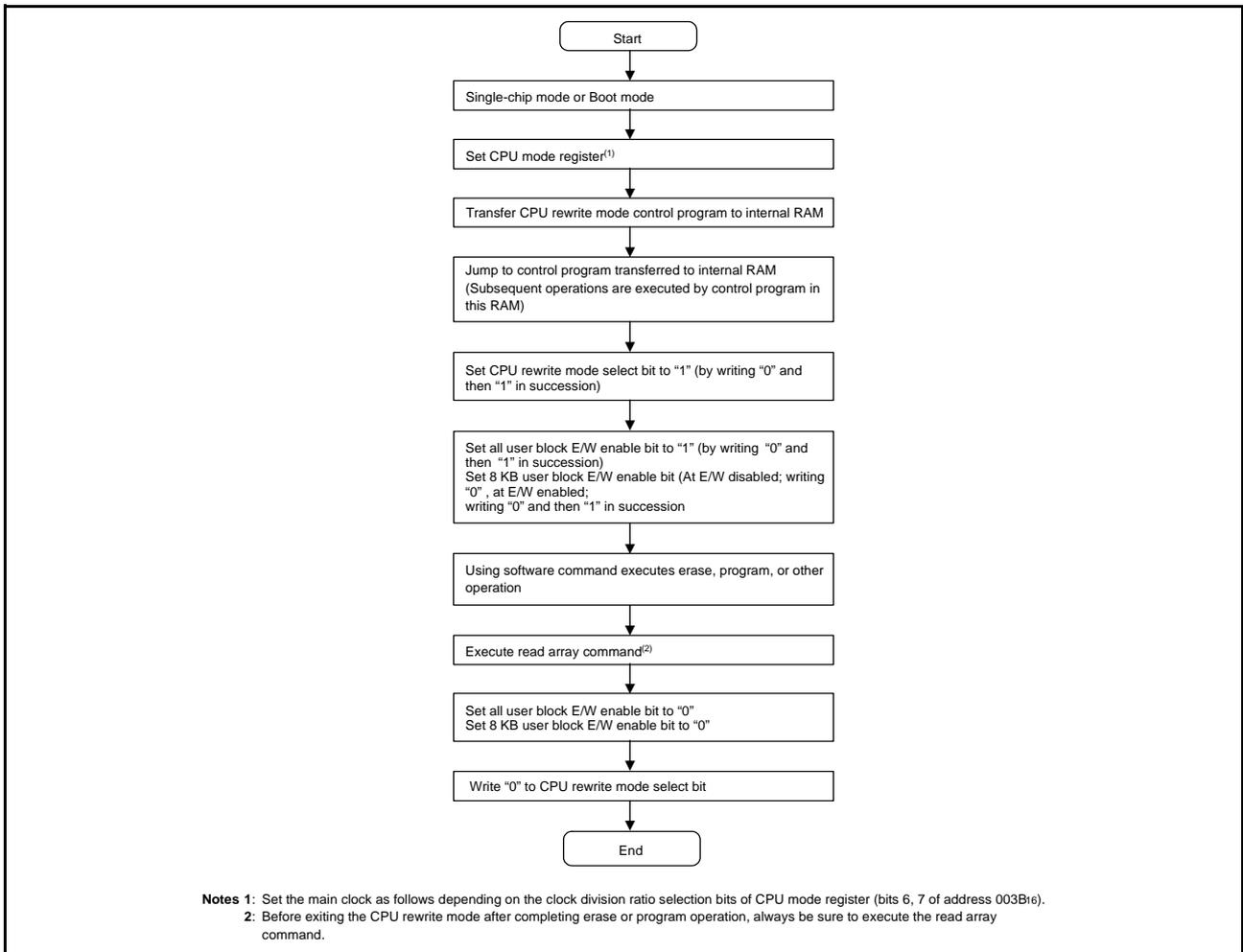


Fig 71. CPU rewrite mode set/release flowchart be sure to execute

<Notes on CPU Rewrite Mode>

Take the notes described below when rewriting the flash memory in CPU rewrite mode.

(1) Operation speed

During CPU rewrite mode, set the system clock ϕ to 4.0 MHz or less using the clock division ratio selection bits (bits 6 and 7 of address 003B16).

(2) Instructions inhibited against use

The instructions which refer to the internal data of the flash memory cannot be used during CPU rewrite mode.

(3) Interrupts

The interrupts cannot be used during CPU rewrite mode because they refer to the internal data of the flash memory.

(4) Watchdog timer

If the watchdog timer has been already activated, internal reset due to an underflow will not occur because the watchdog timer is surely cleared during program or erase.

(5) Reset

Reset is always valid. The MCU is activated using the boot mode at release of reset in the condition of CNVSS = "H", so that the program will begin at the address which is stored in addresses FFFC16 and FFFD16 of the boot ROM area.

Software Commands

Table 12 lists the software commands. After setting the CPU rewrite mode select bit to “1”, execute a software command to specify an erase or program operation. Each software command is explained below.

• Read Array Command (FF₁₆)

The read array mode is entered by writing the command code “FF₁₆” in the first bus cycle. When an address to be read is input in one of the bus cycles that follow, the contents of the specified address are read out at the data bus (D₀ to D₇). The read array mode is retained until another command is written.

• Read Status Register Command (70₁₆)

When the command code “70₁₆” is written in the first bus cycle, the contents of the status register are read out at the data bus (D₀ to D₇) by a read in the second bus cycle. The status register is explained in the next section.

• Clear Status Register Command (50₁₆)

This command is used to clear the bits SR₄ and SR₅ of the status register after they have been set. These bits indicate that operation has ended in an error. To use this command, write the command code “50₁₆” in the first bus cycle.

• Program Command (40₁₆)

Program operation starts when the command code “40₁₆” is written in the first bus cycle. Then, if the address and data to program are written in the 2nd bus cycle, program operation (data programming and verification) will start. Whether the write operation is completed can be confirmed by read status register or the RY/ $\overline{\text{BY}}$ status flag. When the program starts, the read status register mode is entered automatically and the contents of the status register is read at the data bus (D₀ to D₇). The status register bit 7 (SR₇) is set to “0” at the same time the write operation starts and is returned to “1” upon completion of the write operation. In this case, the read status register mode remains active until the read array command (FF₁₆) is written.

The RY/ $\overline{\text{BY}}$ status flag of the flash memory control register is “0” during write operation and “1” when the write operation is completed as is the status register bit 7.

At program end, program results can be checked by reading the status register.

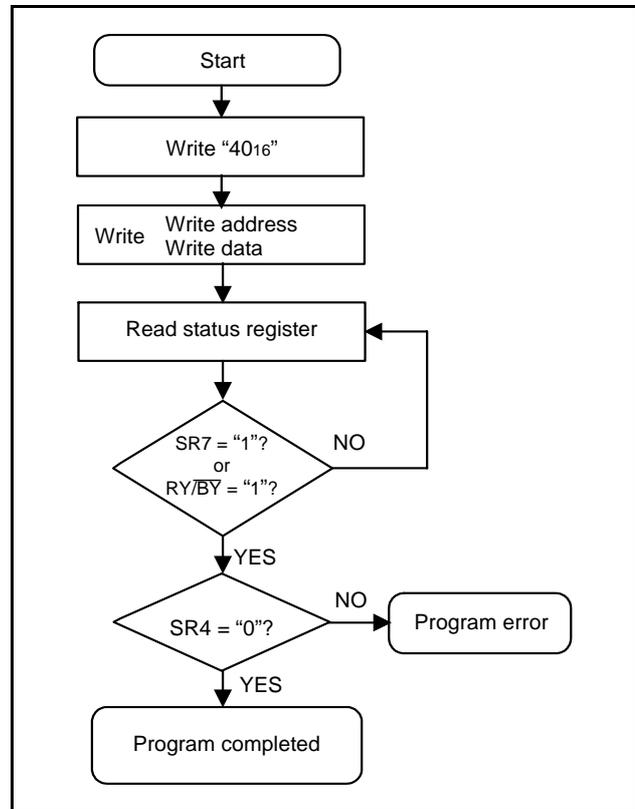


Fig 72. Program flowchart

Table 12 List of software commands (CPU rewrite mode)

Command	cycle number	First bus cycle			Second bus cycle		
		Mode	Address	Data (D ₀ to D ₇)	Mode	Address	Data (D ₀ to D ₇)
Read array	1	Write	X ⁽⁴⁾	FF ₁₆			
Read status register	2	Write	X	70 ₁₆	Read	X	SRD ⁽¹⁾
Clear status register	1	Write	X	50 ₁₆			
Program	2	Write	X	40 ₁₆	Write	WA ⁽²⁾	WD ⁽²⁾
Block erase	2	Write	X	20 ₁₆	Write	BA ⁽³⁾	D0 ₁₆

NOTES:

1. SRD = Status Register Data
2. WA = Write Address, WD = Write Data
3. BA = Block Address to be erased (Input the maximum address of each block.)
4. X denotes a given address in the User ROM area.

• Block Erase Command (20₁₆/D0₁₆)

By writing the command code "20₁₆" in the first bus cycle and the confirmation command code "D0₁₆" and the block address in the second bus cycle that follows, the block erase (erase and erase verify) operation starts for the block address of the flash memory to be specified.

Whether the block erase operation is completed can be confirmed by read status register or the RY/ $\overline{\text{BY}}$ status flag of flash memory control register. At the same time the block erase operation starts, the read status register mode is automatically entered, so that the contents of the status register can be read out. The status register

bit 7 (SR7) is set to "0" at the same time the block erase operation starts and is returned to "1" upon completion of the block erase operation. In this case, the read status register mode remains active until the read array command (FF₁₆) is written.

The RY/ $\overline{\text{BY}}$ status flag is "0" during block erase operation and "1" when the block erase operation is completed as is the status register bit 7.

After the block erase ends, erase results can be checked by reading the status register. For details, refer to the section where the status register is detailed.

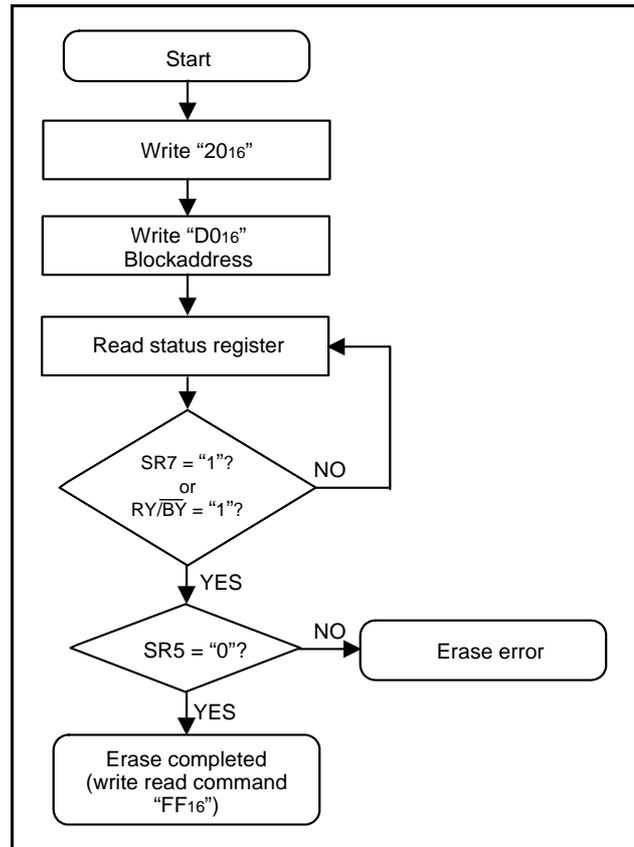


Fig 73. Erase flowchart

• Status Register

The status register shows the operating status of the flash memory and whether erase operations and programs ended successfully or in error. It can be read in the following ways:

- (1) By reading an arbitrary address from the User ROM area after writing the read status register command (70₁₆)
- (2) By reading an arbitrary address from the User ROM area in the period from when the program starts or erase operation starts to when the read array command (FF₁₆) is input.

Also, the status register can be cleared by writing the clear status register command (50₁₆).

After reset, the status register is set to “80₁₆”.

Table 13 shows the status register. Each bit in this register is explained below.

• Sequencer status (SR7)

The sequencer status indicates the operating status of the flash memory. This bit is set to “0” (busy) during write or erase operation and is set to “1” when these operations ends.

After power-on, the sequencer status is set to “1” (ready).

• Erase status (SR5)

The erase status indicates the operating status of erase operation. If an erase error occurs, it is set to “1”. When the erase status is cleared, it is reset to “0”.

• Program status (SR4)

The program status indicates the operating status of write operation.

When a write error occurs, it is set to “1”.

The program status is reset to “0” when it is cleared.

If “1” is written for any of the SR5 and SR4 bits, the read array, program, and block erase commands are not accepted. Before executing these commands, execute the clear status register command (50₁₆) and clear the status register.

Also, if any commands are not correct, both SR5 and SR4 are set to “1”.

Table 13 Definition of each bit in status register

Each bit of SRD bits	Status name	Definition	
		“1”	“0”
SR7 (bit7)	Sequencer status	Ready	Busy
SR6 (bit6)	Reserved	–	–
SR5 (bit5)	Erase status	Terminated in error	Terminated normally
SR4 (bit4)	Program status	Terminated in error	Terminated normally
SR3 (bit3)	Reserved	–	–
SR2 (bit2)	Reserved	–	–
SR1 (bit1)	Reserved	–	–
SR0 (bit0)	Reserved	–	–

Full Status Check

By performing full status check, it is possible to know the execution results of erase and program operations. Figure 74 shows a full status check flowchart and the action to be taken when each error occurs.

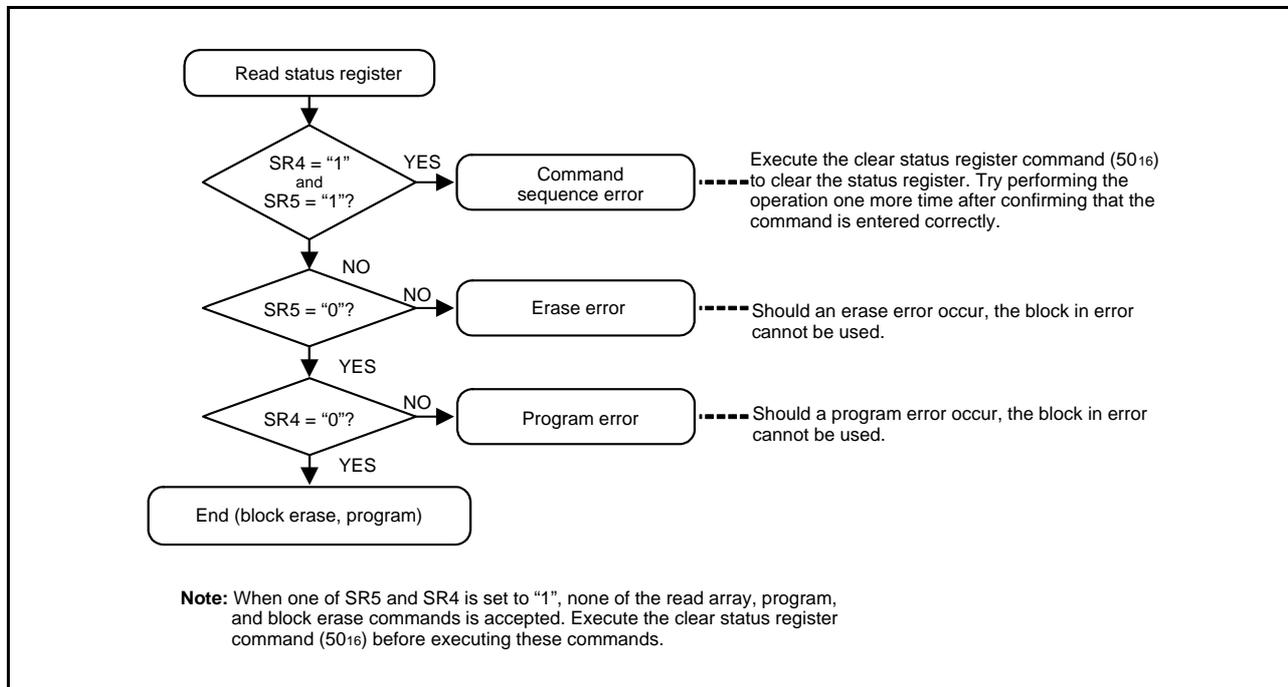


Fig 74. Full status check flowchart and remedial procedure for errors

Functions To Inhibit Rewriting Flash Memory Version

To prevent the contents of internal flash memory from being read out or rewritten easily, this MCU incorporates a ROM code protect function for use in parallel I/O mode and an ID code check function for use in standard serial I/O mode.

• ROM Code Protect Function

The ROM code protect function is the function to inhibit reading out or modifying the contents of internal flash memory by using the ROM code protect control address (address FFDB₁₆) in parallel I/O mode. Figure 75 shows the ROM code protect control address (address FFDB₁₆). (This address exists in the User ROM area.)

If one or both of the pair of ROM code protect bits is set to “0”, the ROM code protect is turned on, so that the contents of internal flash memory are protected against readout and modification. The ROM code protect is implemented in two levels. If level 2 is selected, the flash memory is protected even against readout by a shipment inspection LSI tester, etc. When an attempt is made to select both level 1 and level 2, level 2 is selected by default.

If both of the two ROM code protect reset bits are set to “00”, the ROM code protect is turned off, so that the contents of internal flash memory can be readout or modified. Once the ROM code protect is turned on, the contents of the ROM code protect reset bits cannot be modified in parallel I/O mode. Use the serial I/O or CPU rewrite mode to rewrite the contents of the ROM code protect reset bits.

Rewriting of only the ROM code protect control address (address FFDB₁₆) cannot be performed. When rewriting the ROM code protect reset bit, rewrite the whole user ROM area (block 0) containing the ROM code protect control address.

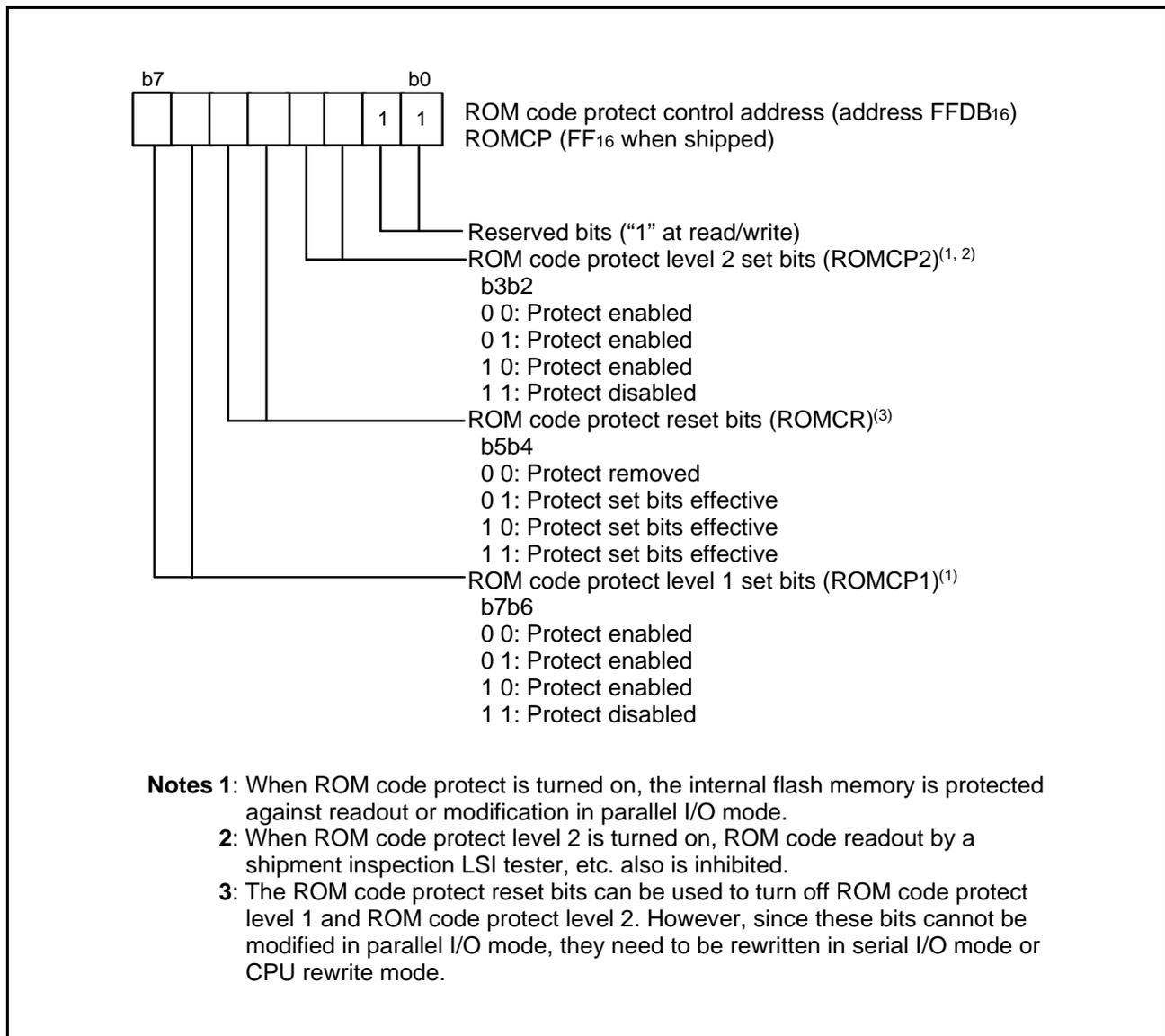


Fig 75. Structure of ROM code protect control address

• ID Code Check Function

Use this function in standard serial I/O mode. When the contents of the flash memory are not blank, the ID code sent from the programmer is compared with the ID code written in the flash memory to see if they match. If the ID codes do not match, the commands sent from the programmer are not accepted. The ID code consists of 8-bit data, and its areas are FFD4₁₆ to FFDA₁₆. Write a program which has had the ID code preset at these addresses to the flash memory.

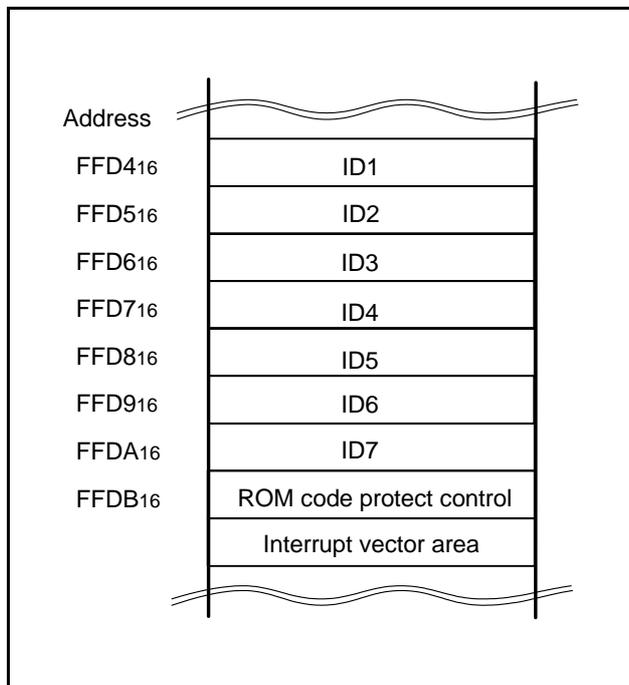


Fig 76. ID code store addresses

Parallel I/O Mode

The parallel I/O mode is used to input/output software commands, address and data in parallel for operation (read, program and erase) to internal flash memory.

Use the external device (writer) only for 3803 group (Spec.L) flash memory version. For details, refer to the user's manual of each writer manufacturer.

• User ROM and Boot ROM Areas

In parallel I/O mode, the User ROM and Boot ROM areas shown in Figure 67 can be rewritten. Both areas of flash memory can be operated on in the same way.

The Boot ROM area is 4 Kbytes in size and located at addresses F000₁₆ through FFFF₁₆. Make sure program and block erase operations are always performed within this address range. (Access to any location outside this address range is prohibited.)

In the Boot ROM area, an erase block operation is applied to only one 4 Kbyte block. The boot ROM area has had a standard serial I/O mode control program stored in it when shipped from the factory. Therefore, using the MCU in standard serial I/O mode, do not rewrite to the Boot ROM area.

Standard serial I/O Mode

The standard serial I/O mode inputs and outputs the software commands, addresses and data needed to operate (read, program, erase, etc.) the internal flash memory. This I/O is clock synchronized serial. This mode requires a purpose-specific peripheral unit.

The standard serial I/O mode is different from the parallel I/O mode in that the CPU controls flash memory rewrite (uses the CPU rewrite mode), rewrite data input and so forth. The standard serial I/O mode is started by connecting “H” to the CNVss pin and “H” to the P45 (BOOTENT) pin, and releasing the reset operation. (In the ordinary microcomputer mode, set CNVss pin to “L” level.) This control program is written in the Boot ROM area when the product is shipped from Renesas. Accordingly, make note of the fact that the standard serial I/O mode cannot be used if the Boot ROM area is rewritten in parallel I/O mode. The standard serial I/O mode has standard serial I/O mode 1 of the clock synchronous serial and standard serial I/O mode 2 of the clock asynchronous serial. Table 14 and 15 show description of pin function (standard serial I/O mode). Figure 77 to 80 show the pin connections for the standard serial I/O mode.

In standard serial I/O mode, only the User ROM area shown in Figure 67 can be rewritten. The Boot ROM area cannot be written.

In standard serial I/O mode, a 7-byte ID code is used. When there is data in the flash memory, this function determines whether the ID code sent from the peripheral unit (programmer) and those written in the flash memory match. The commands sent from the peripheral unit (programmer) are not accepted unless the ID code matches.

Table 14 Description of pin function (Flash Memory Serial I/O Mode 1)

Pin name	Signal name	I/O	Function
Vcc,Vss	Power supply	I	Apply 2.7 to 5.5 V to the Vcc pin and 0 V to the Vss pin.
CNVss	CNVss	I	After input of port is set, input "H" level.
$\overline{\text{RESET}}$	Reset input	I	Reset input pin. To reset the microcomputer, $\overline{\text{RESET}}$ pin should be held at an "L" level for 16 cycles or more of XIN.
XIN	Clock input	I	Connect an oscillation circuit between the XIN and XOUT pins.
XOUT	Clock output	O	As for the connection method, refer to the "clock generating circuit".
AVss	Analog power supply input		Connect AVss to Vss.
VREF	Reference voltage input	I	Apply reference voltage of A/D to this pin.
P00–P07, P10–P17, P20–P27, P30–P37, P40–P43, P50–P57, P60–P67	I/O port	I/O	Input "L" or "H" level, or keep open.
P44	RxD input	I	Serial data input pin.
P45	TxD output	O	Serial data output pin.
P46	SCLK input	I	Serial clock input pin.
P47	BUSY output	O	BUSY signal output pin.

Table 15 Description of pin function (Flash Memory Serial I/O Mode 2)

Pin name	Signal name	I/O	Function
Vcc,Vss	Power supply	I	Apply 2.7 to 5.5 V to the Vcc pin and 0 V to the Vss pin.
CNVss	CNVss	I	After input of port is set, input "H" level.
$\overline{\text{RESET}}$	Reset input	I	Reset input pin. To reset the microcomputer, $\overline{\text{RESET}}$ pin should be held at an "L" level for 16 cycles or more of XIN.
XIN	Clock input	I	Connect an oscillation circuit between the XIN and XOUT pins.
XOUT	Clock output	O	As for the connection method, refer to the "clock generating circuit".
AVss	Analog power supply input		Connect AVss to Vss.
VREF	Reference voltage input	I	Apply reference voltage of A/D to this pin.
P00–P07, P10–P17, P20–P27, P30–P37, P40–P43, P50–P57, P60–P67	I/O port	I/O	Input "L" or "H" level, or keep open.
P44	RxD input	I	Serial data input pin.
P45	TxD output	O	Serial data output pin.
P46	SCLK input	I	Input "L" level.
P47	BUSY output	O	BUSY signal output pin.

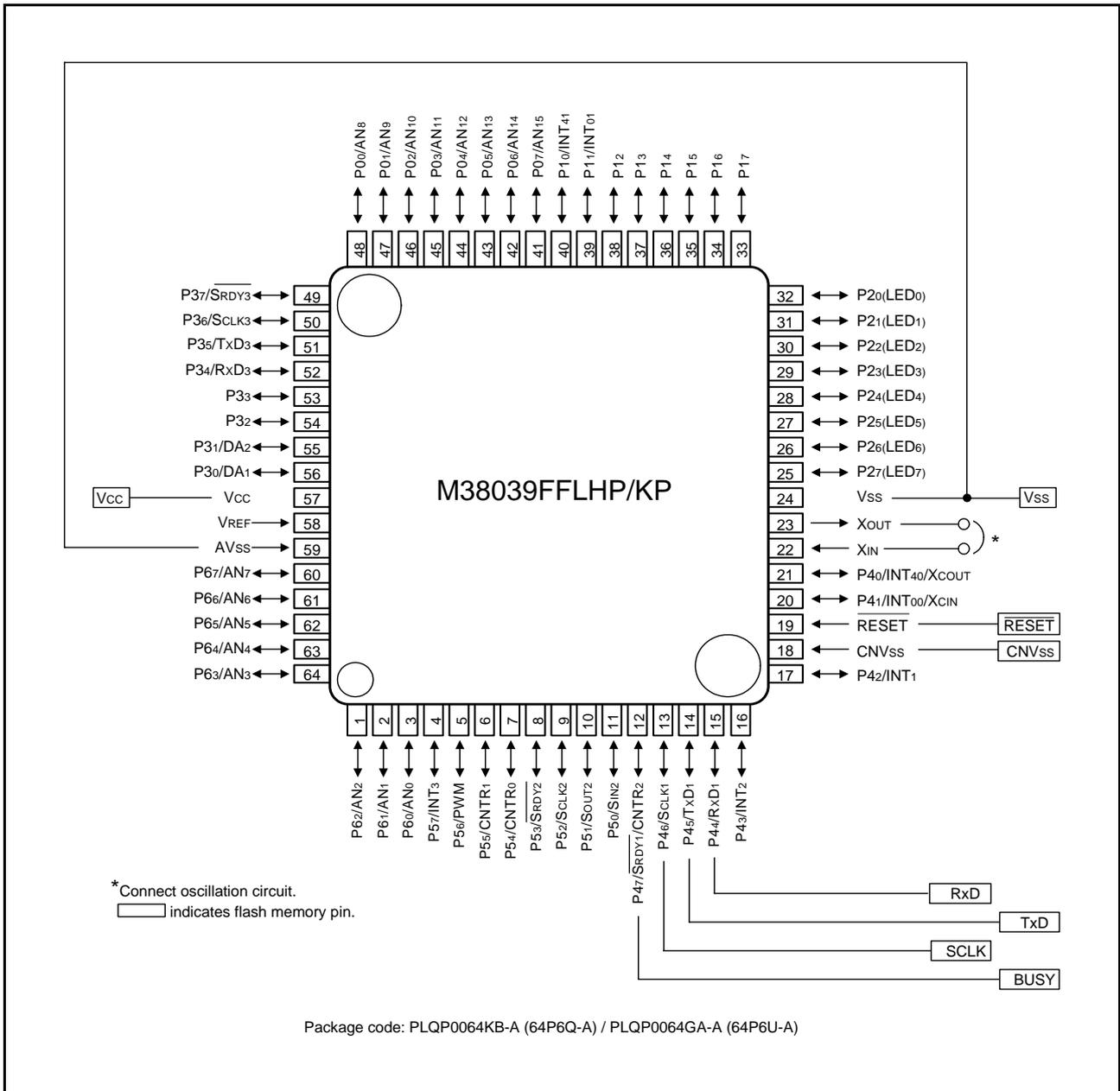


Fig 77. Connection for standard serial I/O mode 1 (M38039FFLHP/KP)

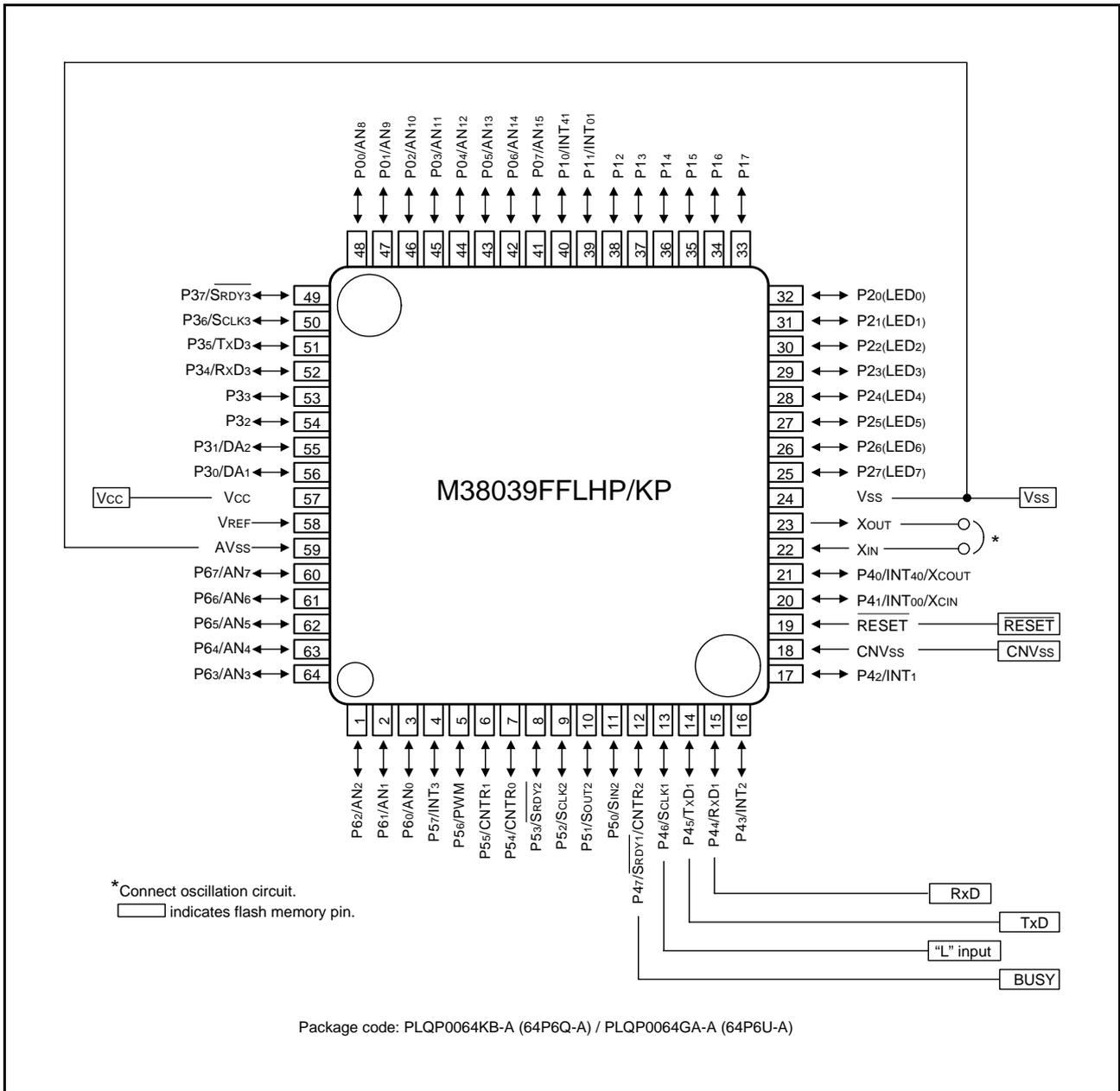


Fig 78. Connection for standard serial I/O mode 2 (M38039FFLHP/KP)

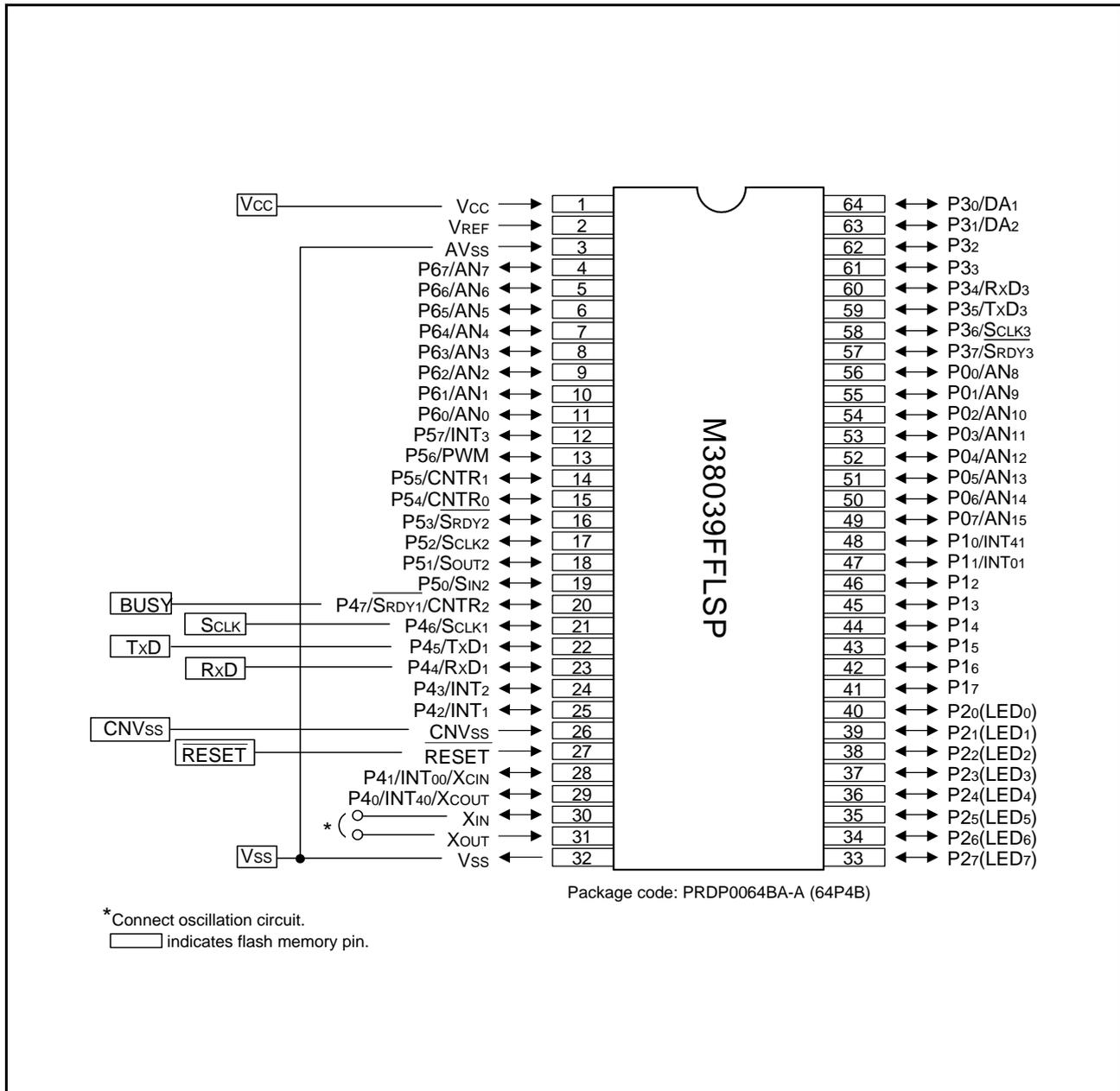


Fig 79. Connection for standard serial I/O mode 1 (M38039FFLSP)

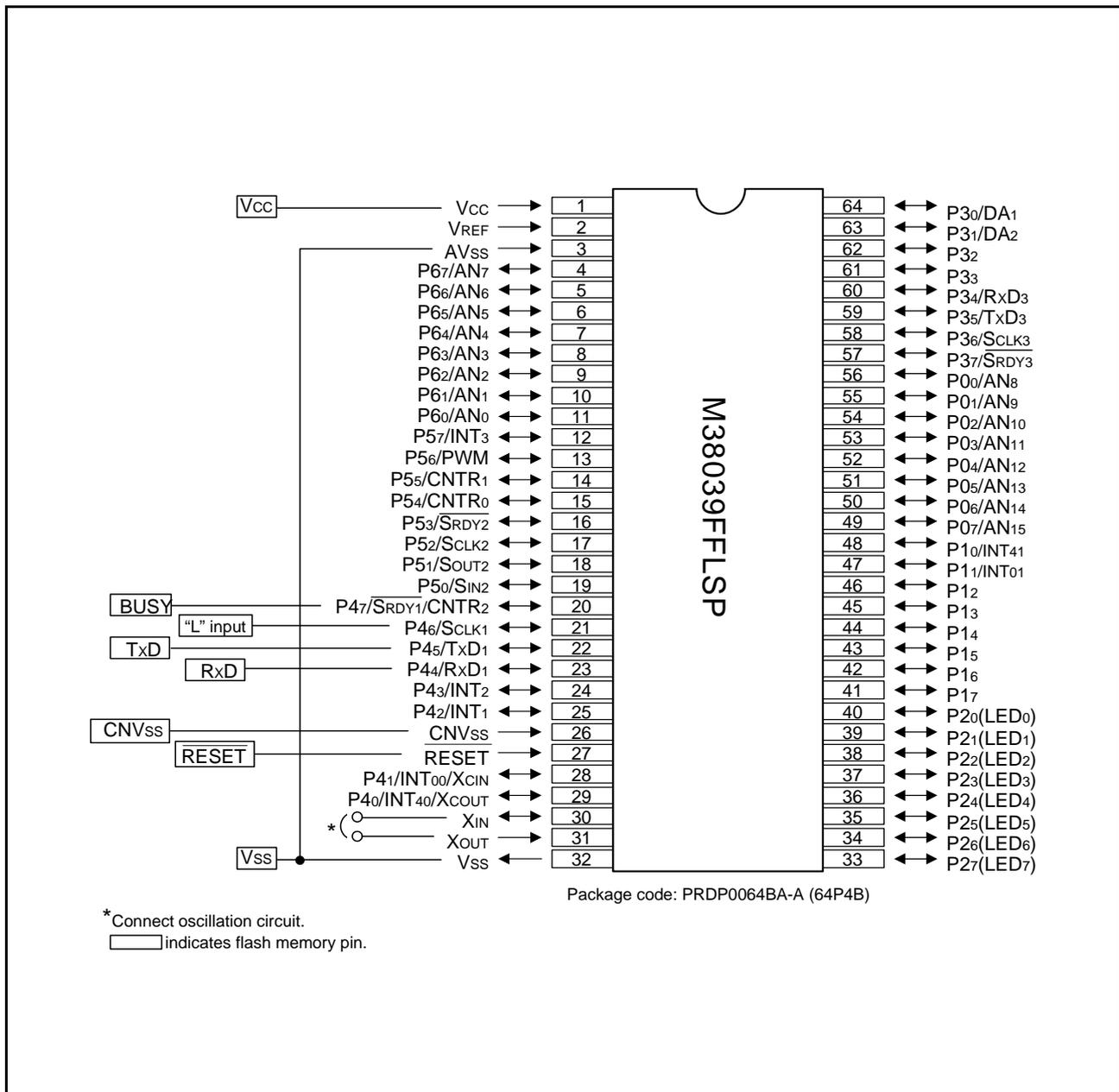


Fig 80. Connection for standard serial I/O mode 2 (M38039FFLSP)

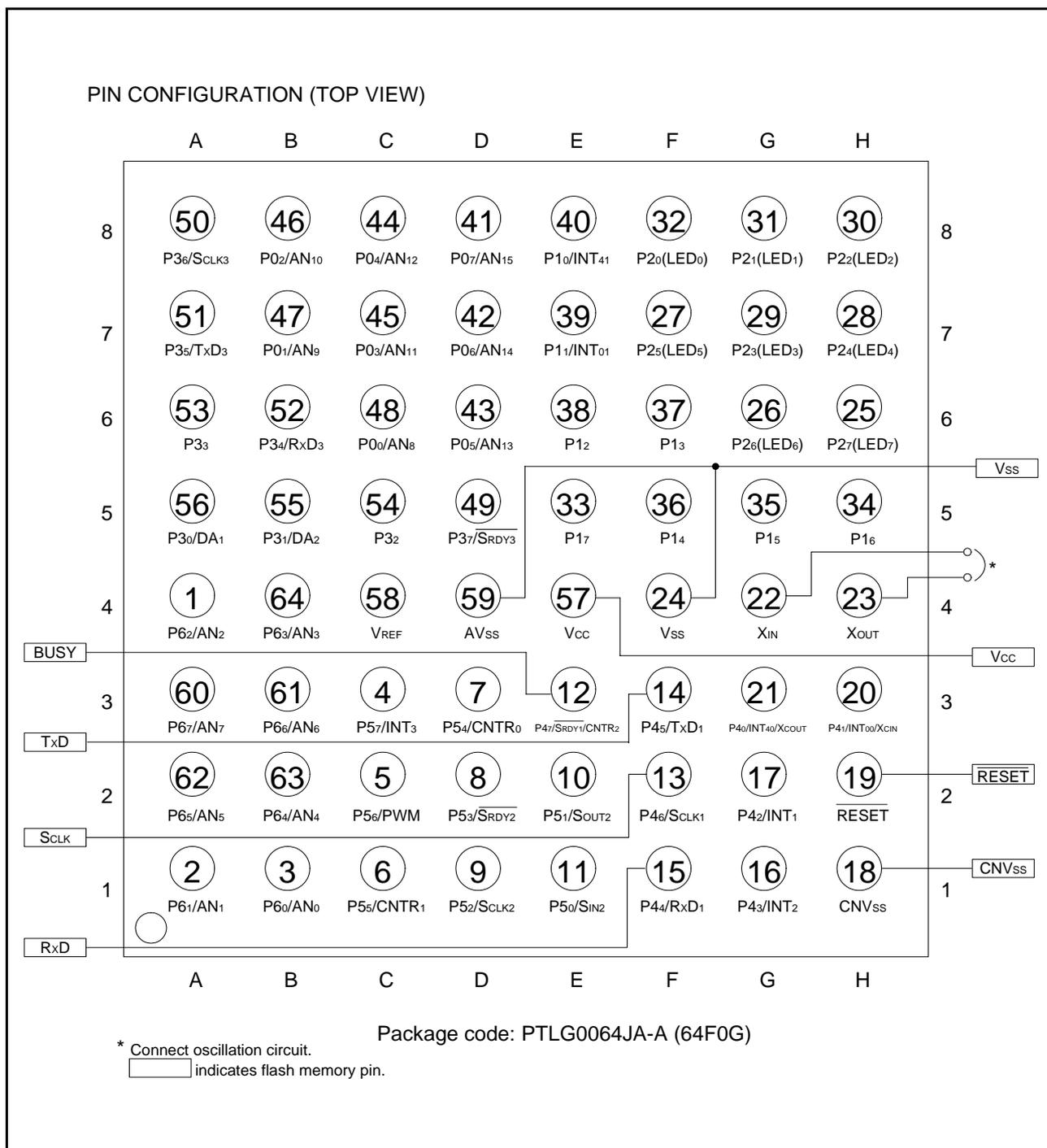


Fig 81. Connection for standard serial I/O mode 1 (M38039FLLWG)

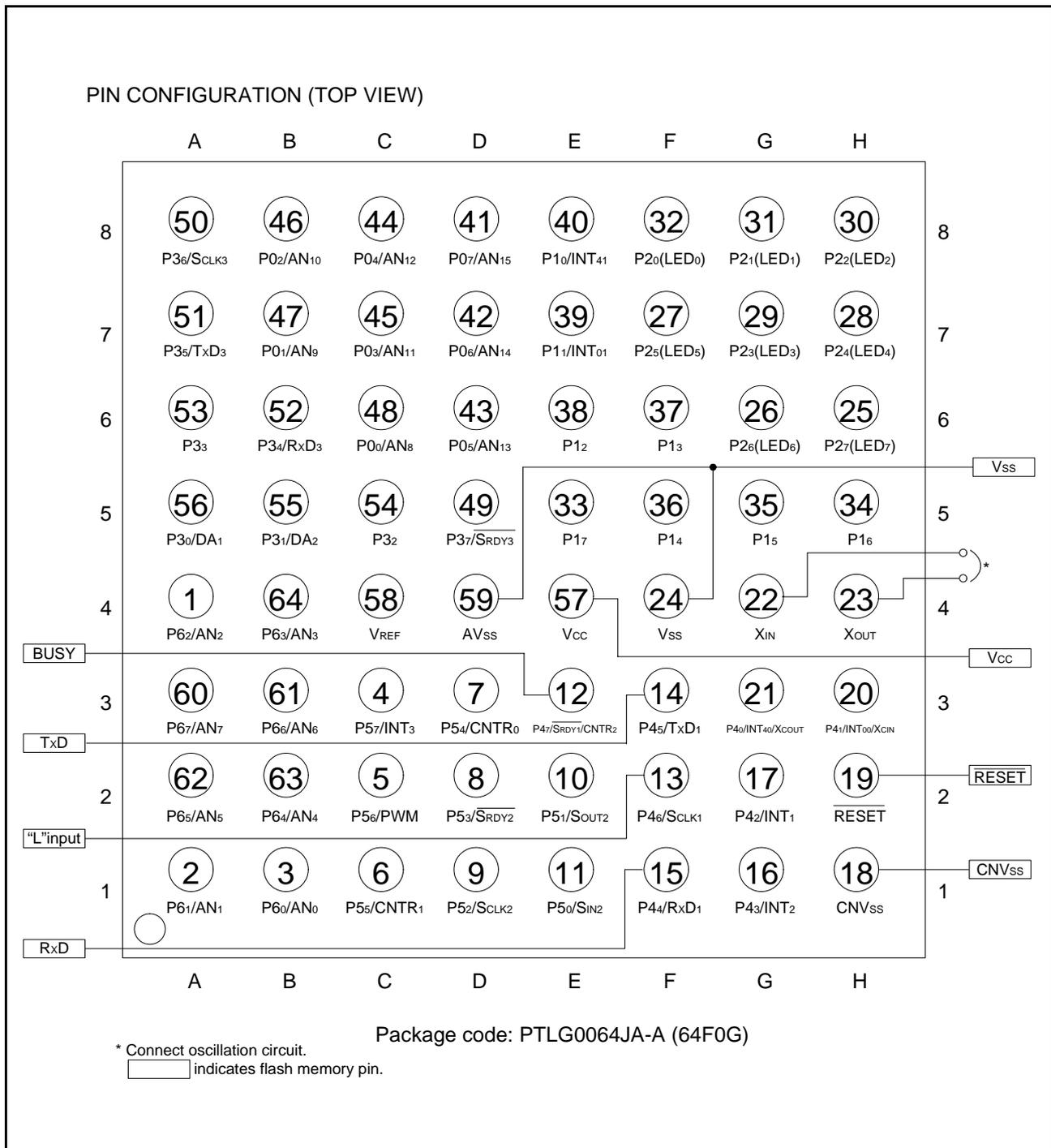


Fig 82. Connection for standard serial I/O mode 2 (M38039FFLWG)

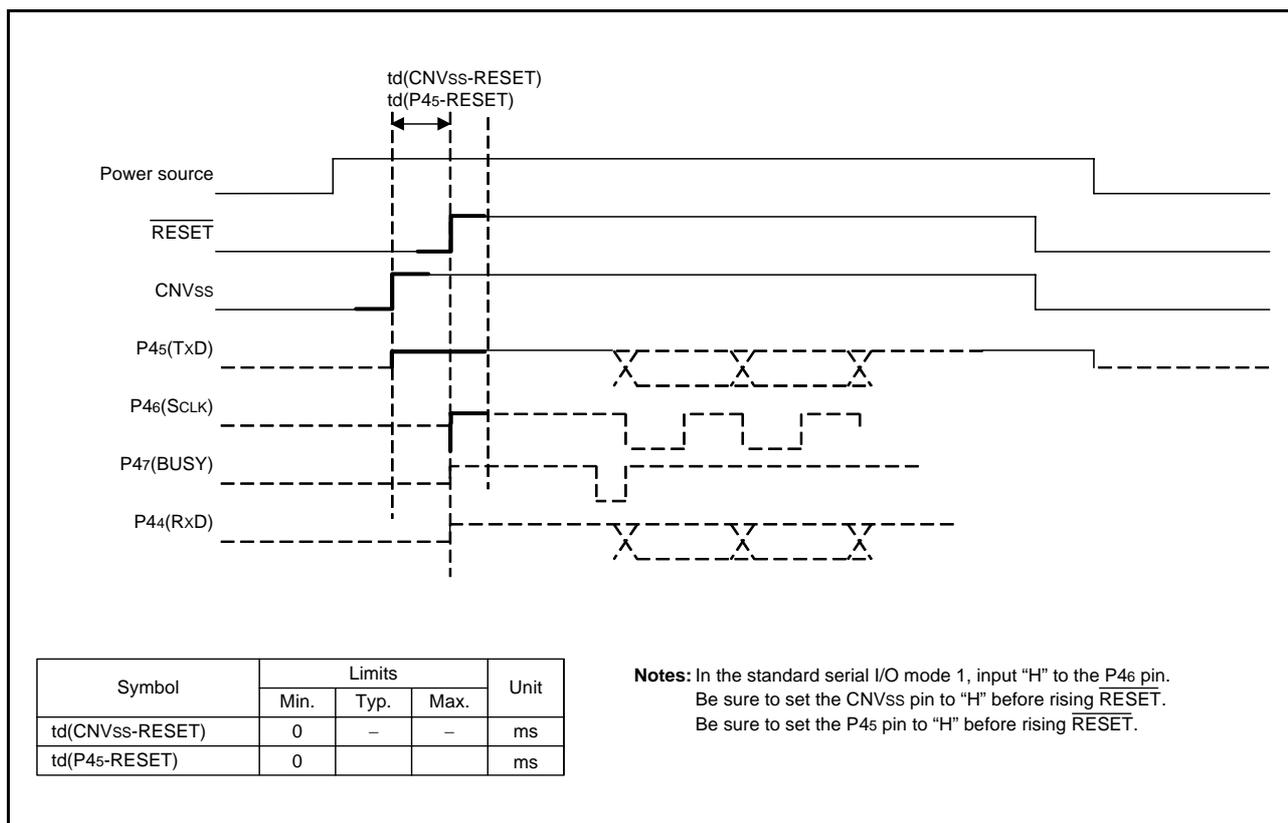


Fig 83. Operating waveform for standard serial I/O mode 1

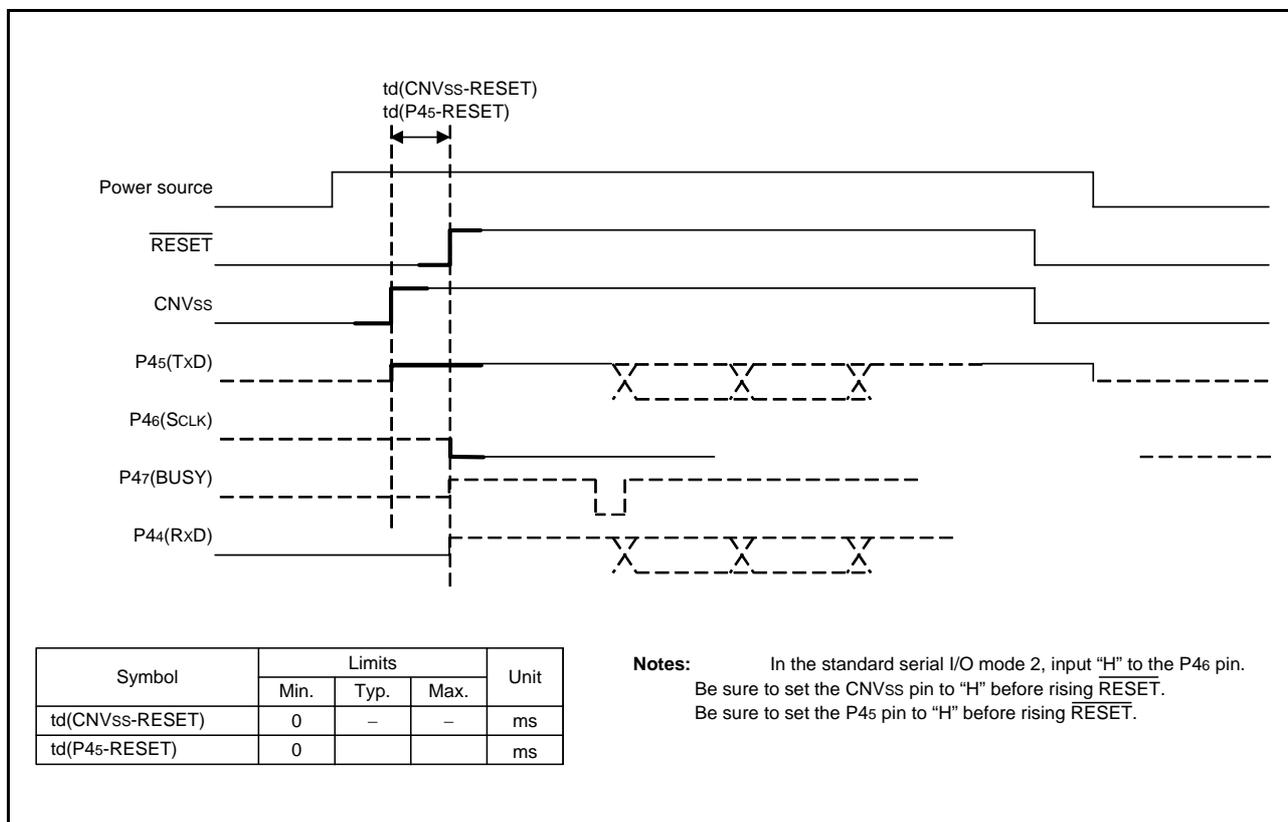


Fig 84. Operating waveform for standard serial I/O mode 2

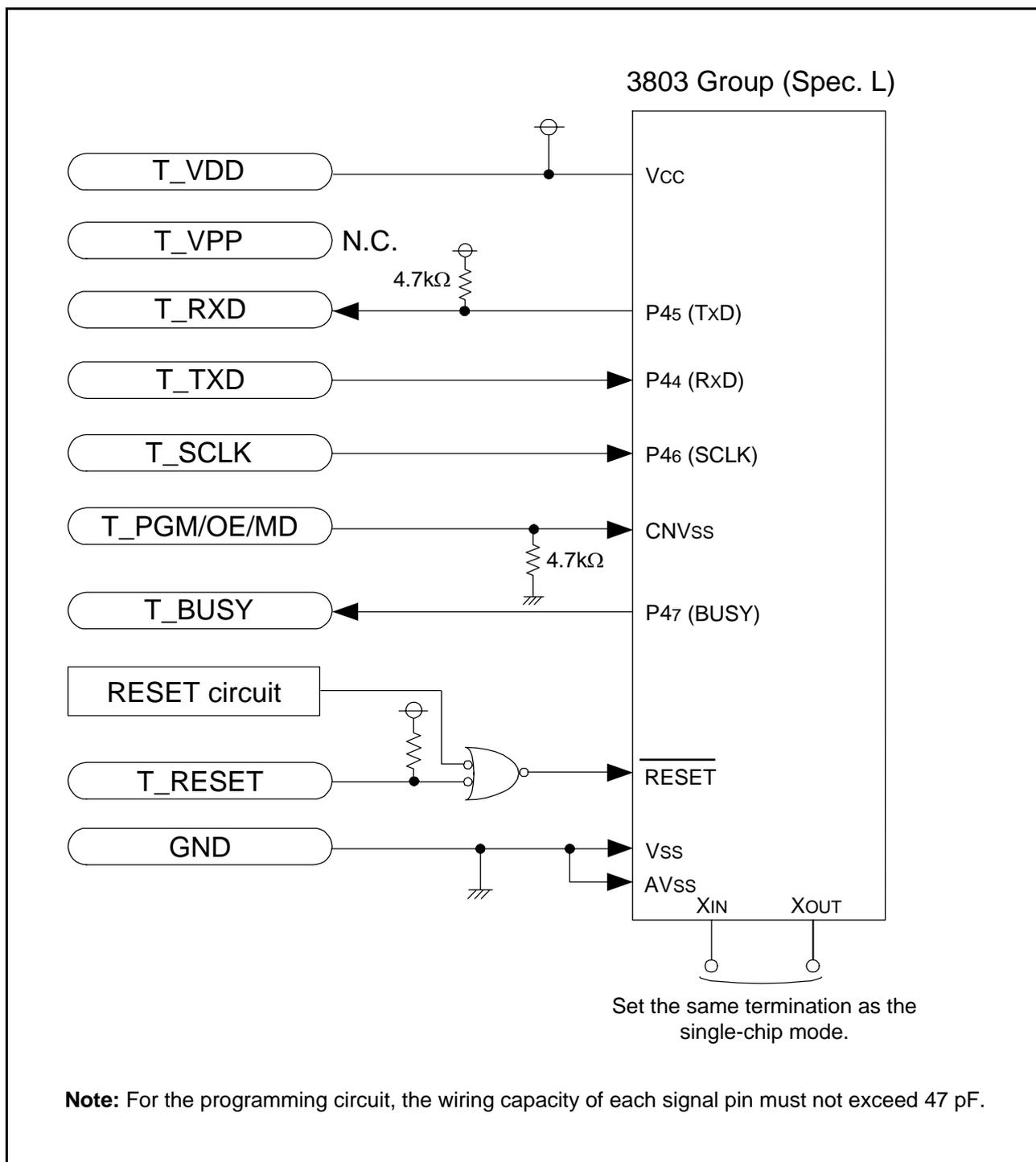


Fig 85. When using programmer (in standard serial I/O mode 1) of Suissei Electronics System Co., LTD, connection example

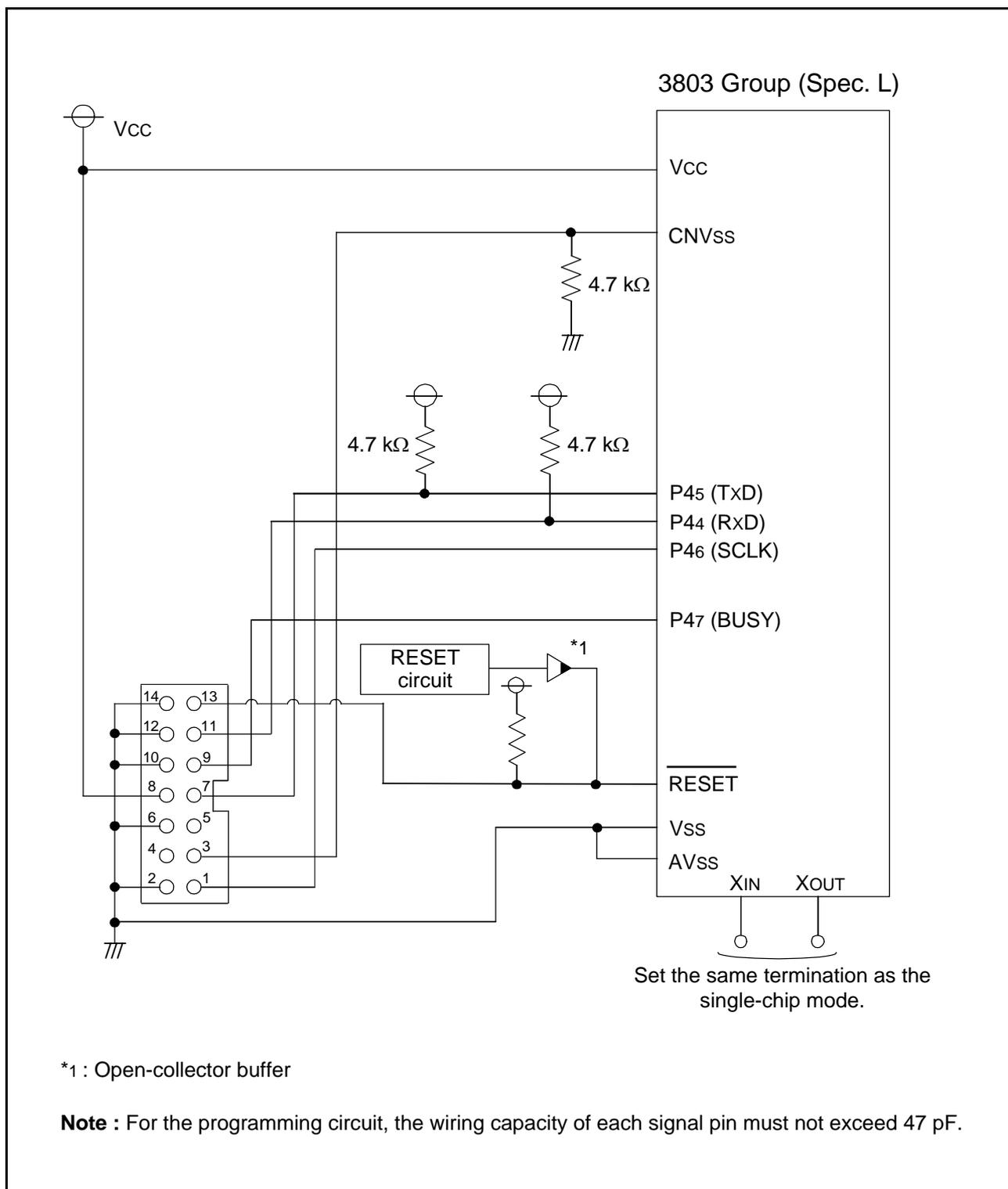


Fig 86. When using E8 programmer (in standard serial I/O mode 1), connection example

NOTES**NOTES ON PROGRAMMING****1. Processor Status Register**

(1) Initializing of processor status register

Flags which affect program execution must be initialized after a reset. In particular, it is essential to initialize the T and D flags because they have an important effect on calculations.

<Reason>

After a reset, the contents of the processor status register (PS) are undefined except for the I flag which is "1".

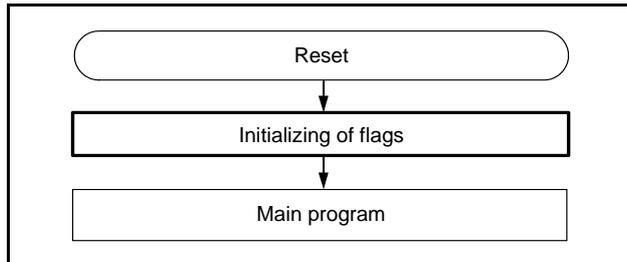


Fig 87. Initialization of processor status register

(2) How to reference the processor status register

To reference the contents of the processor status register (PS), execute the PHP instruction once then read the contents of (S+1). If necessary, execute the PLP instruction to return the PS to its original status.



Fig 88. Stack memory contents after PHP instruction execution

2. Decimal calculations

(1) Execution of decimal calculations

The ADC and SBC are the only instructions which will yield proper decimal notation, set the decimal mode flag (D) to "1" with the SED instruction. After executing the ADC or SBC instruction, execute another instruction before executing the SEC, CLC, or CLD instruction.

(2) Notes on status flag in decimal mode

When decimal mode is selected, the values of three of the flags in the status register (the N, V, and Z flags) are invalid after a ADC or SBC instruction is executed.

The carry flag (C) is set to "1" if a carry is generated as a result of the calculation, or is cleared to "0" if a borrow is generated. To determine whether a calculation has generated a carry, the C flag must be initialized to "0" before each calculation. To check for a borrow, the C flag must be initialized to "1" before each calculation.

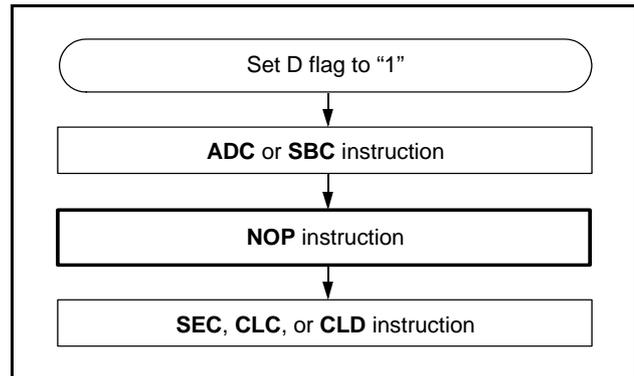


Fig 89. Execution of decimal calculations

3. JMP instruction

When using the JMP instruction in indirect addressing mode, do not specify the last address on a page as an indirect address.

4. Multiplication and Division Instructions

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

5. Ports

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

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

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

6. Instruction Execution Timing

The instruction execution time can be obtained by multiplying the frequency of the internal clock ϕ by the number of cycles mentioned in the 740 Family Software Manual.

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

Countermeasures against noise

(1) Shortest wiring length

1. Wiring for $\overline{\text{RESET}}$ pin

Make the length of wiring which is connected to the $\overline{\text{RESET}}$ pin as short as possible. Especially, connect a capacitor across the $\overline{\text{RESET}}$ pin and the Vss pin with the shortest possible wiring (within 20mm).

<Reason>

The width of a pulse input into the $\overline{\text{RESET}}$ pin is determined by the timing necessary conditions. If noise having a shorter pulse width than the standard is input to the $\overline{\text{RESET}}$ pin, the reset is released before the internal state of the microcomputer is completely initialized. This may cause a program runaway.

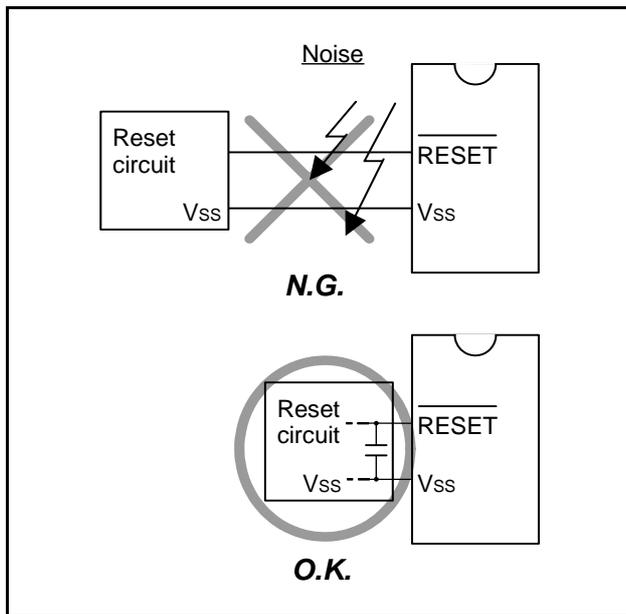


Fig 90. Wiring for the RESET pin

2. Wiring for clock input/output pins

- Make the length of wiring which is connected to clock I/O pins as short as possible.
- Make the length of wiring (within 20 mm) across the grounding lead of a capacitor which is connected to an oscillator and the Vss pin of a microcomputer as short as possible.
- Separate the Vss pattern only for oscillation from other Vss pat-terns.

<Reason>

If noise enters clock I/O pins, clock waveforms may be deformed. This may cause a program failure or program runaway. Also, if a potential difference is caused by the noise between the Vss level of a microcomputer and the Vss level of an oscillator, the correct clock will not be input in the microcomputer.

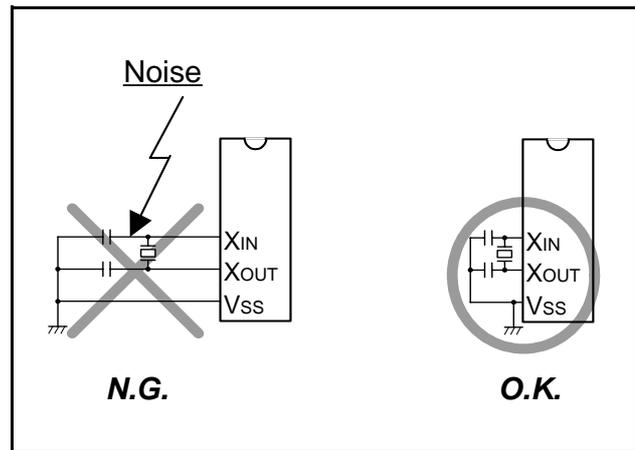


Fig 91. Wiring for clock I/O pins

(2) Connection of bypass capacitor across Vss line and Vcc line
In order to stabilize the system operation and avoid the latch-up, connect an approximately 0.1 μF bypass capacitor across the Vss line and the Vcc line as follows:

- Connect a bypass capacitor across the Vss pin and the Vcc pin at equal length.
- Connect a bypass capacitor across the Vss pin and the Vcc pin with the shortest possible wiring.
- Use lines with a larger diameter than other signal lines for Vss line and Vcc line.
- Connect the power source wiring via a bypass capacitor to the Vss pin and the Vcc pin.

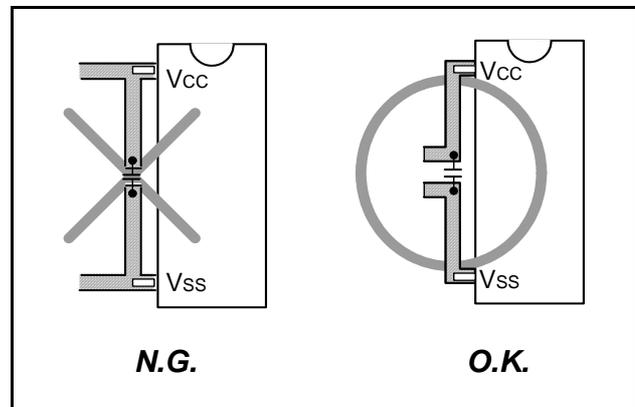


Fig 92. Bypass capacitor across the Vss line and the Vcc line

(3) Oscillator concerns

In order to obtain the stabilized operation clock on the user system and its condition, contact the oscillator manufacturer and select the oscillator and oscillation circuit constants. Be careful especially when range of voltage and temperature is wide. Also, take care to prevent an oscillator that generates clocks for a microcomputer operation from being affected by other signals.

1. Keeping oscillator away from large current signal lines

Install a microcomputer (and especially an oscillator) as far as possible from signal lines where a current larger than the tolerance of current value flows.

<Reason>

In the system using a microcomputer, there are signal lines for controlling motors, LEDs, and thermal heads or others. When a large current flows through those signal lines, strong noise occurs because of mutual inductance.

2. Installing oscillator away from signal lines where potential levels change frequently

Install an oscillator and a connecting pattern of an oscillator away from signal lines where potential levels change frequently. Also, do not cross such signal lines over the clock lines or the signal lines which are sensitive to noise.

<Reason>

Signal lines where potential levels change frequently (such as the CNTR pin signal line) may affect other lines at signal rising edge or falling edge. If such lines cross over a clock line, clock waveforms may be deformed, which causes a microcomputer failure or a program runaway.

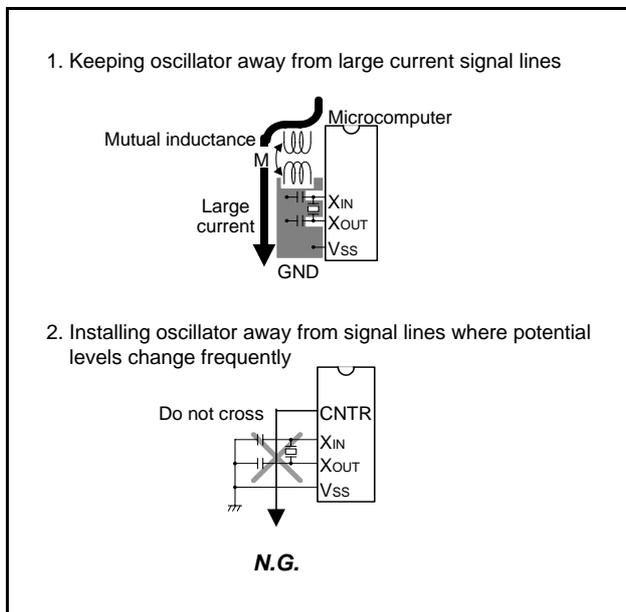


Fig 93. Wiring for a large current signal line/Wiring of signal lines where potential levels change frequently

(4) Analog input

The analog input pin is connected to the capacitor of a voltage comparator. Accordingly, sufficient accuracy may not be obtained by the charge/discharge current at the time of A/D conversion when the analog signal source of high-impedance is connected to an analog input pin. In order to obtain the A/D conversion result stabilized more, please lower the impedance of an analog signal source, or add the smoothing capacitor to an analog input pin.

(5) Difference of memory size

When memory size differ in one group, actual values such as an electrical characteristics, A/D conversion accuracy, and the amount of -proof of noise incorrect operation may differ from the ideal values. When these products are used switching, perform system evaluation for each product of every after confirming product specification.

(6) Wiring to CNVSS pin

The CNVSS pin determines the flash memory mode. Connect the CNVSS pin the shortest possible to the GND pattern which is supplied to the VSS pin of the microcomputer. In addition connecting an approximately 5 kΩ resistor in series to the GND could improve noise immunity. In this case as well as the above mention, connect the pin the shortest possible to the GND pattern which is supplied to the VSS pin of the microcomputer.

Note. When the boot mode or the standard serial I/O mode is used, a switch of the input level to the CNVSS pin is required.

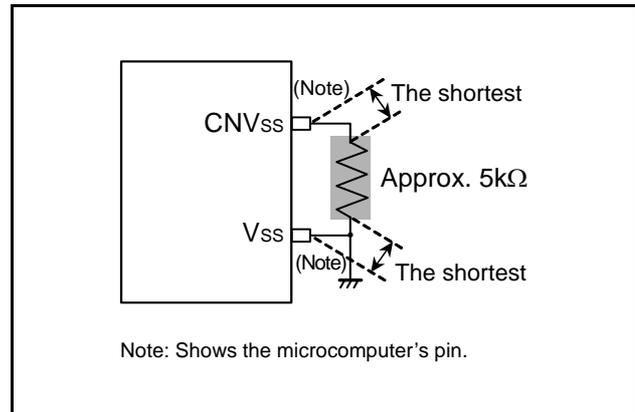


Fig 94. Wiring for the CNVSS

NOTES ON PERIPHERAL FUNCTIONS

Notes on Input and Output Ports

1. Notes in standby state

In standby state^{*1} for low-power dissipation, do not make input levels of an I/O port “undefined”. Even when an I/O port of Nchannel open-drain is set as output mode, if output data is “1”, the aforementioned notes are necessary.

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

When determining a resistance value, note the following points:

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

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

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

<Reason>

Exclusive input ports are always in a high-impedance state. An output transistor becomes an OFF state when an I/O port is set as input mode by the direction register, so that the port enter a highimpedance state. At this time, the potential which is input to the input buffer in a microcomputer is unstable in the state that input levels are “undefined”. This may cause power source current.

Even when an I/O port of N-channel open-drain is set as output mode by the direction register, if the contents of the port latch is “1”, the same phenomenon as that of an input port will occur.

*1 Standby state : stop mode by executing STP instruction
wait mode by executing WIT instruction

2. Modifying output data with bit managing instruction

When the port latch of an I/O port is modified with the bit managing instruction^{*1}, the value of the unspecified bit may be changed.

<Reason>

I/O ports are set to input or output mode in bit units. Reading from a port register or writing to it involves the following operations.

- Port in input mode
 - Read: Read the pin level.
 - Write: Write to the port latch.
- Port in output mode
 - Read: Read the port latch or read the output from the peripheral function (specifications differ depending on the port).
 - Write: Write to the port latch. (The port latch value is output from the pin.)

Since bit managing instructions^{*1} are read-modify-write instructions, ^{*2} using such an instruction on a port register causes a read and write to be performed simultaneously on the bits other than the one specified by the instruction.

When an unspecified bit is in input mode, its pin level is read and that value is written to the port latch. If the previous value of the port latch differs from the pin level, the port latch value is changed. If an unspecified bit is in output mode, the port latch is generally read. However, for some ports the peripheral function output is read, and the value is written to the port latch. In this case, if the previous value of the port latch differs from the peripheral function output, the port latch value is changed.

*1 Bit managing instructions: SEB and CLB instructions

*2 Read-modify-write instructions: Instructions that read memory in byte units, modify the value, and then write the result to the same location in memory in byte units

Termination of Unused Pins

1. Terminate unused pins

(1) Output ports : Open

(2) I/O ports :

- Set the I/O ports for the input mode and connect them to VCC or VSS through each resistor of 1 kΩ to 10 kΩ
Ports that permit the selecting of a built-in pull-up resistor can also use this resistor. Set the I/O ports for the output mode and open them at “L” or “H”.
- When opening them in the output mode, the input mode of the initial status remains until the mode of the ports is switched over to the output mode by the program after reset. Thus, the potential at these pins is undefined and the power source current may increase in the input mode. With regard to an effects on the system, thoroughly perform system evaluation on the user side.
- Since the direction register setup may be changed because of a program runaway or noise, set direction registers by program periodically to increase the reliability of program.

(3) The AVSS pin when not using the A/D converter :

- When not using the A/D converter, handle a power source pin for the A/D converter, AVSS pin as follows:
AVSS: Connect to the VSS pin.

2. Termination remarks

(1) I/O ports :

Do not open in the input mode.

<Reason>

- The power source current may increase depending on the firststage circuit.
- An effect due to noise may be easily produced as compared with proper termination (2) in 1 and shown on the above.

(2) I/O ports :

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

<Reason>

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

(3) I/O ports :

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

<Reason>

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

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

Notes on Interrupts

1. Change of relevant register settings

When the setting of the following registers or bits is changed, the interrupt request bit may be set to "1". When not requiring the interrupt occurrence synchronized with these setting, take the following sequence.

- Interrupt edge selection register (address 003A16)
- Timer XY mode register (address 002316)
- Timer Z mode register (address 002A16)

Set the above listed registers or bits as the following sequence.

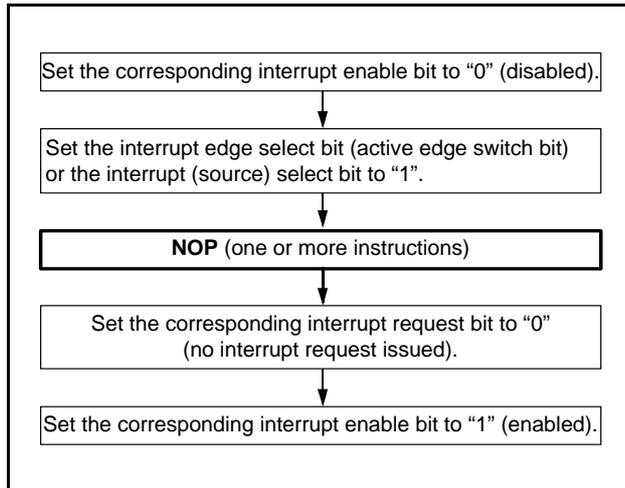


Fig 95. Sequence of changing relevant register

<Reason>

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

- When setting external interrupt active edge
Concerned register: Interrupt edge selection register (address 003A16)
Timer XY mode register (address 002316)
Timer Z mode register (address 002A16)
- When switching interrupt sources of an interrupt vector address where two or more interrupt sources are allocated.
Concerned register: Interrupt source selection register (address 003916)

2. Check of interrupt request bit

When executing the BBC or BBS instruction to an interrupt request bit of an interrupt request register immediately after this bit is set to "0", execute one or more instructions before executing the BBC or BBS instruction.

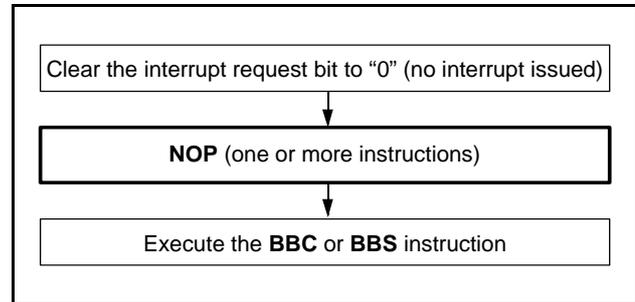


Fig 96. Sequence of check of interrupt request bit

<Reason>

If the BBC or BBS instruction is executed immediately after an interrupt request bit of an interrupt request register is cleared to "0", the value of the interrupt request bit before being cleared to "0" is read.

Notes on 8-bit Timer (timer 1, 2, X, Y)

- If a value n (between 0 and 255) is written to a timer latch, the frequency division ratio is $1/(n+1)$.
- When switching the count source by the timer 12, X and Y count source selection bits, the value of timer count is altered in unconsiderable amount owing to generating of thin pulses in the count input signals.
Therefore, select the timer count source before set the value to the prescaler and the timer.
- Set the double-function port of the CNTR0/CNTR1 pin and port P54/P55 to output in the pulse output mode.
- Set the double-function port of CNTR0/CNTR1 pin and port P54/P55 to input in the event counter mode and the pulse width measurement mode.

Notes on 16-bit Timer (timer Z)**1. Pulse output mode**

- Set the double-function port of the CNTR2 pin and port P47 to output.

2. Pulse period measurement mode

- Set the double-function port of the CNTR2 pin and port P47 to input.
- A read-out of timer value is impossible in this mode. The timer can be written to only during timer stop (no measurement of pulse period).
- Since the timer latch in this mode is specialized for the read-out of measured values, do not perform any write operation during measurement.
- “FFFF16” is set to the timer when the timer underflows or when the valid edge of measurement start/completion is detected.
Consequently, the timer value at start of pulse period measurement depends on the timer value just before measurement start.

3. Pulse width measurement mode

- Set the double-function port of the CNTR2 pin and port P47 to input.
- A read-out of timer value is impossible in this mode. The timer can be written to only during timer stop (no measurement of pulse period).
- Since the timer latch in this mode is specialized for the read-out of measured values, do not perform any write operation during measurement.
- “FFFF16” is set to the timer when the timer underflows or when the valid edge of measurement start/completion is detected.
Consequently, the timer value at start of pulse width measurement depends on the timer value just before measurement start.

4. Programmable waveform generating mode

- Set the double-function port of the CNTR2 pin and port P47 to output.

5. Programmable one-shot generating mode

- Set the double-function port of CNTR2 pin and port P47 to output, and of INT1 pin and port P42 to input in this mode.
- This mode cannot be used in low-speed mode.
- If the value of the CNTR2 active edge switch bit is changed during one-shot generating enabled or generating one-shot pulse, then the output level from CNTR2 pin changes.

6. All modes

- Timer Z write control

Which write control can be selected by the timer Z write control bit (bit 3) of the timer Z mode register (address 002A16), writing data to both the latch and the timer at the same time or writing data only to the latch.

When the operation “writing data only to the latch” is selected, the value is set to the timer latch by writing data to the address of timer Z and the timer is updated at next underflow. After reset release, the operation “writing data to both the latch and the timer at the same time” is selected, and the value is set to both the latch and the timer at the same time by writing data to the address of timer Z.

In the case of writing data only to the latch, if writing data to the latch and an underflow are performed almost at the same time, the timer value may become undefined.

- Timer Z read control

A read-out of timer value is impossible in pulse period measurement mode and pulse width measurement mode. In the other modes, a read-out of timer value is possible regardless of count operating or stopped.

However, a read-out of timer latch value is impossible.

- Switch of interrupt active edge of CNTR2 and INT1

Each interrupt active edge depends on setting of the CNTR2 active edge switch bit and the INT1 active edge selection bit.

- Switch of count source

When switching the count source by the timer Z count source selection bits, the value of timer count is altered in inconsiderable amount owing to generating of thin pulses on the count input signals.

Therefore, select the timer count source before setting the value to the prescaler and the timer.

Notes on Serial Interface

1. Notes when selecting clock synchronous serial I/O

(1) Stop of transmission operation

As for serial I/O_i (i = 1, 3) that can be used as either a clock synchronous or an asynchronous (UART) serial I/O, clear the serial I/O_i enable bit and the transmit enable bit to "0" (serial I/O_i and transmit disabled).

<Reason>

Since transmission is not stopped and the transmission circuit is not initialized even if only the serial I/O_i enable bit is cleared to "0" (serial I/O_i disabled), the internal transmission is running (in this case, since pins TxDi, RxDi, SCLKi, and SRDY_i function as I/O ports, the transmission data is not output). When data is written to the transmit buffer register in this state, data starts to be shifted to the transmit shift register. When the serial I/O_i enable bit is set to "1" at this time, the data during internally shifting is output to the TxDi pin and an operation failure occurs.

(2) Stop of receive operation

As for serial I/O_i (i = 1, 3) that can be used as either a clock synchronous or an asynchronous (UART) serial I/O, clear the receive enable bit to "0" (receive disabled), or clear the serial I/O_i enable bit to "0" (serial I/O_i disabled).

(3) Stop of transmit/receive operation

As for serial I/O_i (i = 1, 3) that can be used as either a clock synchronous or an asynchronous (UART) serial I/O, clear both the transmit enable bit and receive enable bit to "0" (transmit and receive disabled).

(when data is transmitted and received in the clock synchronous serial I/O mode, any one of data transmission and reception cannot be stopped.)

<Reason>

In the clock synchronous serial I/O mode, the same clock is used for transmission and reception. If any one of transmission and reception is disabled, a bit error occurs because transmission and reception cannot be synchronized.

In this mode, the clock circuit of the transmission circuit also operates for data reception. Accordingly, the transmission circuit does not stop by clearing only the transmit enable bit to "0" (transmit disabled). Also, the transmission circuit is not initialized by clearing the serial I/O_i enable bit to "0" (serial I/O_i disabled) (refer to (1) in 1.).

2. Notes when selecting clock asynchronous serial I/O

(1) Stop of transmission operation

Clear the transmit enable bit to "0" (transmit disabled). The transmission operation does not stop by clearing the serial I/O_i enable bit (i = 1, 3) to "0".

<Reason>

This is the same as (1) in 1.

(2) Stop of receive operation

Clear the receive enable bit to "0" (receive disabled).

(3) Stop of transmit/receive operation

Only transmission operation is stopped.

Clear the transmit enable bit to "0" (transmit disabled). The transmission operation does not stop by clearing the serial I/O_i enable bit (i = 1, 3) to "0".

<Reason>

This is the same as (1) in 1.

Only receive operation is stopped.

Clear the receive enable bit to "0" (receive disabled).

3. SRDY_i (i = 1, 3) output of reception side

When signals are output from the SRDY_i pin on the reception side by using an external clock in the clock synchronous serial I/O mode, set all of the receive enable bit, the SRDY_i output enable bit, and the transmit enable bit to "1" (transmit enabled).

4. Setting serial I/O_i (i = 1, 3) control register again

Set the serial I/O_i control register again after the transmission and the reception circuits are reset by clearing both the transmit enable bit and the receive enable bit to "0."

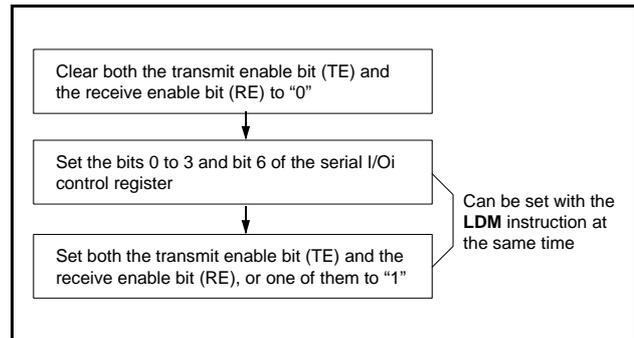


Fig 97. Sequence of setting serial I/O_i (i = 1, 3) control register again

5. Data transmission control with referring to transmit shift register completion flag

After the transmit data is written to the transmit buffer register, the transmit shift register completion flag changes from "1" to "0" with a delay of 0.5 to 1.5 shift clocks. When data transmission is controlled with referring to the flag after writing the data to the transmit buffer register, note the delay.

6. Transmission control when external clock is selected

When an external clock is used as the synchronous clock for data transmission, set the transmit enable bit to "1" at "H" of the SCLKi (i = 1, 3) input level. Also, write the transmit data to the transmit buffer register at "H" of the SCLKi input level.

7. Transmit interrupt request when transmit enable bit is set

When using the transmit interrupt, take the following sequence.

- (1) Set the serial I/O_i transmit interrupt enable bit (i = 1, 3) to "0" (disabled).
- (2) Set the transmit enable bit to "1".
- (3) Set the serial I/O_i transmit interrupt request bit (i = 1, 3) to "0" after 1 or more instruction has executed.
- (4) Set the serial I/O_i transmit interrupt enable bit (i = 1, 3) to "1" (enabled).

<Reason>

When the transmission enable bit is set to "1", the transmit buffer empty flag and transmit shift register shift completion flag are also set to "1".

Therefore, regardless of selecting which timing for the generating of transmit interrupts, the interrupt request is generated and the transmit interrupt request bit is set at this point.

8. Writing to baud rate generator i (BRGi) (i = 1, 3)

Write data to the baud rate generator i (BRGi) (i = 1, 3) while the transmission/reception operation is stopped.

Notes on PWM

The PWM starts from “H” level after the PWM enable bit is set to enable and “L” level is temporarily output from the PWM pin. The length of this “L” level output is as follows:

$$\frac{n+1}{2 \times f(XIN)} \quad (s) \quad \text{(Count source selection bit = “0”, where n is the value set in the prescaler)}$$

$$\frac{n+1}{f(XIN)} \quad (s) \quad \text{(Count source selection bit = “1”, where n is the value set in the prescaler)}$$

Notes on A/D Converter**1. Analog input pin**

Make the signal source impedance for analog input low, or equip an analog input pin with an external capacitor of 0.01 μF to 1 μF . Further, be sure to verify the operation of application products on the user side.

<Reason>

An analog input pin includes the capacitor for analog voltage comparison. Accordingly, when signals from signal source with high impedance are input to an analog input pin, charge and discharge noise generates. This may cause the A/D conversion precision to be worse.

2. A/D converter power source pin

The AVSS pin is A/D converter power source pins. Regardless of using the A/D conversion function or not, connect it as following :

- AVSS : Connect to the VSS line

<Reason>

If the AVSS pin is opened, the microcomputer may have a failure because of noise or others.

3. Clock frequency during A/D conversion

The comparator consists of a capacity coupling, and a charge of the capacity will be lost if the clock frequency is too low. Thus, make sure the following during an A/D conversion.

- $f(XIN)$ is 500 kHz or more
- Do not execute the STP instruction

4. Difference between at 8-bit reading in 10-bit A/D mode and at 8-bit A/D mode

At 8-bit reading in the 10-bit A/D mode, “-1/2 LSB” correction is not performed to the A/D conversion result.

In the 8-bit A/D mode, the A/D conversion characteristics is the same as 3802 group’s characteristics because “-1/2 LSB” correction is performed.

Notes on D/A Converter**1. Vcc when using D/A converter**

The D/A converter accuracy when VCC is 4.0 V or less differs from that of when VCC is 4.0 V or more. When using the D/A converter, we recommend using a VCC of 4.0 V or more.

2. DAi conversion register when not using D/A converter

When a D/A converter is not used, set all values of the DAi conversion registers ($i = 1, 2$) to “0016”. The initial value after reset is “0016”.

Notes on Watchdog Timer

- Make sure that the watchdog timer H does not underflow while waiting Stop release, because the watchdog timer keeps counting during that term.
- When the STP instruction disable bit has been set to “1”, it is impossible to switch it to “0” by a program.

Notes on RESET Pin**Connecting capacitor**

In case where the RESET signal rise time is long, connect a ceramic capacitor or others across the RESET pin and the VSS pin.

Use a 1000 pF or more capacitor for high frequency use. When connecting the capacitor, note the following :

- Make the length of the wiring which is connected to a capacitor as short as possible.
- Be sure to verify the operation of application products on the user side.

<Reason>

If the several nanosecond or several ten nanosecond impulse noise enters the RESET pin, it may cause a microcomputer failure.

Notes on Low-speed Operation Mode**1. Using sub-clock**

To use a sub-clock, fix bit 3 of the CPU mode register to “1” or control the Rd (refer to Figure 98) resistance value to a certain level to stabilize an oscillation. For resistance value of Rd, consult the oscillator manufacturer.

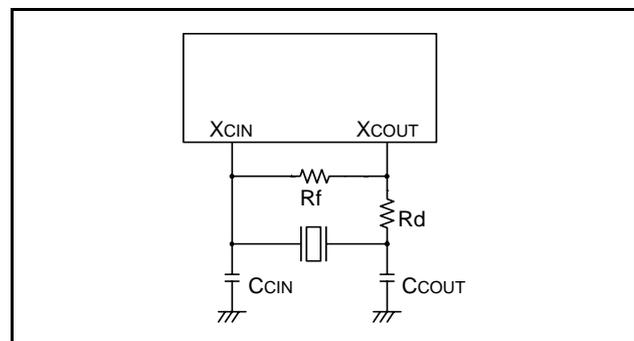


Fig 98. Ceramic resonator circuit

<Reason>

When bit 3 of the CPU mode register is set to “0”, the sub-clock oscillation may stop.

2. Switch between middle/high-speed mode and low-speed mode

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

Quartz-Crystal Oscillator

When using the quartz-crystal oscillator of high frequency, such as 16 MHz etc., it may be necessary to select a specific oscillator with the specification demanded.

Notes on Restarting Oscillation

- Restarting oscillation

Usually, when the MCU stops the clock oscillation by STP instruction and the STP instruction has been released by an external interrupt source, the fixed values of Timer 1 and Prescaler 12 (Timer 1 = "0116", Prescaler 12 = "FF16") are automatically reloaded in order for the oscillation to stabilize. The user can inhibit the automatic setting by writing "1" to bit 0 of MISRG (address 001016).

However, by setting this bit to "1", the previous values, set just before the STP instruction was executed, will remain in Timer 1 and Prescaler 12. Therefore, you will need to set an appropriate value to each register, in accordance with the oscillation stabilizing time, before executing the STP instruction.

<Reason>

Oscillation will restart when an external interrupt is received. However, internal clock ϕ is supplied to the CPU only when Timer 1 starts to underflow. This ensures time for the clock oscillation using the ceramic resonators to be stabilized.

Notes on Using Stop Mode

- Register setting

Since values of the prescaler 12 and Timer 1 are automatically reloaded when returning from the stop mode, set them again, respectively. (When the oscillation stabilizing time set after STP instruction released bit is "0")

- Clock restoration

After restoration from the stop mode to the normal mode by an interrupt request, the contents of the CPU mode register previous to the STP instruction execution are retained. Accordingly, if both main clock and sub clock were oscillating before execution of the STP instruction, the oscillation of both clocks is resumed at restoration.

In the above case, when the main clock side is set as a system clock, the oscillation stabilizing time for approximately 8,000 cycles of the XIN input is reserved at restoration from the stop mode. At this time, note that the oscillation on the sub clock side may not be stabilized even after the lapse of the oscillation stabilizing time of the main clock side.

Notes on Wait Mode

- Clock restoration

If the wait mode is released by a reset when XCIN is set as the system clock and XIN oscillation is stopped during execution of the WIT instruction, XCIN oscillation stops, XIN oscillations starts, and XIN is set as the system clock.

In the above case, the RESET pin should be held at "L" until the oscillation is stabilized.

Notes on CPU rewrite mode of flash memory version

1. Operation speed

During CPU rewrite mode, set the system clock ϕ 4.0 MHz or less using the main clock division ratio selection bits (bits 6 and 7 of address 003B16).

2. Instructions inhibited against use

The instructions which refer to the internal data of the flash memory cannot be used during the CPU rewrite mode.

3. Interrupts inhibited against use

The interrupts cannot be used during the CPU rewrite mode because they refer to the internal data of the flash memory.

4. Watchdog timer

In case of the watchdog timer has been running already, the internal reset generated by watchdog timer underflow does not happen, because of watchdog timer is always clearing during program or erase operation.

5. Reset

Reset is always valid. In case of CNVss = "H" when reset is released, boot mode is active. So the program starts from the address contained in address FFFC16 and FFDD16 in boot ROM area.

Notes on flash memory version

The CNVss pin determines the flash memory mode.

Connect the CNVss pin the shortest possible to the GND pattern which is supplied to the Vss pin of the microcomputer.

In addition connecting an approximately 5 k Ω resistor in series to the GND could improve noise immunity. In this case as well as the above mention, connect the pin the shortest possible to the GND pattern which is supplied to the Vss pin of the microcomputer.

Note. When the boot mode or the standard serial I/O mode is used, a switch of the input level to the CNVss pin is required.

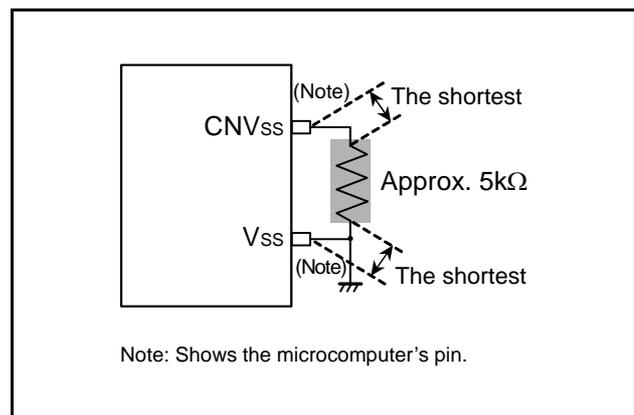


Fig 99. Wiring for the CNVss

Notes on electric characteristic differences between mask ROM and flash memory version MCUs

There are differences in electric characteristics, operation margin, noise immunity, and noise radiation between Mask ROM and Flash Memory version MCUs due to the difference in the manufacturing processes, built-in ROM, and layout pattern etc. When manufacturing an application system with the Flash Memory version and then switching to use of the Mask ROM version, please conduct evaluations equivalent to the system evaluations conducted for the flash memory version.

DATA REQUIRED FOR MASK ORDERS

The following are necessary when ordering a mask ROM production:

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

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

Notes on Handling of Power Source Pins

In order to avoid a latch-up occurrence, connect a capacitor suitable for high frequencies as bypass capacitor between power source pin (VCC pin) and GND pin (VSS pin), and between power source pin (VCC pin) and analog power source input pin (AVSS pin). Besides, connect the capacitor to as close as possible. For bypass capacitor which should not be located too far from the pins to be connected, a ceramic capacitor of 0.01 μF –0.1 μF is recommended.

Power Source Voltage

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

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

ELECTRICAL CHARACTERISTICS**Absolute maximum ratings**

Table 16 Absolute maximum ratings

Symbol	Parameter	Conditions	Ratings	Unit
V _{CC}	Power source voltages	All voltages are based on V _{SS} .	−0.3 to 6.5	V
V _I	Input voltage P00-P07, P10-P17, P20-P27, P30, P31, P34-P37, P40-P47, P50-P57, P60-P67, V _{REF}	When an input voltage is measured, output transistors are cut off.	−0.3 to V _{CC} + 0.3	V
V _I	Input voltage P32, P33		−0.3 to 5.8	V
V _I	Input voltage $\overline{\text{RESET}}$, X _{IN}		−0.3 to V _{CC} + 0.3	V
V _I	Input voltage CNV _{SS}		−0.3 to V _{CC} + 0.3	V
V _O	Output voltage P00-P07, P10-P17, P20-P27, P30, P31, P34-P37, P40-P47, P50-P57, P60-P67, X _{OUT}		−0.3 to V _{CC} + 0.3	V
V _O	Output voltage P32, P33		−0.3 to 5.8	V
P _d	Power dissipation	T _a =25 °C	1000 ⁽¹⁾	mW
T _{opr}	Operating temperature	—	−20 to 85	°C
T _{stg}	Storage temperature	—	−65 to 125	°C

NOTE:

1. This value is 300 mW except SP package.

Recommended operating conditions

Table 17 Recommended operating conditions (1) (Mask ROM version)
(V_{CC} = 1.8 to 5.5 V, V_{SS} = 0 V, T_a = -20 to 85 °C, unless otherwise noted)

Symbol	Parameter	Conditions	Limits			Unit	
			Min.	Typ.	Max.		
V _{CC}	Power source voltage ⁽¹⁾	When start oscillating ⁽²⁾	2.2	5.0	5.5	V	
		High-speed mode f(φ) = f(X _{IN})/2	f(X _{IN}) ≤ 2.1 MHz	2.0	5.0	5.5	V
			f(X _{IN}) ≤ 4.2 MHz	2.2	5.0	5.5	
			f(X _{IN}) ≤ 8.4 MHz	2.7	5.0	5.5	
			f(X _{IN}) ≤ 12.5 MHz	4.0	5.0	5.5	
			f(X _{IN}) ≤ 16.8 MHz	4.5	5.0	5.5	
		Middle-speed mode f(φ) = f(X _{IN})/8	f(X _{IN}) ≤ 6.3 MHz	1.8	5.0	5.5	V
			f(X _{IN}) ≤ 8.4 MHz	2.2	5.0	5.5	
			f(X _{IN}) ≤ 12.5 MHz	2.7	5.0	5.5	
			f(X _{IN}) ≤ 16.8 MHz	4.5	5.0	5.5	
V _{SS}	Power source voltage		0		V		
V _{IH}	"H" input voltage P00-P07, P10-P17, P20-P27, P30, P31, P34-P37, P40-P47, P50-P57, P60-P67	1.8 ≤ V _{CC} < 2.7 V	0.85 V _{CC}		V _{CC}	V	
		2.7 ≤ V _{CC} ≤ 5.5 V	0.8 V _{CC}		V _{CC}		
V _{IH}	"H" input voltage P32, P33	1.8 ≤ V _{CC} < 2.7 V	0.85 V _{CC}		5.5	V	
		2.7 ≤ V _{CC} ≤ 5.5 V	0.8 V _{CC}		5.5		
V _{IH}	"H" input voltage RESET, X _{IN} , X _{CIN} , CNV _{SS}	1.8 ≤ V _{CC} < 2.7 V	0.85 V _{CC}		V _{CC}	V	
		2.7 ≤ V _{CC} ≤ 5.5 V	0.8 V _{CC}		V _{CC}		
V _{IL}	"L" input voltage P00-P07, P10-P17, P20-P27, P30-P37, P40-P47, P50-P57, P60-P67	1.8 ≤ V _{CC} < 2.7 V	0		0.16 V _{CC}	V	
		2.7 ≤ V _{CC} ≤ 5.5 V	0		0.2 V _{CC}		
V _{IL}	"L" input voltage RESET, CNV _{SS}	1.8 ≤ V _{CC} < 2.7 V	0		0.16 V _{CC}	V	
		2.7 ≤ V _{CC} ≤ 5.5 V	0		0.2 V _{CC}		
V _{IL}	"L" input voltage X _{IN} , X _{CIN}	1.8 ≤ V _{CC} ≤ 5.5 V	0		0.16 V _{CC}	V	
f(X _{IN})	Main clock input oscillation frequency ⁽³⁾	High-speed mode f(φ) = f(X _{IN})/2	2.0 ≤ V _{CC} < 2.2 V		$\frac{(20 \times V_{CC} - 36) \times 1.05}{2}$	MHz	
			2.2 ≤ V _{CC} < 2.7 V		$\frac{(24 \times V_{CC} - 40.8) \times 1.05}{3}$	MHz	
			2.7 ≤ V _{CC} < 4.0 V		$\frac{(9 \times V_{CC} - 0.3) \times 1.05}{3}$	MHz	
			4.0 ≤ V _{CC} < 4.5 V		$\frac{(24 \times V_{CC} - 60) \times 1.05}{3}$	MHz	
			4.5 ≤ V _{CC} ≤ 5.5 V		16.8	MHz	
		Middle-speed mode f(φ) = f(X _{IN})/8	1.8 ≤ V _{CC} < 2.2 V		$\frac{(15 \times V_{CC} - 9) \times 1.05}{3}$	MHz	
			2.2 ≤ V _{CC} < 2.7 V		$\frac{(24 \times V_{CC} - 28.8) \times 1.05}{3}$	MHz	
			2.7 ≤ V _{CC} < 4.5 V		$\frac{(15 \times V_{CC} + 39) \times 1.1}{7}$	MHz	
			4.5 ≤ V _{CC} ≤ 5.5 V		16.8	MHz	
f(X _{CIN})	Sub-clock input oscillation frequency ^(3, 4)		32.768	50	kHz		

NOTES:

- When using A/D converter, see A/D converter recommended operating conditions.
- The start voltage and the start time for oscillation depend on the using oscillator, oscillation circuit constant value and operating temperature range, etc.. Particularly a high-frequency oscillator might require some notes in the low voltage operation.
- When the oscillation frequency has a duty cycle of 50%.
- When using the microcomputer in low-speed mode, set the sub-clock input oscillation frequency on condition that f(X_{CIN}) < f(X_{IN})/3.

Table 18 Recommended operating conditions (2) (Flash memory version)
 (V_{CC} = 2.7 to 5.5 V, V_{SS} = 0 V, T_a = -20 to 85 °C, unless otherwise noted)

Symbol	Parameter	Conditions	Limits			Unit	
			Min.	Typ.	Max.		
V _{CC}	Power source voltage ⁽¹⁾	When start oscillating ⁽²⁾	2.2	5.0	5.5	V	
		High-speed mode f(φ) = f(X _{IN})/2	f(X _{IN}) ≤ 8.4 MHz	2.7	5.0	5.5	V
			f(X _{IN}) ≤ 12.5 MHz	4.0	5.0	5.5	
			f(X _{IN}) ≤ 16.8 MHz	4.5	5.0	5.5	
		Middle-speed mode f(φ) = f(X _{IN})/8	f(X _{IN}) ≤ 12.5 MHz	2.7	5.0	5.5	V
f(X _{IN}) ≤ 16.8 MHz	4.5		5.0	5.5			
V _{SS}	Power source voltage		0		V		
V _{IH}	"H" input voltage P00-P07, P10-P17, P20-P27, P30, P31, P34-P37, P40-P47, P50-P57, P60-P67		0.8 V _{CC}		V _{CC}	V	
V _{IH}	"H" input voltage P32, P33		0.8 V _{CC}		5.5	V	
V _{IH}	"H" input voltage RESET, X _{IN} , CNV _{SS}		0.8 V _{CC}		V _{CC}	V	
V _{IH}	"H" input voltage X _{CIN}		2		V _{CC}	V	
V _{IL}	"L" input voltage P00-P07, P10-P17, P20-P27, P30-P37, P40-P47, P50-P57, P60-P67		0		0.2 V _{CC}	V	
V _{IL}	"L" input voltage RESET, CNV _{SS}		0		0.2 V _{CC}	V	
V _{IL}	"L" input voltage X _{IN}				0.16 V _{CC}	V	
V _{IL}	"L" input voltage X _{CIN}				0.4	V	
f(X _{IN})	Main clock input oscillation frequency ⁽³⁾	High-speed mode f(φ) = f(X _{IN})/2	2.7 ≤ V _{CC} < 4.0 V		$\frac{(9 \times V_{CC} - 0.3) \times 1.05}{3}$	MHz	
			4.0 ≤ V _{CC} < 4.5 V		$\frac{(24 \times V_{CC} - 60) \times 1.05}{3}$	MHz	
			4.5 ≤ V _{CC} ≤ 5.5 V		16.8	MHz	
		Middle-speed mode f(φ) = f(X _{IN})/8	2.7 ≤ V _{CC} < 4.5 V		$\frac{(15 \times V_{CC} + 39) \times 1.1}{7}$	MHz	
			4.5 ≤ V _{CC} ≤ 5.5 V		16.8	MHz	
f(X _{CIN})	Sub-clock input oscillation frequency ^(3, 4)			32.768	50	kHz	

NOTES:

- When using A/D converter, see A/D converter recommended operating conditions.
- The start voltage and the start time for oscillation depend on the using oscillator, oscillation circuit constant value and operating temperature range, etc.. Particularly a high-frequency oscillator might require some notes in the low voltage operation.
- When the oscillation frequency has a duty cycle of 50%.
- When using the microcomputer in low-speed mode, set the sub-clock input oscillation frequency on condition that f(X_{CIN}) < f(X_{IN})/3.

Table 19 Recommended operating conditions (3)

(Mask ROM version: $V_{CC} = 1.8$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)(Flash memory version: $V_{CC} = 2.7$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter	Limits			Unit
		Min.	Typ.	Max.	
$\Sigma I_{OH(peak)}$	"H" total peak output current ⁽¹⁾ P00-P07, P10-P17, P20-P27, P30, P31, P34-P37			-80	mA
$\Sigma I_{OH(peak)}$	"H" total peak output current ⁽¹⁾ P40-P47, P50-P57, P60-P67			-80	mA
$\Sigma I_{OL(peak)}$	"L" total peak output current ⁽¹⁾ P00-P07, P10-P17, P30-P37			80	mA
$\Sigma I_{OL(peak)}$	"L" total peak output current ⁽¹⁾ P20-P27			80	mA
$\Sigma I_{OL(peak)}$	"L" total peak output current ⁽¹⁾ P40-P47, P50-P57, P60-P67			80	mA
$\Sigma I_{OH(avg)}$	"H" total average output current ⁽¹⁾ P00-P07, P10-P17, P20-P27, P30, P31, P34-P37			-40	mA
$\Sigma I_{OH(avg)}$	"H" total average output current ⁽¹⁾ P40-P47, P50-P57, P60-P67			-40	mA
$\Sigma I_{OL(avg)}$	"L" total average output current ⁽¹⁾ P00-P07, P10-P17, P30-P37			40	mA
$\Sigma I_{OL(avg)}$	"L" total average output current ⁽¹⁾ P20-P27			40	mA
$\Sigma I_{OL(avg)}$	"L" total average output current ⁽¹⁾ P40-P47, P50-P57, P60-P67			40	mA
$I_{OH(peak)}$	"H" peak output current ⁽²⁾ P00-P07, P10-P17, P20-P27, P30, P31, P34-P37, P40-P47, P50-P57, P60-P67			-10	mA
$I_{OL(peak)}$	"L" peak output current ⁽²⁾ P00-P07, P10-P17, P30-P37, P40-P47, P50-P57, P60-P67			10	mA
$I_{OL(peak)}$	"L" peak output current ⁽²⁾ P20-P27			20	mA
$I_{OH(avg)}$	"H" average output current ⁽³⁾ P00-P07, P10-P17, P20-P27, P30, P31, P34-P37, P40-P47, P50-P57, P60-P67			-5	mA
$I_{OL(avg)}$	"L" average output current ⁽³⁾ P00-P07, P10-P17, P30-P37, P40-P47, P50-P57, P60-P67			5	mA
$I_{OL(avg)}$	"L" average output current ⁽³⁾ P20-P27			10	mA

NOTES:

1. The total output current is the sum of all the currents flowing through all the applicable ports. The total average current is an average value measured over 100 ms. The total peak current is the peak value of all the currents.
2. The peak output current is the peak current flowing in each port.
3. The average output current $I_{OL(avg)}$, $I_{OH(avg)}$ are average value measured over 100 ms.

Electrical characteristics

Table 20 Electrical characteristics (1)

(Mask ROM version: $V_{CC} = 1.8$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)(Flash memory version: $V_{CC} = 2.7$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min.	Typ.	Max.	
V _{OH}	"H" output voltage ⁽¹⁾ P00-P07, P10-P17, P20-P27, P30, P31, P34-P37, P40-P47, P50-P57, P60-P67	I _{OH} = -10 mA V _{CC} = 4.0 to 5.5 V	V _{CC} - 2.0			V
		I _{OH} = -1.0 mA V _{CC} = 1.8 to 5.5 V	V _{CC} - 1.0			
V _{OL}	"L" output voltage P00-P07, P10-P17, P20-P27, P30-P37, P40-P47, P50-P57, P60-P67	I _{OL} = 10 mA V _{CC} = 4.0 to 5.5 V			2.0	V
		I _{OL} = 1.6 mA V _{CC} = 1.8 to 5.5 V			1.0	
V _{OL}	"L" output voltage P20-P27	I _{OL} = 20 mA V _{CC} = 4.0 to 5.5 V			2.0	V
		I _{OL} = 1.6 mA V _{CC} = 1.8 to 5.5 V			0.4	
V _{T+} - V _{T-}	Hysteresis CNTR ₀ , CNTR ₁ , CNTR ₂ , INT ₀ -INT ₄			0.4		V
V _{T+} - V _{T-}	Hysteresis RxD ₁ , SCLK ₁ , SIN ₂ , SCLK ₂ , RxD ₃ , SCLK ₃			0.5		V
V _{T+} - V _{T-}	Hysteresis RESET			0.5		V
I _{IH}	"H" input current P00-P07, P10-P17, P20-P27, P30-P37, P40-P47, P50-P57, P60-P67	V _I = V _{CC} (Pin floating, Pull-up transistor "off")			5.0	μA
I _{IH}	"H" input current RESET, CNV _{SS}	V _I = V _{CC}			5.0	μA
I _{IH}	"H" input current X _{IN}	V _I = V _{CC}		4.0		μA
I _{IL}	"L" input current P00-P07, P10-P17, P20-P27, P30-P37, P40-P47, P50-P57, P60-P67	V _I = V _{SS} (Pin floating, Pull-up transistor "off")			-5.0	μA
I _{IL}	"L" input current RESET, CNV _{SS}	V _I = V _{SS}			-5.0	μA
I _{IL}	"L" input current X _{IN}	V _I = V _{SS}		-4.0		μA
		V _I = V _{SS}				
I _{IL}	"L" input current (at Pull-up) P00-P07, P10-P17, P20-P27, P30, P31, P34-P37, P40-P47, P50-P57, P60-P67	V _I = V _{SS} V _{CC} = 5.0 V	-80	-210	-420	μA
		V _I = V _{SS} V _{CC} = 3.0 V	-30	-70	-140	
V _{RAM}	RAM hold voltage	When clock stopped	1.8		V _{CC}	V

NOTE:

1. P₃₅ is measured when the P₃₅/TxD₃ P-channel output disable bit of the UART3 control register (bit 4 of address 0033₁₆) is "0".
P₄₅ is measured when the P₄₅/TxD₁ P-channel output disable bit of the UART1 control register (bit 4 of address 001B₁₆) is "0".

Table 21 Electrical characteristics (2) (Mask ROM version)
 (V_{CC} = 1.8 to 5.5 V, T_a = -20 to 85 °C, f(X_{IN})=32.768 kHz (Stopped in middle-speed mode),
 Output transistors "off", AD converter not operated)

Symbol	Parameter	Test conditions			Limits			Unit	
					Min.	Typ.	Max.		
I _{CC}	Power source current	High-speed mode	V _{CC} = 5.0 V	f(X _{IN}) = 16.8 MHz		8.0	15.0	mA	
				f(X _{IN}) = 12.5 MHz		6.5	12.0		
				f(X _{IN}) = 8.4 MHz		5.0	9.0		
				f(X _{IN}) = 4.2 MHz		2.5	5.0		
				f(X _{IN}) = 16.8 MHz (in WIT state)		2.0	3.6		
			V _{CC} = 3.0 V	f(X _{IN}) = 8.4 MHz		1.9	3.8	mA	
				f(X _{IN}) = 4.2 MHz		1.0	2.0		
				f(X _{IN}) = 2.1 MHz		0.6	1.2		
			Middle-speed mode	V _{CC} = 5.0 V	f(X _{IN}) = 16.8 MHz		4.0	7.0	mA
					f(X _{IN}) = 12.5 MHz		3.0	6.0	
		f(X _{IN}) = 8.4 MHz				2.5	5.0		
		f(X _{IN}) = 16.8 MHz (in WIT state)				1.8	3.3		
		V _{CC} = 3.0 V		f(X _{IN}) = 12.5 MHz		1.5	3.0	mA	
				f(X _{IN}) = 8.4 MHz		1.2	2.4		
		Low-speed mode	V _{CC} = 5.0 V	f(X _{IN}) = stopped		55	200	μA	
				In WIT state		40	70		
			V _{CC} = 3.0 V	f(X _{IN}) = stopped		15	40	μA	
				In WIT state		8	15		
			V _{CC} = 2.0 V	f(X _{IN}) = stopped		6	15	μA	
				In WIT state		3	6		
In STP state (All oscillation stopped)		T _a = 25 °C		0.1	1.0	μA			
		T _a = 85 °C			10	μA			
Increment when A/D conversion is executed		f(X _{IN}) = 16.8 MHz, V _{CC} = 5.0 V In Middle-, high-speed mode		500		μA			

Table 22 Electrical characteristics (3) (Flash memory version)
 (V_{CC} = 2.7 to 5.5 V, T_a = -20 to 85 °C, f(X_{IN})=32.768 kHz (Stopped in middle-speed mode),
 Output transistors “off”, AD converter not operated)

Symbol	Parameter	Test conditions			Limits			Unit
					Min.	Typ.	Max.	
I _{CC}	Power source current	High-speed mode	V _{CC} = 5.0 V	f(X _{IN}) = 16.8 MHz		5.5	8.3	mA
				f(X _{IN}) = 12.5 MHz		4.5	6.8	
				f(X _{IN}) = 8.4 MHz		3.5	5.3	
				f(X _{IN}) = 4.2 MHz		2.2	3.3	
				f(X _{IN}) = 16.8 MHz (in WIT state)		2.2	3.3	
		V _{CC} = 3.0 V	f(X _{IN}) = 8.4 MHz		2.7	4.1	mA	
			f(X _{IN}) = 4.2 MHz		1.8	2.7		
			f(X _{IN}) = 2.1 MHz		1.1	1.7		
		Middle-speed mode	V _{CC} = 5.0 V	f(X _{IN}) = 16.8 MHz		3.0	4.5	mA
				f(X _{IN}) = 12.5 MHz		2.4	3.6	
				f(X _{IN}) = 8.4 MHz		2.0	3.0	
				f(X _{IN}) = 16.8 MHz (in WIT state)		2.1	3.2	
			V _{CC} = 3.0 V	f(X _{IN}) = 12.5 MHz		1.7	2.6	mA
		f(X _{IN}) = 8.4 MHz			1.5	2.3		
		f(X _{IN}) = 6.3 MHz			1.3	2.0		
		Low-speed mode	V _{CC} = 5.0 V	f(X _{IN}) = stopped		410	630	μA
				In WIT state		4.5	6.8	
V _{CC} = 3.0 V	f(X _{IN}) = stopped			400	600	μA		
	In WIT state			3.7	5.6			
In STP state (All oscillation stopped)	T _a = 25 °C				0.55	3.0	μA	
	T _a = 85 °C				0.75			
Increment when A/D conversion is executed		f(X _{IN}) = 16.8 MHz, V _{CC} = 5.0 V In Middle-, high-speed mode				1000		μA

A/D converter characteristics

Table 23 A/D converter recommended operating conditions (Mask ROM version)
($V_{CC} = 2.0$ to 5.5 V, $V_{SS} = AV_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter	Conditions	Limits			Unit
			Min.	Typ.	Max.	
V _{CC}	Power source voltage (When A/D converter is used)	8-bit A/D mode ⁽¹⁾	2.0	5.0	5.5	V
		10-bit A/D mode ⁽²⁾	2.2	5.0	5.5	
V _{REF}	Analog convert reference voltage		2.0		V _{CC}	V
AV _{SS}	Analog power source voltage			0		V
V _{IA}	Analog input voltage AN ₀ -AN ₁₅		0		V _{CC}	V
f(X _{IN})	Main clock input oscillation frequency (When A/D converter is used)	$2.0 \leq V_{CC} = V_{REF} < 2.2$ V	0.5		$\frac{(20 \times V_{CC} - 36) \times 1.05}{2}$	MHz
		$2.2 \leq V_{CC} = V_{REF} < 2.7$ V	0.5		$\frac{(24 \times V_{CC} - 40.8) \times 1.05}{3}$	
		$2.7 \leq V_{CC} = V_{REF} < 4.0$ V	0.5		$\frac{(9 \times V_{CC} - 0.3) \times 1.05}{3}$	
		$4.0 \leq V_{CC} = V_{REF} < 4.5$ V	0.5		$\frac{(24.6 \times V_{CC} - 62.7) \times 1.05}{3}$	
		$4.5 \leq V_{CC} = V_{REF} \leq 5.5$ V	0.5		16.8	

NOTES:

1. 8-bit A/D mode: When the conversion mode selection bit (bit 7 of address 0038₁₆) is "1".
2. 10-bit A/D mode: When the conversion mode selection bit (bit 7 of address 0038₁₆) is "0".

Table 24 A/D converter characteristics (Mask ROM version)
($V_{CC} = 2.0$ to 5.5 V, $V_{SS} = AV_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter		Test conditions	Limits			Unit
				Min.	Typ.	Max.	
–	Resolution		8-bit A/D mode ⁽¹⁾			8	bit
			10-bit A/D mode ⁽²⁾			10	
–	Absolute accuracy (excluding quantization error)		8-bit A/D mode ⁽¹⁾	$2.0 \leq V_{REF} < 2.2$ V		±3	LSB
				$2.2 \leq V_{REF} \leq 5.5$ V		±2	
			10-bit A/D mode ⁽²⁾	$2.2 \leq V_{REF} < 2.7$ V		±5	LSB
				$2.7 \leq V_{REF} \leq 5.5$ V		±4	
t _{CONV}	Conversion time		8-bit A/D mode ⁽¹⁾			50	2t _c (X _{IN})
			10-bit A/D mode ⁽²⁾			61	
RLADDER	Ladder resistor			12	35	100	kΩ
I _{VREF}	Reference power source input current	at A/D converter operated	V _{REF} = 5.0 V	50	150	200	μA
		at A/D converter stopped	V _{REF} = 5.0 V			5.0	
I _{I(AD)}	A/D port input current					5.0	μA

NOTES:

1. 8-bit A/D mode: When the conversion mode selection bit (bit 7 of address 0038₁₆) is "1".
2. 10-bit A/D mode: When the conversion mode selection bit (bit 7 of address 0038₁₆) is "0".

D/A converter characteristics

Table 25 D/A converter characteristics (Mask ROM version)
($V_{CC} = 2.7$ to 5.5 V, $V_{REF} = 2.7$ V to V_{CC} , $V_{SS} = AV_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter		Limits			Unit
			Min.	Typ.	Max.	
–	Resolution				8	bit
–	Absolute accuracy		$4.0 \leq V_{REF} \leq 5.5$ V		1.0	%
			$2.7 \leq V_{REF} < 4.0$ V		2.5	
t _{su}	Setting time				3	μs
RO	Output resistor		2	3.5	5	kΩ
I _{VREF}	Reference power source input current ⁽¹⁾				3.2	mA

NOTE:

1. Using one D/A converter, with the value in the DA conversion register of the other D/A converter being "0016".

A/D converter characteristics

Table 26 A/D converter recommended operating conditions (Flash memory version)
($V_{CC} = 2.7$ to 5.5 V, $V_{SS} = AV_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter	Conditions	Limits			Unit
			Min.	Typ.	Max.	
V _{CC}	Power source voltage (When A/D converter is used)	8-bit A/D mode ⁽¹⁾	2.7	5.0	5.5	V
		10-bit A/D mode ⁽²⁾	2.7	5.0	5.5	
V _{REF}	Analog convert reference voltage		2.0		V _{CC}	V
AV _{SS}	Analog power source voltage			0		V
V _{IA}	Analog input voltage AN ₀ -AN ₁₅		0		V _{CC}	V
f(X _{IN})	Main clock input oscillation frequency (When A/D converter is used)	$2.7 \leq V_{CC} = V_{REF} < 4.0$ V	0.5		$\frac{(9 \times V_{CC} - 0.3) \times 1.05}{3}$	MHz
		$4.0 \leq V_{CC} = V_{REF} < 4.5$ V	0.5		$\frac{(24.6 \times V_{CC} - 62.7) \times 1.05}{3}$	
		$4.5 \leq V_{CC} = V_{REF} \leq 5.5$ V	0.5		16.8	

NOTES:

- 8-bit A/D mode: When the conversion mode selection bit (bit 7 of address 003816) is "1".
- 10-bit A/D mode: When the conversion mode selection bit (bit 7 of address 003816) is "0".

Table 27 A/D converter characteristics (Flash memory version)
($V_{CC} = 2.7$ to 5.5 V, $V_{SS} = AV_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter		Test conditions	Limits			Unit
				Min.	Typ.	Max.	
–	Resolution		8-bit A/D mode ⁽¹⁾			8	bit
			10-bit A/D mode ⁽²⁾			10	
–	Absolute accuracy (excluding quantization error)		8-bit A/D mode ⁽¹⁾	$2.7 \leq V_{REF} \leq 5.5$ V		±2	LSB
			10-bit A/D mode ⁽²⁾	$2.7 \leq V_{REF} \leq 5.5$ V		±4	LSB
t _{CONV}	Conversion time		8-bit A/D mode ⁽¹⁾			50	2t _c (X _{IN})
			10-bit A/D mode ⁽²⁾			61	
R _{LADDER}	Ladder resistor			12	35	100	kΩ
I _{VREF}	Reference power source input current	at A/D converter operated	V _{REF} = 5.0 V	50	150	200	μA
		at A/D converter stopped	V _{REF} = 5.0 V			5.0	μA
I _{I(AD)}	A/D port input current					5.0	μA

NOTES:

- 8-bit A/D mode: When the conversion mode selection bit (bit 7 of address 003816) is "1".
- 10-bit A/D mode: When the conversion mode selection bit (bit 7 of address 003816) is "0".

D/A converter characteristics

Table 28 D/A converter characteristics (Flash memory version)
($V_{CC} = 2.7$ to 5.5 V, $V_{REF} = 2.7$ V to V_{CC} , $V_{SS} = AV_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter		Limits			Unit
			Min.	Typ.	Max.	
–	Resolution				8	bit
–	Absolute accuracy	$4.0 \leq V_{REF} \leq 5.5$ V			1.0	%
		$2.7 \leq V_{REF} < 4.0$ V			2.5	
t _{su}	Setting time				3	μs
R _O	Output resistor		2	3.5	5	kΩ
I _{VREF}	Reference power source input current ⁽¹⁾				3.2	mA

NOTE:

- Using one D/A converter, with the value in the DA conversion register of the other D/A converter being "0016".

Power source circuit timing characteristics (Flash memory version)

Table 29 Power source circuit timing characteristics (Flash memory version)
($V_{CC} = 2.7$ to 5.5 V, $V_{REF} = 2.7$ V to V_{CC} , $V_{SS} = AV_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min.	Typ.	Max.	
td(P–R)	Internal power source stable time at power-on	$2.7 \leq V_{CC} < 5.5$ V			2	ms

Timing requirements and switching characteristics

Table 30 Timing requirements (1)

(Mask ROM version: $V_{CC} = 2.0$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)(Flash memory version: $V_{CC} = 2.7$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter		Limits			Unit
			Min.	Typ.	Max.	
$t_w(\overline{\text{RESET}})$	Reset input "L" pulse width		16			X_{IN} cycle
$t_c(X_{IN})$	Main clock X_{IN} input cycle time	$4.5 \leq V_{CC} \leq 5.5$ V	59.5			ns
		$4.0 \leq V_{CC} < 4.5$ V	$10000/(86 V_{CC} - 219)$			
		$2.7 \leq V_{CC} < 4.0$ V	$26 \times 10^3/(82 V_{CC} - 3)$			
		$2.2 \leq V_{CC} < 2.7$ V	$10000/(84 V_{CC} - 143)$			
		$2.0 \leq V_{CC} < 2.2$ V	$10000/(105 V_{CC} - 189)$			
$t_{WH}(X_{IN})$	Main clock X_{IN} input "H" pulse width	$4.5 \leq V_{CC} \leq 5.5$ V	25			ns
		$4.0 \leq V_{CC} < 4.5$ V	$4000/(86 V_{CC} - 219)$			
		$2.7 \leq V_{CC} < 4.0$ V	$10000/(82 V_{CC} - 3)$			
		$2.2 \leq V_{CC} < 2.7$ V	$4000/(84 V_{CC} - 143)$			
		$2.0 \leq V_{CC} < 2.2$ V	$4000/(105 V_{CC} - 189)$			
$t_{WL}(X_{IN})$	Main clock X_{IN} input "L" pulse width	$4.5 \leq V_{CC} \leq 5.5$ V	25			ns
		$4.0 \leq V_{CC} < 4.5$ V	$4000/(86 V_{CC} - 219)$			
		$2.7 \leq V_{CC} < 4.0$ V	$10000/(82 V_{CC} - 3)$			
		$2.2 \leq V_{CC} < 2.7$ V	$4000/(84 V_{CC} - 143)$			
		$2.0 \leq V_{CC} < 2.2$ V	$4000/(105 V_{CC} - 189)$			
$t_c(X_{CIN})$	Sub-clock X_{CIN} input cycle time		20			μ s
$t_{WH}(X_{CIN})$	Sub-clock X_{CIN} input "H" pulse width		5			μ s
$t_{WL}(X_{CIN})$	Sub-clock X_{CIN} input "L" pulse width		5			μ s
$t_c(\text{CNTR})$	CNTR_0 – CNTR_2 input cycle time	$4.5 \leq V_{CC} \leq 5.5$ V	120			ns
		$4.0 \leq V_{CC} < 4.5$ V	160			
		$2.7 \leq V_{CC} < 4.0$ V	250			
		$2.2 \leq V_{CC} < 2.7$ V	500			
		$2.0 \leq V_{CC} < 2.2$ V	1000			
$t_{WH}(\text{CNTR})$	CNTR_0 – CNTR_2 input "H" pulse width	$4.5 \leq V_{CC} \leq 5.5$ V	48			ns
		$4.0 \leq V_{CC} < 4.5$ V	64			
		$2.7 \leq V_{CC} < 4.0$ V	115			
		$2.2 \leq V_{CC} < 2.7$ V	230			
		$2.0 \leq V_{CC} < 2.2$ V	460			
$t_{WL}(\text{CNTR})$	CNTR_0 – CNTR_2 input "L" pulse width	$4.5 \leq V_{CC} \leq 5.5$ V	48			ns
		$4.0 \leq V_{CC} < 4.5$ V	64			
		$2.7 \leq V_{CC} < 4.0$ V	115			
		$2.2 \leq V_{CC} < 2.7$ V	230			
		$2.0 \leq V_{CC} < 2.2$ V	460			
$t_{WH}(\text{INT})$	INT_{00} , INT_{01} , INT_1 , INT_2 , INT_3 , INT_{40} , INT_{41} input "H" pulse width	$4.5 \leq V_{CC} \leq 5.5$ V	48			ns
		$4.0 \leq V_{CC} < 4.5$ V	64			
		$2.7 \leq V_{CC} < 4.0$ V	115			
		$2.2 \leq V_{CC} < 2.7$ V	230			
		$2.0 \leq V_{CC} < 2.2$ V	460			
$t_{WL}(\text{INT})$	INT_{00} , INT_{01} , INT_1 , INT_2 , INT_3 , INT_{40} , INT_{41} input "L" pulse width	$4.5 \leq V_{CC} \leq 5.5$ V	48			ns
		$4.0 \leq V_{CC} < 4.5$ V	64			
		$2.7 \leq V_{CC} < 4.0$ V	115			
		$2.2 \leq V_{CC} < 2.7$ V	230			
		$2.0 \leq V_{CC} < 2.2$ V	460			

Table 31 Timing requirements (2)

(Mask ROM version: $V_{CC} = 2.0$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)(Flash memory version: $V_{CC} = 2.7$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter	Limits			Unit
		Min.	Typ.	Max.	
tc(SCLK1) tc(SCLK3)	Serial I/O1, serial I/O3 clock input cycle time ⁽¹⁾	$4.5 \leq V_{CC} \leq 5.5$ V	250		ns
		$4.0 \leq V_{CC} < 4.5$ V	320		
		$2.7 \leq V_{CC} < 4.0$ V	500		
		$2.2 \leq V_{CC} < 2.7$ V	1000		
		$2.0 \leq V_{CC} < 2.2$ V	2000		
tWH(SCLK1) tWH(SCLK3)	Serial I/O1, serial I/O3 clock input "H" pulse width ⁽¹⁾	$4.5 \leq V_{CC} \leq 5.5$ V	120		ns
		$4.0 \leq V_{CC} < 4.5$ V	150		
		$2.7 \leq V_{CC} < 4.0$ V	240		
		$2.2 \leq V_{CC} < 2.7$ V	480		
		$2.0 \leq V_{CC} < 2.2$ V	950		
tWL(SCLK1) tWL(SCLK3)	Serial I/O1, serial I/O3 clock input "L" pulse width ⁽¹⁾	$4.5 \leq V_{CC} \leq 5.5$ V	120		ns
		$4.0 \leq V_{CC} < 4.5$ V	150		
		$2.7 \leq V_{CC} < 4.0$ V	240		
		$2.2 \leq V_{CC} < 2.7$ V	480		
		$2.0 \leq V_{CC} < 2.2$ V	950		
tsu(RxD1-SCLK1) tsu(RxD3-SCLK3)	Serial I/O1, serial I/O3 clock input setup time	$4.5 \leq V_{CC} \leq 5.5$ V	70		ns
		$4.0 \leq V_{CC} < 4.5$ V	90		
		$2.7 \leq V_{CC} < 4.0$ V	100		
		$2.2 \leq V_{CC} < 2.7$ V	200		
		$2.0 \leq V_{CC} < 2.2$ V	400		
th(SCLK1-RxD1) th(SCLK3-RxD3)	Serial I/O1, serial I/O3 clock input hold time	$4.5 \leq V_{CC} \leq 5.5$ V	32		ns
		$4.0 \leq V_{CC} < 4.5$ V	40		
		$2.7 \leq V_{CC} < 4.0$ V	50		
		$2.2 \leq V_{CC} < 2.7$ V	100		
		$2.0 \leq V_{CC} < 2.2$ V	200		
tc(SCLK2)	Serial I/O2 clock input cycle time	$4.5 \leq V_{CC} \leq 5.5$ V	500		ns
		$4.0 \leq V_{CC} < 4.5$ V	650		
		$2.7 \leq V_{CC} < 4.0$ V	1000		
		$2.2 \leq V_{CC} < 2.7$ V	2000		
		$2.0 \leq V_{CC} < 2.2$ V	4000		
tWH(SCLK2)	Serial I/O2 clock input "H" pulse width	$4.5 \leq V_{CC} \leq 5.5$ V	200		ns
		$4.0 \leq V_{CC} < 4.5$ V	260		
		$2.7 \leq V_{CC} < 4.0$ V	400		
		$2.2 \leq V_{CC} < 2.7$ V	950		
		$2.0 \leq V_{CC} < 2.2$ V	2000		
tWL(SCLK2)	Serial I/O2 clock input "L" pulse width	$4.5 \leq V_{CC} \leq 5.5$ V	200		ns
		$4.0 \leq V_{CC} < 4.5$ V	260		
		$2.7 \leq V_{CC} < 4.0$ V	400		
		$2.2 \leq V_{CC} < 2.7$ V	950		
		$2.0 \leq V_{CC} < 2.2$ V	2000		
tsu(SIN2-SCLK2)	Serial I/O2 clock input setup time	$4.5 \leq V_{CC} \leq 5.5$ V	100		ns
		$4.0 \leq V_{CC} < 4.5$ V	130		
		$2.7 \leq V_{CC} < 4.0$ V	200		
		$2.2 \leq V_{CC} < 2.7$ V	400		
		$2.0 \leq V_{CC} < 2.2$ V	800		
th(SCLK2-SIN2)	Serial I/O2 clock input hold time	$4.5 \leq V_{CC} \leq 5.5$ V	100		ns
		$4.0 \leq V_{CC} < 4.5$ V	130		
		$2.7 \leq V_{CC} < 4.0$ V	150		
		$2.2 \leq V_{CC} < 2.7$ V	300		
		$2.0 \leq V_{CC} < 2.2$ V	600		

NOTE:

- When bit 6 of address 001A₁₆ and bit 6 of address 0032₁₆ are "1" (clock synchronous).
Divide this value by four when bit 6 of address 001A₁₆ and bit 6 of address 0032₁₆ are "0" (UART).

Table 32 Switching characteristics (1)

(Mask ROM version: $V_{CC} = 2.0$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)(Flash memory version: $V_{CC} = 2.7$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min.	Typ.	Max.	
t _{WH} (SCLK1) t _{WH} (SCLK3)	Serial I/O1, serial I/O3 clock output "H" pulse width	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V	tc(SCLK1)/2-30, tc(SCLK3)/2-30 tc(SCLK1)/2-35, tc(SCLK3)/2-35 tc(SCLK1)/2-40, tc(SCLK3)/2-40 tc(SCLK1)/2-45, tc(SCLK3)/2-45 tc(SCLK1)/2-50, tc(SCLK3)/2-50			ns
t _{WL} (SCLK1) t _{WL} (SCLK3)	Serial I/O1, serial I/O3 clock output "L" pulse width	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V	tc(SCLK1)/2-30, tc(SCLK3)/2-30 tc(SCLK1)/2-35, tc(SCLK3)/2-35 tc(SCLK1)/2-40, tc(SCLK3)/2-40 tc(SCLK1)/2-45, tc(SCLK3)/2-45 tc(SCLK1)/2-50, tc(SCLK3)/2-50			ns
t _d (SCLK1-TxD1) t _d (SCLK3-TxD3)	Serial I/O1, serial I/O3 output delay time ⁽¹⁾	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V			140	ns
					200	
					350	
					400	
					420	
t _v (SCLK1-TxD1) t _v (SCLK3-TxD3)	Serial I/O1, serial I/O3 output valid time ⁽¹⁾	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V	-30 -30 -30 -30 -30			ns
t _r (SCLK1) t _r (SCLK3)	Serial I/O1, serial I/O3 rise time of clock output	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V			30	ns
					35	
					40	
					45	
					50	
t _f (SCLK1) t _f (SCLK3)	Serial I/O1, serial I/O3 fall time of clock output	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V			30	ns
					35	
					40	
					45	
					50	
t _{WH} (SCLK2)	Serial I/O2 clock output "H" pulse width	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V	tc(SCLK2)/2-160 tc(SCLK2)/2-200 tc(SCLK2)/2-240 tc(SCLK2)/2-260 tc(SCLK2)/2-280			ns
t _{WL} (SCLK2)	Serial I/O2 clock output "L" pulse width	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V	tc(SCLK2)/2-160 tc(SCLK2)/2-200 tc(SCLK2)/2-240 tc(SCLK2)/2-260 tc(SCLK2)/2-280			ns
t _d (SCLK2-SOUT2)	Serial I/O2 output delay time	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V			200	ns
					250	
					300	
					350	
					400	
t _v (SCLK2-SOUT2)	Serial I/O2 output valid time	4.5 ≤ V _{CC} ≤ 5.5 V 4.0 ≤ V _{CC} < 4.5 V 2.7 ≤ V _{CC} < 4.0 V 2.2 ≤ V _{CC} < 2.7 V 2.0 ≤ V _{CC} < 2.2 V			0	ns
					0	
					0	
					0	
					0	

Fig.100

NOTE:

- When the P4s/TxD1 P-channel output disable bit of the UART1 control register (bit 4 of address 001B16) is "0".

Table 33 Switching characteristics (2)

(Mask ROM version: $V_{CC} = 2.0$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)
 (Flash memory version: $V_{CC} = 2.7$ to 5.5 V, $V_{SS} = 0$ V, $T_a = -20$ to 85 °C, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min.	Typ.	Max.	
tr(SCLK2)	Serial I/O2 fall time of clock output	Fig.100	$4.5 \leq V_{CC} \leq 5.5$ V		30	ns
			$4.0 \leq V_{CC} < 4.5$ V		35	
			$2.7 \leq V_{CC} < 4.0$ V		40	
			$2.2 \leq V_{CC} < 2.7$ V		45	
			$2.0 \leq V_{CC} < 2.2$ V		50	
tr(CMOS)	CMOS rise time of output ⁽¹⁾	Fig.100	$4.5 \leq V_{CC} \leq 5.5$ V	10	30	ns
			$4.0 \leq V_{CC} < 4.5$ V	12	35	
			$2.7 \leq V_{CC} < 4.0$ V	15	40	
			$2.2 \leq V_{CC} < 2.7$ V	17	45	
			$2.0 \leq V_{CC} < 2.2$ V	20	50	
tr(CMOS)	CMOS fall time of output ⁽¹⁾	Fig.100	$4.5 \leq V_{CC} \leq 5.5$ V	10	30	ns
			$4.0 \leq V_{CC} < 4.5$ V	12	35	
			$2.7 \leq V_{CC} < 4.0$ V	15	40	
			$2.2 \leq V_{CC} < 2.7$ V	17	45	
			$2.0 \leq V_{CC} < 2.2$ V	20	50	

NOTE:

1. When the P35/TxD3 P4-channel output disable bit of the UART3 control register (bit 4 of address 003316) is "0".

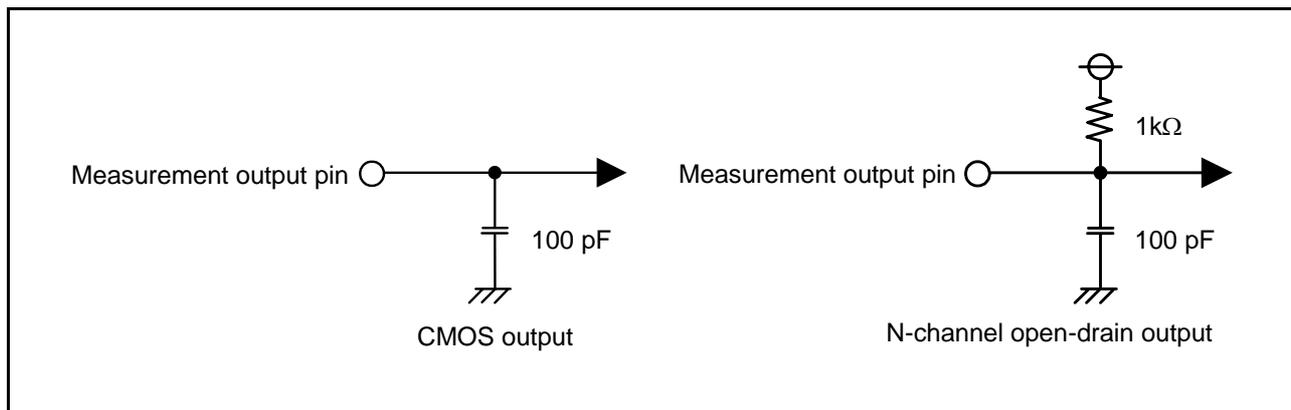


Fig 100. Circuit for measuring output switching characteristics

Single-chip mode timing diagram

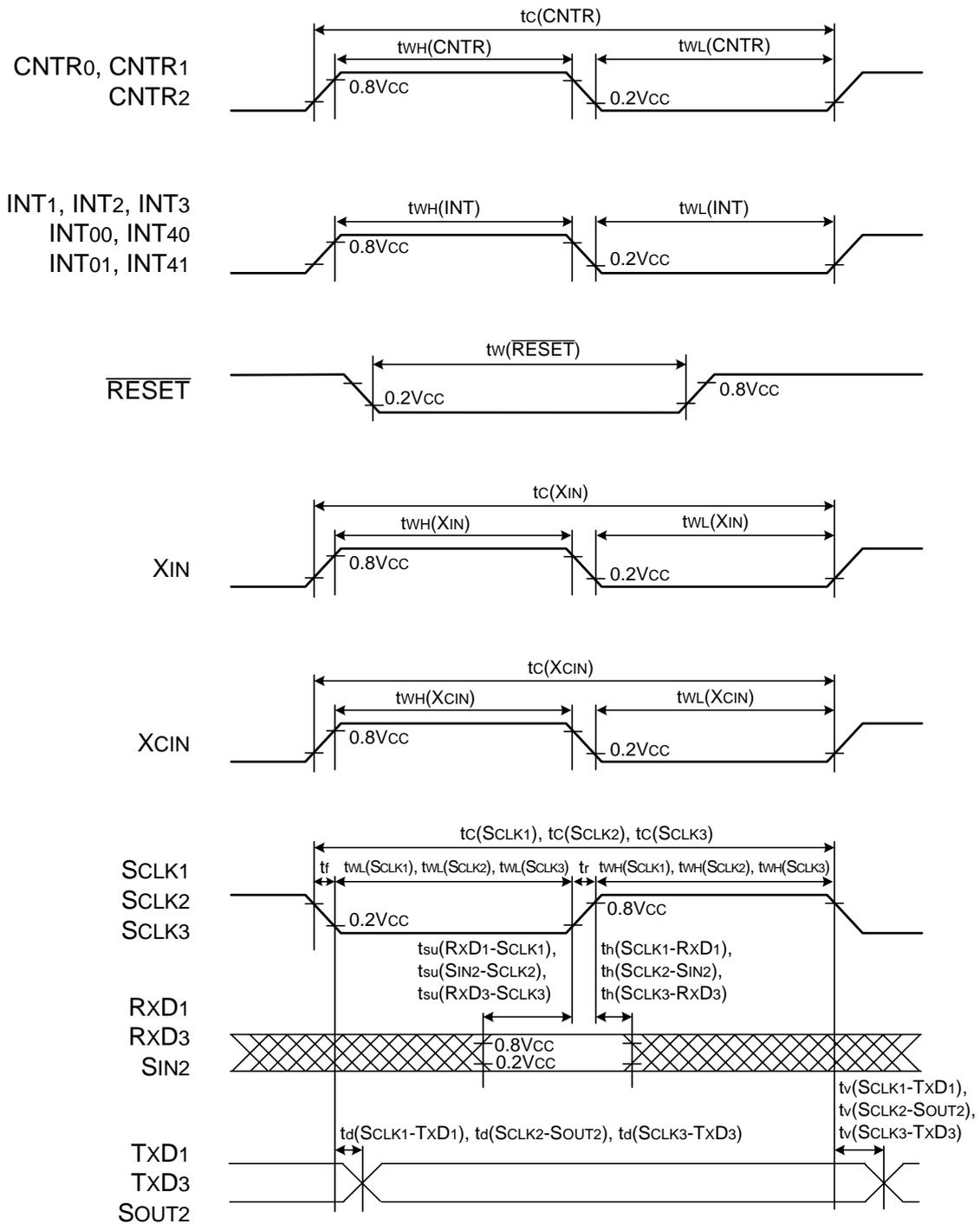
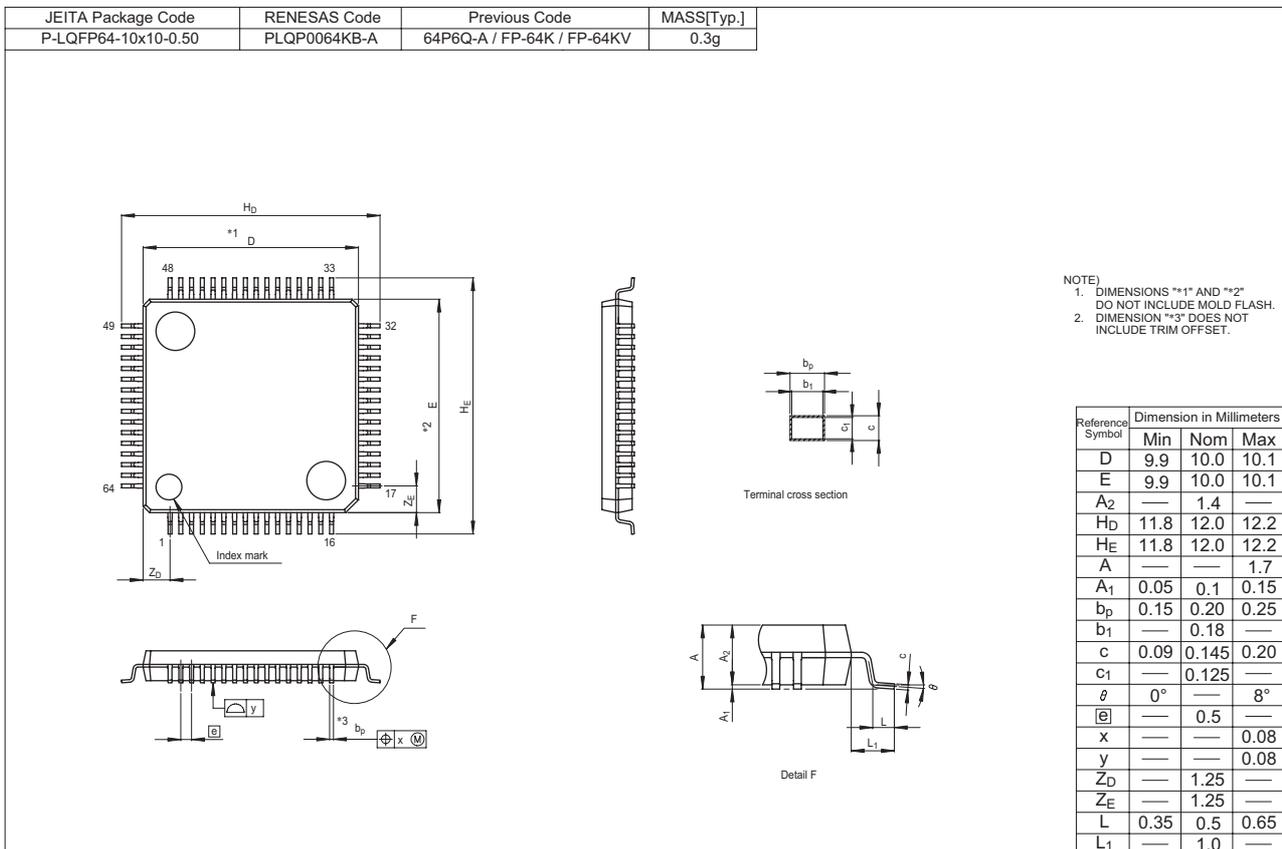
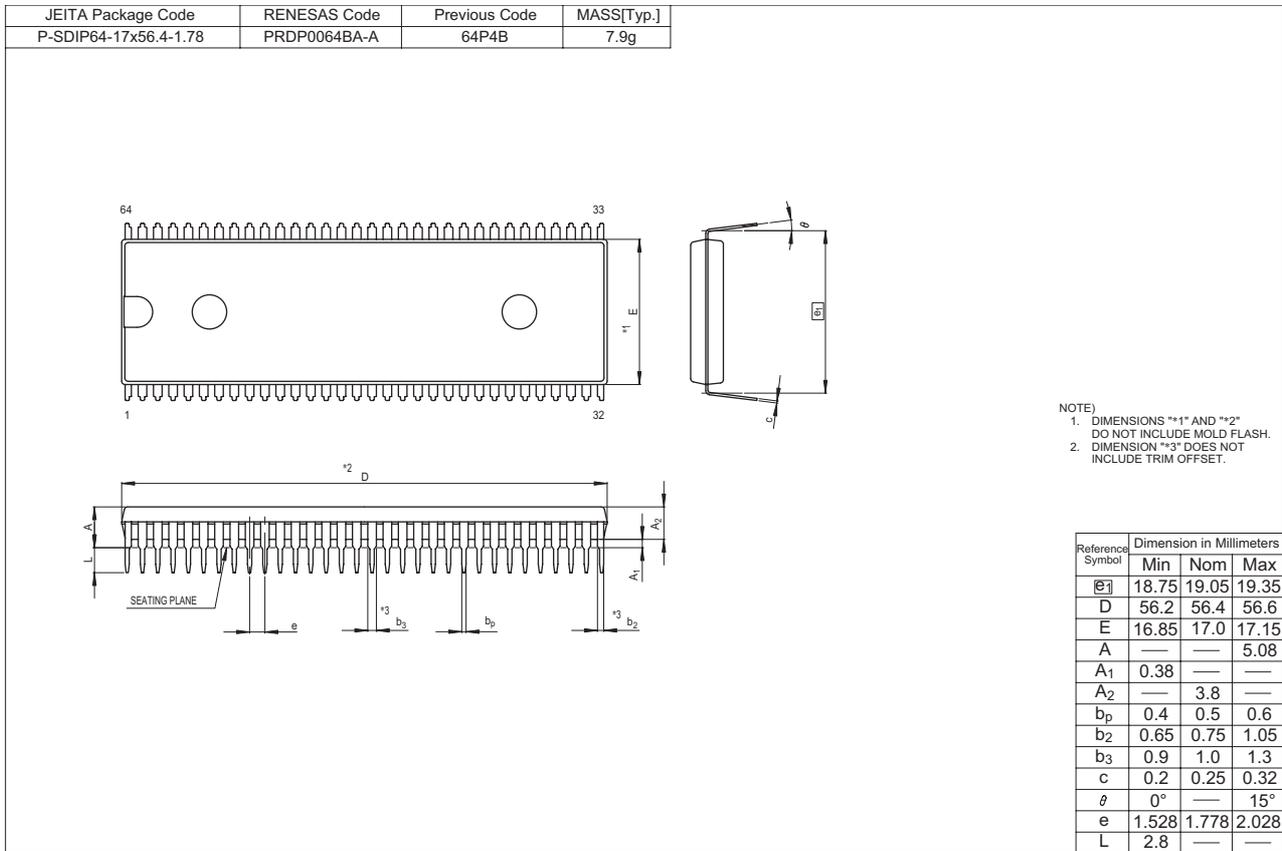
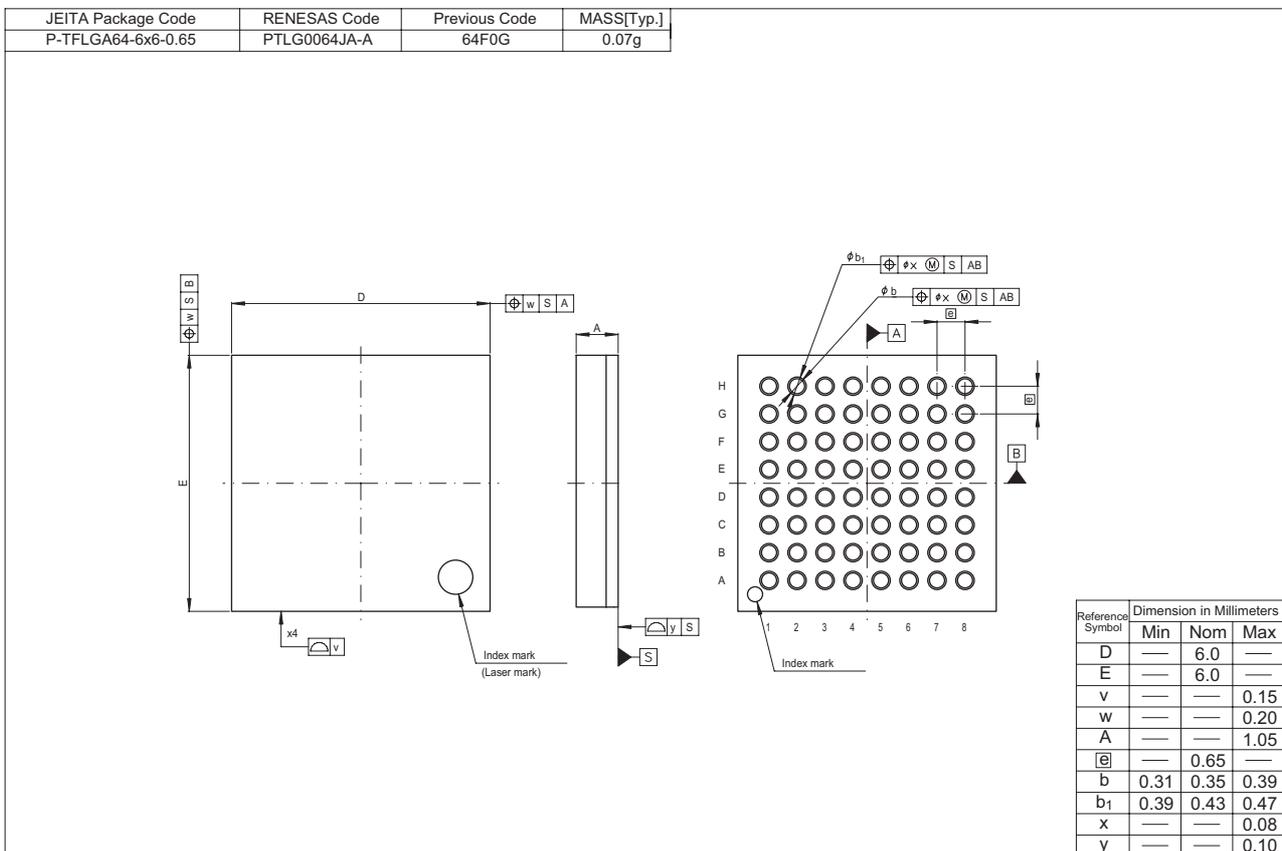
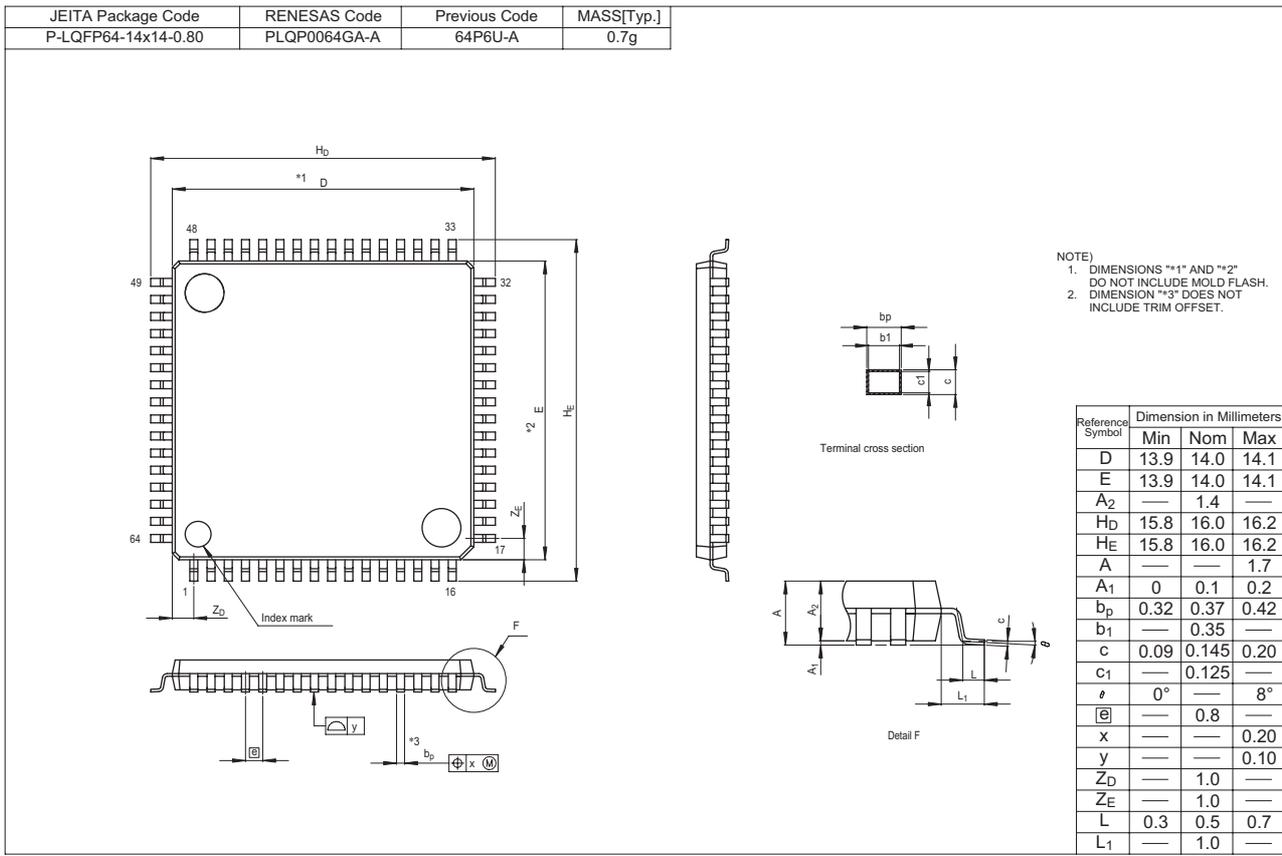


Fig 101. Timing diagram (in single-chip mode)

PACKAGE OUTLINE

Diagrams showing the latest package dimensions and mounting information are available in the “Packages” section of the Renesas Technology website.





REVISION HISTORY	3803 Group (Spec.L) Data Sheet
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Rev.	Date	Description	
		Page	Summary
1.00	Apr.2, 2007	-	First edition issued
1.01	Jan.25, 2008	110	The title "Power source circuit timing characteristics (Flash memory version)" is added and the value "2 ms" is revised from minimum value to maximum value.

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