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# User's Manual

## 78K0/KB1

### 8-Bit Single-Chip Microcontrollers

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|                                  |                                     |                                      |                                     |
|----------------------------------|-------------------------------------|--------------------------------------|-------------------------------------|
| <b><math>\mu</math>PD780101</b>  | <b><math>\mu</math>PD780101(A)</b>  | <b><math>\mu</math>PD780101(A1)</b>  | <b><math>\mu</math>PD780101(A2)</b> |
| <b><math>\mu</math>PD780102</b>  | <b><math>\mu</math>PD780102(A)</b>  | <b><math>\mu</math>PD780102(A1)</b>  | <b><math>\mu</math>PD780102(A2)</b> |
| <b><math>\mu</math>PD780103</b>  | <b><math>\mu</math>PD780103(A)</b>  | <b><math>\mu</math>PD780103(A1)</b>  | <b><math>\mu</math>PD780103(A2)</b> |
| <b><math>\mu</math>PD78F0103</b> | <b><math>\mu</math>PD78F0103(A)</b> | <b><math>\mu</math>PD78F0103(A1)</b> |                                     |

Document No. U15836EJ5V0UD00 (5th edition)

Date Published February 2005 N CP(K)

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Printed in Japan

[MEMO]

## NOTES FOR CMOS DEVICES

### ① VOLTAGE APPLICATION WAVEFORM AT INPUT PIN

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between  $V_{IL}$  (MAX) and  $V_{IH}$  (MIN) due to noise, etc., the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between  $V_{IL}$  (MAX) and  $V_{IH}$  (MIN).

### ② HANDLING OF UNUSED INPUT PINS

Unconnected CMOS device inputs can be cause of malfunction. If an input pin is unconnected, it is possible that an internal input level may be generated due to noise, etc., causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using pull-up or pull-down circuitry. Each unused pin should be connected to  $V_{DD}$  or GND via a resistor if there is a possibility that it will be an output pin. All handling related to unused pins must be judged separately for each device and according to related specifications governing the device.

### ③ PRECAUTION AGAINST ESD

A strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it when it has occurred. Environmental control must be adequate. When it is dry, a humidifier should be used. It is recommended to avoid using insulators that easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors should be grounded. The operator should be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with mounted semiconductor devices.

### ④ STATUS BEFORE INITIALIZATION

Power-on does not necessarily define the initial status of a MOS device. Immediately after the power source is turned ON, devices with reset functions have not yet been initialized. Hence, power-on does not guarantee output pin levels, I/O settings or contents of registers. A device is not initialized until the reset signal is received. A reset operation must be executed immediately after power-on for devices with reset functions.

### ⑤ POWER ON/OFF SEQUENCE

In the case of a device that uses different power supplies for the internal operation and external interface, as a rule, switch on the external power supply after switching on the internal power supply. When switching the power supply off, as a rule, switch off the external power supply and then the internal power supply. Use of the reverse power on/off sequences may result in the application of an overvoltage to the internal elements of the device, causing malfunction and degradation of internal elements due to the passage of an abnormal current.

The correct power on/off sequence must be judged separately for each device and according to related specifications governing the device.

### ⑥ INPUT OF SIGNAL DURING POWER OFF STATE

Do not input signals or an I/O pull-up power supply while the device is not powered. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Input of signals during the power off state must be judged separately for each device and according to related specifications governing the device.

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- Device availability
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- Product release schedule
- Availability of related technical literature
- Development environment specifications (for example, specifications for third-party tools and components, host computers, power plugs, AC supply voltages, and so forth)
- Network requirements

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## INTRODUCTION

### Readers

This manual is intended for user engineers who wish to understand the functions of the 78K0/KB1 and design and develop application systems and programs for these devices.

The target products are as follows.

78K0/KB1:  $\mu$ PD780101, 780102, 780103, 78F0103, 780101(A), 780102(A),  
780103(A), 78F0103(A), 780101(A1), 780102(A1), 780103(A1),  
78F0103(A1), 780101(A2), 780102(A2), 780103(A2)

### Purpose

This manual is intended to give users an understanding of the functions described in the **Organization** below.

### Organization

The 78K0/KB1 manual is separated into two parts: this manual and the instructions edition (common to the 78K/0 Series).

**78K0/KB1  
User's Manual  
(This Manual)**

**78K/0 Series  
User's Manual  
Instructions**

- Pin functions
- Internal block functions
- Interrupts
- Other on-chip peripheral functions
- Electrical specifications
- CPU functions
- Instruction set
- Explanation of each instruction

## How to Read This Manual

It is assumed that the readers of this manual have general knowledge of electrical engineering, logic circuits, and microcontrollers.

- When using this manual as the manual for (A) grade, (A1) grade, and (A2) grade products:
  - Only the quality grade differs between standard products and (A) grade, (A1) grade, and (A2) grade products. Read the part number as follows.
    - $\mu$ PD780101 →  $\mu$ PD780101(A), 780101(A1), 780101(A2)
    - $\mu$ PD780102 →  $\mu$ PD780102(A), 780102(A1), 780102(A2)
    - $\mu$ PD780103 →  $\mu$ PD780103(A), 780103(A1), 780103(A2)
    - $\mu$ PD78F0103 →  $\mu$ PD78F0103(A), 78F0103(A1)
- To gain a general understanding of functions:
  - Read this manual in the order of the **CONTENTS**. The mark ★ shows major revised points.
- ★ How to interpret the register format:
  - For a bit number enclosed in angle brackets, the bit name is defined as a reserved word in the RA78K0, and is defined as an sfr variable using the #pragma sfr directive in the CC78K0.
- To check the details of a register when you know the register name:
  - See **APPENDIX C REGISTER INDEX**.
- To know details of the 78K/0 Series instructions:
  - Refer to the separate document **78K/0 Series Instructions User's Manual (U12326E)**.

**Caution** Examples in this manual employ the “standard” quality grade for general electronics. When using examples in this manual for the “special” quality grade, review the quality grade of each part and/or circuit actually used.

## Conventions

|                             |  |
|-----------------------------|--|
| Data significance:          | Higher digits on the left and lower digits on the right      |
| Active low representations: | $\overline{\text{xxx}}$ (overscore over pin and signal name) |
| <b>Note:</b>                | Footnote for item marked with <b>Note</b> in the text        |
| <b>Caution:</b>             | Information requiring particular attention                   |
| <b>Remark:</b>              | Supplementary information                                    |
| Numerical representations:  | Binary      ...xxxx or xxxxB                                 |
|                             | Decimal      ...xxxx   |
|                             | Hexadecimal    ...xxxxH                                      |

★ **Differences Between 78K0/KB1 and 78K0/KB1+**

| Series Name                        |                           | 78K0/KB1  | 78K0/KB1+  |
|------------------------------------|---------------------------|---|--|
| Item                               |                           |   |  |
| Mask ROM version                   |                           | Available   | None   |
| Flash memory version               | Power supply              | Two power supplies                                  | Single power supply                                  |
|                                    | Self-programming function | None  | Available  |
|                                    | Option byte               | None  | Ring-OSC can be stopped/cannot be stopped selectable |
| Power-on clear function            |                           | 2.85 V $\pm$ 0.15 V or 3.5 V $\pm$ 0.2 V selectable | 2.1 V $\pm$ 0.1 V (fixed) <sup>Note</sup>            |
| Minimum instruction execution time |                           | 0.166 $\mu$ s (at 12 MHz operation)                 | 0.125 $\mu$ s (at 16 MHz operation)                  |

**Note** This value may change after evaluation.

- ★ **Related Documents** The related documents indicated in this publication may include preliminary versions. However, preliminary versions are not marked as such.

**Documents Related to Devices**

| Document Name                           | Document No. |
|---|--------------|
| 78K0/KB1 User's Manual                  | This manual  |
| 78K0/KB1+ User's Manual                 | U16846E      |
| 78K/0 Series Instructions User's Manual | U12326E      |

**Documents Related to Development Tools (Software) (User's Manuals)**

| Document Name                           | Document No.                                     |         |
|---|--|---------|
| RA78K0 Assembler Package                | Operation  | U16629E |
|   | Language   | U14446E |
|   | Structured Assembly Language                     | U11789E |
| CC78K0 C Compiler                       | Operation  | U16613E |
|   | Language   | U14298E |
| SM78K Series Ver. 2.52 System Simulator | Operation  | U16768E |
|   | External Part User Open Interface Specifications | U15802E |
| ID78K0-NS Ver. 2.52 Integrated Debugger | Operation  | U16488E |
| ID78K0-QB Ver. 2.81 Integrated Debugger | Operation  | U16996E |
| PM plus Ver. 5.10                       |  | U16569E |

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**Documents Related to Development Tools (Hardware) (User's Manuals)**

| Document Name                    | Document No.   |
|----------------------------------|----------------|
| IE-78K0-NS In-Circuit Emulator   | U13731E        |
| IE-78K0-NS-A In-Circuit Emulator | U14889E        |
| IE-78K0K1-ET In-Circuit Emulator | U16604E        |
| QB-78K0KX1H In-Circuit Emulator  | U17081E        |
| IE-780148-NS-EM1 Emulation Board | To be prepared |

**Documents Related to Flash Memory Programming**

| Document Name                                | Document No. |
|--|--------------|
| PG-FP3 Flash Memory Programmer User's Manual | U13502E      |
| PG-FP4 Flash Memory Programmer User's Manual | U15260E      |

**Other Documents**

| Document Name  | Document No. |
|--|--------------|
| SEMICONDUCTOR SELECTION GUIDE – Products and Packages –                            | X13769X      |
| Semiconductor Device Mount Manual  | <b>Note</b>  |
| Quality Grades on NEC Semiconductor Devices  | C11531E      |
| NEC Semiconductor Device Reliability/Quality Control System                        | C10983E      |
| Guide to Prevent Damage for Semiconductor Devices by Electrostatic Discharge (ESD) | C11892E      |

**Note** See the "Semiconductor Device Mount Manual" website (<http://www.necel.com/pkg/en/mount/index.html>).

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## CHAPTER 1 OUTLINE

### ★ 1.1 Expanded-Specification Products and Conventional Products (Standard Products, (A) Grade Products Only)

The expanded-specification products and conventional products refer to the following products.

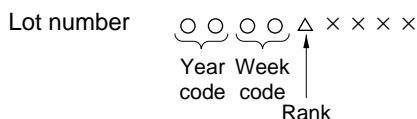
Expanded-specification products: Products with a rank<sup>Note</sup> E or after

- Mask ROM version for which order was received on or after mid-March, 2004
- Flash memory version for which order was received on or after mid-July, 2004

Conventional products: Products with rank<sup>Note</sup> I or K

- Products other than the above expanded-specification products

**Note** The rank is indicated by the 5th digit from the left in the 3rd column (lot number) marked on the package.



Expanded-specification products and conventional products of standard products and (A) grade products differ in the operating frequency ratings. Table 1-1 shows the differences between these products.

**Table 1-1. Differences Between Expanded-Specification Products and Conventional Products of Standard Products and (A) Grade Products**

| Guaranteed Operating Speed<br>(Minimum Instruction Execution Time) | Power Supply Voltage ( $V_{DD}$ )     |   |
|--|---------------------------------------|---|
|  | Conventional Products<br>(Rank: I, K) | Expanded-Specification Products<br>(Rank: E or After) |
| 12 MHz (0.166 $\mu$ s)   | Not used                              | 4.0 to 5.5 V  |
| 10 MHz (0.2 $\mu$ s)   | 4.0 to 5.5 V                          | 3.5 to 4.0 V  |
| 8.38 MHz (0.238 $\mu$ s)   | 3.3 to 4.0 V                          | 3.0 to 3.5 V  |
| 5 MHz (0.4 $\mu$ s)  | 2.7 to 3.3 V                          | 2.5 to 3.0 V  |

**Cautions** 1. The specifications of the peripheral functions (such as the timer, serial interface, and A/D converter) at  $V_{DD} = 2.7$  to 5.5 V remain unchanged. Consequently when selecting the count clock or base clock of a peripheral function, set to satisfy the following conditions.

- $V_{DD} = 4.0$  to 5.5 V: Count clock or base clock  $\leq 10$  MHz
- $V_{DD} = 3.3$  to 4.0 V: Count clock or base clock  $\leq 8.38$  MHz
- $V_{DD} = 2.7$  to 3.3 V: Count clock or base clock  $\leq 5$  MHz
- $V_{DD} = 2.5$  to 2.7 V: Count clock or base clock  $\leq 2.5$  MHz

2. Rewrite the flash memory within the ranges of  $f_x = 2$  to 10 MHz and  $V_{DD} = 2.7$  to 5.5 V as before.

## 1.2 Features

- ★ ○ Minimum instruction execution time can be changed from high speed (0.166  $\mu$ s: @ 12 MHz operation with X1 input clock) to low-speed (2.666  $\mu$ s: @ 12 MHz operation with X1 input clock)
- General-purpose register: 8 bits  $\times$  32 registers (8 bits  $\times$  8 registers  $\times$  4 banks)
- ROM, RAM capacities

| Item \ Part Number | Program Memory (ROM) |                       | Data Memory (Internal High-Speed RAM) |
|--------------------|----------------------|-----------------------|---------------------------------------|
| $\mu$ PD780101     | Mask ROM             | 8 KB                  | 512 bytes                             |
| $\mu$ PD780102     |                      | 16 KB                 | 768 bytes                             |
| $\mu$ PD780103     |                      | 24 KB                 |                                       |
| $\mu$ PD78F0103    | Flash memory         | 24 KB <sup>Note</sup> |                                       |

**Note** The internal flash memory and internal high-speed RAM capacities can be changed using the internal memory size switching register (IMS).

- On-chip power-on-clear (POC) circuit and low-voltage detector (LVI)
- Short startup is possible via the CPU default start using the on-chip Ring-OSC
- On-chip clock monitor function using on-chip Ring-OSC
- On-chip watchdog timer (operable with Ring-OSC clock)
- I/O ports: 22
- Timer: 5 channels
- Serial interface: 2 channels
  - UART (LIN (Local Interconnect Network)-bus supported): 1 channel
  - CSI1/UART<sup>Note 1</sup>: 1 channel ( $\mu$ PD780101 only, CSI1: 1 channel)
- 10-bit resolution A/D converter: 4 channels
- ★ ○ Supply voltage:  $V_{DD} = 2.5$  to  $5.5$  V<sup>Notes 2, 3</sup> (expanded-specification products of standard and (A) grade products)
  - $V_{DD} = 2.7$  to  $5.5$  V<sup>Notes 2, 3</sup> (conventional products of standard and (A) grade products)
  - $V_{DD} = 3.3$  to  $5.5$  V<sup>Note 3</sup> ((A1) grade and (A2) grade products)
- Operating ambient temperature:  $T_A = -40$  to  $+85^\circ\text{C}$  (standard and (A) grade products)
  - $T_A = -40$  to  $+105^\circ\text{C}$  (flash memory version of (A1) grade product)
  - $T_A = -40$  to  $+110^\circ\text{C}$  (mask ROM version of (A1) grade product)
  - $T_A = -40$  to  $+125^\circ\text{C}$  (mask ROM version of (A2) grade product)

**Notes 1.** Select either of the functions of these alternate-function pins.

- ★ **2.** If the POC circuit detection voltage ( $V_{POC}$ ) is used with  $2.85$  V  $\pm 0.15$  V, then use the products in the voltage range of 3.0 to 5.5 V.
- ★ **3.** If the POC circuit detection voltage ( $V_{POC}$ ) is used with  $3.5$  V  $\pm 0.2$  V, then use the products in the voltage range of 3.7 to 5.5 V.

### 1.3 Applications

- Automotive equipment
  - System control for body electricals (power windows, keyless entry reception, etc.)
  - Sub-microcontrollers for control
- Home audio, car audio
- AV equipment
- PC peripheral equipment (keyboards, etc.)
- Household electrical appliances
  - Outdoor air conditioner units
  - Microwave ovens, electric rice cookers
- Industrial equipment
  - Pumps
  - Vending machines
  - FA (Factory Automation)

## 1.4 Ordering Information

### (1) Mask ROM version

| Part Number                  | Package                             | Quality Grade |
|------------------------------|-------------------------------------|---------------|
| $\mu$ PD780101MC-xxx-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD780102MC-xxx-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD780103MC-xxx-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD780101MC(A)-xxx-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD780102MC(A)-xxx-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD780103MC(A)-xxx-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD780101MC(A1)-xxx-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD780102MC(A1)-xxx-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD780103MC(A1)-xxx-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD780101MC(A2)-xxx-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD780102MC(A2)-xxx-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD780103MC(A2)-xxx-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |

### (2) Flash memory version

| Part Number                 | Package                             | Quality Grade |
|-----------------------------|-------------------------------------|---------------|
| $\mu$ PD78F0103M1MC-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD78F0103M2MC-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD78F0103M3MC-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD78F0103M4MC-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD78F0103M5MC-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD78F0103M6MC-5A4     | 30-pin plastic SSOP (7.62 mm (300)) | Standard      |
| $\mu$ PD78F0103M1MC(A)-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M2MC(A)-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M3MC(A)-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M4MC(A)-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M5MC(A)-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M6MC(A)-5A4  | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M1MC(A1)-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M2MC(A1)-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M5MC(A1)-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |
| $\mu$ PD78F0103M6MC(A1)-5A4 | 30-pin plastic SSOP (7.62 mm (300)) | Special       |

**Remark** xxx indicates ROM code suffix.

Please refer to "Quality Grades on NEC Semiconductor Devices" (Document No. C11531E) published by NEC Electronics Corporation to know the specification of quality grade on the devices and its recommended applications.

Mask ROM versions ( $\mu$ PD780101, 780102, and 780103) include mask options. When ordering, it is possible to select “Power-on-clear (POC) circuit can be used/cannot be used” and “Ring-OSC can be stopped/cannot be stopped by software”.

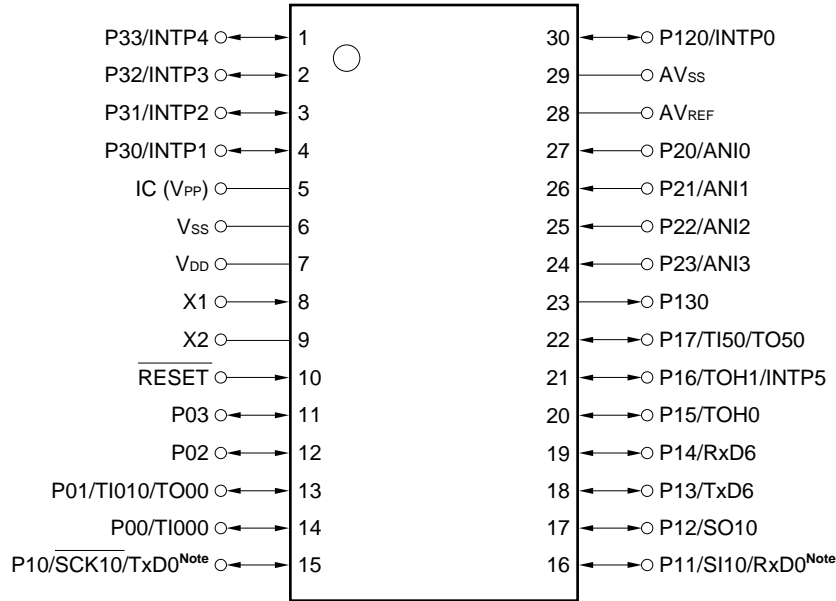
Flash memory versions supporting the mask options of the mask ROM versions are as follows.

**Table 1-2. Flash Memory Versions Supporting Mask Options of Mask ROM Versions**

| Mask Option  |                            | Flash Memory Versions<br>(Part Number)   |
|--|----------------------------|--|
| POC Circuit  | Ring-OSC                   |  |
| POC cannot be used                                       | Cannot be stopped          | $\mu$ PD78F0103M1MC-5A4<br>$\mu$ PD78F0103M1MC(A)-5A4<br>$\mu$ PD78F0103M1MC(A1)-5A4 |
|  | Can be stopped by software | $\mu$ PD78F0103M2MC-5A4<br>$\mu$ PD78F0103M2MC(A)-5A4<br>$\mu$ PD78F0103M2MC(A1)-5A4 |
| POC used ( $V_{POC} = 2.85\text{ V} \pm 0.15\text{ V}$ ) | Cannot be stopped          | $\mu$ PD78F0103M3MC-5A4<br>$\mu$ PD78F0103M3MC(A)-5A4                                |
|  | Can be stopped by software | $\mu$ PD78F0103M4MC-5A4<br>$\mu$ PD78F0103M4MC(A)-5A4                                |
| POC used ( $V_{POC} = 3.5\text{ V} \pm 0.2\text{ V}$ )   | Cannot be stopped          | $\mu$ PD78F0103M5MC-5A4<br>$\mu$ PD78F0103M5MC(A)-5A4<br>$\mu$ PD78F0103M5MC(A1)-5A4 |
|  | Can be stopped by software | $\mu$ PD78F0103M6MC-5A4<br>$\mu$ PD78F0103M6MC(A)-5A4<br>$\mu$ PD78F0103M6MC(A1)-5A4 |

### 1.5 Pin Configuration (Top View)

- 30-pin plastic SSOP (7.62 mm (300))



**Note** TxD0 and RxD0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.

- Cautions**
1. Connect the IC (Internally Connected) pin directly to Vss.
  2. Connect the AVss pin to Vss.
  3. Connect the VPP pin to Vss during normal operation.

**Remark** Figures in parentheses apply only to the  $\mu$ PD78F0103.

#### Pin Identification

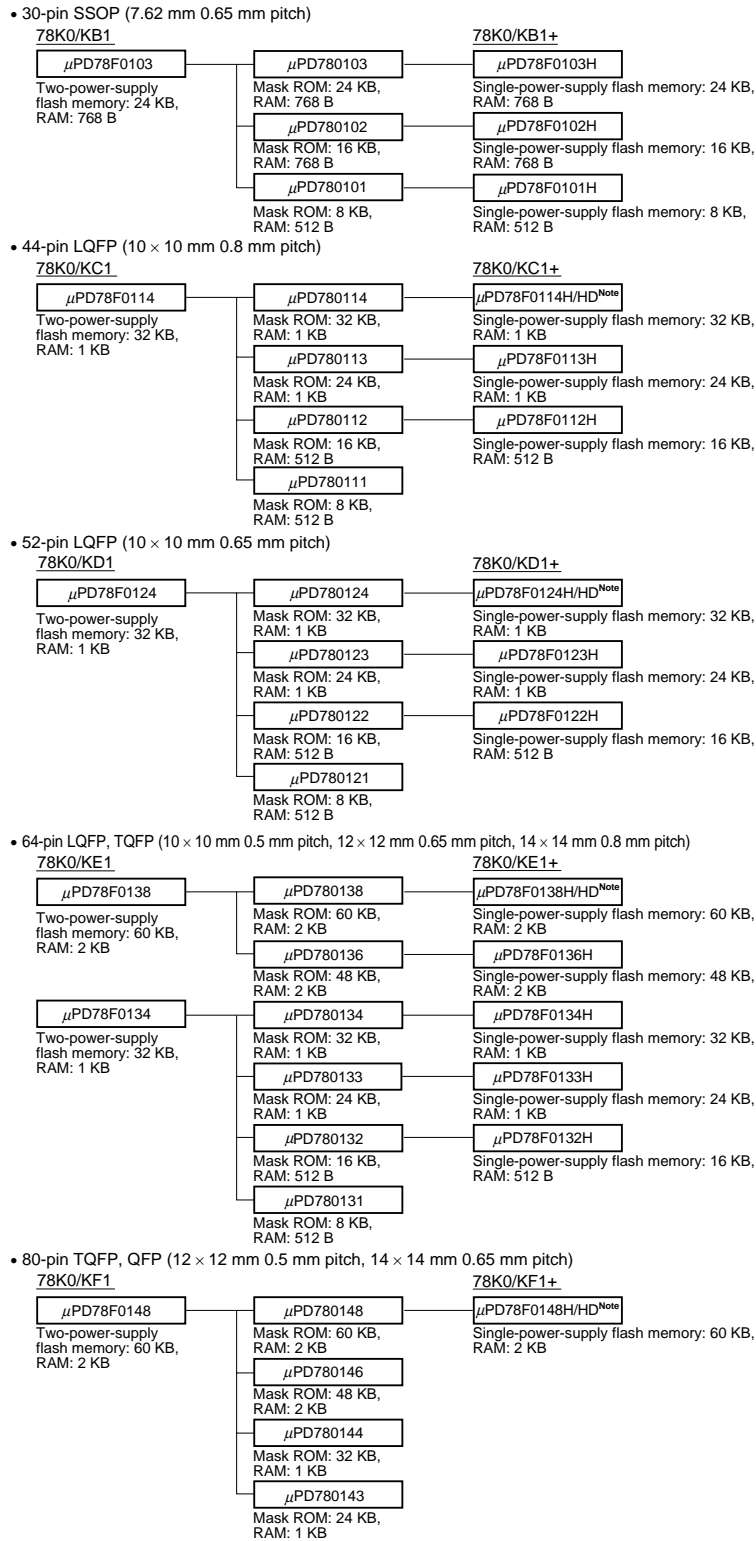
|                             |                          |                              |                                     |
|-----------------------------|--------------------------|------------------------------|-------------------------------------|
| ANI0 to ANI3:               | Analog input             | RxD0 <sup>Note</sup> , RxD6: | Receive data                        |
| AVREF:                      | Analog reference voltage | $\overline{\text{SCK10}}$ :  | Serial clock input/output           |
| IC:                         | Internally connected     | SI10:                        | Serial data input                   |
| INTP0 to INTP5:             | External interrupt input | SO10:                        | Serial data output                  |
| P00 to P03:                 | Port 0                   | TI000, TI010, TI50:          | Timer input                         |
| P10 to P17:                 | Port 1                   | TO00, TO50, TOH0, TOH1:      | Timer output                        |
| P20 to P23:                 | Port 2                   | TxD0 <sup>Note</sup> , TxD6: | Transmit data                       |
| P30 to P33:                 | Port 3                   | VDD:                         | Power supply                        |
| P120:                       | Port 12                  | VPP:                         | Programming power supply            |
| P130:                       | Port 13                  | VSS:                         | Ground                              |
| $\overline{\text{RESET}}$ : | Reset                    | X1, X2:                      | Crystal oscillator (X1 input clock) |

**Note** TxD0 and RxD0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.



★ 1.6 Kx1 Series Lineup

1.6.1 78K0/Kx1, 78K0/Kx1+ product lineup



**Note** Product with on-chip debug function

The list of functions in the 78K0/Kx1 is shown below.

| Part Number                        |                                       | 78K0/KB1  |       |    | 78K0/KC1   |       |   | 78K0/KD1 |       |    | 78K0/KE1 |          |          |       | 78K0/KF1 |       |       |    |      |  |  |
|------------------------------------|---------------------------------------|---|-------|----|------------|-------|---|----------|-------|----|----------|----------|----------|-------|----------|-------|-------|----|------|--|--|
| Item                               |                                       |   |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Number of pins                     |                                       | 30 pins   |       |    | 44 pins    |       |   | 52 pins  |       |    | 64 pins  |          |          |       | 80 pins  |       |       |    |      |  |  |
| Internal memory (KB)               | Mask ROM                              | 8   | 16/24 | –  | 8/16       | 24/32 | –   | 8/16     | 24/32 | –  | 8/16     | 24/32    | –        | 48/60 | –        | 24/32 | 48/60 | –  |      |  |  |
|                                    | Flash memory                          | –   |       | 24 | –          |       | 32  | –        |       | 32 | –        |          | 32       | –     | 60       | –     |       | 60 |      |  |  |
|                                    | RAM                                   | 0.5   | 0.75  | –  | 0.5        | 1     | –   | 0.5      | 1     | –  | 0.5      | 1        | –        | 2     | –        | 1     | 2     | –  |      |  |  |
| Power supply voltage               |                                       | V <sub>DD</sub> = 2.5 to 5.5 V <sup>Notes 1, 2</sup>  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Minimum instruction execution time |                                       | 0.166 μs (when 12 MHz, V <sub>DD</sub> = 4.0 to 5.5 V)<br>0.2 μs (when 10 MHz, V <sub>DD</sub> = 3.5 to 5.5 V)<br>0.238 μs (when 8.38 MHz, V <sub>DD</sub> = 3.0 to 5.5 V)<br>0.4 μs (when 5 MHz, V <sub>DD</sub> = 2.5 to 5.5 V) |       |    |            |       | <Connect REGC pin to V <sub>DD</sub> ><br>0.166 μs (when 12 MHz, V <sub>DD</sub> = 4.0 to 5.5 V)<br>0.2 μs (when 10 MHz, V <sub>DD</sub> = 3.5 to 5.5 V)<br>0.238 μs (when 8.38 MHz, V <sub>DD</sub> = 3.0 to 5.5 V)<br>0.4 μs (when 5 MHz, V <sub>DD</sub> = 2.5 to 5.5 V) |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Clock                              | X1 input                              | 2 to 12 MHz   |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | Subclock                              | –   |       |    | 32.768 kHz |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | Ring-OSC                              | 240 kHz (TYP.)  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Port                               | CMOS I/O                              | 17  |       |    | 19         |       |   | 26       |       |    | 38       |          |          |       | 54       |       |       |    |      |  |  |
|                                    | CMOS input                            | 4   |       |    | 8          |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | CMOS output                           | 1   |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | N-ch open-drain I/O                   | –   |       |    | 4          |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Timer                              | 16 bits (TM0)                         | –   |       |    |            |       | 1 ch  |          |       |    |          | 2 ch     |          |       |          | 1 ch  |       |    | 2 ch |  |  |
|                                    | 8 bits (TM5)                          | 1 ch  |       |    | 2 ch       |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | 8 bits (TMH)                          | 2 ch  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | For watch                             | –   |       |    | 1 ch       |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | WDT                                   | 1 ch  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Serial interface                   | 3-wire CSI <sup>Note 3</sup>          | –   |       |    |            |       | 1 ch  |          |       |    |          | 2 ch     |          |       |          | 1 ch  |       |    | 2 ch |  |  |
|                                    | Automatic transmit/receive 3-wire CSI | –   |       |    |            |       | –   |          |       |    |          |          |          |       |          |       |       |    | 1 ch |  |  |
|                                    | UART <sup>Note 3</sup>                | –   |       |    | 1 ch       |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | UART supporting LIN-bus               | 1 ch  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| 10-bit A/D converter               |                                       | 4 ch  |       |    | 8 ch       |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Interrupt                          | External                              | 6   |       |    | 7          |       |   | 8        |       |    | 9        |          |          |       | 9        |       |       |    |      |  |  |
|                                    | Internal                              | 11  | 12    | –  | 15         |       |   | 16       |       |    | 19       |          |          |       | 17       | 20    | –     |    |      |  |  |
| Key return input                   |                                       | –   |       |    | 4 ch       |       |   | 8 ch     |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Reset                              | RESET pin                             | Provided  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | POC                                   | 2.85 V ±0.15 V/3.5 V ±0.20 V (selectable by mask option)  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | LVI                                   | 2.85 V/3.1 V/3.3 V ±0.15 V/3.5 V/3.7 V/3.9 V/4.1 V/4.3 V ±0.2 V (selectable by software)  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | Clock monitor                         | Provided  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
|                                    | WDT                                   | Provided  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Clock output/buzzer output         |                                       | –   |       |    |            |       | Clock output only   |          |       |    |          | Provided |          |       |          |       |       |    |      |  |  |
| Multiplier/divider                 |                                       | –   |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| ROM correction                     |                                       | –   |       |    |            |       |   |          |       |    |          |          | Provided |       |          | –     |       |    |      |  |  |
| Standby function                   |                                       | HALT/STOP mode  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |
| Operating ambient temperature      |                                       | Standard and special (A) grade products: –40 to +85°C<br>Special (A1) grade products: –40 to +110°C (mask ROM version),<br>–40 to +105°C (flash memory version)<br>Special (A2) grade products: –40 to +125°C (mask ROM version)  |       |    |            |       |   |          |       |    |          |          |          |       |          |       |       |    |      |  |  |

- Notes 1.** If the POC circuit detection voltage (V<sub>POC</sub>) is used with 2.85 V ±0.15 V, then use the products in the voltage range of 3.0 to 5.5 V.
- 2.** If the POC circuit detection voltage (V<sub>POC</sub>) is used with 3.5 V ±0.2 V, then use the products in the voltage range of 3.7 to 5.5 V.
- 3.** Select either of the functions of these alternate-function pins.

The list of functions in the 78K0/Kx1+ is shown below.

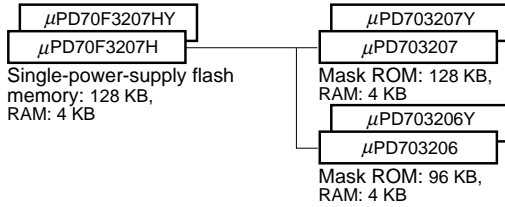
| Part Number                         |                                       | 78K0/KB1+   |       | 78K0/KC1+  |       | 78K0/KD1+         |       | 78K0/KE1+  |       |          | 78K0/KF1+ |  |
|-------------------------------------|---------------------------------------|---|-------|------------|-------|-------------------|-------|--|-------|----------|-----------|--|
| Item                                |                                       |   |       |            |       |                   |       |  |       |          |           |  |
| Number of pins                      |                                       | 30 pins   |       | 44 pins    |       | 52 pins           |       | 64 pins  |       |          | 80 pins   |  |
| Internal memory (KB)                | Flash memory                          | 8   | 16/24 | 16         | 24/32 | 16                | 24/32 | 16   | 24/32 | 48/60    | 60        |  |
|                                     | RAM                                   | 0.5   | 0.75  | 0.5        | 1     | 0.5               | 1     | 0.5  | 1     | 2        | 2         |  |
| Power supply voltage                |                                       | $V_{DD} = 2.5$ to $5.5$ V (with Ring-OSC clock or subclock: $V_{DD} = 2.0$ to $5.5$ V <sup>Note 1</sup> )   |       |            |       |                   |       |  |       |          |           |  |
| Minimum instruction execution time  |                                       | 0.125 $\mu$ s (when 16 MHz, $V_{DD} = 4.0$ to $5.5$ V), 0.2 $\mu$ s (when 10 MHz, $V_{DD} = 3.5$ to $5.5$ V), 0.238 $\mu$ s (when 8.38 MHz, $V_{DD} = 3.0$ to $5.5$ V), 0.4 $\mu$ s (when 5 MHz, $V_{DD} = 2.5$ to $5.5$ V) |       |            |       |                   |       |  |       |          |           |  |
| Clock                               | Crystal/ceramic                       | 2 to 16 MHz   |       |            |       |                   |       |  |       |          |           |  |
|                                     | RC                                    | 3 to 4 MHz  |       |            |       | -                 |       |  |       |          |           |  |
|                                     | Subclock                              | -   |       | 32.768 kHz |       |                   |       |  |       |          |           |  |
|                                     | Ring-OSC                              | 240 kHz (TYP.)  |       |            |       |                   |       |  |       |          |           |  |
| Ports                               | CMOS I/O                              | 17  |       | 19         |       | 26                |       | 38   |       |          | 54        |  |
|                                     | CMOS input                            | 4   |       | 8          |       |                   |       |  |       |          |           |  |
|                                     | CMOS output                           | 1   |       |            |       |                   |       |  |       |          |           |  |
|                                     | N-ch open-drain I/O                   | -   |       | 4          |       |                   |       |  |       |          |           |  |
| Timer                               | 16 bits (TM0)                         | 1 ch  |       |            |       |                   | 2 ch  |  |       |          |           |  |
|                                     | 8 bits (TM5)                          | 1 ch  |       | 2 ch       |       |                   |       |  |       |          |           |  |
|                                     | 8 bits (TMH)                          | 2 ch  |       |            |       |                   |       |  |       |          |           |  |
|                                     | For watch                             | -   |       | 1 ch       |       |                   |       |  |       |          |           |  |
|                                     | WDT                                   | 1 ch  |       |            |       |                   |       |  |       |          |           |  |
| Serial interface                    | 3-wire CSI <sup>Note 2</sup>          | 1 ch  |       |            |       |                   |       | 2 ch   |       |          |           |  |
|                                     | Automatic transmit/receive 3-wire CSI | -   |       |            |       |                   |       |  |       | 1 ch     |           |  |
|                                     | UART <sup>Note 2</sup>                | -   |       | 1 ch       |       |                   |       |  |       |          |           |  |
|                                     | UART supporting LIN-bus               | 1 ch  |       |            |       |                   |       |  |       |          |           |  |
| 10-bit A/D converter                |                                       | 4 ch  |       | 8 ch       |       |                   |       |  |       |          |           |  |
| Interrupts                          | External                              | 6   |       | 7          |       | 8                 |       | 9  |       |          | 9         |  |
|                                     | Internal                              | 11  | 12    | 15         |       |                   |       | 16   | 19    |          | 20        |  |
| Key return input                    |                                       | -   |       | 4 ch       |       |                   | 8 ch  |  |       |          |           |  |
| Reset                               | RESET pin                             | Provided  |       |            |       |                   |       |  |       |          |           |  |
|                                     | POC                                   | 2.1 V $\pm$ 0.1 V (detection voltage is fixed)  |       |            |       |                   |       |  |       |          |           |  |
|                                     | LVI                                   | 2.35 V/2.6 V/2.85 V/3.1 V/3.3 V $\pm$ 0.15 V/3.5 V/3.7 V/3.9 V/4.1 V/4.3 V $\pm$ 0.2 V (selectable by software)   |       |            |       |                   |       |  |       |          |           |  |
|                                     | Clock monitor                         | Provided  |       |            |       |                   |       |  |       |          |           |  |
|                                     | WDT                                   | Provided  |       |            |       |                   |       |  |       |          |           |  |
| Clock output/buzzer output          |                                       | -   |       |            |       | Clock output only |       | Provided   |       |          |           |  |
| External bus interface              |                                       | -   |       |            |       |                   |       |  |       | Provided |           |  |
| Multiplier/divider                  |                                       | -   |       |            |       |                   |       | 16 bits $\times$ 16 bits, 32 bits $\div$ 16 bits |       |          |           |  |
| ROM correction                      |                                       | -   |       |            |       |                   |       |  |       | Provided | -         |  |
| Self-programming function           |                                       | Provided  |       |            |       |                   |       |  |       |          |           |  |
| Product with on-chip debug function |                                       | $\mu$ PD78F0114HD, 78F0124HD, 78F0138HD, 78F0148HD  |       |            |       |                   |       |  |       |          |           |  |
| Standby function                    |                                       | HALT/STOP mode  |       |            |       |                   |       |  |       |          |           |  |
| Operating ambient temperature       |                                       | $T_A = -40$ to $+85^\circ\text{C}$  |       |            |       |                   |       |  |       |          |           |  |

- Notes**
1. Because the POC circuit detection voltage ( $V_{POC}$ ) is 2.1 V  $\pm$ 0.1 V, use the products in the voltage range of 2.2 to 5.5 V.
  2. Select either of the functions of these alternate-function pins.

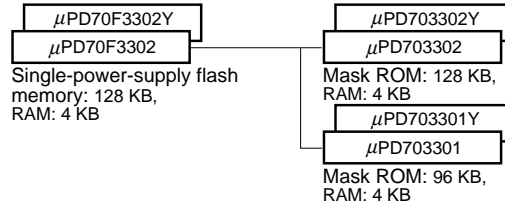
1.6.2 V850ES/Kx1, V850ES/Kx1+ product lineup

- 64-pin plastic LQFP (10 × 10 mm, 0.5 mm pitch)
- 64-pin plastic TQFP (12 × 12 mm, 0.65 mm pitch)
- 64-pin plastic LQFP (14 × 14 mm, 0.8 mm pitch)

V850ES/KE1

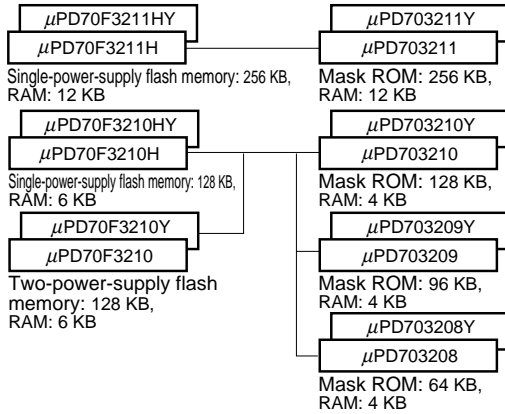


V850ES/KE1+

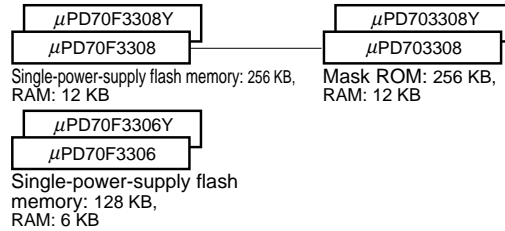


- 80-pin plastic TQFP (12 × 12 mm, 0.5 mm pitch)
- 80-pin plastic QFP (14 × 14 mm, 0.65 mm pitch)

V850ES/KF1

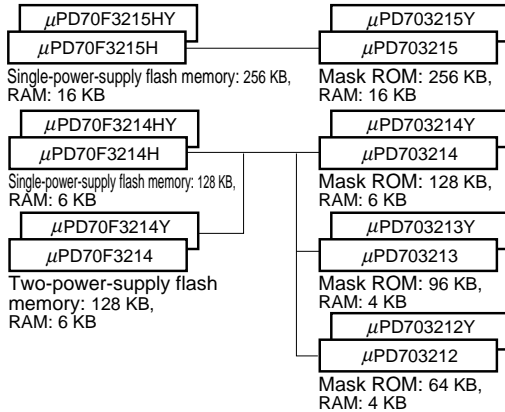


V850ES/KF1+

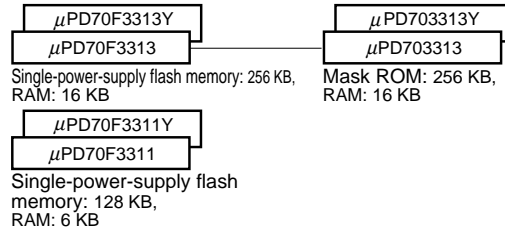


- 100-pin plastic LQFP (14 × 14 mm, 0.5 mm pitch)
- 100-pin plastic QFP (14 × 20 mm, 0.65 mm pitch)

V850ES/KG1

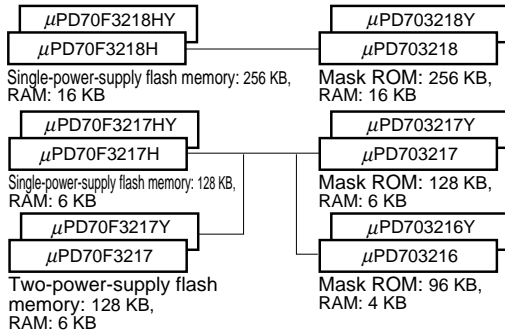


V850ES/KG1+

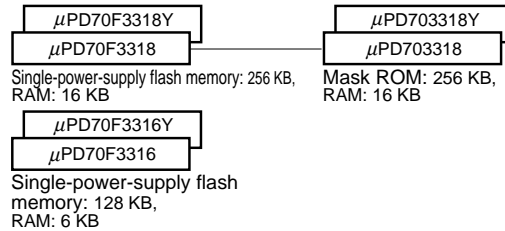


- 144-pin plastic LQFP (20 × 20 mm, 0.5 mm pitch)

V850ES/KJ1



V850ES/KJ1+



The list of functions in the V850ES/Kx1 is shown below.

| Part Number                        |                                       | V850ES/KE1                     |     |       |      | V850ES/KF1            |     |     |       | V850ES/KG1                |     |     |      | V850ES/KJ1    |     |     |     |      |  |  |  |
|------------------------------------|---------------------------------------|--------------------------------|-----|-------|------|-----------------------|-----|-----|-------|---------------------------|-----|-----|------|---------------|-----|-----|-----|------|--|--|--|
| Item                               |                                       | 64 pins                        |     |       |      | 80 pins               |     |     |       | 100 pins                  |     |     |      | 144 pins      |     |     |     |      |  |  |  |
| Internal memory (KB)               | Mask ROM                              | 96/128                         | –   | 64/96 | 128  | –                     | 256 | –   | 64/96 | 128                       | –   | 256 | –    | 96/128        | –   | 256 | –   |      |  |  |  |
|                                    | Flash memory                          | –                              | 128 | –     | –    | 128                   | –   | 256 | –     | –                         | 128 | –   | 256  | –             | 128 | –   | 256 |      |  |  |  |
|                                    | RAM                                   | 4                              |     | 4     | 6    |                       | 12  |     | 4     | 6                         |     | 16  |      | 6             | 16  |     |     |      |  |  |  |
| Power supply voltage               |                                       | V <sub>DD</sub> = 2.7 to 5.5 V |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
| Minimum instruction execution time |                                       | 50 ns @ 20 MHz                 |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
| Clock                              | X1 input                              | 2 to 10 MHz                    |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
|                                    | Subclock                              | 32.768 kHz                     |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
|                                    | Ring-OSC                              | –                              |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
| Ports                              | CMOS input                            | 8                              |     |       |      | 8                     |     |     |       | 8                         |     |     |      | 16            |     |     |     |      |  |  |  |
|                                    | CMOS I/O                              | 43                             |     |       |      | 59                    |     |     |       | 76                        |     |     |      | 112           |     |     |     |      |  |  |  |
|                                    | N-ch open-drain I/O                   | 1                              |     |       |      | 2                     |     |     |       | 4                         |     |     |      | 6             |     |     |     |      |  |  |  |
| Timer                              | 16 bits (TMP)                         | 1 ch                           |     |       |      | –                     |     |     |       | 1 ch                      |     |     |      | –             |     |     |     | 1 ch |  |  |  |
|                                    | 16 bits (TM0)                         | 1 ch                           |     |       |      | 2 ch                  |     |     |       | 4 ch                      |     |     |      | 6 ch          |     |     |     |      |  |  |  |
|                                    | 8 bits (TM5)                          | 2 ch                           |     |       |      | 2 ch                  |     |     |       | 2 ch                      |     |     |      | 2 ch          |     |     |     |      |  |  |  |
|                                    | 8 bits (TMH)                          | 2 ch                           |     |       |      | 2 ch                  |     |     |       | 2 ch                      |     |     |      | 2 ch          |     |     |     |      |  |  |  |
|                                    | Interval timer                        | 1 ch                           |     |       |      | 1 ch                  |     |     |       | 1 ch                      |     |     |      | 1 ch          |     |     |     |      |  |  |  |
|                                    | For watch                             | 1 ch                           |     |       |      | 1 ch                  |     |     |       | 1 ch                      |     |     |      | 1 ch          |     |     |     |      |  |  |  |
|                                    | WDT1                                  | 1 ch                           |     |       |      | 1 ch                  |     |     |       | 1 ch                      |     |     |      | 1 ch          |     |     |     |      |  |  |  |
| WDT2                               | 1 ch                                  |                                |     |       | 1 ch |                       |     |     | 1 ch  |                           |     |     | 1 ch |               |     |     |     |      |  |  |  |
| RTO                                |                                       | 6 bits × 1 ch                  |     |       |      | 6 bits × 1 ch         |     |     |       | 6 bits × 1 ch             |     |     |      | 6 bits × 2 ch |     |     |     |      |  |  |  |
| Serial interface                   | CSI                                   | 2 ch                           |     |       |      | 2 ch                  |     |     |       | 2 ch                      |     |     |      | 3 ch          |     |     |     |      |  |  |  |
|                                    | Automatic transmit/receive 3-wire CSI | –                              |     |       |      | 1 ch                  |     |     |       | 2 ch                      |     |     |      | 2 ch          |     |     |     |      |  |  |  |
|                                    | UART                                  | 2 ch                           |     |       |      | 2 ch                  |     |     |       | 2 ch                      |     |     |      | 3 ch          |     |     |     |      |  |  |  |
|                                    | UART supporting LIN-bus               | –                              |     |       |      | –                     |     |     |       | –                         |     |     |      | –             |     |     |     |      |  |  |  |
|                                    | I <sup>2</sup> C <sup>Note</sup>      | 1 ch                           |     |       |      | 1 ch                  |     |     |       | 1 ch                      |     |     |      | 2 ch          |     |     |     |      |  |  |  |
| External bus                       | Address space                         | –                              |     |       |      | 128 KB                |     |     |       | 3 MB                      |     |     |      | 15 MB         |     |     |     |      |  |  |  |
|                                    | Address bus                           | –                              |     |       |      | 16 bits               |     |     |       | 22 bits                   |     |     |      | 24 bits       |     |     |     |      |  |  |  |
|                                    | Mode                                  | –                              |     |       |      | Multiplexed mode only |     |     |       | Multiplexed/separate mode |     |     |      | –             |     |     |     |      |  |  |  |
| DMA controller                     |                                       | –                              |     |       |      | –                     |     |     |       | –                         |     |     |      | –             |     |     |     |      |  |  |  |
| 10-bit A/D converter               |                                       | 8 ch                           |     |       |      | 8 ch                  |     |     |       | 8 ch                      |     |     |      | 16 ch         |     |     |     |      |  |  |  |
| 8-bit D/A converter                |                                       | –                              |     |       |      | –                     |     |     |       | 2 ch                      |     |     |      | 2 ch          |     |     |     |      |  |  |  |
| Interrupts                         | External                              | 8                              |     |       |      | 8                     |     |     |       | 8                         |     |     |      | 8             |     |     |     |      |  |  |  |
|                                    | Internal                              | 26                             |     |       |      | 26                    |     | 29  |       | 31                        |     | 34  |      | 40            |     | 43  |     |      |  |  |  |
| Key return input                   |                                       | 8 ch                           |     |       |      | 8 ch                  |     |     |       | 8 ch                      |     |     |      | 8 ch          |     |     |     |      |  |  |  |
| Reset                              | RESET pin                             | Provided                       |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
|                                    | POC                                   | Not provided                   |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
|                                    | LVI                                   | Not provided                   |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
|                                    | Clock monitor                         | Not provided                   |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
|                                    | WDT1                                  | Provided                       |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
|                                    | WDT2                                  | Provided                       |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
| ROM correction                     |                                       | 4 points                       |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
| Regulator                          |                                       | Not provided                   |     |       |      | Provided              |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
| Standby function                   |                                       | HALT/IDLE/STOP/sub-IDLE mode   |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |
| Operating ambient temperature      |                                       | T <sub>A</sub> = –40 to +85°C  |     |       |      |                       |     |     |       |                           |     |     |      |               |     |     |     |      |  |  |  |

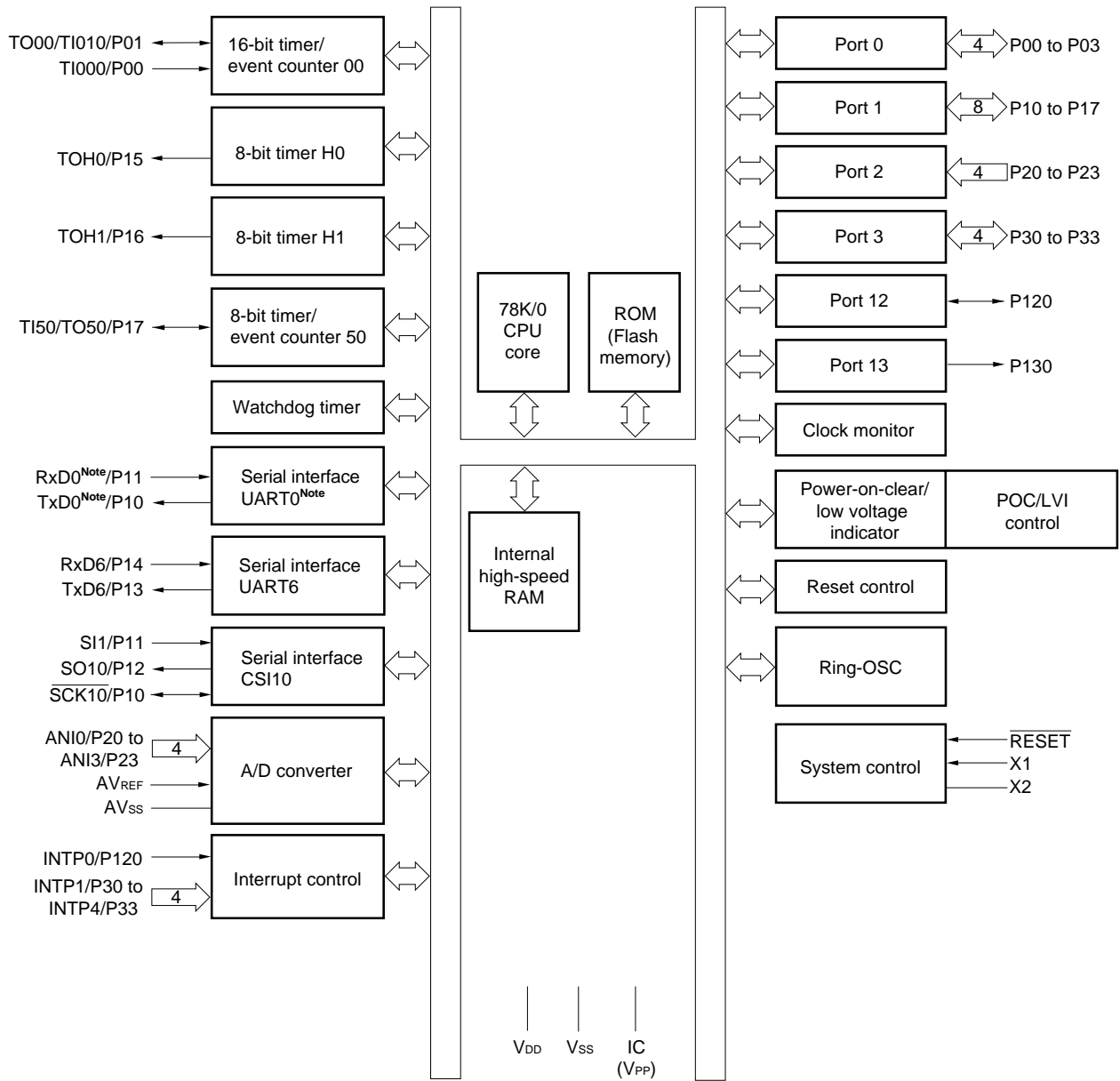
**Note** Provided in the Y version only.

The list of functions in the V850ES/Kx1+ is shown below.

| Part Number                        |                                       | V850ES/KE1+  |     | V850ES/KF1+           |          |     | V850ES/KG1+               |     | V850ES/KJ1+   |     |
|------------------------------------|---------------------------------------|--|-----|-----------------------|----------|-----|---------------------------|-----|---------------|-----|
| Item                               |                                       |  |     |                       |          |     |                           |     |               |     |
| Number of pins                     |                                       | 64 pins  |     | 80 pins               |          |     | 100 pins                  |     | 144 pins      |     |
| Internal memory (KB)               | Mask ROM                              | 96/128   | –   | 128                   | 256      | –   | 128/256                   | –   | 128/256       | –   |
|                                    | Flash memory                          | –  | 128 | –                     | –        | 256 | –                         | 256 | –             | 256 |
|                                    | RAM                                   | 4  |     | 6                     | 12       |     | 6                         | 16  | 6             | 16  |
| Power supply voltage               |                                       | V <sub>DD</sub> = 2.7 to 5.5 V   |     |                       |          |     |                           |     |               |     |
| Minimum instruction execution time |                                       | 50 ns @ 20 MHz   |     |                       |          |     |                           |     |               |     |
| Clock                              | X1 input                              | 2 to 10 MHz  |     |                       |          |     |                           |     |               |     |
|                                    | Subclock                              | 32.768 kHz   |     |                       |          |     |                           |     |               |     |
|                                    | Ring-OSC                              | 240 kHz (TYP.)   |     |                       |          |     |                           |     |               |     |
| Ports                              | CMOS input                            | 8  |     | 8                     |          |     | 8                         |     | 16            |     |
|                                    | CMOS I/O                              | 43   |     | 59                    |          |     | 76                        |     | 112           |     |
|                                    | N-ch open-drain I/O                   | 1  |     | 2                     |          |     | 4                         |     | 6             |     |
| Timer                              | 16 bits (TMP)                         | 1 ch   |     | 1 ch                  |          |     | 1 ch                      |     | 1 ch          |     |
|                                    | 16 bits (TM0)                         | 1 ch   |     | 2 ch                  |          |     | 4 ch                      |     | 6 ch          |     |
|                                    | 8 bits (TM5)                          | 2 ch   |     | 2 ch                  |          |     | 2 ch                      |     | 2 ch          |     |
|                                    | 8 bits (TMH)                          | 2 ch   |     | 2 ch                  |          |     | 2 ch                      |     | 2 ch          |     |
|                                    | Interval timer                        | 1 ch   |     | 1 ch                  |          |     | 1 ch                      |     | 1 ch          |     |
|                                    | For watch                             | 1 ch   |     | 1 ch                  |          |     | 1 ch                      |     | 1 ch          |     |
|                                    | WDT1                                  | 1 ch   |     | 1 ch                  |          |     | 1 ch                      |     | 1 ch          |     |
|                                    | WDT2                                  | 1 ch   |     | 1 ch                  |          |     | 1 ch                      |     | 1 ch          |     |
| RTO                                |                                       | 6 bits × 1 ch  |     | 6 bits × 1 ch         |          |     | 6 bits × 1 ch             |     | 6 bits × 2 ch |     |
| Serial interface                   | CSI                                   | 2 ch   |     | 2 ch                  |          |     | 2 ch                      |     | 3 ch          |     |
|                                    | Automatic transmit/receive 3-wire CSI | –  |     | 1 ch                  |          |     | 2 ch                      |     | 2 ch          |     |
|                                    | UART                                  | 1 ch   |     | 1 ch                  |          |     | 1 ch                      |     | 2 ch          |     |
|                                    | UART supporting LIN-bus               | 1 ch   |     | 1 ch                  |          |     | 1 ch                      |     | 1 ch          |     |
|                                    | I <sup>2</sup> C <sup>Note</sup>      | 1 ch   |     | 1 ch                  |          |     | 1 ch                      |     | 2 ch          |     |
| External bus                       | Address space                         | –  |     | 128 KB                |          |     | 3 MB                      |     | 15 MB         |     |
|                                    | Address bus                           | –  |     | 16 bits               |          |     | 22 bits                   |     | 24 bits       |     |
|                                    | Mode                                  | –  |     | Multiplexed mode only |          |     | Multiplexed/separate mode |     |               |     |
| DMA controller                     |                                       | –  |     | –                     |          |     | 4 ch                      |     | 4 ch          |     |
| 10-bit A/D converter               |                                       | 8 ch   |     | 8 ch                  |          |     | 8 ch                      |     | 16 ch         |     |
| 8-bit D/A converter                |                                       | –  |     | –                     |          |     | 2 ch                      |     | 2 ch          |     |
| Interrupts                         | External                              | 9  |     | 9                     |          |     | 9                         |     | 9             |     |
|                                    | Internal                              | 27   |     | 30                    |          |     | 42                        |     | 48            |     |
| Key return input                   |                                       | 8 ch   |     | 8 ch                  |          |     | 8 ch                      |     | 8 ch          |     |
| Reset                              | RESET pin                             | Provided   |     |                       |          |     |                           |     |               |     |
|                                    | POC                                   | Fixed to 2.7 V or lower  |     |                       |          |     |                           |     |               |     |
|                                    | LVI                                   | 3.1 V/3.3 V ±0.15 V or 3.5 V/3.7 V/3.9 V/4.1 V/4.3 V ±0.2 V (selectable by software) |     |                       |          |     |                           |     |               |     |
|                                    | Clock monitor                         | Provided (monitoring by Ring-OSC)  |     |                       |          |     |                           |     |               |     |
|                                    | WDT1                                  | Provided   |     |                       |          |     |                           |     |               |     |
|                                    | WDT2                                  | Provided   |     |                       |          |     |                           |     |               |     |
| ROM correction                     |                                       | 4 points   |     |                       |          |     |                           |     |               |     |
| Regulator                          |                                       | Not provided   |     |                       | Provided |     |                           |     |               |     |
| Standby function                   |                                       | HALT/IDLE/STOP/sub-IDLE mode   |     |                       |          |     |                           |     |               |     |
| Operating ambient temperature      |                                       | T <sub>A</sub> = –40 to +85°C  |     |                       |          |     |                           |     |               |     |

**Note** Provided in the Y version only.

1.7 Block Diagram



**Note**  $\mu$ PD780102, 780103, and 78F0103 only.

**Remark** Items in parentheses are available only in the  $\mu$ PD78F0103.

1.8 Outline of Functions

(1/2)

| Item                                   |  | $\mu$ PD780101  | $\mu$ PD780102   | $\mu$ PD780103 | $\mu$ PD78F0103         |
|--|--|---|--|----------------|-------------------------|
| Internal memory                        | ROM  | 8 KB  | 16 KB  | 24 KB          | 24 KB<br>(flash memory) |
|  | High-speed RAM   | 512 bytes   | 768 bytes  |                |                         |
| Memory space                           |  | 64 KB   |  |                |                         |
| ★                                      | X1 input clock (oscillation frequency)                             |   | Ceramic/crystal/external clock oscillation   |                |                         |
|  | Expanded-specification products of standard and (A) grade products | 2 to 12 MHz: $V_{DD} = 4.0$ to $5.5$ V, 2 to 10 MHz: $V_{DD} = 3.5$ to $5.5$ V, 2 to 8.38 MHz: $V_{DD} = 3.0$ to $5.5$ V, 2 to 5 MHz: $V_{DD} = 2.5$ to $5.5$ V   |  |                |                         |
|  | Conventional products of standard and (A) grade products           | 2 to 10 MHz: $V_{DD} = 4.0$ to $5.5$ V, 2 to 8.38 MHz: $V_{DD} = 3.3$ to $5.5$ V, 2 to 5 MHz: $V_{DD} = 2.7$ to $5.5$ V   |  |                |                         |
|  | (A1) grade products  | 2 to 10 MHz: $V_{DD} = 4.5$ to $5.5$ V, 2 to 8.38 MHz: $V_{DD} = 4.0$ to $5.5$ V, 2 to 5 MHz: $V_{DD} = 3.3$ to $5.5$ V   |  |                |                         |
|  | (A2) grade products  | 2 to 8.38 MHz: $V_{DD} = 4.0$ to $5.5$ V, 2 to 5 MHz: $V_{DD} = 3.3$ to $5.5$ V   |  |                |                         |
| Ring-OSC clock (oscillation frequency) |  | On-chip Ring oscillation (240 kHz (TYP.): $V_{DD} = 2.5$ to $5.5$ V)  |  |                |                         |
| General-purpose registers              |  | 8 bits $\times$ 32 registers (8 bits $\times$ 8 registers $\times$ 4 banks)   |  |                |                         |
| ★                                      | Minimum instruction execution time                                 |   | 0.166 $\mu$ s/0.333 $\mu$ s/0.666 $\mu$ s/1.333 $\mu$ s/2.666 $\mu$ s (X1 input clock: @ $f_{XP} = 12$ MHz operation)<br>8.3 $\mu$ s/16.6 $\mu$ s/33.2 $\mu$ s/66.4 $\mu$ s/132.8 $\mu$ s (TYP.)<br>(Ring-OSC clock: @ $f_R = 240$ kHz (TYP.) operation) |                |                         |
| Instruction set                        |  | <ul style="list-style-type: none"> <li>• 16-bit operation</li> <li>• Multiply/divide (8 bits <math>\times</math> 8 bits, 16 bits <math>\div</math> 8 bits)</li> <li>• Bit manipulate (set, reset, test, and Boolean operation)</li> <li>• BCD adjust, etc.</li> </ul>                         |  |                |                         |
| I/O ports                              |  | Total: <span style="float: right;">22</span><br>CMOS I/O <span style="float: right;">17</span><br>CMOS input <span style="float: right;">4</span><br>CMOS output <span style="float: right;">1</span>   |  |                |                         |
| Timers                                 |  | <ul style="list-style-type: none"> <li>• 16-bit timer/event counter: 1 channel</li> <li>• 8-bit timer/event counter: 1 channel</li> <li>• 8-bit timer: 2 channels</li> <li>• Watchdog timer: 1 channel</li> </ul>   |  |                |                         |
|  | Timer outputs  | 4 (PWM: 3)  |  |                |                         |
| A/D converter                          |  | 10-bit resolution $\times$ 4 channels   |  |                |                         |
| Serial interface                       |  | <ul style="list-style-type: none"> <li>• UART mode supporting LIN-bus: 1 channel</li> <li>• 3-wire serial I/O mode/UART mode<sup>Note</sup>: 1 channel (<math>\mu</math>PD780101 only, 3-wire serial I/O mode: 1 channel)</li> </ul>  |  |                |                         |
| Vectored interrupt sources             | Internal   | 10  | 12   |                |                         |
|  | External   | 6   |  |                |                         |
| Reset                                  |  | <ul style="list-style-type: none"> <li>• Reset using <math>\overline{\text{RESET}}</math> pin</li> <li>• Internal reset by watchdog timer</li> <li>• Internal reset by clock monitor</li> <li>• Internal reset by power-on-clear</li> <li>• Internal reset by low-voltage detector</li> </ul> |  |                |                         |

**Note** Select either of the functions of these alternate-function pins.



| Item                          | $\mu$ PD780101   | $\mu$ PD780102 | $\mu$ PD780103 | $\mu$ PD78F0103 |
|-------------------------------|--|----------------|----------------|-----------------|
| Supply voltage                | <ul style="list-style-type: none"> <li>Expanded-specification products of standard and (A) grade products: <math>V_{DD} = 2.5</math> to <math>5.5</math> V<sup>Notes 1, 2</sup></li> <li>Conventional products of standard and (A) grade products: <math>V_{DD} = 2.7</math> to <math>5.5</math> V<sup>Notes 1, 2</sup></li> <li>(A1) grade and (A2) grade products: <math>V_{DD} = 3.3</math> to <math>5.5</math> V<sup>Note 2</sup></li> </ul> |                |                |                 |
| Operating ambient temperature | <ul style="list-style-type: none"> <li>Standard and (A) grade products: <math>T_A = -40</math> to <math>+85^\circ\text{C}</math></li> <li>(A1) grade products: <math>T_A = -40</math> to <math>+110^\circ\text{C}</math> (mask ROM version), <math>-40</math> to <math>+105^\circ\text{C}</math> (flash memory version)</li> <li>(A2) grade products: <math>T_A = -40</math> to <math>+125^\circ\text{C}</math> (mask ROM version)</li> </ul>    |                |                |                 |
| Package                       | 30-pin plastic SSOP (7.62 mm (300))  |                |                |                 |

- ★ **Notes 1.** If the POC circuit detection voltage ( $V_{POC}$ ) is used with  $2.85\text{ V} \pm 0.15\text{ V}$ , then use the products in the voltage range of 3.0 to 5.5 V.
- ★ **2.** If the POC circuit detection voltage ( $V_{POC}$ ) is used with  $3.5\text{ V} \pm 0.2\text{ V}$ , then use the products in the voltage range of 3.7 to 5.5 V.

An outline of the timer is shown below.

|                |                         | 16-Bit Timer/Event Counter 00 | 8-Bit Timer/Event Counter 50 | 8-Bit Timers H0 and H1 |           | Watchdog Timer |
|----------------|-------------------------|-------------------------------|------------------------------|------------------------|-----------|----------------|
|                |                         |                               |                              | TMH0                   | TMH1      |                |
| Operation mode | Interval timer          | 1 channel                     | 1 channel                    | 1 channel              | 1 channel | –              |
|                | External event counter  | 1 channel                     | 1 channel                    | –                      | –         | –              |
|                | Watchdog timer          | –                             | –                            | –                      | –         | 1 channel      |
| Function       | Timer output            | 1 output                      | 1 output                     | 1 output               | 1 output  | –              |
|                | PPG output              | 1 output                      | –                            | –                      | –         | –              |
|                | PWM output              | –                             | 1 output                     | 1 output               | 1 output  | –              |
|                | Pulse width measurement | 2 inputs                      | –                            | –                      | –         | –              |
|                | Square-wave output      | 1 output                      | 1 output                     | 1 output               | 1 output  | –              |
|                | Interrupt source        | 2                             | 1                            | 1                      | 1         | –              |

## CHAPTER 2 PIN FUNCTIONS

### 2.1 Pin Function List

There are two types of pin I/O buffer power supplies:  $V_{REF}$  and  $V_{DD}$ . The relationship between these power supplies and the pins is shown below.

**Table 2-1. Pin I/O Buffer Power Supplies**

| Power Supply | Corresponding Pins         |
|--------------|----------------------------|
| $V_{REF}$    | P20 to P23                 |
| $V_{DD}$     | Pins other than P20 to P23 |

#### (1) Port pins

| Pin Name   | I/O    | Function  | After Reset | Alternate Function             |
|------------|--------|---|-------------|--------------------------------|
| P00        | I/O    | Port 0.<br>4-bit I/O port.<br>Input/output can be specified in 1-bit units.<br>Use of an on-chip pull-up resistor can be specified by a software setting. | Input       | TI000                          |
| P01        |        |   |             | TI010/TO00                     |
| P02        |        |   |             | —                              |
| P03        |        |   |             | —                              |
| P10        | I/O    | Port 1.<br>8-bit I/O port.<br>Input/output can be specified in 1-bit units.<br>Use of an on-chip pull-up resistor can be specified by a software setting. | Input       | $\overline{SCK10}/TxD0^{Note}$ |
| P11        |        |   |             | SI10/RxD0 <sup>Note</sup>      |
| P12        |        |   |             | SO10                           |
| P13        |        |   |             | TxD6                           |
| P14        |        |   |             | RxD6                           |
| P15        |        |   |             | TOH0                           |
| P16        |        |   |             | TOH1/INTP5                     |
| P17        |        |   |             | TI50/TO50                      |
| P20 to P23 | Input  | Port 2.<br>4-bit input-only port.   | Input       | ANI0 to ANI3                   |
| P30 to P33 | I/O    | Port 3.<br>4-bit I/O port.<br>Input/output can be specified in 1-bit units.<br>Use of an on-chip pull-up resistor can be specified by a software setting. | Input       | INTP1 to INTP4                 |
| P120       | I/O    | Port 12.<br>1-bit I/O port.<br>Use of an on-chip pull-up resistor can be specified by a software setting.   | Input       | INTP0                          |
| P130       | Output | Port 13.<br>1-bit output-only port.   | Output      | —                              |

**Note** TxD0 and RxD0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.

## (2) Non-port pins

| Pin Name                  | I/O    | Function  | After Reset | Alternate Function             |
|---------------------------|--------|---|-------------|--------------------------------|
| INTP0                     | Input  | External interrupt request input for which the valid edge (rising edge, falling edge, or both rising and falling edges) can be specified                  | Input       | P120                           |
| INTP1 to INTP4            |        |   |             | P30 to P33                     |
| INTP5                     |        |   |             | P16/TOH1                       |
| SI10                      | Input  | Serial data input to serial interface   | Input       | P11/RxD0 <sup>Note</sup>       |
| SO10                      | Output | Serial data output from serial interface  | Input       | P12                            |
| $\overline{\text{SCK10}}$ | I/O    | Clock input/output for serial interface   | Input       | P10/TxD0 <sup>Note</sup>       |
| RxD0 <sup>Note</sup>      | Input  | Serial data input to asynchronous serial interface  | Input       | P11/SI10                       |
| RxD6                      |        |   |             | P14                            |
| TxD0 <sup>Note</sup>      | Output | Serial data output from asynchronous serial interface   | Input       | P10/ $\overline{\text{SCK10}}$ |
| TxD6                      |        |   |             | P13                            |
| TI000                     | Input  | External count clock input to 16-bit timer/event counter 00<br>Capture trigger input to capture registers (CR000, CR010) of 16-bit timer/event counter 00 | Input       | P00                            |
| TI010                     |        | Capture trigger input to capture register (CR000) of 16-bit timer/event counter 00  |             | P01/TO00                       |
| TO00                      | Output | 16-bit timer/event counter 00 output  | Input       | P01/TI010                      |
| TI50                      | Input  | External count clock input to 8-bit timer/event counter 50  | Input       | P17/TO50                       |
| TO50                      | Output | 8-bit timer/event counter 50 output   | Input       | P17/TI50                       |
| TOH0                      | Output | 8-bit timer H0 output   | Input       | P15                            |
| TOH1                      |        | 8-bit timer H1 output   |             | P16/INTP5                      |
| ANI0 to ANI3              | Input  | A/D converter analog input  | Input       | P20 to P23                     |
| AV <sub>REF</sub>         | Input  | A/D converter reference voltage input and positive power supply for port 2  | –           | –                              |
| AV <sub>SS</sub>          | –      | A/D converter ground potential. Make the same potential as V <sub>SS</sub> .  | –           | –                              |
| $\overline{\text{RESET}}$ | Input  | System reset input  | –           | –                              |
| X1                        | Input  | Connecting resonator for X1 input clock   | –           | –                              |
| X2                        | –      |   | –           | –                              |
| V <sub>DD</sub>           | –      | Positive power supply   | –           | –                              |
| V <sub>SS</sub>           | –      | Ground potential  | –           | –                              |
| IC                        | –      | Internally connected. Connect directly to V <sub>SS</sub> .   | –           | –                              |
| V <sub>PP</sub>           | –      | Flash memory programming mode setting. High-voltage application for program write/verify. Connect to V <sub>SS</sub> in normal operation mode.            | –           | –                              |

**Note** TxD0 and RxD0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.

## 2.2 Description of Pin Functions

### 2.2.1 P00 to P03 (port 0)

P00 to P03 function as a 4-bit I/O port. These pins also function as timer I/O.

The following operation modes can be specified in 1-bit units.

#### (1) Port mode

P00 to P03 function as a 4-bit I/O port. P00 to P03 can be set to input or output in 1-bit units using port mode register 0 (PM0). Use of an on-chip pull-up resistor can be specified by pull-up resistor option register 0 (PU0).

#### (2) Control mode

P00 to P03 function as timer I/O.

##### (a) TI000

This is the pins for inputting an external count clock to 16-bit timer/event counter 00 and is also for inputting a capture trigger signal to the capture registers (CR000, CR010) of 16-bit timer/event counter 00.

##### (b) TI010

This is the pin for inputting a capture trigger signal to the capture register (CR000) of 16-bit timer/event counter 00.

##### (c) TO00

This is a timer output pin.

### 2.2.2 P10 to P17 (port 1)

P10 to P17 function as an 8-bit I/O port. These pins also function as pins for external interrupt request input, serial interface data I/O, clock I/O, and timer I/O.

The following operation modes can be specified in 1-bit units.

#### (1) Port mode

P10 to P17 function as an 8-bit I/O port. P10 to P17 can be set to input or output in 1-bit units using port mode register 1 (PM1). Use of an on-chip pull-up resistor can be specified by pull-up resistor option register 1 (PU1).

#### (2) Control mode

P10 to P17 function as external interrupt request input, serial interface data I/O, clock I/O, and timer I/O.

##### (a) SI10

This is a serial data input pin of the serial interface.

##### (b) SO10

This is a serial data output pin of the serial interface.

##### (c) $\overline{\text{SCK10}}$

This is a serial clock I/O pin of the serial interface.

##### (d) RxD0<sup>Note</sup>, RxD6

These are the serial data input pins of the asynchronous serial interface.

**(e) TxD0<sup>Note</sup>, TxD6**

These are serial data output pins of the asynchronous serial interface.

**Note** TxD0 and RxD0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.

**(f) TI50**

This is the pin for inputting an external count clock to 8-bit timer/event counter 50.

**(g) TO50, TOH0, and TOH1**

These are timer output pins.

**(h) INTP5**

This is an external interrupt request input pin for which the valid edge (rising edge, falling edge, or both rising and falling edges) can be specified.

**2.2.3 P20 to P23 (port 2)**

P20 to P23 function as a 4-bit input-only port. These pins also function as pins for A/D converter analog input.

The following operation modes can be specified in 1-bit units.

**(1) Port mode**

P20 to P23 function as a 4-bit input-only port.

**(2) Control mode**

P20 to P23 function as A/D converter analog input pins (ANI0 to ANI3). When using these pins as analog input pins, see **(5) ANI0/P20 to ANI3/P23** in **10.6 Cautions for A/D Converter**.

**2.2.4 P30 to P33 (port 3)**

P30 to P33 function as a 4-bit I/O port. These pins also function as pins for external interrupt request input.

The following operation modes can be specified in 1-bit units.

**(1) Port mode**

P30 to P33 function as a 4-bit I/O port. P30 to P33 can be set to input or output in 1-bit units using port mode register 3 (PM3). Use of an on-chip pull-up resistor can be specified by pull-up resistor option register 3 (PU3).

**(2) Control mode**

P30 to P33 function as external interrupt request input pins (INTP1 to INTP4) for which the valid edge (rising edge, falling edge, or both rising and falling edges) can be specified.

**2.2.5 P120 (port 12)**

P120 functions as a 1-bit I/O port. This pin also functions as a pin for external interrupt request input.

The following operation modes can be specified.

**(1) Port mode**

P120 functions as a 1-bit I/O port. P120 can be set to input or output using port mode register 12 (PM12). Use of an on-chip pull-up resistor can be specified by pull-up resistor option register 12 (PU12).

**(2) Control mode**

P120 functions as an external interrupt request input pin (INTP0) for which the valid edge (rising edge, falling edge, or both rising and falling edges) can be specified.

**2.2.6 P130 (port 13)**

P130 functions as a 1-bit output-only port.

**2.2.7 AV<sub>REF</sub>**

This is the A/D converter reference voltage input pin.

When A/D converter is not used, connect this pin directly to V<sub>DD</sub>.

**2.2.8 AV<sub>SS</sub>**

This is the A/D converter ground potential pin. Even when the A/D converter is not used, always use this pin with the same potential as the V<sub>SS</sub> pin.

**2.2.9  $\overline{\text{RESET}}$** 

This is the active-low system reset input pin.

**2.2.10 X1 and X2**

These are the pins for connecting a resonator for X1 input clock oscillation.

When supplying an external clock, input a signal to the X1 pin and input the inverse signal to the X2 pin.

**2.2.11 V<sub>DD</sub>**

This is the positive power supply pin.

**2.2.12 V<sub>SS</sub>**

This is the ground potential pin.

**2.2.13 V<sub>PP</sub> (flash memory versions only)**

This is a pin for flash memory programming mode setting and high-voltage application for program write/verify.

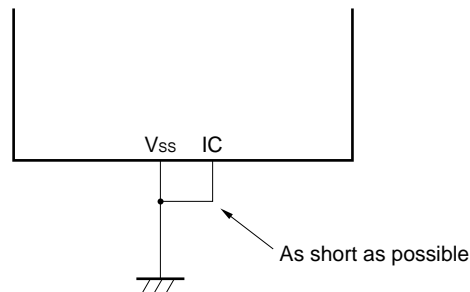
Connect to V<sub>SS</sub> in the normal operation mode.

**2.2.14 IC (mask ROM versions only)**

The IC (Internally Connected) pin is provided to set the test mode to check the 78K0/KB1 at shipment. Connect it directly to V<sub>SS</sub> with the shortest possible wire in the normal operation mode.

When a potential difference is produced between the IC pin and the V<sub>SS</sub> pin because the wiring between these two pins is too long or external noise is input to the IC pin, the user's program may not operate normally.

- Connect the IC pin directly to V<sub>SS</sub>.



## 2.3 Pin I/O Circuits and Recommended Connection of Unused Pins

Table 2-2 shows the types of pin I/O circuit and the recommended connections of unused pins.

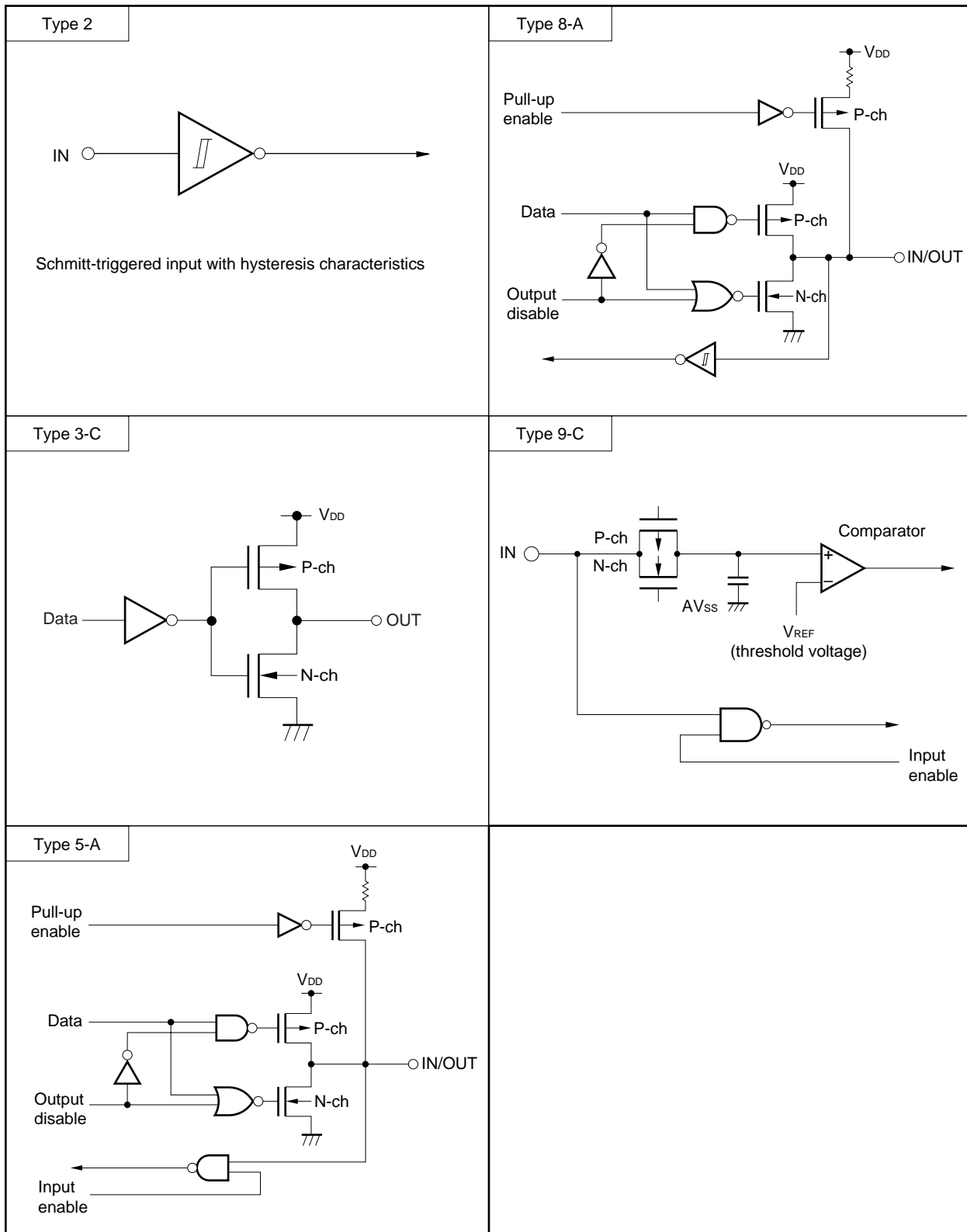
See Figure 2-1 for the configuration of the I/O circuits of each type.

**Table 2-2. Pin I/O Circuit Types**

| Pin Name                                      | I/O Circuit Type | I/O    | Recommended Connection of Unused Pins   |                       |
|---|------------------|--------|---|-----------------------|
| P00/TI000                                     | 8-A              | I/O    | Input: Independently connect to $V_{DD}$ or $V_{SS}$ via a resistor.<br>Output: Leave open. |                       |
| P01/TI010/TO00                                |                  |        |   |                       |
| P02   |                  |        |   |                       |
| P03   |                  |        |   |                       |
| P10/ $\overline{SCK10}$ /TxD0 <sup>Note</sup> |                  |        |   |                       |
| P11/SI10/RxD0 <sup>Note</sup>                 |                  |        |   |                       |
| P12/SO10                                      |                  |        |   | 5-A                   |
| P13/TxD6                                      |                  |        |   |                       |
| P14/RxD6                                      |                  |        |   | 8-A                   |
| P15/TOH0                                      |                  |        |   | 5-A                   |
| P16/TOH1/INTP5                                | 8-A              |        |   |                       |
| P17/TI50/TO50                                 |                  |        |   |                       |
| P20/ANI0 to P23/ANI3                          | 9-C              | Input  | Connect to $V_{DD}$ or $V_{SS}$ .   |                       |
| P30/INTP1 to P33/INTP4                        | 8-A              | I/O    | Input: Independently connect to $V_{SS}$ via a resistor.<br>Output: Leave open.             |                       |
| P120/INTP0                                    |                  |        | Input: Independently connect to $V_{DD}$ or $V_{SS}$ via a resistor.<br>Output: Leave open. |                       |
| P130  | 3-C              | Output | Leave open.   |                       |
| ★ RESE $\overline{T}$                         | 2                | Input  | Connect to $V_{DD}$ .   |                       |
| AV <sub>REF</sub>                             | -                | Input  | Connect directly to $V_{DD}$ .  |                       |
| AV <sub>SS</sub>                              |                  | -      | Connect directly to $V_{SS}$ .  |                       |
| IC  |                  |        |   |                       |
| V <sub>PP</sub>                               |                  |        |   | Connect to $V_{SS}$ . |
|   |                  |        |   |                       |

**Note** TxD0 and RxD0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.

Figure 2-1. Pin I/O Circuit List





## CHAPTER 3 CPU ARCHITECTURE

### 3.1 Memory Space

Products in the 78K0/KB1 can each access a 64 KB memory space. Figures 3-1 to 3-4 show the memory maps.

**Caution** Regardless of the internal memory capacity, the initial values of internal memory size switching register (IMS) of all products in the 78K0/KB1 are fixed (IMS = CFH). Therefore, set the value corresponding to each product as indicated below.

**Table 3-1. Internal Memory Size Switching Register (IMS) Set Value**

|                 | Internal Memory Size Switching Register (IMS) |
|-----------------|---|
| $\mu$ PD780101  | 42H   |
| $\mu$ PD780102  | 04H   |
| $\mu$ PD780103  | 06H   |
| $\mu$ PD78F0103 | Value corresponding to mask ROM version       |

Figure 3-1. Memory Map ( $\mu$ PD780101)

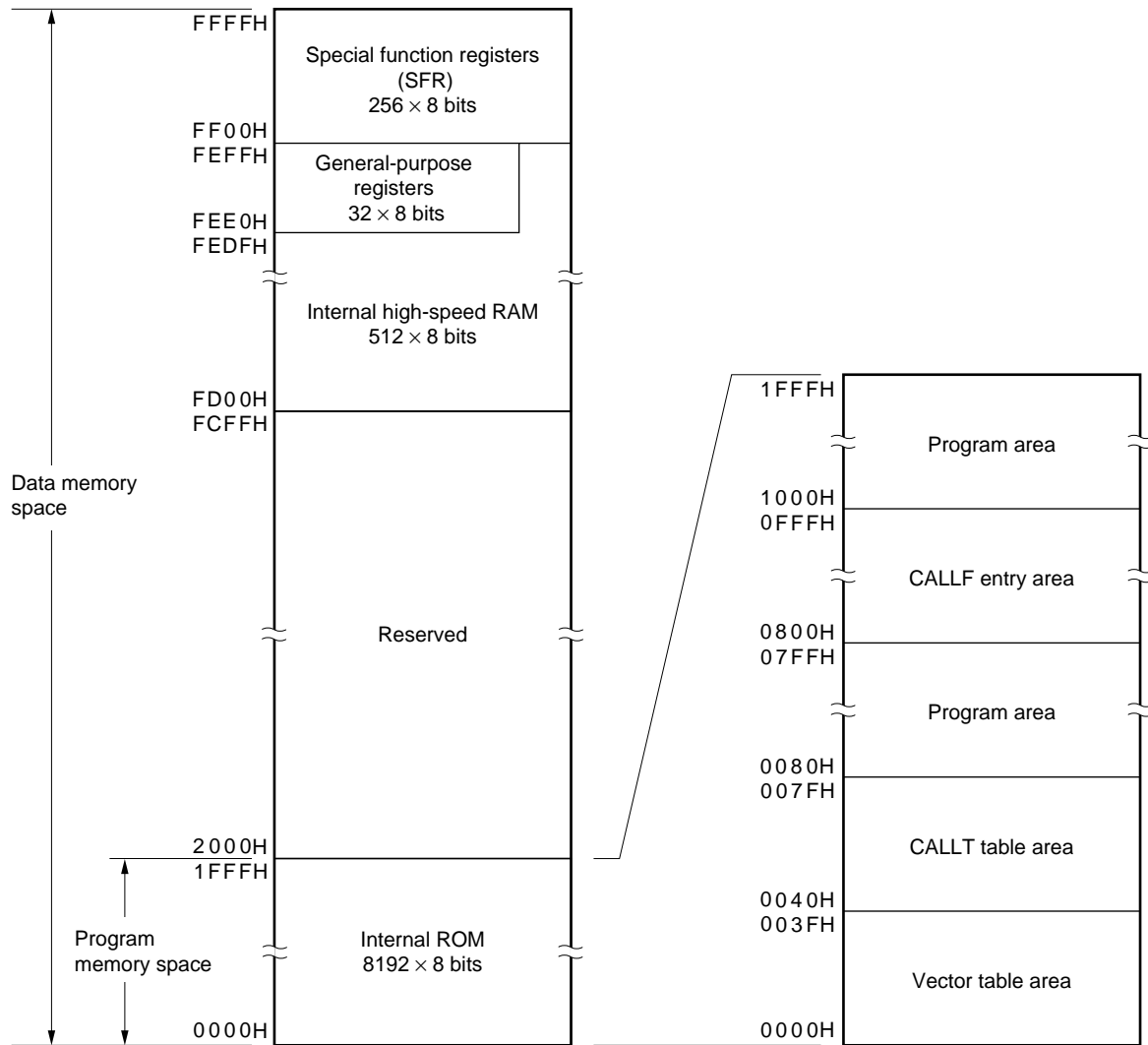


Figure 3-2. Memory Map ( $\mu$ PD780102)

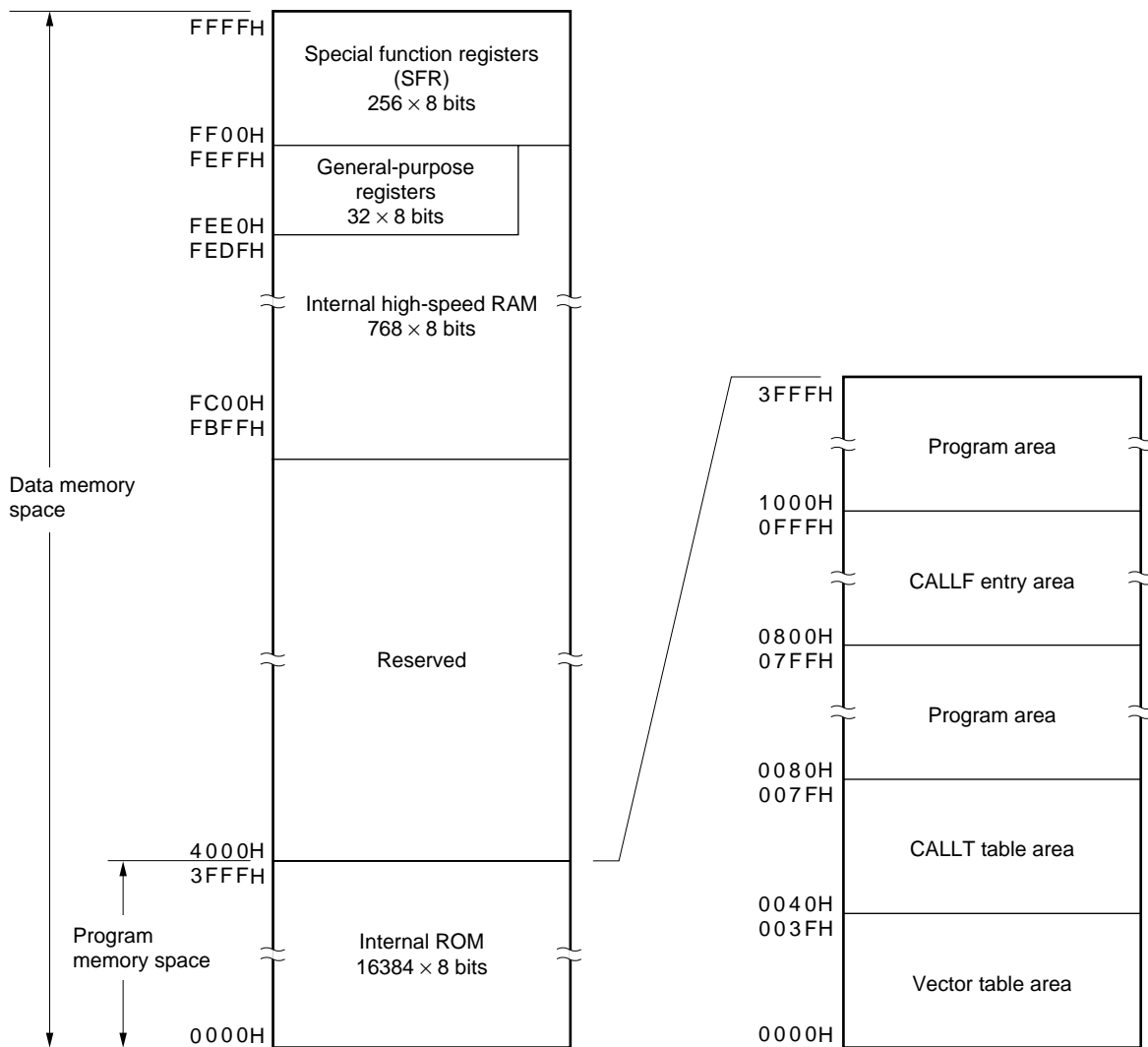


Figure 3-3. Memory Map ( $\mu$ PD780103)

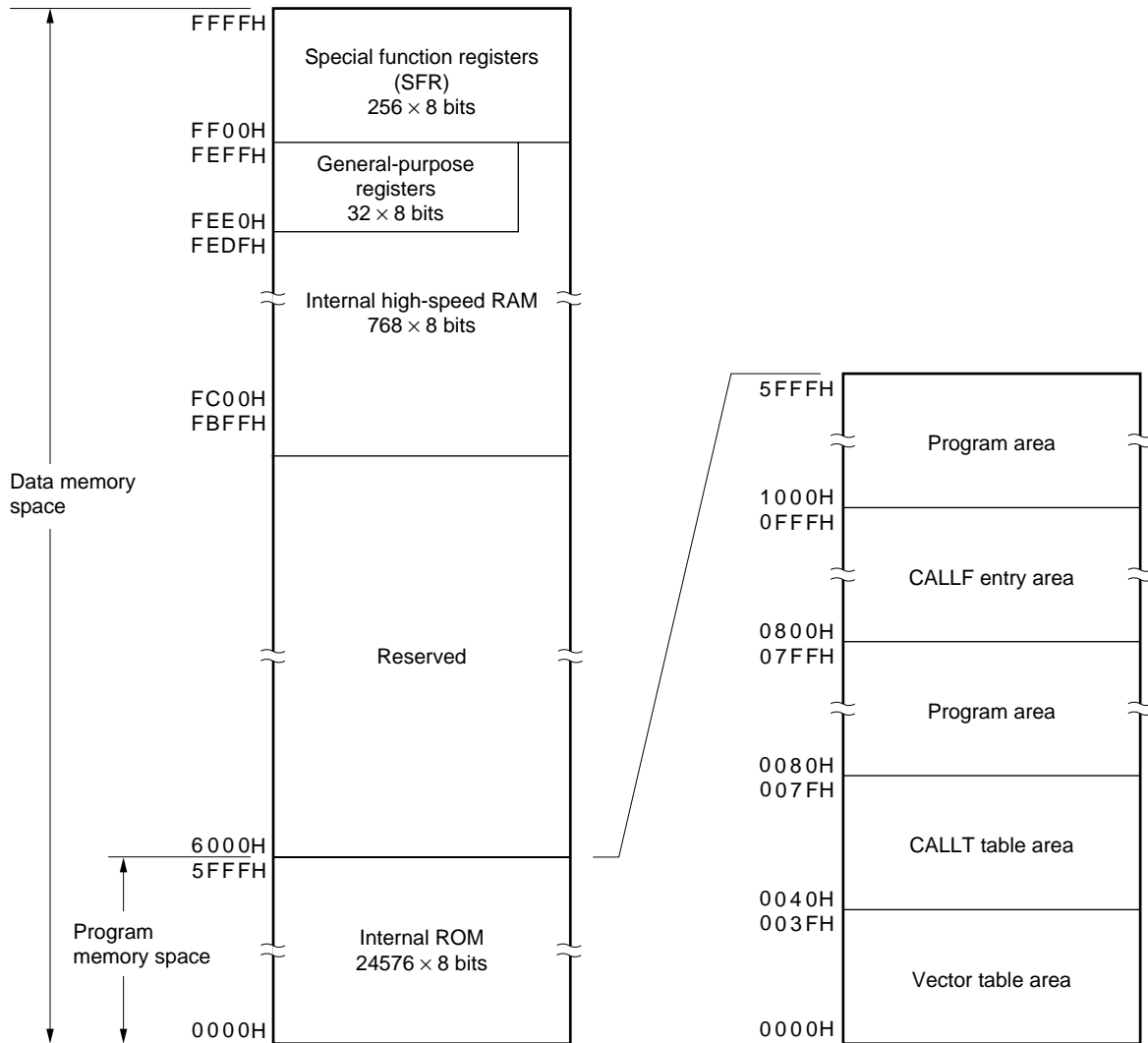
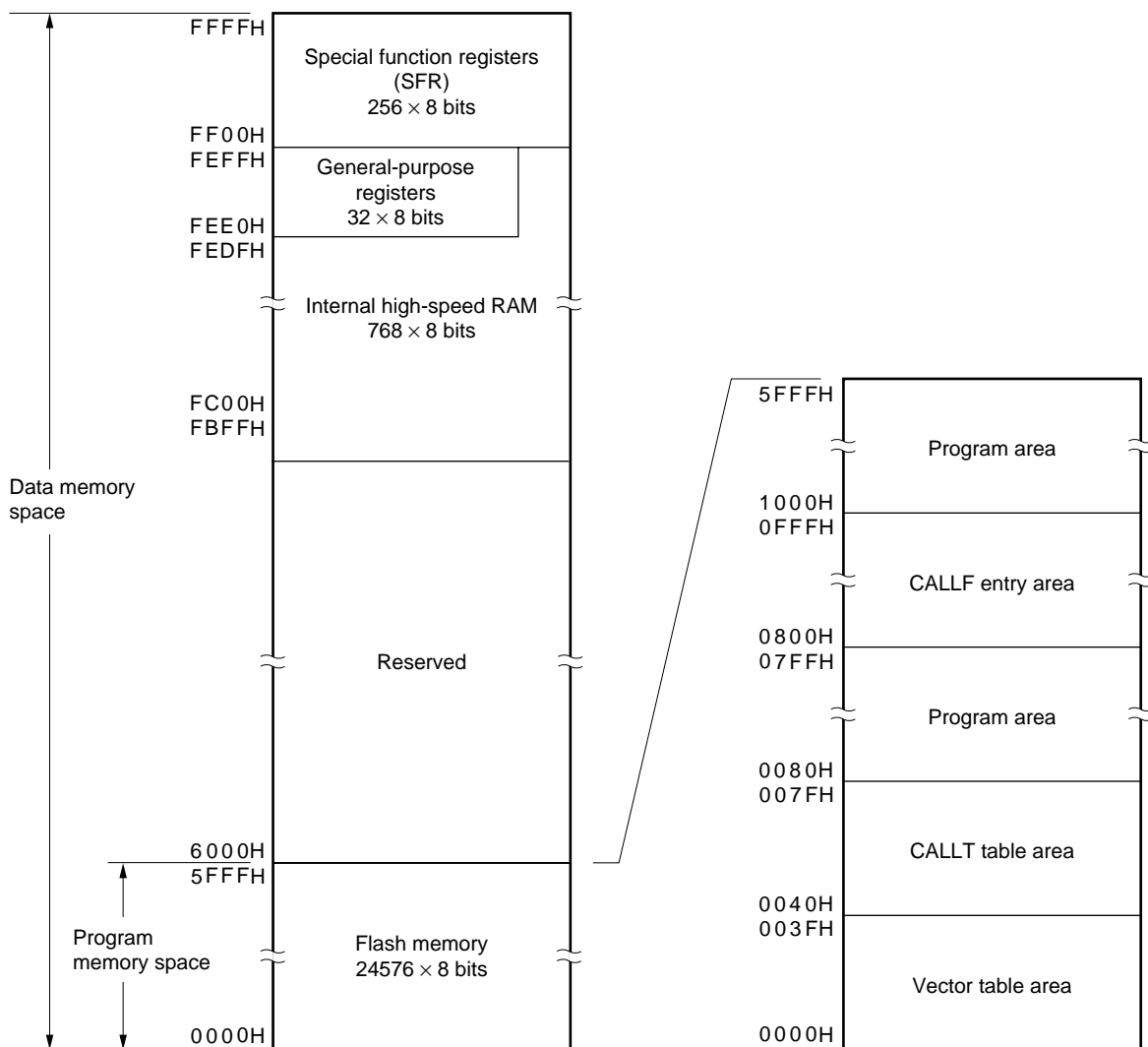


Figure 3-4. Memory Map ( $\mu$ PD78F0103)



### 3.1.1 Internal program memory space

The internal program memory space stores the program and table data. Normally, it is addressed with the program counter (PC).

78K0/KB1 products incorporate internal ROM (mask ROM or flash memory), as shown below.

**Table 3-2. Internal ROM Capacity**

| Part Number     | Internal ROM |  |
|-----------------|--------------|--|
|                 | Structure    | Capacity                               |
| $\mu$ PD780101  | Mask ROM     | 8192 $\times$ 8 bits (0000H to 1FFFH)  |
| $\mu$ PD780102  |              | 16384 $\times$ 8 bits (0000H to 3FFFH) |
| $\mu$ PD780103  |              | 24576 $\times$ 8 bits (0000H to 5FFFH) |
| $\mu$ PD78F0103 | Flash memory | 24576 $\times$ 8 bits (0000H to 5FFFH) |

The internal program memory space is divided into the following areas.

#### (1) Vector table area

The 64-byte area 0000H to 003FH is reserved as a vector table area. The program start addresses for branch upon reset signal input or generation of each interrupt request are stored in the vector table area.

Of the 16-bit address, the lower 8 bits are stored at even addresses and the higher 8 bits are stored at odd addresses.

**Table 3-3. Vector Table**

| Vector Table Address | Interrupt Source                         | Vector Table Address | Interrupt Source                |
|----------------------|--|----------------------|---------------------------------|
| 0000H                | RESET input, POC, LVI clock monitor, WDT | 0016H                | INTST6                          |
|                      |  | 0018H                | INTCSI10/INTST0 <sup>Note</sup> |
| 0004H                | INTLVI                                   | 001AH                | INTTMH1                         |
| 0006H                | INTP0                                    | 001CH                | INTTMH0                         |
| 0008H                | INTP1                                    | 001EH                | INTTM50                         |
| 000AH                | INTP2                                    | 0020H                | INTTM000                        |
| 000CH                | INTP3                                    | 0022H                | INTTM010                        |
| 000EH                | INTP4                                    | 0024H                | INTAD                           |
| 0010H                | INTP5                                    | 0026H                | INTSR0 <sup>Note</sup>          |
| 0012H                | INTSRE6                                  | 003EH                | BRK                             |
| 0014H                | INTSR6                                   |                      |                                 |

**Note** Available only in the  $\mu$ PD780102, 780103, and 78F0103.

#### (2) CALLT instruction table area

The 64-byte area 0040H to 007FH can store the subroutine entry address of a 1-byte call instruction (CALLT).

#### (3) CALLF instruction entry area

The area 0800H to 0FFFH can perform a direct subroutine call with a 2-byte call instruction (CALLF).

### 3.1.2 Internal data memory space

78K0/KB1 products incorporate the following internal high-speed RAM.

**Table 3-4. Internal High-Speed RAM Capacity**

| Part Number     | Internal High-Speed RAM              |
|-----------------|--------------------------------------|
| $\mu$ PD780101  | 512 $\times$ 8 bits (FD00H to FEFFH) |
| $\mu$ PD780102  | 768 $\times$ 8 bits (FC00H to FEFFH) |
| $\mu$ PD780103  |                                      |
| $\mu$ PD78F0103 |                                      |

The 32-byte area FEE0H to FEFFH is assigned to four general-purpose register banks consisting of eight 8-bit registers per bank.

This area cannot be used as a program area in which instructions are written and executed.

The internal high-speed RAM can also be used as a stack memory.

### 3.1.3 Special function register (SFR) area

On-chip peripheral hardware special function registers (SFRs) are allocated in the area FF00H to FFFFH (see **Table 3-5 Special Function Register List** in **3.2.3 Special function registers (SFRs)**).

**Caution** Do not access addresses to which SFRs are not assigned.

### 3.1.4 Data memory addressing

Addressing refers to the method of specifying the address of the instruction to be executed next or the address of the register or memory relevant to the execution of instructions.

Several addressing modes are provided for addressing the memory relevant to the execution of instructions for the 78K0/KB1, based on operability and other considerations. For areas containing data memory in particular, special addressing methods designed for the functions of special function registers (SFR) and general-purpose registers are available for use. Figures 3-5 to 3-8 show the correspondence between data memory and addressing. For details of each addressing mode, see **3.4 Operand Address Addressing**.

**Figure 3-5. Correspondence Between Data Memory and Addressing ( $\mu$ PD780101)**

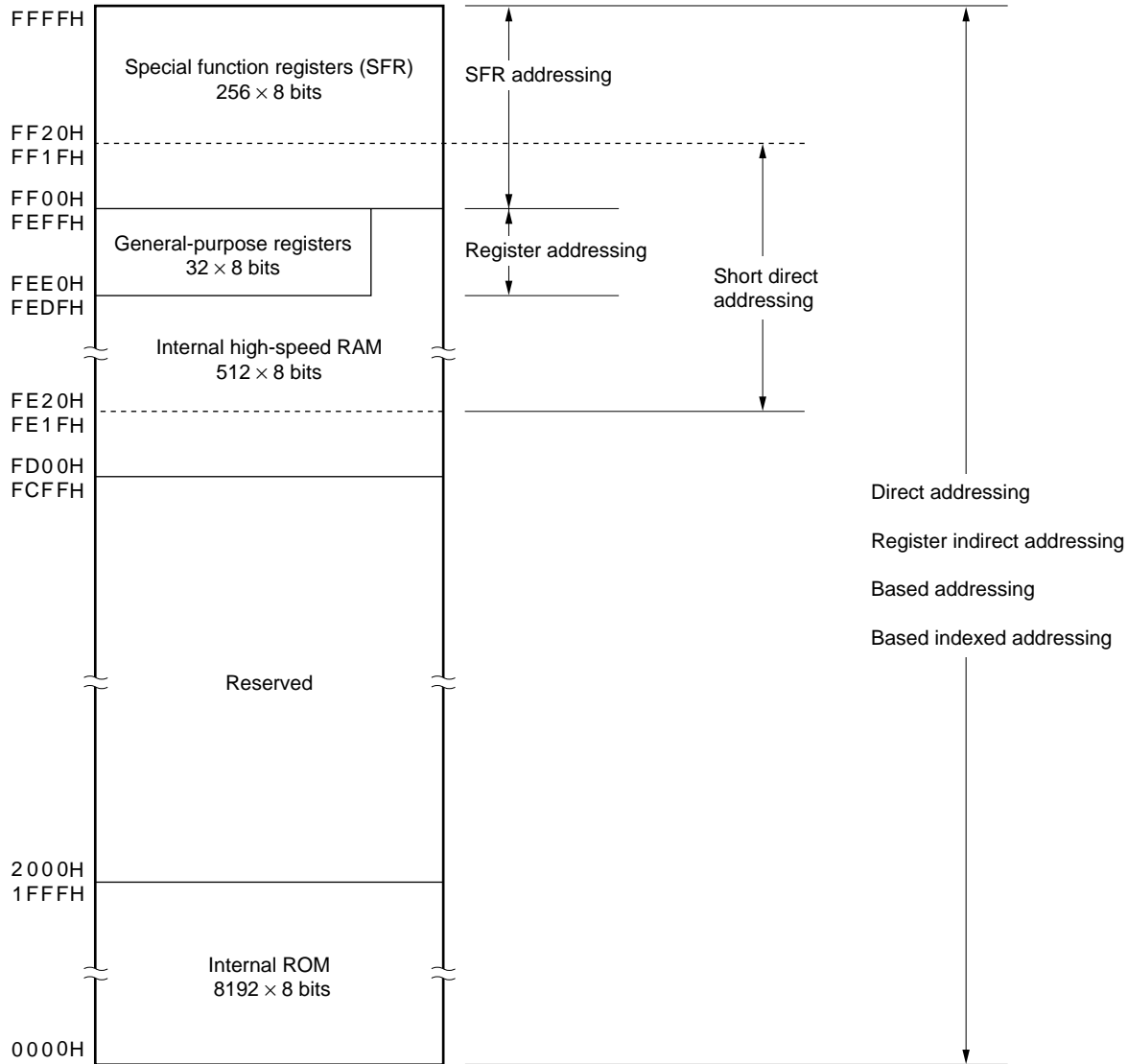




Figure 3-6. Correspondence Between Data Memory and Addressing ( $\mu$ PD780102)

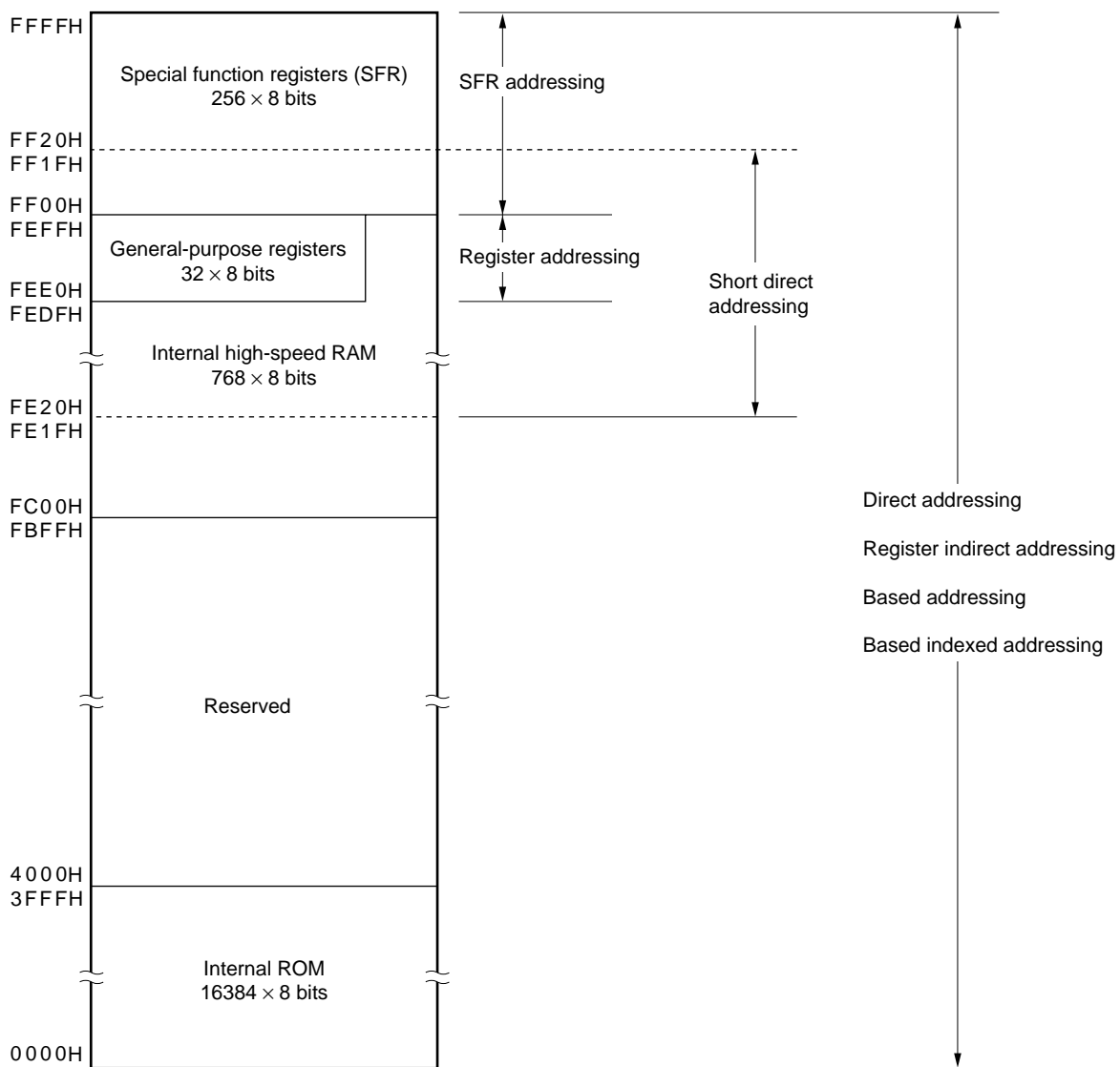


Figure 3-7. Correspondence Between Data Memory and Addressing ( $\mu$ PD780103)

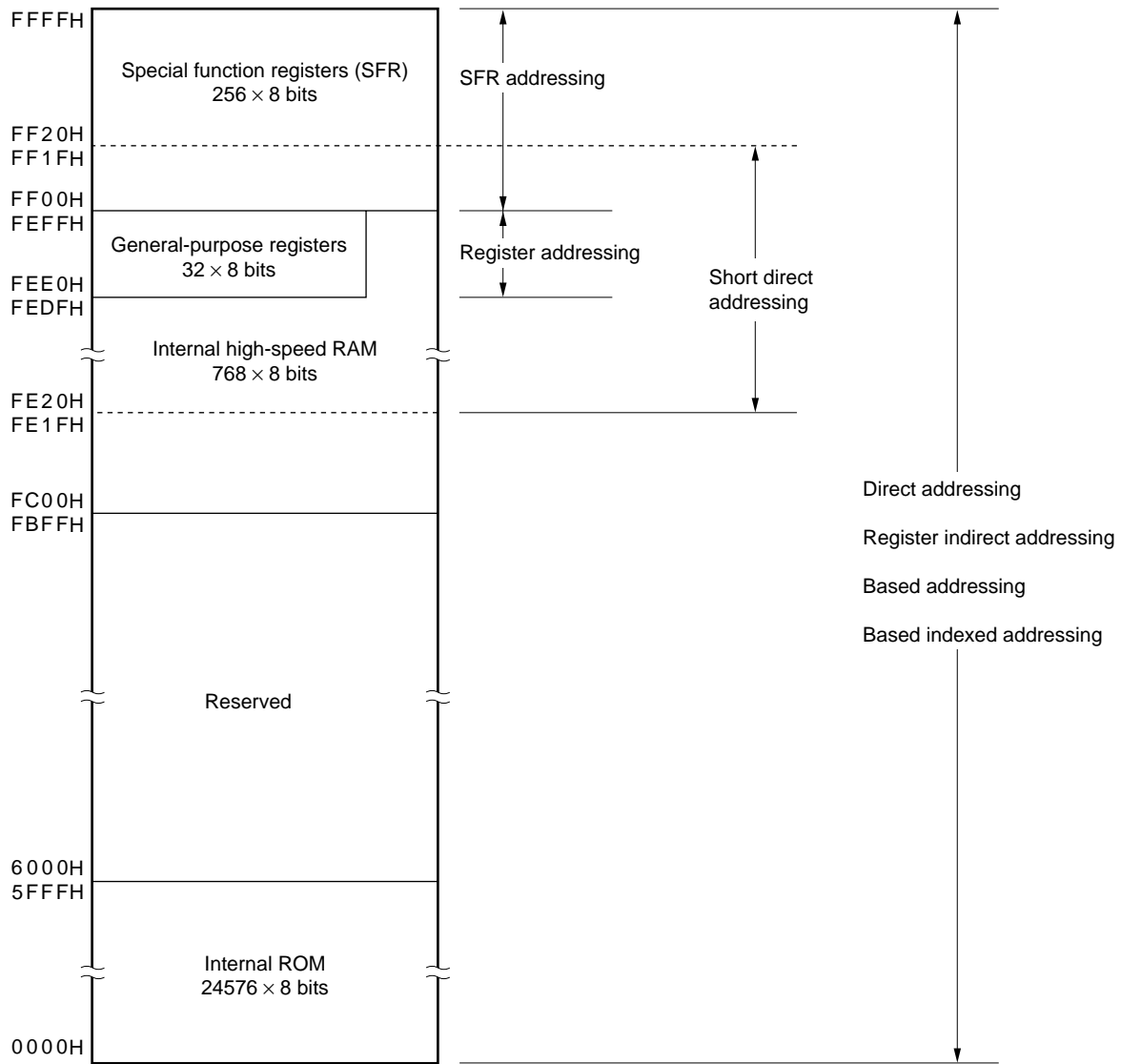
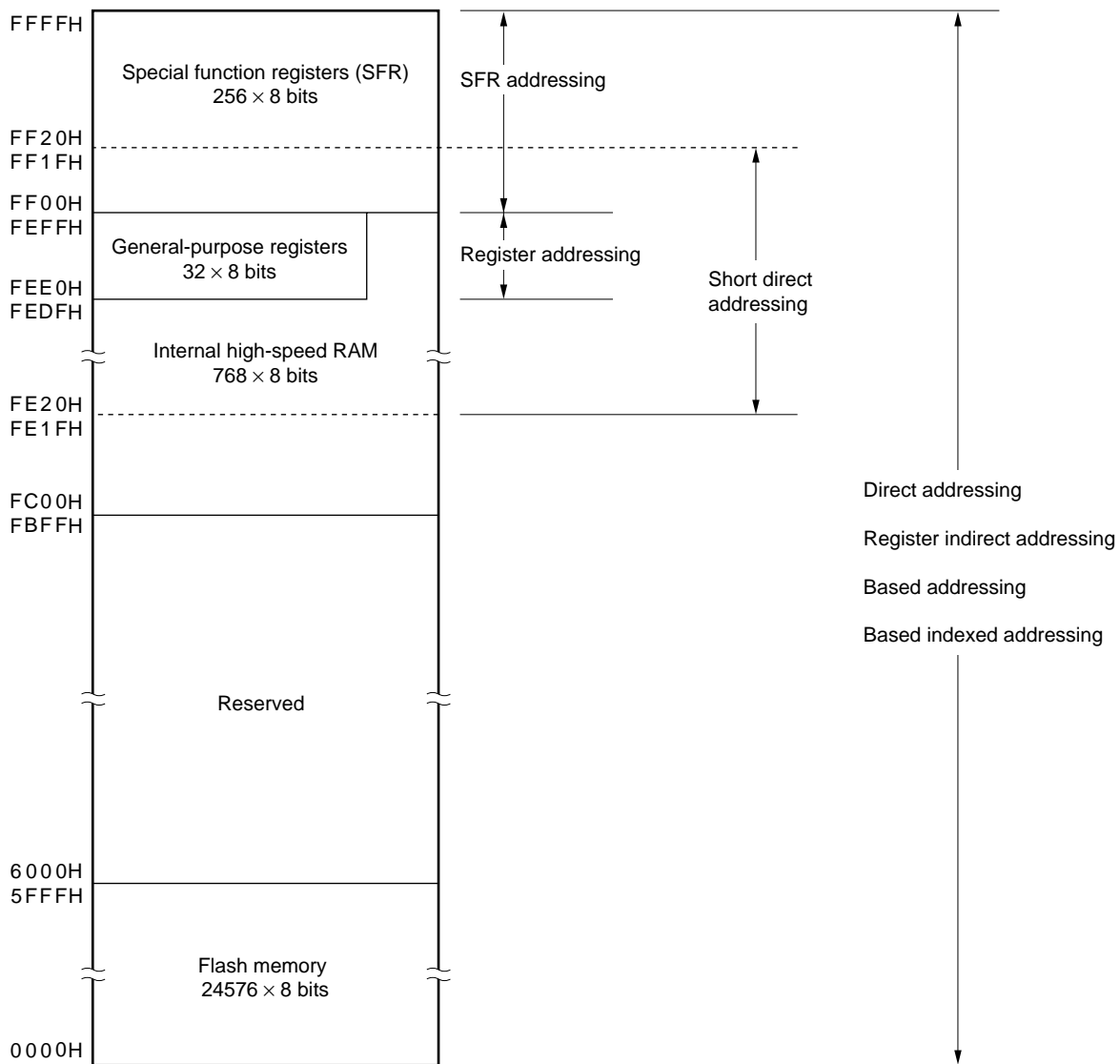


Figure 3-8. Correspondence Between Data Memory and Addressing ( $\mu$ PD78F0103)



### 3.2 Processor Registers

78K0/KB1 products incorporate the following processor registers.

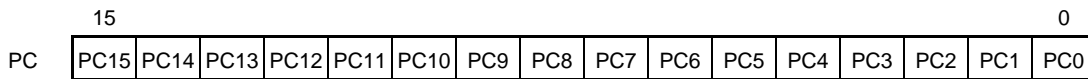
#### 3.2.1 Control registers

The control registers control the program sequence, statuses and stack memory. The control registers consist of a program counter (PC), a program status word (PSW) and a stack pointer (SP).

##### (1) Program counter (PC)

The program counter is a 16-bit register that holds the address information of the next program to be executed. In normal operation, the PC is automatically incremented according to the number of bytes of the instruction to be fetched. When a branch instruction is executed, immediate data and register contents are set.  $\overline{\text{RESET}}$  input sets the reset vector table values at addresses 0000H and 0001H to the program counter.

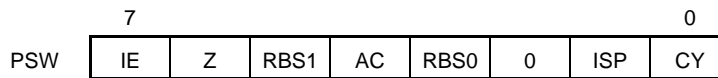
Figure 3-9. Format of Program Counter



##### (2) Program status word (PSW)

The program status word is an 8-bit register consisting of various flags to be set/reset by instruction execution. Program status word contents are automatically stacked upon interrupt request generation or PUSH PSW instruction execution and are reset upon execution of the RETB, RETI and POP PSW instructions.  $\overline{\text{RESET}}$  input sets the PSW to 02H.

Figure 3-10. Format of Program Status Word



##### (a) Interrupt enable flag (IE)

This flag controls the interrupt request acknowledgment operations of the CPU. When 0, the IE flag is set to the interrupt disabled (DI) state, and maskable interrupt requests are all disabled. When 1, the IE flag is set to the interrupt enabled (EI) state and interrupt request acknowledgment enable is controlled with an in-service priority flag (ISP), an interrupt mask flag for various interrupt sources and a priority specification flag. The IE flag is reset (0) upon DI instruction execution or interrupt acknowledgment and is set (1) upon EI instruction execution.

##### (b) Zero flag (Z)

When the operation result is zero, this flag is set (1). It is reset (0) in all other cases.

**(c) Register bank select flags (RBS0 and RBS1)**

These are 2-bit flags to select one of the four register banks.

In these flags, the 2-bit information that indicates the register bank selected by SEL RBn instruction execution is stored.

**(d) Auxiliary carry flag (AC)**

If the operation result has a carry from bit 3 or a borrow at bit 3, this flag is set (1). It is reset (0) in all other cases.

**(e) In-service priority flag (ISP)**

This flag manages the priority of acknowledgeable maskable vectored interrupts. When this flag is 0, low-level vectored interrupt requests specified by a priority specification flag register (PR0L, PR0H, PR1L) (see **14.3 (3) Priority specification flag registers (PR0L, PR0H, PR1L)**) can not be acknowledged. Actual request acknowledgment is controlled by the interrupt enable flag (IE).

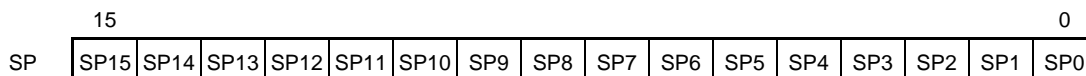
**(f) Carry flag (CY)**

This flag stores on overflow or underflow upon add/subtract instruction execution. It stores the shift-out value upon rotate instruction execution and functions as a bit accumulator during bit operation instruction execution.

**(3) Stack pointer (SP)**

This is a 16-bit register to hold the start address of the memory stack area. Only the internal high-speed RAM area can be set as the stack area.

**Figure 3-11. Format of Stack Pointer**



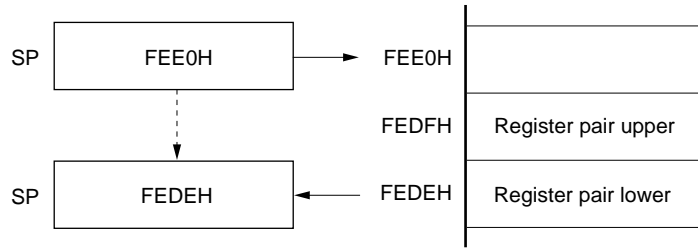
The SP is decremented ahead of write (save) to the stack memory and is incremented after read (restore) from the stack memory.

Each stack operation saves/restores data as shown in Figures 3-12 and 3-13.

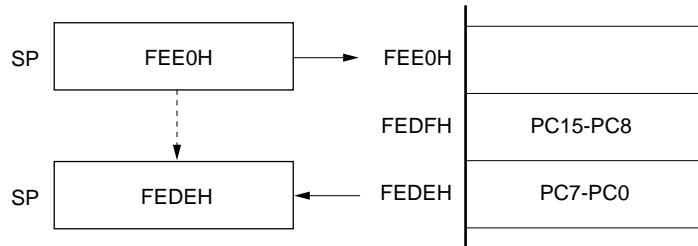
**Caution** Since  $\overline{\text{RESET}}$  input makes the SP contents undefined, be sure to initialize the SP before use.

Figure 3-12. Data to Be Saved to Stack Memory

(a) PUSH rp instruction (when SP = FEE0H)



(b) CALL, CALLF, CALLT instructions (when SP = FEE0H)



(c) Interrupt, BRK instructions (when SP = FEE0H)

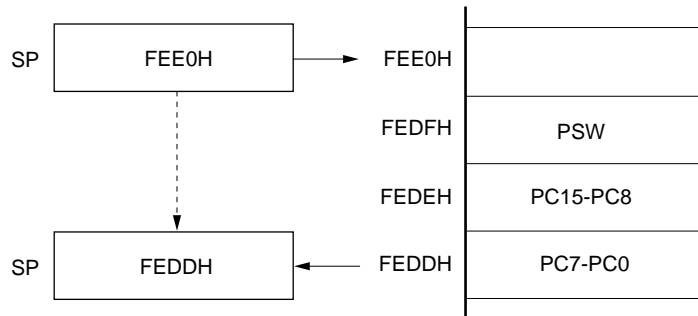
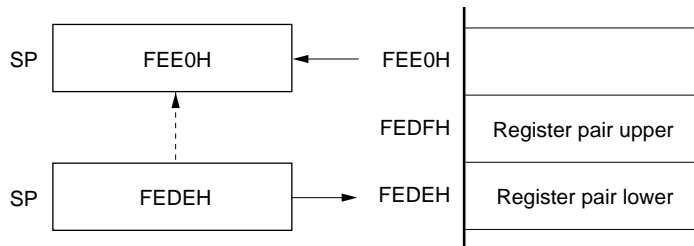
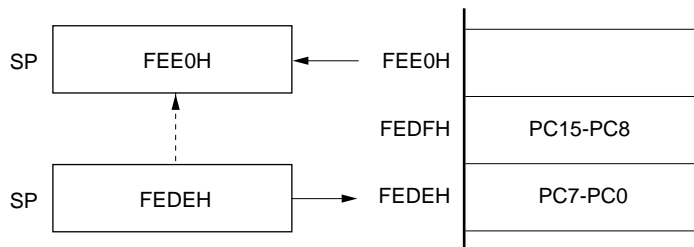


Figure 3-13. Data to Be Restored from Stack Memory

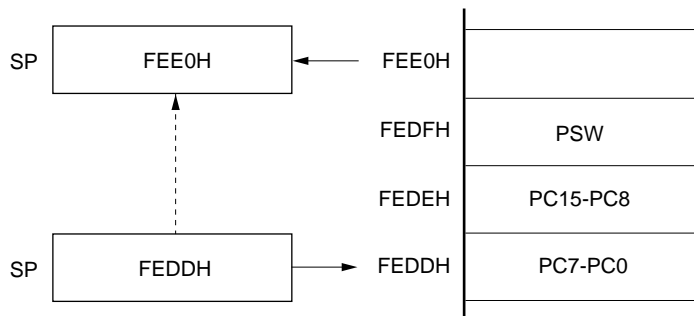
(a) POP rp instruction (when SP = FEDEH)



(b) RET instruction (when SP = FEDEH)



(c) RETI, RETB instructions (when SP = FEDDH)



**3.2.2 General-purpose registers**

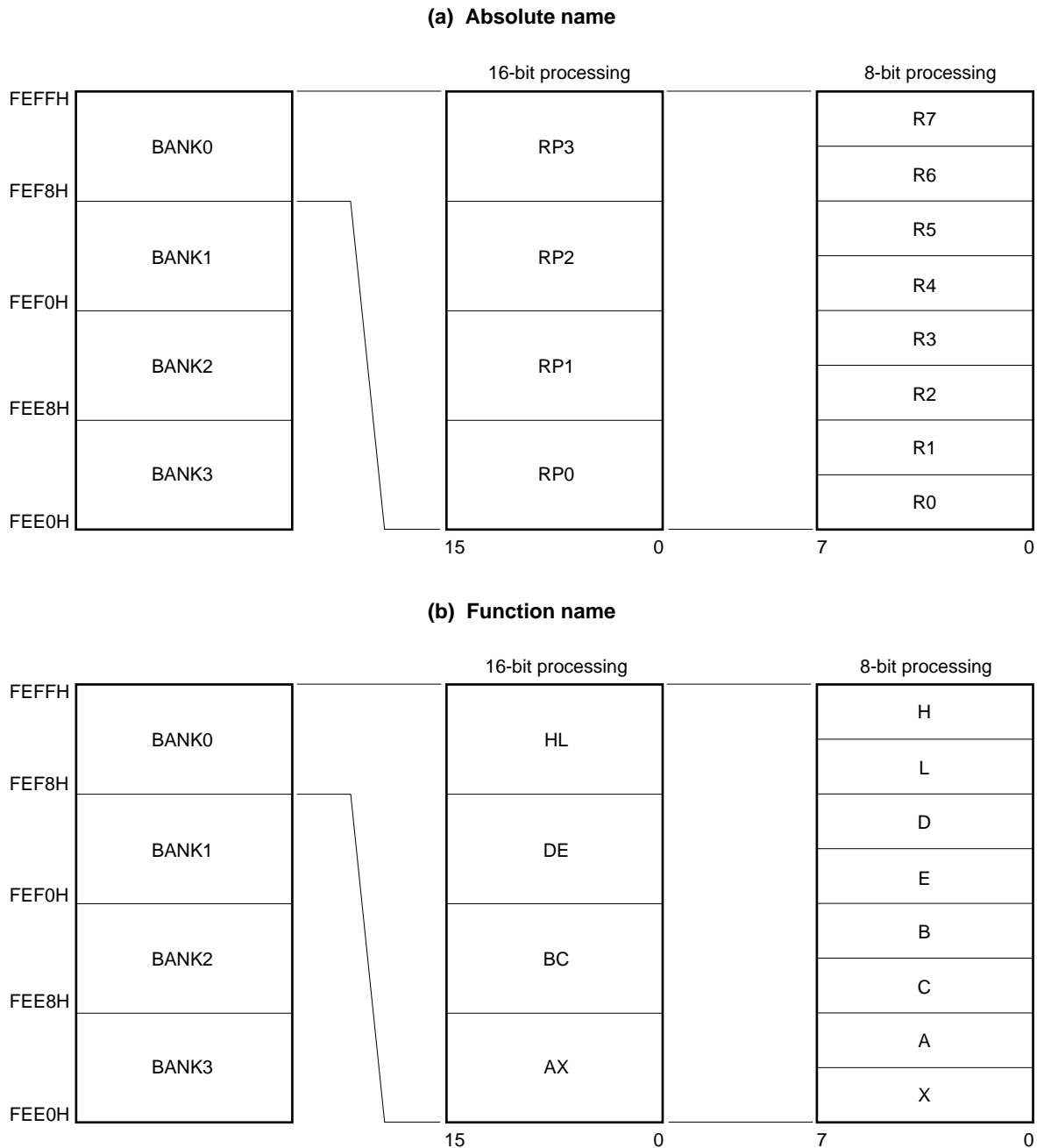
General-purpose registers are mapped at particular addresses (FEE0H to FEFFH) of the data memory. The general-purpose registers consists of 4 banks, each bank consisting of eight 8-bit registers (X, A, C, B, E, D, L, and H).

Each register can be used as an 8-bit register, and two 8-bit registers can also be used in a pair as a 16-bit register (AX, BC, DE, and HL).

These registers can be described in terms of function names (X, A, C, B, E, D, L, H, AX, BC, DE, and HL) and absolute names (R0 to R7 and RP0 to RP3).

Register banks to be used for instruction execution are set by the CPU control instruction (SEL RBn). Because of the 4-register bank configuration, an efficient program can be created by switching between a register for normal processing and a register for interrupts for each bank.

**Figure 3-14. Configuration of General-Purpose Registers**





### 3.2.3 Special function registers (SFRs)

Unlike a general-purpose register, each special function register has a special function.

SFRs are allocated to the FF00H to FFFFH area.

Special function registers can be manipulated like general-purpose registers, using operation, transfer and bit manipulation instructions. The manipulatable bit units, 1, 8, and 16, depend on the special function register type.

Each manipulation bit unit can be specified as follows.

- 1-bit manipulation  
Describe the symbol reserved by the assembler for the 1-bit manipulation instruction operand (sfr.bit).  
This manipulation can also be specified with an address.
- 8-bit manipulation  
Describe the symbol reserved by the assembler for the 8-bit manipulation instruction operand (sfr).  
This manipulation can also be specified with an address.
- 16-bit manipulation  
Describe the symbol reserved by the assembler for the 16-bit manipulation instruction operand (sfrp).  
When specifying an address, describe an even address.

Table 3-5 gives a list of the special function registers. The meanings of items in the table are as follows.

- Symbol  
★ Symbol indicating the address of a special function register. It is a reserved word in the RA78K0, and is defined as an sfr variable using the #pragma sfr directive in the CC78K0. When using the RA78K0, ID78K0-NS, ID78K0, and SM78K0, symbols can be written as an instruction operand.
- R/W  
Indicates whether the corresponding special function register can be read or written.  
R/W: Read/write enable  
R: Read only  
W: Write only
- Manipulatable bit units  
Indicates the manipulatable bit unit (1, 8, or 16). “–” indicates a bit unit for which manipulation is not possible.
- After reset  
Indicates each register status upon  $\overline{\text{RESET}}$  input.

Table 3-5. Special Function Register List (1/3)

| Address | Special Function Register (SFR) Name            | Symbol | R/W | Manipulatable Bit Unit |        |         | After Reset |
|---------|---|--------|-----|------------------------|--------|---------|-------------|
|         |   |        |     | 1 Bit                  | 8 Bits | 16 Bits |             |
| FF00H   | Port register 0                                 | P0     | R/W | √                      | √      | –       | 00H         |
| FF01H   | Port register 1                                 | P1     | R/W | √                      | √      | –       | 00H         |
| FF02H   | Port register 2                                 | P2     | R   | √                      | √      | –       | Undefined   |
| FF03H   | Port register 3                                 | P3     | R/W | √                      | √      | –       | 00H         |
| FF08H   | A/D conversion result register                  | ADCR   | R   | –                      | –      | √       | Undefined   |
| FF09H   |   |        |     |                        |        |         |             |
| FF0AH   | Receive buffer register 6                       | RXB6   | R   | –                      | √      | –       | FFH         |
| FF0BH   | Transmit buffer register 6                      | TXB6   | R/W | –                      | √      | –       | FFH         |
| FF0CH   | Port register 12                                | P12    | R/W | √                      | √      | –       | 00H         |
| FF0DH   | Port register 13                                | P13    | R/W | √                      | √      | –       | 00H         |
| FF0FH   | Serial I/O shift register 10                    | SIO10  | R   | –                      | √      | –       | 00H         |
| FF10H   | 16-bit timer counter 00                         | TM00   | R   | –                      | –      | √       | 0000H       |
| FF11H   |   |        |     |                        |        |         |             |
| FF12H   | 16-bit timer capture/compare register 000       | CR000  | R/W | –                      | –      | √       | 0000H       |
| FF13H   |   |        |     |                        |        |         |             |
| FF14H   | 16-bit timer capture/compare register 010       | CR010  | R/W | –                      | –      | √       | 0000H       |
| FF15H   |   |        |     |                        |        |         |             |
| FF16H   | 8-bit timer counter 50                          | TM50   | R   | –                      | √      | –       | 00H         |
| FF17H   | 8-bit timer compare register 50                 | CR50   | R/W | –                      | √      | –       | 00H         |
| FF18H   | 8-bit timer H compare register 00               | CMP00  | R/W | –                      | √      | –       | 00H         |
| FF19H   | 8-bit timer H compare register 10               | CMP10  | R/W | –                      | √      | –       | 00H         |
| FF1AH   | 8-bit timer H compare register 01               | CMP01  | R/W | –                      | √      | –       | 00H         |
| FF1BH   | 8-bit timer H compare register 11               | CMP11  | R/W | –                      | √      | –       | 00H         |
| FF20H   | Port mode register 0                            | PM0    | R/W | √                      | √      | –       | FFH         |
| FF21H   | Port mode register 1                            | PM1    | R/W | √                      | √      | –       | FFH         |
| FF23H   | Port mode register 3                            | PM3    | R/W | √                      | √      | –       | FFH         |
| FF28H   | A/D converter mode register                     | ADM    | R/W | √                      | √      | –       | 00H         |
| FF29H   | Analog input channel specification register     | ADS    | R/W | √                      | √      | –       | 00H         |
| FF2AH   | Power-fail comparison mode register             | PFM    | R/W | √                      | √      | –       | 00H         |
| FF2BH   | Power-fail comparison threshold register        | PFT    | R/W | –                      | √      | –       | 00H         |
| FF2CH   | Port mode register 12                           | PM12   | R/W | √                      | √      | –       | FFH         |
| FF30H   | Pull-up resistor option register 0              | PU0    | R/W | √                      | √      | –       | 00H         |
| FF31H   | Pull-up resistor option register 1              | PU1    | R/W | √                      | √      | –       | 00H         |
| FF33H   | Pull-up resistor option register 3              | PU3    | R/W | √                      | √      | –       | 00H         |
| FF3CH   | Pull-up resistor option register 12             | PU12   | R/W | √                      | √      | –       | 00H         |
| FF48H   | External interrupt rising edge enable register  | EGP    | R/W | √                      | √      | –       | 00H         |
| FF49H   | External interrupt falling edge enable register | EGN    | R/W | √                      | √      | –       | 00H         |
| FF4FH   | Input switch control register                   | ISC    | R/W | √                      | √      | –       | 00H         |

Table 3-5. Special Function Register List (2/3)

| Address | Special Function Register (SFR) Name  | Symbol | R/W | Manipulatable Bit Unit |        |         | After Reset           |
|---------|---|--------|-----|------------------------|--------|---------|-----------------------|
|         |   |        |     | 1 Bit                  | 8 Bits | 16 Bits |                       |
| FF50H   | Asynchronous serial interface operation mode register 6                           | ASIM6  | R/W | √                      | √      | –       | 01H                   |
| FF53H   | Asynchronous serial interface reception error status register 6                   | ASIS6  | R   | –                      | √      | –       | 00H                   |
| FF55H   | Asynchronous serial interface transmission status register 6                      | ASIF6  | R   | –                      | √      | –       | 00H                   |
| FF56H   | Clock selection register 6  | CKSR6  | R/W | –                      | √      | –       | 00H                   |
| FF57H   | Baud rate generator control register 6  | BRGC6  | R/W | –                      | √      | –       | FFH                   |
| FF58H   | Asynchronous serial interface control register 6                                  | ASICL6 | R/W | √                      | √      | –       | 16H                   |
| FF69H   | 8-bit timer H mode register 0   | TMHMD0 | R/W | √                      | √      | –       | 00H                   |
| FF6AH   | Timer clock selection register 50   | TCL50  | R/W | –                      | √      | –       | 00H                   |
| FF6BH   | 8-bit timer mode control register 50  | TMC50  | R/W | √                      | √      | –       | 00H                   |
| FF6CH   | 8-bit timer H mode register 1   | TMHMD1 | R/W | √                      | √      | –       | 00H                   |
| FF70H   | Asynchronous serial interface operation mode register 0 <sup>Note 1</sup>         | ASIM0  | R/W | √                      | √      | –       | 01H                   |
| FF71H   | Baud rate generator control register 0 <sup>Note 1</sup>                          | BRGC0  | R/W | –                      | √      | –       | 1FH                   |
| FF72H   | Receive buffer register 0 <sup>Note 1</sup>                                       | RXB0   | R   | –                      | √      | –       | FFH                   |
| FF73H   | Asynchronous serial interface reception error status register 0 <sup>Note 1</sup> | ASIS0  | R   | –                      | √      | –       | 00H                   |
| FF74H   | Transmit shift register 0 <sup>Note 1</sup>                                       | TXS0   | W   | –                      | √      | –       | FFH                   |
| FF80H   | Serial operation mode register 10   | CSIM10 | R/W | √                      | √      | –       | 00H                   |
| FF81H   | Serial clock selection register 10  | CSIC10 | R/W | √                      | √      | –       | 00H                   |
| FF84H   | Transmit buffer register 10   | SOTB10 | R/W | –                      | √      | –       | Undefined             |
| FF98H   | Watchdog timer mode register  | WDTM   | R/W | –                      | √      | –       | 67H                   |
| FF99H   | Watchdog timer enable register  | WDTE   | R/W | –                      | √      | –       | 9AH                   |
| FFA0H   | Ring-OSC mode register  | RCM    | R/W | √                      | √      | –       | 00H                   |
| FFA1H   | Main clock mode register  | MCM    | R/W | √                      | √      | –       | 00H                   |
| FFA2H   | Main OSC control register   | MOC    | R/W | √                      | √      | –       | 00H                   |
| FFA3H   | Oscillation stabilization time counter status register                            | OSTC   | R   | √                      | √      | –       | 00H                   |
| FFA4H   | Oscillation stabilization time select register                                    | OSTS   | R/W | –                      | √      | –       | 05H                   |
| FFA9H   | Clock monitor mode register   | CLM    | R/W | √                      | √      | –       | 00H                   |
| FFACH   | Reset control flag register   | RESF   | R   | –                      | √      | –       | 00H <sup>Note 2</sup> |
| FFBAH   | 16-bit timer mode control register 00   | TMC00  | R/W | √                      | √      | –       | 00H                   |
| FFBBH   | Prescaler mode register 00  | PRM00  | R/W | √                      | √      | –       | 00H                   |

- Notes**
1.  $\mu$ PD780102, 780103, and 78F0103 only.
  2. This value varies depending on the reset source.

Table 3-5. Special Function Register List (3/3)

| Address | Special Function Register (SFR) Name                    | Symbol |      | R/W | Manipulatable Bit Unit |        |         | After Reset |
|---------|---|--------|------|-----|------------------------|--------|---------|-------------|
|         |   |        |      |     | 1 Bit                  | 8 Bits | 16 Bits |             |
| FFBCH   | Capture/compare control register 00                     | CRC00  |      | R/W | √                      | √      | –       | 00H         |
| FFBDH   | 16-bit timer output control register 00                 | TOC00  |      | R/W | √                      | √      | –       | 00H         |
| FFBEH   | Low-voltage detection register                          | LVIM   |      | R/W | √                      | √      | –       | 00H         |
| FFBFH   | Low-voltage detection level selection register          | LVIS   |      | R/W | –                      | √      | –       | 00H         |
| FFE0H   | Interrupt request flag register 0L                      | IF0    | IF0L | R/W | √                      | √      | √       | 00H         |
| FFE1H   | Interrupt request flag register 0H                      |        | IF0H | R/W | √                      | √      |         |             |
| FFE2H   | Interrupt request flag register 1L                      | IF1L   |      | R/W | √                      | √      | –       | 00H         |
| FFE4H   | Interrupt mask flag register 0L                         | MK0    | MK0L | R/W | √                      | √      | √       | FFH         |
| FFE5H   | Interrupt mask flag register 0H                         |        | MK0H | R/W | √                      | √      |         |             |
| FFE6H   | Interrupt mask flag register 1L                         | MK1L   |      | R/W | √                      | √      | –       | FFH         |
| FFE8H   | Priority specification flag register 0L                 | PR0    | PR0L | R/W | √                      | √      | √       | FFH         |
| FFE9H   | Priority specification flag register 0H                 |        | PR0H | R/W | √                      | √      |         |             |
| FFEAH   | Priority specification flag register 1L                 | PR1L   |      | R/W | √                      | √      | –       | FFH         |
| FFF0H   | Internal memory size switching register <sup>Note</sup> | IMS    |      | R/W | –                      | √      | –       | CFH         |
| FFFBH   | Processor clock control register                        | PCC    |      | R/W | √                      | √      | –       | 00H         |

**Note** The default value of IMS is fixed (IMS = CFH) in all products in the 78K0/KB1 regardless of the internal memory capacity. Therefore, set the following value to each product.

|            | Internal Memory Size Switching Register (IMS) |
|------------|---|
| μPD780101  | 42H   |
| μPD780102  | 04H   |
| μPD780103  | 06H   |
| μPD78F0103 | Value corresponding to mask ROM version       |

### 3.3 Instruction Address Addressing

An instruction address is determined by program counter (PC) contents and is normally incremented (+1 for each byte) automatically according to the number of bytes of an instruction to be fetched each time another instruction is executed. When a branch instruction is executed, the branch destination information is set to the PC and branched by the following addressing (for details of instructions, refer to **78K/0 Series Instructions User's Manual (U12326E)**).

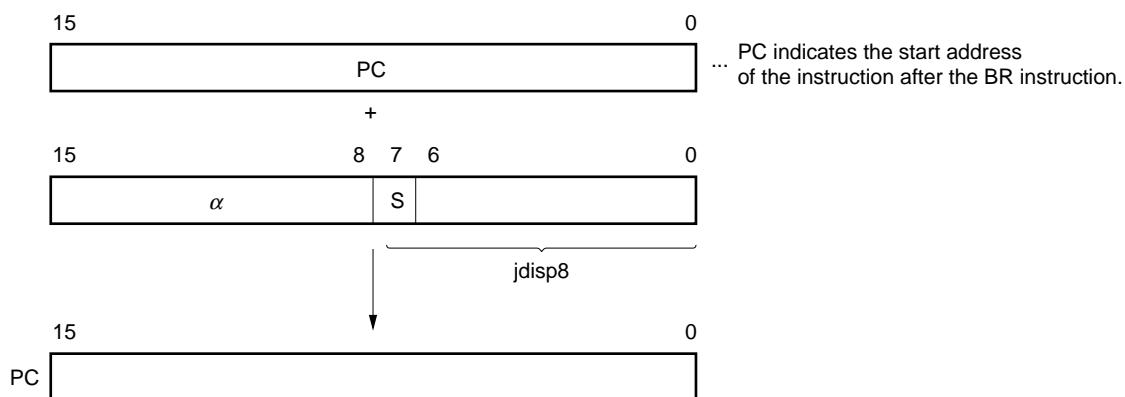
#### 3.3.1 Relative addressing

##### [Function]

The value obtained by adding 8-bit immediate data (displacement value:  $jdisp8$ ) of an instruction code to the start address of the following instruction is transferred to the program counter (PC) and branched. The displacement value is treated as signed two's complement data ( $-128$  to  $+127$ ) and bit 7 becomes a sign bit. In other words, relative addressing consists of relative branching from the start address of the following instruction to the  $-128$  to  $+127$  range.

This function is carried out when the BR \$addr16 instruction or a conditional branch instruction is executed.

##### [Illustration]



When S = 0, all bits of  $\alpha$  are 0.  
When S = 1, all bits of  $\alpha$  are 1.

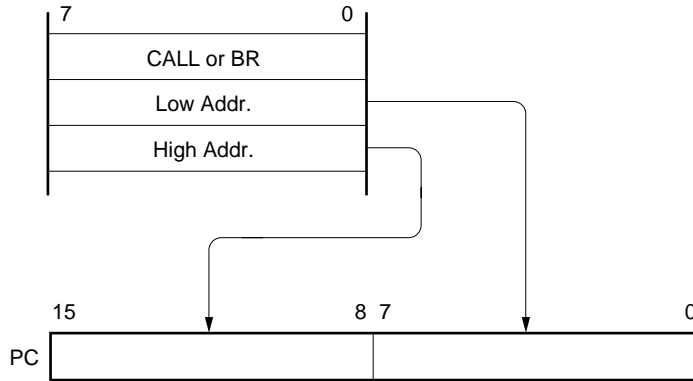
### 3.3.2 Immediate addressing

**[Function]**

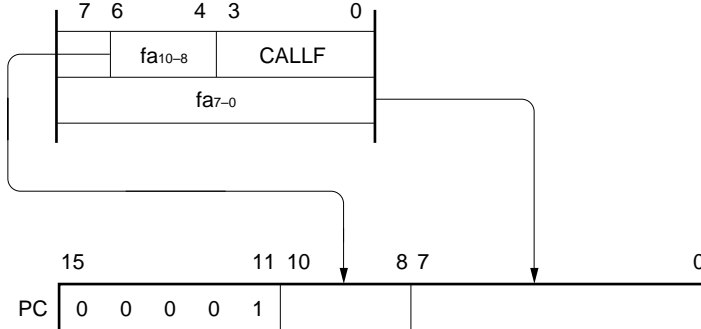
Immediate data in the instruction word is transferred to the program counter (PC) and branched. This function is carried out when the CALL !addr16 or BR !addr16 or CALLF !addr11 instruction is executed. CALL !addr16 and BR !addr16 instructions can be branched to the entire memory space. The CALLF !addr11 instruction is branched to the 0800H to 0FFFH area.

**[Illustration]**

In the case of CALL !addr16 and BR !addr16 instructions



In the case of CALLF !addr11 instruction



### 3.3.3 Table indirect addressing

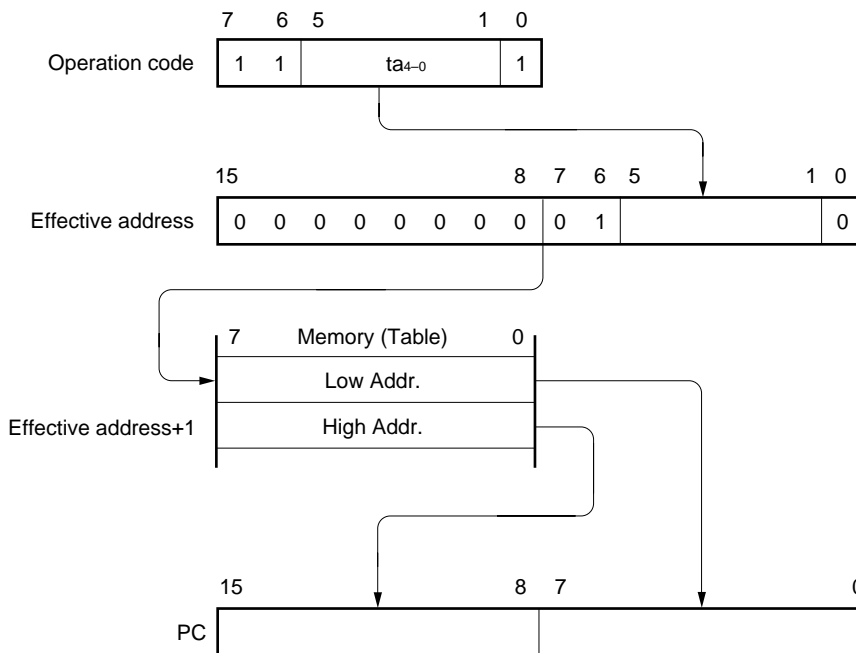
**[Function]**

Table contents (branch destination address) of the particular location to be addressed by bits 1 to 5 of the immediate data of an operation code are transferred to the program counter (PC) and branched.

This function is carried out when the CALLT [addr5] instruction is executed.

This instruction references the address stored in the memory table from 40H to 7FH, and allows branching to the entire memory space.

**[Illustration]**



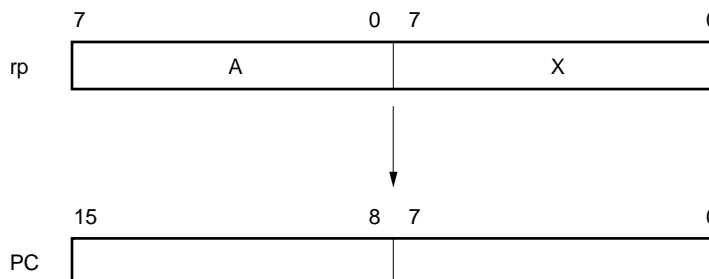
### 3.3.4 Register addressing

**[Function]**

Register pair (AX) contents to be specified with an instruction word are transferred to the program counter (PC) and branched.

This function is carried out when the BR AX instruction is executed.

**[Illustration]**



### 3.4 Operand Address Addressing

The following methods are available to specify the register and memory (addressing) to undergo manipulation during instruction execution.

#### 3.4.1 Implied addressing

##### [Function]

The register that functions as an accumulator (A and AX) among the general-purpose registers is automatically (implicitly) addressed.

Of the 78K0/KB1 instruction words, the following instructions employ implied addressing.

| Instruction | Register to Be Specified by Implied Addressing                                  |
|-------------|---|
| MULU        | A register for multiplicand and AX register for product storage                 |
| DIVUW       | AX register for dividend and quotient storage                                   |
| ADJBA/ADJBS | A register for storage of numeric values that become decimal correction targets |
| ROR4/ROL4   | A register for storage of digit data that undergoes digit rotation              |

##### [Operand format]

Because implied addressing can be automatically employed with an instruction, no particular operand format is necessary.

##### [Description example]

In the case of MULU X

With an 8-bit  $\times$  8-bit multiply instruction, the product of A register and X register is stored in AX. In this example, the A and AX registers are specified by implied addressing.



### 3.4.2 Register addressing

#### [Function]

The general-purpose register to be specified is accessed as an operand with the register bank select flags (RBS0 to RBS1) and the register specify codes (Rn and RPn) of an operation code.

Register addressing is carried out when an instruction with the following operand format is executed. When an 8-bit register is specified, one of the eight registers is specified with 3 bits in the operation code.

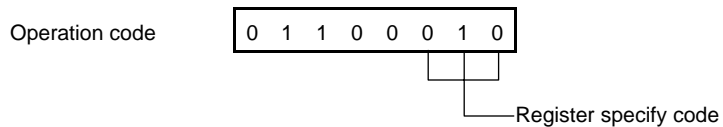
#### [Operand format]

| Identifier | Description            |
|------------|------------------------|
| r          | X, A, C, B, E, D, L, H |
| rp         | AX, BC, DE, HL         |

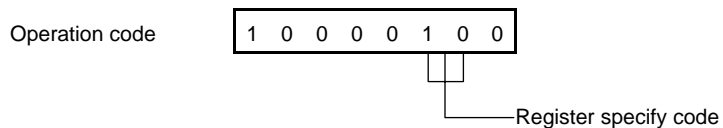
'r' and 'rp' can be described by absolute names (R0 to R7 and RP0 to RP3) as well as function names (X, A, C, B, E, D, L, H, AX, BC, DE, and HL).

#### [Description example]

MOV A, C; when selecting C register as r



INCW DE; when selecting DE register pair as rp



### 3.4.3 Direct addressing

**[Function]**

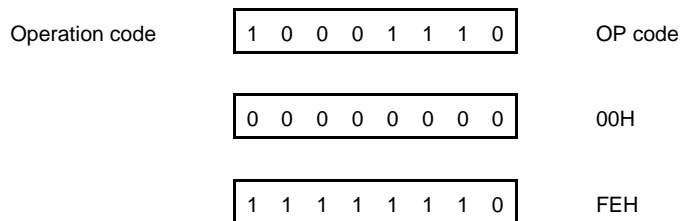
The memory to be manipulated is directly addressed with immediate data in an instruction word becoming an operand address.

**[Operand format]**

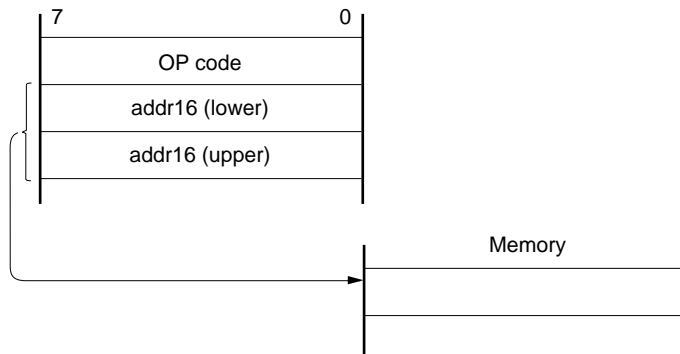
| Identifier | Description                    |
|------------|--------------------------------|
| addr16     | Label or 16-bit immediate data |

**[Description example]**

MOV A, !0FE00H; when setting !addr16 to FE00H



**[Illustration]**



### 3.4.4 Short direct addressing

**[Function]**

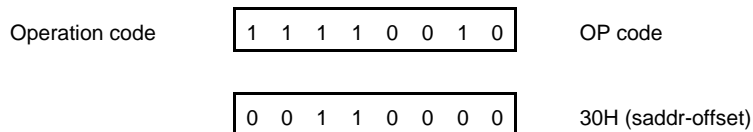
The memory to be manipulated in the fixed space is directly addressed with 8-bit data in an instruction word. This addressing is applied to the 256-byte space FE20H to FF1FH. Internal RAM and special function registers (SFRs) are mapped at FE20H to FEFFH and FF00H to FF1FH, respectively. The SFR area (FF00H to FF1FH) where short direct addressing is applied is a part of the overall SFR area. Ports that are frequently accessed in a program and compare and capture registers of the timer/event counter are mapped in this area, allowing SFRs to be manipulated with a small number of bytes and clocks. When 8-bit immediate data is at 20H to FFH, bit 8 of an effective address is cleared to 0. When it is at 00H to 1FH, bit 8 is set to 1. See the **[Illustration]**.

**[Operand format]**

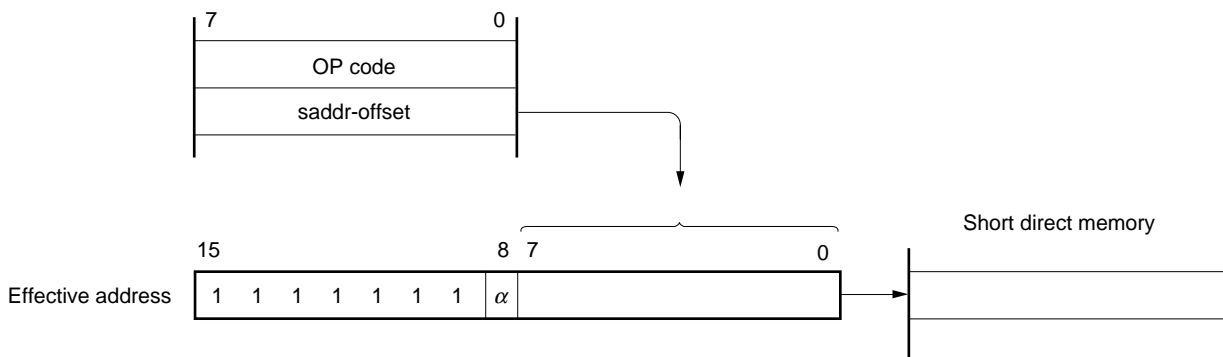
| Identifier | Description  |
|------------|--|
| saddr      | Immediate data that indicate label or FE20H to FF1FH                     |
| saddrp     | Immediate data that indicate label or FE20H to FF1FH (even address only) |

**[Description example]**

MOV 0FE30H, A; when transferring value of A register to saddr (FE30H)



**[Illustration]**



When 8-bit immediate data is 20H to FFH,  $\alpha = 0$

When 8-bit immediate data is 00H to 1FH,  $\alpha = 1$

### 3.4.5 Special function register (SFR) addressing

**[Function]**

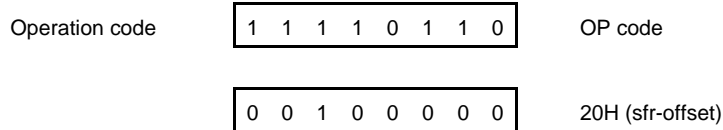
A memory-mapped special function register (SFR) is addressed with 8-bit immediate data in an instruction word. This addressing is applied to the 240-byte spaces FF00H to FFCFH and FFE0H to FFFFH. However, the SFRs mapped at FF00H to FF1FH can be accessed with short direct addressing.

**[Operand format]**

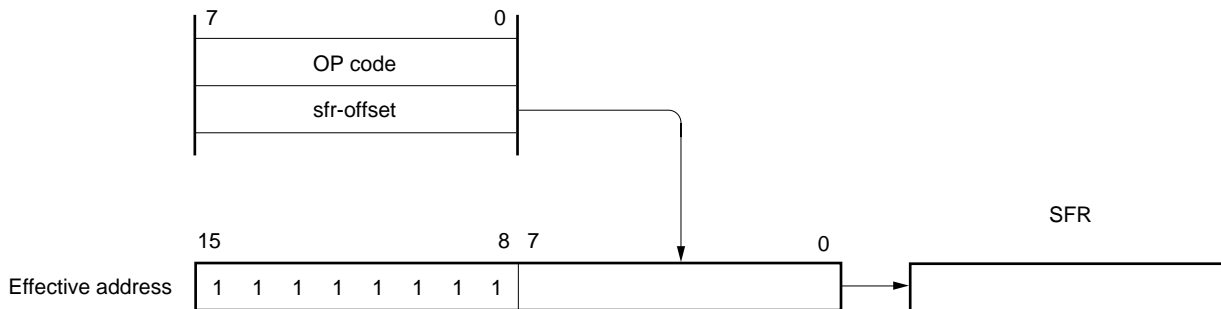
| Identifier | Description   |
|------------|---|
| sfr        | Special function register name  |
| sfrp       | 16-bit manipulatable special function register name (even address only) |

**[Description example]**

MOV PM0, A; when selecting PM0 (FF20H) as sfr



**[Illustration]**



### 3.4.6 Register indirect addressing

**[Function]**

Register pair contents specified by a register pair specify code in an instruction word and by a register bank select flag (RBS0 and RBS1) serve as an operand address for addressing the memory. This addressing can be carried out for all the memory spaces.

**[Operand format]**

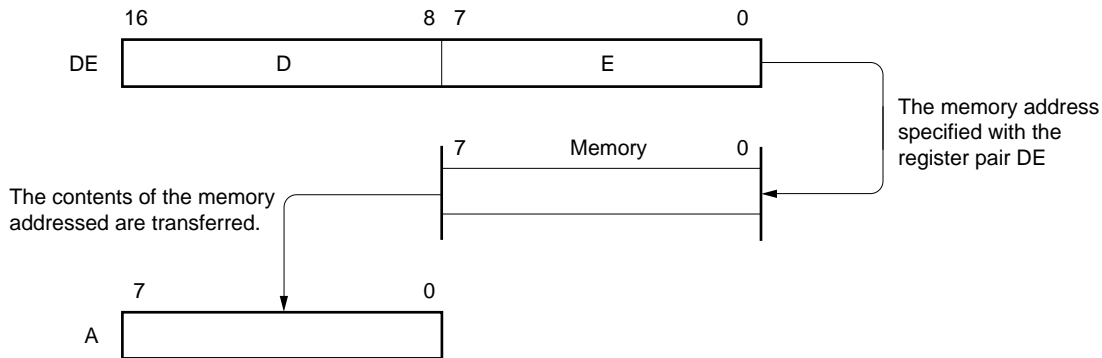
| Identifier | Description |
|------------|-------------|
| -          | [DE], [HL]  |

**[Description example]**

MOV A, [DE]; when selecting [DE] as register pair

Operation code 1 0 0 0 0 1 0 1

**[Illustration]**



3.4.7 Based addressing

[Function]

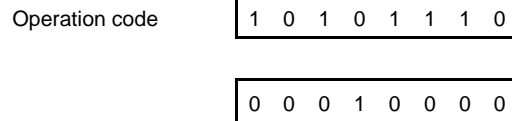
8-bit immediate data is added as offset data to the contents of the base register, that is, the HL register pair in the register bank specified by the register bank select flag (RBS0 and RBS1), and the sum is used to address the memory. Addition is performed by expanding the offset data as a positive number to 16 bits. A carry from the 16th bit is ignored. This addressing can be carried out for all the memory spaces.

[Operand format]

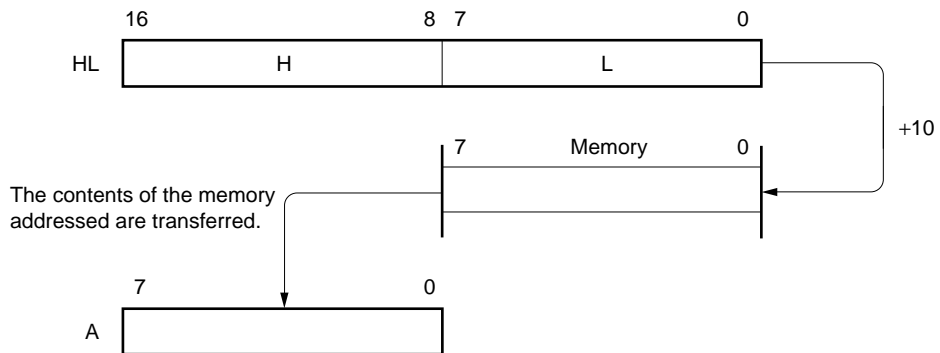
| Identifier | Description |
|------------|-------------|
| –          | [HL + byte] |

[Description example]

MOV A, [HL + 10H]; when setting byte to 10H



[Illustration]



### 3.4.8 Based indexed addressing

**[Function]**

The B or C register contents specified in an instruction word are added to the contents of the base register, that is, the HL register pair in the register bank specified by the register bank select flag (RBS0 and RBS1), and the sum is used to address the memory. Addition is performed by expanding the B or C register contents as a positive number to 16 bits. A carry from the 16th bit is ignored. This addressing can be carried out for all the memory spaces.

**[Operand format]**

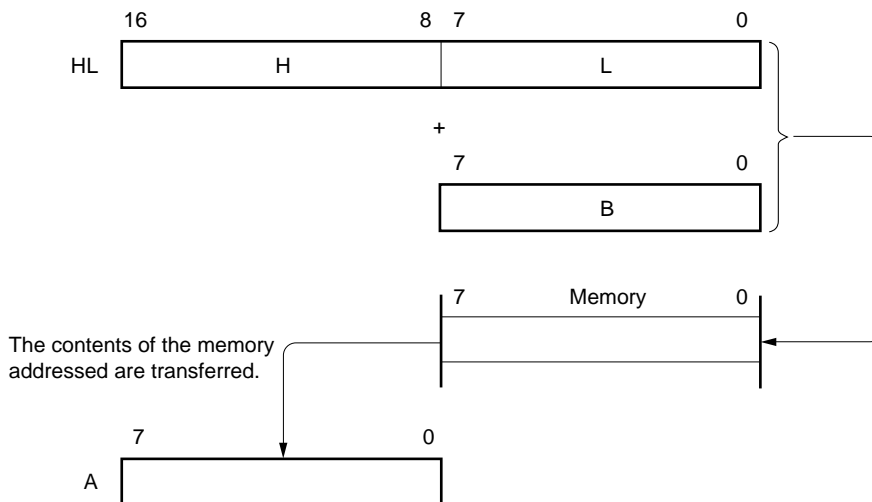
| Identifier | Description        |
|------------|--------------------|
| -          | [HL + B], [HL + C] |

**[Description example]**

In the case of MOV A, [HL + B] (selecting B register)

Operation code 1 0 1 0 1 0 1 1

**[Illustration]**



### 3.4.9 Stack addressing

**[Function]**

The stack area is indirectly addressed with the stack pointer (SP) contents.

This addressing method is automatically employed when the PUSH, POP, subroutine call and return instructions are executed or the register is saved/reset upon generation of an interrupt request.

With stack addressing, only the internal high-speed RAM area can be accessed.

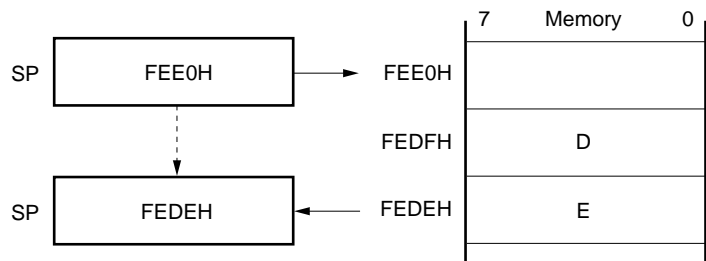
**[Description example]**

In the case of PUSH DE (saving DE register)

Operation code 

|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
|---|---|---|---|---|---|---|---|

**[Illustration]**





## CHAPTER 4 PORT FUNCTIONS

### 4.1 Port Functions

There are two types of pin I/O buffer power supplies:  $AV_{REF}$  and  $V_{DD}$ . The relationship between these power supplies and the pins is shown below.

**Table 4-1. Pin I/O Buffer Power Supplies**

| Power Supply | Corresponding Pins         |
|--------------|----------------------------|
| $AV_{REF}$   | P20 to P23                 |
| $V_{DD}$     | Pins other than P20 to P23 |

78K0/KB1 products are provided with the ports shown in Figure 4-1, which enable variety of control operations. The functions of each port are shown in Table 4-2.

In addition to the function as digital I/O ports, these ports have several alternate functions. For details of the alternate functions, see **CHAPTER 2 PIN FUNCTIONS**.

**Figure 4-1. Port Types**

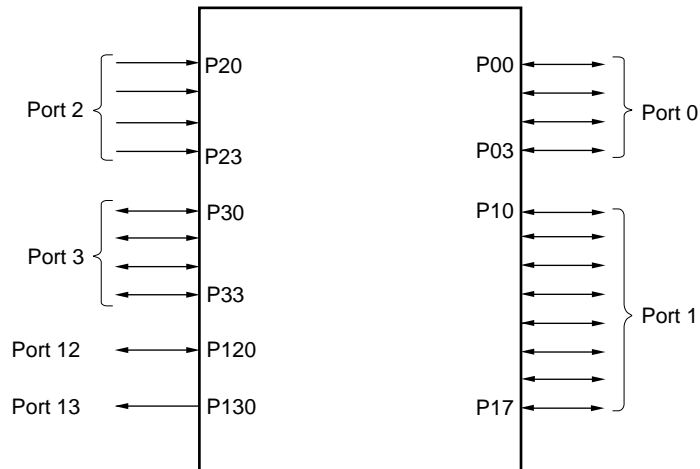


Table 4-2. Port Functions

| Pin Name   | I/O    | Function  | After Reset | Alternate Function                                  |
|------------|--------|---|-------------|---|
| P00        | I/O    | Port 0.<br>4-bit I/O port.<br>Input/output can be specified in 1-bit units.<br>Use of an on-chip pull-up resistor can be specified by a software setting. | Input       | TI000   |
| P01        |        |   |             | TI010/TO00  |
| P02        |        |   |             | —   |
| P03        |        |   |             | —   |
| P10        | I/O    | Port 1.<br>8-bit I/O port.<br>Input/output can be specified in 1-bit units.<br>Use of an on-chip pull-up resistor can be specified by a software setting. | Input       | $\overline{\text{SCK10}}/\text{TxD0}^{\text{Note}}$ |
| P11        |        |   |             | SI10/RxD0 <sup>Note</sup>                           |
| P12        |        |   |             | SO10  |
| P13        |        |   |             | TxD6  |
| P14        |        |   |             | RxD6  |
| P15        |        |   |             | TOH0  |
| P16        |        |   |             | TOH1/INTP5  |
| P17        |        |   |             | TI50/TO50   |
| P20 to P23 | Input  | Port 2.<br>4-bit input-only port.   | Input       | ANI0 to ANI3  |
| P30 to P33 | I/O    | Port 3.<br>4-bit I/O port.<br>Input/output can be specified in 1-bit units.<br>Use of an on-chip pull-up resistor can be specified by a software setting. | Input       | INTP1 to INTP4                                      |
| P120       | I/O    | Port 12.<br>1-bit I/O port.<br>Use of an on-chip pull-up resistor can be specified by a software setting.   | Input       | INTP0   |
| P130       | Output | Port 13.<br>1-bit output-only port.   | Output      | —   |

**Note** TxD0 and RxD0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.

## 4.2 Port Configuration

A port includes the following hardware.

Table 4-3. Port Configuration

| Item              | Configuration  |
|-------------------|--|
| Control registers | Port mode register (PM0, PM1, PM3, PM12)<br>Port register (P0 to P3, P12, P13)<br>Pull-up resistor option register (PU0, PU1, PU3, PU12) |
| Port              | Total: 22 (CMOS I/O: 17, CMOS input: 4, CMOS output: 1)  |
| Pull-up resistors | Total: 17 (software control only)  |

4.2.1 Port 0

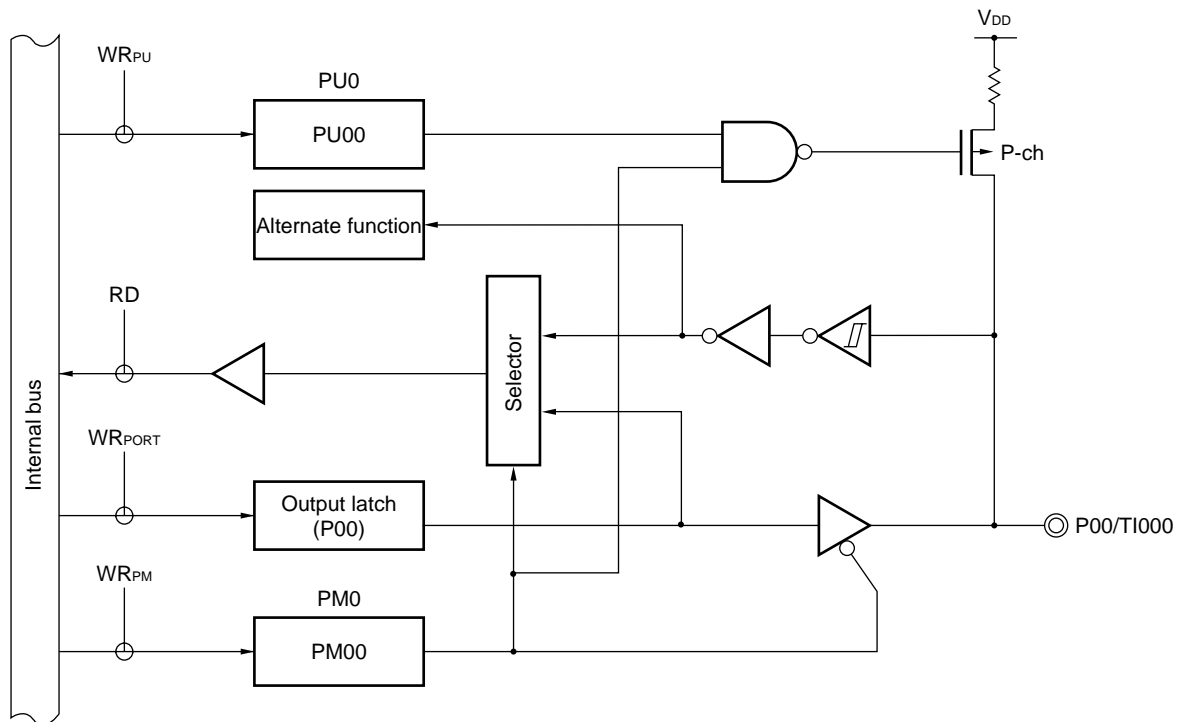
Port 0 is a 4-bit I/O port with an output latch. Port 0 can be set to the input mode or output mode in 1-bit units using port mode register 0 (PM0). When the P00 to P03 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 0 (PU0).

This port can also be used for timer I/O.

$\overline{\text{RESET}}$  input sets port 0 to input mode.

Figures 4-2 to 4-4 show block diagrams of port 0.

Figure 4-2. Block Diagram of P00



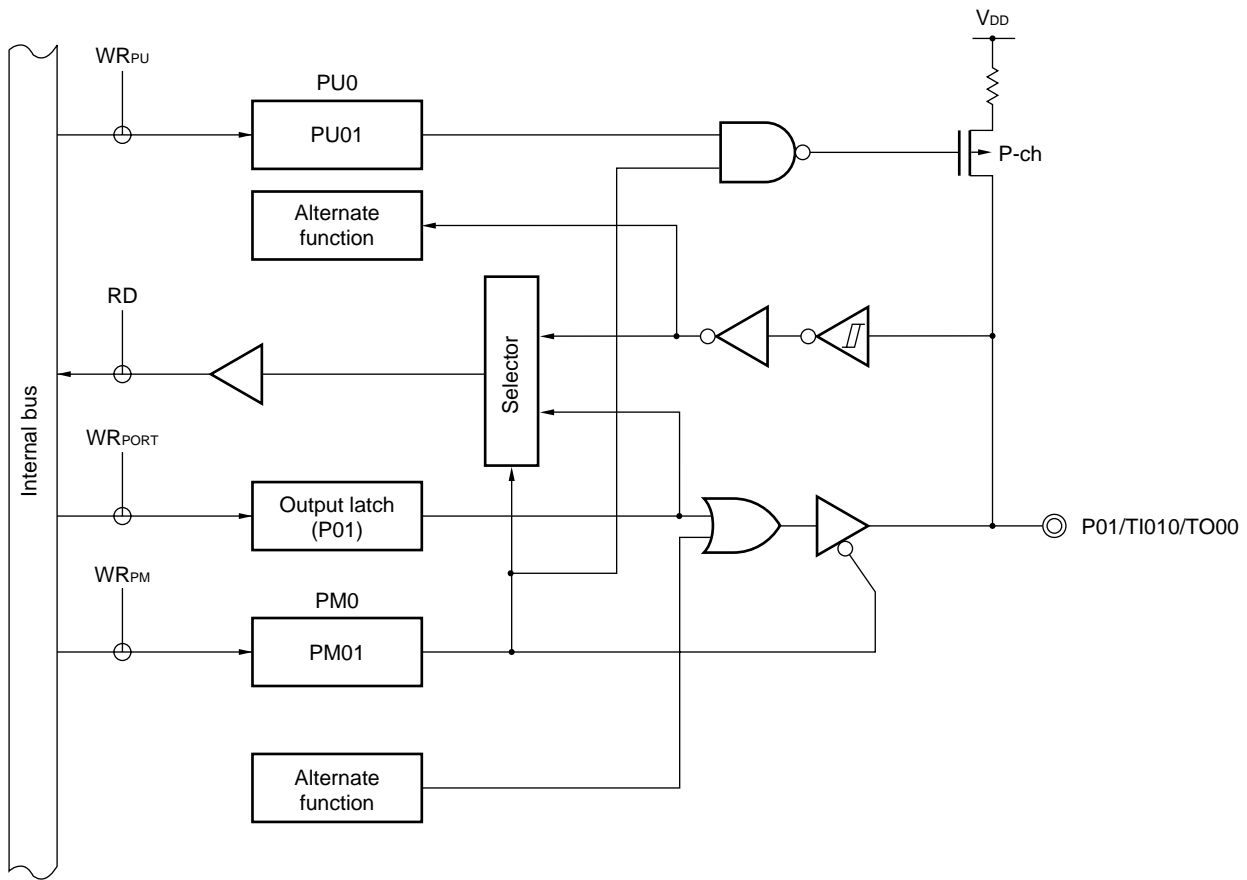
PU0: Pull-up resistor option register 0

PM0: Port mode register 0

RD: Read signal

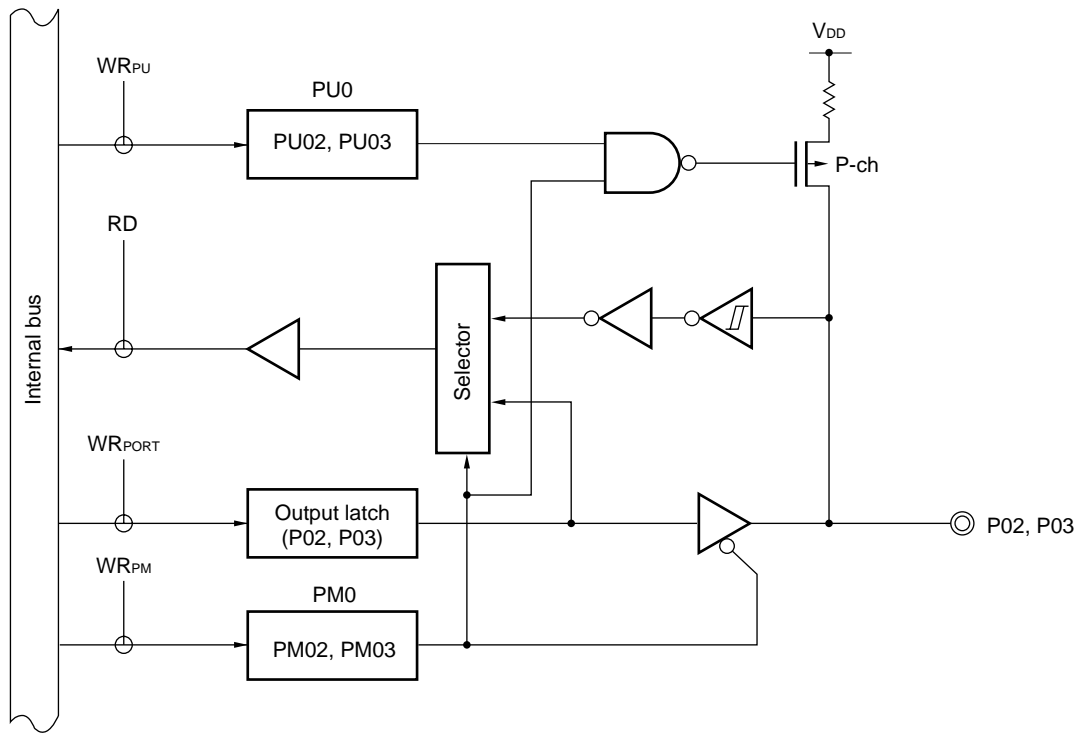
WR<sub>xx</sub>: Write signal

Figure 4-3. Block Diagram of P01



- PU0: Pull-up resistor option register 0
- PM0: Port mode register 0
- RD: Read signal
- $WR_{xx}$ : Write signal

Figure 4-4. Block Diagram of P02 and P03



- PU0: Pull-up resistor option register 0
- PM0: Port mode register 0
- RD: Read signal
- WR<sub>xx</sub>: Write signal

4.2.2 Port 1

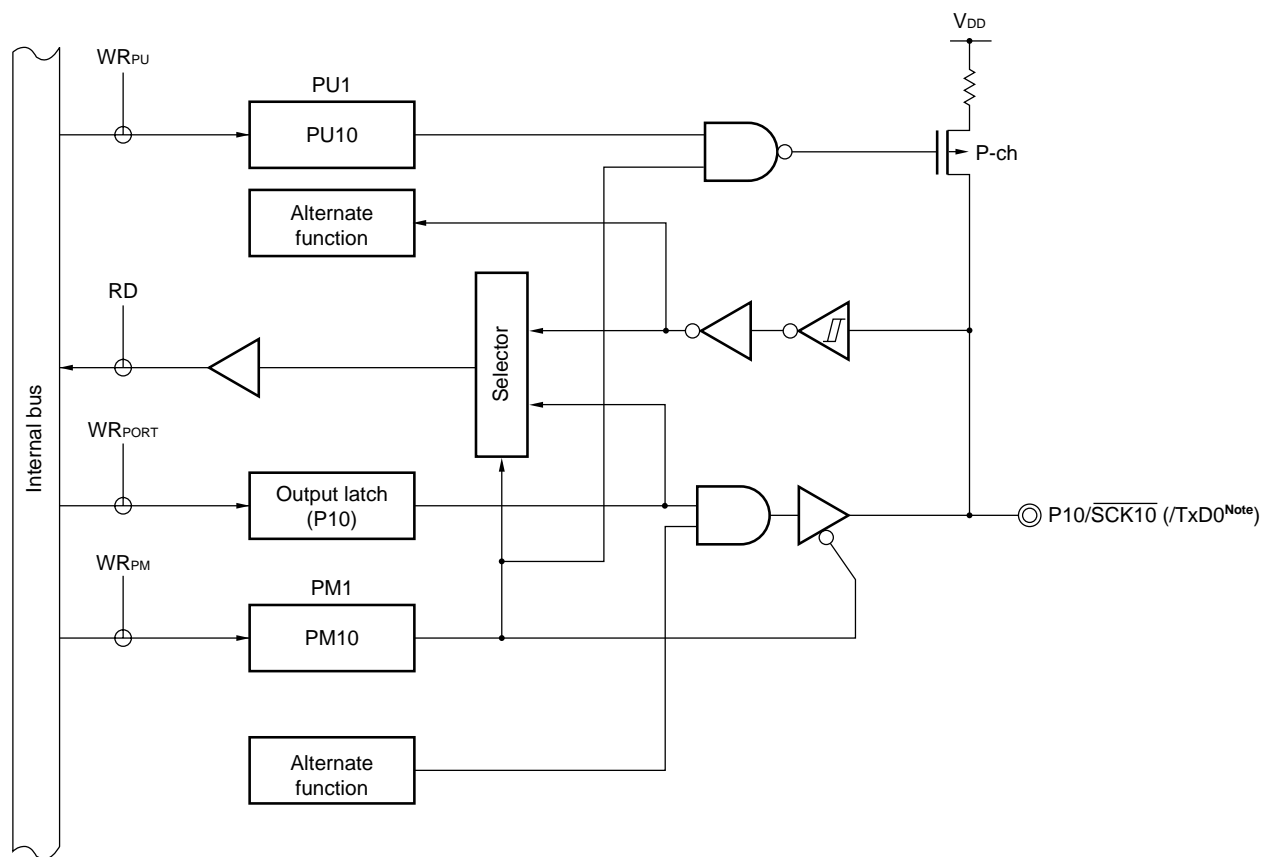
Port 1 is an 8-bit I/O port with an output latch. Port 1 can be set to the input mode or output mode in 1-bit units using port mode register 1 (PM1). When the P10 to P17 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 1 (PU1).

This port can also be used for external interrupt request input, serial interface data I/O, clock I/O, and timer I/O.  $\overline{\text{RESET}}$  input sets port 1 to input mode.

Figures 4-5 to 4-9 show block diagrams of port 1.

**Caution** When using P10/ $\overline{\text{SCK10}}$  (/TxD0<sup>Note</sup>), P11/SI10 (/RxD0<sup>Note</sup>), and P12/SO10 as general-purpose ports, do not write to serial clock selection register 10 (CSIC10).

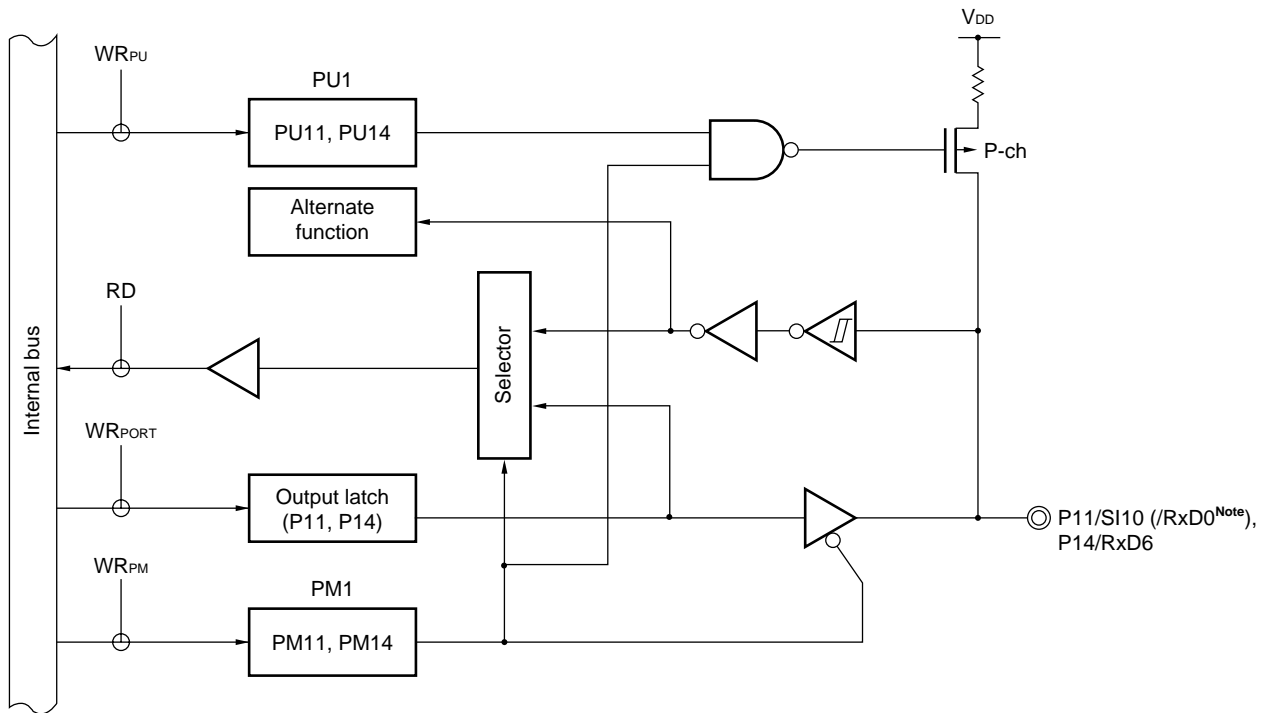
Figure 4-5. Block Diagram of P10



**Note** Available only in the  $\mu$ PD780102, 780103, and 78F0103.

- PU1: Pull-up resistor option register 1
- PM1: Port mode register 1
- RD: Read signal
- WR<sub>xx</sub>: Write signal

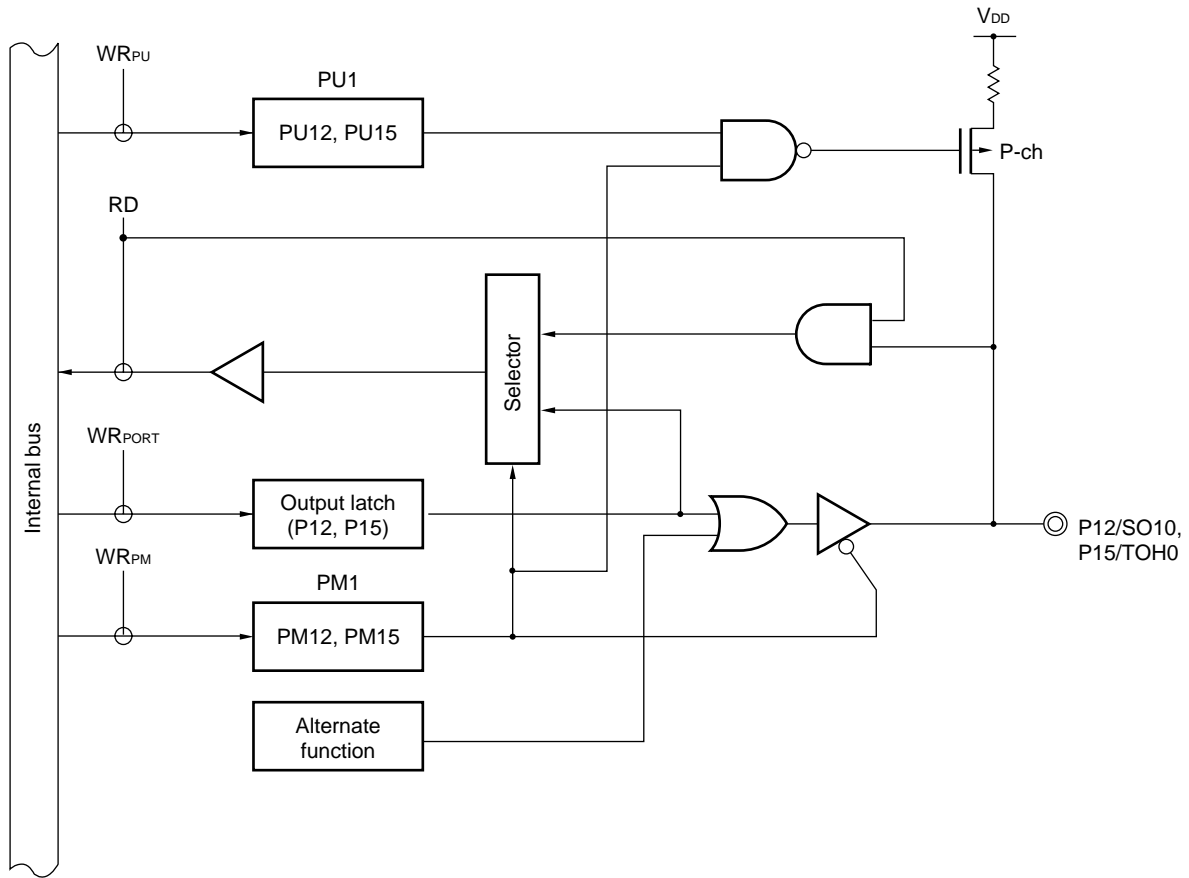
Figure 4-6. Block Diagram of P11 and P14



**Note** Available only in the  $\mu$ PD780102, 780103, and 78F0103.

- PU1: Pull-up resistor option register 1
- PM1: Port mode register 1
- RD: Read signal
- $WR_{xx}$ : Write signal

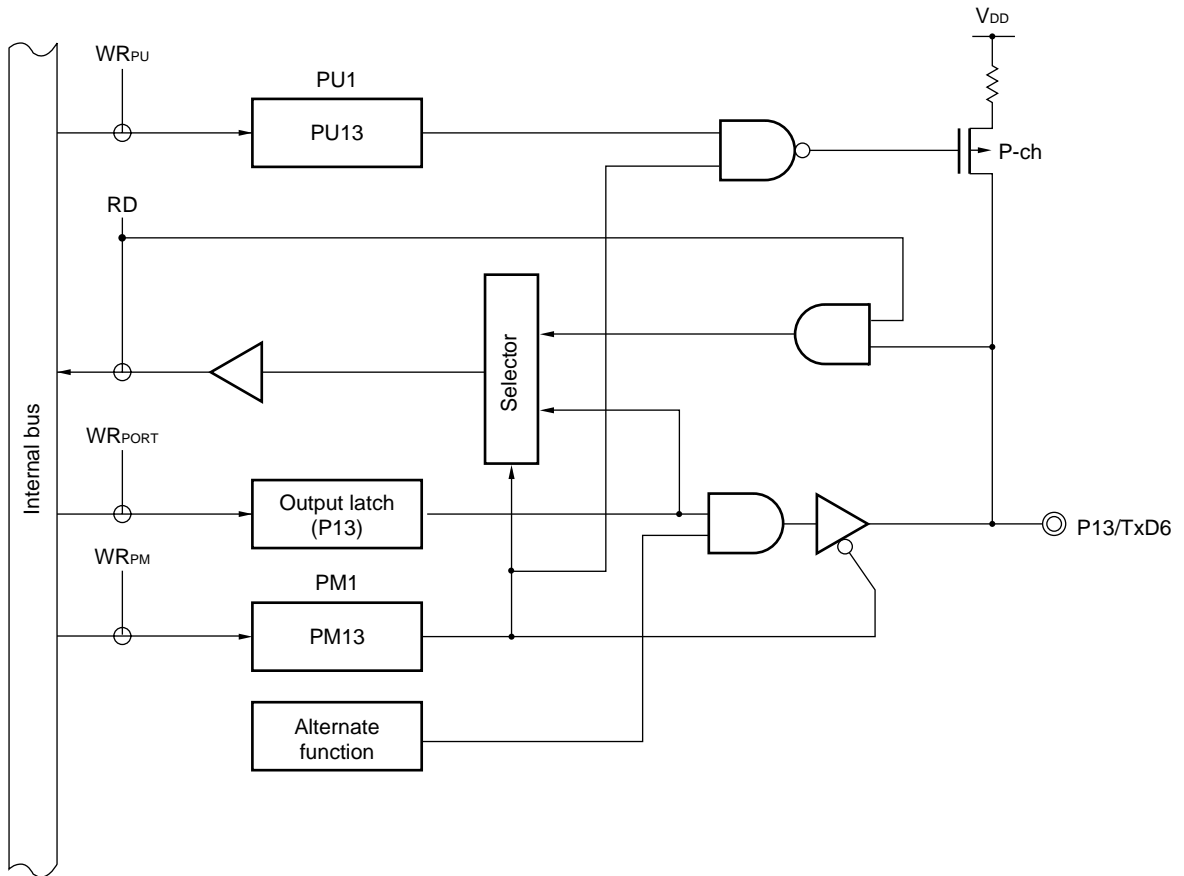
Figure 4-7. Block Diagram of P12 and P15



- PU1: Pull-up resistor option register 1
- PM1: Port mode register 1
- RD: Read signal
- WR<sub>xx</sub>: Write signal

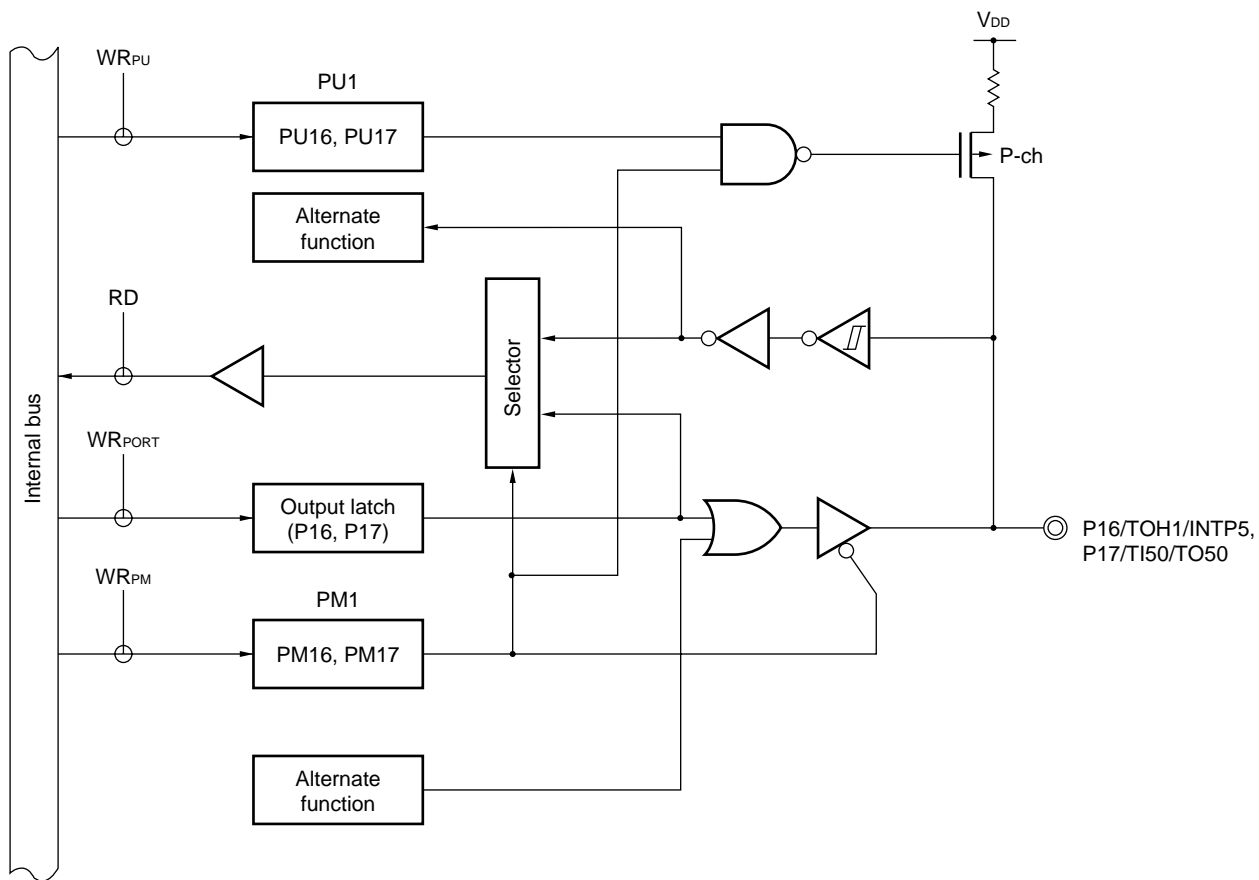


Figure 4-8. Block Diagram of P13



- PU1: Pull-up resistor option register 1
- PM1: Port mode register 1
- RD: Read signal
- WR<sub>xx</sub>: Write signal

Figure 4-9. Block Diagram of P16 and P17



- PU1: Pull-up resistor option register 1
- PM1: Port mode register 1
- RD: Read signal
- WR<sub>xx</sub>: Write signal

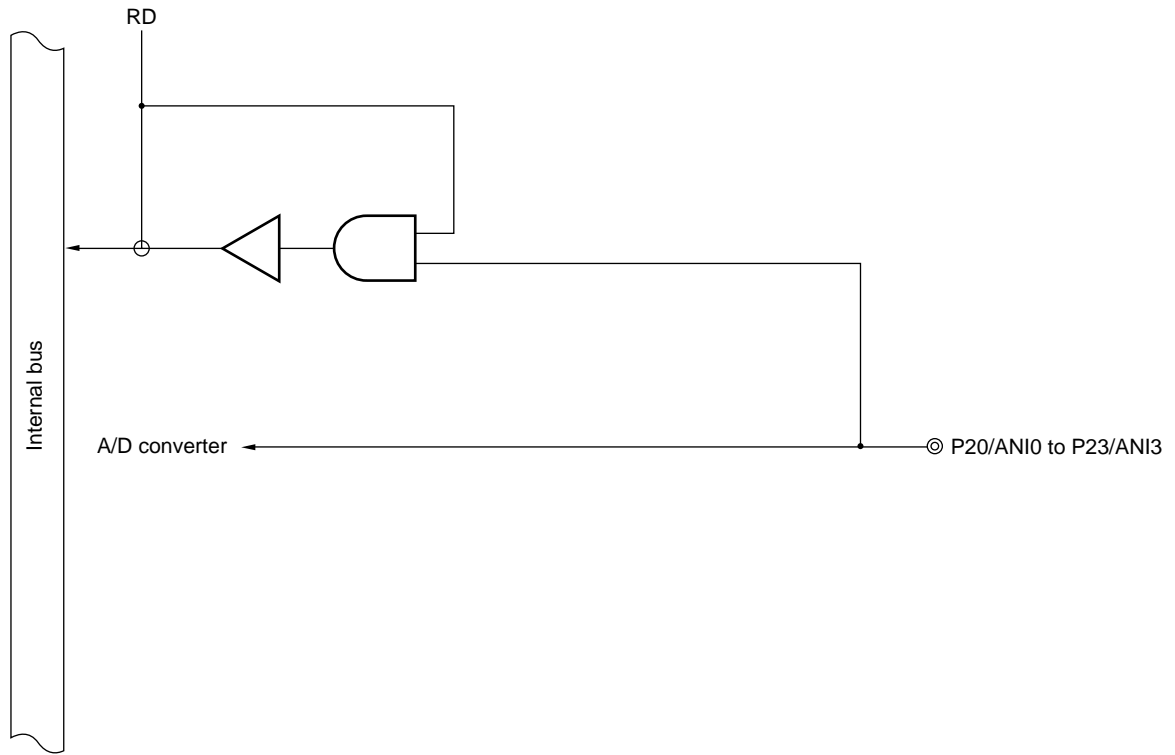
4.2.3 Port 2

Port 2 is a 4-bit input-only port.

This port can also be used for A/D converter analog input.

Figure 4-10 shows a block diagram of port 2.

Figure 4-10. Block Diagram of P20 to P23



RD: Read signal

4.2.4 Port 3

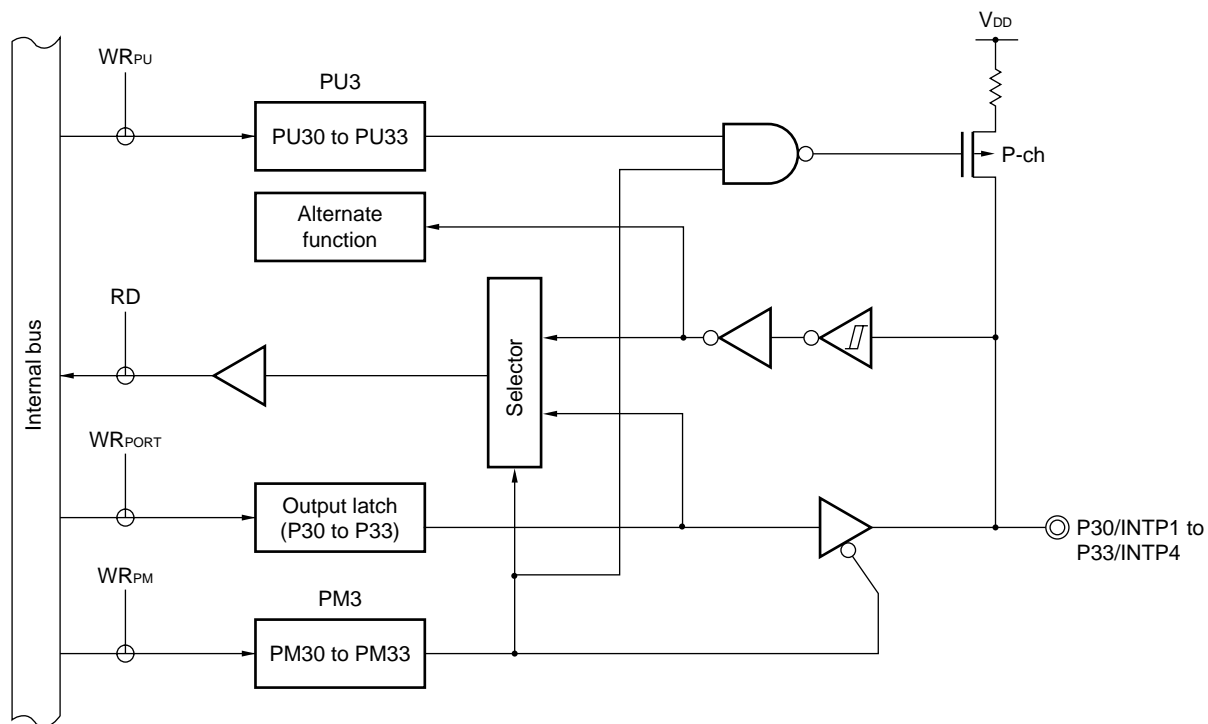
Port 3 is a 4-bit I/O port with an output latch. Port 3 can be set to the input mode or output mode in 1-bit units using port mode register 3 (PM3). When the P30 to P33 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 3 (PU3).

This port can also be used for external interrupt request input.

RESET input sets port 3 to input mode.

Figure 4-11 shows a block diagram of port 3.

Figure 4-11. Block Diagram of P30 to P33



- PU3: Pull-up resistor option register 3
- PM3: Port mode register 3
- RD: Read signal
- WR<sub>xx</sub>: Write signal

#### 4.2.5 Port 12

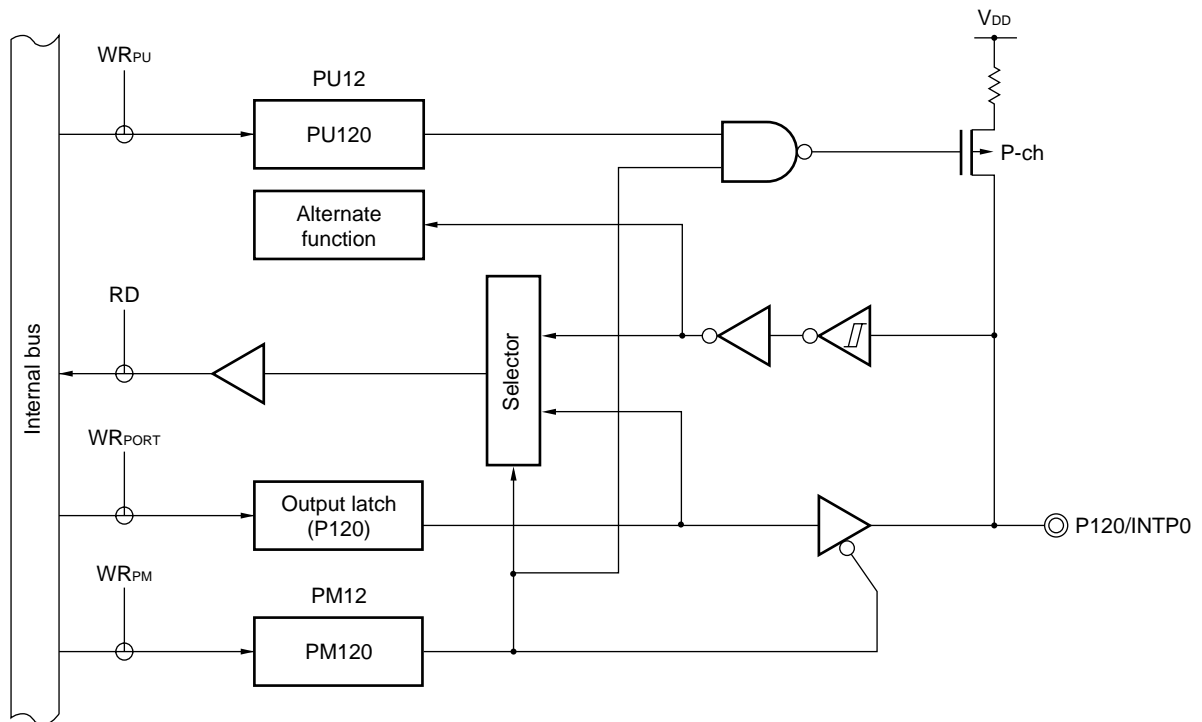
Port 12 is a 1-bit I/O port with an output latch. Port 12 can be set to the input mode or output mode in 1-bit units using port mode register 12 (PM12). When the P120 pin is used as an input port, use of an on-chip pull-up resistor can be specified by pull-up resistor option register 12 (PU12).

This port can also be used for external interrupt request input.

$\overline{\text{RESET}}$  input sets port 12 to input mode.

Figure 4-12 shows a block diagram of port 12.

**Figure 4-12. Block Diagram of P120**



PU12: Pull-up resistor option register 12

PM12: Port mode register 12

RD: Read signal

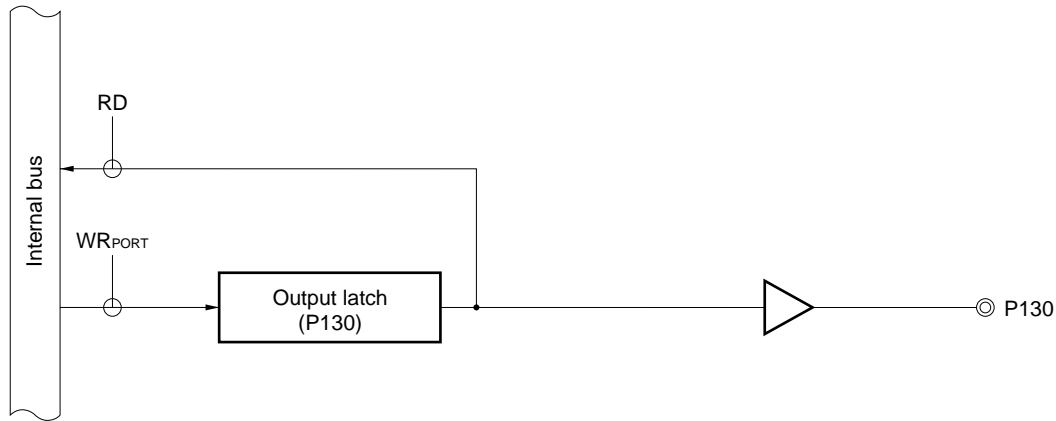
$\text{WR}_{\text{xx}}$ : Write signal

### 4.2.6 Port 13

Port 13 is a 1-bit output-only port.

Figure 4-13 shows a block diagram of port 13.

Figure 4-13. Block Diagram of P130



RD: Read signal

WR<sub>xx</sub>: Write signal

**Remark** When reset is effected, P130 outputs a low level. If P130 is set to output a high level before reset is effected, the output signal of P130 can be dummy-output as the reset signal to the CPU.

## 4.3 Registers Controlling Port Function

Port functions are controlled by the following three types of registers.

- Port mode registers (PM0, PM1, PM3, PM12)
- Port registers (P0 to P3, P12, P13)
- Pull-up resistor option registers (PU0, PU1, PU3, PU12)

### (1) Port mode registers (PM0, PM1, PM3, and PM12)

These registers specify input or output mode for the port in 1-bit units.

These registers can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets these registers to FFH.

When port pins are used as alternate-function pins, set the port mode register and output latch as shown in Table 4-4.

Figure 4-14. Format of Port Mode Register

| Symbol | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0     | Address | After reset | R/W |
|--------|------|------|------|------|------|------|------|-------|---------|-------------|-----|
| PM0    | 1    | 1    | 1    | 1    | PM03 | PM02 | PM01 | PM00  | FF20H   | FFH         | R/W |
| PM1    | PM17 | PM16 | PM15 | PM14 | PM13 | PM12 | PM11 | PM10  | FF21H   | FFH         | R/W |
| PM3    | 1    | 1    | 1    | 1    | PM33 | PM32 | PM31 | PM30  | FF23H   | FFH         | R/W |
| PM12   | 1    | 1    | 1    | 1    | 1    | 1    | 1    | PM120 | FF2CH   | FFH         | R/W |

| PMmn | Pmn pin I/O mode selection<br>(m = 0, 1, 3, 12; n = 0 to 7) |
|------|---|
| 0    | Output mode (output buffer on)                              |
| 1    | Input mode (output buffer off)                              |

Table 4-4. Settings of Port Mode Register and Output Latch When Alternate Function Is Used

| Pin Name   | Alternate Function   |        | PM <sub>xx</sub> | P <sub>xx</sub> |
|------------|----------------------|--------|------------------|-----------------|
|            | Name                 | I/O    |                  |                 |
| P00        | TI000                | Input  | 1                | ×               |
| P01        | TI010                | Input  | 1                | ×               |
|            | TO00                 | Output | 0                | 0               |
| P10        | SCK10                | Input  | 1                | ×               |
|            |                      | Output | 0                | 1               |
|            | TxD0 <sup>Note</sup> | Output | 0                | 1               |
| P11        | SI10                 | Input  | 1                | ×               |
|            | RxD0 <sup>Note</sup> | Input  | 1                | ×               |
| P12        | SO10                 | Output | 0                | 0               |
| P13        | TxD6                 | Output | 0                | 1               |
| P14        | RxD6                 | Input  | 1                | ×               |
| P15        | TOH0                 | Output | 0                | 0               |
| P16        | TOH1                 | Output | 0                | 0               |
|            | INTP5                | Input  | 1                | ×               |
| P17        | TI50                 | Input  | 1                | ×               |
|            | TO50                 | Output | 0                | 0               |
| P30 to P33 | INTP1 to INTP4       | Input  | 1                | ×               |
| P120       | INTP0                | Input  | 1                | ×               |

**Note** TxD0 and RxD0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.

**Remark** ×: Don't care  
 PM<sub>xx</sub>: Port mode register  
 P<sub>xx</sub>: Port output latch

**(2) Port registers (P0 to P3, P12, P13)**

These registers write the data that is output from the chip when data is output from a port.

If the data is read in the input mode, the pin level is read. If it is read in the output mode, the value of the output latch is read.

These registers can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears these registers to 00H (but P2 is undefined).

**Figure 4-15. Format of Port Register**

| Symbol | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0    | Address | After reset        | R/W |
|--------|-----|-----|-----|-----|-----|-----|-----|------|---------|--------------------|-----|
| P0     | 0   | 0   | 0   | 0   | P03 | P02 | P01 | P00  | FF00H   | 00H (output latch) | R/W |
| P1     | P17 | P16 | P15 | P14 | P13 | P12 | P11 | P10  | FF01H   | 00H (output latch) | R/W |
| P2     | 0   | 0   | 0   | 0   | P23 | P22 | P21 | P20  | FF02H   | Undefined          | R   |
| P3     | 0   | 0   | 0   | 0   | P33 | P32 | P31 | P30  | FF03H   | 00H (output latch) | R/W |
| P12    | 0   | 0   | 0   | 0   | 0   | 0   | 0   | P120 | FF0CH   | 00H (output latch) | R/W |
| P13    | 0   | 0   | 0   | 0   | 0   | 0   | 0   | P130 | FF0DH   | 00H (output latch) | R/W |

| Pmn | m = 0 to 3, 12, 13; n = 0 to 7       |                                 |
|-----|--------------------------------------|---------------------------------|
|     | Output data control (in output mode) | Input data read (in input mode) |
| 0   | Output 0                             | Input low level                 |
| 1   | Output 1                             | Input high level                |



**(3) Pull-up resistor option registers (PU0, PU1, PU3, and PU12)**

These registers specify whether the on-chip pull-up resistors of P00 to P03, P10 to P17, P30 to P33, or P120 is to be used or not. An on-chip pull-up resistors can be used in 1-bit units only for the bits set to input mode of the pins to which the use of an on-chip pull-up resistor has been specified. On-chip pull-up resistor cannot be connected for bits set to output mode and bits used as alternate-function output pins, regardless of the settings of PU0, PU1, PU3 and PU12.

These registers can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears these registers to 00H.

**Figure 4-16. Format of Pull-up Resistor Option Register**

| Symbol | 7 | 6 | 5 | 4 | 3    | 2    | 1    | 0     | Address | After reset | R/W |
|--------|---|---|---|---|------|------|------|-------|---------|-------------|-----|
| PU0    | 0 | 0 | 0 | 0 | PU03 | PU02 | PU01 | PU00  | FF30H   | 00H         | R/W |
| PU1    | 7 | 6 | 5 | 4 | 3    | 2    | 1    | 0     | FF31H   | 00H         | R/W |
| PU3    | 7 | 6 | 5 | 4 | 3    | 2    | 1    | 0     | FF33H   | 00H         | R/W |
| PU12   | 7 | 6 | 5 | 4 | 3    | 2    | 1    | 0     | FF3CH   | 00H         | R/W |
|        | 0 | 0 | 0 | 0 | 0    | 0    | 0    | PU120 |         |             |     |

| PUmn | Pmn pin on-chip pull-up resistor selection<br>(m = 0, 1, 3, 12; n = 0 to 7) |
|------|---|
| 0    | On-chip pull-up resistor not connected                                      |
| 1    | On-chip pull-up resistor connected  |

## 4.4 Port Function Operations

Port operations differ depending on whether the input or output mode is set, as shown below.

**Caution** In the case of a 1-bit memory manipulation instruction, although a single bit is manipulated, the port is accessed as an 8-bit unit. Therefore, on a port with a mixture of input and output pins, the output latch contents for pins specified as input are undefined, even for bits other than the manipulated bit.

### 4.4.1 Writing to I/O port

#### (1) Output mode

A value is written to the output latch by a transfer instruction, and the output latch contents are output from the pin.

Once data is written to the output latch, it is retained until data is written to the output latch again.

The data of the output latch is cleared by reset.

#### (2) Input mode

A value is written to the output latch by a transfer instruction, but since the output buffer is off, the pin status does not change.

Once data is written to the output latch, it is retained until data is written to the output latch again.

### 4.4.2 Reading from I/O port

#### (1) Output mode

The output latch contents are read by a transfer instruction. The output latch contents do not change.

#### (2) Input mode

The pin status is read by a transfer instruction. The output latch contents do not change.

### 4.4.3 Operations on I/O port

#### (1) Output mode

An operation is performed on the output latch contents, and the result is written to the output latch. The output latch contents are output from the pins.

Once data is written to the output latch, it is retained until data is written to the output latch again.

The data of the output latch is cleared by reset.

#### (2) Input mode

The pin level is read and an operation is performed on its contents. The result of the operation is written to the output latch, but since the output buffer is off, the pin status does not change.

## CHAPTER 5 CLOCK GENERATOR

### 5.1 Functions of Clock Generator

The clock generator generates the clock to be supplied to the CPU and peripheral hardware. The following two system clock oscillators are available.

- X1 oscillator
    - ★ The X1 oscillator oscillates a clock of  $f_{XP} = 2.0$  to  $12.0$  MHz<sup>Note</sup>. Oscillation can be stopped by executing the STOP instruction or setting the main OSC control register (MOC).
  - Ring-OSC oscillator
    - The Ring-OSC oscillator oscillates a clock of  $f_R = 240$  kHz (TYP.). Oscillation can be stopped by setting the Ring-OSC mode register (RCM) when “Can be stopped by software” is set by a mask option and the X1 input clock is used as the CPU clock.
- ★ **Note** Expanded-specification products of standard products and (A) grade products:  $f_{XP} = 2.0$  to  $12.0$  MHz  
 Conventional products of standard products and (A) grade products, (A1) grade products:  $f_{XP} = 2.0$  to  $10.0$  MHz  
 (A2) grade products:  $f_{XP} = 2.0$  to  $8.38$  MHz

- Remarks**
1.  $f_{XP}$ : X1 input clock oscillation frequency
  2.  $f_R$ : Ring-OSC clock oscillation frequency

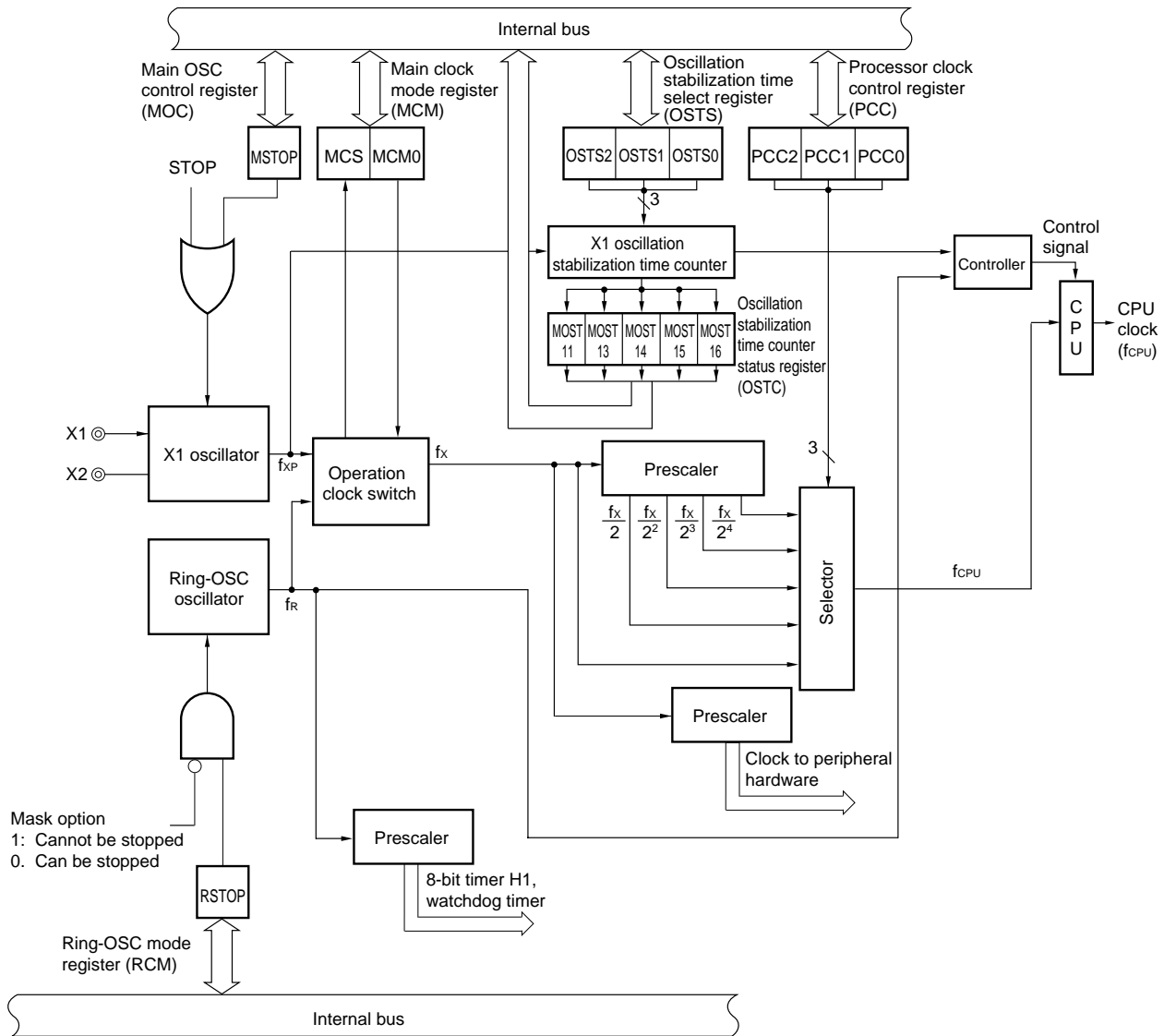
### 5.2 Configuration of Clock Generator

The clock generator includes the following hardware.

**Table 5-1. Configuration of Clock Generator**

| Item              | Configuration   |
|-------------------|---|
| Control registers | Processor clock control register (PCC)<br>Ring-OSC mode register (RCM)<br>Main clock mode register (MCM)<br>Main OSC control register (MOC)<br>Oscillation stabilization time counter status register (OSTC)<br>Oscillation stabilization time select register (OSTS) |
| Oscillator        | X1 oscillator<br>Ring-OSC oscillator  |

Figure 5-1. Block Diagram of Clock Generator



### 5.3 Registers Controlling Clock Generator

The following six registers are used to control the clock generator.

- Processor clock control register (PCC)
- Ring-OSC mode register (RCM)
- Main clock mode register (MCM)
- Main OSC control register (MOC)
- Oscillation stabilization time counter status register (OSTC)
- Oscillation stabilization time select register (OSTS)

#### (1) Processor clock control register (PCC)

This register sets the division ratio of the CPU clock.

PCC can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 5-2. Format of Processor Clock Control Register (PCC)**

Address: FFFBH After reset: 00H R/W

|        |   |   |   |   |   |      |      |      |
|--------|---|---|---|---|---|------|------|------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2    | 1    | 0    |
| PCC    | 0 | 0 | 0 | 0 | 0 | PCC2 | PCC1 | PCC0 |

| PCC2             | PCC1 | PCC0 | CPU clock selection ( $f_{\text{CPU}}$ ) |                       |              |
|------------------|------|------|--|-----------------------|--------------|
|                  |      |      | MCM0 = 0                                 |                       | MCM0 = 1     |
| 0                | 0    | 0    | $f_x$                                    | $f_R$                 | $f_{XP}$     |
| 0                | 0    | 1    | $f_x/2$                                  | $f_R/2^{\text{Note}}$ | $f_{XP}/2$   |
| 0                | 1    | 0    | $f_x/2^2$                                | Setting prohibited    | $f_{XP}/2^2$ |
| 0                | 1    | 1    | $f_x/2^3$                                | Setting prohibited    | $f_{XP}/2^3$ |
| 1                | 0    | 0    | $f_x/2^4$                                | Setting prohibited    | $f_{XP}/2^4$ |
| Other than above |      |      | Setting prohibited                       |                       |              |

★ **Note** The setting of (A1) grade products and (A2) grade products is prohibited.

**Remarks** 1. MCM0: Bit 0 of the main clock mode register (MCM)

2.  $f_x$ : Main system clock oscillation frequency (X1 input clock oscillation frequency or Ring-OSC clock oscillation frequency)
3.  $f_R$ : Ring-OSC clock oscillation frequency
4.  $f_{XP}$ : X1 input clock oscillation frequency

The fastest instruction can be executed in 2 clocks of the CPU clock in the 78K0/KB1. Therefore, the relationship between the CPU clock ( $f_{CPU}$ ) and minimum instruction execution time is as shown in the Table 5-2.

★ **Table 5-2. Relationship Between CPU Clock and Minimum Instruction Execution Time**

| CPU Clock ( $f_{CPU}$ ) <sup>Note 1</sup> | Minimum Instruction Execution Time: $2/f_{CPU}$ |  |   |
|---|---|--|---|
|   | X1 Input Clock                                  |  | Ring-OSC Clock<br>(at 240 kHz (TYP.) Operation) |
|   | At 10 MHz<br>Operation                          | At 12 MHz<br>Operation <sup>Note 2</sup> |   |
| $f_x$                                     | 0.2 $\mu s$                                     | 0.166 $\mu s$                            | 8.3 $\mu s$ (TYP.)                              |
| $f_x/2$                                   | 0.4 $\mu s$                                     | 0.333 $\mu s$                            | 16.6 $\mu s$ (TYP.) <sup>Note 3</sup>           |
| $f_x/2^2$                                 | 0.8 $\mu s$                                     | 0.666 $\mu s$                            | Setting prohibited                              |
| $f_x/2^3$                                 | 1.6 $\mu s$                                     | 1.333 $\mu s$                            | Setting prohibited                              |
| $f_x/2^4$                                 | 3.2 $\mu s$                                     | 2.666 $\mu s$                            | Setting prohibited                              |

- Notes**
1. The main clock mode register (MCM) is used to set the CPU clock (X1 input clock/Ring-OSC clock) (see **Figure 5-4**).
  2. Expanded-specification products of standard products and (A) grade products only
  3. The setting of (A1) grade products and (A2) grade products is prohibited.

**(2) Ring-OSC mode register (RCM)**

This register sets the operation mode of Ring-OSC.

This register is valid when “Can be stopped by software” is set for Ring-OSC by a mask option, and the X1 input clock is input to the CPU clock. If “Cannot be stopped” is selected for Ring-OSC by a mask option, settings for this register are invalid.

RCM can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears this register to 00H.

**Figure 5-3. Format of Ring-OSC Mode Register (RCM)**

Address: FFA0H After reset: 00H R/W

|        |   |   |   |   |   |   |   |       |
|--------|---|---|---|---|---|---|---|-------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2 | 1 | <0>   |
| RCM    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | RSTOP |

|       |                              |
|-------|------------------------------|
| RSTOP | Ring-OSC oscillating/stopped |
| 0     | Ring-OSC oscillating         |
| 1     | Ring-OSC stopped             |

**Caution** Make sure that bit 1 (MCS) of the main clock mode register (MCM) is 1 before setting RSTOP.

**(3) Main clock mode register (MCM)**

This register sets the CPU clock (X1 input clock/Ring-OSC clock).

MCM can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears this register to 00H.

**Figure 5-4. Format of Main Clock Mode Register (MCM)**

Address: FFA1H After reset: 00H R/W<sup>Note</sup>

|        |   |   |   |   |   |   |     |      |
|--------|---|---|---|---|---|---|-----|------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2 | <1> | <0>  |
| MCM    | 0 | 0 | 0 | 0 | 0 | 0 | MCS | MCM0 |

|     |                              |
|-----|------------------------------|
| MCS | CPU clock status             |
| 0   | Operates with Ring-OSC clock |
| 1   | Operates with X1 input clock |

|      |                                    |
|------|------------------------------------|
| MCM0 | Selection of clock supplied to CPU |
| 0    | Ring-OSC clock                     |
| 1    | X1 input clock                     |

**Note** Bit 1 is read-only.

**Caution** When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the divided clock of the Ring-OSC oscillator output ( $f_x$ ) is supplied to the peripheral hardware ( $f_x = 240 \text{ kHz (TYP.)}$ ).

Operation of the peripheral hardware with the Ring-OSC clock cannot be guaranteed. Therefore, when the Ring-OSC clock is selected as the clock supplied to the CPU, do not use peripheral hardware. In addition, stop the peripheral hardware before switching the clock supplied to the CPU from the X1 input clock to the Ring-OSC clock. Note, however, that the following peripheral hardware can be used when the CPU operates on the Ring-OSC clock.

- Watchdog timer
- Clock monitor
- 8-bit timer H1 when  $f_R/2^7$  is selected as the count clock
- Peripheral hardware with an external clock selected as the clock source (Except when the external count clock of TM00 is selected (TI000 valid edge))

**(4) Main OSC control register (MOC)**

This register selects the operation mode of the X1 input clock.

This register is used to stop the X1 oscillator operation when the CPU is operating with the Ring-OSC clock. Therefore, this register is valid only when the CPU is operating with the Ring-OSC clock.

MOC can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 5-5. Format of Main OSC Control Register (MOC)**

Address: FFA2H After reset: 00H R/W

| Symbol | <7>                                | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|------------------------------------|---|---|---|---|---|---|---|
| MOC    | MSTOP                              | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MSTOP  | Control of X1 oscillator operation |   |   |   |   |   |   |   |
| 0      | X1 oscillator operating            |   |   |   |   |   |   |   |
| 1      | X1 oscillator stopped              |   |   |   |   |   |   |   |

**Caution** Make sure that bit 1 (MCS) of the main clock mode register (MCM) is 0 before setting MSTOP.



**(5) Oscillation stabilization time counter status register (OSTC)**

This is the status register of the X1 input clock oscillation stabilization time counter. If the Ring-OSC clock is used as the CPU clock, the X1 input clock oscillation stabilization time can be checked.

OSTC can be read by a 1-bit or 8-bit memory manipulation instruction.

When reset is released (reset by  $\overline{\text{RESET}}$  input, POC, LVI, clock monitor, and WDT), the STOP instruction, MSTOP = 1 clear OSTC to 00H.

**Figure 5-6. Format of Oscillation Stabilization Time Counter Status Register (OSTC)**

Address: FFA3H After reset: 00H R

|        |   |   |   |        |        |        |        |        |
|--------|---|---|---|--------|--------|--------|--------|--------|
| Symbol | 7 | 6 | 5 | 4      | 3      | 2      | 1      | 0      |
| OSTC   | 0 | 0 | 0 | MOST11 | MOST13 | MOST14 | MOST15 | MOST16 |

★

| MOST11 | MOST13 | MOST14 | MOST15 | MOST16 | Oscillation stabilization time status |   |                          |
|--------|--------|--------|--------|--------|---------------------------------------|---|--------------------------|
|        |        |        |        |        | $f_{XP} = 10 \text{ MHz}$             | $f_{XP} = 12 \text{ MHz}$ <sup>Note</sup> |                          |
| 1      | 0      | 0      | 0      | 0      | $2^{11}/f_{XP}$ min.                  | 204.8 $\mu\text{s}$ min.                  | 170.7 $\mu\text{s}$ min. |
| 1      | 1      | 0      | 0      | 0      | $2^{13}/f_{XP}$ min.                  | 819.2 $\mu\text{s}$ min.                  | 682.7 $\mu\text{s}$ min. |
| 1      | 1      | 1      | 0      | 0      | $2^{14}/f_{XP}$ min.                  | 1.64 ms min.                              | 1.37 ms min.             |
| 1      | 1      | 1      | 1      | 0      | $2^{15}/f_{XP}$ min.                  | 3.27 ms min.                              | 2.73 ms min.             |
| 1      | 1      | 1      | 1      | 1      | $2^{16}/f_{XP}$ min.                  | 6.55 ms min.                              | 5.46 ms min.             |

★

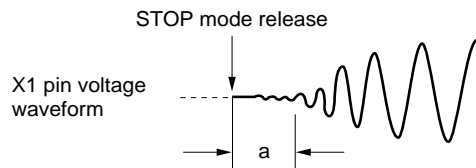
**Note** Expanded-specification products of standard products and (A) grade products only

**Cautions 1.** After the above time has elapsed, the bits are set to 1 in order from MOST11 and remain 1.

- 2.** If the STOP mode is entered and then released while the Ring-OSC clock is being used as the CPU clock, set the oscillation stabilization time as follows.
- Desired OSTC oscillation stabilization time  $\leq$  Oscillation stabilization time set by OSTC

The X1 oscillation stabilization time counter counts up to the oscillation stabilization time set by OSTC. Note, therefore, that only the status up to the oscillation stabilization time set by OSTC is set to OSTC after STOP mode is released.

- 3.** The wait time when STOP mode is released does not include the time after STOP mode release until clock oscillation starts (“a” below) regardless of whether STOP mode is released by  $\overline{\text{RESET}}$  input or interrupt generation.



**Remark**  $f_{XP}$ : X1 input clock oscillation frequency

**(6) Oscillation stabilization time select register (OSTS)**

This register is used to select the X1 oscillation stabilization wait time when STOP mode is released.

The wait time set by OSTS is valid only after STOP mode is released with the X1 input clock selected as the CPU clock. After STOP mode is released with Ring-OSC selected as the CPU clock, the oscillation stabilization time must be confirmed by OSTC.

OSTS can be set by an 8-bit memory manipulation instruction.

RESET input sets OSTS to 05H.

**Figure 5-7. Format of Oscillation Stabilization Time Select Register (OSTS)**

Address: FFA4H After reset: 05H R/W

|        |   |   |   |   |   |       |       |       |
|--------|---|---|---|---|---|-------|-------|-------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2     | 1     | 0     |
| OSTS   | 0 | 0 | 0 | 0 | 0 | OSTS2 | OSTS1 | OSTS0 |

| OSTS2            | OSTS1 | OSTS0 | Oscillation stabilization time selection |                           |   |
|------------------|-------|-------|--|---------------------------|---|
|                  |       |       |  | $f_{XP} = 10 \text{ MHz}$ | $f_{XP} = 12 \text{ MHz}^{\text{Note}}$ |
| 0                | 0     | 1     | $2^{11}/f_{XP}$                          | 204.8 $\mu\text{s}$       | 170.7 $\mu\text{s}$                     |
| 0                | 1     | 0     | $2^{13}/f_{XP}$                          | 819.2 $\mu\text{s}$       | 682.7 $\mu\text{s}$                     |
| 0                | 1     | 1     | $2^{14}/f_{XP}$                          | 1.64 ms                   | 1.37 ms                                 |
| 1                | 0     | 0     | $2^{15}/f_{XP}$                          | 3.27 ms                   | 2.73 ms                                 |
| 1                | 0     | 1     | $2^{16}/f_{XP}$                          | 6.55 ms                   | 5.46 ms                                 |
| Other than above |       |       | Setting prohibited                       |                           |   |

★ **Note** Expanded-specification products of standard products and (A) grade products only

★ **Cautions 1.** To set the STOP mode when the X1 input clock is used as the CPU clock, set OSTS before executing the STOP instruction.

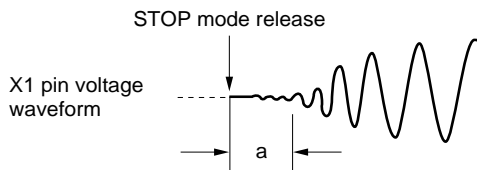
★ **2.** Execute the OSTS setting after confirming that the oscillation stabilization time has elapsed as expected in the OSTC.

**3.** If the STOP mode is entered and then released while the Ring-OSC clock is being used as the CPU clock, set the oscillation stabilization time as follows.

- Desired OSTC oscillation stabilization time  $\leq$  Oscillation stabilization time set by OSTS

The X1 oscillation stabilization time counter counts up to the oscillation stabilization time set by OSTS. Note, therefore, that only the status up to the oscillation stabilization time set by OSTS is set to OSTC after STOP mode is released.

**4.** The wait time when STOP mode is released does not include the time after STOP mode release until clock oscillation starts (“a” below) regardless of whether STOP mode is released by RESET input or interrupt generation.



**Remark**  $f_{XP}$ : X1 input clock oscillation frequency

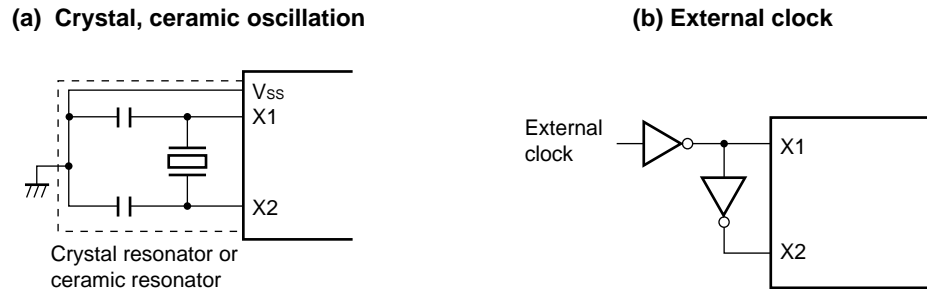
## 5.4 System Clock Oscillator

### 5.4.1 X1 oscillator

- ★ The X1 oscillator oscillates with a crystal resonator or ceramic resonator connected to the X1 and X2 pins. An external clock can be input to the X1 oscillator. In this case, input the clock signal to the X1 pin and input the inverse signal to the X2 pin.

Figure 5-8 shows the external circuit of the X1 oscillator.

**Figure 5-8. External Circuit of X1 Oscillator**



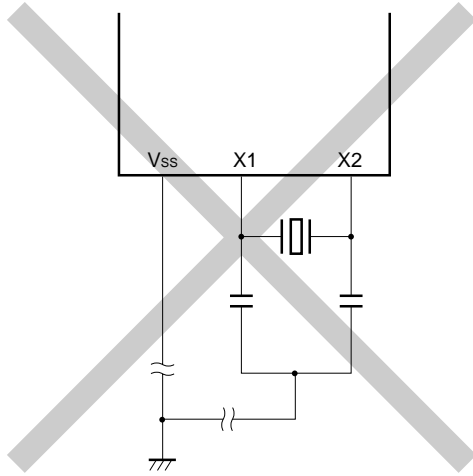
**Caution** When using the X1 oscillator, wire as follows in the area enclosed by the broken lines in the Figure 5-8 to avoid an adverse effect from wiring capacitance.

- Keep the wiring length as short as possible.
- Do not cross the wiring with the other signal lines.
- Do not route the wiring near a signal line through which a high fluctuating current flows.
- Always make the ground point of the oscillator capacitor the same potential as  $V_{ss}$ . Do not ground the capacitor to a ground pattern through which a high current flows.
- Do not fetch signals from the oscillator.

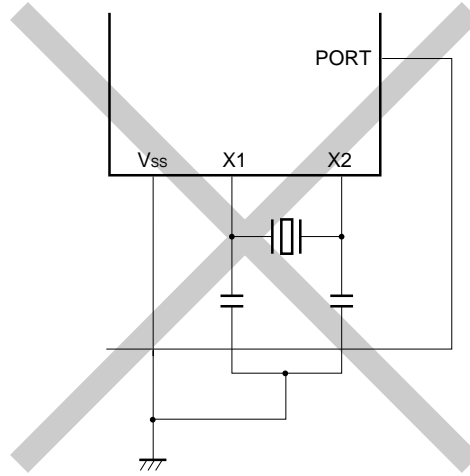
Figure 5-9 shows examples of incorrect resonator connection.

Figure 5-9. Examples of Incorrect Resonator Connection

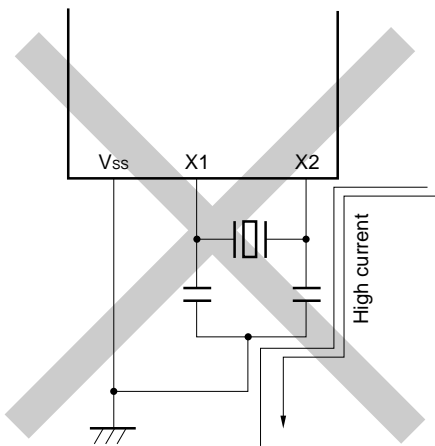
(a) Too long wiring



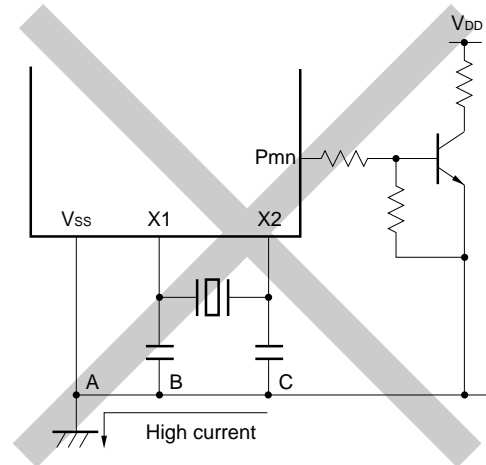
(b) Crossed signal line



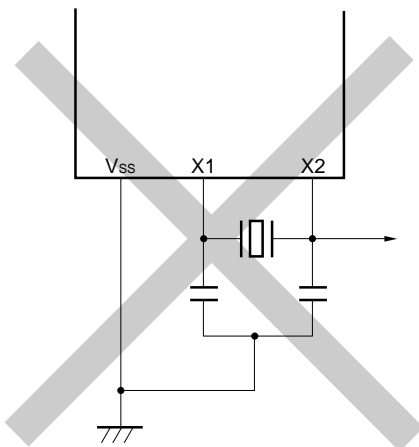
(c) Wiring near high alternating current



(d) Current flowing through ground line of oscillator (potential at points A, B, and C fluctuates)



(e) Signals are fetched



### 5.4.2 Ring-OSC oscillator

A Ring-OSC oscillator is incorporated in the 78K0/KB1.

“Can be stopped by software” or “Cannot be stopped” can be selected by a mask option. The Ring-OSC clock always oscillates after  $\overline{\text{RESET}}$  release (240 kHz (TYP.)).

### 5.4.3 Prescaler

The prescaler generates various clocks by dividing the X1 oscillator output when the X1 input clock is selected as the clock to be supplied to the CPU.

**Caution** When the Ring-OSC clock is selected as the clock supplied to the CPU, the prescaler generates various clocks by dividing the Ring-OSC oscillator output ( $f_x = 240 \text{ kHz (TYP.)}$ ).

## 5.5 Clock Generator Operation

The clock generator generates the following clocks and controls the operation modes of the CPU, such as standby mode.

- X1 input clock  $f_{XP}$
- Ring-OSC clock  $f_R$
- CPU clock  $f_{CPU}$
- Clock to peripheral hardware

The CPU starts operation when the on-chip Ring-OSC oscillator starts outputting after reset release in the 78K0/KB1, thus enabling the following.

### (1) Enhancement of security function

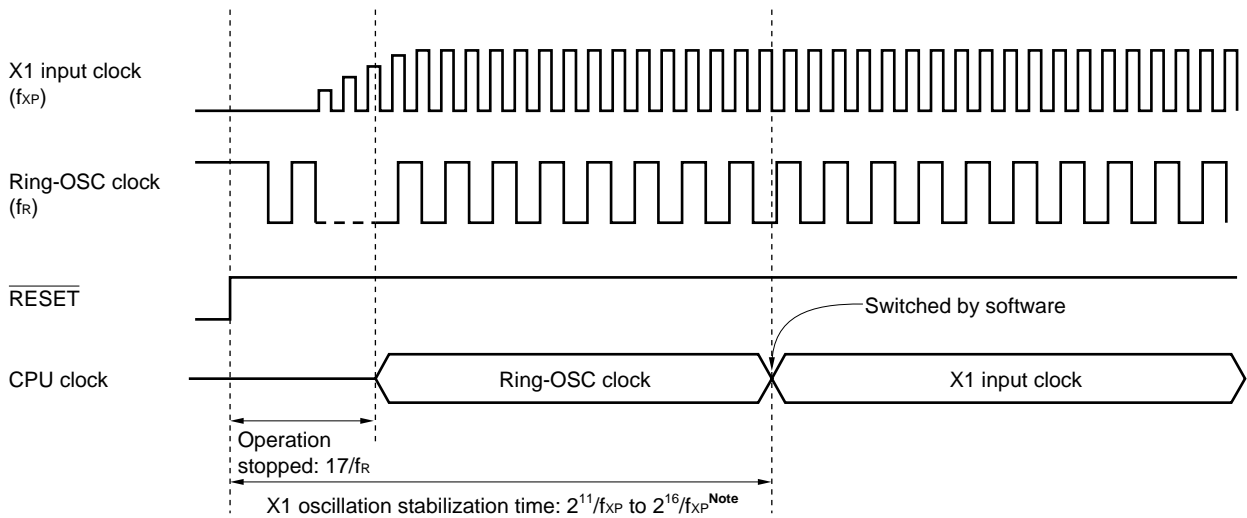
When the X1 input clock is set as the CPU clock by the default setting, the device cannot operate if the X1 input clock is damaged or badly connected and therefore does not operate after reset is released. However, the start clock of the CPU is the on-chip Ring-OSC clock, so the device can be started by the Ring-OSC clock after reset release by the clock monitor (detection of X1 input clock stop). Consequently, the system can be safely shut down by performing a minimum operation, such as acknowledging a reset source by software or performing safety processing when there is a malfunction.

**(2) Improvement of performance**

Because the CPU can be started without waiting for the X1 input clock oscillation stabilization time, the total performance can be improved.

A timing diagram of the CPU default start using Ring-OSC is shown in Figure 5-10.

**Figure 5-10. Timing Diagram of CPU Default Start Using Ring-OSC**



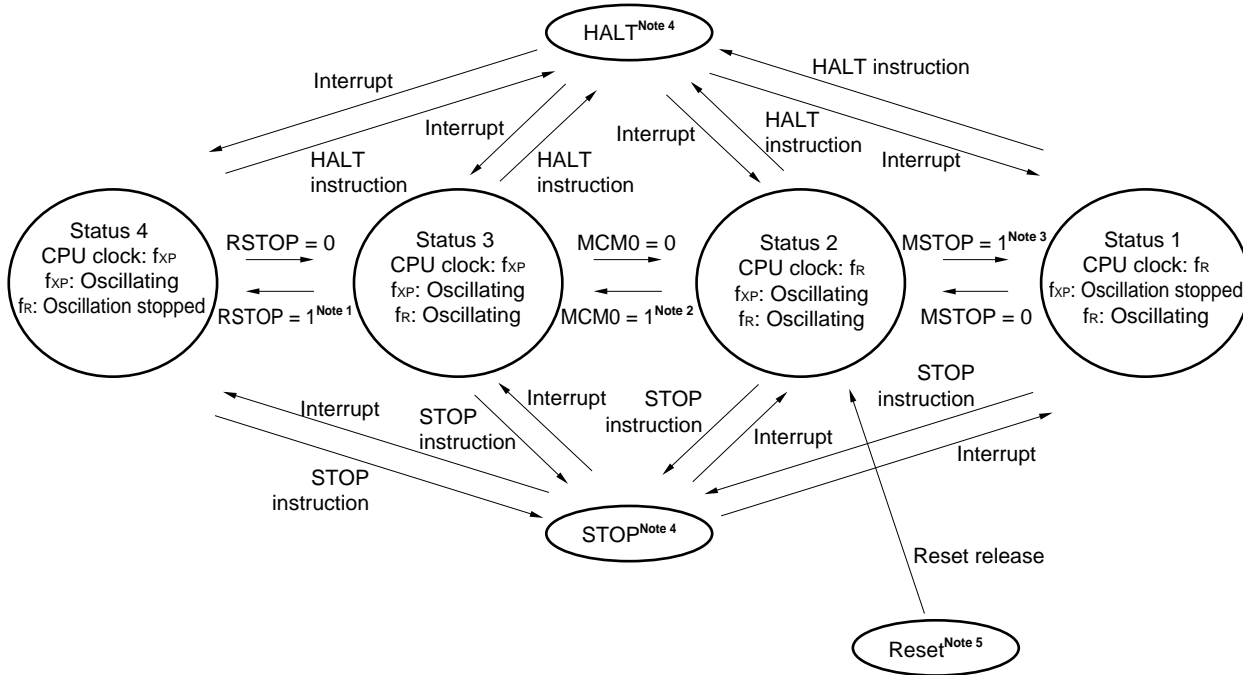
**Note** Check using the oscillation stabilization time counter status register (OSTC).

- When the  $\overline{\text{RESET}}$  signal is generated, bit 0 of the main clock mode register (MCM) is set to 0 and the Ring-OSC clock is set as the CPU clock. However, a clock is supplied to the CPU after 17 clocks of the Ring-OSC clock have elapsed after  $\overline{\text{RESET}}$  release (or clock supply to the CPU stops for 17 clocks). During the  $\overline{\text{RESET}}$  period, oscillation of the X1 input clock and Ring-OSC clock is stopped.
- After  $\overline{\text{RESET}}$  release, the CPU clock can be switched from the Ring-OSC clock to the X1 input clock using bit 0 (MCM0) of the main clock mode register (MCM) after the X1 input clock oscillation stabilization time has elapsed. At this time, check the oscillation stabilization time using the oscillation stabilization time counter status register (OSTC) before switching the CPU clock. The CPU clock status can be checked using bit 1 (MCS) of MCM.
- Ring-OSC can be set to stopped/oscillating using the Ring-OSC mode register (RCM) when "Can be stopped by software" is selected for the Ring-OSC by a mask option, if the X1 input is used as the CPU clock. Make sure that MCS is 1 at this time.
- When Ring-OSC is used as the CPU clock, the X1 input clock can be set to stopped/oscillating using the main OSC control register (MOC). Make sure that MCS is 0 at this time.
- Select the X1 input clock oscillation stabilization time ( $2^{11}/f_{xP}$ ,  $2^{13}/f_{xP}$ ,  $2^{14}/f_{xP}$ ,  $2^{15}/f_{xP}$ ,  $2^{16}/f_{xP}$ ) using the oscillation stabilization time select register (OSTS) when releasing STOP mode while the X1 input clock is being used as the CPU clock. In addition, when releasing STOP mode while  $\overline{\text{RESET}}$  is released and the Ring-OSC clock is being used as the CPU clock, check the X1 input clock oscillation stabilization time using the oscillation stabilization time counter status register (OSTC).

A status transition diagram of this product is shown in Figure 5-11, and the relationship between the operation clocks in each operation status and between the oscillation control flag and oscillation status of each clock are shown in Tables 5-3 and 5-4, respectively.

Figure 5-11. Status Transition Diagram (1/2)

(1) When “Ring-OSC can be stopped by software” is selected by mask option

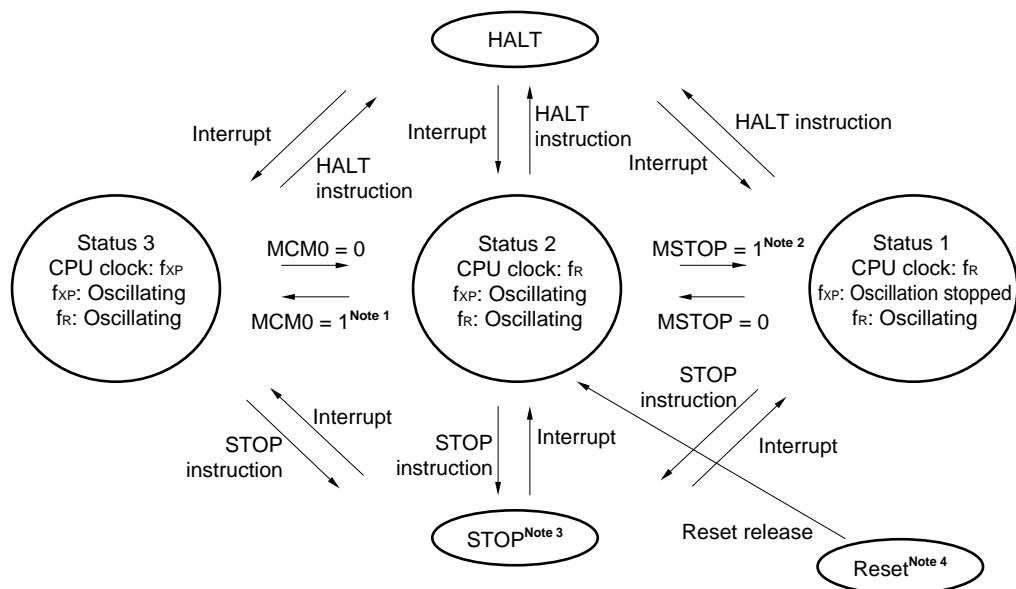


- Notes**
1. When shifting from status 3 to status 4, make sure that bit 1 (MCS) of the main clock mode register (MCM) is 1.
  2. Before shifting from status 2 to status 3 after reset and STOP are released, check the X1 input clock oscillation stabilization time status using the oscillation stabilization time counter status register (OSTC).
  3. When shifting from status 2 to status 1, make sure that MCS is 0.
  4. When “Ring-OSC can be stopped by software” is selected by a mask option, the watchdog timer stops operating in the HALT and STOP modes, regardless of the source clock of the watchdog timer. However, oscillation of Ring-OSC does not stop even in the HALT and STOP modes if RSTOP = 0.
  5. All reset sources ( $\overline{\text{RESET}}$  input, POC, LVI, clock monitor, and WDT)



Figure 5-11. Status Transition Diagram (2/2)

(2) When “Ring-OSC cannot be stopped” is selected by mask option



- Notes**
1. Before shifting from status 2 to status 3 after reset and STOP are released, check the X1 input clock oscillation stabilization time status using the oscillation stabilization time counter status register (OSTC).
  2. When shifting from status 2 to status 1, make sure that MCS is 0.
  3. The watchdog timer operates using Ring-OSC even in STOP mode if “Ring-OSC cannot be stopped” is selected by a mask option. Ring-OSC division can be selected as the count source of 8-bit timer H1 (TMH1), so clear the watchdog timer using the TMH1 interrupt request before watchdog timer overflow. If this processing is not performed, an internal reset signal is generated at watchdog timer overflow after STOP instruction execution.
  4. All reset sources ( $\overline{\text{RESET}}$  input, POC, LVI, clock monitor, and WDT)

**Table 5-3. Relationship Between Operation Clocks in Each Operation Status**

| Operation Mode \ Status | X1 Oscillator | Ring-OSC Oscillator |             |           | CPU Clock After Release | Prescaler Clock Supplied to Peripherals |          |
|-------------------------|---------------|---------------------|-------------|-----------|-------------------------|---|----------|
|                         |               | Note 1              | Note 2      |           |                         | MCM0 = 0                                | MCM0 = 1 |
|                         |               |                     | RSTOP = 0   | RSTOP = 1 |                         |   |          |
| Reset                   | Stopped       | Stopped             |             |           | Ring-OSC                | Stopped                                 |          |
| STOP                    |               | Oscillating         | Oscillating | Stopped   | Note 3                  | Stopped                                 |          |
| HALT                    | Oscillating   |                     |             |           | Note 4                  | Ring-OSC                                | X1       |

- Notes**
1. When “Cannot be stopped” is selected for Ring-OSC by a mask option.
  2. When “Can be stopped by software” is selected for Ring-OSC by a mask option.
  3. Operates using the CPU clock at STOP instruction execution.
  4. Operates using the CPU clock at HALT instruction execution.

**Caution** The RSTOP setting is valid only when “Can be stopped by software” is set for Ring-OSC by a mask option.

**Remark** RSTOP: Bit 0 of the Ring-OSC mode register (RCM)  
MCM0: Bit 0 of the main clock mode register (MCM)

**Table 5-4. Oscillation Control Flags and Clock Oscillation Status**

|           |           | X1 Oscillator      | Ring-OSC Oscillator |
|-----------|-----------|--------------------|---------------------|
| MSTOP = 1 | RSTOP = 0 | Stopped            | Oscillating         |
|           | RSTOP = 1 | Setting prohibited |                     |
| MSTOP = 0 | RSTOP = 0 | Oscillating        | Oscillating         |
|           | RSTOP = 1 |                    | Stopped             |

**Caution** The RSTOP setting is valid only when “Can be stopped by software” is set for Ring-OSC by a mask option.

**Remark** MSTOP: Bit 7 of the main OSC control register (MOC)  
RSTOP: Bit 0 of the Ring-OSC mode register (RCM)

## 5.6 Time Required to Switch Between Ring-OSC Clock and X1 Input Clock

Bit 0 (MCM0) of the main clock mode register (MCM) is used to switch between the Ring-OSC clock and X1 input clock.

In the actual switching operation, switching does not occur immediately after MCM0 rewrite; several instructions are executed using the pre-switch over clock after switching MCM0 (see **Table 5-5**).

Bit 1 (MCS) of MCM is used to judge that operation is performed using either the Ring-OSC clock or X1 input clock.

To stop the original clock after changing the clock, wait for the number of clocks shown in Table 5-5.

★ **Table 5-5. Maximum Time Required to Switch Between Ring-OSC Clock and X1 Input Clock**

| PCC  |      |      | Maximum Time Required for Switching     |                          |
|------|------|------|---|--------------------------|
| PCC2 | PCC1 | PCC0 | X1→Ring-OSC                             | Ring-OSC→X1              |
| 0    | 0    | 0    | $f_{XP}/f_R + 1$ clock                  | 2 clocks                 |
| 0    | 0    | 1    | $f_{XP}/2f_R + 1$ clock <sup>Note</sup> | 2 clocks <sup>Note</sup> |

★ **Note** The setting of (A1) grade products and (A2) grade products is prohibited.

**Caution** To calculate the maximum time, set  $f_R = 120$  kHz.

- Remarks 1.** PCC: Processor clock control register
2.  $f_{XP}$ : X1 input clock oscillation frequency
  3.  $f_R$ : Ring-OSC clock oscillation frequency
  4. The maximum time is the number of clocks of the CPU clock before switching.

### 5.7 Time Required for CPU Clock Switchover

The CPU clock can be switched using bits 0 to 2 (PCC0 to PCC2) of the processor clock control register (PCC).

The actual switchover operation is not performed immediately after rewriting to the PCC; operation continues on the pre-switchover clock for several instructions (see **Table 5-6**).

**Table 5-6. Maximum Time Required for CPU Clock Switchover**

| Set Value Before Switchover |      |      | Set Value After Switchover |      |      |           |      |      |           |      |      |           |      |      |           |      |      |
|-----------------------------|------|------|----------------------------|------|------|-----------|------|------|-----------|------|------|-----------|------|------|-----------|------|------|
| PCC2                        | PCC1 | PCC0 | PCC2                       | PCC1 | PCC0 | PCC2      | PCC1 | PCC0 | PCC2      | PCC1 | PCC0 | PCC2      | PCC1 | PCC0 | PCC2      | PCC1 | PCC0 |
|                             |      |      | 0                          | 0    | 0    | 0         | 0    | 1    | 0         | 1    | 0    | 0         | 1    | 1    | 1         | 0    | 0    |
| 0                           | 0    | 0    | /                          |      |      | 16 clocks |      |      | 16 clocks |      |      | 16 clocks |      |      | 16 clocks |      |      |
| 0                           | 0    | 1    |                            |      |      | 8 clocks  |      |      | 8 clocks  |      |      | 8 clocks  |      |      | 8 clocks  |      |      |
| 0                           | 1    | 0    | 4 clocks                   |      |      | 4 clocks  |      |      | /         |      |      | 4 clocks  |      |      | 4 clocks  |      |      |
| 0                           | 1    | 1    | 2 clocks                   |      |      | 2 clocks  |      |      |           |      |      | 2 clocks  |      |      | 2 clocks  |      |      |
| 1                           | 0    | 0    | 1 clock                    |      |      | 1 clock   |      |      | 1 clock   |      |      | 1 clock   |      |      | /         |      |      |
|                             |      |      |                            |      |      |           |      |      |           |      |      |           |      |      |           |      |      |

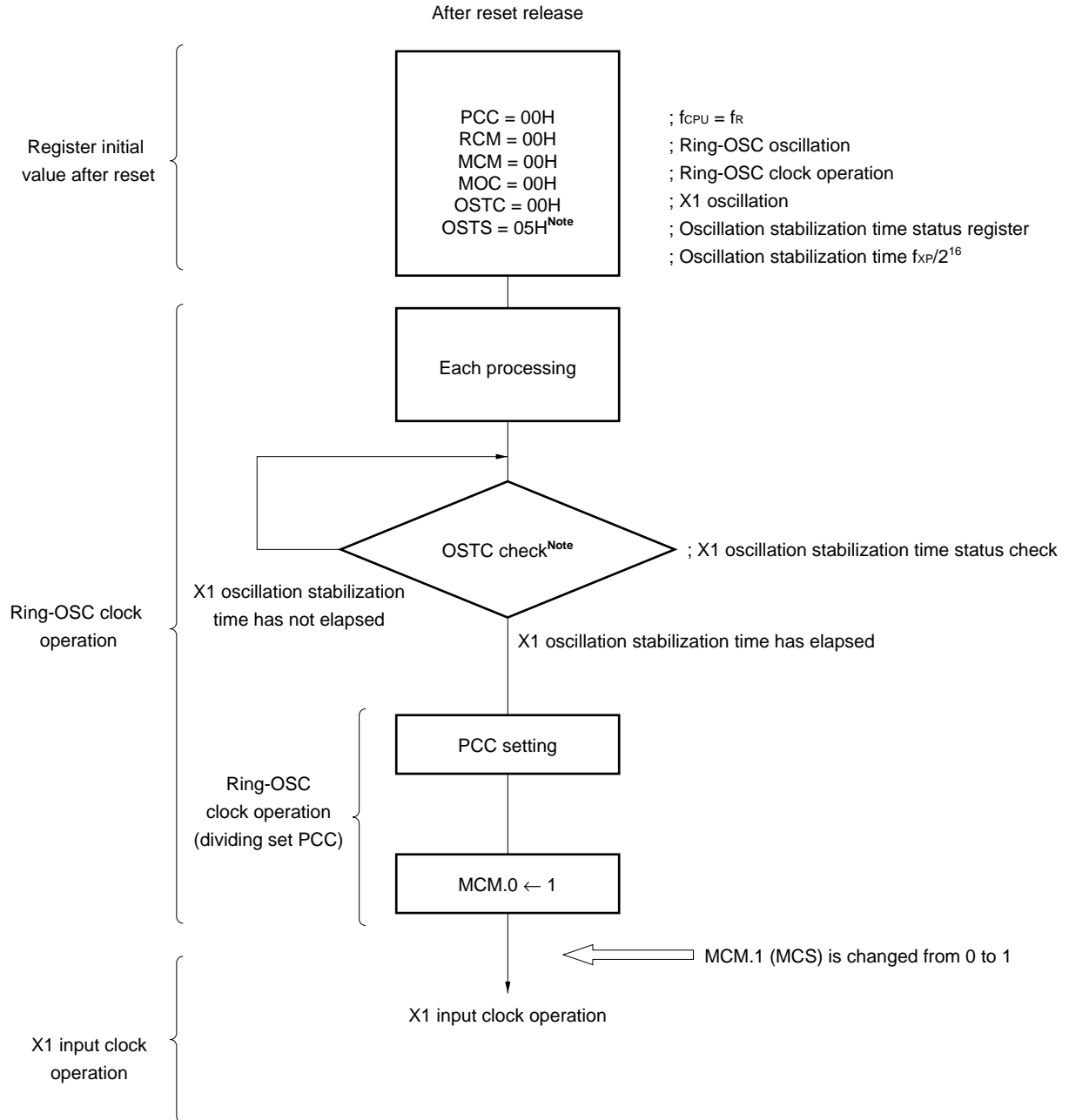
**Remark** The maximum time is the number of clocks of the CPU clock before switching.

- ★ **Caution** Setting the following values is prohibited when the CPU operates on the Ring-OSC clock.
  - PCC2, PCC1, PCC0 = 0, 0, 1 (settable only for standard products and (A) grade products)
  - PCC2, PCC1, PCC0 = 0, 1, 0
  - PCC2, PCC1, PCC0 = 0, 1, 1
  - PCC2, PCC1, PCC0 = 1, 0, 0

## 5.8 Clock Switching Flowchart and Register Setting

### 5.8.1 Switching from Ring-OSC clock to X1 input clock

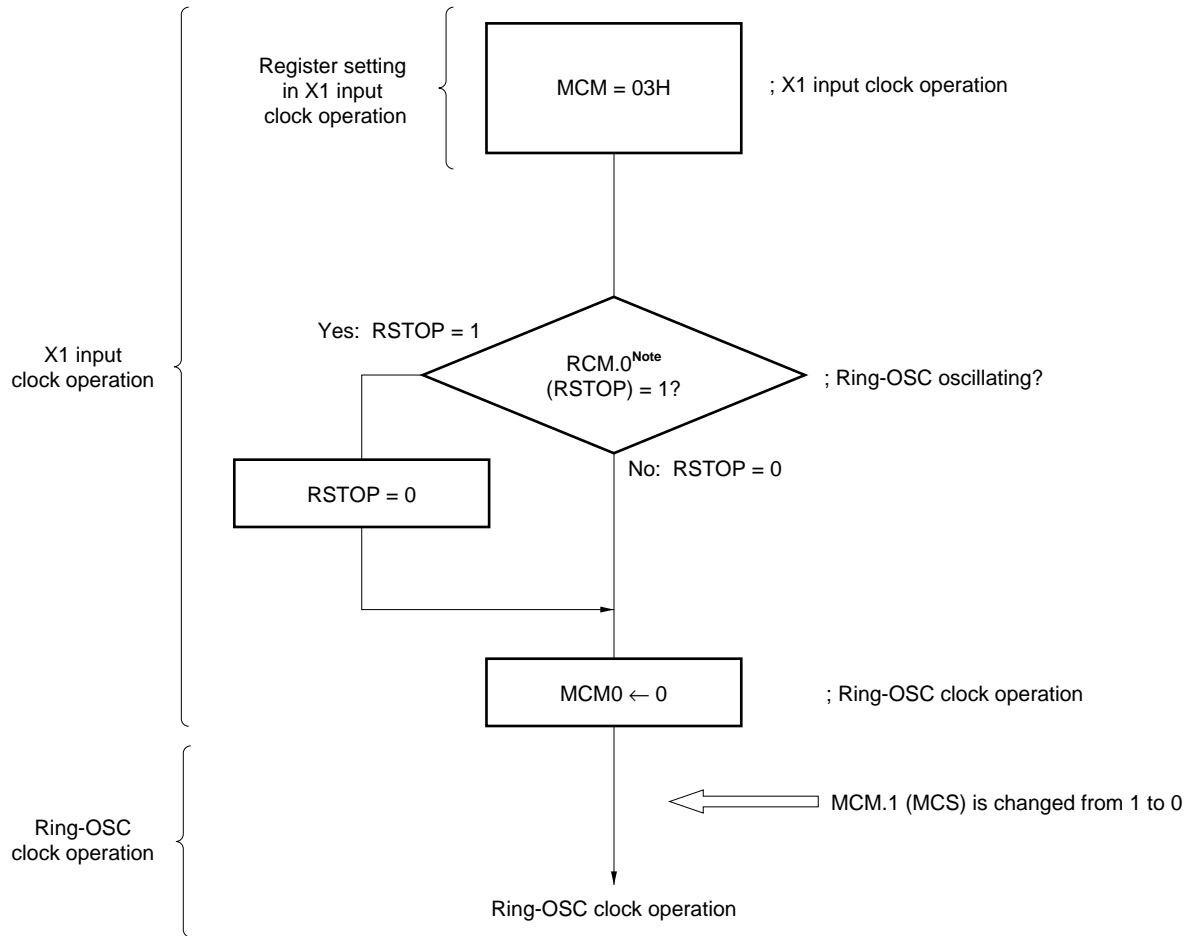
Figure 5-12. Switching from Ring-OSC Clock to X1 Input Clock (Flowchart)



**Note** Check the oscillation stabilization wait time of the X1 oscillator after reset release using the OSTC register and then switch to the X1 input clock operation after the oscillation stabilization wait time has elapsed. The OSTS register setting is valid only after STOP mode is released by interrupt during X1 input clock operation.

5.8.2 Switching from X1 input clock to Ring-OSC clock

Figure 5-13. Switching from X1 Input Clock to Ring-OSC Clock (Flowchart)



**Note** Required only when “Can be stopped by software” is selected for Ring-OSC by a mask option.

### 5.8.3 Register settings

The table below shows the statuses of the setting flags and status flags when each mode is set.

**Table 5-7. Clock and Register Settings**

| f <sub>CPU</sub>                 | Mode                 | Setting Flag |              |                         | Status Flag  |
|----------------------------------|----------------------|--------------|--------------|-------------------------|--------------|
|                                  |                      | MCM Register | MOC Register | RCM Register            | MCM Register |
|                                  |                      | MCM0         | MSTOP        | RSTOP <sup>Note 1</sup> | MCS          |
| X1 input clock <sup>Note 2</sup> | Ring-OSC oscillating | 1            | 0            | 0                       | 1            |
|                                  | Ring-OSC stopped     | 1            | 0            | 1                       | 1            |
| Ring-OSC clock                   | X1 oscillating       | 0            | 0            | 0                       | 0            |
|                                  | X1 stopped           | 0            | 1            | 0                       | 0            |

- Notes**
1. This is valid only when “Can be stopped by software” is selected for Ring-OSC by mask option.
  2. Do not set MSTOP to 1 during X1 input clock operation (oscillation of X1 is not stopped even when MSTOP = 1).

### 6.1 Functions of 16-Bit Timer/Event Counter 00

16-bit timer/event counter 00 has the following functions.

- Interval timer
- PPG output
- Pulse width measurement
- External event counter
- Square-wave output
- One-shot pulse output

#### (1) Interval timer

16-bit timer/event counter 00 generates an interrupt request at the preset time interval.

#### (2) PPG output

16-bit timer/event counter 00 can output a rectangular wave whose frequency and output pulse width can be set freely.

#### (3) Pulse width measurement

16-bit timer/event counter 00 can measure the pulse width of an externally input signal.

#### (4) External event counter

16-bit timer/event counter 00 can measure the number of pulses of an externally input signal.

#### (5) Square-wave output

16-bit timer/event counter 00 can output a square wave with any selected frequency.

#### (6) One-shot pulse output

16-bit timer/event counter 00 can output a one-shot pulse whose output pulse width can be set freely.



## 6.2 Configuration of 16-Bit Timer/Event Counter 00

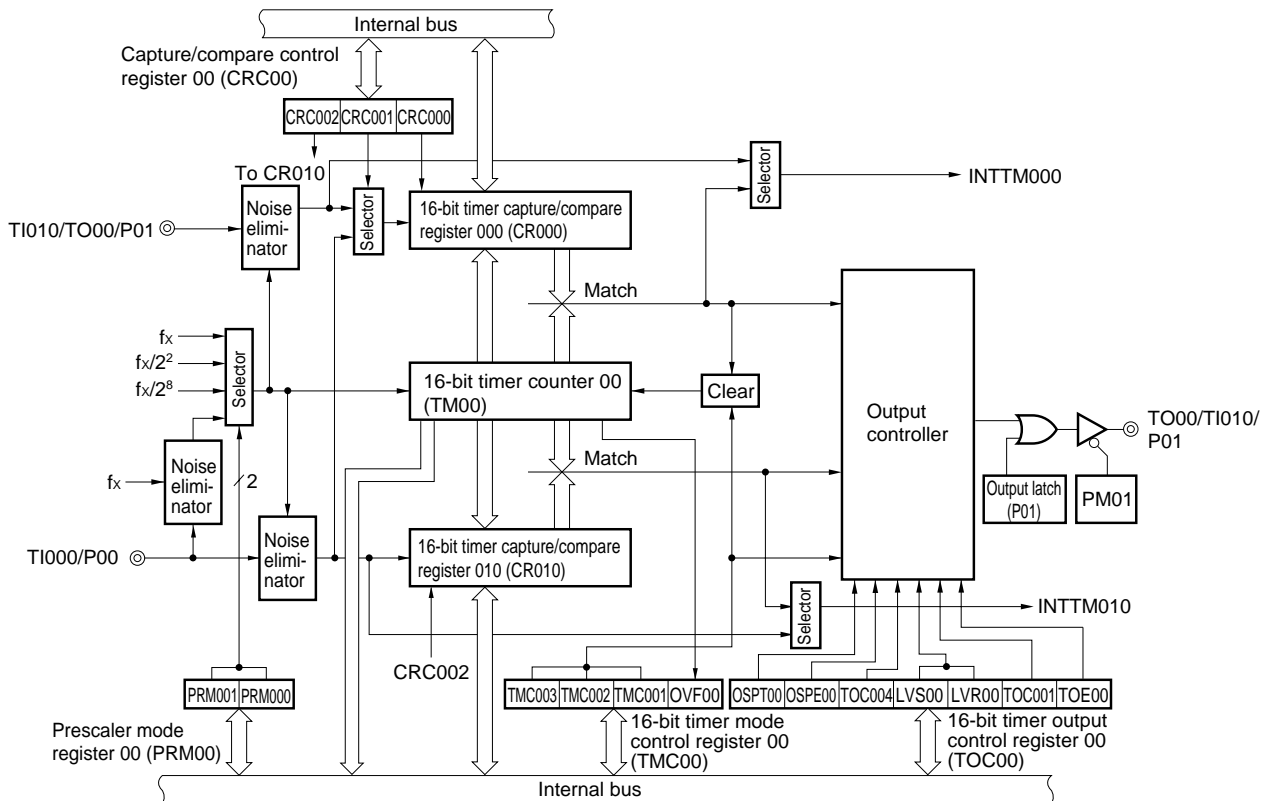
16-bit timer/event counter 00 includes the following hardware.

**Table 6-1. Configuration of 16-Bit Timer/Event Counter 00**

| Item              | Configuration   |
|-------------------|---|
| Timer counter     | 16 bits (TM00)  |
| Register          | 16-bit timer capture/compare register: 16 bits (CR000, CR010)   |
| Timer input       | TI000, TI010  |
| Timer output      | TO00, output controller   |
| Control registers | 16-bit timer mode control register 00 (TMC00)<br>Capture/compare control register 00 (CRC00)<br>16-bit timer output control register 00 (TOC00)<br>Prescaler mode register 00 (PRM00)<br>Port mode register 0 (PM0)<br>Port register 0 (P0) |

Figure 6-1 shows the block diagram.

**Figure 6-1. Block Diagram of 16-Bit Timer/Event Counter 00**

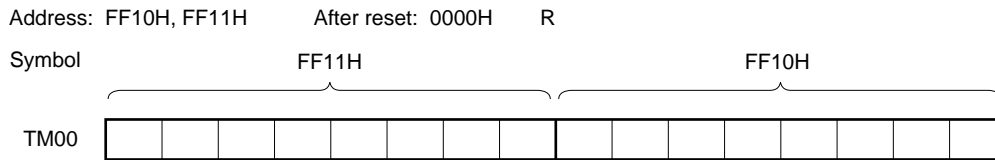


**(1) 16-bit timer counter 00 (TM00)**

TM00 is a 16-bit read-only register that counts count pulses.

The counter is incremented in synchronization with the rising edge of the input clock.

**Figure 6-2. Format of 16-Bit Timer Counter 00 (TM00)**



The count value is reset to 0000H in the following cases.

- <1> At  $\overline{\text{RESET}}$  input
- <2> If TMC003 and TMC002 are cleared
- <3> If the valid edge of TI000 is input in the mode in which clear & start occurs when inputting the valid edge of TI000
- <4> If TM00 and CR000 match in the mode in which clear & start occurs on a match of TM00 and CR000
- <5> OSPT00 is set to 1 in one-shot pulse output mode

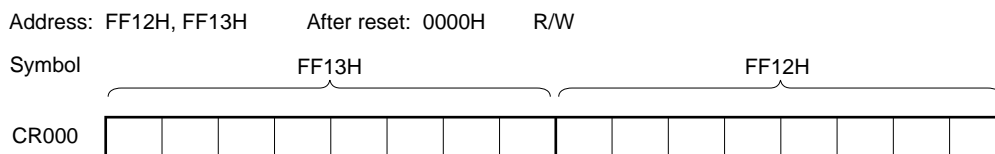
**(2) 16-bit timer capture/compare register 000 (CR000)**

CR000 is a 16-bit register that has the functions of both a capture register and a compare register. Whether it is used as a capture register or as a compare register is set by bit 0 (CRC000) of capture/compare control register 00 (CRC00).

CR000 can be set by a 16-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears CR000 to 0000H.

**Figure 6-3. Format of 16-Bit Timer Capture/Compare Register 000 (CR000)**



- **When CR000 is used as a compare register**

The value set in CR000 is constantly compared with the 16-bit timer counter 00 (TM00) count value, and an interrupt request (INTTM000) is generated if they match. The set value is held until CR000 is rewritten.

- **When CR000 is used as a capture register**

It is possible to select the valid edge of the TI000 pin or the TI010 pin as the capture trigger. The TI000 or TI010 pin valid edge is set using prescaler mode register 00 (PRM00) (see **Table 6-2**).

Table 6-2. CR000 Capture Trigger and Valid Edges of TI000 and TI010 Pins

## (1) TI000 pin valid edge selected as capture trigger (CRC001 = 1, CRC000 = 1)

| CR000 Capture Trigger | TI000 Pin Valid Edge          |       |   |
|-----------------------|-------------------------------|-------|---|
|                       | ES001                         | ES000 |   |
| Falling edge          | Rising edge                   | 0     | 1 |
| Rising edge           | Falling edge                  | 0     | 0 |
| No capture operation  | Both rising and falling edges | 1     | 1 |

## (2) TI010 pin valid edge selected as capture trigger (CRC001 = 0, CRC000 = 1)

| CR000 Capture Trigger         | TI010 Pin Valid Edge          |       |   |
|-------------------------------|-------------------------------|-------|---|
|                               | ES101                         | ES100 |   |
| Falling edge                  | Falling edge                  | 0     | 0 |
| Rising edge                   | Rising edge                   | 0     | 1 |
| Both rising and falling edges | Both rising and falling edges | 1     | 1 |

**Remarks** 1. Setting ES001, ES000 = 1, 0 and ES101, ES100 = 1, 0 is prohibited.

2. ES001, ES000: Bits 5 and 4 of prescaler mode register 00 (PRM00)  
 ES101, ES100: Bits 7 and 6 of prescaler mode register 00 (PRM00)  
 CRC001, CRC000: Bits 1 and 0 of capture/compare control register 00 (CRC00)

**Cautions** 1. Set a value other than 0000H in CR000 in the mode in which clear & start occurs on a match of TM00 and CR000.

- ★ 2. If CR000 is set to 0000H in the free-running mode and in the clear mode using the valid edge of the TI000 pin, an interrupt request (INTTM000) is generated when the value of CR000 changes from 0000H to 0001H following TM00 overflow (FFFFH). Moreover, INTTM000 is generated after a match of TM00 and CR000 is detected, a valid edge of the TI010 pin is detected, and the timer is cleared by a one-shot trigger.
3. When P01 is used as the valid edge input pin of TI010, it cannot be used as the timer output (TO00). Moreover, when P01 is used as TO00, it cannot be used as the valid edge input pin of TI010.
4. When CR000 is used as a capture register, read data is undefined if the register read time and capture trigger input conflict (the capture data itself is the correct value).  
 If timer count stop and capture trigger input conflict, the captured data is undefined.
5. Do not rewrite CR000 during TM00 operation.



### 6.3 Registers Controlling 16-Bit Timer/Event Counter 00

The following six registers are used to control 16-bit timer/event counter 00.

- 16-bit timer mode control register 00 (TMC00)
- Capture/compare control register 00 (CRC00)
- 16-bit timer output control register 00 (TOC00)
- Prescaler mode register 00 (PRM00)
- Port mode register 0 (PM0)
- Port register 0 (P0)

#### (1) 16-bit timer mode control register 00 (TMC00)

This register sets the 16-bit timer operating mode, the 16-bit timer counter 00 (TM00) clear mode, and output timing, and detects an overflow.

TMC00 can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears TMC00 to 00H.

**Caution** 16-bit timer counter 00 (TM00) starts operation at the moment TMC002 and TMC003 are set to values other than 0, 0 (operation stop mode), respectively. Clear TMC002 and TMC003 to 0, 0 to stop operation.

Figure 6-5. Format of 16-Bit Timer Mode Control Register 00 (TMC00)

|         |       |              |     |     |        |        |        |       |
|---------|-------|--------------|-----|-----|--------|--------|--------|-------|
| Address | FFBAH | After reset: | 00H | R/W |        |        |        |       |
| Symbol  | 7     | 6            | 5   | 4   | 3      | 2      | 1      | <0>   |
| TMC00   | 0     | 0            | 0   | 0   | TMC003 | TMC002 | TMC001 | OVF00 |

| TMC003 | TMC002 | TMC001 | Operating mode and clear mode selection              | TO00 inversion timing selection  | Interrupt request generation  |
|--------|--------|--------|--|--|---|
| 0      | 0      | 0      | Operation stop (TM00 cleared to 0)                   | No change  | Not generated   |
| 0      | 0      | 1      |  |  |   |
| 0      | 1      | 0      | Free-running mode                                    | Match between TM00 and CR000 or match between TM00 and CR010                   | <When used as compare register><br>Generated on match between TM00 and CR000, or match between TM00 and CR010 |
| 0      | 1      | 1      |  | Match between TM00 and CR000, match between TM00 and CR010 or TI000 valid edge |   |
| 1      | 0      | 0      | Clear & start occurs on TI000 valid edge             | -  | <When used as capture register><br>Generated by inputting CR000 capture trigger                               |
| 1      | 0      | 1      |  |  |   |
| 1      | 1      | 0      | Clear & start occurs on match between TM00 and CR000 | Match between TM00 and CR000 or match between TM00 and CR010                   |   |
| 1      | 1      | 1      |  | Match between TM00 and CR000, match between TM00 and CR010 or TI000 valid edge |   |

| OVF00 | 16-bit timer counter 00 (TM00) overflow detection |
|-------|---|
| 0     | Overflow not detected                             |
| 1     | Overflow detected                                 |

- Cautions**
1. Timer operation must be stopped before writing to bits other than the OVF00 flag.
  2. Set the valid edge of the TI000/P00 pin using prescaler mode register 00 (PRM00).
  3. If any of the following modes: the mode in which clear & start occurs on match between TM00 and CR000, the mode in which clear & start occurs at the TI000 valid edge, or free-running mode is selected, when the set value of CR000 is FFFFH and the TM00 value changes from FFFFH to 0000H, the OVF00 flag is set to 1.

**Remark**

TO00: 16-bit timer/event counter 00 output pin  
 TI000: 16-bit timer/event counter 00 input pin  
 TM00: 16-bit timer counter 00  
 CR000: 16-bit timer capture/compare register 000  
 CR010: 16-bit timer capture/compare register 010

**(2) Capture/compare control register 00 (CRC00)**

This register controls the operation of the 16-bit timer capture/compare registers (CR000, CR010).

CRC00 can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears CRC00 to 00H.

**Figure 6-6. Format of Capture/Compare Control Register 00 (CRC00)**

Address: FFBC<sub>H</sub> After reset: 00H R/W

| Symbol | 7 | 6 | 5 | 4 | 3 | 2      | 1      | 0      |
|--------|---|---|---|---|---|--------|--------|--------|
| CRC00  | 0 | 0 | 0 | 0 | 0 | CRC002 | CRC001 | CRC000 |

| CRC002 | CR010 operating mode selection |
|--------|--------------------------------|
| 0      | Operates as compare register   |
| 1      | Operates as capture register   |

| CRC001 | CR000 capture trigger selection                                  |
|--------|--|
| 0      | Captures on valid edge of TI010                                  |
| 1      | Captures on valid edge of TI000 by reverse phase <sup>Note</sup> |

| CRC000 | CR000 operating mode selection |
|--------|--------------------------------|
| 0      | Operates as compare register   |
| 1      | Operates as capture register   |

**Note** The capture operation is not performed if both the rising and falling edges are specified as the valid edge of TI000.

**Cautions** 1. Timer operation must be stopped before setting CRC00.

2. When the mode in which clear & start occurs on a match between TM00 and CR000 is selected with 16-bit timer mode control register 00 (TMC00), CR000 should not be specified as a capture register.

3. To ensure that the capture operation is performed properly, the capture trigger requires a pulse two cycles longer than the count clock selected by prescaler mode register 00 (PRM00).

**(3) 16-bit timer output control register 00 (TOC00)**

This register controls the operation of the 16-bit timer/event counter 00 output controller. It sets/resets the timer output F/F (LV00), enables/disables output inversion and 16-bit timer/event counter 00 timer output, enables/disables the one-shot pulse output operation, and sets the one-shot pulse output trigger via software.

TOC00 can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears TOC00 to 00H.

Figure 6-7. Format of 16-Bit Timer Output Control Register 00 (TOC00)

Address: FFBDH After reset: 00H R/W

| Symbol | 7  | <6>                             | <5>    | 4      | <3>   | <2>   | 1      | <0>   |  |
|--------|--|---------------------------------|--------|--------|-------|-------|--------|-------|--|
| TOC00  | 0  | OSPT00                          | OSPE00 | TOC004 | LVS00 | LVR00 | TOC001 | TOE00 |  |
| OSPT00 | One-shot pulse output trigger control via software     |                                 |        |        |       |       |        |       |  |
| 0      | No one-shot pulse output trigger                       |                                 |        |        |       |       |        |       |  |
| 1      | One-shot pulse output trigger                          |                                 |        |        |       |       |        |       |  |
| OSPE00 | One-shot pulse output operation control                |                                 |        |        |       |       |        |       |  |
| 0      | Successive pulse output mode                           |                                 |        |        |       |       |        |       |  |
| 1      | One-shot pulse output mode <sup>Note</sup>             |                                 |        |        |       |       |        |       |  |
| TOC004 | Timer output F/F control using match of CR010 and TM00 |                                 |        |        |       |       |        |       |  |
| 0      | Disables inversion operation                           |                                 |        |        |       |       |        |       |  |
| 1      | Enables inversion operation                            |                                 |        |        |       |       |        |       |  |
| LVS00  | LVR00  | Timer output F/F status setting |        |        |       |       |        |       |  |
| 0      | 0  | No change                       |        |        |       |       |        |       |  |
| 0      | 1  | Timer output F/F reset (0)      |        |        |       |       |        |       |  |
| 1      | 0  | Timer output F/F set (1)        |        |        |       |       |        |       |  |
| 1      | 1  | Setting prohibited              |        |        |       |       |        |       |  |
| TOC001 | Timer output F/F control using match of CR000 and TM00 |                                 |        |        |       |       |        |       |  |
| 0      | Disables inversion operation                           |                                 |        |        |       |       |        |       |  |
| 1      | Enables inversion operation                            |                                 |        |        |       |       |        |       |  |
| TOE00  | Timer output control                                   |                                 |        |        |       |       |        |       |  |
| 0      | Disables output (output fixed to level 0)              |                                 |        |        |       |       |        |       |  |
| 1      | Enables output   |                                 |        |        |       |       |        |       |  |

**Note** The one-shot pulse output mode operates correctly only in the free-running mode and the mode in which clear & start occurs at the T1000 valid edge. In the mode in which clear & start occurs on a match between the TM00 register and CR000 register, one-shot pulse output is not possible because an overflow does not occur.

- Cautions**
1. Timer operation must be stopped before setting other than TOC004.
  2. LVS00 and LVR00 are 0 when they are read.
  3. OSPT00 is automatically cleared after data is set, so 0 is read.
  4. Do not set OSPT00 to 1 other than in one-shot pulse output mode.
  5. A write interval of two cycles or more of the count clock selected by prescaler mode register 00 (PRM00) is required to write to OSPT00 successively.
  6. Do not set LVS00 to 1 before TOE00, and do not set LVS00 and TOE00 to 1 simultaneously.
  7. Do not make settings <1> and <2> below simultaneously. In addition, follow the setting procedure shown below.

<1> Setting of TOC001, TOC004, TOE00, and OSPE00: Setting of timer output operation

<2> Setting of LVS00 and LVR00: Setting of timer output F/F



**(4) Prescaler mode register 00 (PRM00)**

This register is used to set the 16-bit timer counter 00 (TM00) count clock and TI000 and TI010 input valid edges. PRM00 can be set by a 1-bit or 8-bit memory manipulation instruction. RESET input clears PRM00 to 00H.

**Figure 6-8. Format of Prescaler Mode Register 00 (PRM00)**

Address: FFBBH After reset: 00H R/W

| Symbol | 7     | 6     | 5     | 4     | 3 | 2 | 1      | 0      |
|--------|-------|-------|-------|-------|---|---|--------|--------|
| PRM00  | ES101 | ES100 | ES001 | ES000 | 0 | 0 | PRM001 | PRM000 |

| ES101 | ES100 | TI010 valid edge selection    |
|-------|-------|-------------------------------|
| 0     | 0     | Falling edge                  |
| 0     | 1     | Rising edge                   |
| 1     | 0     | Setting prohibited            |
| 1     | 1     | Both falling and rising edges |

| ES001 | ES000 | TI000 valid edge selection    |
|-------|-------|-------------------------------|
| 0     | 0     | Falling edge                  |
| 0     | 1     | Rising edge                   |
| 1     | 0     | Setting prohibited            |
| 1     | 1     | Both falling and rising edges |

| PRM001 | PRM000 | Count clock selection <sup>Note 1</sup> |
|--------|--------|---|
| 0      | 0      | $f_x$ (10 MHz)                          |
| 0      | 1      | $f_x/2^2$ (2.5 MHz)                     |
| 1      | 0      | $f_x/2^3$ (39.06 kHz)                   |
| 1      | 1      | TI000 valid edge <sup>Note 2</sup>      |

★

**Notes 1.** Be sure to set the count clock so that the following condition is satisfied.

- $V_{DD} = 4.0$  to  $5.5$  V: Count clock  $\leq 10$  MHz
  - $V_{DD} = 3.3$  to  $4.0$  V: Count clock  $\leq 8.38$  MHz
  - $V_{DD} = 2.7$  to  $3.3$  V: Count clock  $\leq 5$  MHz
  - $V_{DD} = 2.5$  to  $2.7$  V: Count clock  $\leq 2.5$  MHz
2. The external clock requires a pulse two cycles longer than the internal clock ( $f_x$ ).

- Cautions 1.** When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the count clock is the Ring-OSC clock, the operation of 16-bit timer/event counter 00 is not guaranteed. When an external clock is used and when the Ring-OSC clock is selected and supplied to the CPU, the operation of 16-bit timer/event counter 00 is not guaranteed, either, because the Ring-OSC clock is supplied as the sampling clock to eliminate noise.
2. Always set data to PRM00 after stopping the timer operation.
3. If the valid edge of TI000 is to be set for the count clock, do not set the clear & start mode using the valid edge of TI000 and the capture trigger.

**Cautions** 4. If the TI000 or TI010 pin is high level immediately after system reset, the rising edge is immediately detected after the rising edge or both the rising and falling edges are set as the valid edge(s) of the TI000 pin or TI010 pin to enable the operation of 16-bit timer counter 00 (TM00). Care is therefore required when pulling up the TI000 or TI010 pin. However, when the TI000 or TI010 pin is high level and re-enabling operation after the operation has been stopped, the rising edge is not detected.

5. When P01 is used as the TI010 valid edge input pin, it cannot be used as the timer output (TO00), and when used as TO00, it cannot be used as the TI010 valid edge input pin.

- Remarks**
1.  $f_x$ : X1 input clock oscillation frequency
  2. TI000, TI010: 16-bit timer/event counter 00 input pin
  3. Figures in parentheses are for operation with  $f_x = 10$  MHz.

#### (5) Port mode register 0 (PM0)

This register sets port 0 input/output in 1-bit units.

When using the P01/TO00/TI010 pin for timer output, set PM01 and the output latch of P01 to 0.

When using the P01/TO00/TI010 pin for timer input, set PM01 to 1. The output latch of P01 at this time may be 0 or 1.

PM0 can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input sets PM0 to FFH.

**Figure 6-9. Format of Port Mode Register 0 (PM0)**

Address: FF20H After reset: FFH R/W

|        |   |   |   |   |      |      |      |      |
|--------|---|---|---|---|------|------|------|------|
| Symbol | 7 | 6 | 5 | 4 | 3    | 2    | 1    | 0    |
| PM0    | 1 | 1 | 1 | 1 | PM03 | PM02 | PM01 | PM00 |

|      |   |
|------|---|
| PM0n | P0n pin I/O mode selection (n = 0 to 3) |
| 0    | Output mode (output buffer on)          |
| 1    | Input mode (output buffer off)          |

## 6.4 Operation of 16-Bit Timer/Event Counter 00

### 6.4.1 Interval timer operation

Setting 16-bit timer mode control register 00 (TMC00) and capture/compare control register 00 (CRC00) as shown in Figure 6-10 allows operation as an interval timer.

#### Setting

The basic operation setting procedure is as follows.

- <1> Set the CRC00 register (see **Figure 6-10** for the set value).
- <2> Set any value to the CR000 register.
- <3> Set the count clock by using the PRM000 register.
- <4> Set the TMC00 register to start the operation (see **Figure 6-10** for the set value).

**Caution** Do not rewrite CR000 during TM00 operation.

**Remark** For how to enable the INTTM000 interrupt, see **CHAPTER 14 INTERRUPT FUNCTIONS**.

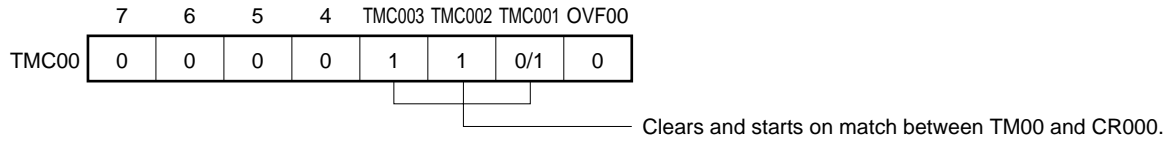
Interrupt requests are generated repeatedly using the count value preset in 16-bit timer capture/compare register 000 (CR000) as the interval.

When the count value of 16-bit timer counter 00 (TM00) matches the value set in CR000, counting continues with the TM00 value cleared to 0 and the interrupt request signal (INTTM000) is generated.

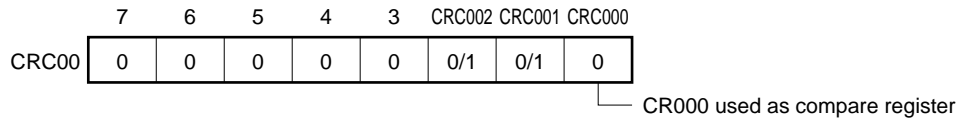
The count clock of 16-bit timer/event counter 00 can be selected with bits 0 and 1 (PRM000, PRM001) of prescaler mode register 00 (PRM00).

Figure 6-10. Control Register Settings for Interval Timer Operation

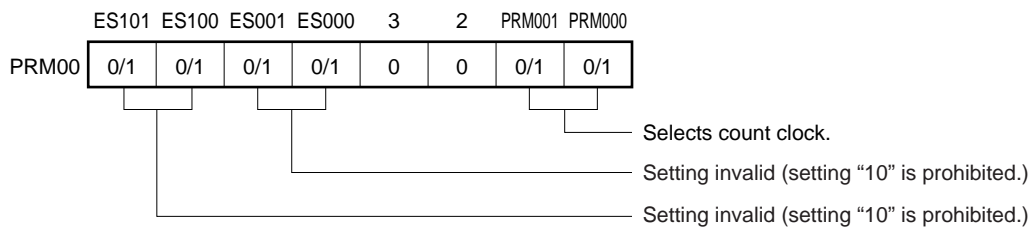
(a) 16-bit timer mode control register 00 (TMC00)



(b) Capture/compare control register 00 (CRC00)

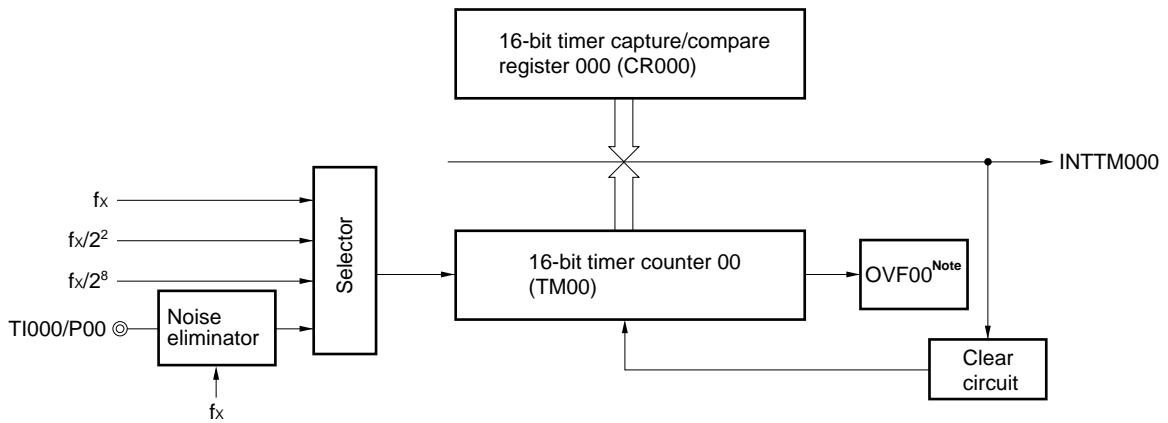


(c) Prescaler mode register 00 (PRM00)



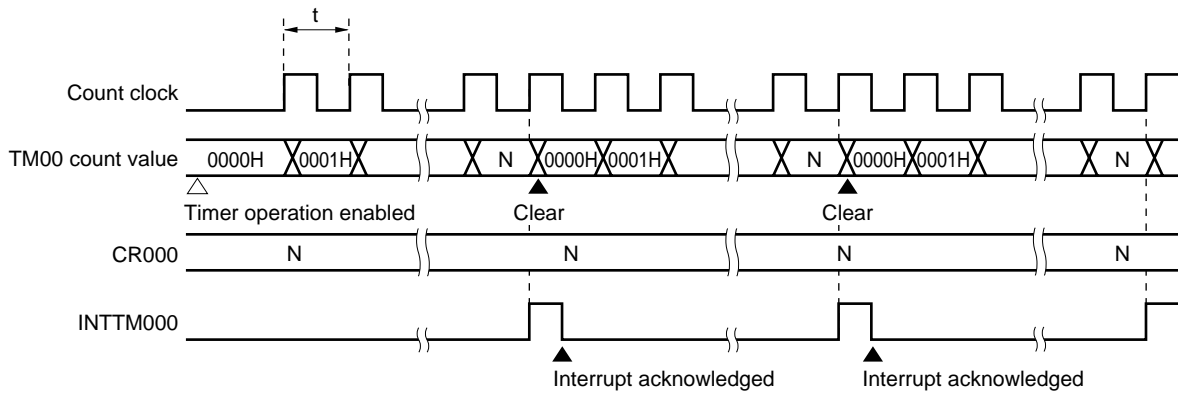
**Remark** 0/1: Setting 0 or 1 allows another function to be used simultaneously with the interval timer. See the description of the respective control registers for details.

Figure 6-11. Interval Timer Configuration Diagram



**Note** OVF00 is set to 1 only when CR000 is set to FFFFH.

Figure 6-12. Timing of Interval Timer Operation



**Remark** Interval time =  $(N + 1) \times t$   
 $N = 0001H$  to  $FFFFH$  (settable range)

### 6.4.2 PPG output operations

Setting 16-bit timer mode control register 00 (TMC00) and capture/compare control register 00 (CRC00) as shown in Figure 6-13 allows operation as PPG (Programmable Pulse Generator) output.

#### Setting

The basic operation setting procedure is as follows.

- <1> Set the CRC00 register (see **Figure 6-13** for the set value).
- <2> Set any value to the CR000 register as the cycle.
- <3> Set any value to the CR010 register as the duty factor.
- <4> Set the TOC00 register (see **Figure 6-13** for the set value).
- <5> Set the count clock by using the PRM00 register.
- <6> Set the TMC00 register to start the operation (see **Figure 6-13** for the set value).

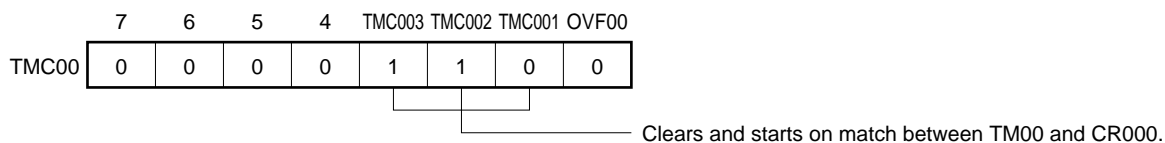
**Caution** To change the value of the duty factor (the value of the CR010 register) during operation, see **Caution 2 in Figure 6-15 PPG Output Operation Timing**.

**Remarks** 1. For the setting of the TO00 pin, see **6.3 (5) Port mode register 0 (PM0)**.  
2. For how to enable the INTTM000 interrupt, see **CHAPTER 14 INTERRUPT FUNCTIONS**.

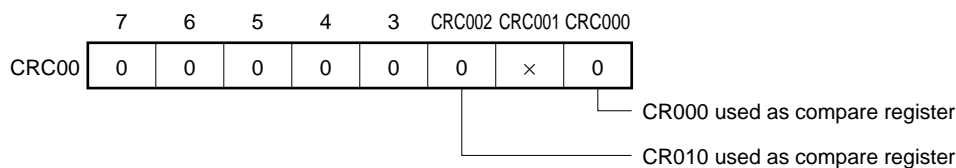
In the PPG output operation, rectangular waves are output from the TO00 pin with the pulse width and the cycle that correspond to the count values preset in 16-bit timer capture/compare register 010 (CR010) and in 16-bit timer capture/compare register 000 (CR000), respectively.

Figure 6-13. Control Register Settings for PPG Output Operation

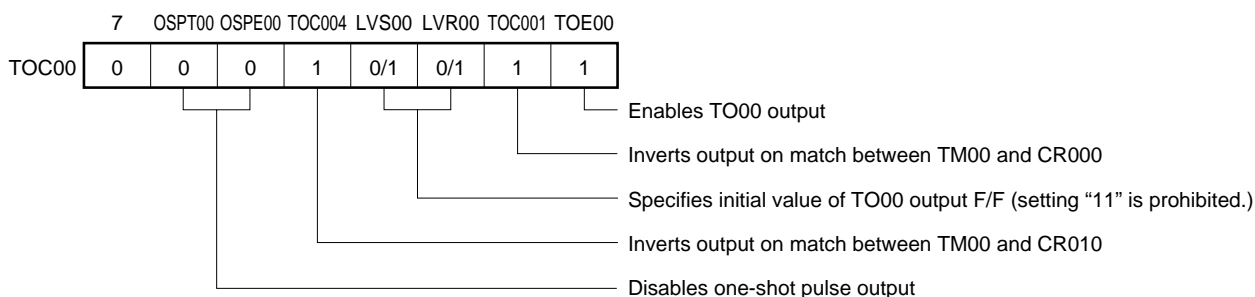
(a) 16-bit timer mode control register 00 (TMC00)



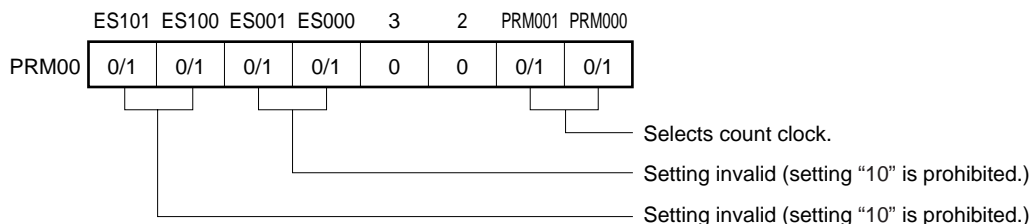
(b) Capture/compare control register 00 (CRC00)



(c) 16-bit timer output control register 00 (TOC00)



(d) Prescaler mode register 00 (PRM00)



**Cautions** 1. Values in the following range should be set in CR000 and CR010:

$$0000H \leq CR010 < CR000 \leq FFFFH$$

2. The cycle of the pulse generated through PPG output (CR000 setting value + 1) has a duty of (CR010 setting value + 1)/(CR000 setting value + 1).

**Remark** ×: Don't care

Figure 6-14. Configuration of PPG Output

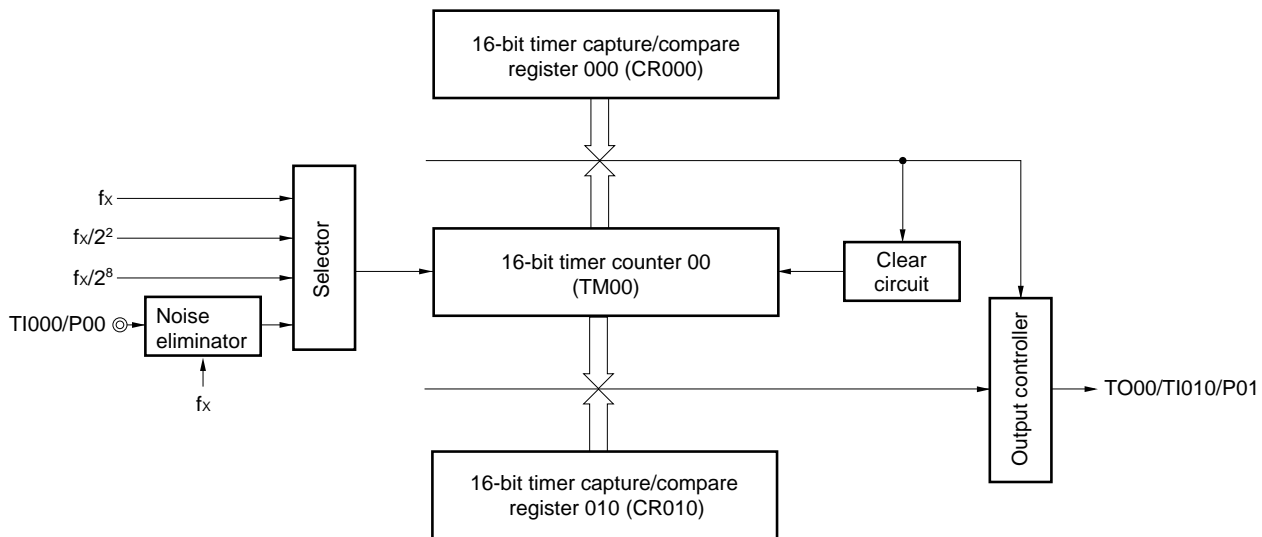
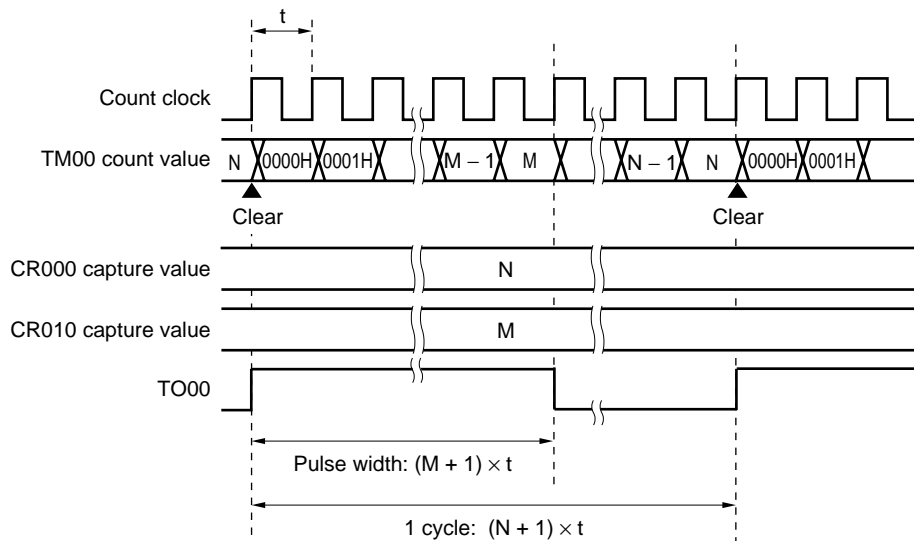


Figure 6-15. PPG Output Operation Timing



- Cautions**
1. Do not rewrite CR000 during TM00 operation.
  2. In the PPG output operation, change the pulse width (rewrite CR010) during TM00 operation using the following procedure.
    - <1> Disable the timer output inversion operation by match of TM00 and CR010 (TOC004 = 0)
    - <2> Disable the INTTM010 interrupt (TMMK010 = 1)
    - <3> Rewrite CR010
    - <4> Wait for 1 cycle of the TM00 count clock
    - <5> Enable the timer output inversion operation by match of TM00 and CR010 (TOC004 = 1)
    - <6> Clear the interrupt request flag of INTTM010 (TMIF010 = 0)
    - <7> Enable the INTTM010 interrupt (TMMK010 = 0)

**Remark**  $0000H \leq M < N \leq FFFFH$



### 6.4.3 Pulse width measurement operations

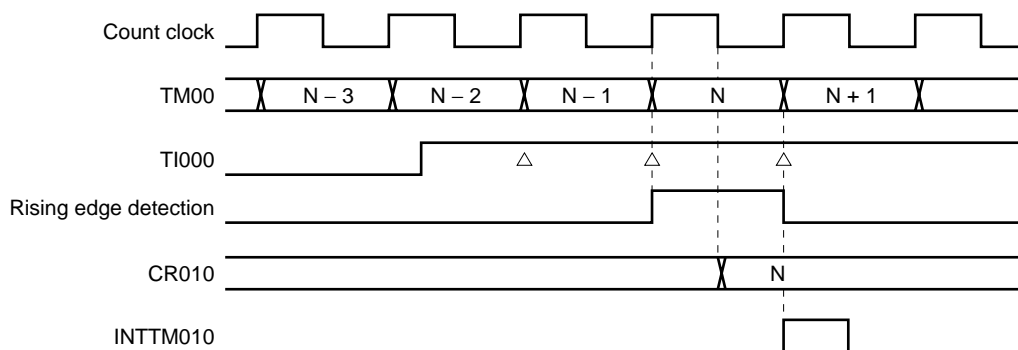
It is possible to measure the pulse width of the signals input to the TI000 pin and TI010 pin using 16-bit timer counter 00 (TM00).

There are two measurement methods: measuring with TM00 used in free-running mode, and measuring by restarting the timer in synchronization with the edge of the signal input to the TI000 pin.

When an interrupt occurs, read the valid value of the capture register, check the overflow flag, and then calculate the necessary pulse width. Clear the overflow flag after checking it.

The capture operation is not performed until the signal pulse width is sampled in the count clock cycle selected by prescaler mode register 00 (PRM00) and the valid level of the TI000 or TI010 pin is detected twice, thus eliminating noise with a short pulse width.

**Figure 6-16. CR010 Capture Operation with Rising Edge Specified**



#### Setting

The basic operation setting procedure is as follows.

- <1> Set the CRC00 register (see **Figures 6-17, 6-20, 6-22, and 6-24** for the set value).
- <2> Set the count clock by using the PRM00 register.
- <3> Set the TMC00 register to start the operation (see **Figures 6-17, 6-20, 6-22, and 6-24** for the set value).

**Caution** To use two capture registers, set the TI000 and TI010 pins.

- Remarks**
1. For the setting of the TI000 (or TI010) pin, see **6.3 (5) Port mode register 0 (PM0)**.
  2. For how to enable the INTTM000 (or INTTM010) interrupt, see **CHAPTER 14 INTERRUPT FUNCTIONS**.

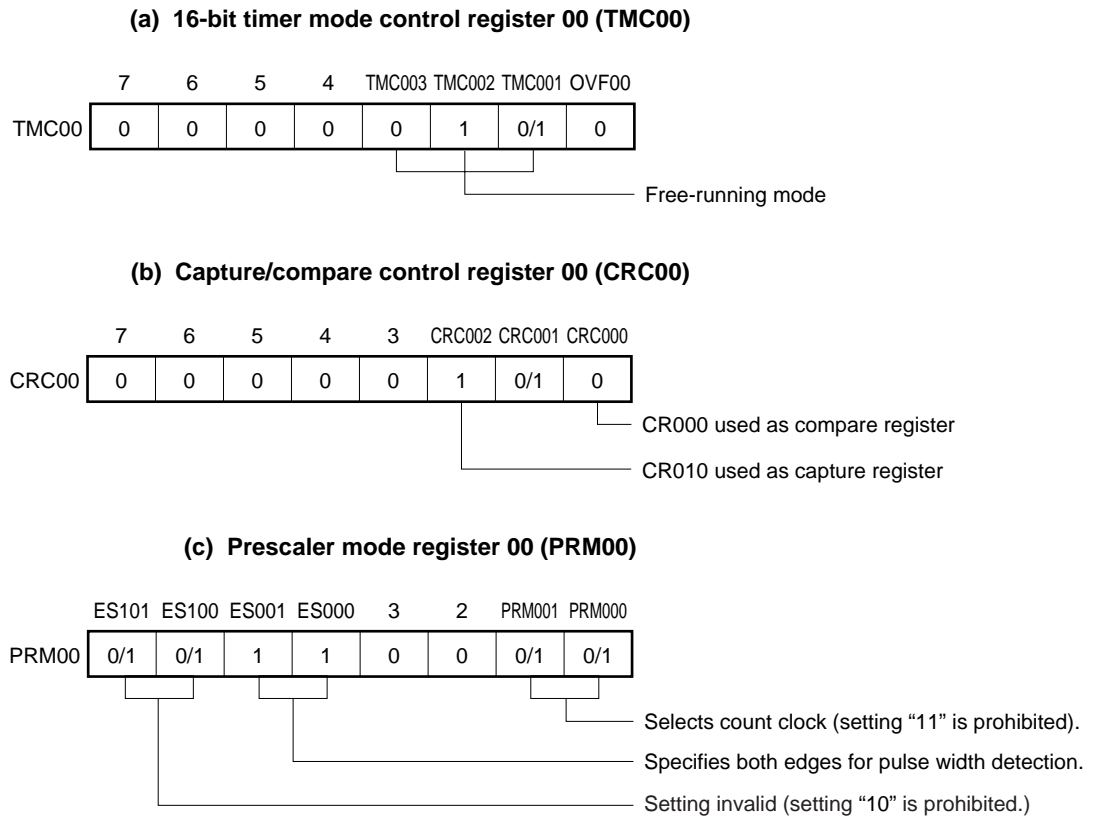
**(1) Pulse width measurement with free-running counter and one capture register**

When 16-bit timer counter 00 (TM00) is operated in free-running mode, and the edge specified by prescaler mode register 00 (PRM00) is input to the TI000 pin, the value of TM00 is taken into 16-bit timer capture/compare register 010 (CR010) and an external interrupt request signal (INTTM010) is set.

Specify both the rising and falling edges of the TI000 pin by using bits 4 and 5 (ES000 and ES001) of PRM00.

Sampling is performed using the count clock selected by PRM00, and a capture operation is only performed when the valid level of the TI000 pin is detected twice, thus eliminating noise with a short pulse width.

**Figure 6-17. Control Register Settings for Pulse Width Measurement with Free-Running Counter and One Capture Register (When TI000 and CR010 Are Used)**



**Remark** 0/1: Setting 0 or 1 allows another function to be used simultaneously with pulse width measurement. See the description of the respective control registers for details.

Figure 6-18. Configuration Diagram for Pulse Width Measurement with Free-Running Counter

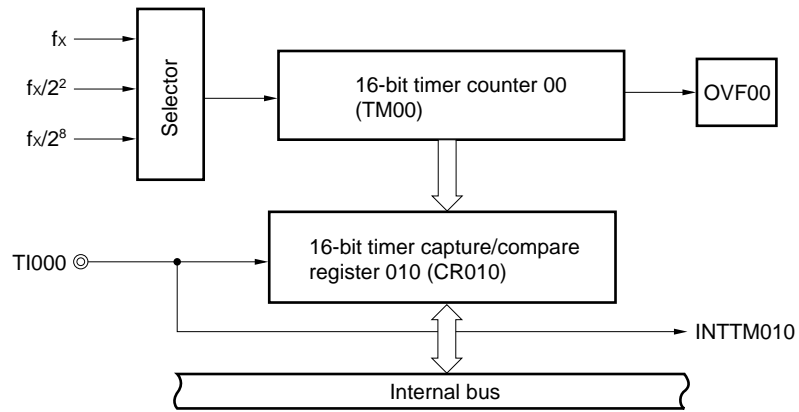
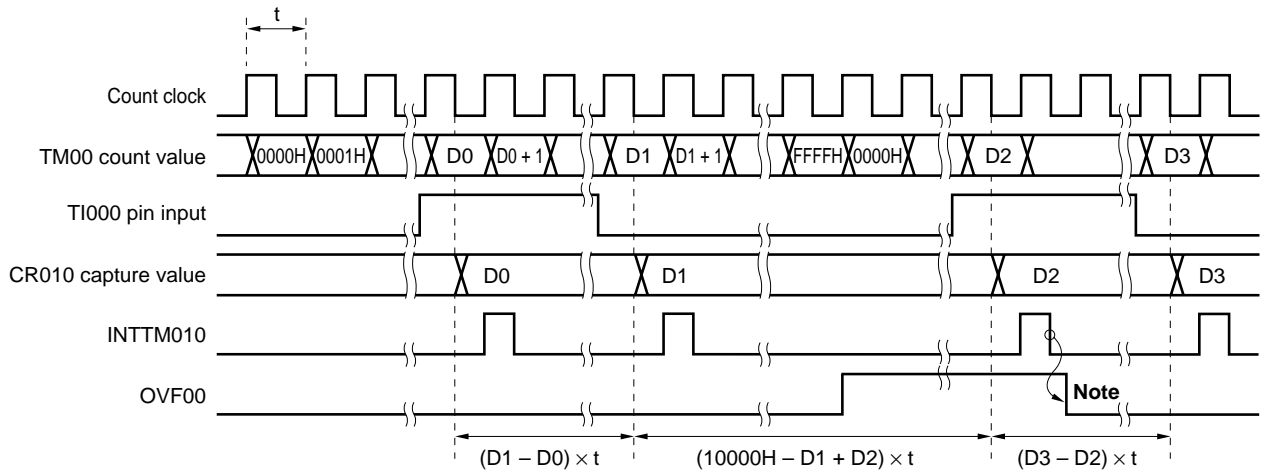


Figure 6-19. Timing of Pulse Width Measurement Operation with Free-Running Counter and One Capture Register (with Both Edges Specified)



**Note** Clear OVF00 by software.

**(2) Measurement of two pulse widths with free-running counter**

When 16-bit timer counter 00 (TM00) is operated in free-running mode, it is possible to simultaneously measure the pulse widths of the two signals input to the TI000 pin and the TI010 pin.

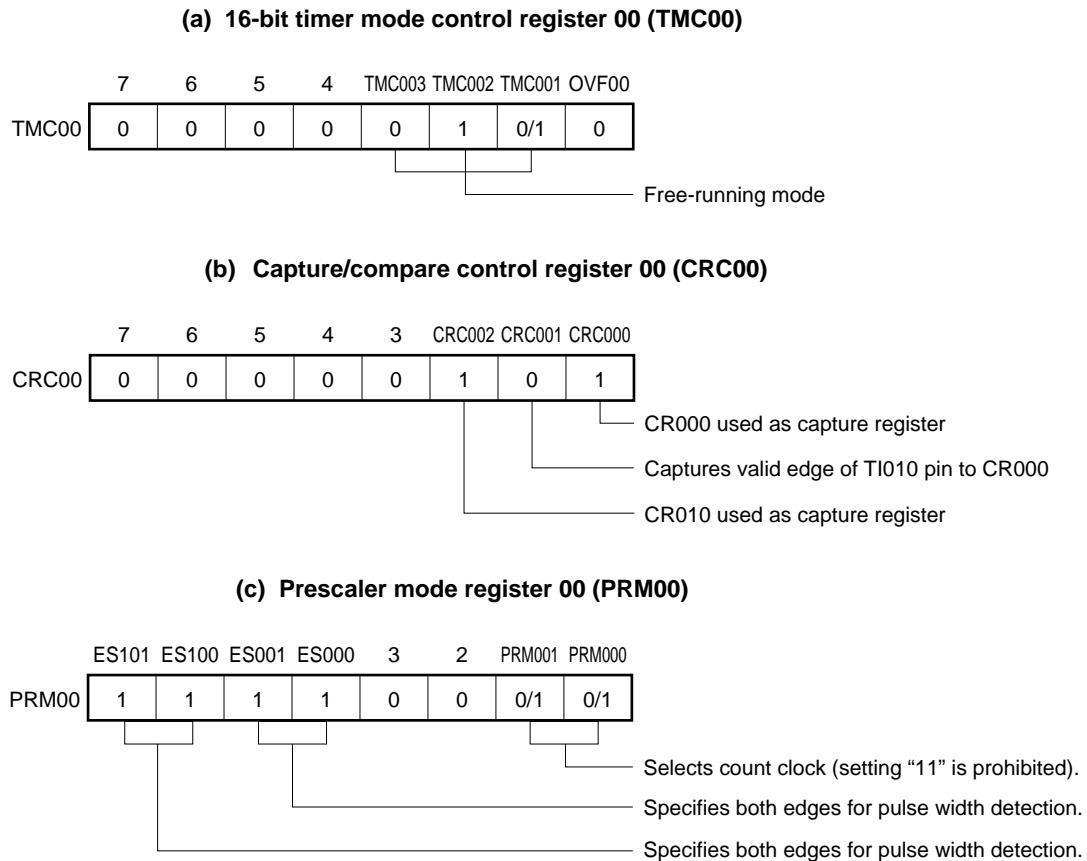
When the edge specified by bits 4 and 5 (ES000 and ES001) of prescaler mode register 00 (PRM00) is input to the TI000 pin, the value of TM00 is taken into 16-bit timer capture/compare register 010 (CR010) and an interrupt request signal (INTTM010) is set.

Also, when the edge specified by bits 6 and 7 (ES100 and ES101) of PRM00 is input to the TI010 pin, the value of TM00 is taken into 16-bit timer capture/compare register 000 (CR000) and an interrupt request signal (INTTM000) is set.

Specify both the rising and falling edges as the edges of the TI000 and TI010 pins, by using bits 4 and 5 (ES000 and ES001) and bits 6 and 7 (ES100 and ES101) of PRM00.

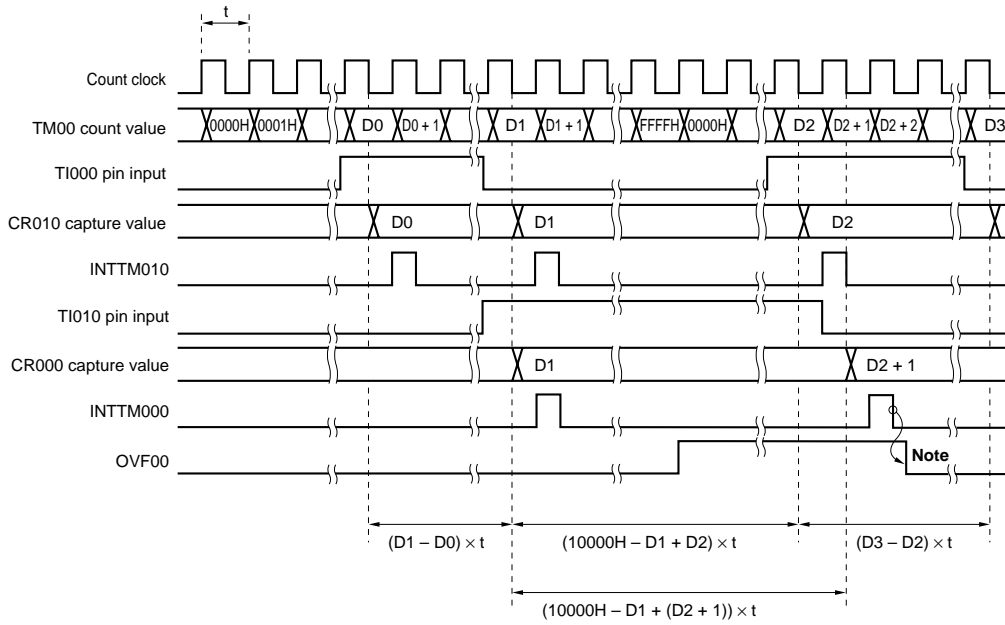
Sampling is performed at the interval selected by prescaler mode register 00 (PRM00), and a capture operation is only performed when the valid level of the TI000 pin or TI010 pin is detected twice, thus eliminating noise with a short pulse width.

**Figure 6-20. Control Register Settings for Measurement of Two Pulse Widths with Free-Running Counter**



**Remark** 0/1: Setting 0 or 1 allows another function to be used simultaneously with pulse width measurement. See the description of the respective control registers for details.

**Figure 6-21. Timing of Pulse Width Measurement Operation with Free-Running Counter (with Both Edges Specified)**



**Note** Clear OVF00 by software.

**(3) Pulse width measurement with free-running counter and two capture registers**

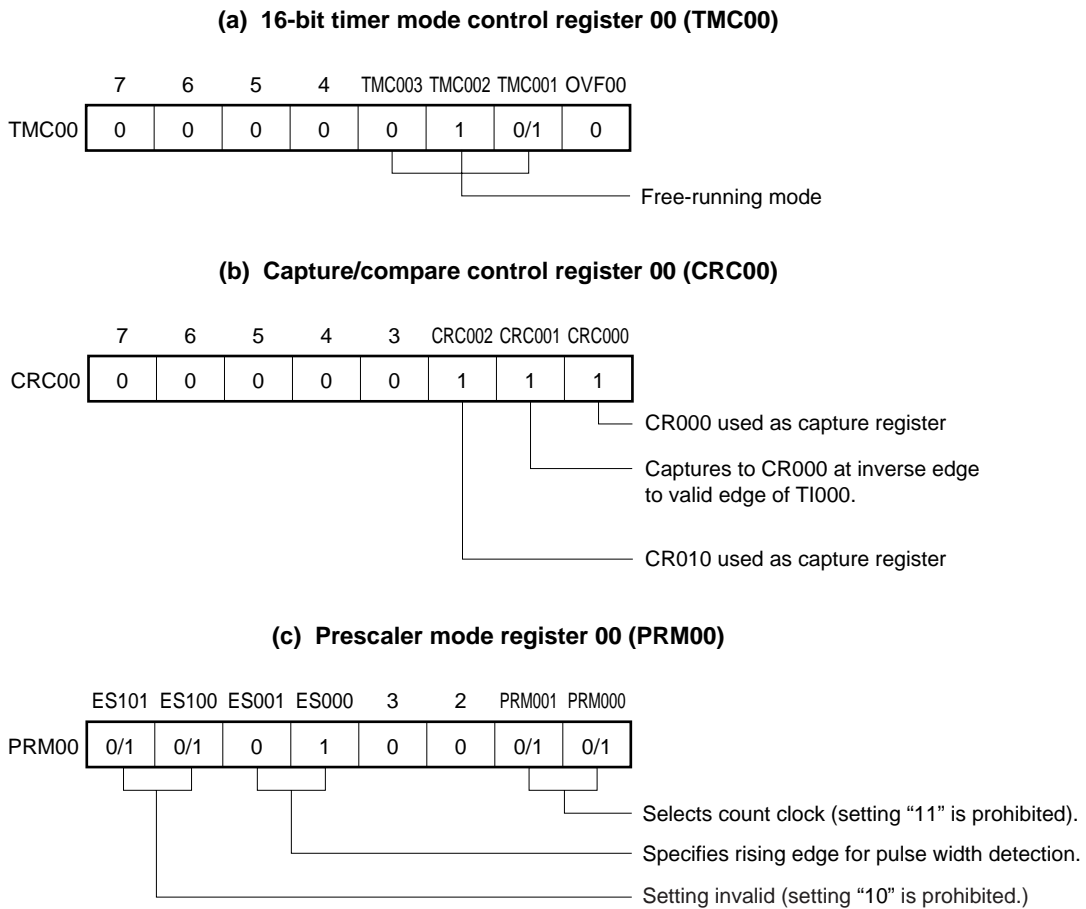
When 16-bit timer counter 00 (TM00) is operated in free-running mode, it is possible to measure the pulse width of the signal input to the TI000 pin.

When the rising or falling edge specified by bits 4 and 5 (ES000 and ES001) of prescaler mode register 00 (PRM00) is input to the TI000 pin, the value of TM00 is taken into 16-bit timer capture/compare register 010 (CR010) and an interrupt request signal (INTTM010) is set.

Also, when the inverse edge to that of the capture operation is input into CR010, the value of TM00 is taken into 16-bit timer capture/compare register 000 (CR000).

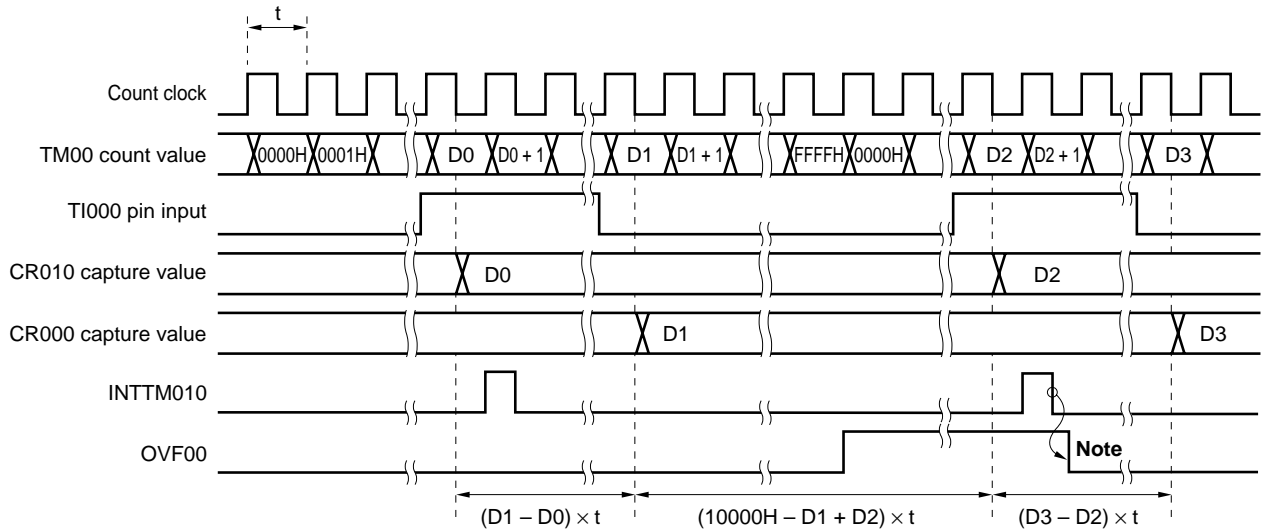
Sampling is performed at the interval selected by prescaler mode register 00 (PRM00), and a capture operation is only performed when the valid level of the TI000 pin is detected twice, thus eliminating noise with a short pulse width.

**Figure 6-22. Control Register Settings for Pulse Width Measurement with Free-Running Counter and Two Capture Registers (with Rising Edge Specified)**



**Remark** 0/1: Setting 0 or 1 allows another function to be used simultaneously with pulse width measurement. See the description of the respective control registers for details.

**Figure 6-23. Timing of Pulse Width Measurement Operation with Free-Running Counter and Two Capture Registers (with Rising Edge Specified)**



**Note** Clear OVF00 by software.

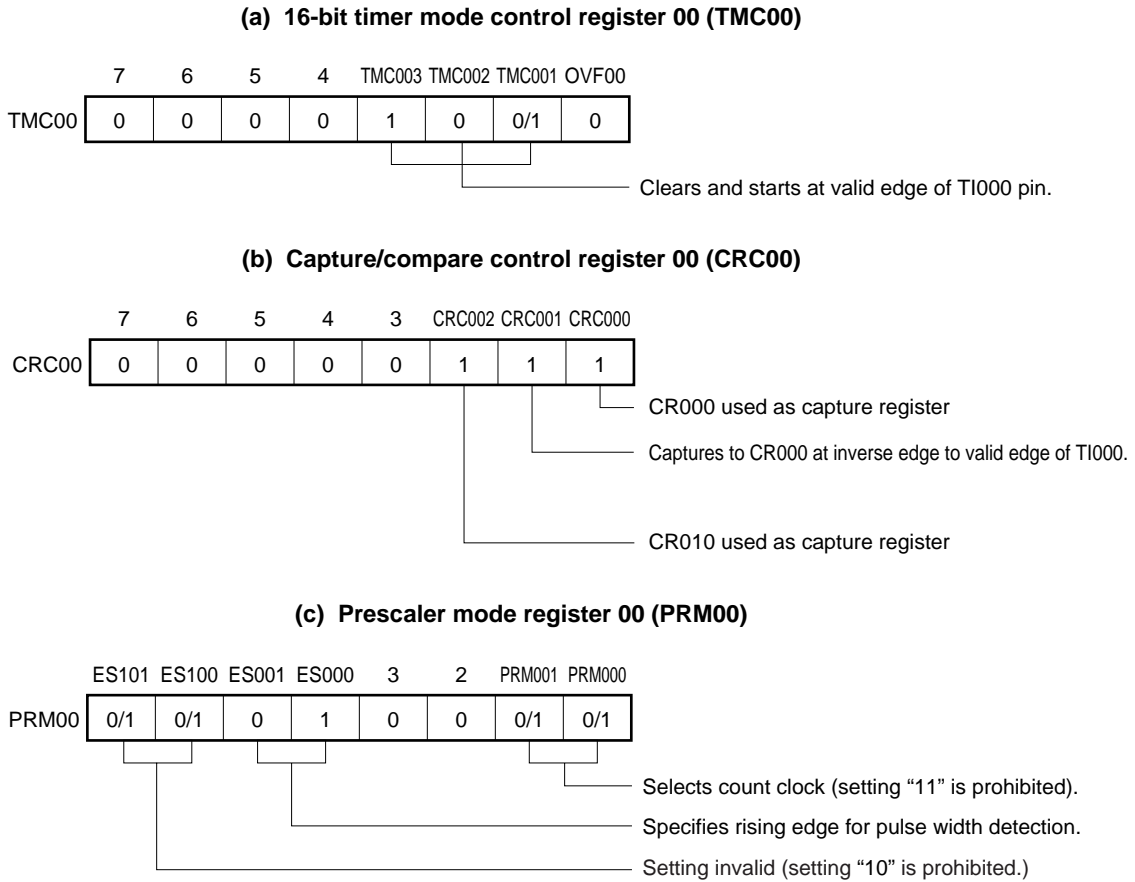
#### (4) Pulse width measurement by means of restart

When input of a valid edge to the TI000 pin is detected, the count value of 16-bit timer counter 00 (TM00) is taken into 16-bit timer capture/compare register 010 (CR010), and then the pulse width of the signal input to the TI000 pin is measured by clearing TM00 and restarting the count operation.

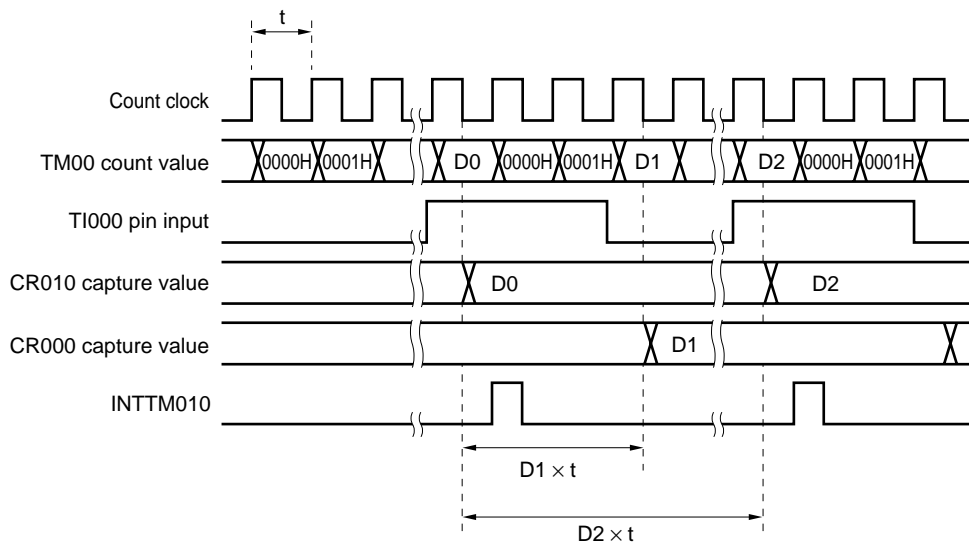
Either of two edges—rising or falling—can be selected using bits 4 and 5 (ES000 and ES001) of prescaler mode register 00 (PRM00).

Sampling is performed using the count clock cycle selected by prescaler mode register 00 (PRM00) and a capture operation is only performed when the valid level of the TI000 pin is detected twice, thus eliminating noise with a short pulse width.

**Figure 6-24. Control Register Settings for Pulse Width Measurement by Means of Restart (with Rising Edge Specified)**



**Figure 6-25. Timing of Pulse Width Measurement Operation by Means of Restart (with Rising Edge Specified)**





#### 6.4.4 External event counter operation

##### Setting

The basic operation setting procedure is as follows.

- <1> Set the CRC00 register (see **Figure 6-26** for the set value).
- <2> Set the count clock by using the PRM00 register.
- <3> Set any value to the CR000 register (0000H cannot be set).
- <4> Set the TMC00 register to start the operation (see **Figure 6-26** for the set value).

- Remarks 1.** For the setting of the TI000 pin, see **6.3 (5) Port mode register 0 (PM0)**.  
**2.** For how to enable the INTTM000 interrupt, see **CHAPTER 14 INTERRUPT FUNCTIONS**.

The external event counter counts the number of external clock pulses input to the TI000 pin using 16-bit timer counter 00 (TM00).

TM00 is incremented each time the valid edge specified by prescaler mode register 00 (PRM00) is input.

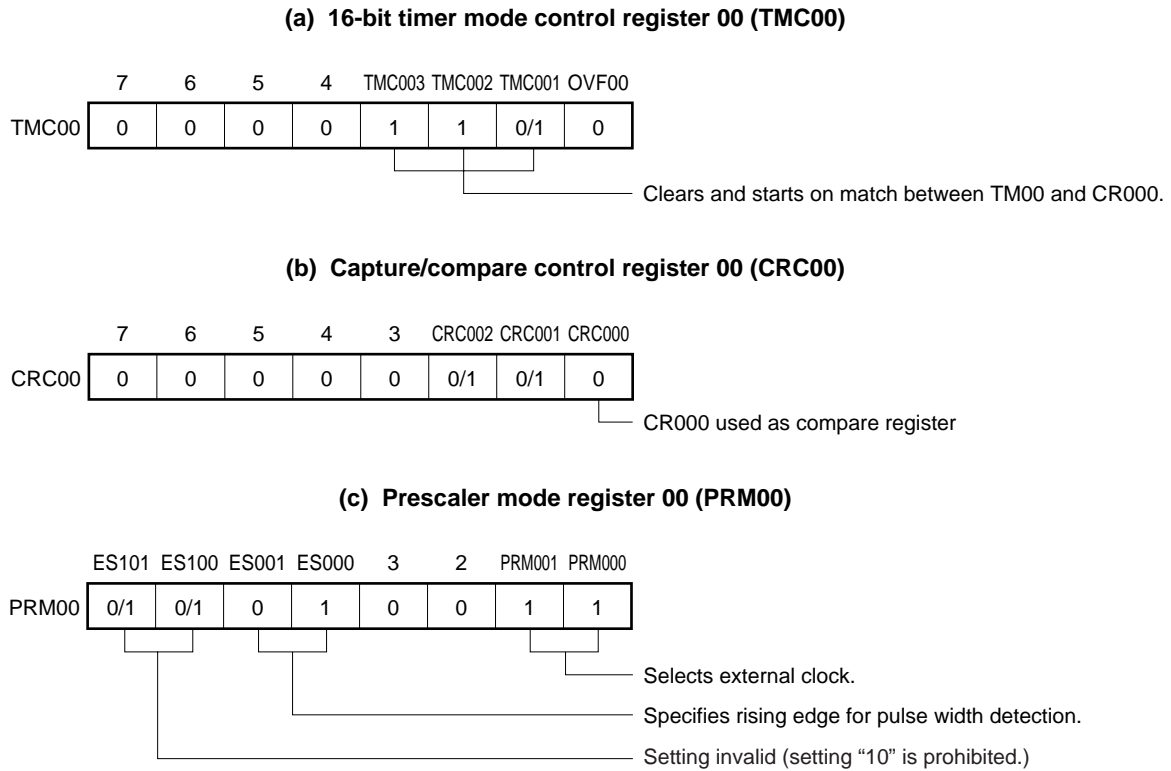
When the TM00 count value matches the 16-bit timer capture/compare register 000 (CR000) value, TM00 is cleared to 0 and the interrupt request signal (INTTM000) is generated.

Input a value other than 0000H to CR000 (a count operation with 1-bit pulse cannot be carried out).

Any of three edges—rising, falling, or both edges—can be selected using bits 4 and 5 (ES000 and ES001) of prescaler mode register 00 (PRM00).

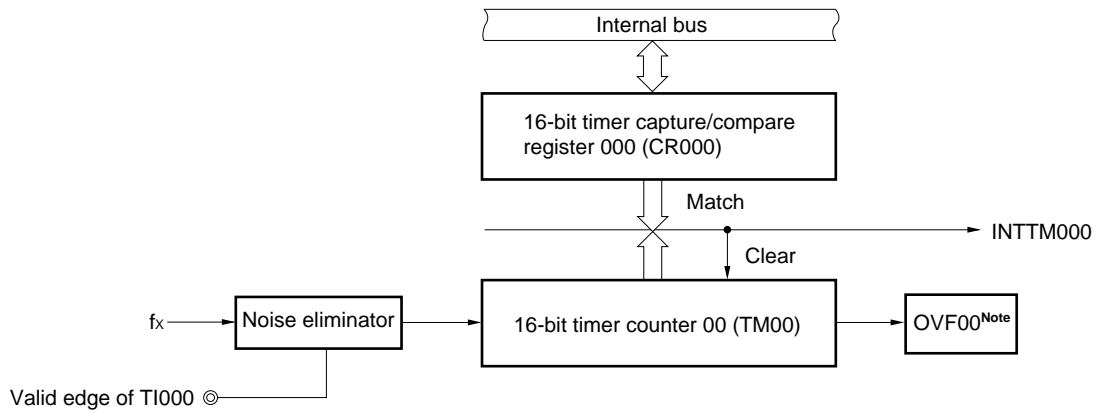
Sampling is performed using the internal clock (fx) and an operation is only performed when the valid level of the TI000 pin is detected twice, thus eliminating noise with a short pulse width.

Figure 6-26. Control Register Settings in External Event Counter Mode (with Rising Edge Specified)



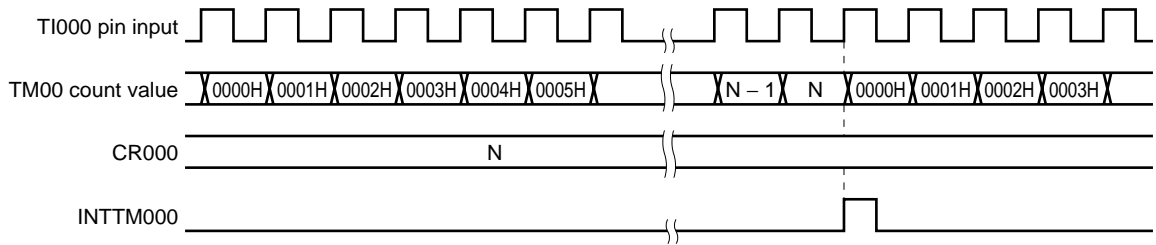
**Remark** 0/1: Setting 0 or 1 allows another function to be used simultaneously with the external event counter. See the description of the respective control registers for details.

Figure 6-27. Configuration Diagram of External Event Counter



**Note** OVF00 is set to 1 only when CR000 is set to FFFFH.

Figure 6-28. External Event Counter Operation Timing (with Rising Edge Specified)

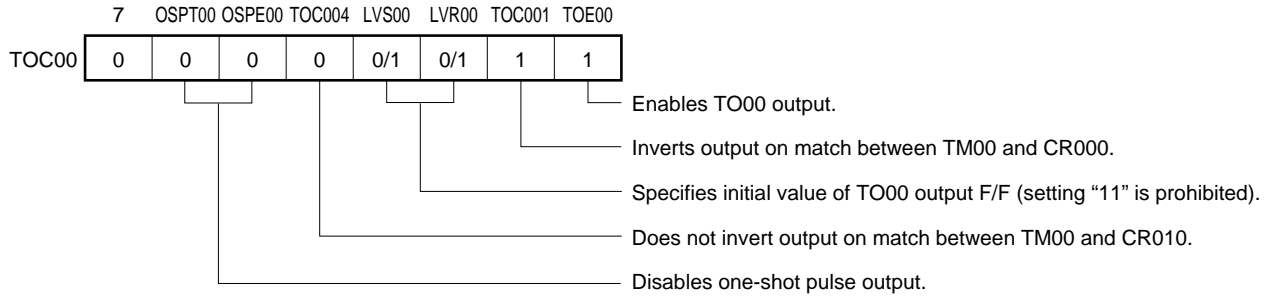


**Caution** When reading the external event counter count value, TM00 should be read.

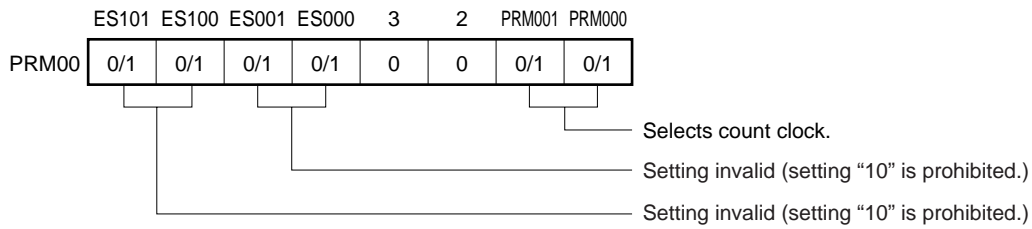


Figure 6-29. Control Register Settings in Square-Wave Output Mode (2/2)

(c) 16-bit timer output control register 00 (TOC00)

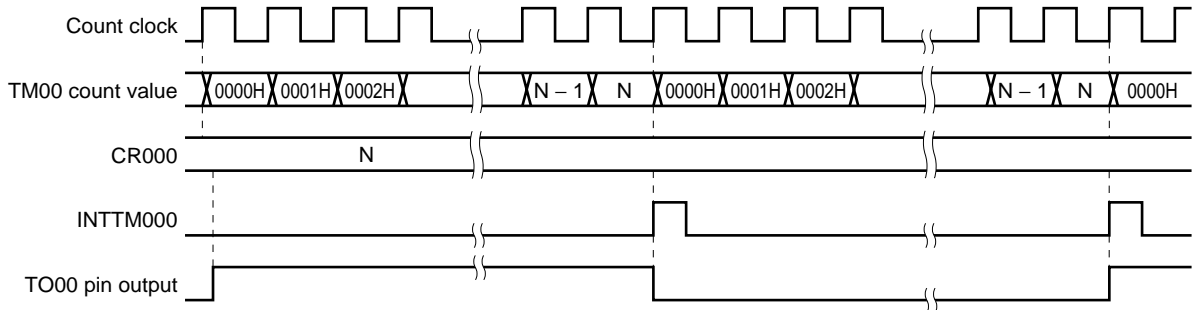


(d) Prescaler mode register 00 (PRM00)



**Remark** 0/1: Setting 0 or 1 allows another function to be used simultaneously with square-wave output. See the description of the respective control registers for details.

Figure 6-30. Square-Wave Output Operation Timing



### 6.4.6 One-shot pulse output operation

16-bit timer/event counter 00 can output a one-shot pulse in synchronization with a software trigger or an external trigger (TI000 pin input).

#### Setting

The basic operation setting procedure is as follows.

- <1> Set the count clock by using the PRM00 register.
- <2> Set the CRC00 register (see **Figures 6-31** and **6-33** for the set value).
- <3> Set the TOC00 register (see **Figures 6-31** and **6-33** for the set value).
- <4> Set any value to the CR000 and CR010 registers (0000H cannot be set).
- <5> Set the TMC00 register to start the operation (see **Figures 6-31** and **6-33** for the set value).

**Remarks 1.** For the setting of the TO00 pin, see **6.3 (5) Port mode register 0 (PM0)**.

- 2. For how to enable the INTTM000 (if necessary, INTTM010) interrupt, see **CHAPTER 14 INTERRUPT FUNCTIONS**.

#### (1) One-shot pulse output with software trigger

A one-shot pulse can be output from the TO00 pin by setting 16-bit timer mode control register 00 (TMC00), capture/compare control register 00 (CRC00), and 16-bit timer output control register 00 (TOC00) as shown in Figure 6-31, and by setting bit 6 (OSPT00) of the TOC00 register to 1 by software.

By setting the OSPT00 bit to 1, 16-bit timer/event counter 00 is cleared and started, and its output becomes active at the count value (N) set in advance to 16-bit timer capture/compare register 010 (CR010). After that, the output becomes inactive at the count value (M) set in advance to 16-bit timer capture/compare register 000 (CR000)<sup>Note</sup>.

Even after the one-shot pulse has been output, the TM00 register continues its operation. To stop the TM00 register, the TMC003 and TMC002 bits of the TMC00 register must be set to 00.

**Note** The case where  $N < M$  is described here. When  $N > M$ , the output becomes active with the CR000 register and inactive with the CR010 register. Do not set N to M.

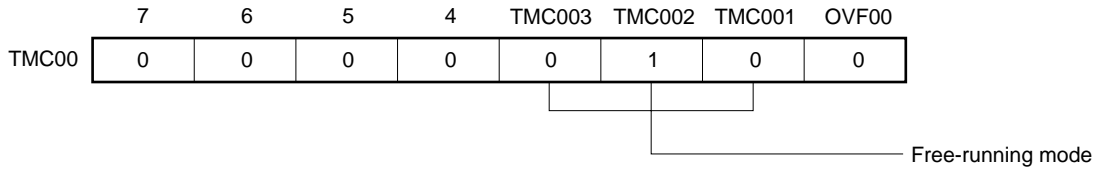
**Cautions 1.** Do not set the OSPT00 bit to 1 while the one-shot pulse is being output. To output the one-shot pulse again, wait until the current one-shot pulse output is completed.

- 2. When using the one-shot pulse output of 16-bit timer/event counter 00 with a software trigger, do not change the level of the TI000 pin or its alternate-function port pin.

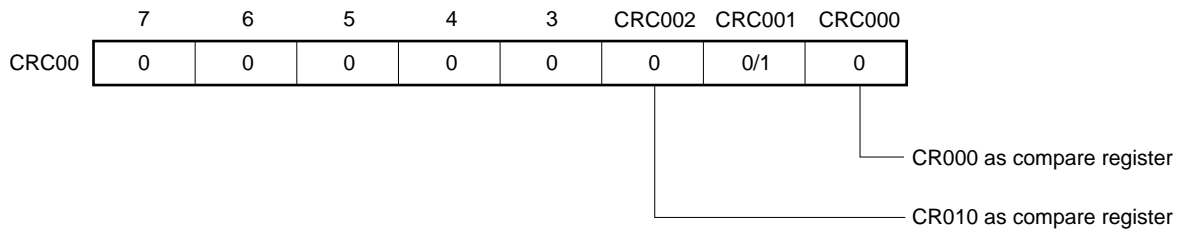
Because the external trigger is valid even in this case, the timer is cleared and started even at the level of the TI000 pin or its alternate-function port pin, resulting in the output of a pulse at an undesired timing.

Figure 6-31. Control Register Settings for One-Shot Pulse Output with Software Trigger

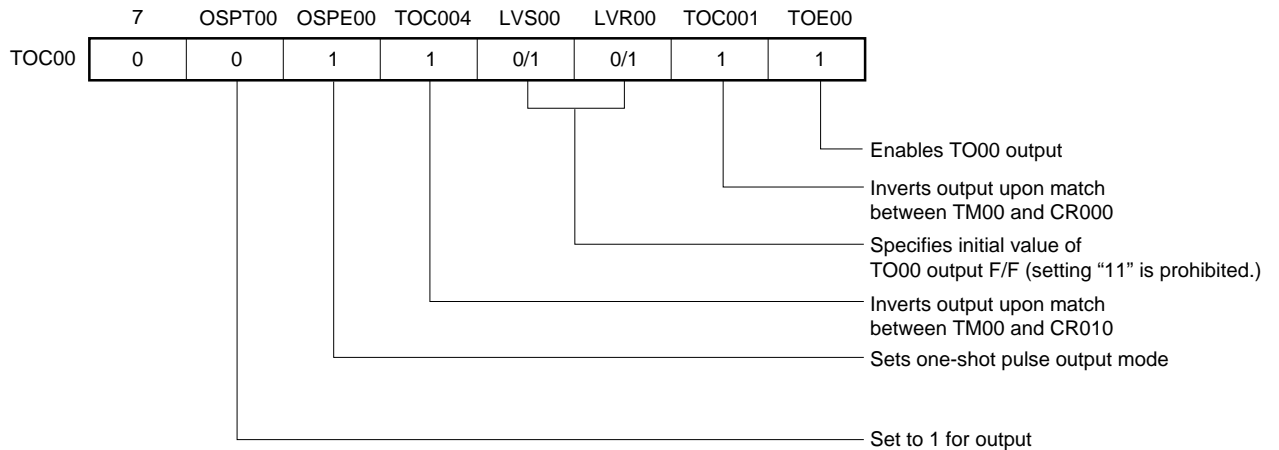
(a) 16-bit timer mode control register 00 (TMC00)



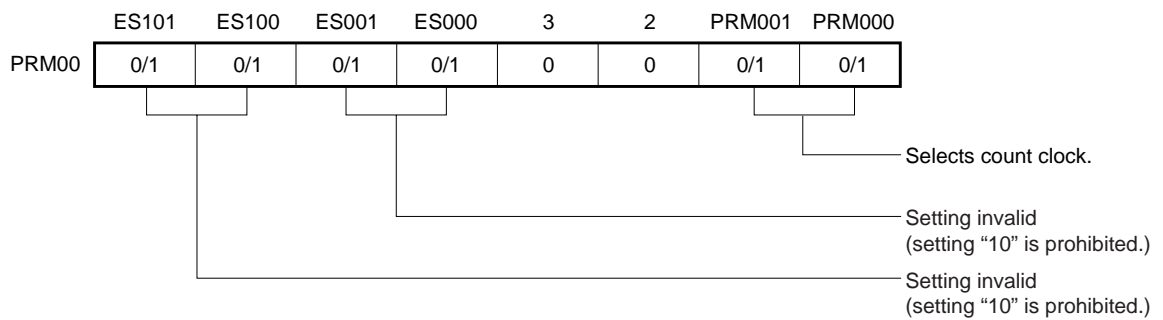
(b) Capture/compare control register 00 (CRC00)



(c) 16-bit timer output control register 00 (TOC00)

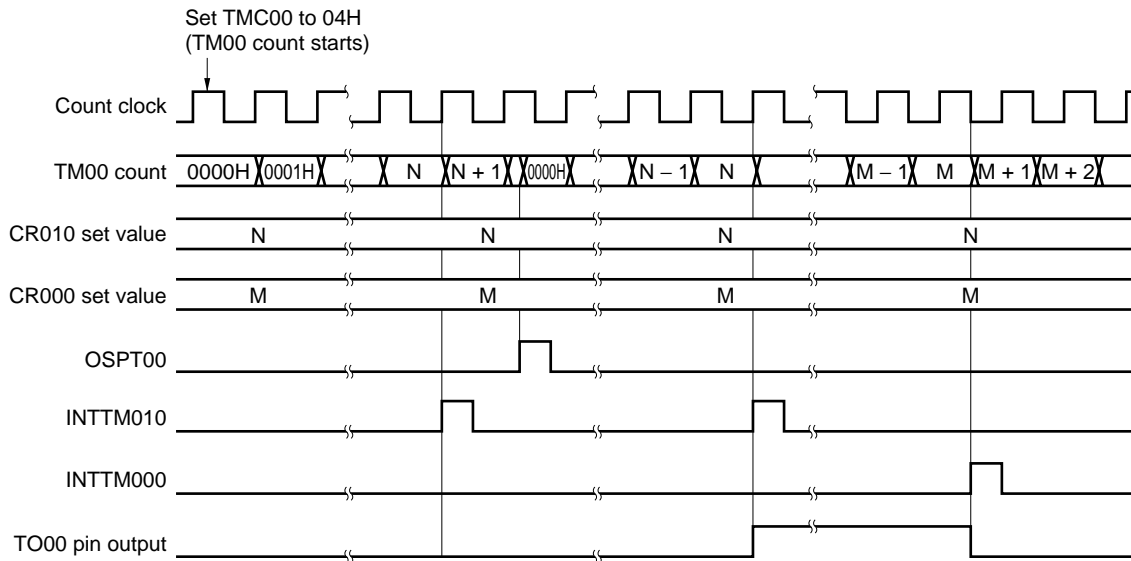


(d) Prescaler mode register 00 (PRM00)



**Caution** Do not set the CR000 and CR010 registers to 0000H.

Figure 6-32. Timing of One-Shot Pulse Output Operation with Software Trigger



**Caution** 16-bit timer counter 00 starts operating as soon as the TMC003 and TMC002 bits are set to a value other than 00 (operation stop mode).

**Remark**  $N < M$

## (2) One-shot pulse output with external trigger

A one-shot pulse can be output from the TO00 pin by setting 16-bit timer mode control register 00 (TMC00), capture/compare control register 00 (CRC00), and 16-bit timer output control register 00 (TOC00) as shown in Figure 6-33, and by using the valid edge of the TI000 pin as an external trigger.

The valid edge of the TI000 pin is specified by bits 4 and 5 (ES000, ES001) of prescaler mode register 00 (PRM00). The rising, falling, or both the rising and falling edges can be specified.

When the valid edge of the TI000 pin is detected, the 16-bit timer/event counter is cleared and started, and the output becomes active at the count value set in advance to 16-bit timer capture/compare register 010 (CR010). After that, the output becomes inactive at the count value set in advance to 16-bit timer capture/compare register 000 (CR000)<sup>Note</sup>.

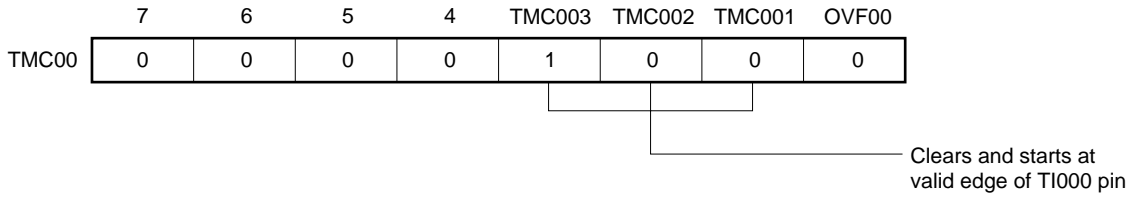
**Note** The case where  $N < M$  is described here. When  $N > M$ , the output becomes active with the CR000 register and inactive with the CR010 register. Do not set N to M.

**Caution** Even if the external trigger is generated again while the one-shot pulse is being output, it is ignored.

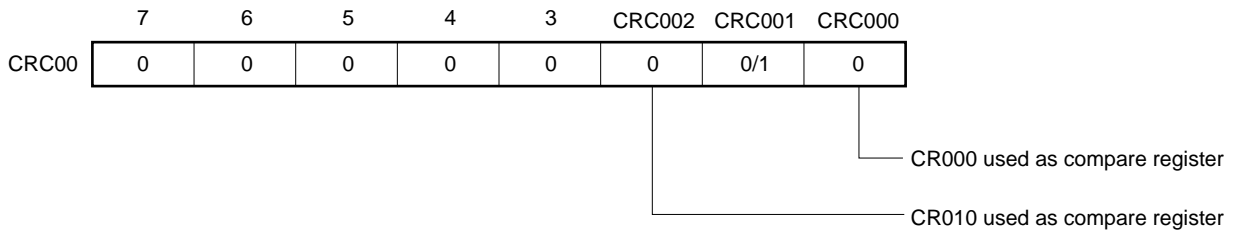


**Figure 6-33. Control Register Settings for One-Shot Pulse Output with External Trigger (with Rising Edge Specified)**

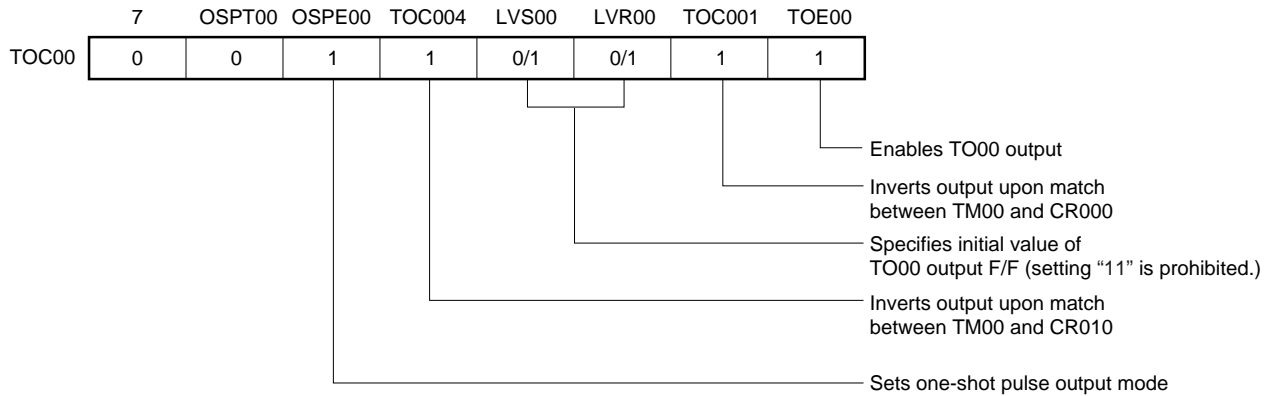
**(a) 16-bit timer mode control register 00 (TMC00)**



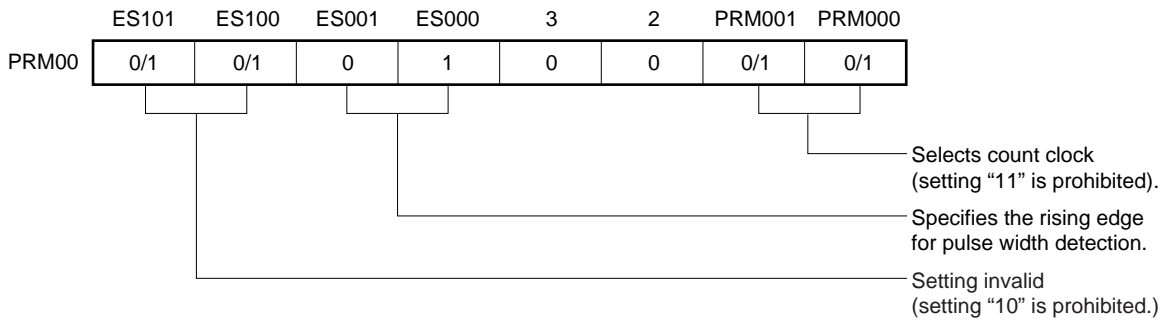
**(b) Capture/compare control register 00 (CRC00)**



**(c) 16-bit timer output control register 00 (TOC00)**

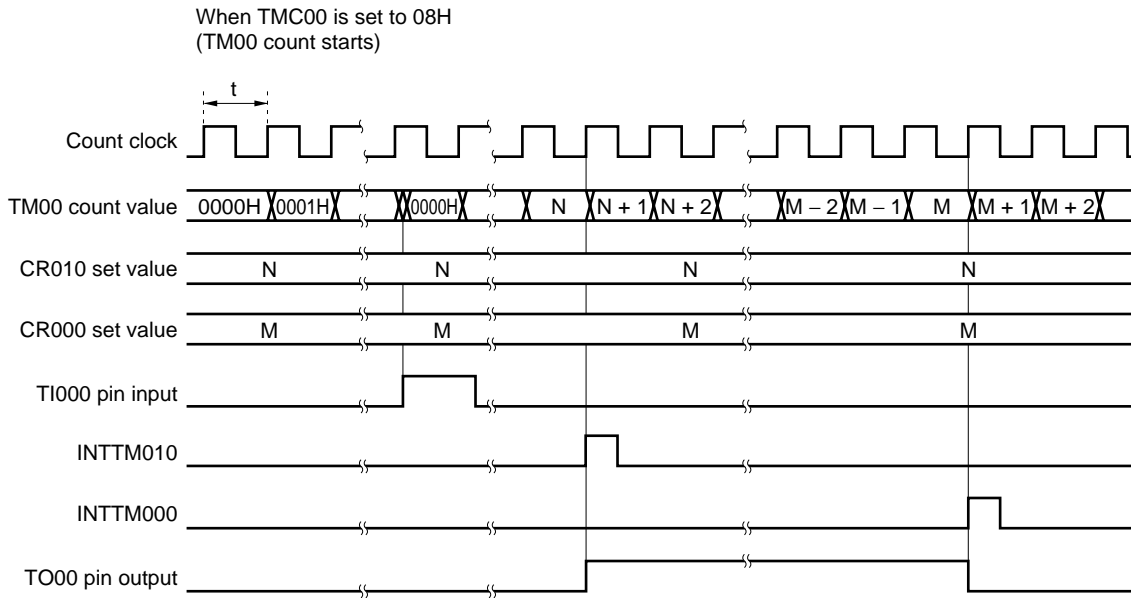


**(d) Prescaler mode register 00 (PRM00)**



**Caution** Do not set the CR000 and CR010 registers to 0000H.

Figure 6-34. Timing of One-Shot Pulse Output Operation with External Trigger (with Rising Edge Specified)



**Caution** 16-bit timer counter 00 starts operating as soon as the TMC002 and TMC003 bits are set to a value other than 00 (operation stop mode).

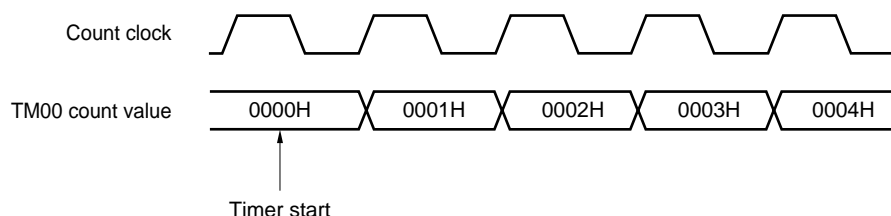
**Remark**  $N < M$

## 6.5 Cautions for 16-Bit Timer/Event Counter 00

### (1) Timer start errors

An error of up to one clock may occur in the time required for a match signal to be generated after timer start. This is because 16-bit timer counter 00 (TM00) is started asynchronously to the count clock.

**Figure 6-35. Start Timing of 16-Bit Timer Counter 00 (TM00)**



### (2) 16-bit timer capture/compare registers 000, 010 setting

In the mode in which clear & start occurs on match between TM00 and CR000, set 16-bit timer capture/compare registers 000, 010 (CR000, CR010) to other than 0000H. This means a 1-pulse count operation cannot be performed when 16-bit timer/event counter 00 is used as an external event counter.

### (3) Capture register data retention timing

The values of 16-bit timer capture/compare registers 000 and 010 (CR000 and CR010) are not guaranteed after 16-bit timer/event counter 00 has been stopped.

### (4) Valid edge setting

Set the valid edge of the TI000 pin after setting bits 2 and 3 (TMC002 and TMC003) of 16-bit timer mode control register 00 (TMC00) to 0, 0, respectively, and then stopping timer operation. The valid edge is set using bits 4 and 5 (ES000 and ES001) of prescaler mode register 00 (PRM00).

### (5) Re-triggering one-shot pulse

#### (a) One-shot pulse output by software

When a one-shot pulse is output, do not set the OSPT00 bit to 1. Do not output the one-shot pulse again until INTTM000, which occurs upon a match with the CR000 register, or INTTM010, which occurs upon a match with the CR010 register, occurs.

#### (b) One-shot pulse output with external trigger

If the external trigger occurs again while a one-shot pulse is output, it is ignored.

#### (c) One-shot pulse output function

When using the one-shot pulse output of 16-bit timer/event counter 00 with a software trigger, do not change the level of the TI000 pin or its alternate function port pin.

Because the external trigger is valid even in this case, the timer is cleared and started even at the level of the TI000 pin or its alternate function port pin, resulting in the output of a pulse at an undesired timing.

**(6) Operation of OVF00 flag**

<1> The OVF00 flag is also set to 1 in the following case.

If any of the following modes: the mode in which clear & start occurs on a match between TM00 and CR000, the mode in which clear & start occurs on a TI000 valid edge, or the free-running mode, is selected

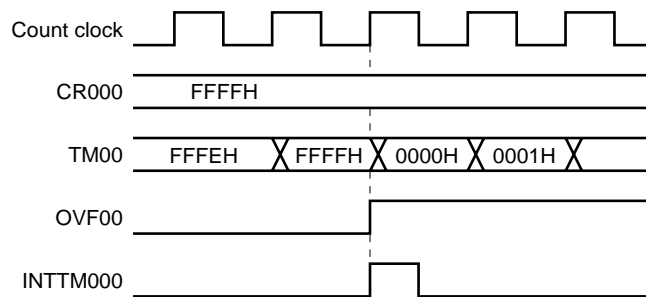


CR000 is set to FFFFH.



TM00 is counted up from FFFFH to 0000H.

**Figure 6-36. Operation Timing of OVF00 Flag**

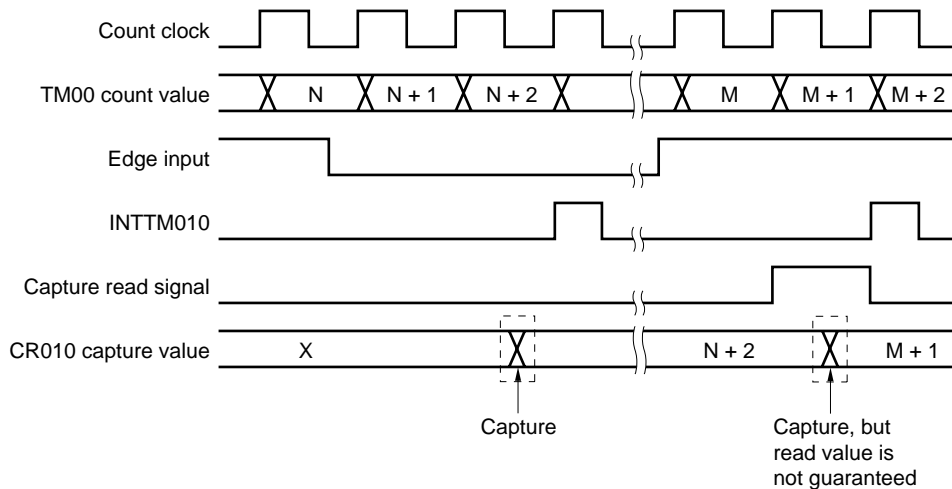


<2> Even if the OVF00 flag is cleared before the next count clock (before TM00 becomes 0001H) after the occurrence of TM00 overflow, the OVF00 flag is re-set newly and clear is disabled.

**(7) Conflicting operations**

When the read period of the 16-bit timer capture/compare register (CR000/CR010) and capture trigger input (CR000/CR010 used as capture register) conflict, capture trigger input has priority. The data read from CR000/CR010 is undefined.

**Figure 6-37. Capture Register Data Retention Timing**



**(8) Timer operation**

- <1> Even if 16-bit timer counter 00 (TM00) is read, the value is not captured by 16-bit timer capture/compare register 010 (CR010).
- <2> Regardless of the CPU's operation mode, when the timer stops, the input signals to the TI000/TI010 pins are not acknowledged.
- <3> The one-shot pulse output mode operates correctly only in the free-running mode and the mode in which clear & start occurs at the TI000 valid edge. In the mode in which clear & start occurs on a match between the TM00 register and CR000 register, one-shot pulse output is not possible because an overflow does not occur.

**(9) Capture operation**

- <1> If TI000 valid edge is specified as the count clock, a capture operation by the capture register specified as the trigger for TI000 is not possible.
- <2> To ensure the reliability of the capture operation, the capture trigger requires a pulse two cycles longer than the count clock selected by prescaler mode register 00 (PRM00).
- <3> The capture operation is performed at the falling edge of the count clock. An interrupt request input (INTTM000/INTTM010), however, is generated at the rise of the next count clock.

**(10) Compare operation**

A capture operation may not be performed for CR000/CR010 set in compare mode even if a capture trigger has been input.

**(11) Edge detection**

- <1> If the TI000 or TI010 pin is high level immediately after system reset and the rising edge or both the rising and falling edges are specified as the valid edge of the TI000 or TI010 pin to enable the 16-bit timer counter 00 (TM00) operation, a rising edge is detected immediately after the operation is enabled. Be careful therefore when pulling up the TI000 or TI010 pin. However, when the TI000 or TI010 pin is high level, the rising edge is not detected at restart after the operation has been stopped.
- <2> The sampling clock used to eliminate noise differs when the TI000 valid edge is used as the count clock and when it is used as a capture trigger. In the former case, the count clock is  $f_x$ , and in the latter case the count clock is selected by prescaler mode register 00 (PRM00). The capture operation is started only after a valid level is detected twice by sampling the valid edge, thus eliminating noise with a short pulse width.

## CHAPTER 7 8-BIT TIMER/EVENT COUNTER 50

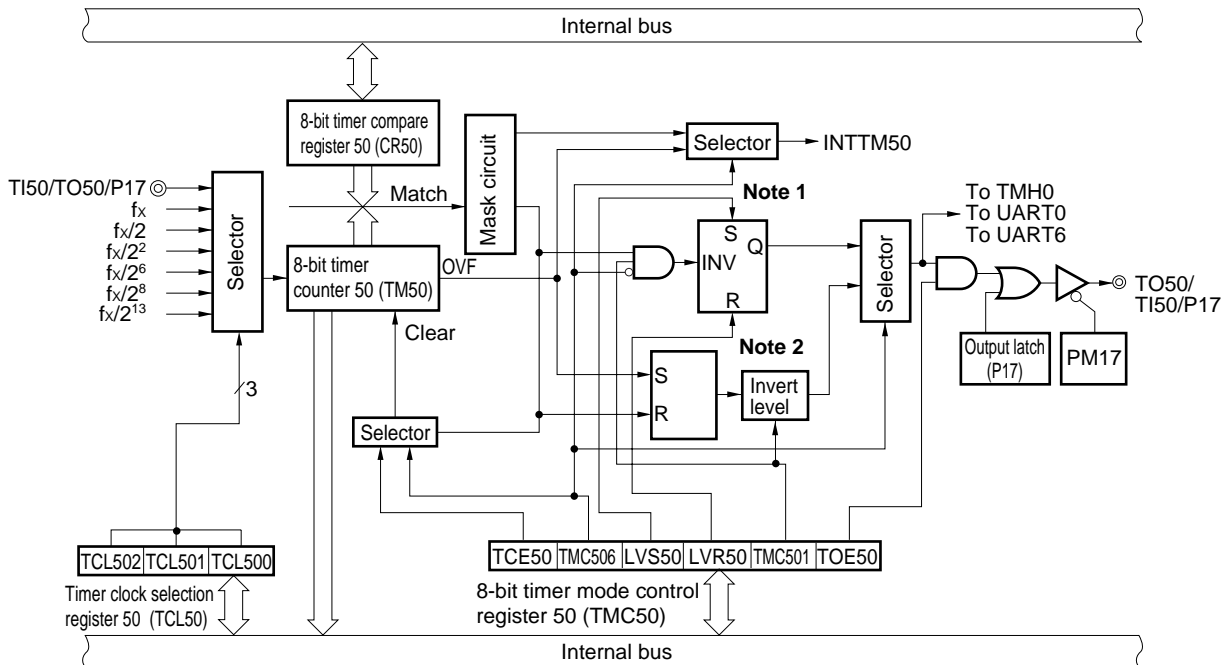
### 7.1 Functions of 8-Bit Timer/Event Counter 50

8-bit timer/event counter 50 has the following functions.

- Interval timer
- External event counter
- Square-wave output
- PWM output

Figure 7-1 shows the block diagram of 8-bit timer/event counter 50.

**Figure 7-1. Block Diagram of 8-Bit Timer/Event Counter 50**



- Notes**
1. Timer output F/F
  2. PWM output F/F

## 7.2 Configuration of 8-Bit Timer/Event Counter 50

8-bit timer/event counter 50 includes the following hardware.

**Table 7-1. Configuration of 8-Bit Timer/Event Counter 50**

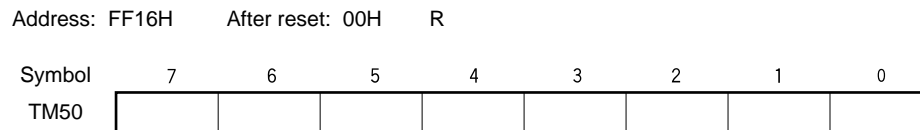
| Item              | Configuration   |
|-------------------|---|
| Timer register    | 8-bit timer counter 50 (TM50)   |
| Register          | 8-bit timer compare register 50 (CR50)  |
| Timer input       | TI50  |
| Timer output      | TO50  |
| Control registers | Timer clock selection register 50 (TCL50)<br>8-bit timer mode control register 50 (TMC50)<br>Port mode register 1 (PM1)<br>Port register 1 (P1) |

### (1) 8-bit timer counter 50 (TM50)

TM50 is an 8-bit register that counts the count pulses and is read-only.

The counter is incremented in synchronization with the rising edge of the count clock.

**Figure 7-2. Format of 8-Bit Timer Counter 50 (TM50)**



In the following situations, the count value is cleared to 00H.

- <1>  $\overline{\text{RESET}}$  input
- <2> When TCE50 is cleared
- <3> When TM50 and CR50 match in clear & start mode if this mode was entered upon a match of TM50 and CR50 values.

**(2) 8-bit timer compare register 50 (CR50)**

CR50 can be read and written by an 8-bit memory manipulation instruction.

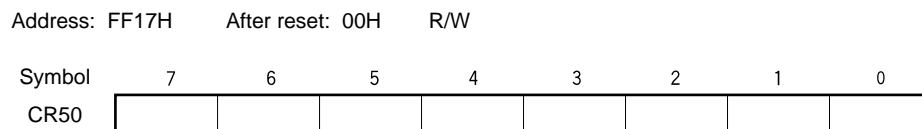
Except in PWM mode, the value set in CR50 is constantly compared with the 8-bit timer counter 50 (TM50) count value, and an interrupt request (INTTM50) is generated if they match.

In PWM mode, when the TO50 pin becomes high level due to a TM50 overflow and the values of TM50 and CR50 match, the TO50 pin becomes inactive.

The value of CR50 can be set within 00H to FFH.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 7-3. Format of 8-Bit Timer Compare Register 50 (CR50)**



- Cautions**
- 1. In the clear & start mode entered on a match of TM50 and CR50 (TMC506 = 0), do not write other values to CR50 during operation.**
  - 2. In PWM mode, make the CR50 rewrite period 3 count clocks of the count clock (clock selected by TCL50) or more.**



### 7.3 Registers Controlling 8-Bit Timer/Event Counter 50

The following four registers are used to control 8-bit timer/event counter 50.

- Timer clock selection register 50 (TCL50)
- 8-bit timer mode control register 50 (TMC50)
- Port mode register 1 (PM1)
- Port register 1 (P1)

#### (1) Timer clock selection register 50 (TCL50)

This register sets the count clock of 8-bit timer/event counter 50 and the valid edge of TI50 input.

TCL50 can be set by an 8-bit memory manipulation instruction.

RESET input clears this register to 00H.

**Figure 7-4. Format of Timer Clock Selection Register 50 (TCL50)**

Address: FF6AH After reset: 00H R/W

| Symbol | 7 | 6 | 5 | 4 | 3 | 2      | 1      | 0      |
|--------|---|---|---|---|---|--------|--------|--------|
| TCL50  | 0 | 0 | 0 | 0 | 0 | TCL502 | TCL501 | TCL500 |

| TCL502 | TCL501 | TCL500 | Count clock selection <sup>Note</sup> |
|--------|--------|--------|---------------------------------------|
| 0      | 0      | 0      | TI50 falling edge                     |
| 0      | 0      | 1      | TI50 rising edge                      |
| 0      | 1      | 0      | $f_x$ (10 MHz)                        |
| 0      | 1      | 1      | $f_x/2$ (5 MHz)                       |
| 1      | 0      | 0      | $f_x/2^2$ (2.5 MHz)                   |
| 1      | 0      | 1      | $f_x/2^6$ (156.25 kHz)                |
| 1      | 1      | 0      | $f_x/2^8$ (39.06 kHz)                 |
| 1      | 1      | 1      | $f_x/2^{13}$ (1.22 kHz)               |

★ **Note** Be sure to set the count clock so that the following condition is satisfied.

- $V_{DD} = 4.0$  to  $5.5$  V: Count clock  $\leq 10$  MHz
- $V_{DD} = 3.3$  to  $4.0$  V: Count clock  $\leq 8.38$  MHz
- $V_{DD} = 2.7$  to  $3.3$  V: Count clock  $\leq 5$  MHz
- $V_{DD} = 2.5$  to  $2.7$  V: Count clock  $\leq 2.5$  MHz

- Cautions**
1. When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the count clock is the Ring-OSC clock, the operation of 8-bit timer/event counter 50 is not guaranteed.
  2. When rewriting TCL50 to other than the same data, stop the timer operation beforehand.
  3. Be sure to clear bits 3 to 7 to 0.

- Remarks**
1.  $f_x$ : X1 input clock oscillation frequency
  2. Figures in parentheses apply to operation at  $f_x = 10$  MHz.

**(2) 8-bit timer mode control register 50 (TMC50)**

TMC50 is a register that performs the following five types of settings.

- <1> 8-bit timer counter 50 (TM50) count operation control
- <2> 8-bit timer counter 50 (TM50) operating mode selection
- <3> Timer output F/F (flip-flop) status setting
- <4> Active level selection in timer F/F control or PWM (free-running) mode
- <5> Timer output control

TMC50 can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears this register to 00H.

Figure 7-5 shows the TMC50 format.

**Figure 7-5. Format of 8-Bit Timer Mode Control Register 50 (TMC50)**

Address: FF6BH After reset: 00H R/W<sup>Note</sup>

|        |       |        |   |   |       |       |        |       |
|--------|-------|--------|---|---|-------|-------|--------|-------|
| Symbol | <7>   | 6      | 5 | 4 | <3>   | <2>   | 1      | <0>   |
| TMC50  | TCE50 | TMC506 | 0 | 0 | LVS50 | LVR50 | TMC501 | TOE50 |

|       |   |
|-------|---|
| TCE50 | TM50 count operation control                                    |
| 0     | After clearing to 0, count operation disabled (counter stopped) |
| 1     | Count operation start   |

|        |   |
|--------|---|
| TMC506 | TM50 operating mode selection                     |
| 0      | Clear & start mode by match between TM50 and CR50 |
| 1      | PWM (free-running) mode                           |

|       |       |                                 |
|-------|-------|---------------------------------|
| LVS50 | LVR50 | Timer output F/F status setting |
| 0     | 0     | No change                       |
| 0     | 1     | Timer output F/F reset (0)      |
| 1     | 0     | Timer output F/F set (1)        |
| 1     | 1     | Setting prohibited              |

|        |                              |                          |
|--------|------------------------------|--------------------------|
| TMC501 | In other modes (TMC506 = 0)  | In PWM mode (TMC506 = 1) |
|        | Timer F/F control            | Active level selection   |
| 0      | Inversion operation disabled | Active high              |
| 1      | Inversion operation enabled  | Active low               |

|       |  |
|-------|--|
| TOE50 | Timer output control                         |
| 0     | Output disabled (TM50 outputs the low level) |
| 1     | Output enabled                               |

★ **Note** Bits 2 and 3 are write-only.

- ★ **Cautions**
1. The settings of LVS50 and LVR50 are valid in other than PWM mode.
  2. Do not make settings <1> to <4> below simultaneously. In addition, follow the setting procedure shown below.
    - <1> Setting of TMC501 and TMC506: Setting of operation mode
    - <2> Setting of TOE50 if enabling output: Enabling timer output
    - <3> Setting of LVS50 and LVR50 (see Caution 1): Setting of timer F/F
    - <4> Setting of TCE50
  3. Stop operation before rewriting TMC506.

- Remarks**
1. In PWM mode, PWM output is made inactive by setting TCE50 to 0.
  2. If LVS50 and LVR50 are read, 0 is read.
  3. The values of the TMC506, LVS50, LVR50, TMC501, and TOE50 bits are reflected at the TO50 pin regardless of the value of TCE50.

**(3) Port mode register 1 (PM1)**

This register sets port 1 input/output in 1-bit units.

When using the P17/TO50/TI50 pin for timer output, clear PM17 and the output latch of P17 to 0.

When using the P17/TO50/TI50 pin for timer input, set PM17 to 1. The output latch of P17 at this time may be 0 or 1.

PM1 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets this register to FFH.

**Figure 7-6. Format of Port Mode Register 1 (PM1)**

Address: FF21H After reset: FFH R/W

|        |      |      |      |      |      |      |      |      |
|--------|------|------|------|------|------|------|------|------|
| Symbol | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PM1    | PM17 | PM16 | PM15 | PM14 | PM13 | PM12 | PM11 | PM10 |

|      |   |
|------|---|
| PM1n | P1n pin I/O mode selection (n = 0 to 7) |
| 0    | Output mode (output buffer on)          |
| 1    | Input mode (output buffer off)          |

## 7.4 Operations of 8-Bit Timer/Event Counter 50

### 7.4.1 Operation as interval timer

8-bit timer/event counter 50 operates as an interval timer that generates interrupt requests repeatedly at intervals of the count value preset to 8-bit timer compare register 50 (CR50).

When the count value of 8-bit timer counter 50 (TM50) matches the value set to CR50, counting continues with the TM50 value cleared to 0 and an interrupt request signal (INTTM50) is generated.

The count clock of TM50 can be selected with bits 0 to 2 (TCL500 to TCL502) of timer clock selection register 50 (TCL50).

#### Setting

<1> Set the registers.

- TCL50: Select the count clock.
- CR50: Compare value
- TMC50: Stop the count operation, select clear & start mode entered on a match of TM50 and CR50.  
(TMC50 = 0000xxx0B x = Don't care)

<2> After TCE50 = 1 is set, the count operation starts.

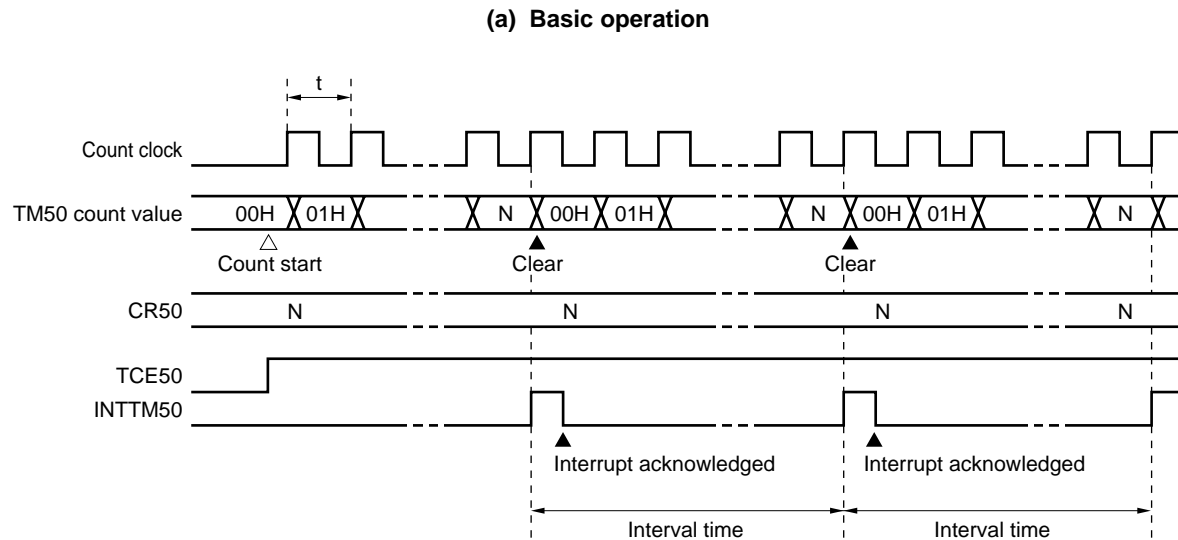
<3> If the values of TM50 and CR50 match, INTTM50 is generated (TM50 is cleared to 00H).

<4> INTTM50 is generated repeatedly at the same interval.

Set TCE50 to 0 to stop the count operation.

**Caution** Do not write other values to CR50 during operation.

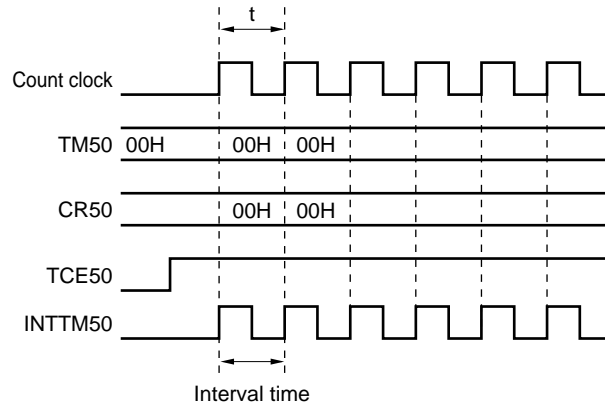
Figure 7-7. Interval Timer Operation Timing (1/2)



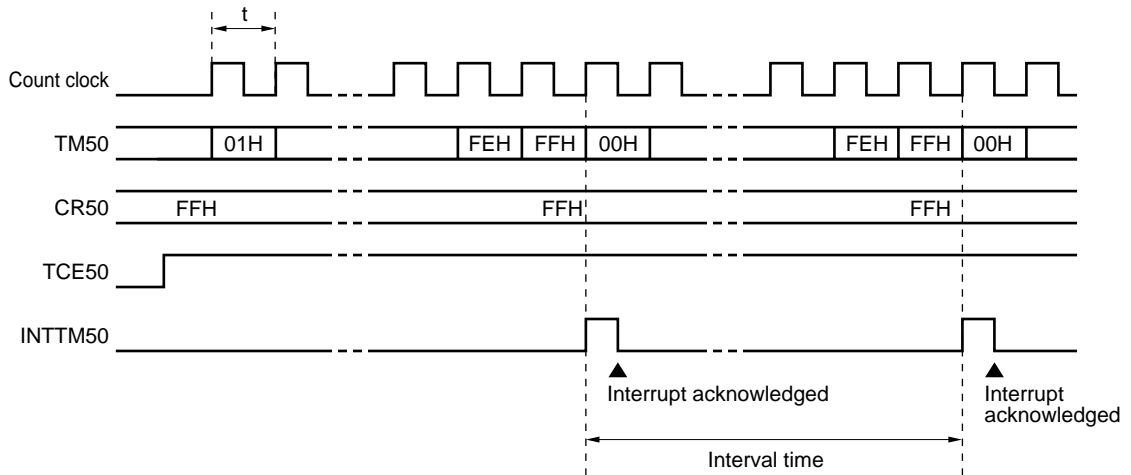
**Remark** Interval time =  $(N + 1) \times t$   
 $N = 01H$  to  $FEH$

Figure 7-7. Interval Timer Operation Timing (2/2)

(b) When CR50 = 00H



(c) When CR50 = FFH



### 7.4.2 Operation as external event counter

The external event counter counts the number of external clock pulses to be input to TI50 by 8-bit timer counter 50 (TM50).

TM50 is incremented each time the valid edge specified by timer clock selection register 50 (TCL50) is input. Either the rising or falling edge can be selected.

When the TM50 count value matches the value of 8-bit timer compare register 50 (CR50), TM50 is cleared to 0 and an interrupt request signal (INTTM50) is generated.

Whenever the TM50 count value matches the value of CR50, INTTM50 is generated.

#### Setting

<1> Set each register.

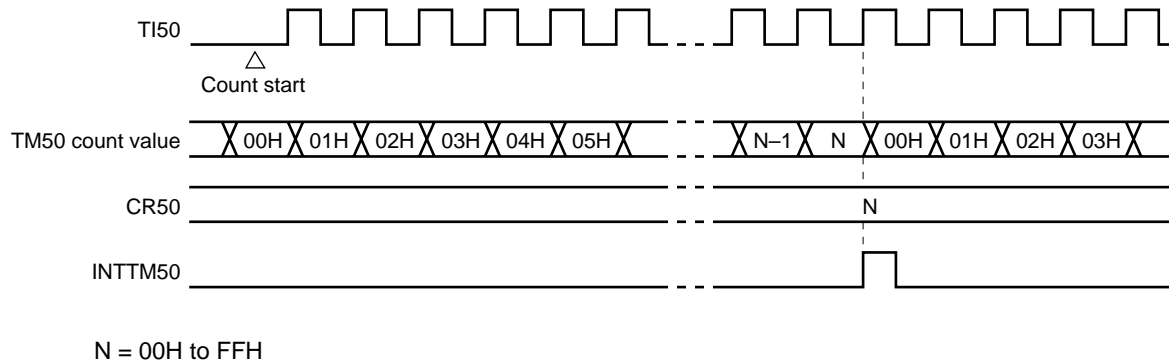
- Set port mode register 1 (PM17) to 1.
- TCL50: Select TI50 edge.  
TI50 falling edge → TCL50 = 00H  
TI50 rising edge → TCL50 = 01H
- CR50: Compare value
- TMC50: Stop the count operation, select clear & start mode entered on match of TM50 and CR50, disable the timer F/F inversion operation, disable timer output.  
(TMC50 = 0000××00B × = Don't care)

<2> When TCE50 = 1 is set, the number of pulses input from TI50 is counted.

<3> When the values of TM50 and CR50 match, INTTM50 is generated (TM50 is cleared to 00H).

<4> After these settings, INTTM50 is generated each time the values of TM50 and CR50 match.

**Figure 7-8. External Event Counter Operation Timing (with Rising Edge Specified)**



### 7.4.3 Operation as square-wave output

A square wave with any selected frequency is output at intervals determined by the value preset to 8-bit timer compare register 50 (CR50).

The TO50 pin output status is inverted at intervals determined by the count value preset to CR50 by setting bit 0 (TOE50) of 8-bit timer mode control register 50 (TMC50) to 1. This enables a square wave with any selected frequency to be output (duty = 50%).

#### Setting

<1> Set each register.

- Set the port output latch (P17) and port mode register 1 (PM17) to 0.
- TCL50: Select the count clock.
- CR50: Compare value
- TMC50: Stop the count operation, select clear & start mode entered on a match of TM50 and CR50.

| LVS50 | LVR50 | Timer Output F/F Status Setting |
|-------|-------|---------------------------------|
| 1     | 0     | High-level output               |
| 0     | 1     | Low-level output                |

Timer output F/F inversion enabled

Timer output enabled

(TMC50 = 00001011B or 00000111B)

<2> After TCE50 = 1 is set, the count operation starts.

<3> The timer output F/F is inverted by a match of TM50 and CR50. After INTTM50 is generated, TM50 is cleared to 00H.

<4> After these settings, the timer output F/F is inverted at the same interval and a square wave is output from TO50.

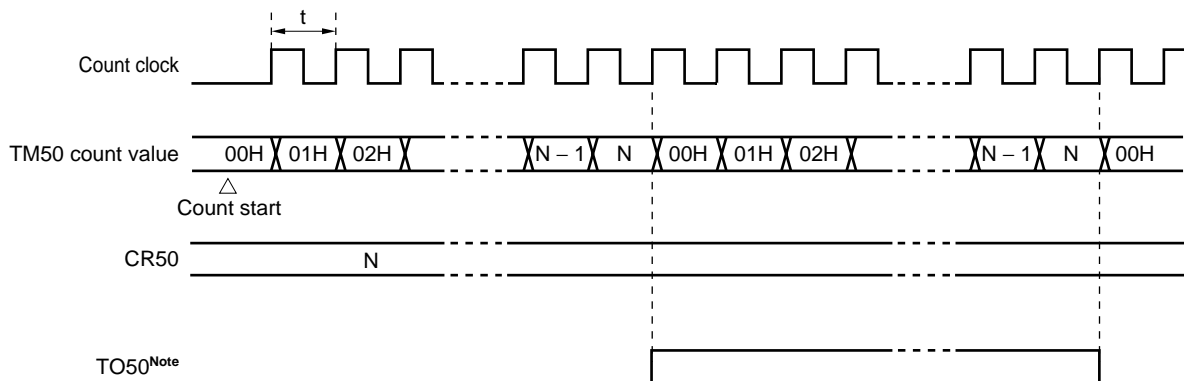
The frequency is as follows.

$$\text{Frequency} = 1/2t (N + 1)$$

(N: 00H to FFH)

**Caution** Do not write other values to CR50 during operation.

**Figure 7-9. Square-Wave Output Operation Timing**



**Note** The initial value of TO50 output can be set by bits 2 and 3 (LVR50, LVS50) of 8-bit timer mode control register 50 (TMC50).

#### 7.4.4 Operation as PWM output

8-bit timer/event counter 50 operates as a PWM output when bit 6 (TMC506) of 8-bit timer mode control register 50 (TMC50) is set to 1.

The duty pulse is determined by the value set to 8-bit timer compare register 50 (CR50).

Set the active level width of the PWM pulse to CR50; the active level can be selected with bit 1 of TMC50 (TMC501).

The count clock can be selected with bits 0 to 2 (TCL500 to TCL502) of timer clock selection register 50 (TCL50).

PWM output can be enabled/disabled with bit 0 of TMC50 (TOE50).

**Caution** In PWM mode, make the CR50 rewrite period 3 count clocks of the count clock (clock selected by TCL50) or more.

#### (1) PWM output basic operation

##### Setting

<1> Set each register.

- Set the port output latch (P17) and port mode register 1 (PM17) to 0.
- TCL50: Select the count clock.
- CR50: Compare value
- TMC50: Stop the count operation, select PWM mode.

The timer output F/F is not changed, timer output is enabled.

| TMC501 | Active Level Selection |
|--------|------------------------|
| 0      | Active-high            |
| 1      | Active-low             |

(TMC50 = 01000001B or 01000011B)

<2> The count operation starts when TCE50 = 1.

Set TCE50 to 0 to stop the count operation.

##### PWM output operation

<1> PWM output (output from TO50) outputs an inactive level until an overflow occurs.

<2> When an overflow occurs, the active level is output.

The active level is output until CR50 matches the count value of 8-bit timer counter 50 (TM50).

<3> After the CR50 matches the count value, the inactive level is output until an overflow occurs again.

<4> Operations <2> and <3> are repeated until the count operation stops.

<5> When the count operation is stopped with TCE50 = 0, PWM output becomes inactive.

For details of timing, see **Figures 7-10** and **7-11**.

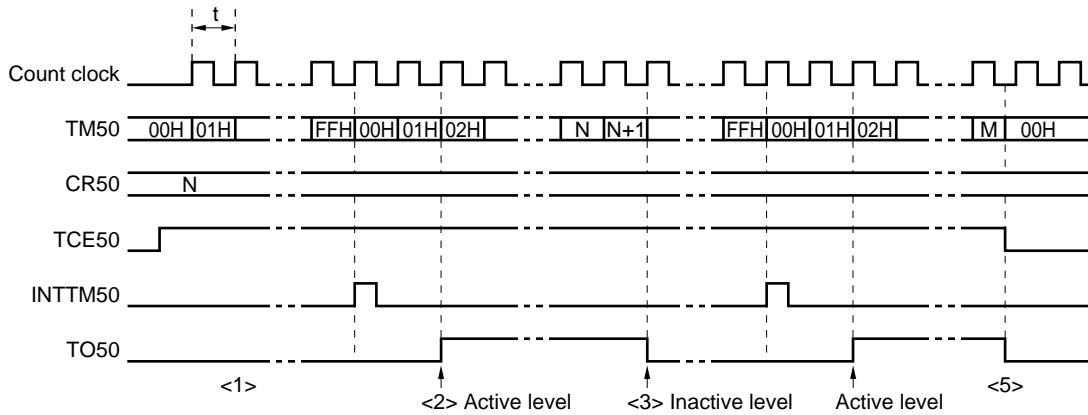
The cycle, active-level width, and duty are as follows.

- Cycle =  $2^8 t$
- Active-level width =  $Nt$
- Duty =  $N/2^8$   
(N = 00H to FFH)

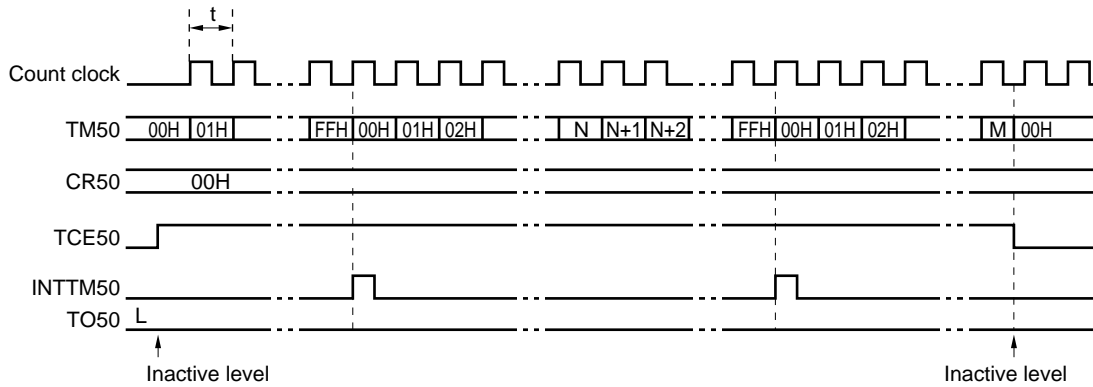


Figure 7-10. PWM Output Operation Timing

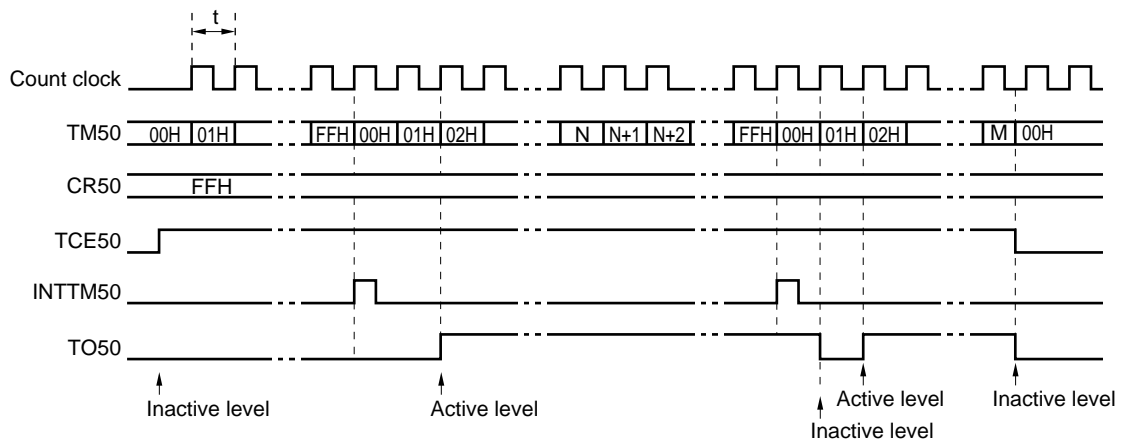
(a) Basic operation (active level = H)



(b) CR50 = 00H



(c) CR50 = FFH



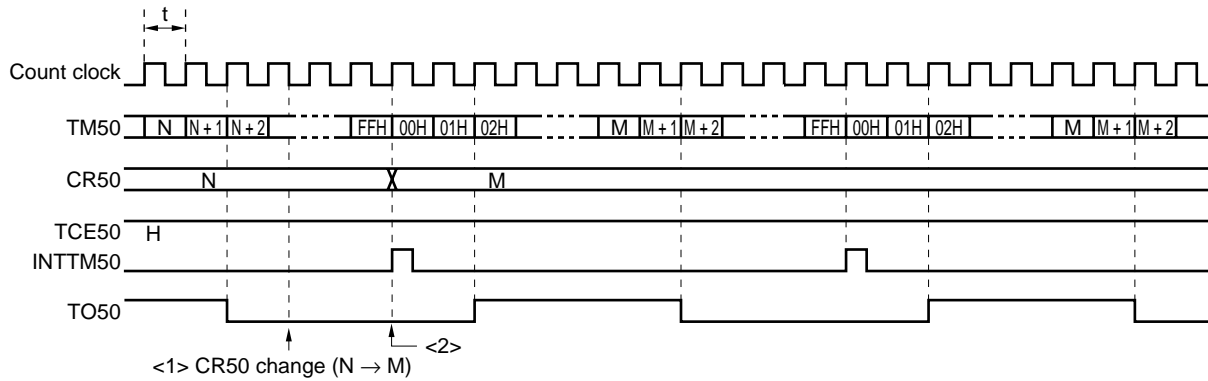
**Remark**  $\langle 1 \rangle$  to  $\langle 3 \rangle$  and  $\langle 5 \rangle$  in Figure 7-10 (a) correspond to  $\langle 1 \rangle$  to  $\langle 3 \rangle$  and  $\langle 5 \rangle$  in PWM output operation in 7.4.4 (1) PWM output basic operation.

(2) Operation with CR50 changed

Figure 7-11. Timing of Operation with CR50 Changed

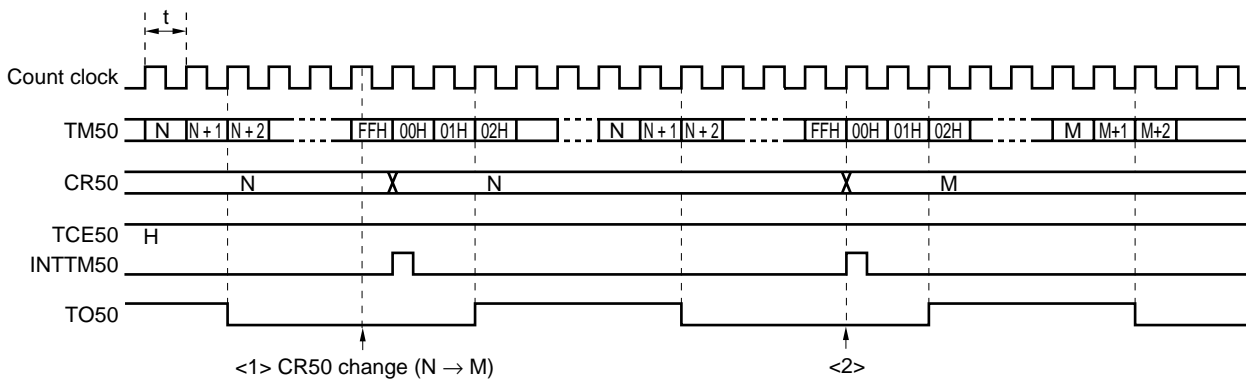
(a) CR50 value is changed from N to M before clock rising edge of FFH

→ Value is transferred to CR50 at overflow immediately after change.



(b) CR50 value is changed from N to M after clock rising edge of FFH

→ Value is transferred to CR50 at second overflow.



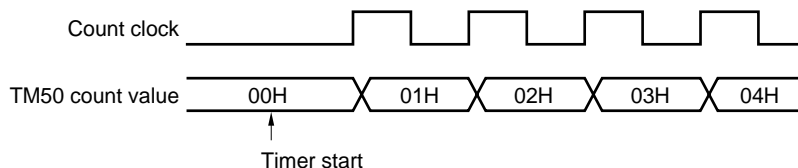
**Caution** When reading from CR50 between <1> and <2> in Figure 7-11, the value read differs from the actual value (read value: M, actual value of CR50: N).

7.5 Cautions for 8-Bit Timer/Event Counter 50

(1) Timer start error

An error of up to one clock may occur in the time required for a match signal to be generated after timer start. This is because 8-bit timer counter 50 (TM50) is started asynchronously to the count clock.

Figure 7-12. 8-Bit Timer Counter 50 Start Timing



## CHAPTER 8 8-BIT TIMERS H0 AND H1

### 8.1 Functions of 8-Bit Timers H0 and H1

8-bit timers H0 and H1 have the following functions.

- Interval timer
- PWM output mode
- Square-wave output

### 8.2 Configuration of 8-Bit Timers H0 and H1

8-bit timers H0 and H1 include the following hardware.

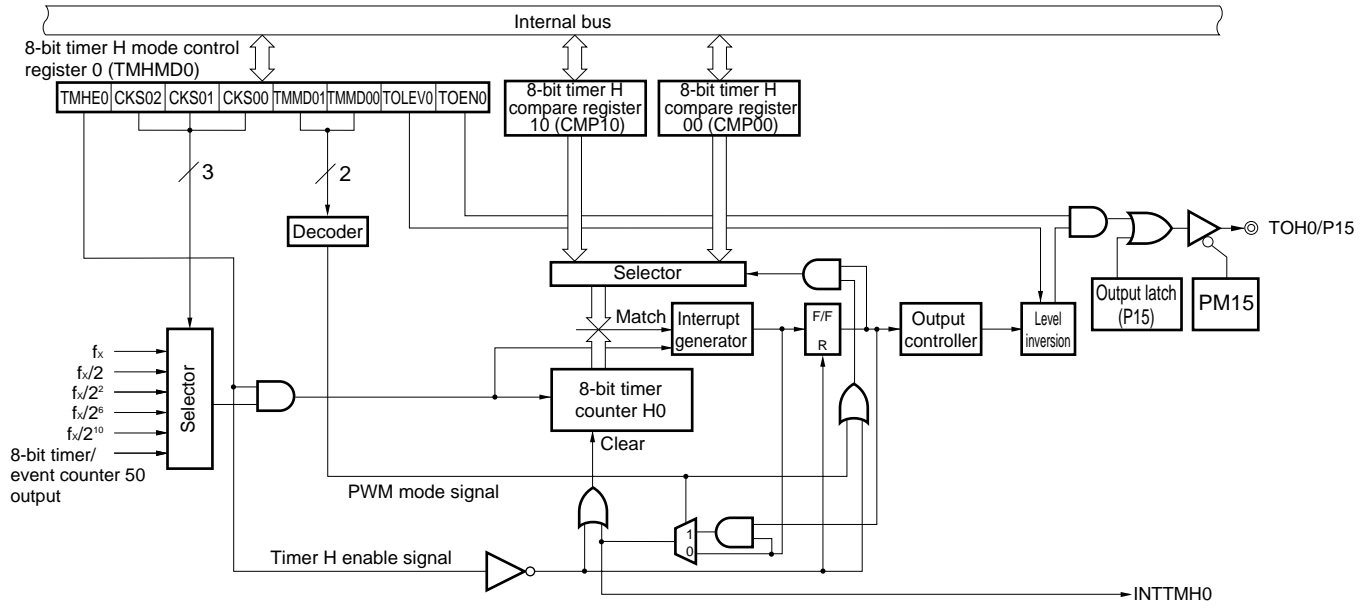
**Table 8-1. Configuration of 8-Bit Timers H0 and H1**

| Item              | Configuration  |
|-------------------|--|
| Timer register    | 8-bit timer counter Hn   |
| Registers         | 8-bit timer H compare register 0n (CMP0n)<br>8-bit timer H compare register 1n (CMP1n)       |
| Timer outputs     | TOHn   |
| Control registers | 8-bit timer H mode register n (TMHMDn)<br>Port mode register 1 (PM1)<br>Port register 1 (P1) |

**Remark** n = 0, 1

Figures 8-1 and 8-2 show the block diagrams.

Figure 8-1. Block Diagram of 8-Bit Timer H0



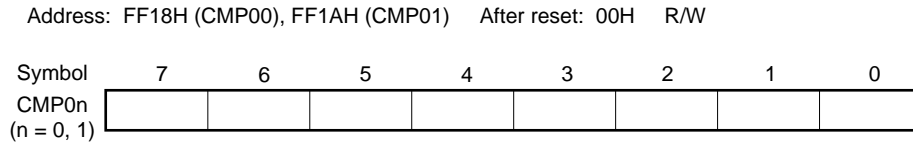


**(1) 8-bit timer H compare register 0n (CMP0n)**

This register can be read/written by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 8-3. Format of 8-Bit Timer H Compare Register 0n (CMP0n)**



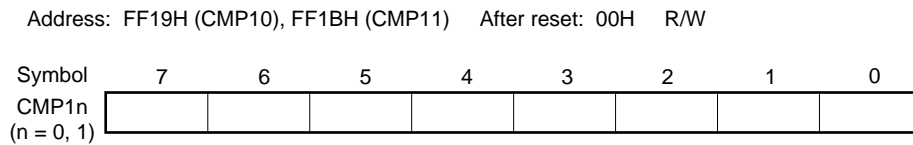
**Caution** CMP0n cannot be rewritten during timer count operation.

**(2) 8-bit timer H compare register 1n (CMP1n)**

This register can be read/written by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 8-4. Format of 8-Bit Timer H Compare Register 1n (CMP1n)**



CMP1n can be rewritten during timer count operation.

If the CMP1n value is rewritten during timer operation, transfer is performed at the timing at which the count value and CMP1n value match. If the transfer timing and writing from CPU to CMP1n conflict, transfer is not performed.

**Caution** In the PWM output mode be sure to set CMP1n when starting the timer count operation (TMHEn = 1) after the timer count operation was stopped (TMHEn = 0) (be sure to set again even if setting the same value to CMP1n).

**Remark** n = 0, 1

### 8.3 Registers Controlling 8-Bit Timers H0 and H1

The following three registers are used to control 8-bit timers H0 and H1.

- 8-bit timer H mode register n (TMHMDn)
- Port mode register 1 (PM1)
- Port register 1 (P1)

**(1) 8-bit timer H mode register n (TMHMDn)**

This register controls the mode of timer H.

This register can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears this register to 00H.

**Remark** n = 0, 1

Figure 8-5. Format of 8-Bit Timer H Mode Register 0 (TMHMD0)

Address: FF69H After reset: 00H R/W

|        |       |       |       |       |        |        |        |       |
|--------|-------|-------|-------|-------|--------|--------|--------|-------|
| Symbol | <7>   | 6     | 5     | 4     | 3      | 2      | <1>    | <0>   |
| TMHMD0 | TMHE0 | CKS02 | CKS01 | CKS00 | TMMD01 | TMMD00 | TOLEV0 | TOEN0 |

|       |  |
|-------|--|
| TMHE0 | Timer operation enable   |
| 0     | Stops timer count operation (counter is cleared to 0)                      |
| 1     | Enables timer count operation (count operation started by inputting clock) |

|                  |       |       |   |
|------------------|-------|-------|---|
| CKS02            | CKS01 | CKS00 | Count clock ( $f_{CNT}$ ) selection <sup>Note 1</sup> |
| 0                | 0     | 0     | $f_x$ (10 MHz)  |
| 0                | 0     | 1     | $f_x/2$ (5 MHz)                                       |
| 0                | 1     | 0     | $f_x/2^2$ (2.5 MHz)                                   |
| 0                | 1     | 1     | $f_x/2^6$ (156.25 kHz)                                |
| 1                | 0     | 0     | $f_x/2^{10}$ (9.77 kHz)                               |
| 1                | 0     | 1     | TM50 output <sup>Note 2</sup>                         |
| Other than above |       |       | Setting prohibited                                    |

|                  |        |                      |
|------------------|--------|----------------------|
| TMMD01           | TMMD00 | Timer operation mode |
| 0                | 0      | Interval timer mode  |
| 1                | 0      | PWM output mode      |
| Other than above |        | Setting prohibited   |

|        |  |
|--------|--|
| TOLEV0 | Timer output level control (in default mode) |
| 0      | Low level                                    |
| 1      | High level                                   |

|       |                      |
|-------|----------------------|
| TOEN0 | Timer output control |
| 0     | Disables output      |
| 1     | Enables output       |

- ★ **Notes 1.** Be sure to set the count clock so that the following condition is satisfied.
  - $V_{DD} = 4.0$  to  $5.5$  V: Count clock  $\leq 10$  MHz
  - $V_{DD} = 3.3$  to  $4.0$  V: Count clock  $\leq 8.38$  MHz
  - $V_{DD} = 2.7$  to  $3.3$  V: Count clock  $\leq 5$  MHz
  - $V_{DD} = 2.5$  to  $2.7$  V: Count clock  $\leq 2.5$  MHz
- ★ **2.** Note the following points when selecting the TM50 output as the count clock.
  - PWM mode (TMC506 = 1)  
Start the operation of 8-bit timer/event counter 50 first and then set the count clock to make the duty = 50%.
  - Mode in which the count clock is cleared and started upon a match of TM50 and CR50 (TMC506 = 0)  
Start the operation of 8-bit timer/event counter 50 first and then enable the timer F/F inversion operation (TMC501 = 1).

It is not necessary to enable the TO50 pin as a timer output pin in any mode.



- Cautions**
1. When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the count clock is the Ring-OSC clock, the operation of 8-bit timer H0 is not guaranteed.
  2. When TMHE0 = 1, setting the other bits of TMHMD0 is prohibited.
  3. In the PWM output mode, be sure to set 8-bit timer H compare register 10 (CMP10) when starting the timer count operation (TMHE0 = 1) after the timer count operation was stopped (TMHE0 = 0) (be sure to set again even if setting the same value to CMP10).

- Remarks**
1. fx: X1 input clock oscillation frequency
  2. Figures in parentheses apply to operation at fx = 10 MHz

**Figure 8-6. Format of 8-Bit Timer H Mode Register 1 (TMHMD1)**

Address: FF6CH After reset: 00H R/W

|        |       |       |       |       |        |        |        |       |
|--------|-------|-------|-------|-------|--------|--------|--------|-------|
| Symbol | <7>   | 6     | 5     | 4     | 3      | 2      | <1>    | <0>   |
| TMHMD1 | TMHE1 | CKS12 | CKS11 | CKS10 | TMMD11 | TMMD10 | TOLEV1 | TOEN1 |

|       |  |
|-------|--|
| TMHE1 | Timer operation enable   |
| 0     | Stops timer count operation (counter is cleared to 0)                      |
| 1     | Enables timer count operation (count operation started by inputting clock) |

|                  |       |       |                                       |
|------------------|-------|-------|---------------------------------------|
| CKS12            | CKS11 | CKS10 | Count clock selection <sup>Note</sup> |
| 0                | 0     | 0     | fx (10 MHz)                           |
| 0                | 0     | 1     | fx/2 <sup>2</sup> (2.5 MHz)           |
| 0                | 1     | 0     | fx/2 <sup>4</sup> (625 kHz)           |
| 0                | 1     | 1     | fx/2 <sup>6</sup> (156.25 kHz)        |
| 1                | 0     | 0     | fx/2 <sup>12</sup> (2.44 kHz)         |
| 1                | 0     | 1     | fR/2 <sup>7</sup> (1.88 kHz (TYP.))   |
| Other than above |       |       | Setting prohibited                    |

|                  |        |                      |
|------------------|--------|----------------------|
| TMMD11           | TMMD10 | Timer operation mode |
| 0                | 0      | Interval timer mode  |
| 1                | 0      | PWM output mode      |
| Other than above |        | Setting prohibited   |

|        |  |
|--------|--|
| TOLEV1 | Timer output level control (in default mode) |
| 0      | Low level                                    |
| 1      | High level                                   |

|       |                      |
|-------|----------------------|
| TOEN1 | Timer output control |
| 0     | Disables output      |
| 1     | Enables output       |

- ★ **Note** Be sure to set the count clock so that the following condition is satisfied.
  - $V_{DD} = 4.0$  to  $5.5$  V: Count clock  $\leq 10$  MHz
  - $V_{DD} = 3.3$  to  $4.0$  V: Count clock  $\leq 8.38$  MHz
  - $V_{DD} = 2.7$  to  $3.3$  V: Count clock  $\leq 5$  MHz
  - $V_{DD} = 2.5$  to  $2.7$  V: Count clock  $\leq 2.5$  MHz

- Cautions**
1. When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the count clock is the Ring-OSC clock, the operation of 8-bit timer H1 is not guaranteed (except when  $CKS12, CKS11, CKS10 = 1, 0, 1 (f_R/2^7)$ ).
  2. When  $TMHE1 = 1$ , setting the other bits of  $TMHMD1$  is prohibited.
  3. In the PWM output mode, be sure to set 8-bit timer H compare register 11 ( $CMP11$ ) when starting the timer count operation ( $TMHE1 = 1$ ) after the timer count operation was stopped ( $TMHE1 = 0$ ) (be sure to set again even if setting the same value to  $CMP11$ ).

- Remarks**
1.  $f_x$ : X1 input clock oscillation frequency
  2.  $f_R$ : Ring-OSC clock oscillation frequency
  3. Figures in parentheses apply to operation at  $f_x = 10$  MHz,  $f_R = 240$  kHz (TYP.).

**(2) Port mode register 1 (PM1)**

This register sets port 1 input/output in 1-bit units.

When using the P15/TOH0 and P16/TOH1/INTP5 pins for timer output, clear PM15 and PM16 and the output latches of P15 and P16 to 0.

PM1 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{RESET}$  input sets this register to FFH.

**Figure 8-7. Format of Port Mode Register 1 (PM1)**

Address: FF21H After reset: FFH R/W

|        |      |      |      |      |      |      |      |      |
|--------|------|------|------|------|------|------|------|------|
| Symbol | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PM1    | PM17 | PM16 | PM15 | PM14 | PM13 | PM12 | PM11 | PM10 |

|      |   |
|------|---|
| PM1n | P1n pin I/O mode selection (n = 0 to 7) |
| 0    | Output mode (output buffer on)          |
| 1    | Input mode (output buffer off)          |

## 8.4 Operation of 8-Bit Timers H0 and H1

### 8.4.1 Operation as interval timer/square-wave output

When 8-bit timer counter Hn and compare register 0n (CMP0n) match, an interrupt request signal (INTTMHn) is generated and 8-bit timer counter Hn is cleared to 00H.

Compare register 1n (CMP1n) is not used in interval timer mode. Since a match of 8-bit timer counter Hn and the CMP1n register is not detected even if the CMP1n register is set, timer output is not affected.

By setting bit 0 (TOENn) of timer H mode register n (TMHMDn) to 1, a square wave of any frequency (duty = 50%) is output from TOHn.

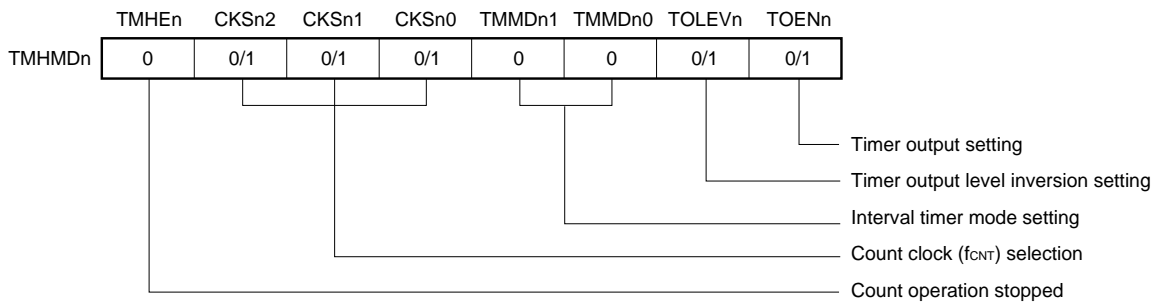
#### (1) Usage

Generates the INTTMHn signal repeatedly at the same interval.

<1> Set each register.

Figure 8-8. Register Setting During Interval Timer/Square-Wave Output Operation

#### (i) Setting timer H mode register n (TMHMDn)



#### (ii) CMP0n register setting

- Compare value (N)

<2> Count operation starts when TMHEn = 1.

<3> When the values of 8-bit timer counter Hn and the CMP0n register match, the INTTMHn signal is generated and 8-bit timer counter Hn is cleared to 00H.

$$\text{Interval time} = (N + 1)/f_{\text{CNT}}$$

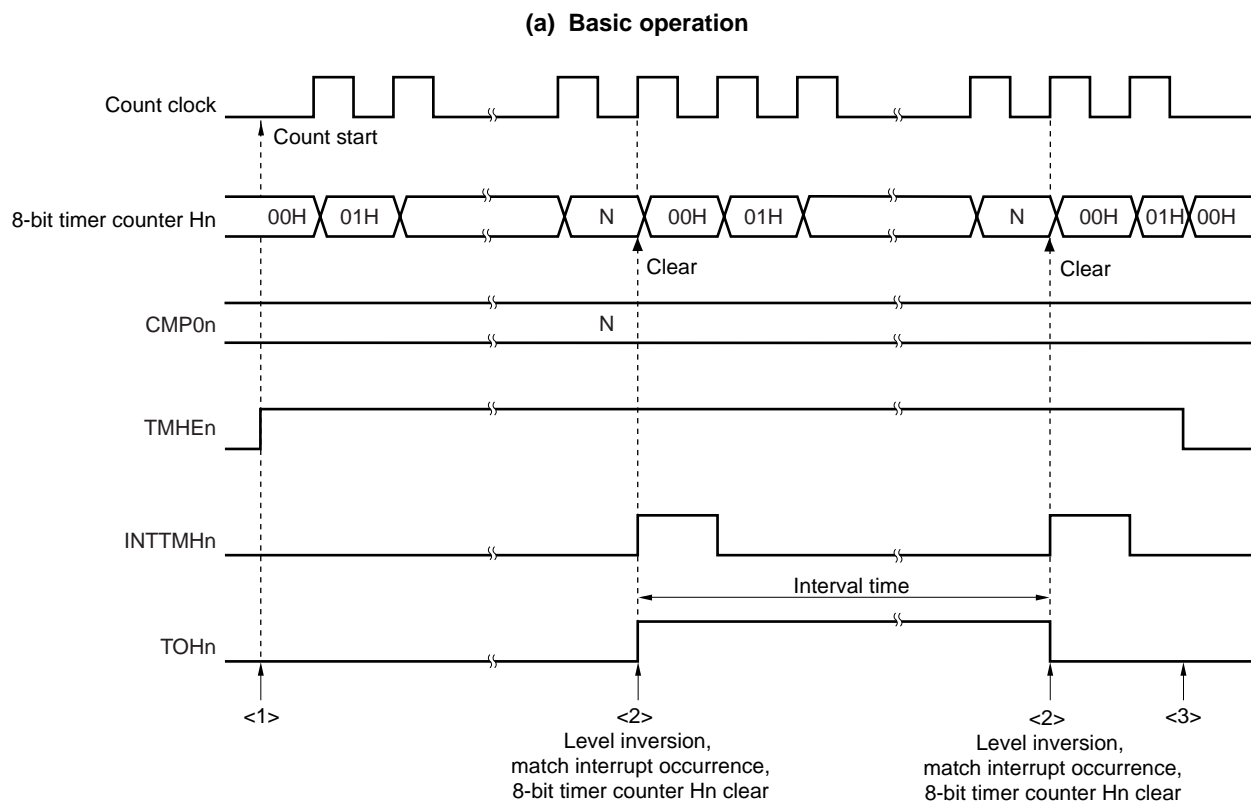
<4> Subsequently, the INTTMHn signal is generated at the same interval. To stop the count operation, set TMHEn to 0.

**Remark** n = 0, 1

**(2) Timing chart**

The timing of the interval timer/square-wave output operation is shown below.

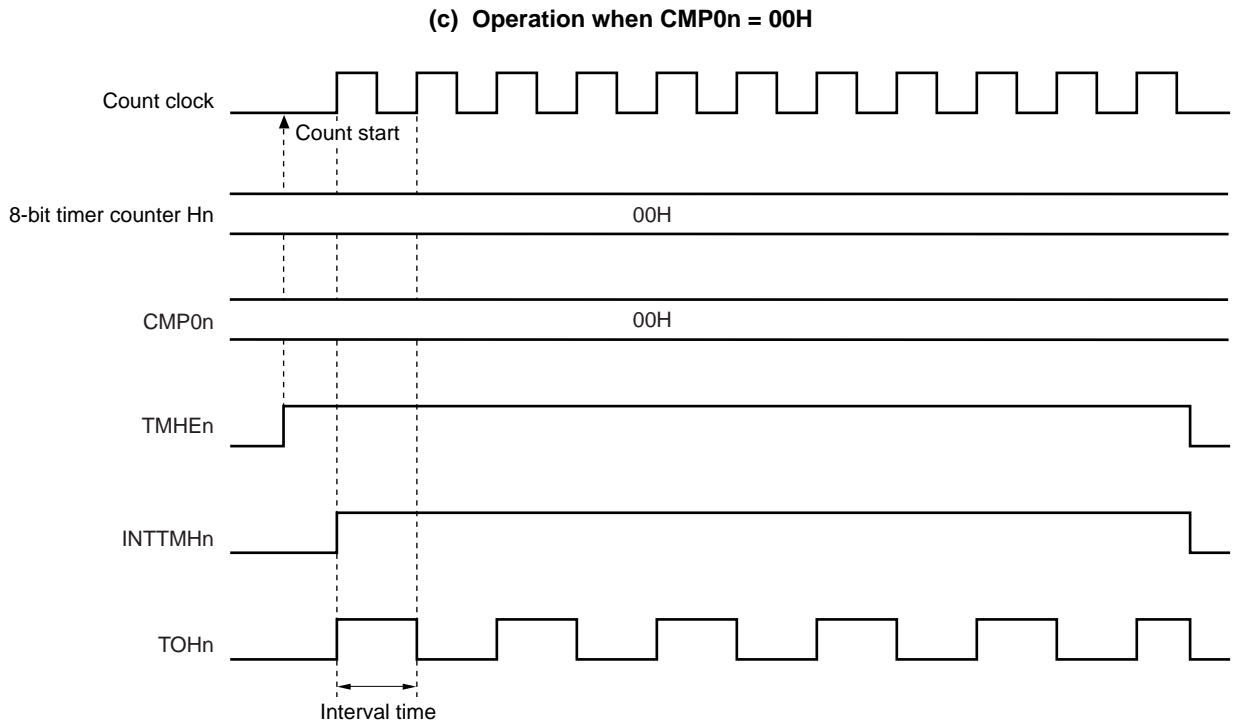
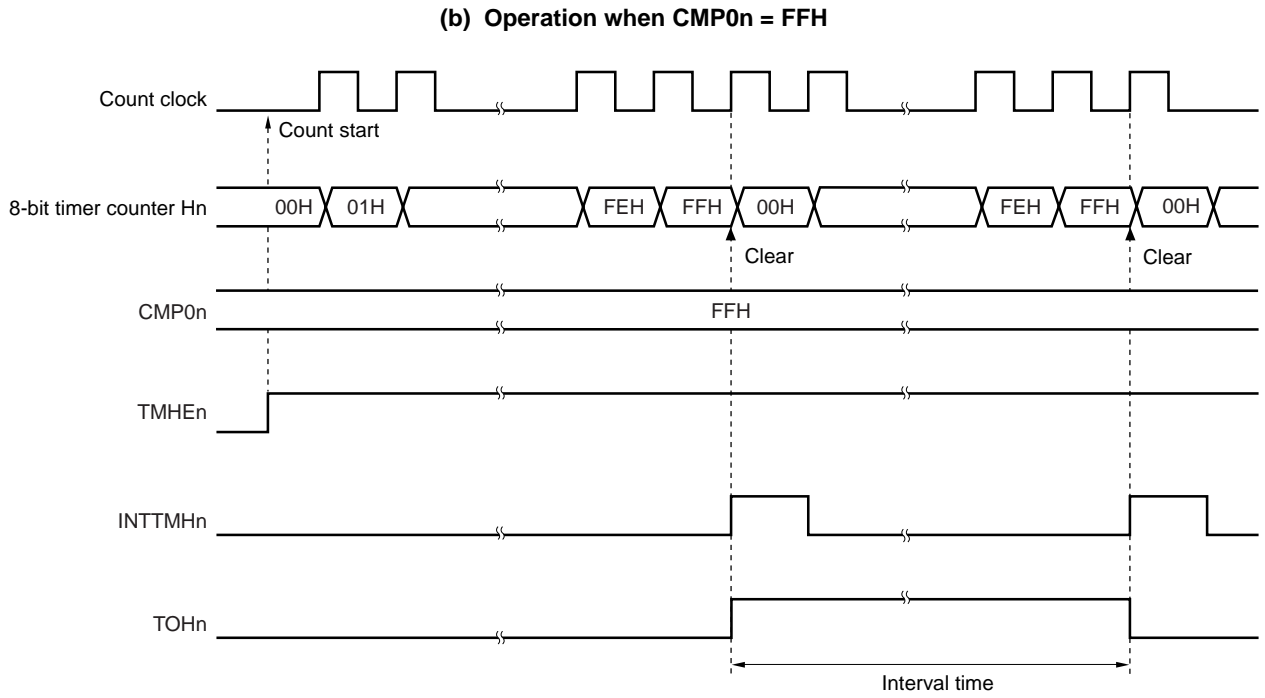
**Figure 8-9. Timing of Interval Timer/Square-Wave Output Operation (1/2)**



- <1> The count operation is enabled by setting the TMHEn bit to 1. The count clock starts counting no more than 1 clock after the operation is enabled.
- <2> When the values of 8-bit timer counter Hn and the CMP0n register match, the value of 8-bit timer counter Hn is cleared, the TOHn output level is inverted, and the INTTMHn signal is output.
- <3> The INTTMHn signal and TOHn output become inactive by setting the TMHEn bit to 0 during timer Hn operation. If these are inactive from the first, the level is retained.

**Remark** n = 0, 1  
N = 01H to FEH

Figure 8-9. Timing of Interval Timer/Square-Wave Output Operation (2/2)



**Remark** n = 0, 1

### 8.4.2 Operation as PWM output mode

In PWM output mode, a pulse with an arbitrary duty and arbitrary cycle can be output.

8-bit timer compare register 0n (CMP0n) controls the cycle of timer output (TOHn). Rewriting the CMP0n register during timer operation is prohibited.

8-bit timer compare register 1n (CMP1n) controls the duty of timer output (TOHn). Rewriting the CMP1n register during timer operation is possible.

The operation in PWM output mode is as follows.

TOHn output becomes active and 8-bit timer counter Hn is cleared to 0 when 8-bit timer counter Hn and the CMP0n register match after the timer count is started. TOHn output becomes inactive when 8-bit timer counter Hn and the CMP1n register match.

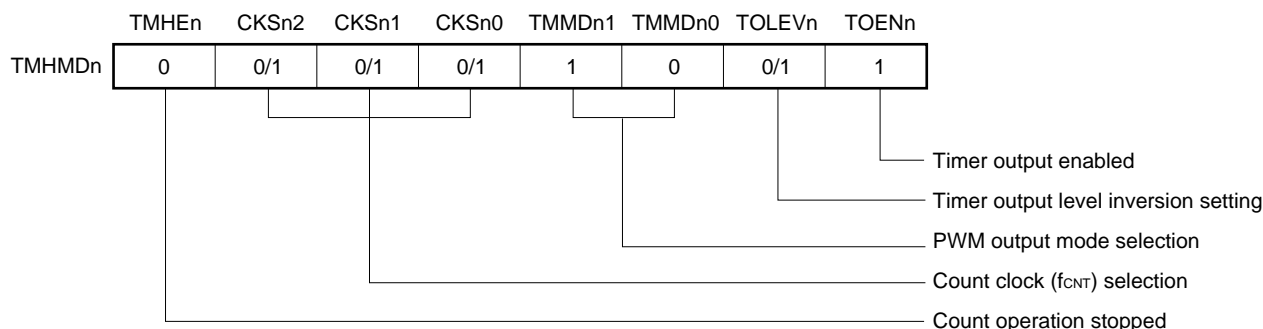
#### (1) Usage

In PWM output mode, a pulse for which an arbitrary duty and arbitrary cycle can be set is output.

<1> Set each register.

Figure 8-10. Register Setting in PWM Output Mode

#### (i) Setting timer H mode register n (TMHMDn)



#### (ii) Setting CMP0n register

- Compare value (N): Cycle setting

#### (iii) Setting CMP1n register

- Compare value (M): Duty setting

**Remarks 1.** n = 0, 1

**2.** 00H ≤ CMP1n (M) < CMP0n (N) ≤ FFH

<2> The count operation starts when TMHE<sub>n</sub> = 1.

<3> The CMP0n register is the compare register that is to be compared first after counter operation is enabled. When the values of 8-bit timer counter Hn and the CMP0n register match, 8-bit timer counter Hn is cleared, an interrupt request signal (INTTMHn) is generated, and TOHn output becomes active. At the same time, the compare register to be compared with 8-bit timer counter Hn is changed from the CMP0n register to the CMP1n register.

- <4> When 8-bit timer counter Hn and the CMP1n register match, TOHn output becomes inactive and the compare register to be compared with 8-bit timer counter Hn is changed from the CMP1n register to the CMP0n register. At this time, 8-bit timer counter Hn is not cleared and the INTTMHn signal is not generated.
- <5> By performing procedures <3> and <4> repeatedly, a pulse with an arbitrary duty can be obtained.
- <6> To stop the count operation, set TMHEn = 0.

If the setting value of the CMP0n register is N, the setting value of the CMP1n register is M, and the count clock frequency is  $f_{CNT}$ , the PWM pulse output cycle and duty are as follows.

|   |
|---|
| $\text{PWM pulse output cycle} = (N+1)/f_{CNT}$ $\text{Duty} = \text{Active width} : \text{Total width of PWM} = (M + 1) : (N + 1)$ |
|---|

- Cautions**
1. In PWM output mode, three operation clocks (signal selected using the CKSn2 to CKSn0 bits of the TMHMDn register) are required to transfer the CMP1n register value after rewriting the register.
  2. Be sure to set the CMP1n register when starting the timer count operation (TMHEn = 1) after the timer count operation was stopped (TMHEn = 0) (be sure to set again even if setting the same value to the CMP1n register).

**(2) Timing chart**

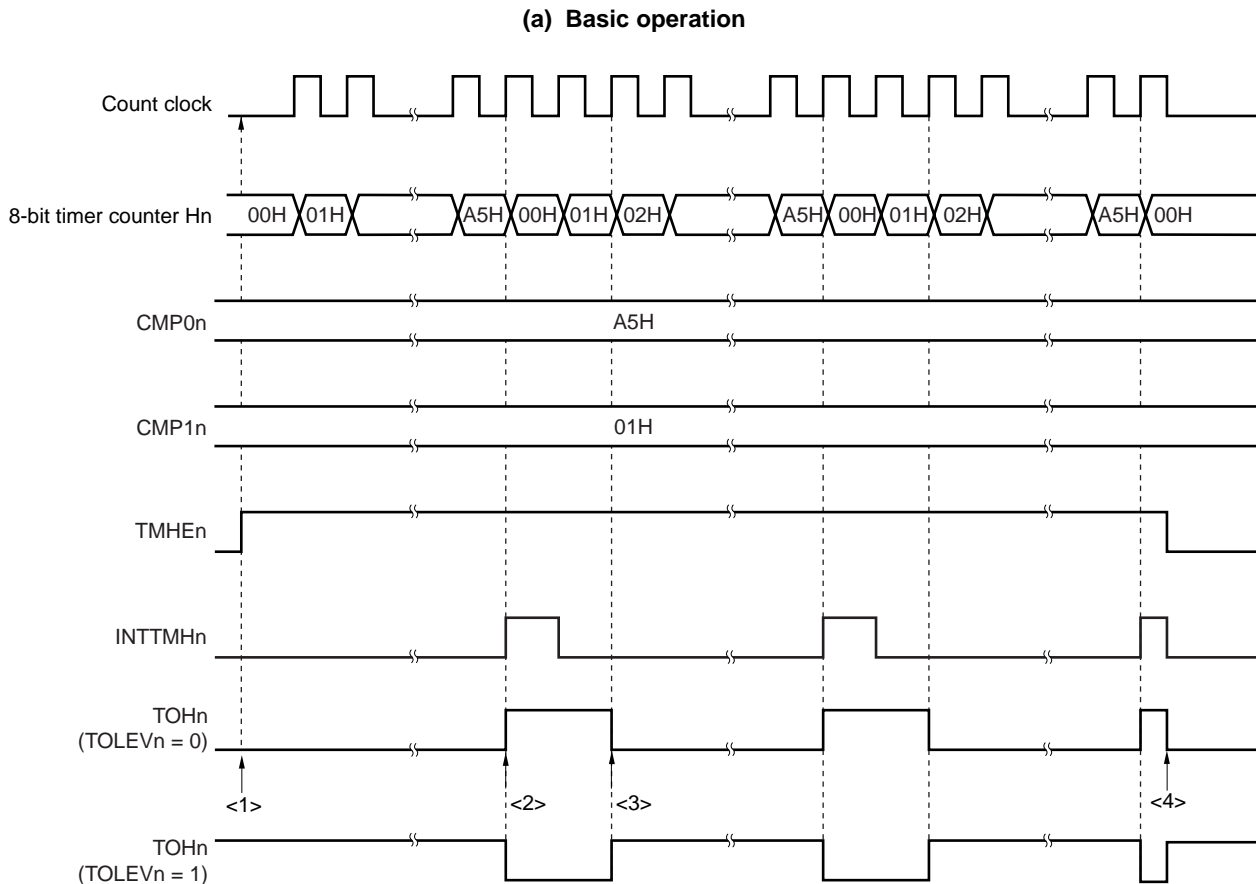
The operation timing in PWM output mode is shown below.

**Caution** Make sure that the CMP1n register setting value (M) and CMP0n register setting value (N) are within the following range.

$$00H \leq \text{CMP1n (M)} < \text{CMP0n (N)} \leq \text{FFH}$$

**Remark** n = 0, 1

**Figure 8-11. Operation Timing in PWM Output Mode (1/4)**



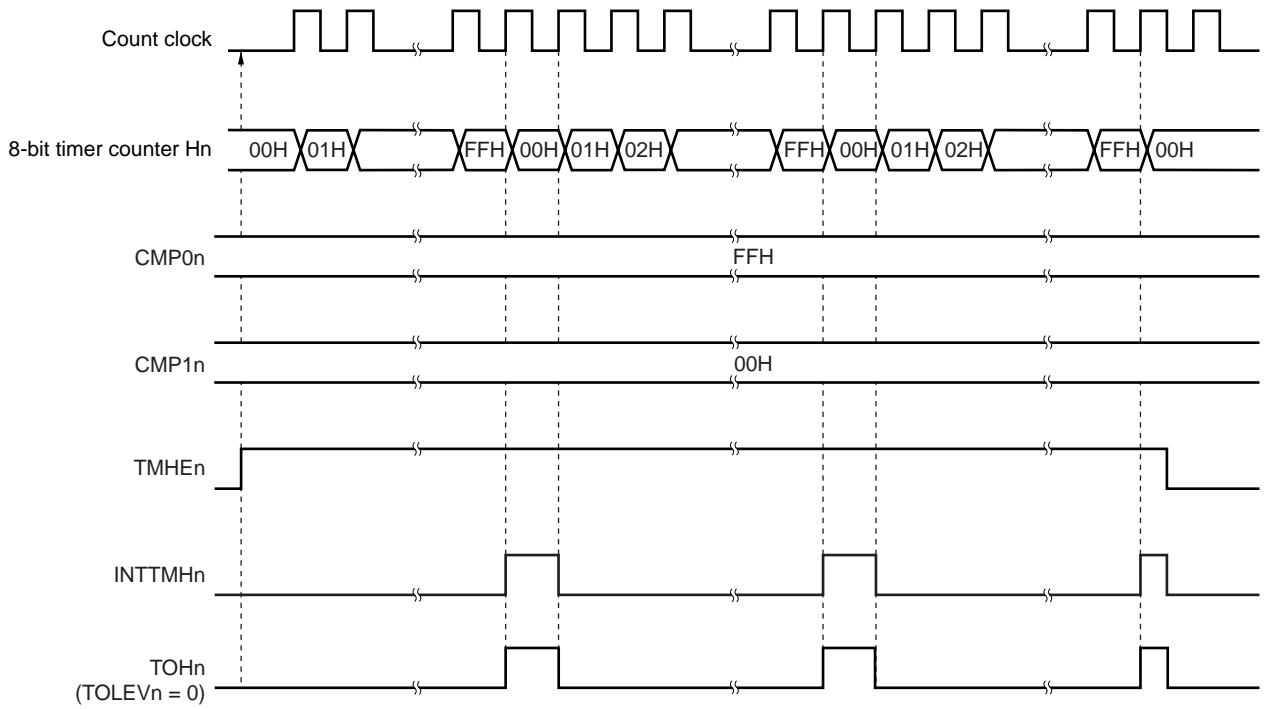
- <1> The count operation is enabled by setting the TMHEn bit to 1. Start 8-bit timer counter Hn by masking one count clock to count up. At this time, TOHn output remains inactive (when TOLEVn = 0).
- <2> When the values of 8-bit timer counter Hn and the CMP0n register match, the TOHn output level is inverted, the value of 8-bit timer counter Hn is cleared, and the INTTMHn signal is output.
- <3> When the values of 8-bit timer counter Hn and the CMP1n register match, the level of the TOHn output is returned. At this time, the 8-bit timer counter value is not cleared and the INTTMHn signal is not output.
- <4> Setting the TMHEn bit to 0 during timer Hn operation makes the INTTMHn signal and TOHn output inactive.

**Remark** n = 0, 1

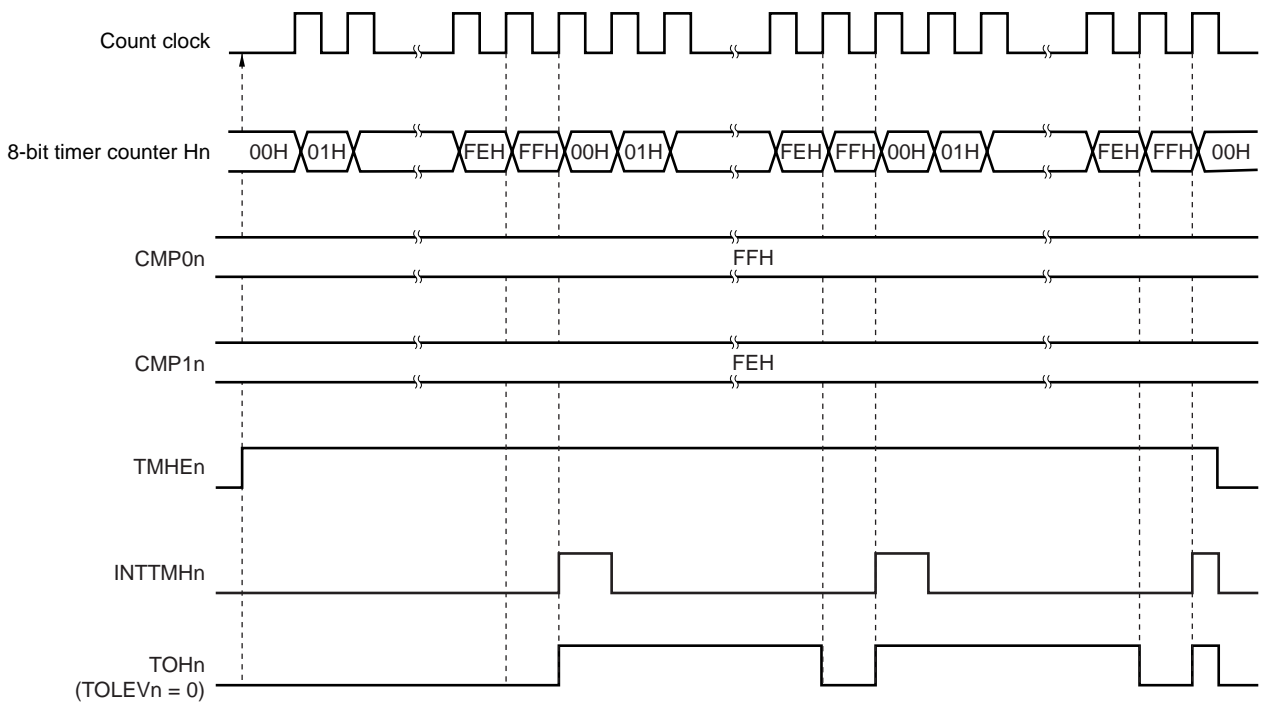


Figure 8-11. Operation Timing in PWM Output Mode (2/4)

(b) Operation when  $CMP0n = FFH$ ,  $CMP1n = 00H$



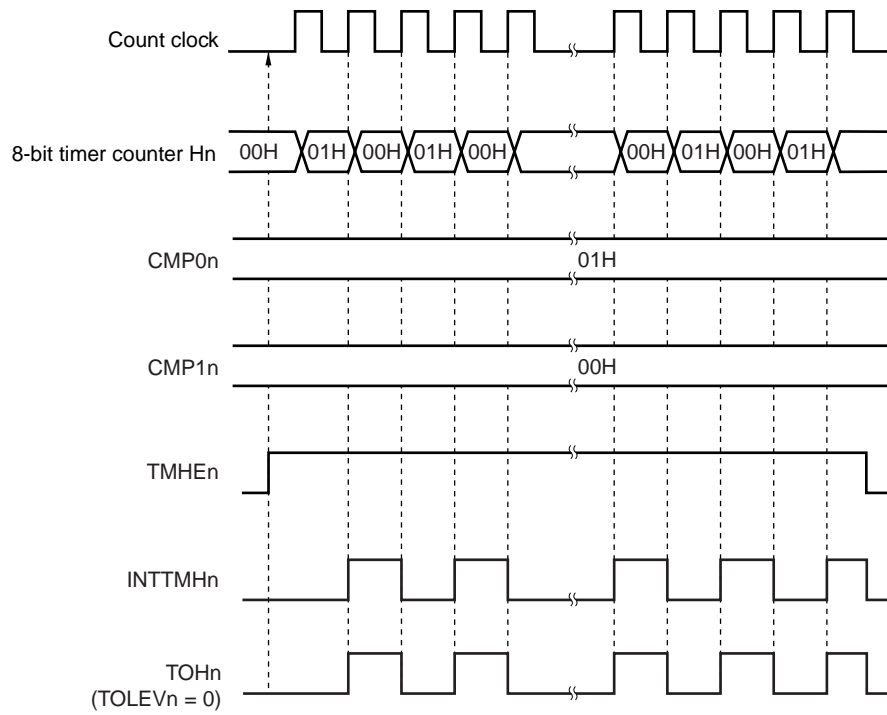
(c) Operation when  $CMP0n = FFH$ ,  $CMP1n = FEH$



Remark n = 0, 1

Figure 8-11. Operation Timing in PWM Output Mode (3/4)

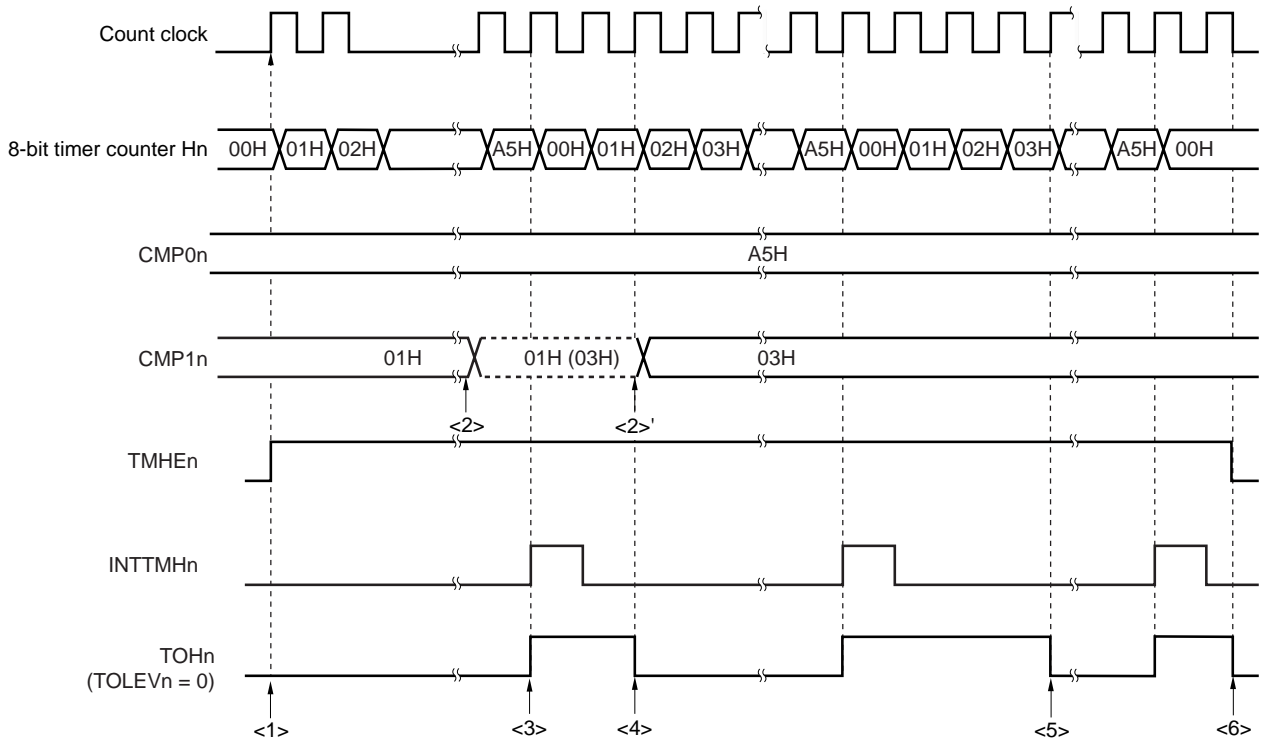
(d) Operation when  $CMP0n = 01H$ ,  $CMP1n = 00H$



**Remark** n = 0, 1

Figure 8-11. Operation Timing in PWM Output Mode (4/4)

## (e) Operation by changing CMP1n (CMP1n = 01H → 03H, CMP0n = A5H)



- <1> The count operation is enabled by setting TMHEn = 1. Start 8-bit timer counter Hn by masking one count clock to count up. At this time, the TOHn output remains inactive (when TOLEVn = 0).
- <2> The CMP1n register value can be changed during timer counter operation. This operation is asynchronous to the count clock.
- <3> When the values of 8-bit timer counter Hn and the CMP0n register match, the value of 8-bit timer counter Hn is cleared, the TOHn output becomes active, and the INTTMHn signal is output.
- <4> If the CMP1n register value is changed, the value is latched and not transferred to the register. When the values of 8-bit timer counter Hn and the CMP1n register before the change match, the value is transferred to the CMP1n register and the CMP1n register value is changed (<2>'). However, three count clocks or more are required from when the CMP1n register value is changed to when the value is transferred to the register. If a match signal is generated within three count clocks, the changed value cannot be transferred to the register.
- <5> When the values of 8-bit timer counter Hn and the CMP1n register after the change match, the TOHn output becomes inactive. 8-bit timer counter Hn is not cleared and the INTTMHn signal is not generated.
- <6> Setting the TMHEn bit to 0 during timer Hn operation makes the INTTMHn signal and TOHn output inactive.

**Remark** n = 0, 1

## CHAPTER 9 WATCHDOG TIMER

### 9.1 Functions of Watchdog Timer

The watchdog timer is used to detect an inadvertent program loop. If a program loop is detected, an internal reset signal is generated.

When a reset occurs due to the watchdog timer, bit 4 (WDTRF) of the reset control flag register (RESF) is set to 1. For details of RESF, see **CHAPTER 16 RESET FUNCTION**.

**Table 9-1. Loop Detection Time of Watchdog Timer**

| Loop Detection Time             |                                 |
|---------------------------------|---------------------------------|
| During Ring-OSC Clock Operation | During X1 Input Clock Operation |
| $2^{11}/f_R$ (4.27 ms)          | $2^{13}/f_{XP}$ (819.2 $\mu$ s) |
| $2^{12}/f_R$ (8.53 ms)          | $2^{14}/f_{XP}$ (1.64 ms)       |
| $2^{13}/f_R$ (17.07 ms)         | $2^{15}/f_{XP}$ (3.28 ms)       |
| $2^{14}/f_R$ (34.13 ms)         | $2^{16}/f_{XP}$ (6.55 ms)       |
| $2^{15}/f_R$ (68.27 ms)         | $2^{17}/f_{XP}$ (13.11 ms)      |
| $2^{16}/f_R$ (136.53 ms)        | $2^{18}/f_{XP}$ (26.21 ms)      |
| $2^{17}/f_R$ (273.07 ms)        | $2^{19}/f_{XP}$ (52.43 ms)      |
| $2^{18}/f_R$ (546.13 ms)        | $2^{20}/f_{XP}$ (104.86 ms)     |

- Remarks**
1.  $f_R$ : Ring-OSC clock oscillation frequency
  2.  $f_{XP}$ : X1 input clock oscillation frequency
  3. Figures in parentheses apply to operation at  $f_R = 480$  kHz (MAX.) (for standard products and (A) grade products),  $f_{XP} = 10$  MHz

The operation mode of the watchdog timer (WDT) is switched according to the mask option setting of the on-chip Ring-OSC as shown in Table 9-2.

Table 9-2. Mask Option Setting and Watchdog Timer Operation Mode

|                             | Mask Option  |   |
|-----------------------------|--|---|
|                             | Ring-OSC Cannot Be Stopped                                   | Ring-OSC Can Be Stopped by Software   |
| Watchdog timer clock source | Fixed to $f_R$ <sup>Note 1</sup> .                           | <ul style="list-style-type: none"> <li>Selectable by software (<math>f_{XP}</math>, <math>f_R</math> or stopped)</li> <li>When reset is released: <math>f_R</math></li> </ul> |
| Operation after reset       | Operation starts with the maximum interval ( $2^{18}/f_R$ ). | Operation starts with maximum interval ( $2^{18}/f_R$ ).  |
| Operation mode selection    | The interval can be changed only once.                       | The clock selection/interval can be changed only once.  |
| Features                    | The watchdog timer cannot be stopped.                        | The watchdog timer can be stopped in standby mode <sup>Note 2</sup> .   |

- Notes**
- As long as power is being supplied, Ring-OSC oscillation cannot be stopped (except in the reset period).
  - The conditions under which clock supply to the watchdog timer is stopped differ depending on the clock source of the watchdog timer.
    - <1> If the clock source is  $f_{XP}$ , clock supply to the watchdog timer is stopped under the following conditions.
      - When  $f_{XP}$  is stopped
      - In HALT/STOP mode
      - During oscillation stabilization time
    - <2> If the clock source is  $f_R$ , clock supply to the watchdog timer is stopped under the following conditions.
      - If the CPU clock is  $f_{XP}$  and if  $f_R$  is stopped by software before execution of the STOP instruction
      - In HALT/STOP mode

- Remarks**
- $f_R$ : Ring-OSC clock oscillation frequency
  - $f_{XP}$ : X1 input clock oscillation frequency

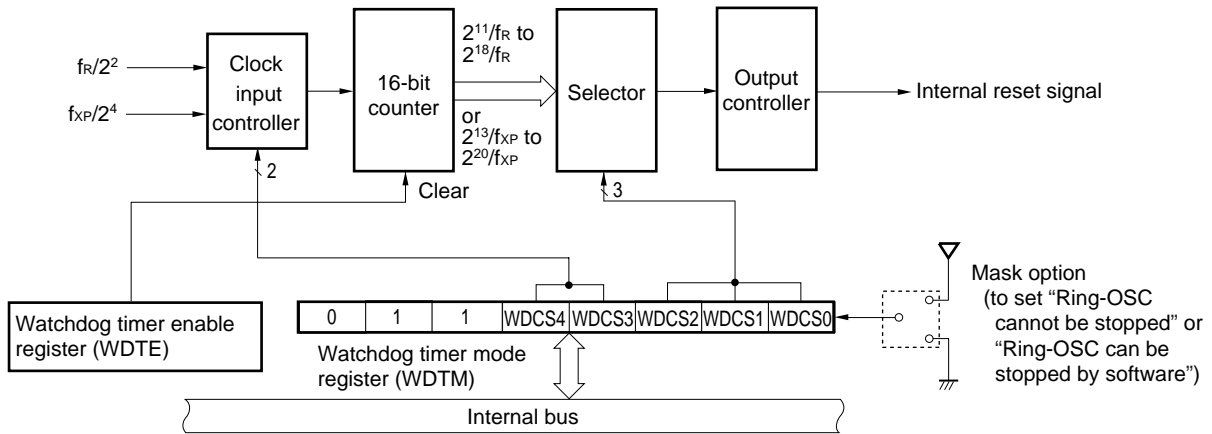
## 9.2 Configuration of Watchdog Timer

The watchdog timer includes the following hardware.

**Table 9-3. Configuration of Watchdog Timer**

| Item              | Configuration  |
|-------------------|--|
| Control registers | Watchdog timer mode register (WDTM)<br>Watchdog timer enable register (WDTE) |

**Figure 9-1. Block Diagram of Watchdog Timer**



### 9.3 Registers Controlling Watchdog Timer

The watchdog timer is controlled by the following two registers.

- Watchdog timer mode register (WDTM)
- Watchdog timer enable register (WDTE)

#### (1) Watchdog timer mode register (WDTM)

This register sets the overflow time and operation clock of the watchdog timer.

This register can be set by an 8-bit memory manipulation instruction and can be read many times, but can be written only once after reset is released.

$\overline{\text{RESET}}$  input sets this register to 67H.

**Figure 9-2. Format of Watchdog Timer Mode Register (WDTM)**

Address: FF98H After reset: 67H R/W

|        |   |   |   |       |       |       |       |       |
|--------|---|---|---|-------|-------|-------|-------|-------|
| Symbol | 7 | 6 | 5 | 4     | 3     | 2     | 1     | 0     |
| WDTM   | 0 | 1 | 1 | WDCS4 | WDCS3 | WDCS2 | WDCS1 | WDCS0 |

| WDCS4 <sup>Note 1</sup> | WDCS3 <sup>Note 1</sup> | Operation clock selection         |
|-------------------------|-------------------------|-----------------------------------|
| 0                       | 0                       | Ring-OSC clock (f <sub>R</sub> )  |
| 0                       | 1                       | X1 input clock (f <sub>XP</sub> ) |
| 1                       | ×                       | Watchdog timer operation stopped  |

| WDCS2 <sup>Note 2</sup> | WDCS1 <sup>Note 2</sup> | WDCS0 <sup>Note 2</sup> | Overflow time setting                       |  |
|-------------------------|-------------------------|-------------------------|---|--|
|                         |                         |                         | During Ring-OSC clock operation             | During X1 input clock operation              |
| 0                       | 0                       | 0                       | 2 <sup>11</sup> /f <sub>R</sub> (4.27 ms)   | 2 <sup>13</sup> /f <sub>XP</sub> (819.2 μs)  |
| 0                       | 0                       | 1                       | 2 <sup>12</sup> /f <sub>R</sub> (8.53 ms)   | 2 <sup>14</sup> /f <sub>XP</sub> (1.64 ms)   |
| 0                       | 1                       | 0                       | 2 <sup>13</sup> /f <sub>R</sub> (17.07 ms)  | 2 <sup>15</sup> /f <sub>XP</sub> (3.28 ms)   |
| 0                       | 1                       | 1                       | 2 <sup>14</sup> /f <sub>R</sub> (34.13 ms)  | 2 <sup>16</sup> /f <sub>XP</sub> (6.55 ms)   |
| 1                       | 0                       | 0                       | 2 <sup>15</sup> /f <sub>R</sub> (68.27 ms)  | 2 <sup>17</sup> /f <sub>XP</sub> (13.11 ms)  |
| 1                       | 0                       | 1                       | 2 <sup>16</sup> /f <sub>R</sub> (136.53 ms) | 2 <sup>18</sup> /f <sub>XP</sub> (26.21 ms)  |
| 1                       | 1                       | 0                       | 2 <sup>17</sup> /f <sub>R</sub> (273.07 ms) | 2 <sup>19</sup> /f <sub>XP</sub> (52.43 ms)  |
| 1                       | 1                       | 1                       | 2 <sup>18</sup> /f <sub>R</sub> (546.13 ms) | 2 <sup>20</sup> /f <sub>XP</sub> (104.86 ms) |

**Notes 1.** If “Ring-OSC cannot be stopped” is specified by a mask option, this cannot be set. The Ring-OSC clock will be selected no matter what value is written.

**2.** Reset is released at the maximum cycle (WDCS2, 1, 0 = 1, 1, 1).

**Cautions 1.** If data is written to WDTM, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.

**2.** Set bits 7, 6, and 5 to 0, 1, and 1, respectively (when “Ring-OSC cannot be stopped” is selected by a mask option, other values are ignored).

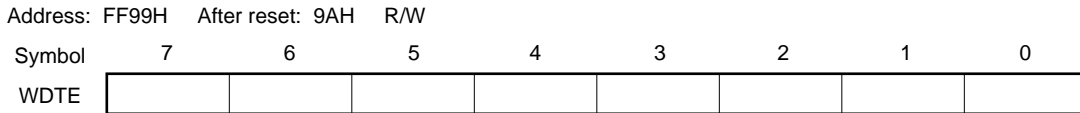
- ★ **Cautions** 3. After reset is released, WDTM can be written only once by an 8-bit memory manipulation instruction. If writing is attempted a second time, an internal reset signal is generated. If the source clock to the watchdog timer is stopped, however, an internal reset signal is generated when the source clock to the watchdog timer resumes operation.
- ★ 4. WDTM cannot be set by a 1-bit memory manipulation instruction.
- ★ 5. If “Ring-OSC can be stopped by software” is selected by the mask option and the watchdog timer is stopped by setting WDCS4 to 1, the watchdog timer does not resume operation even if WDCS4 is cleared to 0. In addition, the internal reset signal is not generated.

- Remarks**
1.  $f_R$ : Ring-OSC clock oscillation frequency
  2.  $f_{XP}$ : X1 input clock oscillation frequency
  3. x: Don't care
  4. Figures in parentheses apply to operation at  $f_R = 480$  kHz (MAX.) (for standard products and (A) grade products),  $f_{XP} = 10$  MHz

**(2) Watchdog timer enable register (WDTE)**

Writing ACH to WDTE clears the watchdog timer counter and starts counting again.  
 This register can be set by an 8-bit memory manipulation instruction.  
 $\overline{\text{RESET}}$  input sets this register to 9AH.

**Figure 9-3. Format of Watchdog Timer Enable Register (WDTE)**



- ★ **Cautions** 1. If a value other than ACH is written to WDTE, an internal reset signal is generated. If the source clock to the watchdog timer is stopped, however, an internal reset signal is generated when the source clock to the watchdog timer resumes operation.
- ★ 2. If a 1-bit memory manipulation instruction is executed for WDTE, an internal reset signal is generated. If the source clock to the watchdog timer is stopped, however, an internal reset signal is generated when the source clock to the watchdog timer resumes operation.
- 3. The value read from WDTE is 9AH (this differs from the written value (ACH)).



The relationship between the watchdog timer operation and the internal reset signal generated by the watchdog timer is shown below.

★

**Table 9-4. Relationship Between Watchdog Timer Operation and Internal Reset Signal Generated by Watchdog Timer**

| Internal Reset Signal Generation Cause               | Watchdog Timer Operation<br>"Ring-OSC Cannot Be Stopped" Is Selected by Mask Option (Watchdog Timer Is Always Operating) | "Ring-OSC Can Be Stopped by Software" Is Selected by Mask Option |  |   |
|--|--|--|--|---|
|  |  | Watchdog Timer Is Operating                                      | Watchdog Timer Stopped   |   |
|  |  |  | WDCS4 Is Set to 1  | Source Clock to Watchdog Timer Is Stopped   |
| Watchdog timer overflows                             | Internal reset signal is generated.  | Internal reset signal is generated.                              | –  | –   |
| Write to WDTM for the second time                    | Internal reset signal is generated.  | Internal reset signal is generated.                              | Internal reset signal is not generated and the watchdog timer does not resume operation. | Internal reset signal is generated when the source clock to the watchdog timer resumes operation. |
| Write other than "ACH" to WDTE                       | Internal reset signal is generated.  | Internal reset signal is generated.                              | Internal reset signal is not generated.  | Internal reset signal is generated when the source clock to the watchdog timer resumes operation. |
| Access WDTE by 1-bit memory manipulation instruction |  |  |  |   |

## 9.4 Operation of Watchdog Timer

### 9.4.1 Watchdog timer operation when “Ring-OSC cannot be stopped” is selected by mask option

The operation clock of watchdog timer is fixed to Ring-OSC.

After reset is released, operation is started at the maximum cycle (bits 2, 1, and 0 (WDCS2, WDCS1, WDCS0) of the watchdog timer mode register (WDTM) = 1, 1, 1). The watchdog timer operation cannot be stopped.

The following shows the watchdog timer operation after reset release.

1. The status after reset release is as follows.
  - Operation clock: Ring-OSC clock
  - Cycle:  $2^{18}/f_R$  (546.13 ms: At operation with  $f_R = 480$  kHz (MAX.))
  - Counting starts
2. The following should be set in the watchdog timer mode register (WDTM) by an 8-bit memory manipulation instruction<sup>Notes 1, 2</sup>.
  - Cycle: Set using bits 2 to 0 (WDCS2 to WDCS0)
3. After the above procedures are executed, writing ACH to WDTE clears the count to 0, enabling recounting.

- Notes**
1. The operation clock (Ring-OSC clock) cannot be changed. If any value is written to bits 3 and 4 (WDCS3, WDCS4) of WDTM, it is ignored.
  2. As soon as WDTM is written, the counter of the watchdog timer is cleared.

**Caution** In this mode, operation of the watchdog timer absolutely cannot be stopped even during STOP instruction execution. For 8-bit timer H1 (TMH1), a division of the Ring-OSC can be selected as the count source, so after STOP instruction execution, clear the watchdog timer using the interrupt request of TMH1 before the watchdog timer overflows. If this processing is not performed, an internal reset signal is generated when the watchdog timer overflows after STOP instruction execution.

### 9.4.2 Watchdog timer operation when “Ring-OSC can be stopped by software” is selected by mask option

The operation clock of the watchdog timer can be selected as either the Ring-OSC clock or the X1 input clock.

After reset is released, operation is started at the maximum cycle (bits 2, 1, and 0 (WDCS2, WDCS1, WDCS0) of the watchdog timer mode register (WDTM) = 1, 1, 1) of the Ring-OSC clock.

The following shows the watchdog timer operation after reset release.

1. The status after reset release is as follows.
  - Operation clock: Ring-OSC clock
  - Cycle:  $2^{18}/f_R$  (546.13 ms: At operation with  $f_R = 480$  kHz (MAX.))
  - Counting starts
2. The following should be set in the watchdog timer mode register (WDTM) by an 8-bit memory manipulation instruction<sup>Notes 1, 2, 3</sup>.
  - Operation clock: Any of the following can be selected using bits 3 and 4 (WDCS3 and WDCS4).
    - Ring-OSC clock ( $f_R$ )
    - X1 input clock ( $f_{XP}$ )
    - Watchdog timer operation stopped
  - Cycle: Set using bits 2 to 0 (WDCS2 to WDCS0)
3. After the above procedures are executed, writing ACH to WDTE clears the count to 0, enabling recounting.

- Notes**
1. As soon as WDTM is written, the counter of the watchdog timer is cleared.
  2. Set bits 7, 6, and 5 to 0, 1, 1, respectively. These bits must not be set to other values.
  3. If the watchdog timer is stopped by setting WDCS4 and WDCS3 to 1 and  $\times$ , respectively, an internal reset signal is not generated even if the following processing is performed.
    - WDTM is written a second time.
    - A 1-bit memory manipulation instruction is executed to WDTE.
    - A value other than ACH is written to WDTE.

**Caution** In this mode, watchdog timer operation is stopped during HALT/STOP instruction execution. After HALT/STOP mode is released, counting is started again using the operation clock of the watchdog timer set before HALT/STOP instruction execution by WDTM. At this time, the counter is not cleared to 0 but holds its value.

For the watchdog timer operation during STOP mode and HALT mode in each status, see 9.4.3 Watchdog timer operation in STOP mode and 9.4.4 Watchdog timer operation in HALT mode.

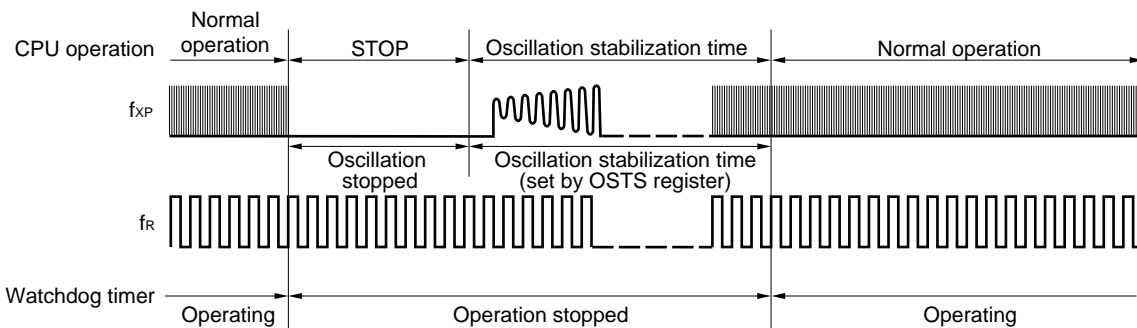
### 9.4.3 Watchdog timer operation in STOP mode (when “Ring-OSC can be stopped by software” is selected by mask option)

The watchdog timer stops counting during STOP instruction execution regardless of whether the X1 input clock or Ring-OSC clock is being used.

#### (1) When the CPU clock and the watchdog timer operation clock are the X1 input clock ( $f_{XP}$ ) when the STOP instruction is executed

When STOP instruction is executed, operation of the watchdog timer is stopped. After STOP mode is released, counting stops for the oscillation stabilization time set by the oscillation stabilization time select register (OSTS) and then counting is started again using the operation clock before the operation was stopped. At this time, the counter is not cleared to 0 but holds its value.

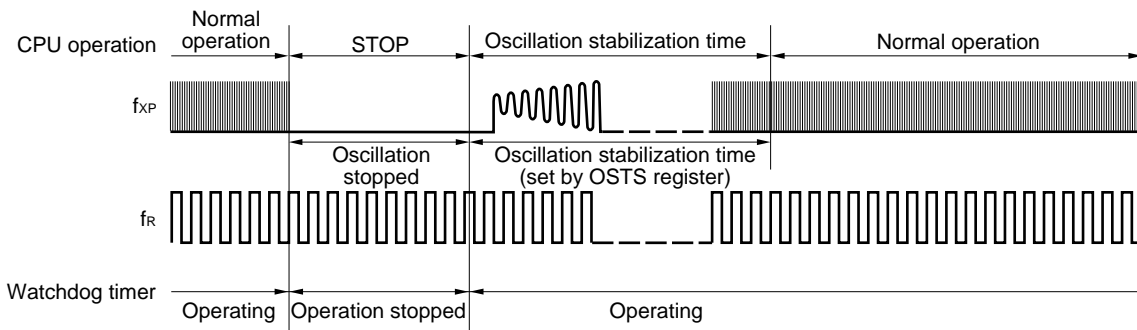
**Figure 9-4. Operation in STOP Mode (CPU Clock and WDT Operation Clock: X1 Input Clock)**



#### (2) When the CPU clock is the X1 input clock ( $f_{XP}$ ) and the watchdog timer operation clock is the Ring-OSC clock ( $f_R$ ) when the STOP instruction is executed

When the STOP instruction is executed, operation of the watchdog timer is stopped. After STOP mode is released, counting is started again using the operation clock before the operation was stopped. At this time, the counter is not cleared to 0 but holds its value.

**Figure 9-5. Operation in STOP Mode (CPU Clock: X1 Input Clock, WDT Operation Clock: Ring-OSC Clock)**



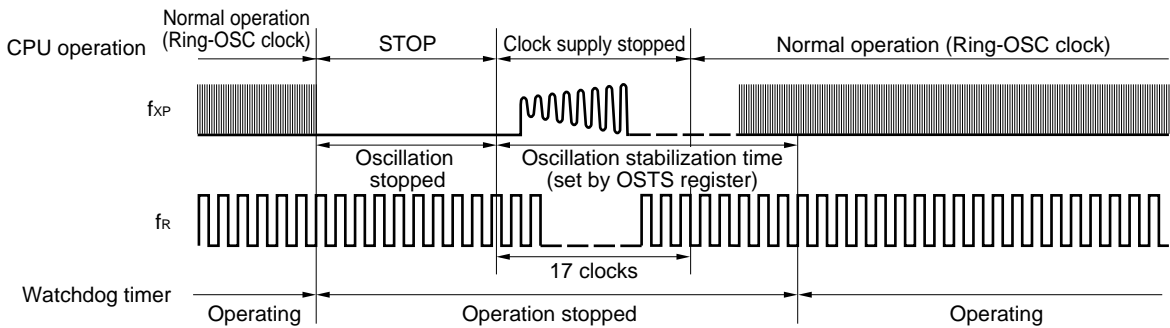
(3) When the CPU clock is the Ring-OSC clock ( $f_R$ ) and the watchdog timer operation clock is the X1 input clock ( $f_{XP}$ ) when the STOP instruction is executed

When the STOP instruction is executed, operation of the watchdog timer is stopped. After STOP mode is released, counting is stopped until the timing of <1> or <2>, whichever is earlier, and then counting is started using the operation clock before the operation was stopped. At this time, the counter is not cleared to 0 but holds its value.

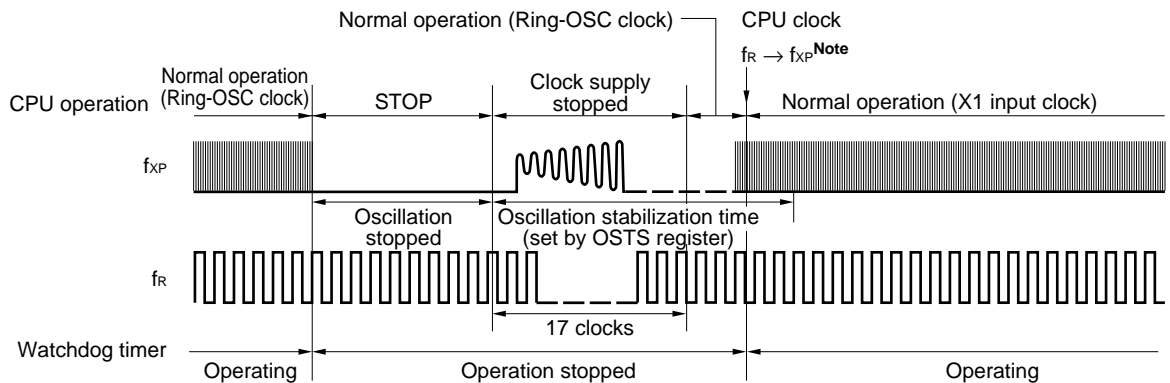
- <1> The oscillation stabilization time set by the oscillation stabilization time select register (OSTS) elapses.
- <2> The CPU clock is switched to the X1 input clock ( $f_{XP}$ ).

**Figure 9-6. Operation in STOP Mode**  
(CPU Clock: Ring-OSC Clock, WDT Operation Clock: X1 Input Clock)

- <1> Timing when counting is started after the oscillation stabilization time set by the oscillation stabilization time select register (OSTS) has elapsed



- <2> Timing when counting is started after the CPU clock is switched to the X1 input clock ( $f_{XP}$ )

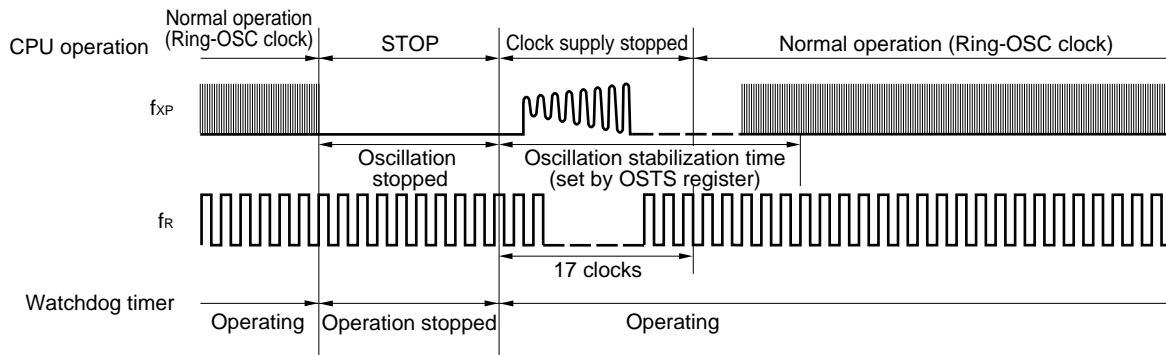


**Note** Confirm the oscillation stabilization time of  $f_{XP}$  using the oscillation stabilization time counter status register (OSTC).

**(4) When CPU clock and watchdog timer operation clock are the Ring-OSC clocks ( $f_R$ ) during STOP instruction execution**

When the STOP instruction is executed, operation of the watchdog timer is stopped. After STOP mode is released, counting is started again using the operation clock before the operation was stopped. At this time, the counter is not cleared to 0 but holds its value.

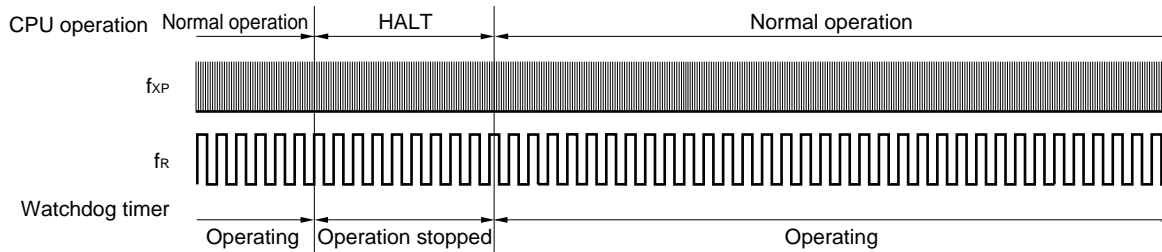
**Figure 9-7. Operation in STOP Mode (CPU Clock and WDT Operation Clock: Ring-OSC Clock)**



**9.4.4 Watchdog timer operation in HALT mode (when “Ring-OSC can be stopped by software” is selected by mask option)**

The watchdog timer stops counting during HALT instruction execution regardless of whether the CPU clock is the X1 input clock ( $f_{XP}$ ) or Ring-OSC clock ( $f_R$ ), or whether the operation clock of the watchdog timer is the X1 input clock ( $f_{XP}$ ) or Ring-OSC clock ( $f_R$ ). After HALT mode is released, counting is started again using the operation clock before the operation was stopped. At this time, the counter is not cleared to 0 but holds its value.

**Figure 9-8. Operation in HALT Mode**



## CHAPTER 10 A/D CONVERTER

### 10.1 Function of A/D Converter

The A/D converter converts an analog input signal into a digital value, and consists of up to four channels (ANI0 to ANI3) with a resolution of 10 bits.

The A/D converter has the following two functions.

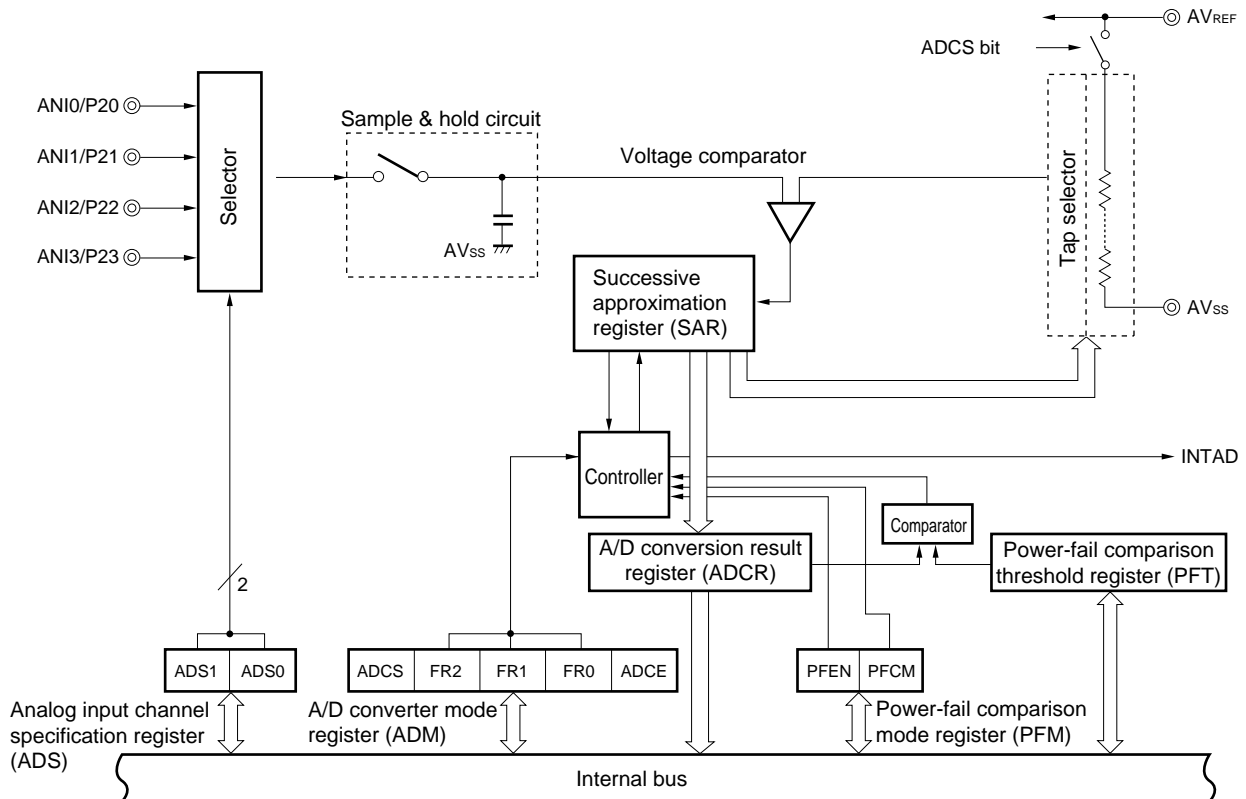
#### (1) 10-bit resolution A/D conversion

10-bit resolution A/D conversion is carried out repeatedly for one channel selected from analog inputs ANI0 to ANI3. Each time an A/D conversion operation ends, an interrupt request (INTAD) is generated.

#### (2) Power-fail detection function

This function is to detect a voltage drop in a battery. The values of the A/D conversion result (ADCR register value) and power-fail comparison threshold register (PFT) are compared. INTAD is generated only when a comparative condition has been matched.

Figure 10-1. Block Diagram of A/D Converter



## 10.2 Configuration of A/D Converter

The A/D converter includes the following hardware.

**Table 10-1. Registers of A/D Converter Used on Software**

| Item      | Configuration  |
|-----------|--|
| Registers | A/D conversion result register (ADCR)<br>A/D converter mode register (ADM)<br>Analog input channel specification register (ADS)<br>Power-fail comparison mode register (PFM)<br>Power-fail comparison threshold register (PFT) |

### (1) ANI0 to ANI3 pins

These are the analog input pins of the 4-channel A/D converter. They input analog signals to be converted into digital signals. Pins other than the one selected as the analog input pin by the analog input channel specification register (ADS) can be used as input port pins.

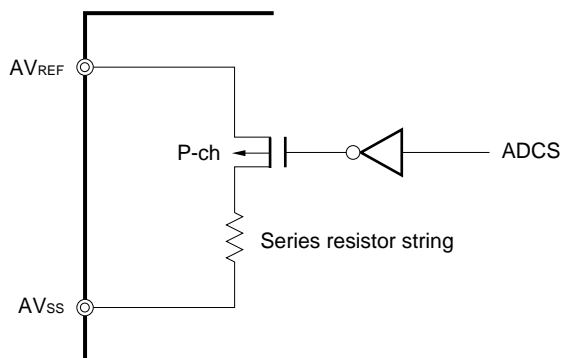
### (2) Sample & hold circuit

The sample & hold circuit samples the input signal of the analog input pin selected by the selector when A/D conversion is started, and holds the sampled analog input voltage value during A/D conversion.

### (3) Series resistor string

The series resistor string is connected between  $AV_{REF}$  and  $AV_{SS}$ , and generates a voltage to be compared with the analog input signal.

**Figure 10-2. Circuit Configuration of Series Resistor String**



### (4) Voltage comparator

The voltage comparator compares the sampled analog input voltage and the output voltage of the series resistor string.

### (5) Successive approximation register (SAR)

This register compares the sampled analog voltage and the voltage of the series resistor string, and converts the result, starting from the most significant bit (MSB).

When the voltage value is converted into a digital value down to the least significant bit (LSB) (end of A/D conversion), the contents of the SAR register are transferred to the A/D conversion result register (ADCR).



**(6) A/D conversion result register (ADCR)**

The result of A/D conversion is loaded from the successive approximation register (SAR) to this register each time A/D conversion is completed, and the ADCR register holds the result of A/D conversion in its higher 10 bits (the lower 6 bits are fixed to 0).

**(7) Controller**

When A/D conversion has been completed or when the power-fail detection function is used, this controller compares the result of A/D conversion (value of the ADCR register) and the value of the power-fail comparison threshold register (PFT). It generates the interrupt INTAD only if a specified comparison condition is satisfied as a result.

**(8) AV<sub>REF</sub> pin**

This pin inputs an analog power/reference voltage to the A/D converter. Always use this pin at the same potential as that of the V<sub>DD</sub> pin even when the A/D converter is not used.

The signal input to ANI0 to ANI3 is converted into a digital signal, based on the voltage applied across AV<sub>REF</sub> and AV<sub>SS</sub>.

**(9) AV<sub>SS</sub> pin**

This is the ground potential pin of the A/D converter. Always use this pin at the same potential as that of the V<sub>SS</sub> pin even when the A/D converter is not used.

**(10) A/D converter mode register (ADM)**

This register is used to set the conversion time of the analog input signal to be converted, and to start or stop the conversion operation.

**(11) Analog input channel specification register (ADS)**

This register is used to specify the port that inputs the analog voltage to be converted into a digital signal.

**(12) Power-fail comparison mode register (PFM)**

This register is used to set the power-fail monitor mode.

**(13) Power-fail comparison threshold register (PFT)**

This register is used to set the threshold value that is to be compared with the value of the A/D conversion result register (ADCR).

### 10.3 Registers Used in A/D Converter

The A/D converter uses the following five registers.

- A/D converter mode register (ADM)
- Analog input channel specification register (ADS)
- A/D conversion result register (ADCR)
- Power-fail comparison mode register (PFM)
- Power-fail comparison threshold register (PFT)

#### (1) A/D converter mode register (ADM)

This register sets the conversion time for analog input to be A/D converted, and starts/stops conversion.

ADM can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 10-3. Format of A/D Converter Mode Register (ADM)**

Address: FF28H After reset: 00H R/W

|        |      |   |     |     |     |   |   |      |
|--------|------|---|-----|-----|-----|---|---|------|
| Symbol | <7>  | 6 | 5   | 4   | 3   | 2 | 1 | <0>  |
| ADM    | ADCS | 0 | FR2 | FR1 | FR0 | 0 | 0 | ADCE |

|      |                                  |
|------|----------------------------------|
| ADCS | A/D conversion operation control |
| 0    | Stops conversion operation       |
| 1    | Enables conversion operation     |

| FR2              | FR1 | FR0 | Conversion time selection <sup>Note 1</sup> |                          |                        |                    |
|------------------|-----|-----|---|--------------------------|------------------------|--------------------|
|                  |     |     | $f_x = 2 \text{ MHz}$                       | $f_x = 8.38 \text{ MHz}$ | $f_x = 10 \text{ MHz}$ |                    |
| 0                | 0   | 0   | 288/ $f_x$                                  | 144 $\mu\text{s}$        | 34.3 $\mu\text{s}$     | 28.8 $\mu\text{s}$ |
| 0                | 0   | 1   | 240/ $f_x$                                  | 120 $\mu\text{s}$        | 28.6 $\mu\text{s}$     | 24.0 $\mu\text{s}$ |
| 0                | 1   | 0   | 192/ $f_x$                                  | 96 $\mu\text{s}$         | 22.9 $\mu\text{s}$     | 19.2 $\mu\text{s}$ |
| 1                | 0   | 0   | 144/ $f_x$                                  | 72 $\mu\text{s}$         | 17.2 $\mu\text{s}$     | 14.4 $\mu\text{s}$ |
| 1                | 0   | 1   | 120/ $f_x$                                  | 60 $\mu\text{s}$         | 14.3 $\mu\text{s}$     | 12.0 $\mu\text{s}$ |
| 1                | 1   | 0   | 96/ $f_x$                                   | 48 $\mu\text{s}$         | 11.5 $\mu\text{s}$     | 9.6 $\mu\text{s}$  |
| Other than above |     |     | Setting prohibited                          |                          |                        |                    |

|      |   |
|------|---|
| ADCE | Boost reference voltage generator operation control <sup>Note 2</sup> |
| 0    | Stops operation of reference voltage generator                        |
| 1    | Enables operation of reference voltage generator                      |

**Notes 1.** Set so that the A/D conversion time is as follows.

- Standard products, (A) grade products: 14  $\mu\text{s}$  or longer but less than 100  $\mu\text{s}$
- (A1) grade products: 14  $\mu\text{s}$  or longer but less than 60  $\mu\text{s}$
- (A2) grade products: 16  $\mu\text{s}$  or longer but less than 48  $\mu\text{s}$

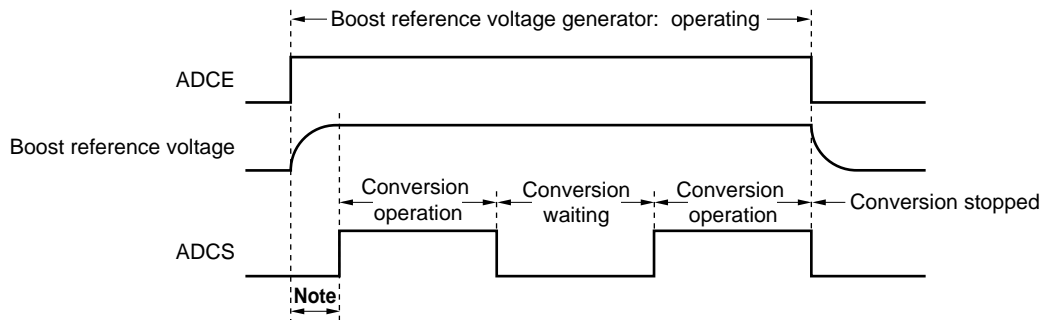
**Notes 2.** A booster circuit is incorporated to realize low-voltage operation. The operation of the circuit that generates the reference voltage for boosting is controlled by ADCE, and it takes 14  $\mu\text{s}$  from operation start to operation stabilization. Therefore, when ADCS is set to 1 after 14  $\mu\text{s}$  or more has elapsed from the time ADCE is set to 1, the conversion result at that time has priority over the first conversion result.

**Table 10-2. Settings of ADCS and ADCE**

| ADCS | ADCE | A/D Conversion Operation   |
|------|------|--|
| 0    | 0    | Stop status (DC power consumption path does not exist)                           |
| 0    | 1    | Conversion waiting mode (only reference voltage generator consumes power)        |
| 1    | 0    | Conversion mode (reference voltage generator operation stopped <sup>Note</sup> ) |
| 1    | 1    | Conversion mode (reference voltage generator operates)                           |

**Note** Data of first conversion cannot be used.

**Figure 10-4. Timing Chart When Boost Reference Voltage Generator Is Used**



**Note** The time from the rising of the ADCE bit to the rising of the ADCS bit must be 14  $\mu\text{s}$  or longer to stabilize the reference voltage.

- Cautions**
1. A/D conversion must be stopped before rewriting bits FR0 to FR2 to values other than the identical data.
  2. For the sampling time of the A/D converter and the A/D conversion start delay time, see (11) in 10.6 Cautions for A/D Converter.
  3. If data is written to ADM, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.

**Remark** fx: X1 input clock oscillation frequency

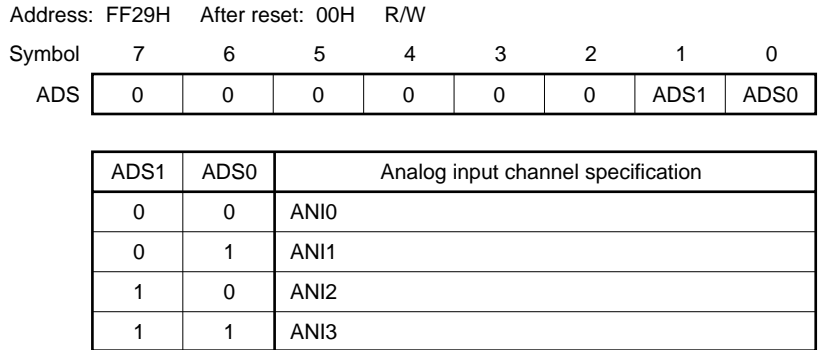
**(2) Analog input channel specification register (ADS)**

This register specifies the analog voltage input port to be A/D converted.

ADS can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears this register to 00H.

**Figure 10-5. Format of Analog Input Channel Specification Register (ADS)**



**Cautions 1. Be sure to clear bits 2 to 7 of ADS to 0.**

**2. If data is written to ADS, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.**

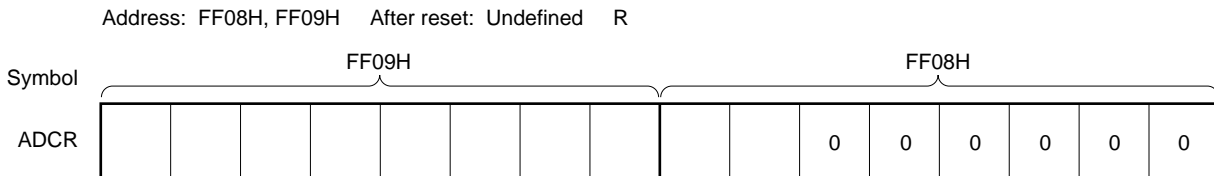
**(3) A/D conversion result register (ADCR)**

This register is a 16-bit register that stores the A/D conversion result. The lower six bits are fixed to 0. Each time A/D conversion ends, the conversion result is loaded from the successive approximation register, and is stored in ADCR in order starting from the most significant bit (MSB). FF09H indicates the higher 8 bits of the conversion result, and FF08H indicates the lower 2 bits of the conversion result.

ADCR can be read by a 16-bit memory manipulation instruction.

RESET input makes ADCR undefined.

**Figure 10-6. Format of A/D Conversion Result Register (ADCR)**



**Cautions 1. When writing to the A/D converter mode register (ADM) and analog input channel specification register (ADS), the contents of ADCR may become undefined. Read the conversion result following conversion completion before writing to ADM and ADS. Using timing other than the above may cause an incorrect conversion result to be read.**

**2. If data is read from ADCR, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.**

**(4) Power-fail comparison mode register (PFM)**

The power-fail comparison mode register (PFM) is used to compare the A/D conversion result (value of the ADCR register) and the value of the power-fail comparison threshold value register (PFT).

PFM can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 10-7. Format of Power-Fail Comparison Mode Register (PFM)**

Address: FF2AH    After reset: 00H    R/W

|        |      |      |   |   |   |   |   |   |
|--------|------|------|---|---|---|---|---|---|
| Symbol | <7>  | <6>  | 5 | 4 | 3 | 2 | 1 | 0 |
| PFM    | PFEN | PFCM | 0 | 0 | 0 | 0 | 0 | 0 |

|      |   |
|------|---|
| PFEN | Power-fail comparison enable                                  |
| 0    | Stops power-fail comparison (used as a normal A/D converter)  |
| 1    | Enables power-fail comparison (used for power-fail detection) |

| PFCM |                                  | Power-fail comparison mode selection        |
|------|----------------------------------|---|
| 0    | Higher 8 bits of ADCR $\geq$ PFT | Interrupt request signal (INTAD) generation |
|      | Higher 8 bits of ADCR $<$ PFT    | No INTAD generation                         |
| 1    | Higher 8 bits of ADCR $\geq$ PFT | No INTAD generation                         |
|      | Higher 8 bits of ADCR $<$ PFT    | INTAD generation                            |

**Caution** If data is written to PFM, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.

**(5) Power-fail comparison threshold register (PFT)**

The power-fail comparison threshold register (PFT) is a register that sets the threshold value when comparing the values with the A/D conversion result.

8-bit data in PFT is compared to the higher 8 bits (FF09H) of the 10-bit A/D conversion result.

PFT can be set by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 10-8. Format of Power-Fail Comparison Threshold Register (PFT)**

Address: FF2BH    After reset: 00H    R/W

|        |      |      |      |      |      |      |      |      |
|--------|------|------|------|------|------|------|------|------|
| Symbol | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PFT    | PFT7 | PFT6 | PFT5 | PFT4 | PFT3 | PFT2 | PFT1 | PFT0 |

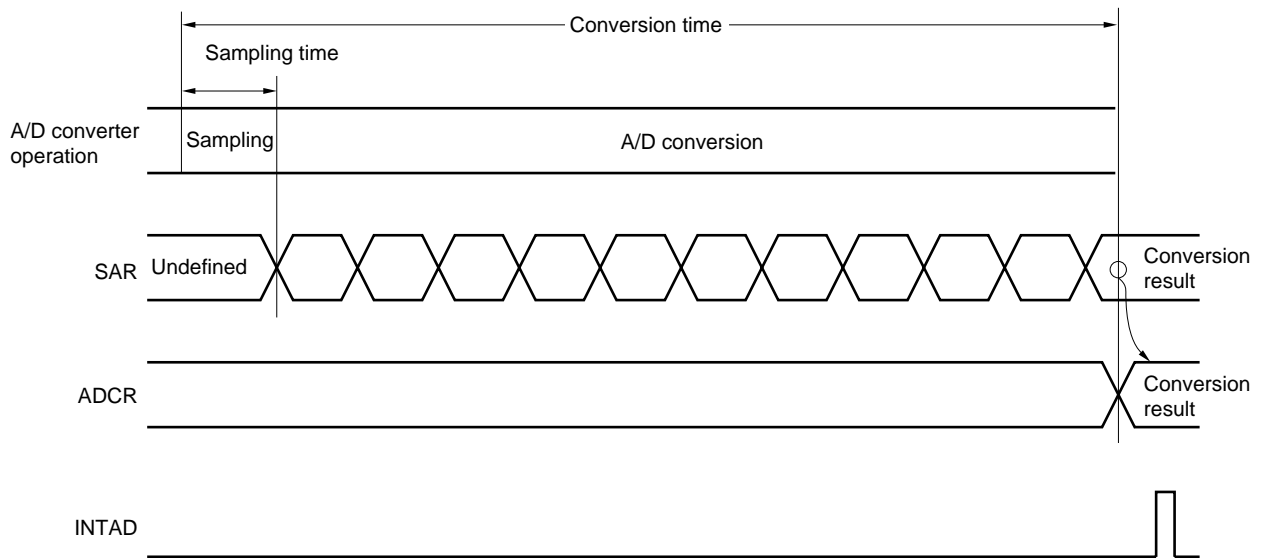
**Caution** If data is written to PFT, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.

## 10.4 A/D Converter Operations

### 10.4.1 Basic operations of A/D converter

- <1> Select one channel for A/D conversion using the analog input channel specification register (ADS).
- <2> Set ADCE to 1 and wait for 14  $\mu$ s or longer.
- <3> Set ADCS to 1 and start the conversion operation.  
(<4> to <10> are operations performed by hardware.)
- <4> The voltage input to the selected analog input channel is sampled by the sample & hold circuit.
- <5> When sampling has been done for a certain time, the sample & hold circuit is placed in the hold state and the input analog voltage is held until the A/D conversion operation has ended.
- <6> Bit 9 of the successive approximation register (SAR) is set. The series resistor string voltage tap is set to  $(1/2) AV_{REF}$  by the tap selector.
- <7> The voltage difference between the series resistor string voltage tap and analog input is compared by the voltage comparator. If the analog input is greater than  $(1/2) AV_{REF}$ , the MSB of SAR remains set to 1. If the analog input is smaller than  $(1/2) AV_{REF}$ , the MSB is reset to 0.
- <8> Next, bit 8 of SAR is automatically set to 1, and the operation proceeds to the next comparison. The series resistor string voltage tap is selected according to the preset value of bit 9, as described below.
  - Bit 9 = 1:  $(3/4) AV_{REF}$
  - Bit 9 = 0:  $(1/4) AV_{REF}$The voltage tap and analog input voltage are compared and bit 8 of SAR is manipulated as follows.
  - Analog input voltage  $\geq$  Voltage tap: Bit 8 = 1
  - Analog input voltage < Voltage tap: Bit 8 = 0
- <9> Comparison is continued in this way up to bit 0 of SAR.
- <10> Upon completion of the comparison of 10 bits, an effective digital result value remains in SAR, and the result value is transferred to the A/D conversion result register (ADCR) and then latched.  
At the same time, the A/D conversion end interrupt request (INTAD) can also be generated.
- <11> Repeat steps <4> to <10>, until ADCS is cleared to 0.  
To stop the A/D converter, clear ADCS to 0.  
To restart A/D conversion from the status of ADCE = 1, start from <3>. To restart A/D conversion from the status of ADCE = 0, however, start from <2>.

Figure 10-9. Basic Operation of A/D Converter



A/D conversion operations are performed continuously until bit 7 (ADCS) of the A/D converter mode register (ADM) is reset (0) by software.

If any of ADM, the analog input channel specification register (ADS), power-fail comparison mode register (PFM), or power-fail comparison threshold register (PFT) is written during an A/D conversion operation, the conversion operation is initialized, and if the ADCS bit is set (1), conversion starts again from the beginning.

$\overline{\text{RESET}}$  input makes the A/D conversion result register (ADCR) undefined.

**10.4.2 Input voltage and conversion results**

The relationship between the analog input voltage input to the analog input pins (ANI0 to ANI3) and the theoretical A/D conversion result (stored in the A/D conversion result register (ADCR)) is shown by the following expression.

$$SAR = INT \left( \frac{V_{AIN}}{AV_{REF}} \times 1024 + 0.5 \right)$$

$$ADCR = SAR \times 64$$

or

$$(ADCR - 0.5) \times \frac{AV_{REF}}{1024} \leq V_{AIN} < (ADCR + 0.5) \times \frac{AV_{REF}}{1024}$$

where, INT( ): Function which returns integer part of value in parentheses

$V_{AIN}$ : Analog input voltage

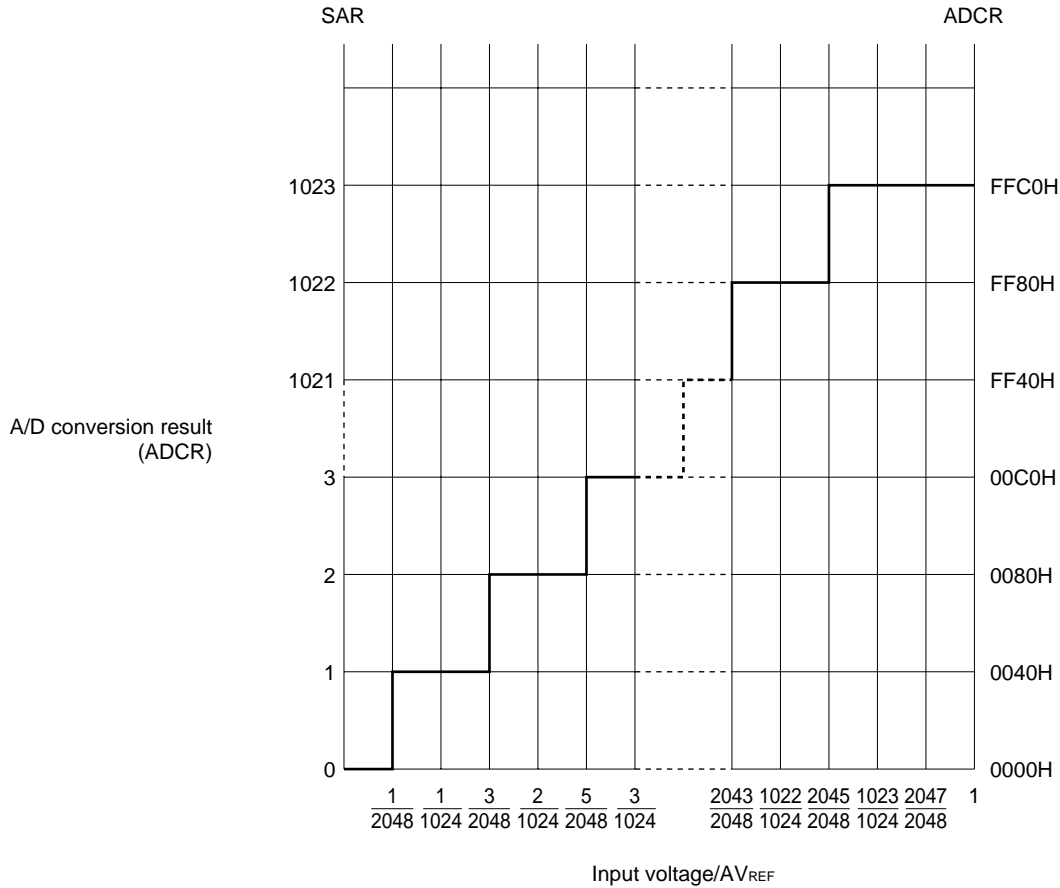
$AV_{REF}$ :  $AV_{REF}$  pin voltage

ADCR: A/D conversion result register (ADCR) value

SAR: Successive approximation register

Figure 10-10 shows the relationship between the analog input voltage and the A/D conversion result.

**Figure 10-10. Relationship Between Analog Input Voltage and A/D Conversion Result**





### 10.4.3 A/D converter operation mode

The operation mode of the A/D converter is the select mode. One analog input channel is selected from ANI0 to ANI3 by the analog input channel specification register (ADS) and A/D conversion is executed.

In addition, the following two functions can be selected by setting bit 7 (PFEN) of the power-fail comparison mode register (PFM).

- Normal 10-bit A/D converter (PFEN = 0)
- Power-fail detection function (PFEN = 1)

#### (1) A/D conversion operation (when PFEN = 0)

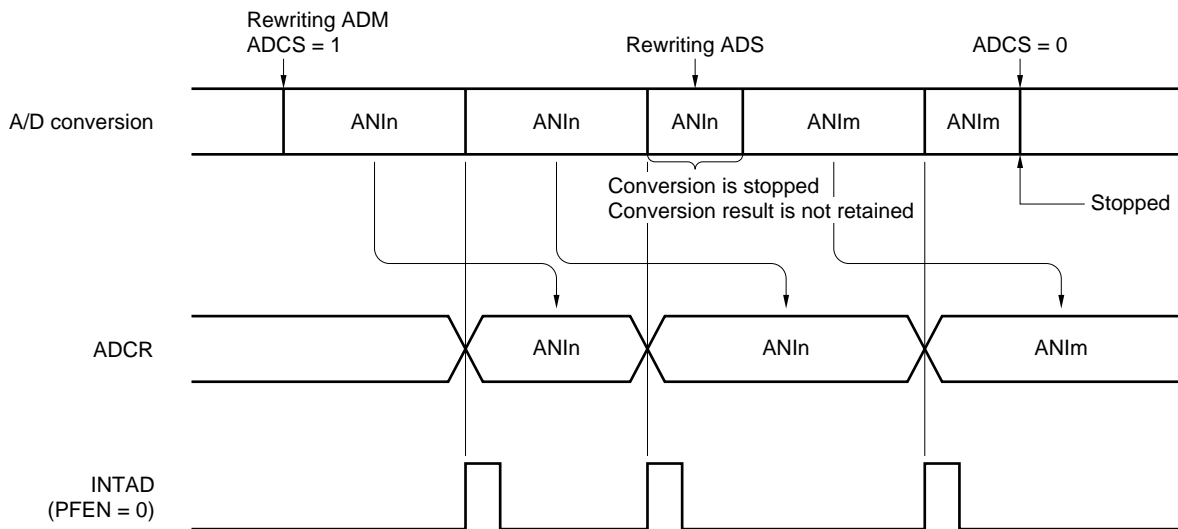
By setting bit 7 (ADCS) of the A/D converter mode register (ADM) to 1 and bit 7 (PFEN) of the power-fail comparison mode register (PFM) to 0, A/D conversion of the voltage applied to the analog input pin specified by the analog input channel specification register (ADS) is started.

When A/D conversion has been completed, the result of the A/D conversion is stored in the A/D conversion result register (ADCR), and an interrupt request signal (INTAD) is generated. Once the next A/D conversion has started and when one A/D conversion has been completed, the A/D conversion operation after that is immediately started. The A/D conversion operations are repeated until new data is written to ADS.

If ADM, ADS, the power-fail comparison mode register (PFM), and the power-fail comparison threshold register (PFT) are rewritten during A/D conversion, the A/D conversion operation under execution is stopped and restarted from the beginning.

If 0 is written to ADCS during A/D conversion, A/D conversion is immediately stopped. At this time, the conversion result is undefined.

Figure 10-11. A/D Conversion Operation



- Remarks 1.** n = 0 to 3  
**2.** m = 0 to 3

**(2) Power-fail detection function (when PFEN = 1)**

By setting bit 7 (ADCS) of the A/D converter mode register (ADM) to 1 and bit 7 (PFEN) of the power-fail comparison mode register (PFM) to 1, the A/D conversion operation of the voltage applied to the analog input pin specified by the analog input channel specification register (ADS) is started.

When the A/D conversion has been completed, the result of the A/D conversion is stored in the A/D conversion result register (ADCR), the values are compared with power-fail comparison threshold register (PFT), and an interrupt request signal (INTAD) is generated under the condition specified by bit 6 (PFCM) of PFM.

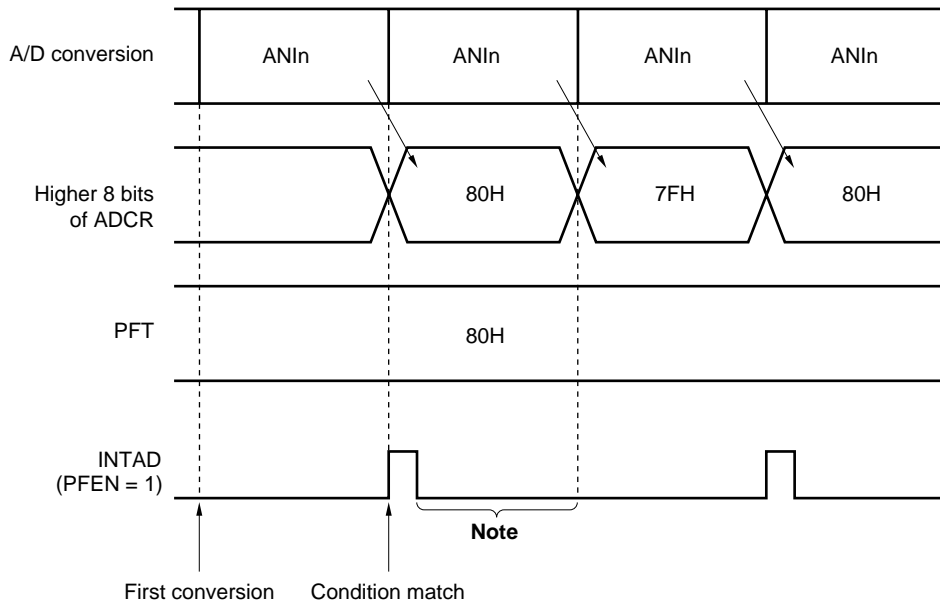
<1> When PFEN = 1 and PFCM = 0

The higher 8 bits of ADCR and PFT values are compared when A/D conversion ends and INTAD is only generated when the higher 8 bits of ADCR  $\geq$  PFT.

<2> When PFEN = 1 and PFCM = 1

The higher 8 bits of ADCR and PFT values are compared when A/D conversion ends and INTAD is only generated when the higher 8 bits of ADCR  $<$  PFT.

**Figure 10-12. Power-Fail Detection (When PFEN = 1 and PFCM = 0)**



**Note** If the conversion result is not read before the end of the next conversion after INTAD is output, the result is replaced by the next conversion result.

**Remark** n = 0 to 3

The setting methods are described below.

- When used as A/D conversion operation
  - <1> Set bit 0 (ADCE) of the A/D converter mode register (ADM) to 1.
  - <2> Select the channel and conversion time using bits 1 and 0 (ADS1 and ADS0) of the analog input channel specification register (ADS) and bits 5 to 3 (FR2 to FR0) of ADM.
  - <3> Set bit 7 (ADCS) of ADM to 1.
  - <4> An interrupt request signal (INTAD) is generated.
  - <5> Transfer the A/D conversion data to the A/D conversion result register (ADCR).

<Change the channel>

  - <6> Change the channel using bits 1 and 0 (ADS1 and ADS0) of ADS.
  - <7> An interrupt request signal (INTAD) is generated.
  - <8> Transfer the A/D conversion data to the A/D conversion result register (ADCR).

<Complete A/D conversion>

  - <9> Clear ADCS to 0.
  - <10> Clear ADCE to 0.

- Cautions**
1. Make sure the period of <1> to <3> is 14  $\mu$ s or more.
  2. It is no problem if the order of <1> and <2> is reversed.
  3. <1> can be omitted. However, do not use the first conversion result after <3> in this case.
  4. The period from <4> to <7> differs from the conversion time set using bits 5 to 3 (FR2 to FR0) of ADM. The period from <6> to <7> is the conversion time set using FR2 to FR0.

- When used as power-fail detection function
  - <1> Set bit 7 (PFEN) of the power-fail comparison mode register (PFM) to 1.
  - <2> Set power-fail comparison condition using bit 6 (PFCM) of PFM.
  - <3> Set bit 0 (ADCE) of the A/D converter mode register (ADM) to 1.
  - <4> Select the channel and conversion time using bits 1 and 0 (ADS1 and ADS0) of the analog input channel specification register (ADS) and bits 5 to 3 (FR2 to FR0) of ADM.
  - <5> Set a threshold value to the power-fail comparison threshold register (PFT).
  - <6> Set bit 7 (ADCS) of ADM to 1.
  - <7> Transfer the A/D conversion data to the A/D conversion result register (ADCR).
  - <8> The higher 8 bits of ADCR and PFT are compared and an interrupt request signal (INTAD) is generated if the conditions match.

<Change the channel>

  - <9> Change the channel using bits 1 and 0 (ADS1 and ADS0) of ADS.
  - <10> Transfer the A/D conversion data to the A/D conversion result register (ADCR).
  - <11> The higher 8 bits of ADCR and the power-fail comparison threshold register (PFT) are compared and an interrupt request signal (INTAD) is generated if the conditions match.

<Complete A/D conversion>

  - <12> Clear ADCS to 0.
  - <13> Clear ADCE to 0.

- Cautions**
1. Make sure the period of <3> to <6> is 14  $\mu$ s or more.
  2. It is no problem if the order of <3>, <4>, and <5> is changed.
  3. <3> must not be omitted if the power-fail function is used.
  4. The period from <7> to <11> differs from the conversion time set using bits 5 to 3 (FR2 to FR0) of ADM. The period from <9> to <11> is the conversion time set using FR2 to FR0.

### 10.5 How to Read A/D Converter Characteristics Table

Here, special terms unique to the A/D converter are explained.

#### (1) Resolution

This is the minimum analog input voltage that can be identified. That is, the percentage of the analog input voltage per bit of digital output is called 1LSB (Least Significant Bit). The percentage of 1LSB with respect to the full scale is expressed by %FSR (Full Scale Range).

1LSB is as follows when the resolution is 10 bits.

$$1\text{LSB} = 1/2^{10} = 1/1024$$

$$= 0.098\%\text{FSR}$$

Accuracy has no relation to resolution, but is determined by overall error.

#### (2) Overall error

This shows the maximum error value between the actual measured value and the theoretical value.

Zero-scale error, full-scale error, integral linearity error, and differential linearity errors that are combinations of these express the overall error.

Note that the quantization error is not included in the overall error in the characteristics table.

#### (3) Quantization error

When analog values are converted to digital values, a  $\pm 1/2\text{LSB}$  error naturally occurs. In an A/D converter, an analog input voltage in a range of  $\pm 1/2\text{LSB}$  is converted to the same digital code, so a quantization error cannot be avoided.

Note that the quantization error is not included in the overall error, zero-scale error, full-scale error, integral linearity error, and differential linearity error in the characteristics table.

Figure 10-13. Overall Error

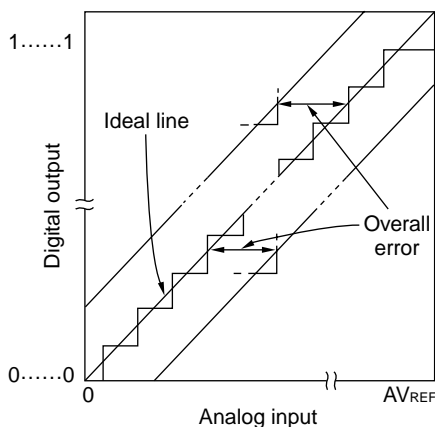
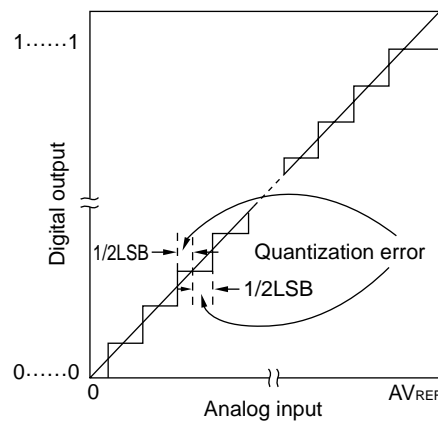


Figure 10-14. Quantization Error



**(4) Zero-scale error**

This shows the difference between the actual measurement value of the analog input voltage and the theoretical value (1/2LSB) when the digital output changes from 0.....000 to 0.....001.

If the actual measurement value is greater than the theoretical value, it shows the difference between the actual measurement value of the analog input voltage and the theoretical value (3/2LSB) when the digital output changes from 0.....001 to 0.....010.

**(5) Full-scale error**

This shows the difference between the actual measurement value of the analog input voltage and the theoretical value (Full-scale – 3/2LSB) when the digital output changes from 1.....110 to 1.....111.

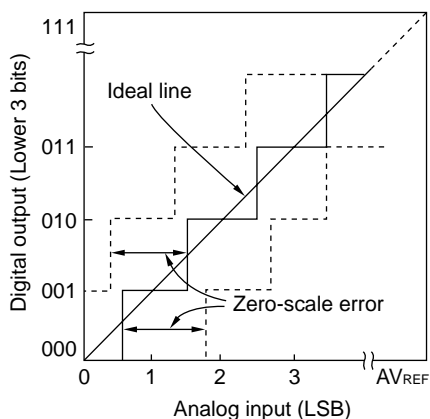
**(6) Integral linearity error**

This shows the degree to which the conversion characteristics deviate from the ideal linear relationship. It expresses the maximum value of the difference between the actual measurement value and the ideal straight line when the zero-scale error and full-scale error are 0.

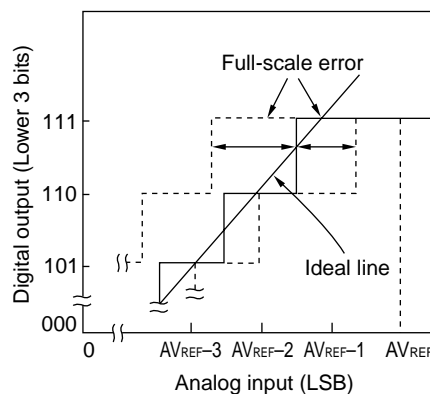
**(7) Differential linearity error**

While the ideal width of code output is 1LSB, this indicates the difference between the actual measurement value and the ideal value.

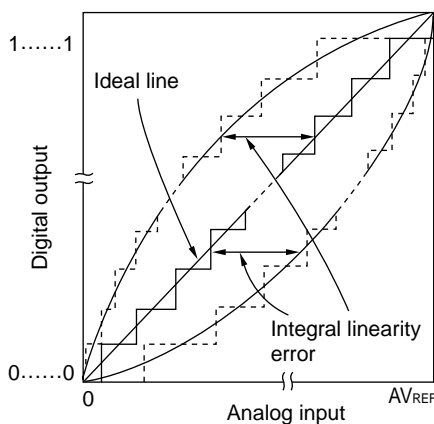
**Figure 10-15. Zero-Scale Error**



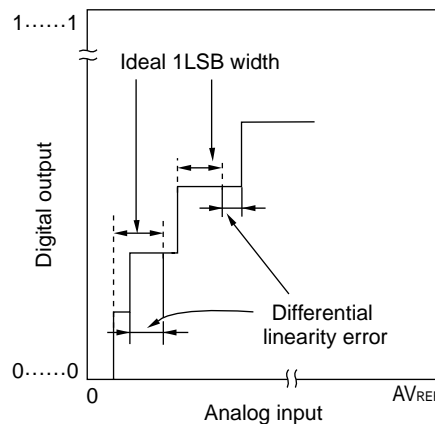
**Figure 10-16. Full-Scale Error**



**Figure 10-17. Integral Linearity Error**



**Figure 10-18. Differential Linearity Error**



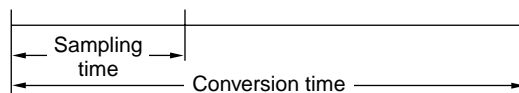
**(8) Conversion time**

This expresses the time since sampling has been started until digital output is obtained.

The sampling time is included in the conversion time in the characteristics table.

**(9) Sampling time**

This is the time the analog switch is turned on for the analog voltage to be sampled by the sample & hold circuit.

**10.6 Cautions for A/D Converter****(1) Operating current in standby mode**

The A/D converter stops operating in the standby mode. At this time, the operating current can be reduced by clearing bit 7 (ADCS) of the A/D converter mode register (ADM) to 0 (see **Figure 10-2**).

**(2) Input range of ANI0 to ANI3**

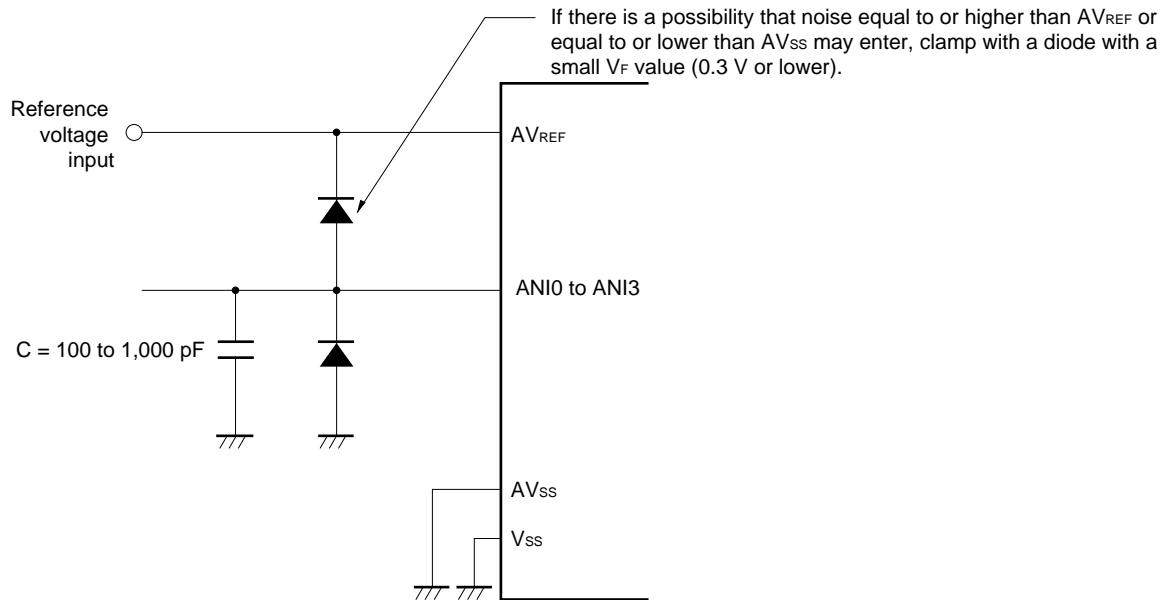
Observe the rated range of the ANI0 to ANI3 input voltage. If a voltage of  $V_{REF}$  or higher and  $V_{SS}$  or lower (even in the range of absolute maximum ratings) is input to an analog input channel, the converted value of that channel becomes undefined. In addition, the converted values of the other channels may also be affected.

**(3) Conflicting operations**

- <1> Conflict between A/D conversion result register (ADCR) write and ADCR read by instruction upon the end of conversion  
ADCR read has priority. After the read operation, the new conversion result is written to ADCR.
- <2> Conflict between ADCR write and A/D converter mode register (ADM) write or analog input channel specification register (ADS) write upon the end of conversion  
ADM or ADS write has priority. ADCR write is not performed, nor is the conversion end interrupt signal (INTAD) generated.

**(4) Noise countermeasures**

To maintain the 10-bit resolution, attention must be paid to noise input to the  $AV_{REF}$  and ANI0 to ANI3 pins. Because the effect increases in proportion to the output impedance of the analog input source, it is recommended that a capacitor be connected externally, as shown in Figure 10-19, to reduce noise.

**Figure 10-19. Analog Input Pin Connection****(5) ANI0/P20 to ANI3/P23**

<1> The analog input pins (ANI0 to ANI3) are also used as input port pins (P20 to P23).

When A/D conversion is performed with any of ANI0 to ANI3 selected, do not access port 2 while conversion is in progress; otherwise the conversion resolution may be degraded.

<2> If a digital pulse is applied to the pins adjacent to the pins currently being used for A/D conversion, the expected value of the A/D conversion may not be obtained due to coupling noise. Therefore, do not apply a pulse to the pins adjacent to the pin undergoing A/D conversion.

**(6) Input impedance of ANI0 to ANI3 pins**

In this A/D converter, the internal sampling capacitor is charged and sampling is performed for approx. one sixth of the conversion time.

Since only the leakage current flows other than during sampling and the current for charging the capacitor also flows during sampling, the input impedance fluctuates and has no meaning.

To perform sufficient sampling, however, it is recommended to make the output impedance of the analog input source 10 k $\Omega$  or lower, or attach a capacitor of around 100 pF to the ANI0 to ANI3 pins (see **Figure 10-19**).

**(7)  $AV_{REF}$  pin input impedance**

A series resistor string of several tens of k $\Omega$  is connected between the  $AV_{REF}$  and  $AV_{SS}$  pins.

Therefore, if the output impedance of the reference voltage source is high, this will result in a series connection to the series resistor string between the  $AV_{REF}$  and  $AV_{SS}$  pins, resulting in a large reference voltage error.

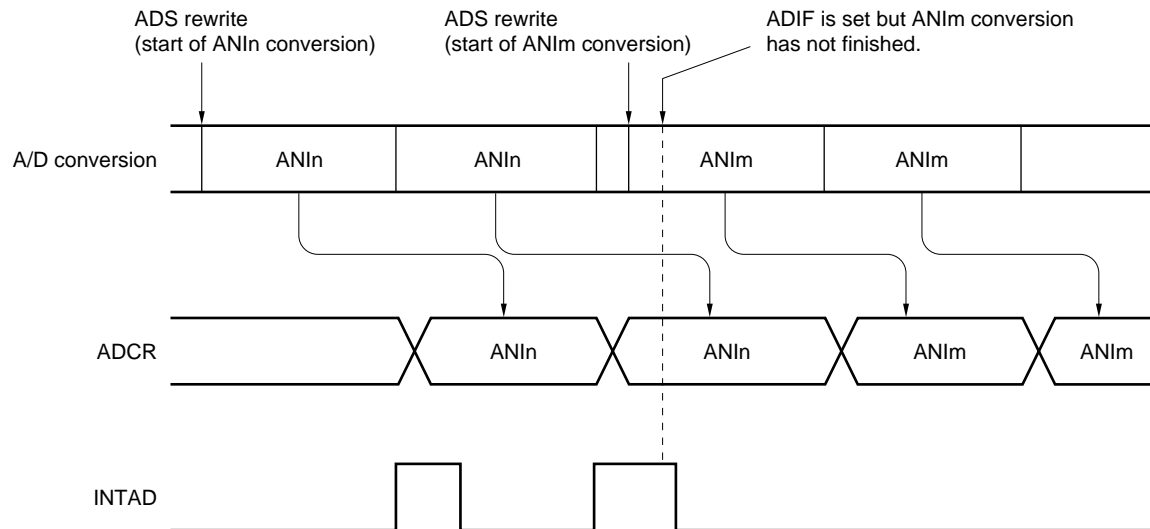
**(8) Interrupt request flag (ADIF)**

The interrupt request flag (ADIF) is not cleared even if the analog input channel specification register (ADS) is changed.

Therefore, if an analog input pin is changed during A/D conversion, the A/D conversion result and ADIF for the pre-change analog input may be set just before the ADS rewrite. Caution is therefore required since, at this time, when ADIF is read immediately after the ADS rewrite, ADIF is set despite the fact A/D conversion for the post-change analog input has not finished.

When A/D conversion is stopped and then resumed, clear ADIF before the A/D conversion operation is resumed.

**Figure 10-20. Timing of A/D Conversion End Interrupt Request Generation**



**Remarks 1.**  $n = 0$  to 3

**2.**  $m = 0$  to 3

**(9) Conversion results just after A/D conversion start**

The first A/D conversion value immediately after A/D conversion starts may not fall within the rating range if the ADCS bit is set to 1 within  $14 \mu\text{s}$  after the ADCE bit was set to 1, or if the ADCS bit is set to 1 with the ADCE bit = 0. Take measures such as polling the A/D conversion end interrupt request (INTAD) and removing the first conversion result.

**(10) A/D conversion result register (ADCR) read operation**

When a write operation is performed to the A/D converter mode register (ADM) and analog input channel specification register (ADS), the contents of ADCR may become undefined. Read the conversion result following conversion completion before writing to ADM and ADS. Using a timing other than the above may cause an incorrect conversion result to be read.

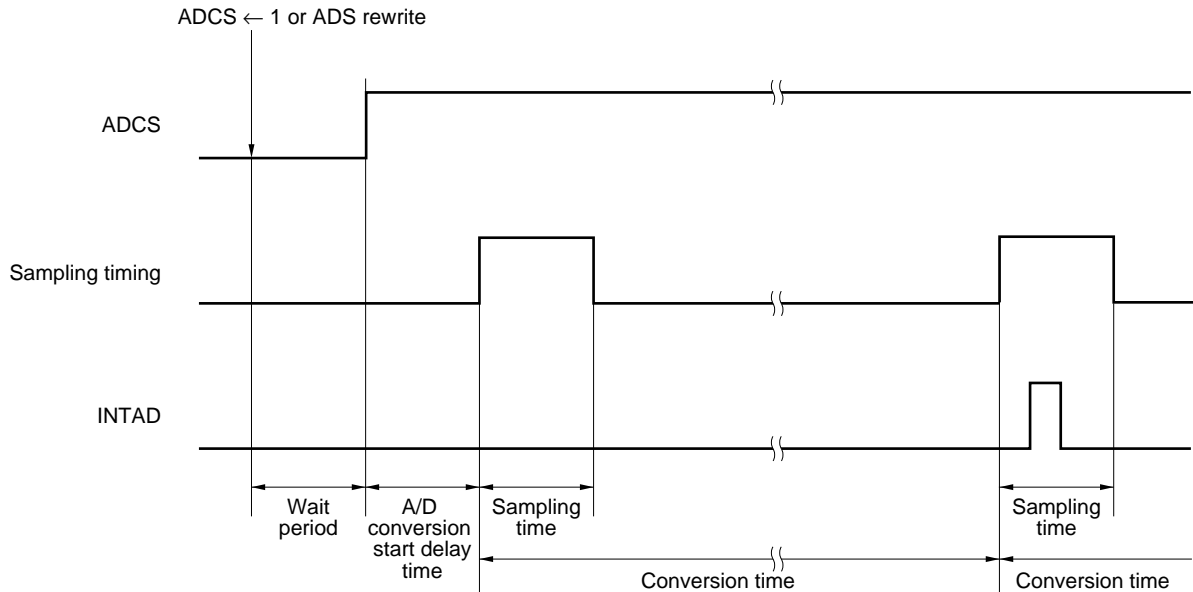


**(11) A/D converter sampling time and A/D conversion start delay time**

The A/D converter sampling time differs depending on the set value of the A/D converter mode register (ADM). A delay time exists until actual sampling is started after A/D converter operation is enabled.

When using a set in which the A/D conversion time must be strictly observed, care is required regarding the contents shown in Figure 10-21 and Table 10-3.

**Figure 10-21. Timing of A/D Converter Sampling and A/D Conversion Start Delay**



**Table 10-3. A/D Converter Sampling Time and A/D Conversion Start Delay Time (ADM Set Value)**

| FR2              | FR1 | FR0 | Conversion Time    | Sampling Time     | A/D Conversion Start Delay Time <sup>Note</sup> |                   |
|------------------|-----|-----|--------------------|-------------------|---|-------------------|
|                  |     |     |                    |                   | MIN.  | MAX.              |
| 0                | 0   | 0   | 288/f <sub>x</sub> | 40/f <sub>x</sub> | 32/f <sub>x</sub>                               | 36/f <sub>x</sub> |
| 0                | 0   | 1   | 240/f <sub>x</sub> | 32/f <sub>x</sub> | 28/f <sub>x</sub>                               | 32/f <sub>x</sub> |
| 0                | 1   | 0   | 192/f <sub>x</sub> | 24/f <sub>x</sub> | 24/f <sub>x</sub>                               | 28/f <sub>x</sub> |
| 1                | 0   | 0   | 144/f <sub>x</sub> | 20/f <sub>x</sub> | 16/f <sub>x</sub>                               | 18/f <sub>x</sub> |
| 1                | 0   | 1   | 120/f <sub>x</sub> | 16/f <sub>x</sub> | 14/f <sub>x</sub>                               | 16/f <sub>x</sub> |
| 1                | 1   | 0   | 96/f <sub>x</sub>  | 12/f <sub>x</sub> | 12/f <sub>x</sub>                               | 14/f <sub>x</sub> |
| Other than above |     |     | Setting prohibited | —                 | —   | —                 |

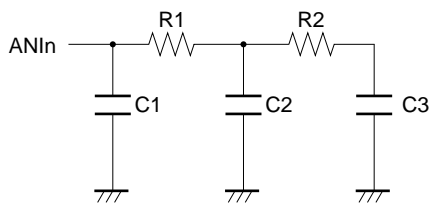
**Note** The A/D conversion start delay time is the time after the wait period. For the wait function, see **CHAPTER 29 CAUTIONS FOR WAIT**.

**Remark** f<sub>x</sub>: X1 input clock oscillation frequency

**(12) Internal equivalent circuit**

The equivalent circuit of the analog input block is shown below.

**Figure 10-22. Internal Equivalent Circuit of ANIn Pin**



**Table 10-4. Resistance and Capacitance Values of Equivalent Circuit (Reference Values)**

| $A_{VREF}$ | R1            | R2             | C1   | C2     | C3   |
|------------|---------------|----------------|------|--------|------|
| 2.7 V      | 12 k $\Omega$ | 8 k $\Omega$   | 8 pF | 3 pF   | 2 pF |
| 4.5 V      | 4 k $\Omega$  | 2.7 k $\Omega$ | 8 pF | 1.4 pF | 2 pF |

- Remarks**
1. The resistance and capacitance values shown in Table 10-4 are not guaranteed values.
  2.  $n = 0$  to 3

## CHAPTER 11 SERIAL INTERFACE UART0 ( $\mu$ PD780102, 780103, 78F0103 ONLY)

### 11.1 Functions of Serial Interface UART0

Serial interface UART0 has the following two modes.

#### (1) Operation stop mode

This mode is used when serial communication is not executed and can enable a reduction in the power consumption.

For details, see **11.4.1 Operation stop mode**.

#### (2) Asynchronous serial interface (UART) mode

The functions of this mode are outlined below.

For details, see **11.4.2 Asynchronous serial interface (UART) mode** and **11.4.3 Dedicated baud rate generator**.

- Two-pin configuration TxD0: Transmit data output pin  
RxD0: Receive data input pin
- Length of communication data can be selected from 7 or 8 bits.
- Dedicated on-chip 5-bit baud rate generator allowing any baud rate to be set
- Transmission and reception can be performed independently.
- Four operating clock inputs selectable
- Fixed to LSB-first communication

- Cautions**
1. If clock supply to serial interface UART0 is not stopped (e.g., in the HALT mode), normal operation continues. If clock supply to serial interface UART0 is stopped (e.g., in the STOP mode), each register stops operating, and holds the value immediately before clock supply was stopped. The TxD0 pin also holds the value immediately before clock supply was stopped and outputs it. However, the operation is not guaranteed after clock supply is resumed. Therefore, reset the circuit so that POWER0 = 0, RXE0 = 0, and TXE0 = 0.
  2. Set POWER0 = 1 and then set TXE0 = 1 (transmission) or RXE0 = 1 (reception) to start communication.
  3. TXE0 and RXE0 are synchronized by the base clock (f<sub>XCLK0</sub>) set by BRGC0. To enable transmission or reception again, set TXE0 or RXE0 to 1 at least two clocks of base clock after TXE0 or RXE0 has been cleared to 0. If TXE0 or RXE0 is set within two clocks of base clock, the transmission circuit or reception circuit may not be initialized.

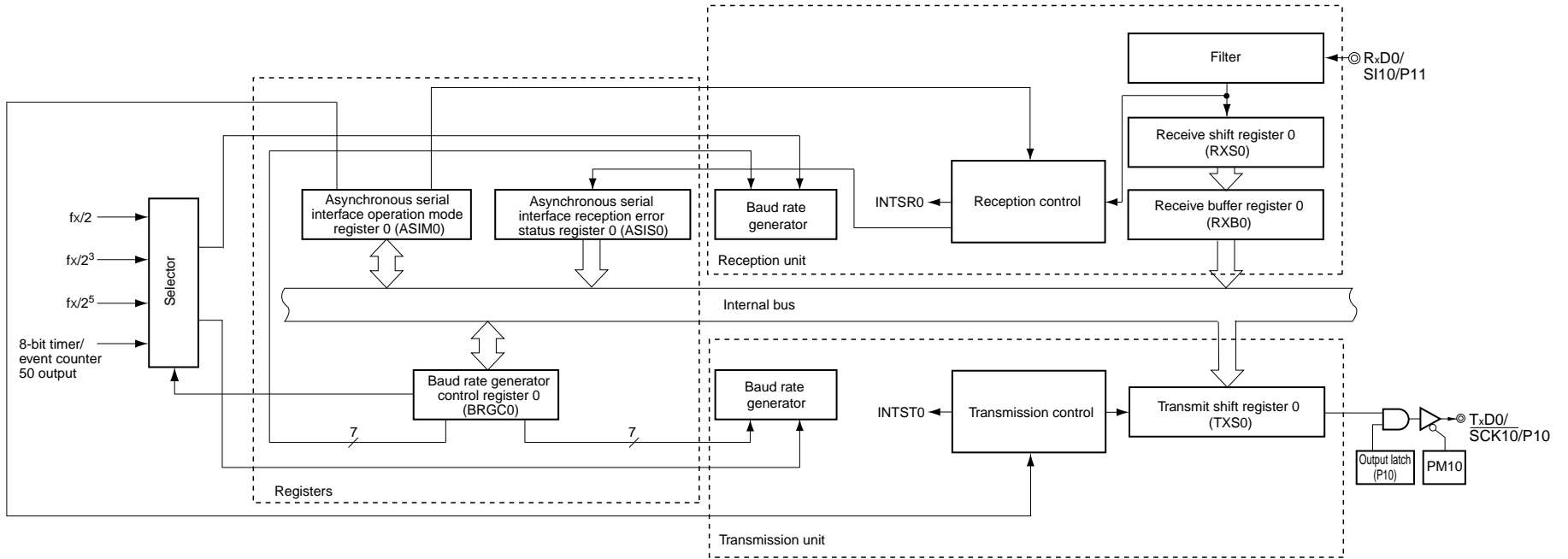
## 11.2 Configuration of Serial Interface UART0

Serial interface UART0 includes the following hardware.

**Table 11-1. Configuration of Serial Interface UART0**

| Item              | Configuration  |
|-------------------|--|
| Registers         | Receive buffer register 0 (RXB0)<br>Receive shift register 0 (RXS0)<br>Transmit shift register 0 (TXS0)  |
| Control registers | Asynchronous serial interface operation mode register 0 (ASIM0)<br>Asynchronous serial interface reception error status register 0 (ASIS0)<br>Baud rate generator control register 0 (BRGC0)<br>Port mode register 1 (PM1)<br>Port register 1 (P1) |

Figure 11-1. Block Diagram of Serial Interface UART0



**(1) Receive buffer register 0 (RXB0)**

This 8-bit register stores parallel data converted by receive shift register 0 (RXS0).

Each time 1 byte of data has been received, new receive data is transferred to this register from receive shift register 0 (RXS0).

If the data length is set to 7 bits the receive data is transferred to bits 0 to 6 of RXB0 and the MSB of RXB0 is always 0.

If an overrun error (OVE0) occurs, the receive data is not transferred to RXB0.

RXB0 can be read by an 8-bit memory manipulation instruction. No data can be written to this register.

$\overline{\text{RESET}}$  input or POWER0 = 0 sets this register to FFH.

**(2) Receive shift register 0 (RXS0)**

This register converts the serial data input to the RxD0 pin into parallel data.

RXS0 cannot be directly manipulated by a program.

**(3) Transmit shift register 0 (TXS0)**

This register is used to set transmit data. Transmission is started when data is written to TXS0, and serial data is transmitted from the TxD0 pin.

TXS0 can be written by an 8-bit memory manipulation instruction. This register cannot be read.

$\overline{\text{RESET}}$  input, POWER0 = 0, or TXE0 = 0 sets this register to FFH.

**Caution** Do not write the next transmit data to TXS0 before the transmission completion interrupt signal (INTST0) is generated.

### 11.3 Registers Controlling Serial Interface UART0

Serial interface UART0 is controlled by the following five registers.

- Asynchronous serial interface operation mode register 0 (ASIM0)
- Asynchronous serial interface reception error status register 0 (ASIS0)
- Baud rate generator control register 0 (BRGC0)
- Port mode register 1 (PM1)
- Port register 1 (P1)

#### (1) Asynchronous serial interface operation mode register 0 (ASIM0)

This 8-bit register controls the serial communication operations of serial interface UART0.

This register can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets this register to 01H.

**Figure 11-2. Format of Asynchronous Serial Interface Operation Mode Register 0 (ASIM0) (1/2)**

Address: FF70H After reset: 01H R/W

| Symbol | <7>    | <6>  | <5>  | 4    | 3    | 2   | 1   | 0 |
|--------|--------|------|------|------|------|-----|-----|---|
| ASIM0  | POWER0 | TXE0 | RXE0 | PS01 | PS00 | CL0 | SL0 | 1 |

| POWER0              | Enables/disables operation of internal operation clock   |
|---------------------|--|
| 0 <sup>Note 1</sup> | Disables operation of the internal operation clock (fixes the clock to low level) and asynchronously resets the internal circuit <sup>Note 2</sup> . |
| 1                   | Enables operation of the internal operation clock.   |

| TXE0 | Enables/disables transmission  |
|------|--|
| 0    | Disables transmission (synchronously resets the transmission circuit). |
| 1    | Enables transmission.  |

| RXE0 | Enables/disables reception                                       |
|------|--|
| 0    | Disables reception (synchronously resets the reception circuit). |
| 1    | Enables reception.   |

- Notes**
1. The input from the RxD0 pin is fixed to high level when POWER0 = 0.
  2. Asynchronous serial interface reception error status register 0 (ASIS0), transmit shift register 0 (TXS0), and receive buffer register 0 (RXB0) are reset.

Figure 11-2. Format of Asynchronous Serial Interface Operation Mode Register 0 (ASIM0) (2/2)

| PS01 | PS00 | Transmission operation      | Reception operation                   |
|------|------|-----------------------------|---------------------------------------|
| 0    | 0    | Does not output parity bit. | Reception without parity              |
| 0    | 1    | Outputs 0 parity.           | Reception as 0 parity <sup>Note</sup> |
| 1    | 0    | Outputs odd parity.         | Judges as odd parity.                 |
| 1    | 1    | Outputs even parity.        | Judges as even parity.                |

| CL0 | Specifies character length of transmit/receive data |
|-----|---|
| 0   | Character length of data = 7 bits                   |
| 1   | Character length of data = 8 bits                   |

| SL0 | Specifies number of stop bits of transmit data |
|-----|--|
| 0   | Number of stop bits = 1                        |
| 1   | Number of stop bits = 2                        |

**Note** If “reception as 0 parity” is selected, the parity is not judged. Therefore, bit 2 (PE0) of asynchronous serial interface reception error status register 0 (ASIS0) is not set and the error interrupt does not occur.

- Cautions**
1. At startup, set POWER0 to 1 and then set TXE0 to 1. To stop the operation, clear TXE0 to 0, and then clear POWER0 to 0.
  2. At startup, set POWER0 to 1 and then set RXE0 to 1. To stop the operation, clear RXE0 to 0, and then clear POWER0 to 0.
  3. Set POWER0 to 1 and then set RXE0 to 1 while a high level is input to the RxD0 pin. If POWER0 is set to 1 and RXE0 is set to 1 while a low level is input, reception is started.
  4. TXE0 and RXE0 are synchronized by the base clock (f<sub>CLK0</sub>) set by BRGC0. To enable transmission or reception again, set TXE0 or RXE0 to 1 at least two clocks of base clock after TXE0 or RXE0 has been cleared to 0. If TXE0 or RXE0 is set within two clocks of base clock, the transmission circuit or reception circuit may not be initialized.
  5. Clear the TXE0 and RXE0 bits to 0 before rewriting the PS01, PS00, and CL0 bits.
  6. Make sure that TXE0 = 0 when rewriting the SL0 bit. Reception is always performed with “number of stop bits = 1”, and therefore, is not affected by the set value of the SL0 bit.
  7. Be sure to set bit 0 to 1.



**(2) Asynchronous serial interface reception error status register 0 (ASIS0)**

This register indicates an error status on completion of reception by serial interface UART0. It includes three error flag bits (PE0, FE0, OVE0).

This register is read-only by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H if bit 7 (POWER0) and bit 5 (RXE0) of ASIM0 = 0. 00H is read when this register is read.

**Figure 11-3. Format of Asynchronous Serial Interface Reception Error Status Register 0 (ASIS0)**

Address: FF73H After reset: 00H R

|        |   |   |   |   |   |     |     |      |
|--------|---|---|---|---|---|-----|-----|------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2   | 1   | 0    |
| ASIS0  | 0 | 0 | 0 | 0 | 0 | PE0 | FE0 | OVE0 |

|     |  |
|-----|--|
| PE0 | Status flag indicating parity error  |
| 0   | If POWER0 = 0 and RXE0 = 0, or if the ASIS0 register is read.                            |
| 1   | If the parity of transmit data does not match the parity bit on completion of reception. |

|     |   |
|-----|---|
| FE0 | Status flag indicating framing error                          |
| 0   | If POWER0 = 0 and RXE0 = 0, or if the ASIS0 register is read. |
| 1   | If the stop bit is not detected on completion of reception.   |

|      |  |
|------|--|
| OVE0 | Status flag indicating overrun error   |
| 0    | If POWER0 = 0 and RXE0 = 0, or if the ASIS0 register is read.  |
| 1    | If receive data is set to the RXB0 register and the next reception operation is completed before the data is read. |

- Cautions**
1. The operation of the PE0 bit differs depending on the set values of the PS01 and PS00 bits of asynchronous serial interface operation mode register 0 (ASIM0).
  2. Only the first bit of the receive data is checked as the stop bit, regardless of the number of stop bits.
  3. If an overrun error occurs, the next receive data is not written to receive buffer register 0 (RXB0) but discarded.
  4. If data is read from ASIS0, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.

**(3) Baud rate generator control register 0 (BRGC0)**

This register selects the base clock of serial interface UART0 and the division value of the 5-bit counter.

BRGC0 can be set by an 8-bit memory manipulation instruction.

RESET input sets this register to 1FH.

**Figure 11-4. Format of Baud Rate Generator Control Register 0 (BRGC0)**

Address: FF71H After reset: 1FH R/W

|        |       |       |   |       |       |       |       |       |
|--------|-------|-------|---|-------|-------|-------|-------|-------|
| Symbol | 7     | 6     | 5 | 4     | 3     | 2     | 1     | 0     |
| BRGC0  | TPS01 | TPS00 | 0 | MDL04 | MDL03 | MDL02 | MDL01 | MDL00 |

| TPS01 | TPS00 | Base clock (f <sub>XCLK0</sub> ) selection <sup>Note 1</sup> |
|-------|-------|--|
| 0     | 0     | TM50 output <sup>Note 2</sup>                                |
| 0     | 1     | f <sub>X</sub> /2 (5 MHz)                                    |
| 1     | 0     | f <sub>X</sub> /2 <sup>3</sup> (1.25 MHz)                    |
| 1     | 1     | f <sub>X</sub> /2 <sup>5</sup> (312.5 kHz)                   |

| MDL04 | MDL03 | MDL02 | MDL01 | MDL00 | k  | Selection of 5-bit counter output clock |
|-------|-------|-------|-------|-------|----|---|
| 0     | 0     | ×     | ×     | ×     | ×  | Setting prohibited                      |
| 0     | 1     | 0     | 0     | 0     | 8  | f <sub>XCLK0</sub> /8                   |
| 0     | 1     | 0     | 0     | 1     | 9  | f <sub>XCLK0</sub> /9                   |
| 0     | 1     | 0     | 1     | 0     | 10 | f <sub>XCLK0</sub> /10                  |
| •     | •     | •     | •     | •     | •  | •                                       |
| •     | •     | •     | •     | •     | •  | •                                       |
| •     | •     | •     | •     | •     | •  | •                                       |
| •     | •     | •     | •     | •     | •  | •                                       |
| •     | •     | •     | •     | •     | •  | •                                       |
| 1     | 1     | 0     | 1     | 0     | 26 | f <sub>XCLK0</sub> /26                  |
| 1     | 1     | 0     | 1     | 1     | 27 | f <sub>XCLK0</sub> /27                  |
| 1     | 1     | 1     | 0     | 0     | 28 | f <sub>XCLK0</sub> /28                  |
| 1     | 1     | 1     | 0     | 1     | 29 | f <sub>XCLK0</sub> /29                  |
| 1     | 1     | 1     | 1     | 0     | 30 | f <sub>XCLK0</sub> /30                  |
| 1     | 1     | 1     | 1     | 1     | 31 | f <sub>XCLK0</sub> /31                  |

- ★ **Notes 1.** Be sure to set the base clock so that the following condition is satisfied.
    - V<sub>DD</sub> = 4.0 to 5.5 V: Base clock ≤ 10 MHz
    - V<sub>DD</sub> = 3.3 to 4.0 V: Base clock ≤ 8.38 MHz
    - V<sub>DD</sub> = 2.7 to 3.3 V: Base clock ≤ 5 MHz
    - V<sub>DD</sub> = 2.5 to 2.7 V: Base clock ≤ 2.5 MHz
  - ★ **2.** Note the following points when selecting the TM50 output as the base clock.
    - PWM mode (TMC506 = 1)
      - Start the operation of 8-bit timer/event counter 50 first and then set the base clock to make the duty = 50%.
    - Mode in which the base clock is cleared and started upon a match of TM50 and CR50 (TMC506 = 0)
      - Start the operation of 8-bit timer/event counter 50 first and then enable the timer F/F inversion operation (TMC501 = 1).
- It is not necessary to enable the TO50 pin as a timer output pin in any mode.

- Cautions**
1. When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the base clock is the Ring-OSC clock, the operation of serial interface UART0 is not guaranteed.
  2. Make sure that bit 6 (TXE0) and bit 5 (RXE0) of the ASIM0 register = 0 when rewriting the MDL04 to MDL00 bits.
  3. The baud rate value is the output clock of the 5-bit counter divided by 2.

- Remarks**
1.  $f_{CLK0}$ : Frequency of base clock selected by the TPS01 and TPS00 bits
  2.  $f_x$ : X1 input clock oscillation frequency
  3.  $k$ : Value set by the MDL04 to MDL00 bits ( $k = 8, 9, 10, \dots, 31$ )
  4.  $x$ : Don't care
  5. Figures in parentheses apply to operation at  $f_x = 10$  MHz
  6. TMC506: Bit 6 of 8-bit timer mode control register 50 (TMC50)
  7. TMC501: Bit 1 of TMC50

**(4) Port mode register 1 (PM1)**

This register sets port 1 input/output in 1-bit units.

When using the P10/TxD0/SCK10 pin for serial interface data output, clear PM10 to 0 and set the output latch of P10 to 1.

When using the P11/RxD0/SI10 pin for serial interface data input, set PM11 to 1. The output latch of P11 at this time may be 0 or 1.

PM1 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{RESET}$  input sets this register to FFH.

**Figure 11-5. Format of Port Mode Register 1 (PM1)**

Address: FF21H After reset: FFH R/W

|        |   |      |      |      |      |      |      |      |
|--------|---|------|------|------|------|------|------|------|
| Symbol | 7                                       | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PM1    | PM17                                    | PM16 | PM15 | PM14 | PM13 | PM12 | PM11 | PM10 |
| PM1n   | P1n pin I/O mode selection (n = 0 to 7) |      |      |      |      |      |      |      |
| 0      | Output mode (output buffer on)          |      |      |      |      |      |      |      |
| 1      | Input mode (output buffer off)          |      |      |      |      |      |      |      |

## 11.4 Operation of Serial Interface UART0

Serial interface UART0 has the following two modes.

- Operation stop mode
- Asynchronous serial interface (UART) mode

### 11.4.1 Operation stop mode

In this mode, serial communication cannot be executed, thus reducing the power consumption. In addition, the pins can be used as ordinary port pins in this mode. To set the operation stop mode, clear bits 7, 6, and 5 (POWER0, TXE0, and RXE0) of ASIM0 to 0.

#### (1) Register used

The operation stop mode is set by asynchronous serial interface operation mode register 0 (ASIM0).

ASIM0 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets this register to 01H.

Address: FF70H After reset: 01H R/W

| Symbol              | <7>  | <6>  | <5>  | 4    | 3    | 2   | 1   | 0 |
|---------------------|--|------|------|------|------|-----|-----|---|
| ASIM0               | POWER0   | TXE0 | RXE0 | PS01 | PS00 | CL0 | SL0 | 1 |
| POWER0              | Enables/disables operation of internal operation clock   |      |      |      |      |     |     |   |
| 0 <sup>Note 1</sup> | Disables operation of the internal operation clock (fixes the clock to low level) and asynchronously resets the internal circuit <sup>Note 2</sup> . |      |      |      |      |     |     |   |
| TXE0                | Enables/disables transmission  |      |      |      |      |     |     |   |
| 0                   | Disables transmission (synchronously resets the transmission circuit).   |      |      |      |      |     |     |   |
| RXE0                | Enables/disables reception   |      |      |      |      |     |     |   |
| 0                   | Disables reception (synchronously resets the reception circuit).   |      |      |      |      |     |     |   |

- Notes**
1. The input from the RxD0 pin is fixed to high level when POWER0 = 0.
  2. Asynchronous serial interface reception error status register 0 (ASIS0), transmit shift register 0 (TXS0), and receive buffer register 0 (RXB0) are reset.

**Caution** Clear POWER0 to 0 after clearing TXE0 and RXE0 to 0 to set the operation stop mode. To start the operation, set POWER0 to 1, and then set TXE0 and RXE0 to 1.

**Remark** To use the RxD0/SI10/P11 and TxD0/ $\overline{\text{SCK}}10$ /P10 pins as general-purpose port pins, see **CHAPTER 4 PORT FUNCTIONS**.

### 11.4.2 Asynchronous serial interface (UART) mode

In this mode, 1-byte data is transmitted/received following a start bit, and a full-duplex operation can be performed.

A dedicated UART baud rate generator is incorporated, so that communication can be executed at a wide range of baud rates.

#### (1) Registers used

- Asynchronous serial interface operation mode register 0 (ASIM0)
- Asynchronous serial interface reception error status register 0 (ASIS0)
- Baud rate generator control register 0 (BRGC0)
- Port mode register 1 (PM1)
- Port register 1 (P1)

The basic procedure of setting an operation in the UART mode is as follows.

- <1> Set the BRGC0 register (see **Figure 11-4**).
- <2> Set bits 1 to 4 (SL0, CL0, PS00, and PS01) of the ASIM0 register (see **Figure 11-2**).
- <3> Set bit 7 (POWER0) of the ASIM0 register to 1.
- <4> Set bit 6 (TXE0) of the ASIM0 register to 1. → Transmission is enabled.  
Set bit 5 (RXE0) of the ASIM0 register to 1. → Reception is enabled.
- <5> Write data to the TXS0 register. → Data transmission is started.

**Caution** Take relationship with the other party of communication when setting the port mode register and port register.

The relationship between the register settings and pins is shown below.

**Table 11-2. Relationship Between Register Settings and Pins**

| POWER0 | TXE0 | RXE0 | PM10              | P10               | PM11              | P11               | UART0<br>Operation         | Pin Function                   |               |
|--------|------|------|-------------------|-------------------|-------------------|-------------------|----------------------------|--------------------------------|---------------|
|        |      |      |                   |                   |                   |                   |                            | TxD0/SCK10/P10                 | RxD0/SI10/P11 |
| 0      | 0    | 0    | x <sup>Note</sup> | x <sup>Note</sup> | x <sup>Note</sup> | x <sup>Note</sup> | Stop                       | $\overline{\text{SCK10}}$ /P10 | SI10/P11      |
| 1      | 0    | 1    | x <sup>Note</sup> | x <sup>Note</sup> | 1                 | x                 | Reception                  | $\overline{\text{SCK10}}$ /P10 | RxD0          |
|        | 1    | 0    | 0                 | 1                 | x <sup>Note</sup> | x <sup>Note</sup> | Transmission               | TxD0                           | SI10/P11      |
|        | 1    | 1    | 0                 | 1                 | 1                 | x                 | Transmission/<br>reception | TxD0                           | RxD0          |

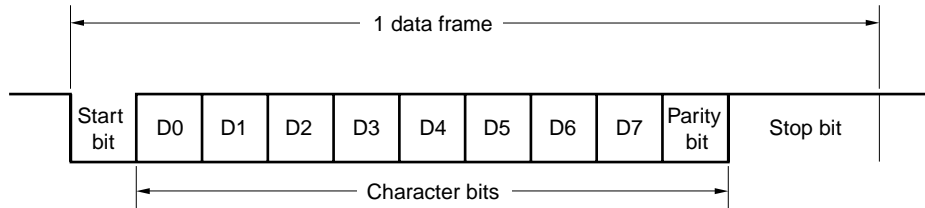
**Note** Can be set as port function.

**Remark** x: don't care  
 POWER0: Bit 7 of asynchronous serial interface operation mode register 0 (ASIM0)  
 TXE0: Bit 6 of ASIM0  
 RXE0: Bit 5 of ASIM0  
 PM1x: Port mode register  
 P1x: Port output latch

**(2) Communication operation****(a) Format and waveform example of normal transmit/receive data**

Figures 11-6 and 11-7 show the format and waveform example of the normal transmit/receive data.

**Figure 11-6. Format of Normal UART Transmit/Receive Data**



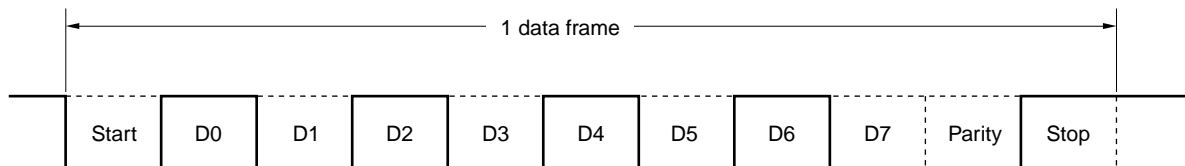
One data frame consists of the following bits.

- Start bit ... 1 bit
- Character bits ... 7 or 8 bits (LSB first)
- Parity bit ... Even parity, odd parity, 0 parity, or no parity
- Stop bit ... 1 or 2 bits

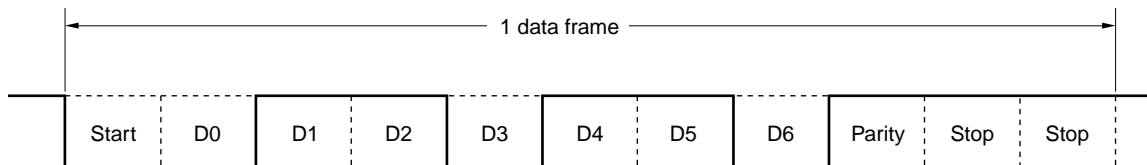
The character bit length, parity, and stop bit length in one data frame are specified by asynchronous serial interface operation mode register 0 (ASIM0).

**Figure 11-7. Example of Normal UART Transmit/Receive Data Waveform**

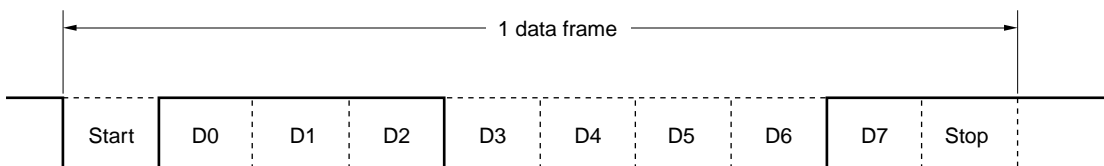
**1. Data length: 8 bits, Parity: Even parity, Stop bit: 1 bit, Communication data: 55H**



**2. Data length: 7 bits, Parity: Odd parity, Stop bit: 2 bits, Communication data: 36H**



**3. Data length: 8 bits, Parity: None, Stop bit: 1 bit, Communication data: 87H**



**(b) Parity types and operation**

The parity bit is used to detect a bit error in communication data. Usually, the same type of parity bit is used on both the transmission and reception sides. With even parity and odd parity, a 1-bit (odd number) error can be detected. With zero parity and no parity, an error cannot be detected.

**(i) Even parity**

- Transmission

Transmit data, including the parity bit, is controlled so that the number of bits that are “1” is even.

The value of the parity bit is as follows.

If transmit data has an odd number of bits that are “1”: 1

If transmit data has an even number of bits that are “1”: 0

- Reception

The number of bits that are “1” in the receive data, including the parity bit, is counted. If it is odd, a parity error occurs.

**(ii) Odd parity**

- Transmission

Unlike even parity, transmit data, including the parity bit, is controlled so that the number of bits that are “1” is odd.

If transmit data has an odd number of bits that are “1”: 0

If transmit data has an even number of bits that are “1”: 1

- Reception

The number of bits that are “1” in the receive data, including the parity bit, is counted. If it is even, a parity error occurs.

**(iii) 0 parity**

The parity bit is cleared to 0 when data is transmitted, regardless of the transmit data.

The parity bit is not detected when the data is received. Therefore, a parity error does not occur regardless of whether the parity bit is “0” or “1”.

**(iv) No parity**

No parity bit is appended to the transmit data.

Reception is performed assuming that there is no parity bit when data is received. Because there is no parity bit, a parity error does not occur.

**(c) Transmission**

The TxD0 pin outputs a high level when bit 7 (POWER0) of asynchronous serial interface operation mode register 0 (ASIM0) is set to 1. If bit 6 (TXE0) of ASIM0 is then set to 1, transmission is enabled. Transmission can be started by writing transmit data to transmit shift register 0 (TXS0). The start bit, parity bit, and stop bit are automatically appended to the data.

When transmission is started, the start bit is output from the TxD0 pin, followed by the rest of the data in order starting from the LSB. When transmission is completed, the parity and stop bits set by ASIM0 are appended and a transmission completion interrupt request (INTST0) is generated.

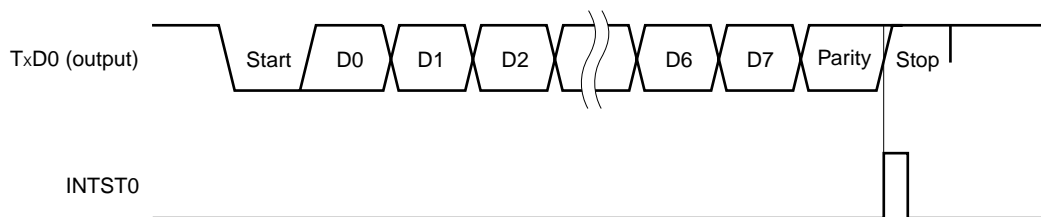
Transmission is stopped until the data to be transmitted next is written to TXS0.

Figure 11-8 shows the timing of the transmission completion interrupt request (INTST0). This interrupt occurs as soon as the last stop bit has been output.

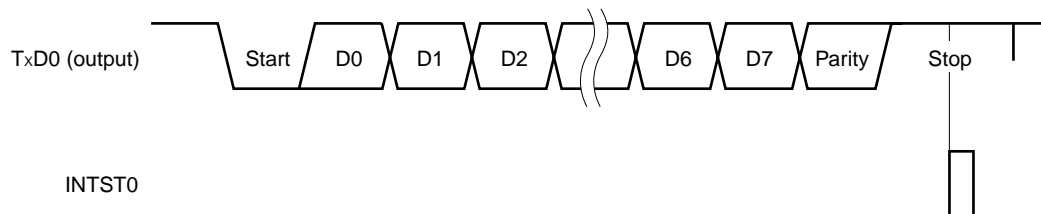
**Caution** After transmit data is written to TXS0, do not write the next transmit data before the transmission completion interrupt signal (INTST0) is generated.

**Figure 11-8. Transmission Completion Interrupt Request Timing**

**1. Stop bit length: 1**



**2. Stop bit length: 2**





**(d) Reception**

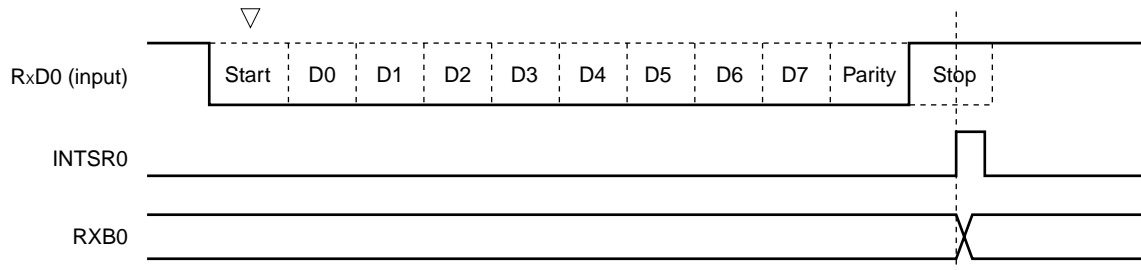
Reception is enabled and the RxD0 pin input is sampled when bit 7 (POWER0) of asynchronous serial interface operation mode register 0 (ASIM0) is set to 1 and then bit 5 (RXE0) of ASIM0 is set to 1.

The 5-bit counter of the baud rate generator starts counting when the falling edge of the RxD0 pin input is detected. When the set value of baud rate generator control register 0 (BRGC0) has been counted, the RxD0 pin input is sampled again (▽ in Figure 11-9). If the RxD0 pin is low level at this time, it is recognized as a start bit.

When the start bit is detected, reception is started, and serial data is sequentially stored in receive shift register 0 (RXS0) at the set baud rate. When the stop bit has been received, the reception completion interrupt (INTSR0) is generated and the data of RXS0 is written to receive buffer register 0 (RXB0). If an overrun error (OVE0) occurs, however, the receive data is not written to RXB0.

Even if a parity error (PE0) occurs while reception is in progress, reception continues to the reception position of the stop bit, and an error interrupt (INTSR0) is generated after completion of reception.

**Figure 11-9. Reception Completion Interrupt Request Timing**



- Cautions**
1. Be sure to read receive buffer register 0 (RXB0) even if a reception error occurs. Otherwise, an overrun error will occur when the next data is received, and the reception error status will persist.
  2. Reception is always performed with the “number of stop bits = 1”. The second stop bit is ignored.
  3. Be sure to read asynchronous serial interface reception error status register 0 (ASIS0) before reading RXB0.

**(e) Reception error**

Three types of errors may occur during reception: a parity error, framing error, or overrun error. If the error flag of asynchronous serial interface reception error status register 0 (ASIS0) is set as a result of data reception, a reception error interrupt request (INTSR0) is generated.

Which error has occurred during reception can be identified by reading the contents of ASIS0 in the reception error interrupt servicing (INTSR0) (see **Figure 11-3**).

The contents of ASIS0 are reset to 0 when ASIS0 is read.

**Table 11-3. Cause of Reception Error**

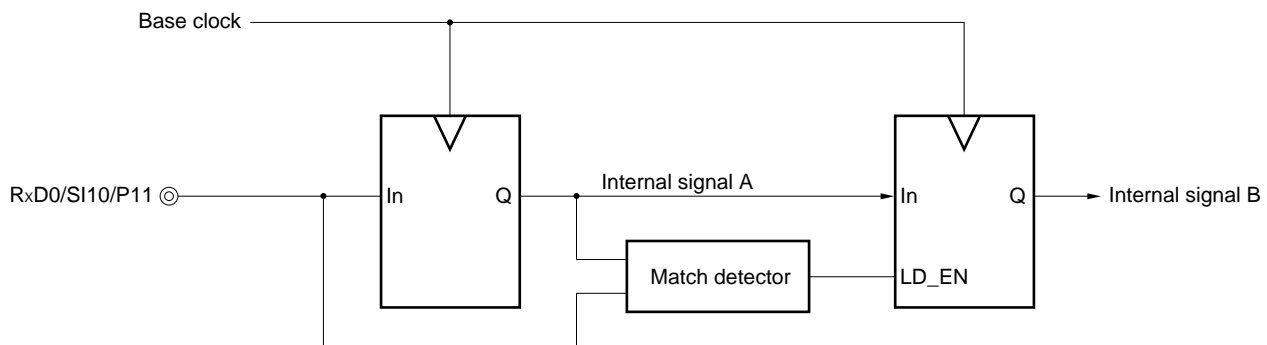
| Reception Error | Cause  |
|-----------------|--|
| Parity error    | The parity specified for transmission does not match the parity of the receive data.               |
| Framing error   | Stop bit is not detected.  |
| Overrun error   | Reception of the next data is completed before data is read from receive buffer register 0 (RXB0). |

**(f) Noise filter of receive data**

The RxD0 signal is sampled using the base clock output by the prescaler block.

If two sampled values are the same, the output of the match detector changes, and the data is sampled as input data.

Because the circuit is configured as shown in Figure 11-10, the internal processing of the reception operation is delayed by two clocks from the external signal status.

**Figure 11-10. Noise Filter Circuit**

### 11.4.3 Dedicated baud rate generator

The dedicated baud rate generator consists of a source clock selector and a 5-bit programmable counter, and generates a serial clock for transmission/reception of UART0.

Separate 5-bit counters are provided for transmission and reception.

#### (1) Configuration of baud rate generator

- Base clock

The clock selected by bits 7 and 6 (TPS01 and TPS00) of baud rate generator control register 0 (BRGC0) is supplied to each module when bit 7 (POWER0) of asynchronous serial interface operation mode register 0 (ASIM0) is 1. This clock is called the base clock and its frequency is called  $f_{XCLK0}$ . The base clock is fixed to low level when POWER0 = 0.

- Transmission counter

This counter stops, cleared to 0, when bit 7 (POWER0) or bit 6 (TXE0) of asynchronous serial interface operation mode register 0 (ASIM0) is 0.

It starts counting when POWER0 = 1 and TXE0 = 1.

The counter is cleared to 0 when the first data transmitted is written to transmit shift register 0 (TXS0).

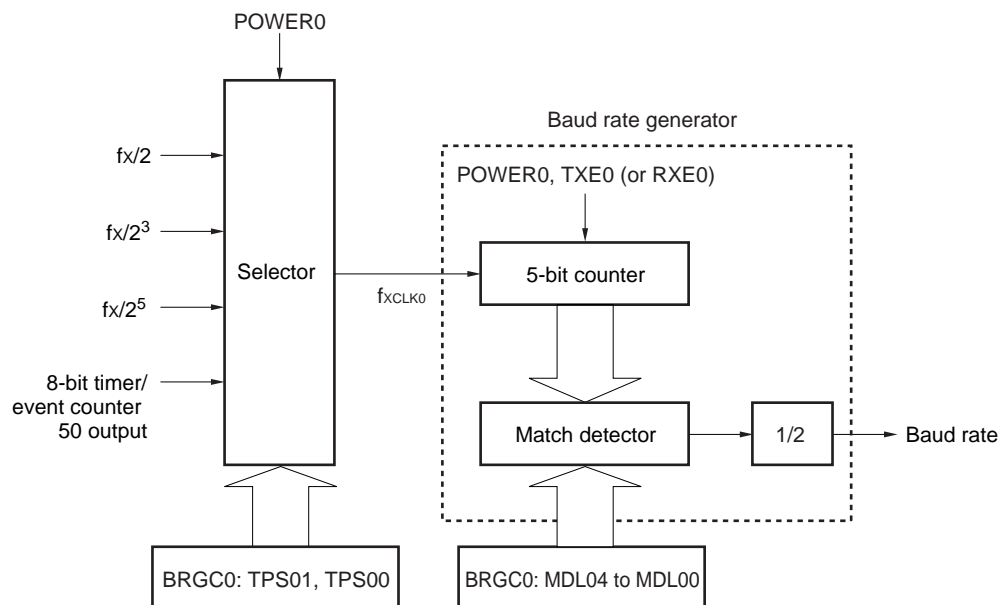
- Reception counter

This counter stops operation, cleared to 0, when bit 7 (POWER0) or bit 5 (RXE0) of asynchronous serial interface operation mode register 0 (ASIM0) is 0.

It starts counting when the start bit has been detected.

The counter stops operation after one frame has been received, until the next start bit is detected.

**Figure 11-11. Configuration of Baud Rate Generator**



**Remark** POWER0: Bit 7 of asynchronous serial interface operation mode register 0 (ASIM0)  
 TXE0: Bit 6 of ASIM0  
 RXE0: Bit 5 of ASIM0  
 BRGC0: Baud rate generator control register 0

**(2) Generation of serial clock**

A serial clock can be generated by using baud rate generator control register 0 (BRGC0).

Select the clock to be input to the 5-bit counter by using bits 7 and 6 (TPS01 and TPS00) of BRGC0.

Bits 4 to 0 (MDL04 to MDL00) of BRGC0 can be used to select the division value of the 5-bit counter.

**(a) Baud rate**

The baud rate can be calculated by the following expression.

- Baud rate =  $\frac{f_{\text{CLK0}}}{2 \times k}$  [bps]

$f_{\text{CLK0}}$ : Frequency of base clock selected by the TPS01 and TPS00 bits of the BRGC0 register

k: Value set by the MDL04 to MDL00 bits of the BRGC0 register (k = 8, 9, 10, ..., 31)

**(b) Error of baud rate**

The baud rate error can be calculated by the following expression.

- Error (%) =  $\left( \frac{\text{Actual baud rate (baud rate with error)}}{\text{Desired baud rate (correct baud rate)}} - 1 \right) \times 100$  [%]

**Cautions** 1. **Keep the baud rate error during transmission to within the permissible error range at the reception destination.**

2. **Make sure that the baud rate error during reception satisfies the range shown in (4) Permissible baud rate range during reception.**

**Example:** Frequency of base clock = 2.5 MHz = 2,500,000 Hz

Set value of MDL04 to MDL00 bits of BRGC0 register = 10000B (k = 16)

Target baud rate = 76,800 bps

$$\begin{aligned} \text{Baud rate} &= 2.5 \text{ M}/(2 \times 16) \\ &= 2,500,000/(2 \times 16) = 78125 \text{ [bps]} \end{aligned}$$

$$\begin{aligned} \text{Error} &= (78,125/76,800 - 1) \times 100 \\ &= 1.725 \text{ [%]} \end{aligned}$$

## (3) Example of setting baud rate

Table 11-4. Set Data of Baud Rate Generator

| Baud Rate<br>[bps] | $f_x = 10.0$ MHz |    |                     |        | $f_x = 8.38$ MHz |    |                     |        | $f_x = 4.19$ MHz |    |                     |        |
|--------------------|------------------|----|---------------------|--------|------------------|----|---------------------|--------|------------------|----|---------------------|--------|
|                    | TPS01,<br>TPS00  | k  | Calculated<br>Value | ERR[%] | TPS01,<br>TPS00  | k  | Calculated<br>Value | ERR[%] | TPS01,<br>TPS00  | k  | Calculated<br>Value | ERR[%] |
| 2400               | –                | –  | –                   | –      | –                | –  | –                   | –      | 3                | 27 | 2425                | 1.03   |
| 4800               | –                | –  | –                   | –      | 3                | 27 | 4850                | 1.03   | 3                | 14 | 4676                | –2.58  |
| 9600               | 3                | 16 | 9766                | 1.73   | 3                | 14 | 9353                | –2.58  | 2                | 27 | 9699                | 1.03   |
| 10400              | 3                | 15 | 10417               | 0.16   | 3                | 13 | 10072               | –3.15  | 2                | 25 | 10475               | 0.72   |
| 19200              | 3                | 8  | 19531               | 1.73   | 2                | 27 | 19398               | 1.03   | 2                | 14 | 18705               | –2.58  |
| 31250              | 2                | 20 | 31250               | 0      | 2                | 17 | 30809               | –1.41  | –                | –  | –                   | –      |
| 38400              | 2                | 16 | 39063               | 1.73   | 2                | 14 | 38796               | –2.58  | 2                | 27 | 38796               | 1.03   |
| 76800              | 2                | 8  | 78125               | 1.73   | 1                | 27 | 77593               | 1.03   | 1                | 14 | 74821               | –2.58  |
| 115200             | 1                | 22 | 113636              | –1.36  | 1                | 18 | 116389              | 1.03   | 1                | 9  | 116389              | 1.03   |
| 153600             | 1                | 16 | 156250              | 1.73   | 1                | 14 | 149643              | –2.58  | –                | –  | –                   | –      |
| 230400             | 1                | 11 | 227273              | –1.36  | 1                | 9  | 232778              | 1.03   | –                | –  | –                   | –      |

**Remark** TPS01, TPS00: Bits 7 and 6 of baud rate generator control register 0 (BRGC0) (setting of base clock ( $f_{xCLK0}$ ))

k: Value set by the MDL04 to MDL00 bits of BRGC0 ( $k = 8, 9, 10, \dots, 31$ )

$f_x$ : X1 input clock oscillation frequency

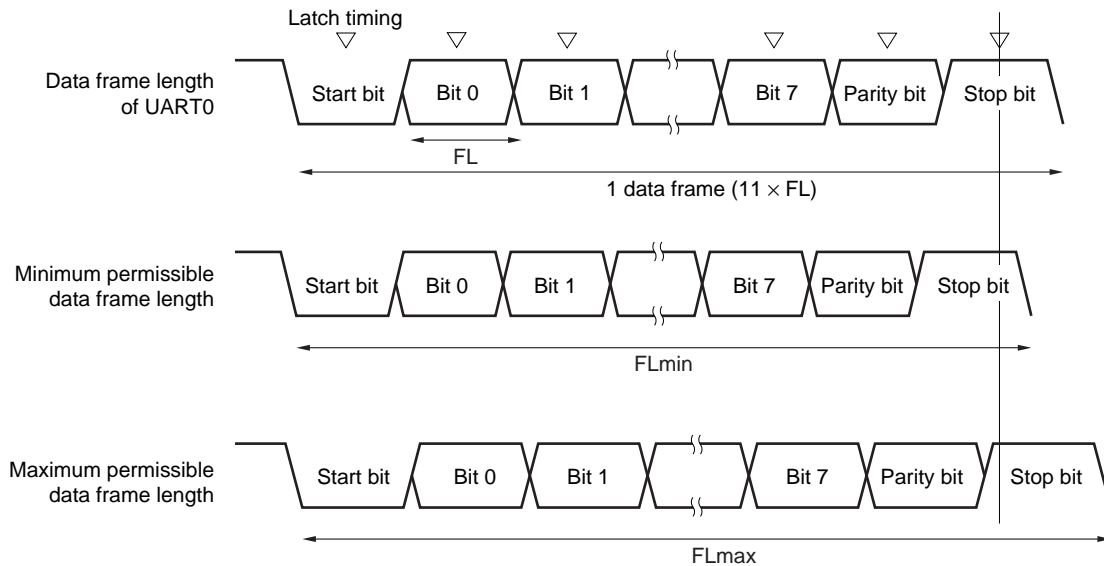
ERR: Baud rate error

**(4) Permissible baud rate range during reception**

The permissible error from the baud rate at the transmission destination during reception is shown below.

**Caution** Make sure that the baud rate error during reception is within the permissible error range, by using the calculation expression shown below.

**Figure 11-12. Permissible Baud Rate Range During Reception**



As shown in Figure 11-12, the latch timing of the receive data is determined by the counter set by baud rate generator control register 0 (BRGC0) after the start bit has been detected. If the last data (stop bit) meets this latch timing, the data can be correctly received.

Assuming that 11-bit data is received, the theoretical values can be calculated as follows.

$$FL = (\text{Brate})^{-1}$$

Brate: Baud rate of UART0

k: Set value of BRGC0

FL: 1-bit data length

Margin of latch timing: 2 clocks

$$\text{Minimum permissible data frame length: } FL_{\min} = 11 \times FL - \frac{k-2}{2k} \times FL = \frac{21k+2}{2k} FL$$

Therefore, the maximum receivable baud rate at the transmission destination is as follows.

$$BR_{\max} = (FL_{\min}/11)^{-1} = \frac{22k}{21k+2} \text{ Brate}$$

Similarly, the maximum permissible data frame length can be calculated as follows.

$$\frac{10}{11} \times FL_{\max} = 11 \times FL - \frac{k+2}{2 \times k} \times FL = \frac{21k-2}{2 \times k} FL$$

$$FL_{\max} = \frac{21k-2}{20k} FL \times 11$$

Therefore, the minimum receivable baud rate at the transmission destination is as follows.

$$BR_{\min} = (FL_{\max}/11)^{-1} = \frac{20k}{21k-2} \text{ Brate}$$

The permissible baud rate error between UART0 and the transmission destination can be calculated from the above minimum and maximum baud rate expressions, as follows.

**Table 11-5. Maximum/Minimum Permissible Baud Rate Error**

| Division Ratio (k) | Maximum Permissible Baud Rate Error | Minimum Permissible Baud Rate Error |
|--------------------|-------------------------------------|-------------------------------------|
| 8                  | +3.53%                              | -3.61%                              |
| 16                 | +4.14%                              | -4.19%                              |
| 24                 | +4.34%                              | -4.38%                              |
| 31                 | +4.44%                              | -4.47%                              |

- Remarks**
1. The permissible reception error depends on the number of bits in one frame, input clock frequency, and division ratio (k). The higher the input clock frequency and the higher the division ratio (k), the higher the permissible reception error.
  2. k: Set value of BRGC0

## CHAPTER 12 SERIAL INTERFACE UART6

### 12.1 Functions of Serial Interface UART6

Serial interface UART6 has the following two modes.

#### (1) Operation stop mode

This mode is used when serial communication is not executed and can enable a reduction in the power consumption.

For details, see **12.4.1 Operation stop mode**.

#### (2) Asynchronous serial interface (UART) mode

This mode supports the LIN (Local Interconnect Network)-bus. The functions of this mode are outlined below.

For details, see **12.4.2 Asynchronous serial interface (UART) mode** and **12.4.3 Dedicated baud rate generator**.

- Two-pin configuration TxD6: Transmit data output pin  
RxD6: Receive data input pin
- Data length of communication data can be selected from 7 or 8 bits.
- Dedicated internal 8-bit baud rate generator allowing any baud rate to be set
- Transmission and reception can be performed independently.
- Twelve operating clock inputs selectable
- MSB- or LSB-first communication selectable
- Inverted transmission operation
- 13-bit length output for synchronous break field transmission
- More than 11 bits can be identified for synchronous break field reception (SBF reception flag provided).

- Cautions**
1. The TxD6 output inversion function inverts only the transmission side and not the reception side. To use this function, the reception side must be ready for reception of inverted data.
  2. If clock supply to serial interface UART6 is not stopped (e.g., in the HALT mode), normal operation continues. If clock supply to serial interface UART6 is stopped (e.g., in the STOP mode), each register stops operating, and holds the value immediately before clock supply was stopped. The TxD6 pin also holds the value immediately before clock supply was stopped and outputs it. However, the operation is not guaranteed after clock supply is resumed. Therefore, reset the circuit so that POWER6 = 0, RXE6 = 0, and TXE6 = 0.
  3. If data is continuously transmitted, the communication timing from the stop bit to the next start bit is extended two operating clocks of the macro. However, this does not affect the result of communication because the reception side initializes the timing when it has detected a start bit. Do not use the continuous transmission function if the interface is incorporated in LIN.



**Remark** LIN stands for Local Interconnect Network and is a low-speed (1 to 20 kbps) serial communication protocol intended to aid the cost reduction of an automotive network.

LIN communication is single-master communication, and up to 15 slaves can be connected to one master.

The LIN slaves are used to control the switches, actuators, and sensors, and these are connected to the LIN master via the LIN network.

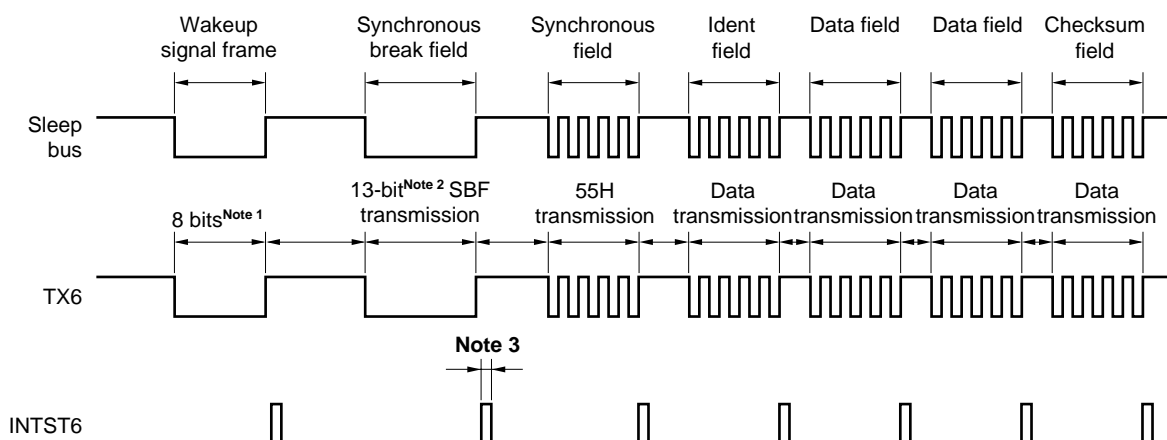
Normally, the LIN master is connected to a network such as CAN (Controller Area Network).

In addition, the LIN bus uses a single-wire method and is connected to the nodes via a transceiver that complies with ISO9141.

In the LIN protocol, the master transmits a frame with baud rate information and the slave receives it and corrects the baud rate error. Therefore, communication is possible when the baud rate error in the slave is  $\pm 15\%$  or less.

Figures 12-1 and 12-2 outline the transmission and reception operations of LIN.

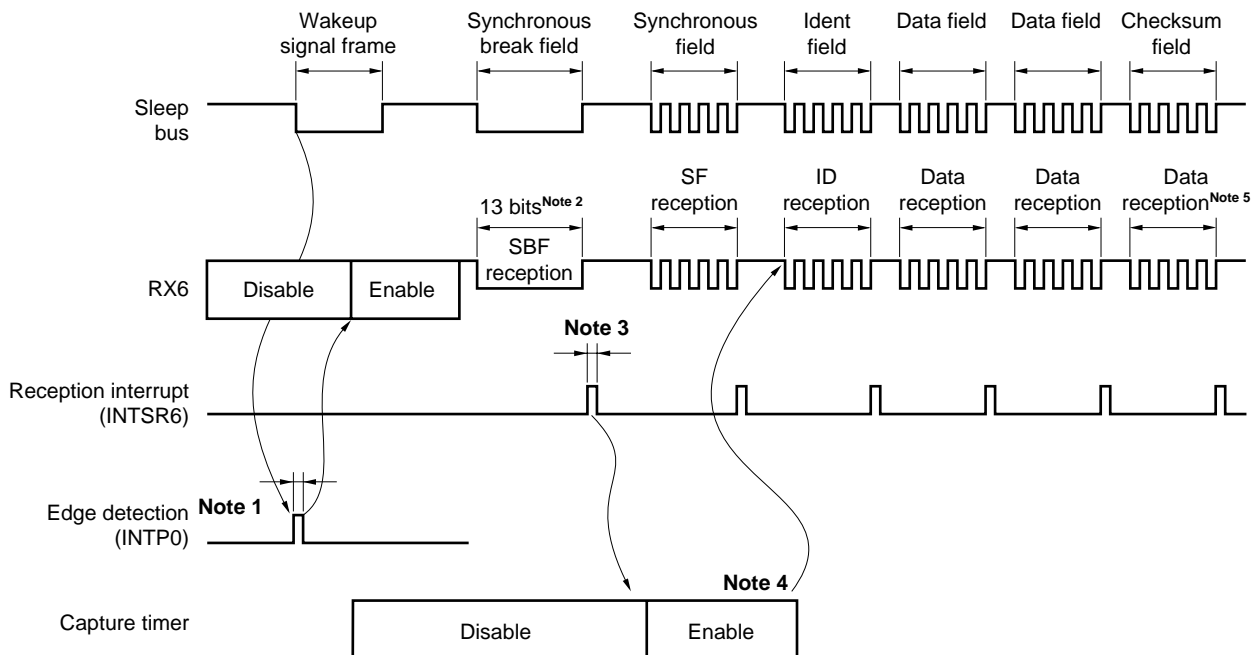
**Figure 12-1. LIN Transmission Operation**



- Notes**
1. The wakeup signal frame is substituted by 80H transmission in the 8-bit mode.
  2. The synchronous break field is output by hardware. The output width is adjusted by baud rate generator control register 6 (BRGC6) (see **12.4.2 (2) (h) SBF transmission**).
  3. INTST6 is output on completion of each transmission. It is also output when SBF is transmitted.

**Remark** The interval between each field is controlled by software.

Figure 12-2. LIN Reception Operation



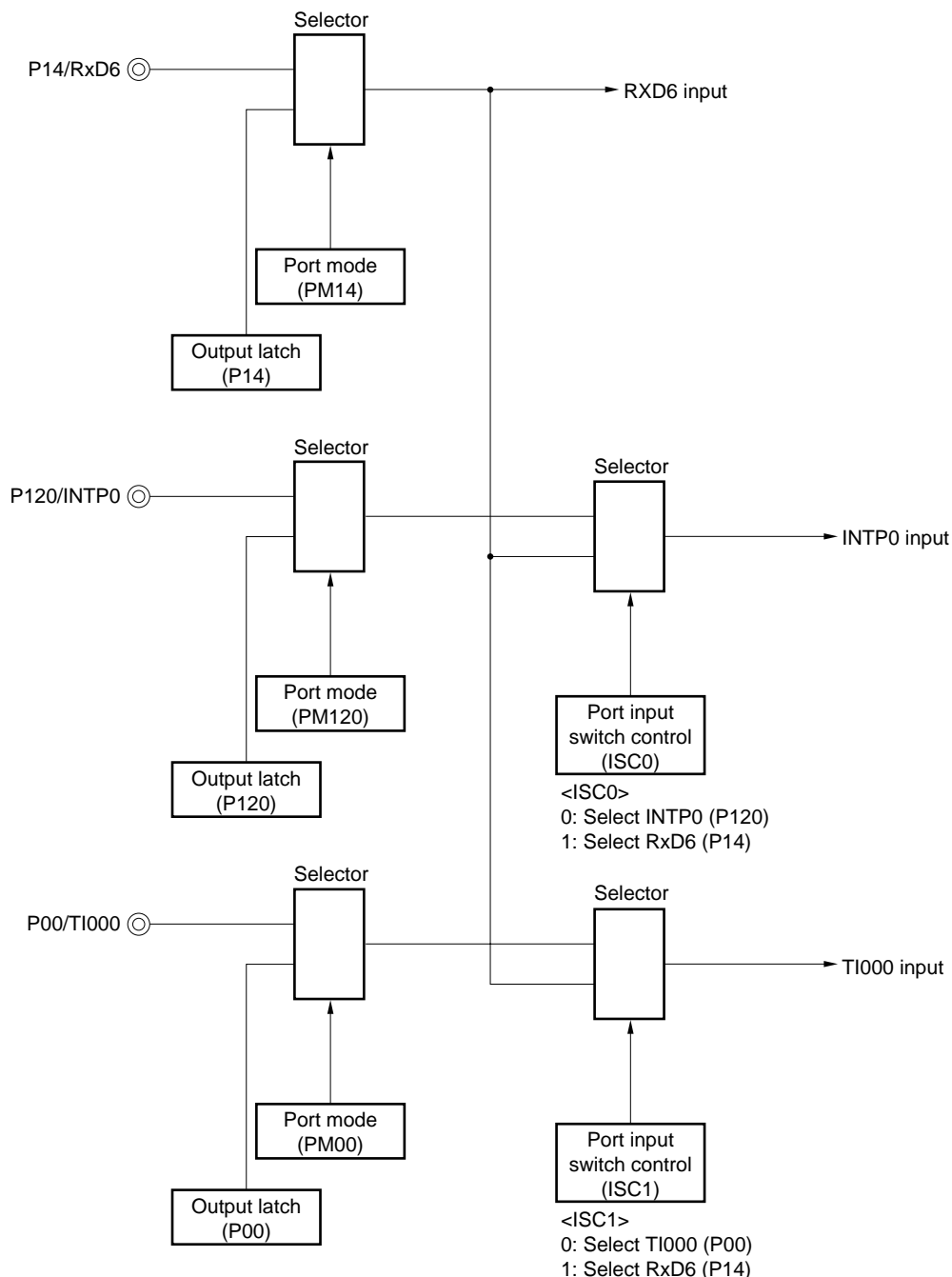
- Notes**
1. The wakeup signal is detected at the edge of the pin, and enables UART6 and sets the SBF reception mode.
  2. Reception continues until the STOP bit is detected. When an SBF with low-level data of 11 bits or more has been detected, it is assumed that SBF reception has been completed correctly, and an interrupt signal is output. If an SBF with low-level data of less than 11 bits has been detected, it is assumed that an SBF reception error has occurred. The interrupt signal is not output and the SBF reception mode is restored.
  3. If SBF reception has been completed correctly, an interrupt signal is output. This SBF reception completion interrupt enables the capture timer. Detection of errors OVE6, PE6, and FE6 is suppressed, and error detection processing of UART communication and data transfer of the shift register and RXB6 is not performed. The shift register holds the reset value FFH.
  4. Calculate the baud rate error from the bit length of the synchronous field, disable UART6 after SF reception, and then re-set baud rate generator control register 6 (BRGC6).
  5. Distinguish the checksum field by software. Also perform processing by software to initialize UART6 after reception of the checksum field and to set the SBF reception mode again.

To perform a LIN receive operation, use a configuration like the one shown in Figure 12-3.

The wakeup signal transmitted from the LIN master is received by detecting the edge of the external interrupt (INTP0). The length of the synchronous field transmitted from the LIN master can be measured using the external event capture operation of 16-bit timer/event counter 00, and the baud rate error can be calculated.

The input signal of the reception port input (RxD6) can be input to the external interrupt (INTP0) and 16-bit timer/event counter 00 by port input switch control (ISC0/ISC1), without connecting RxD6 and INTP0/TI000 externally.

Figure 12-3. Port Configuration for LIN Reception Operation



**Remark** ISC0, ISC1: Bits 0 and 1 of the input switch control register (ISC) (see **Figure 12-11**)

The peripheral functions used in the LIN communication operation are shown below.

<Peripheral functions used>

- External interrupt (INTP0); wakeup signal detection  
Use: Detects the wakeup signal edges and detects start of communication.
- 16-bit timer/event counter 00 (TI000); baud rate error detection  
★ Use: Detects the baud rate error (measures the TI000 input edge interval in the capture mode) by detecting the sync field (SF) length and divides it by the number of bits.
- Serial interface UART6

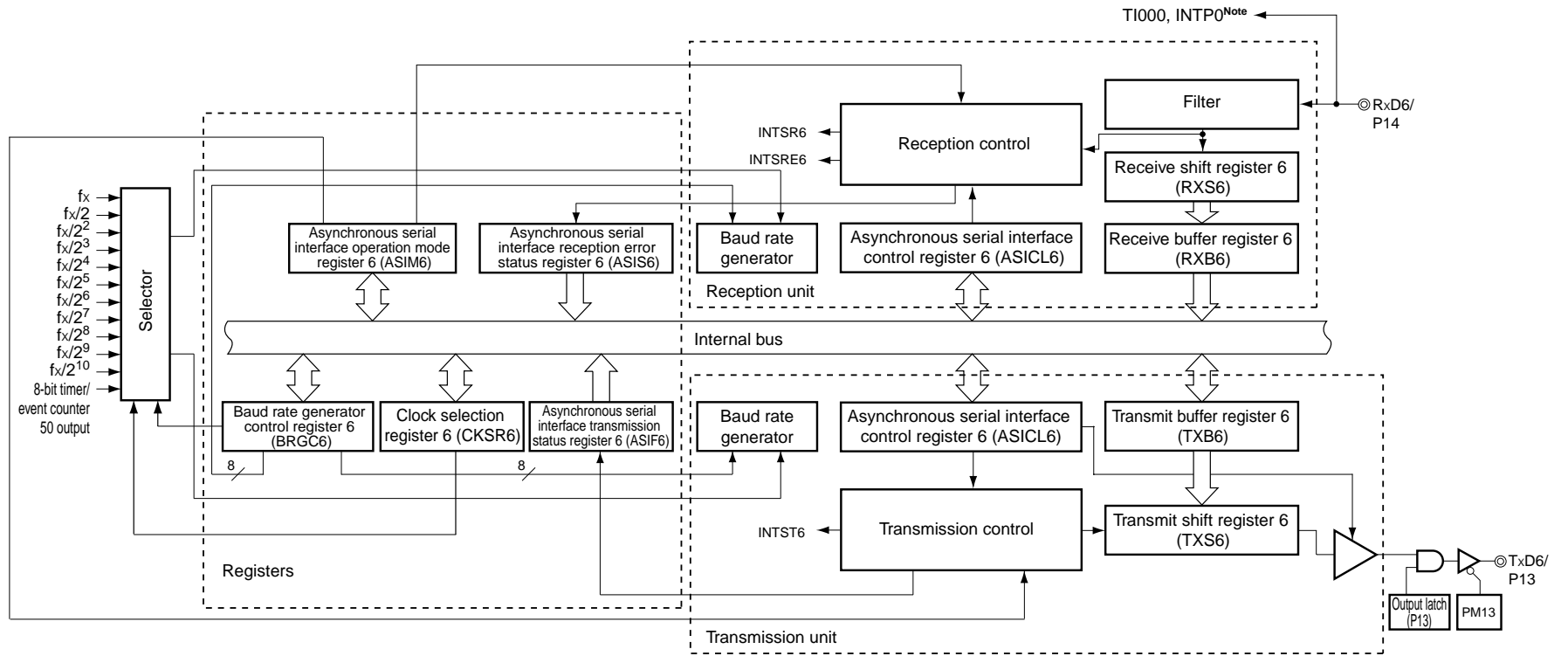
## 12.2 Configuration of Serial Interface UART6

Serial interface UART6 includes the following hardware.

**Table 12-1. Configuration of Serial Interface UART6**

| Item              | Configuration  |
|-------------------|--|
| Registers         | Receive buffer register 6 (RXB6)<br>Receive shift register 6 (RXS6)<br>Transmit buffer register 6 (TXB6)<br>Transmit shift register 6 (TXS6)   |
| Control registers | Asynchronous serial interface operation mode register 6 (ASIM6)<br>Asynchronous serial interface reception error status register 6 (ASIS6)<br>Asynchronous serial interface transmission status register 6 (ASIF6)<br>Clock selection register 6 (CKSR6)<br>Baud rate generator control register 6 (BRGC6)<br>Asynchronous serial interface control register 6 (ASICL6)<br>Input switch control register (ISC)<br>Port mode register 1 (PM1)<br>Port register 1 (P1) |

Figure 12-4. Block Diagram of Serial Interface UART6



**Note** Selectable with input switch control register (ISC).

**(1) Receive buffer register 6 (RXB6)**

This 8-bit register stores parallel data converted by receive shift register 6 (RXS6).

Each time 1 byte of data has been received, new receive data is transferred to this register from receive shift register 6 (RXS6). If the data length is set to 7 bits, data is transferred as follows.

- In LSB-first reception, the receive data is transferred to bits 0 to 6 of RXB6 and the MSB of RXB6 is always 0.
- In MSB-first reception, the receive data is transferred to bits 1 to 7 of RXB6 and the LSB of RXB6 is always 0.

If an overrun error (OVE6) occurs, the receive data is not transferred to RXB6.

RXB6 can be read by an 8-bit memory manipulation instruction. No data can be written to this register.

$\overline{\text{RESET}}$  input sets this register to FFH.

**(2) Receive shift register 6 (RXS6)**

This register converts the serial data input to the RxD6 pin into parallel data.

RXS6 cannot be directly manipulated by a program.

**(3) Transmit buffer register 6 (TXB6)**

This buffer register is used to set transmit data. Transmission is started when data is written to TXB6.

This register can be read or written by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets this register to FFH.

**Cautions** 1. Do not write data to TXB6 when bit 1 (TXBF6) of asynchronous serial interface transmission status register 6 (ASIF6) is 1.

2. Do not refresh (write the same value to) TXB6 by software during a communication operation (when bit 7 (POWER6) and bit 6 (TXE6) of asynchronous serial interface operation mode register 6 (ASIM6) are 1 or when bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 are 1).

**(4) Transmit shift register 6 (TXS6)**

This register transmits the data transferred from TXB6 from the TxD6 pin as serial data. Data is transferred from TXB6 immediately after TXB6 is written for the first transmission, or immediately before INTST6 occurs after one frame was transmitted for continuous transmission. Data is transferred from TXB6 and transmitted from the TxD6 pin at the falling edge of the base clock.

TXS6 cannot be directly manipulated by a program.

## 12.3 Registers Controlling Serial Interface UART6

Serial interface UART6 is controlled by the following nine registers.

- Asynchronous serial interface operation mode register 6 (ASIM6)
- Asynchronous serial interface reception error status register 6 (ASIS6)
- Asynchronous serial interface transmission status register 6 (ASIF6)
- Clock selection register 6 (CKSR6)
- Baud rate generator control register 6 (BRGC6)
- Asynchronous serial interface control register 6 (ASICL6)
- Input switch control register (ISC)
- Port mode register 1 (PM1)
- Port register 1 (P1)

### (1) Asynchronous serial interface operation mode register 6 (ASIM6)

This 8-bit register controls the serial communication operations of serial interface UART6.

This register can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets this register to 01H.

**Remark** ASIM6 can be refreshed (the same value is written) by software during a communication operation (when bit 7 (POWER6) and bit 6 (TXE6) of ASIM6 = 1 or bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 = 1).

**Figure 12-5. Format of Asynchronous Serial Interface Operation Mode Register 6 (ASIM6) (1/2)**

Address: FF50H After reset: 01H R/W

| Symbol | <7>    | <6>  | <5>  | 4    | 3    | 2   | 1   | 0     |
|--------|--------|------|------|------|------|-----|-----|-------|
| ASIM6  | POWER6 | TXE6 | RXE6 | PS61 | PS60 | CL6 | SL6 | ISRM6 |

| POWER6              | Enables/disables operation of internal operation clock   |
|---------------------|--|
| 0 <sup>Note 1</sup> | Disables operation of the internal operation clock (fixes the clock to low level) and asynchronously resets the internal circuit <sup>Note 2</sup> . |
| 1 <sup>Note 3</sup> | Enables operation of the internal operation clock  |

| TXE6 | Enables/disables transmission  |
|------|--|
| 0    | Disables transmission (synchronously resets the transmission circuit). |
| 1    | Enables transmission   |

- Notes**
1. The output of the TxD6 pin goes high and the input from the RxD6 pin is fixed to the high level when POWER6 = 0.
  2. Asynchronous serial interface reception error status register 6 (ASIS6), asynchronous serial interface transmission status register 6 (ASIF6), bit 7 (SBRF6) and bit 6 (SBRT6) of asynchronous serial interface control register 6 (ASICL6), and receive buffer register 6 (RXB6) are reset.
  3. Operation of the 8-bit counter output is enabled at the second base clock after 1 is written to the POWER6 bit.

Figure 12-5. Format of Asynchronous Serial Interface Operation Mode Register 6 (ASIM6) (2/2)

|      |  |  |  |
|------|--|--|--|
| RXE6 | Enables/disables reception                                       |  |  |
| 0    | Disables reception (synchronously resets the reception circuit). |  |  |
| 1    | Enables reception  |  |  |

| PS61 | PS60 | Transmission operation      | Reception operation                   |
|------|------|-----------------------------|---------------------------------------|
| 0    | 0    | Does not output parity bit. | Reception without parity              |
| 0    | 1    | Outputs 0 parity.           | Reception as 0 parity <sup>Note</sup> |
| 1    | 0    | Outputs odd parity.         | Judges as odd parity.                 |
| 1    | 1    | Outputs even parity.        | Judges as even parity.                |

|     |   |  |  |
|-----|---|--|--|
| CL6 | Specifies character length of transmit/receive data |  |  |
| 0   | Character length of data = 7 bits                   |  |  |
| 1   | Character length of data = 8 bits                   |  |  |

|     |  |  |  |
|-----|--|--|--|
| SL6 | Specifies number of stop bits of transmit data |  |  |
| 0   | Number of stop bits = 1                        |  |  |
| 1   | Number of stop bits = 2                        |  |  |

|       |  |  |  |
|-------|--|--|--|
| ISRM6 | Enables/disables occurrence of reception completion interrupt in case of error |  |  |
| 0     | "INTSRE6" occurs in case of error (at this time, INTSR6 does not occur).       |  |  |
| 1     | "INTSR6" occurs in case of error (at this time, INTSRE6 does not occur).       |  |  |

**Note** If "reception as 0 parity" is selected, the parity is not judged. Therefore, bit 2 (PE6) of asynchronous serial interface reception error status register 6 (ASIS6) is not set and the error interrupt does not occur.

- Cautions**
1. At startup, set POWER6 to 1 and then set TXE6 to 1. To stop the operation, clear TXE6 to 0 and then clear POWER6 to 0.
  2. At startup, set POWER6 to 1 and then set RXE6 to 1. To stop the operation, clear RXE6 to 0 and then clear POWER6 to 0.
  3. Set POWER6 to 1 and then set RXE6 to 1 while a high level is input to the RxD6 pin. If POWER6 is set to 1 and RXE6 is set to 1 while a low level is input, reception is started.
  4. Clear the TXE6 and RXE6 bits to 0 before rewriting the PS61, PS60, and CL6 bits.
  5. Fix the PS61 and PS60 bits to 0 when mounting the device on LIN.
  6. Make sure that TXE6 = 0 when rewriting the SL6 bit. Reception is always performed with "the number of stop bits = 1", and therefore, is not affected by the set value of the SL6 bit.
  7. Make sure that RXE6 = 0 when rewriting the ISRM6 bit.



**(2) Asynchronous serial interface reception error status register 6 (ASIS6)**

This register indicates an error status on completion of reception by serial interface UART6. It includes three error flag bits (PE6, FE6, OVE6).

This register is read-only by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H if bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 = 0. 00H is read when this register is read.

**Figure 12-6. Format of Asynchronous Serial Interface Reception Error Status Register 6 (ASIS6)**

Address: FF53H After reset: 00H R

|        |   |   |   |   |   |     |     |      |
|--------|---|---|---|---|---|-----|-----|------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2   | 1   | 0    |
| ASIS6  | 0 | 0 | 0 | 0 | 0 | PE6 | FE6 | OVE6 |

|     |   |
|-----|---|
| PE6 | Status flag indicating parity error   |
| 0   | If POWER6 = 0 and RXE6 = 0, or if ASIS6 register is read                                |
| 1   | If the parity of transmit data does not match the parity bit on completion of reception |

|     |  |
|-----|--|
| FE6 | Status flag indicating framing error                       |
| 0   | If POWER6 = 0 and RXE6 = 0, or if ASIS6 register is read   |
| 1   | If the stop bit is not detected on completion of reception |

|      |  |
|------|--|
| OVE6 | Status flag indicating overrun error   |
| 0    | If POWER6 = 0 and RXE6 = 0, or if ASIS6 register is read   |
| 1    | If receive data is set to the RXB6 register and the next reception operation is completed before the data is read. |

- Cautions**
1. The operation of the PE6 bit differs depending on the set values of the PS61 and PS60 bits of asynchronous serial interface operation mode register 6 (ASIM6).
  2. The first bit of the receive data is checked as the stop bit, regardless of the number of stop bits.
  3. If an overrun error occurs, the next receive data is not written to receive buffer register 6 (RXB6) but discarded.
  4. If data is read from ASIS6, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.

**(3) Asynchronous serial interface transmission status register 6 (ASIF6)**

This register indicates the status of transmission by serial interface UART6. It includes two status flag bits (TXBF6 and TXSF6).

Transmission can be continued without disruption even during an interrupt period, by writing the next data to the TXB6 register after data has been transferred from the TXB6 register to the TXS6 register.

This register is read-only by an 8-bit memory manipulation instruction.

RESET input clears this register to 00H if bit 7 (POWER6) and bit 6 (TXE6) of ASIM6 = 0.

**Figure 12-7. Format of Asynchronous Serial Interface Transmission Status Register 6 (ASIF6)**

Address: FF55H After reset: 00H R

|        |   |   |   |   |   |   |       |       |
|--------|---|---|---|---|---|---|-------|-------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2 | 1     | 0     |
| ASIF6  | 0 | 0 | 0 | 0 | 0 | 0 | TXBF6 | TXSF6 |

|       |  |
|-------|--|
| TXBF6 | Transmit buffer data flag  |
| 0     | If POWER6 = 0 or TXE6 = 0, or if data is transferred to transmit shift register 6 (TXS6) |
| 1     | If data is written to transmit buffer register 6 (TXB6) (if data exists in TXB6)         |

|       |   |
|-------|---|
| TXSF6 | Transmit shift register data flag   |
| 0     | If POWER6 = 0 or TXE6 = 0, or if the next data is not transferred from transmit buffer register 6 (TXB6) after completion of transfer |
| 1     | If data is transferred from transmit buffer register 6 (TXB6) (if data transmission is in progress)                                   |

- Cautions**
- 1. To transmit data continuously, write the first transmit data (first byte) to the TXB6 register. Be sure to check that the TXBF6 flag is “0”. If so, write the next transmit data (second byte) to the TXB6 register. If data is written to the TXB6 register while the TXBF6 flag is “1”, the transmit data cannot be guaranteed.**
  - 2. To initialize the transmission unit upon completion of continuous transmission, be sure to check that the TXSF6 flag is “0” after generation of the transmission completion interrupt, and then execute initialization. If initialization is executed while the TXSF6 flag is “1”, the transmit data cannot be guaranteed.**

#### (4) Clock selection register 6 (CKSR6)

This register selects the base clock of serial interface UART6.

CKSR6 can be set by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Remark** CKSR6 can be refreshed (the same value is written) by software during a communication operation (when bit 7 (POWER6) and bit 6 (TXE6) of ASIM6 = 1 or bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 = 1).

**Figure 12-8. Format of Clock Selection Register 6 (CKSR6)**

Address: FF56H After reset: 00H R/W

|        |   |   |   |   |       |       |       |       |
|--------|---|---|---|---|-------|-------|-------|-------|
| Symbol | 7 | 6 | 5 | 4 | 3     | 2     | 1     | 0     |
| CKSR6  | 0 | 0 | 0 | 0 | TPS63 | TPS62 | TPS61 | TPS60 |

| TPS63 | TPS62 | TPS61 | TPS60 | Base clock ( $f_{\text{CLK6}}$ ) selection <sup>Note 1</sup> |
|-------|-------|-------|-------|--|
| 0     | 0     | 0     | 0     | $f_x$ (10 MHz)   |
| 0     | 0     | 0     | 1     | $f_x/2$ (5 MHz)  |
| 0     | 0     | 1     | 0     | $f_x/2^2$ (2.5 MHz)  |
| 0     | 0     | 1     | 1     | $f_x/2^3$ (1.25 MHz)   |
| 0     | 1     | 0     | 0     | $f_x/2^4$ (625 kHz)  |
| 0     | 1     | 0     | 1     | $f_x/2^5$ (312.5 kHz)  |
| 0     | 1     | 1     | 0     | $f_x/2^6$ (156.25 kHz)                                       |
| 0     | 1     | 1     | 1     | $f_x/2^7$ (78.13 kHz)  |
| 1     | 0     | 0     | 0     | $f_x/2^8$ (39.06 kHz)  |
| 1     | 0     | 0     | 1     | $f_x/2^9$ (19.53 kHz)  |
| 1     | 0     | 1     | 0     | $f_x/2^{10}$ (9.77 kHz)                                      |
| 1     | 0     | 1     | 1     | TM50 output <sup>Note 2</sup>                                |
| Other |       |       |       | Setting prohibited   |

- ★ **Notes**
- Be sure to set the base clock so that the following condition is satisfied.
    - $V_{\text{DD}} = 4.0$  to  $5.5$  V: Base clock  $\leq 10$  MHz
    - $V_{\text{DD}} = 3.3$  to  $4.0$  V: Base clock  $\leq 8.38$  MHz
    - $V_{\text{DD}} = 2.7$  to  $3.3$  V: Base clock  $\leq 5$  MHz
    - $V_{\text{DD}} = 2.5$  to  $2.7$  V: Base clock  $\leq 2.5$  MHz
  - Note the following points when selecting the TM50 output as the base clock.
    - PWM mode (TMC506 = 1)
      - Start the operation of 8-bit timer/event counter 50 first and then set the base clock to make the duty = 50%.
    - Mode in which the base clock is cleared and started upon a match of TM50 and CR50 (TMC506 = 0)
      - Start the operation of 8-bit timer/event counter 50 first and then enable the timer F/F inversion operation (TMC501 = 1).

It is not necessary to enable the TO50 pin as a timer output pin in any mode.

- Cautions**
- When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the base clock is the Ring-OSC clock, the operation of serial interface UART6 is not guaranteed.
  - Make sure POWER6 = 0 when rewriting TPS63 to TPS60.

- Remarks**
- Figures in parentheses are for operation with  $f_x = 10$  MHz
  - $f_x$ : X1 input clock oscillation frequency

**(5) Baud rate generator control register 6 (BRGC6)**

This register sets the division value of the 8-bit counter of serial interface UART6.

BRGC6 can be set by an 8-bit memory manipulation instruction.

RESET input sets this register to FFH.

**Remark** BRGC6 can be refreshed (the same value is written) by software during a communication operation (when bit 7 (POWER6) and bit 6 (TXE6) of ASIM6 = 1 or bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 = 1).

**Figure 12-9. Format of Baud Rate Generator Control Register 6 (BRGC6)**

Address: FF57H After reset: FFH R/W

|        |       |       |       |       |       |       |       |       |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|
| Symbol | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
| BRGC6  | MDL67 | MDL66 | MDL65 | MDL64 | MDL63 | MDL62 | MDL61 | MDL60 |

| MDL67 | MDL66 | MDL65 | MDL64 | MDL63 | MDL62 | MDL61 | MDL60 | k   | Output clock selection of 8-bit counter |
|-------|-------|-------|-------|-------|-------|-------|-------|-----|---|
| 0     | 0     | 0     | 0     | 0     | ×     | ×     | ×     | ×   | Setting prohibited                      |
| 0     | 0     | 0     | 0     | 1     | 0     | 0     | 0     | 8   | $f_{XCLK6}/8$                           |
| 0     | 0     | 0     | 0     | 1     | 0     | 0     | 1     | 9   | $f_{XCLK6}/9$                           |
| 0     | 0     | 0     | 0     | 1     | 0     | 1     | 0     | 10  | $f_{XCLK6}/10$                          |
| •     | •     | •     | •     | •     | •     | •     | •     | •   | •                                       |
| •     | •     | •     | •     | •     | •     | •     | •     | •   | •                                       |
| •     | •     | •     | •     | •     | •     | •     | •     | •   | •                                       |
| •     | •     | •     | •     | •     | •     | •     | •     | •   | •                                       |
| •     | •     | •     | •     | •     | •     | •     | •     | •   | •                                       |
| 1     | 1     | 1     | 1     | 1     | 1     | 0     | 0     | 252 | $f_{XCLK6}/252$                         |
| 1     | 1     | 1     | 1     | 1     | 1     | 0     | 1     | 253 | $f_{XCLK6}/253$                         |
| 1     | 1     | 1     | 1     | 1     | 1     | 1     | 0     | 254 | $f_{XCLK6}/254$                         |
| 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 255 | $f_{XCLK6}/255$                         |

**Cautions** 1. Make sure that bit 6 (TXE6) and bit 5 (RXE6) of the ASIM6 register = 0 when rewriting the MDL67 to MDL60 bits.

2. The baud rate value is the output clock of the 8-bit counter divided by 2.

**Remarks** 1.  $f_{XCLK6}$ : Frequency of base clock selected by the TPS63 to TPS60 bits of CKSR6 register  
 2. k: Value set by MDL67 to MDL60 bits (k = 8, 9, 10, ..., 255)  
 3. ×: Don't care

**(6) Asynchronous serial interface control register 6 (ASICL6)**

This register controls the serial communication operations of serial interface UART6.

ASICL6 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets this register to 16H.

**Caution** ASICL6 can be refreshed (the same value is written) by software during a communication operation (when bit 7 (POWER6) and bit 6 (TXE6) of ASIM6 = 1 or bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 = 1). Note, however, that communication is started by the refresh operation because bit 6 (SBRT6) of ASICL6 is cleared to 0 when communication is completed (when an interrupt signal is generated).

**Figure 12-10. Format of Asynchronous Serial Interface Control Register 6 (ASICL6)**

Address: FF58H After reset: 16H R/W<sup>Note</sup>

| Symbol | <7>   | <6>   | 5 | 4 | 3 | 2 | 1    | 0      |
|--------|-------|-------|---|---|---|---|------|--------|
| ASICL6 | SBRF6 | SBRT6 | 0 | 1 | 0 | 1 | DIR6 | TXDLV6 |

| SBRF6 | SBF reception status flag   |
|-------|---|
| 0     | If POWER6 = 0 and RXE6 = 0 or if SBF reception has been completed correctly |
| 1     | SBF reception in progress   |

| SBRT6 | SBF reception trigger |
|-------|-----------------------|
| 0     | –                     |
| 1     | SBF reception trigger |

| DIR6 | First bit specification |
|------|-------------------------|
| 0    | MSB                     |
| 1    | LSB                     |

| TXDLV6 | Enables/disables inverting TxD6 output |
|--------|--|
| 0      | Normal output of TxD6                  |
| 1      | Inverted output of TxD6                |

**Note** Bits 2 to 5 and 7 are read-only.

- Cautions**
1. In the case of an SBF reception error, return the mode to the SBF reception mode again. The status of the SBRF6 flag is held (1).
  2. Before setting the SBRT6 bit, make sure that bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 = 1.
  3. The read value of the SBRT6 bit is always 0. SBRT6 is automatically cleared to 0 after SBF reception has been correctly completed.
  4. Before rewriting the DIR6 and TXDLV6 bits, clear the TXE6 and RXE6 bits to 0.

**(7) Input switch control register (ISC)**

The input switch control register (ISC) is used to receive a status signal transmitted from the master during LIN (Local Interconnect Network) reception. The input signal is switched by setting ISC.

This register can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 12-11. Format of Input Switch Control Register (ISC)**

Address: FF4FH After reset: 00H R/W

| Symbol | 7                            | 6 | 5 | 4 | 3 | 2 | 1    | 0    |  |
|--------|------------------------------|---|---|---|---|---|------|------|--|
| ISC    | 0                            | 0 | 0 | 0 | 0 | 0 | ISC1 | ISC0 |  |
| ISC1   | TI000 input source selection |   |   |   |   |   |      |      |  |
| 0      | TI000 (P00)                  |   |   |   |   |   |      |      |  |
| 1      | RxD6 (P14)                   |   |   |   |   |   |      |      |  |
| ISC0   | INTP0 input source selection |   |   |   |   |   |      |      |  |
| 0      | INTP0 (P120)                 |   |   |   |   |   |      |      |  |
| 1      | RxD6 (P14)                   |   |   |   |   |   |      |      |  |

**(8) Port mode register 1 (PM1)**

This register sets port 1 input/output in 1-bit units.

When using the P13/TxD6 pin for serial interface data output, clear PM13 to 0 and set the output latch of P13 to 1.

When using the P14/RxD6 pin for serial interface data input, set PM14 to 1. The output latch of P14 at this time may be 0 or 1.

PM1 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets this register to FFH.

**Figure 12-12. Format of Port Mode Register 1 (PM1)**

Address: FF21H After reset: FFH R/W

| Symbol | 7                                       | 6    | 5    | 4    | 3    | 2    | 1    | 0    |  |
|--------|---|------|------|------|------|------|------|------|--|
| PM1    | PM17                                    | PM16 | PM15 | PM14 | PM13 | PM12 | PM11 | PM10 |  |
| PM1n   | P1n pin I/O mode selection (n = 0 to 7) |      |      |      |      |      |      |      |  |
| 0      | Output mode (output buffer on)          |      |      |      |      |      |      |      |  |
| 1      | Input mode (output buffer off)          |      |      |      |      |      |      |      |  |

## 12.4 Operation of Serial Interface UART6

Serial interface UART6 has the following two modes.

- Operation stop mode
- Asynchronous serial interface (UART) mode

### 12.4.1 Operation stop mode

In this mode, serial communication cannot be executed; therefore, the power consumption can be reduced. In addition, the pins can be used as ordinary port pins in this mode. To set the operation stop mode, clear bits 7, 6, and 5 (POWER6, TXE6, and RXE6) of ASIM6 to 0.

#### (1) Register used

The operation stop mode is set by asynchronous serial interface operation mode register 6 (ASIM6).

ASIM6 can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input sets this register to 01H.

Address: FF50H After reset: 01H R/W

| Symbol | <7>                 | <6>  | <5>  | 4    | 3    | 2   | 1   | 0     |
|--------|---------------------|--|------|------|------|-----|-----|-------|
| ASIM6  | POWER6              | TXE6   | RXE6 | PS61 | PS60 | CL6 | SL6 | ISRM6 |
|        | POWER6              | Enables/disables operation of internal operation clock   |      |      |      |     |     |       |
|        | 0 <sup>Note 1</sup> | Disables operation of the internal operation clock (fixes the clock to low level) and asynchronously resets the internal circuit <sup>Note 2</sup> . |      |      |      |     |     |       |
|        | TXE6                | Enables/disables transmission  |      |      |      |     |     |       |
|        | 0                   | Disables transmission operation (synchronously resets the transmission circuit).   |      |      |      |     |     |       |
|        | RXE6                | Enables/disables reception   |      |      |      |     |     |       |
|        | 0                   | Disables reception (synchronously resets the reception circuit).   |      |      |      |     |     |       |

- Notes**
1. The output of the TxD6 pin goes high and the input from the RxD6 pin is fixed to high level when POWER6 = 0.
  2. Asynchronous serial interface reception error status register 6 (ASIS6), asynchronous serial interface transmission status register 6 (ASIF6), bit 7 (SBRF6) and bit 6 (SBRT6) of asynchronous serial interface control register 6 (ASICL6), and receive buffer register 6 (RXB6) are reset.

**Caution** Clear POWER6 to 0 after clearing TXE6 and RXE6 to 0 to set the operation stop mode. To start the operation, set POWER6 to 1, and then set TXE6 and RXE6 to 1.

**Remark** To use the RxD6/P14 and TxD6/P13 pins as general-purpose port pins, see **CHAPTER 4 PORT FUNCTIONS**.

**12.4.2 Asynchronous serial interface (UART) mode**

In this mode, data of 1 byte is transmitted/received following a start bit, and a full-duplex operation can be performed.

A dedicated UART baud rate generator is incorporated, so that communication can be executed at a wide range of baud rates.

**(1) Registers used**

- Asynchronous serial interface operation mode register 6 (ASIM6)
- Asynchronous serial interface reception error status register 6 (ASIS6)
- Asynchronous serial interface transmission status register 6 (ASIF6)
- Clock selection register 6 (CKSR6)
- Baud rate generator control register 6 (BRGC6)
- Asynchronous serial interface control register 6 (ASICL6)
- Input switch control register (ISC)
- Port mode register 1 (PM1)
- Port register 1 (P1)

The basic procedure of setting an operation in the UART mode is as follows.

- <1> Set the CKSR6 register (see **Figure 12-8**).
- <2> Set the BRGC6 register (see **Figure 12-9**).
- <3> Set bits 0 to 4 (ISRM6, SL6, CL6, PS60, PS61) of the ASIM6 register (see **Figure 12-5**).
- <4> Set bits 0 and 1 (TXDLV6, DIR6) of the ASICL6 register (see **Figure 12-10**).
- <5> Set bit 7 (POWER6) of the ASIM6 register to 1.
- <6> Set bit 6 (TXE6) of the ASIM6 register to 1. → Transmission is enabled.  
Set bit 5 (RXE6) of the ASIM6 register to 1. → Reception is enabled.
- <7> Write data to transmit buffer register 6 (TXB6). → Data transmission is started.

**Caution** Take relationship with the other party of communication when setting the port mode register and port register.

The relationship between the register settings and pins is shown below.

**Table 12-2. Relationship Between Register Settings and Pins**

| POWER6 | TXE6 | RXE6 | PM13              | P13               | PM14              | P14               | UART6 Operation        | Pin Function |          |
|--------|------|------|-------------------|-------------------|-------------------|-------------------|------------------------|--------------|----------|
|        |      |      |                   |                   |                   |                   |                        | TxD6/P13     | RxD6/P14 |
| 0      | 0    | 0    | x <sup>Note</sup> | x <sup>Note</sup> | x <sup>Note</sup> | x <sup>Note</sup> | Stop                   | P13          | P14      |
| 1      | 0    | 1    | x <sup>Note</sup> | x <sup>Note</sup> | 1                 | x                 | Reception              | P13          | RxD6     |
|        | 1    | 0    | 0                 | 1                 | x <sup>Note</sup> | x <sup>Note</sup> | Transmission           | TxD6         | P14      |
|        | 1    | 1    | 0                 | 1                 | 1                 | x                 | Transmission/reception | TxD6         | RxD6     |

**Note** Can be set as port function.

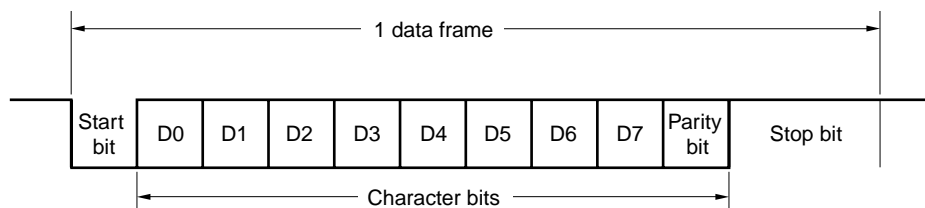
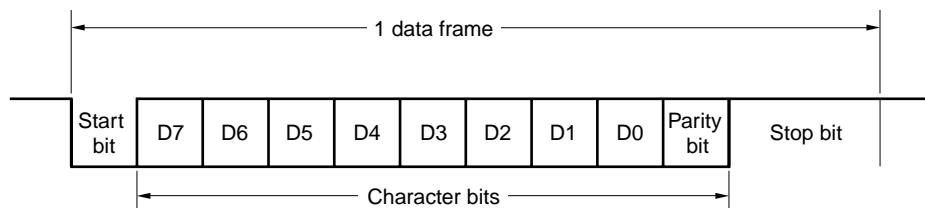
- Remark**
- x: don't care
  - POWER6: Bit 7 of asynchronous serial interface operation mode register 6 (ASIM6)
  - TXE6: Bit 6 of ASIM6
  - RXE6: Bit 5 of ASIM6
  - PM1x: Port mode register
  - P1x: Port output latch



**(2) Communication operation****(a) Format and waveform example of normal transmit/receive data**

Figures 12-13 and 12-14 show the format and waveform example of the normal transmit/receive data.

**Figure 12-13. Format of Normal UART Transmit/Receive Data**

**1. LSB-first transmission/reception****2. MSB-first transmission/reception**

One data frame consists of the following bits.

- Start bit ... 1 bit
- Character bits ... 7 or 8 bits
- Parity bit ... Even parity, odd parity, 0 parity, or no parity
- Stop bit ... 1 or 2 bits

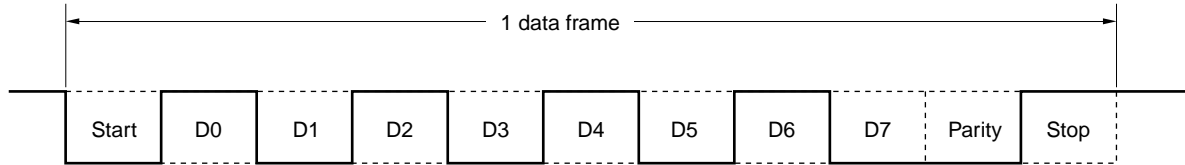
The character bit length, parity, and stop bit length in one data frame are specified by asynchronous serial interface operation mode register 6 (ASIM6).

Whether data is communicated with the LSB or MSB first is specified by bit 1 (DIR6) of asynchronous serial interface control register 6 (ASICL6).

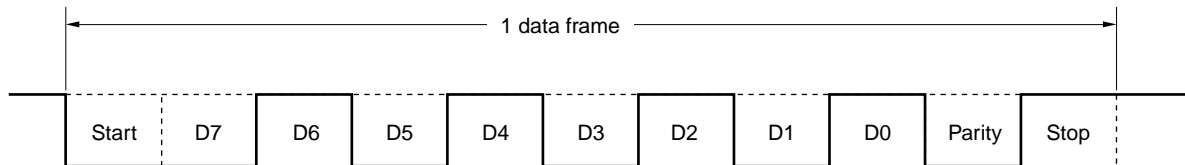
Whether the TxD6 pin outputs normal or inverted data is specified by bit 0 (TXDLV6) of ASICL6.

Figure 12-14. Example of Normal UART Transmit/Receive Data Waveform

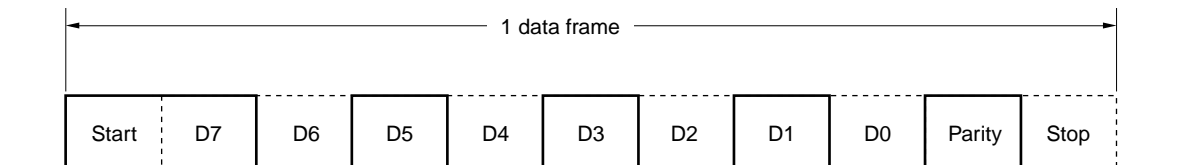
1. Data length: 8 bits, LSB first, Parity: Even parity, Stop bit: 1 bit, Communication data: 55H



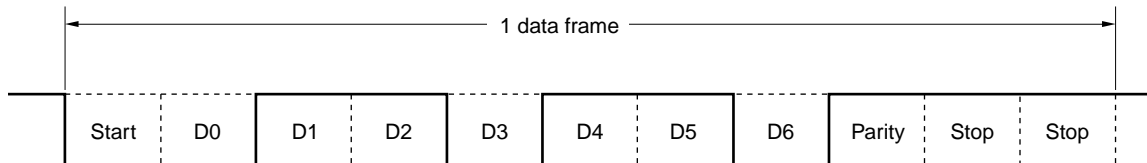
2. Data length: 8 bits, MSB first, Parity: Even parity, Stop bit: 1 bit, Communication data: 55H



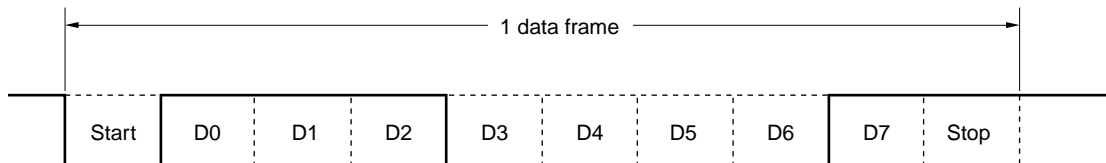
3. Data length: 8 bits, MSB first, Parity: Even parity, Stop bit: 1 bit, Communication data: 55H, Tx/D6 pin inverted output



4. Data length: 7 bits, LSB first, Parity: Odd parity, Stop bit: 2 bits, Communication data: 36H



5. Data length: 8 bits, LSB first, Parity: None, Stop bit: 1 bit, Communication data: 87H



**(b) Parity types and operation**

The parity bit is used to detect a bit error in communication data. Usually, the same type of parity bit is used on both the transmission and reception sides. With even parity and odd parity, a 1-bit (odd number) error can be detected. With zero parity and no parity, an error cannot be detected.

**Caution** Fix the PS61 and PS60 bits to 0 when the device is incorporated in LIN.

**(i) Even parity**

- Transmission

Transmit data, including the parity bit, is controlled so that the number of bits that are “1” is even. The value of the parity bit is as follows.

If transmit data has an odd number of bits that are “1”: 1

If transmit data has an even number of bits that are “1”: 0

- Reception

The number of bits that are “1” in the receive data, including the parity bit, is counted. If it is odd, a parity error occurs.

**(ii) Odd parity**

- Transmission

Unlike even parity, transmit data, including the parity bit, is controlled so that the number of bits that are “1” is odd.

If transmit data has an odd number of bits that are “1”: 0

If transmit data has an even number of bits that are “1”: 1

- Reception

The number of bits that are “1” in the receive data, including the parity bit, is counted. If it is even, a parity error occurs.

**(iii) 0 parity**

The parity bit is cleared to 0 when data is transmitted, regardless of the transmit data.

The parity bit is not detected when the data is received. Therefore, a parity error does not occur regardless of whether the parity bit is “0” or “1”.

**(iv) No parity**

No parity bit is appended to the transmit data.

Reception is performed assuming that there is no parity bit when data is received. Because there is no parity bit, a parity error does not occur.

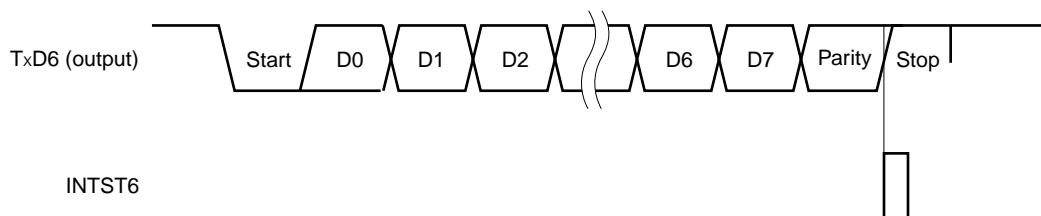
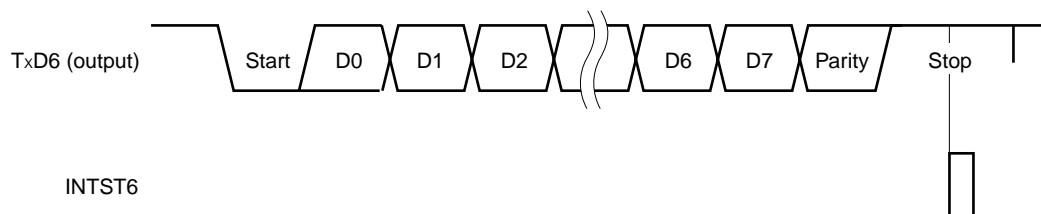
**(c) Normal transmission**

The TxD6 pin outputs a high level when bit 7 (POWER6) of asynchronous serial interface operation mode register 6 (ASIM6) is set to 1. If bit 6 (TXE6) of ASIM6 is then set to 1, transmission is enabled. Transmission can be started by writing transmit data to transmit buffer register 6 (TXB6). The start bit, parity bit, and stop bit are automatically appended to the data.

When transmission is started, the data in TXB6 is transferred to transmit shift register 6 (TXS6). After that, the data is sequentially output from TXS6 to the TxD6 pin. When transmission is completed, the parity bit and stop bit set by ASIM6 are added and a transmission completion interrupt request (INTST6) is generated. Transmission is stopped until the data to be transmitted next is written to TXB6.

Figure 12-15 shows the timing of the transmission completion interrupt request (INTST6). This interrupt occurs as soon as the last stop bit has been output.

**Figure 12-15. Normal Transmission Completion Interrupt Request Timing**

**1. Stop bit length: 1****2. Stop bit length: 2**

**(d) Continuous transmission**

The next transmit data can be written to transmit buffer register 6 (TXB6) as soon as transmit shift register 6 (TXS6) has started its shift operation. Consequently, even while the INTST6 interrupt is being serviced after transmission of one data frame, data can be continuously transmitted and an efficient communication rate can be realized. In addition, the TXB6 register can be efficiently written twice (2 bytes) without having to wait for the transmission time of one data frame, by reading bit 0 (TXSF6) of asynchronous serial interface transmission status register 6 (ASIF6) when the transmission completion interrupt has occurred.

To transmit data continuously, be sure to reference the ASIF6 register to check the transmission status and whether the TXB6 register can be written, and then write the data.

- Cautions**
1. The TXBF6 and TXSF6 flags of the ASIF6 register change from “10” to “11”, and to “01” during continuous transmission. To check the status, therefore, do not use a combination of the TXBF6 and TXSF6 flags for judgment. Read only the TXBF6 flag when executing continuous transmission.
  2. When the device is incorporated in a LIN, the continuous transmission function cannot be used. Make sure that asynchronous serial interface transmission status register 6 (ASIF6) is 00H before writing transmit data to transmit buffer register 6 (TXB6).

| TXBF6 | Writing to TXB6 Register |
|-------|--------------------------|
| 0     | Writing enabled          |
| 1     | Writing disabled         |

**Caution** To transmit data continuously, write the first transmit data (first byte) to the TXB6 register. Be sure to check that the TXBF6 flag is “0”. If so, write the next transmit data (second byte) to the TXB6 register. If data is written to the TXB6 register while the TXBF6 flag is “1”, the transmit data cannot be guaranteed.

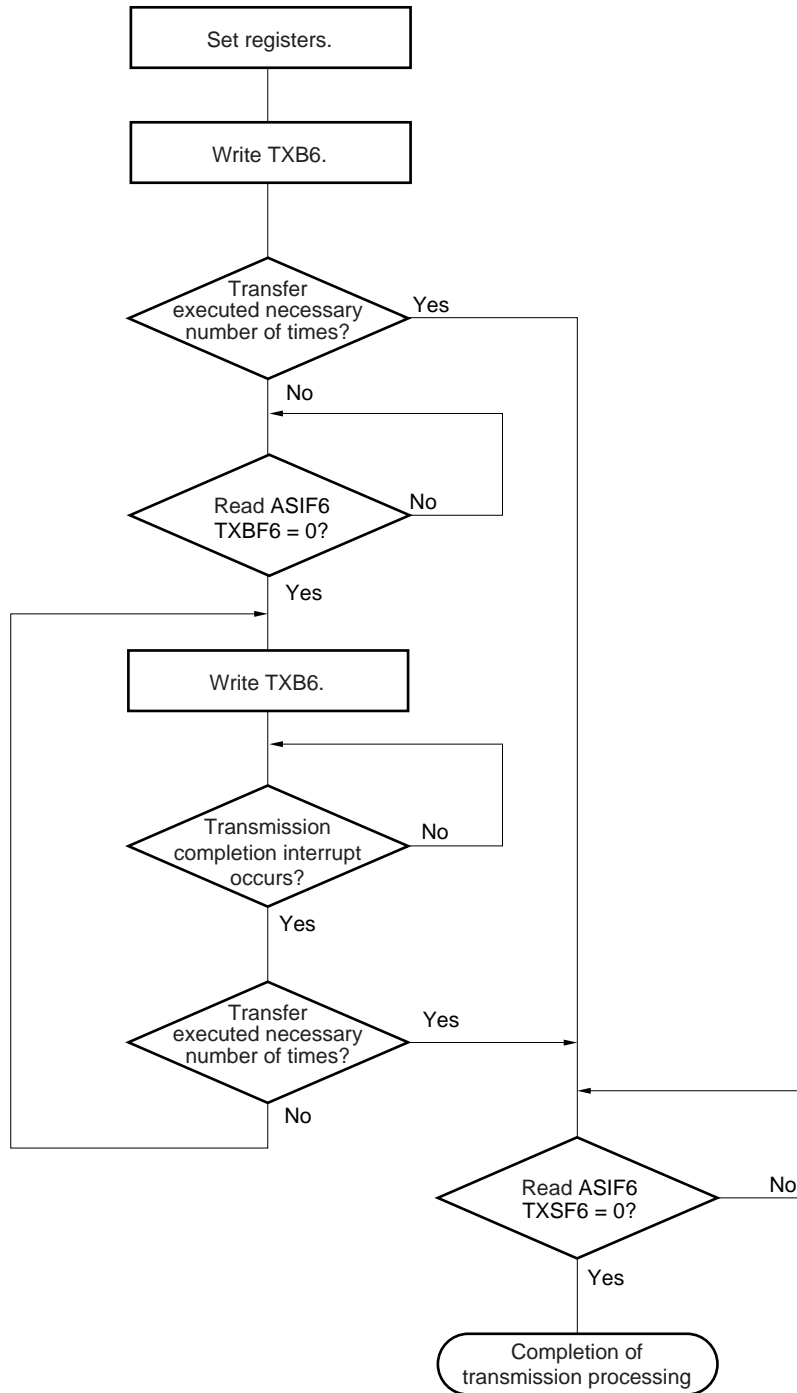
The communication status can be checked using the TXSF6 flag.

| TXSF6 | Transmission Status          |
|-------|------------------------------|
| 0     | Transmission is completed.   |
| 1     | Transmission is in progress. |

- Cautions**
1. To initialize the transmission unit upon completion of continuous transmission, be sure to check that the TXSF6 flag is “0” after generation of the transmission completion interrupt, and then execute initialization. If initialization is executed while the TXSF6 flag is “1”, the transmit data cannot be guaranteed.
  2. During continuous transmission, an overrun error may occur, which means that the next transmission was completed before execution of INTST6 interrupt servicing after transmission of one data frame. An overrun error can be detected by developing a program that can count the number of transmit data and by referencing the TXSF6 flag.

Figure 12-16 shows an example of the continuous transmission processing flow.

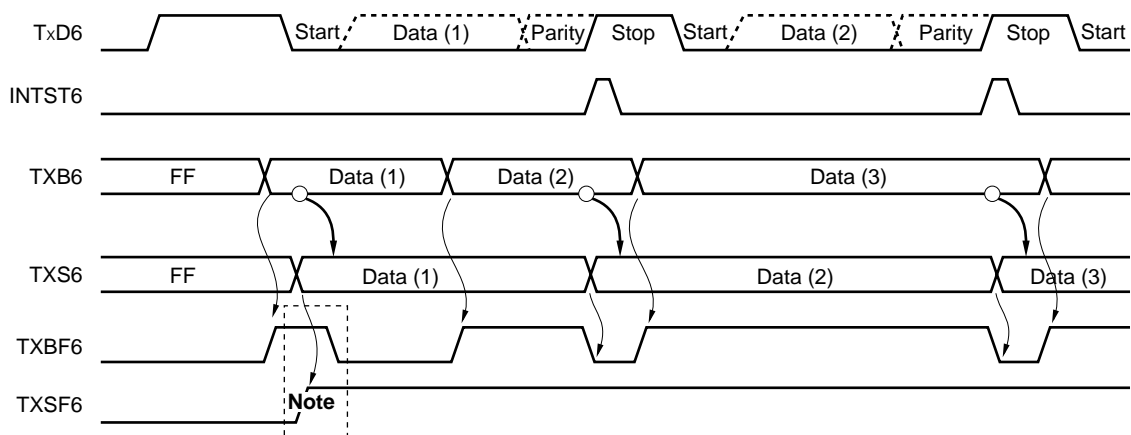
**Figure 12-16. Example of Continuous Transmission Processing Flow**



**Remark** TXB6: Transmit buffer register 6  
 ASIF6: Asynchronous serial interface transmission status register 6  
 TXBF6: Bit 1 of ASIF6 (transmit buffer data flag)  
 TXSF6: Bit 0 of ASIF6 (transmit shift register data flag)

Figure 12-17 shows the timing of starting continuous transmission, and Figure 12-18 shows the timing of ending continuous transmission.

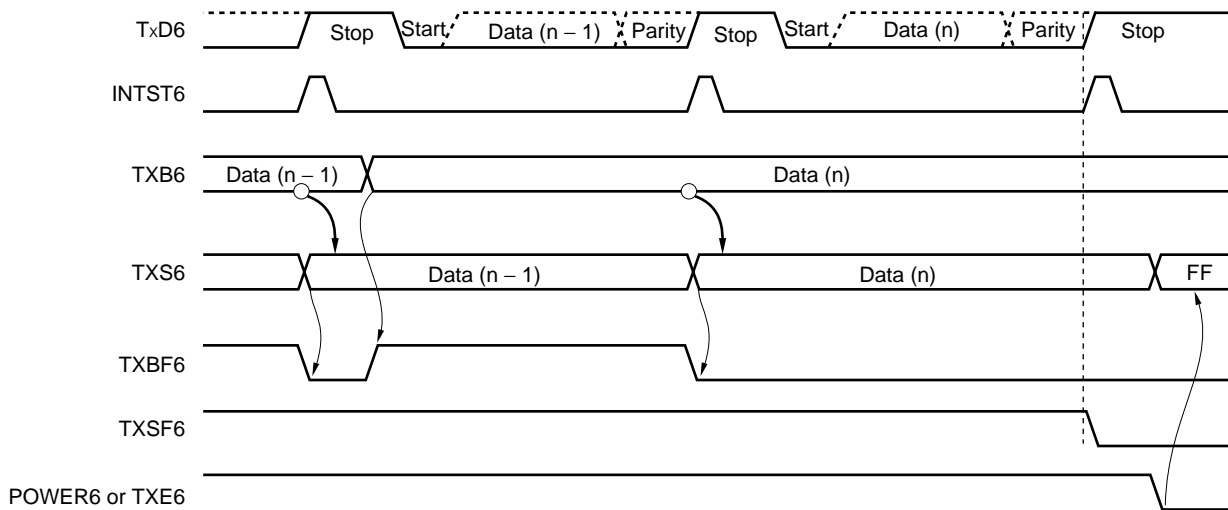
**Figure 12-17. Timing of Starting Continuous Transmission**



**Note** When ASIF6 is read, there is a period in which TXBF6 and TXSF6 = 1, 1. Therefore, judge whether writing is enabled using only the TXBF6 bit.

**Remark** TxD6: TxD6 pin (output)  
 INTST6: Interrupt request signal  
 TXB6: Transmit buffer register 6  
 TXS6: Transmit shift register 6  
 ASIF6: Asynchronous serial interface transmission status register 6  
 TXBF6: Bit 1 of ASIF6  
 TXSF6: Bit 0 of ASIF6

Figure 12-18. Timing of Ending Continuous Transmission



|               |         |  |
|---------------|---------|--|
| <b>Remark</b> | TxD6:   | TxD6 pin (output)  |
|               | INTST6: | Interrupt request signal   |
|               | TXB6:   | Transmit buffer register 6   |
|               | TXS6:   | Transmit shift register 6  |
|               | ASIF6:  | Asynchronous serial interface transmission status register 6           |
|               | TXBF6:  | Bit 1 of ASIF6   |
|               | TXSF6:  | Bit 0 of ASIF6   |
|               | POWER6: | Bit 7 of asynchronous serial interface operation mode register (ASIM6) |
|               | TXE6:   | Bit 6 of asynchronous serial interface operation mode register (ASIM6) |



**(e) Normal reception**

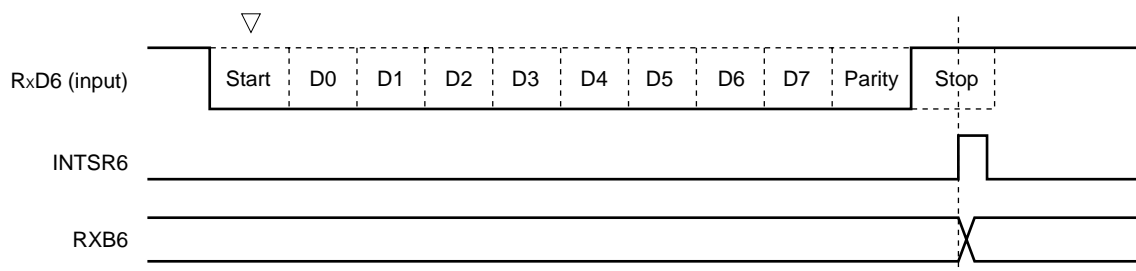
Reception is enabled and the RxD6 pin input is sampled when bit 7 (POWER6) of asynchronous serial interface operation mode register 6 (ASIM6) is set to 1 and then bit 5 (RXE6) of ASIM6 is set to 1.

The 8-bit counter of the baud rate generator starts counting when the falling edge of the RxD6 pin input is detected. When the set value of baud rate generator control register 6 (BRGC6) has been counted, the RxD6 pin input is sampled again (▽ in Figure 12-19). If the RxD6 pin is low level at this time, it is recognized as a start bit.

When the start bit is detected, reception is started, and serial data is sequentially stored in the receive shift register (RXS6) at the set baud rate. When the stop bit has been received, the reception completion interrupt (INTSR6) is generated and the data of RXS6 is written to receive buffer register 6 (RXB6). If an overrun error (OVE6) occurs, however, the receive data is not written to RXB6.

Even if a parity error (PE6) occurs while reception is in progress, reception continues to the reception position of the stop bit, and an error interrupt (INTSR6/INTSRE6) is generated on completion of reception.

**Figure 12-19. Reception Completion Interrupt Request Timing**



- Cautions**
1. Be sure to read receive buffer register 6 (RXB6) even if a reception error occurs. Otherwise, an overrun error will occur when the next data is received, and the reception error status will persist.
  2. Reception is always performed with the “number of stop bits = 1”. The second stop bit is ignored.
  3. Be sure to read asynchronous serial interface reception error status register 6 (ASIS6) before reading RXB6.

**(f) Reception error**

Three types of errors may occur during reception: a parity error, framing error, or overrun error. If the error flag of asynchronous serial interface reception error status register 6 (ASIS6) is set as a result of data reception, a reception error interrupt request (INTSR6/INTSRE6) is generated.

Which error has occurred during reception can be identified by reading the contents of ASIS6 in the reception error interrupt servicing (INTSR6/INTSRE6) (see **Figure 12-6**).

The contents of ASIS6 are reset to 0 when ASIS6 is read.

**Table 12-3. Cause of Reception Error**

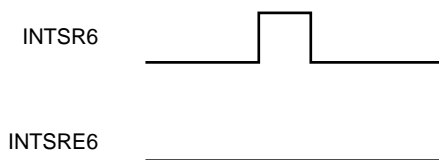
| Reception Error | Cause  |
|-----------------|--|
| Parity error    | The parity specified for transmission does not match the parity of the receive data.               |
| Framing error   | Stop bit is not detected.  |
| Overrun error   | Reception of the next data is completed before data is read from receive buffer register 6 (RXB6). |

The error interrupt can be separated into reception completion interrupt (INTSR6) and error interrupt (INTSRE6) by clearing bit 0 (ISRM6) of asynchronous serial interface operation mode register 6 (ASIM6) to 0.

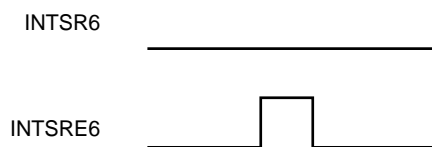
**Figure 12-20. Reception Error Interrupt**

1. If ISRM6 is cleared to 0 (reception completion interrupt (INTSR6) and error interrupt (INTSRE6) are separated)

**(a) No error during reception**

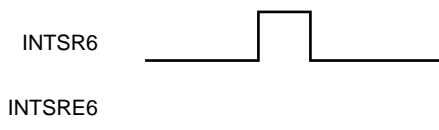


**(b) Error during reception**

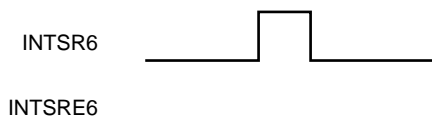


2. If ISRM6 is set to 1 (error interrupt is included in INTSR6)

**(a) No error during reception**



**(b) Error during reception**



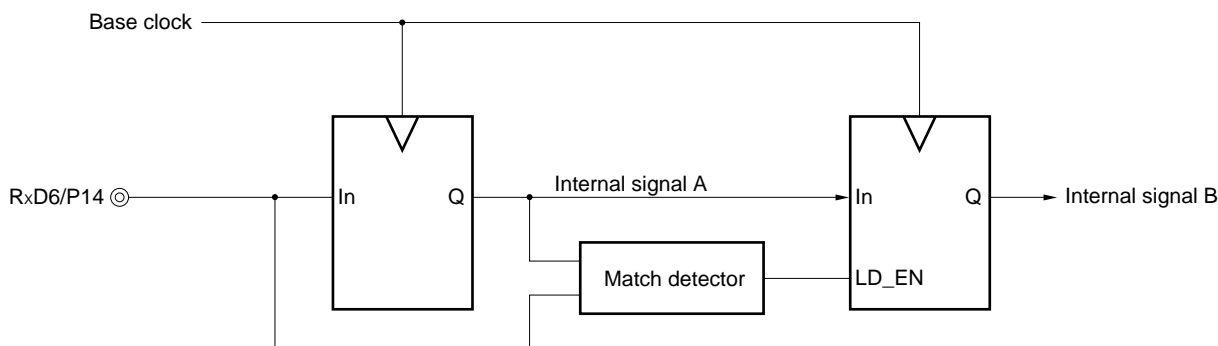
**(g) Noise filter of receive data**

The RxD6 signal is sampled with the base clock output by the prescaler block.

If two sampled values are the same, the output of the match detector changes, and the data is sampled as input data.

Because the circuit is configured as shown in Figure 12-21, the internal processing of the reception operation is delayed by two clocks from the external signal status.

**Figure 12-21. Noise Filter Circuit**

**(h) SBF transmission**

When the device is incorporated in LIN, the SBF (Synchronous Break Field) transmission control function is used for transmission. For the transmission operation of LIN, see **Figure 12-1 LIN Transmission Operation**.

SBF transmission is used to transmit an SBF length that is a low-level width of 13 bits or more by adjusting the baud rate value of the ordinary UART transmission function.

[Setting method]

Transmit 00H by setting the number of character bits of the data to 8 bits and the parity bit to 0 parity or even parity. This enables a low-level transmission of a data frame consisting of 10 bits (1 bit (start bit) + 8 bits (character bits) + 1 bit (parity bit)).

Adjust the baud rate value to adjust this 10-bit low level to the targeted SBF length.

**Example** If LIN is to be transmitted under the following conditions

- Base clock of UART6 = 5 MHz (set by clock selection register 6 (CKSR6))
- Target baud rate value = 19200 bps

To realize the above baud rate value, the length of a 13-bit SBF is as follows if the baud rate generator control register 6 (BRGC6) is set to 130.

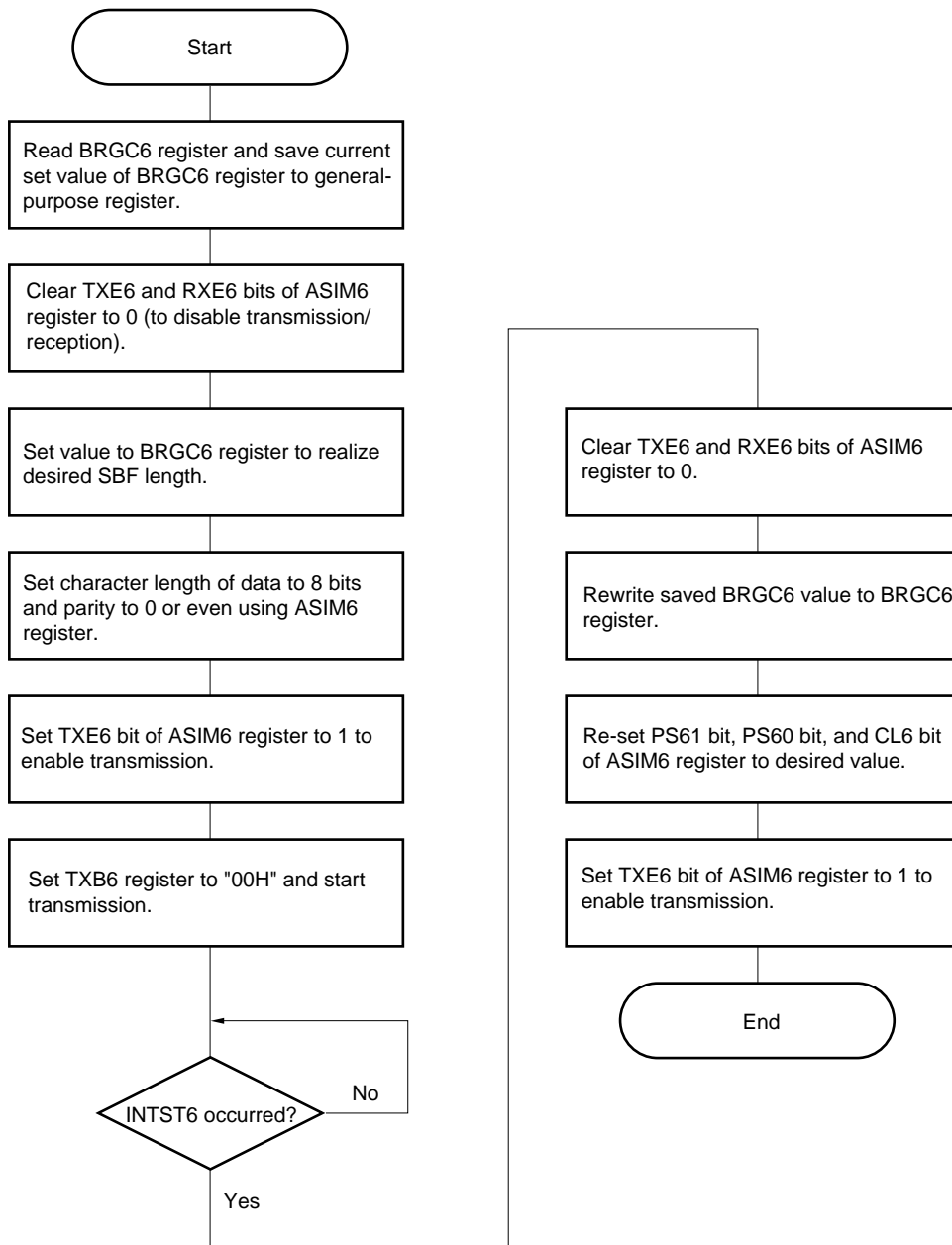
- 13-bit SBF length =  $0.2 \mu\text{s} \times 130 \times 2 \times 13 = 676 \mu\text{s}$

To realize a 13-bit SBF length in 10 bits, set a value 1.3 times the targeted baud rate to BRGC6. In this example, set 169 to BRGC6. The transmission length of a 10-bit low level in this case is as follows, and matches the 13-bit SBF length.

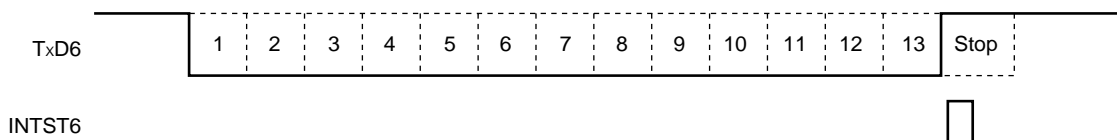
- 10-bit low-level transmission length =  $0.2 \mu\text{s} \times 169 \times 2 \times 10 = 676 \mu\text{s}$

If the number of bits set by BRGC6 runs short, adjust the number of bits by setting the base clock of UART6.

**Figure 12-22. Example of Setting Procedure of SBF Transmission (Flowchart)**



**Figure 12-23. SBF Transmission**



**Remark** TxD6: TxD6 pin (output)  
 INTST6: Transmission completion interrupt request

**(i) SBF reception**

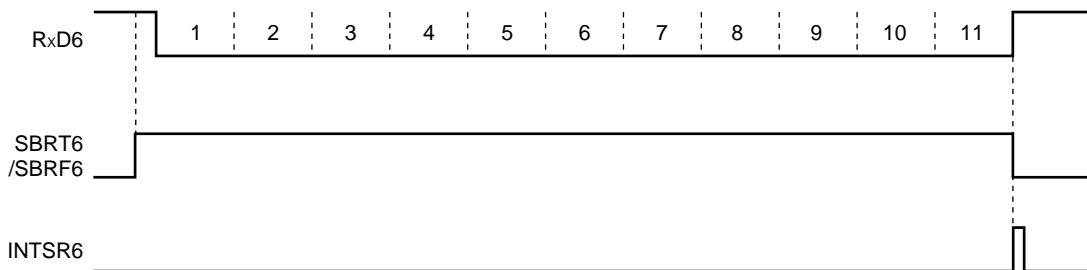
When the device is incorporated in LIN, the SBF (Synchronous Break Field) reception control function is used for reception. For the reception operation of LIN, see **Figure 12-2 LIN Reception Operation**.

Reception is enabled when bit 7 (POWER6) of asynchronous serial interface operation mode register 6 (ASIM6) is set to 1 and then bit 5 (RXE6) of ASIM6 is set to 1. SBF reception is enabled when bit 6 (SBRT6) of asynchronous serial interface control register 6 (ASICL6) is set to 1. In the SBF reception enabled status, the RxD6 pin is sampled and the start bit is detected in the same manner as the normal reception enable status.

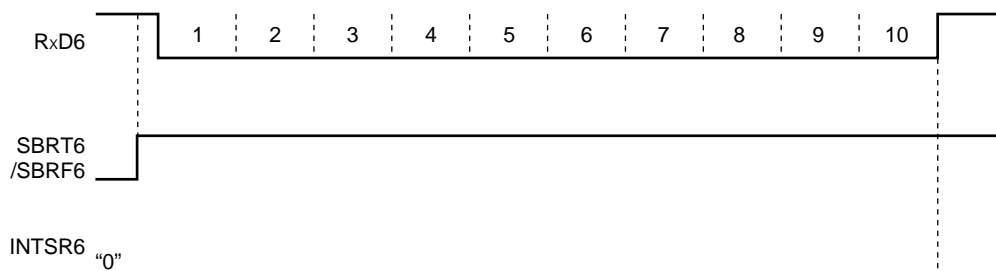
When the start bit has been detected, reception is started, and serial data is sequentially stored in receive shift register 6 (RXS6) at the set baud rate. When the stop bit is received and if the width of SBF is 11 bits or more, a reception completion interrupt request (INTSR6) is generated as normal processing. At this time, the SBRF6 and SBRT6 bits are automatically cleared, and SBF reception ends. Detection of errors, such as OVE6, PE6, and FE6 (bits 0 to 2 of asynchronous serial interface reception error status register 6 (ASIS6)) is suppressed, and error detection processing of UART communication is not performed. In addition, data transfer between receive shift register 6 (RXS6) and receive buffer register 6 (RXB6) is not performed, and the reset value of FFH is retained. If the width of SBF is 10 bits or less, an interrupt does not occur as error processing after the stop bit has been received, and the SBF reception mode is restored. In this case, the SBRF6 and SBRT6 bits are not cleared.

**Figure 12-24. SBF Reception**

**1. Normal SBF reception (stop bit is detected with a width of more than 10.5 bits)**



**2. SBF reception error (stop bit is detected with a width of 10.5 bits or less)**



**Remark** RxD6: RxD6 pin (input)  
 SBRT6: Bit 6 of asynchronous serial interface control register 6 (ASICL6)  
 SBRF6: Bit 7 of ASICL6  
 INTSR6: Reception completion interrupt request

### 12.4.3 Dedicated baud rate generator

The dedicated baud rate generator consists of a source clock selector and an 8-bit programmable counter, and generates a serial clock for transmission/reception of UART6.

Separate 8-bit counters are provided for transmission and reception.

#### (1) Configuration of baud rate generator

- Base clock

The clock selected by bits 3 to 0 (TPS63 to TPS60) of clock selection register 6 (CKSR6) is supplied to each module when bit 7 (POWER6) of asynchronous serial interface operation mode register 6 (ASIM6) is 1. This clock is called the base clock and its frequency is called  $f_{CLK6}$ . The base clock is fixed to low level when POWER6 = 0.

- Transmission counter

This counter stops, cleared to 0, when bit 7 (POWER6) or bit 6 (TXE6) of asynchronous serial interface operation mode register 6 (ASIM6) is 0.

It starts counting when POWER6 = 1 and TXE6 = 1.

The counter is cleared to 0 when the first data transmitted is written to transmit buffer register 6 (TXB6).

If data are continuously transmitted, the counter is cleared to 0 again when one frame of data has been completely transmitted. If there is no data to be transmitted next, the counter is not cleared to 0 and continues counting until POWER6 or TXE6 is cleared to 0.

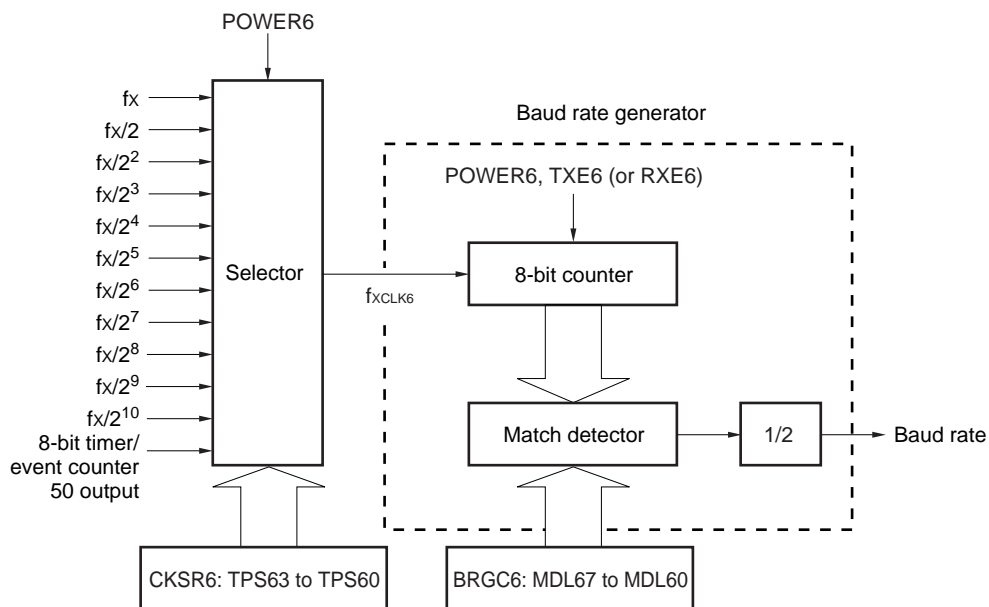
- Reception counter

This counter stops operation, cleared to 0, when bit 7 (POWER6) or bit 5 (RXE6) of asynchronous serial interface operation mode register 6 (ASIM6) is 0.

It starts counting when the start bit has been detected.

The counter stops operation after one frame has been received, until the next start bit is detected.

Figure 12-25. Configuration of Baud Rate Generator



- Remark** POWER6: Bit 7 of asynchronous serial interface operation mode register 6 (ASIM6)  
 TXE6: Bit 6 of ASIM6  
 RXE6: Bit 5 of ASIM6  
 CKSR6: Clock selection register 6  
 BRGC6: Baud rate generator control register 6

**(2) Generation of serial clock**

A serial clock can be generated by using clock selection register 6 (CKSR6) and baud rate generator control register 6 (BRGC6).

Select the clock to be input to the 8-bit counter by using bits 3 to 0 (TPS63 to TPS60) of CKSR6.

Bits 7 to 0 (MDL67 to MDL60) of BRGC6 can be used to select the division value of the 8-bit counter.

**(a) Baud rate**

The baud rate can be calculated by the following expression.

- Baud rate =  $\frac{f_{\text{CLK6}}}{2 \times k}$  [bps]

$f_{\text{CLK6}}$ : Frequency of base clock selected by TPS63 to TPS60 bits of CKSR6 register

k: Value set by MDL67 to MDL60 bits of BRGC6 register (k = 8, 9, 10, ..., 255)

**(b) Error of baud rate**

The baud rate error can be calculated by the following expression.

- Error (%) =  $\left( \frac{\text{Actual baud rate (baud rate with error)}}{\text{Desired baud rate (correct baud rate)}} - 1 \right) \times 100$  [%]

**Cautions 1. Keep the baud rate error during transmission to within the permissible error range at the reception destination.**

**2. Make sure that the baud rate error during reception satisfies the range shown in (4) Permissible baud rate range during reception.**

**Example:** Frequency of base clock = 10 MHz = 10,000,000 Hz

Set value of MDL67 to MDL60 bits of BRGC6 register = 00100001B (k = 33)

Target baud rate = 153600 bps

$$\begin{aligned} \text{Baud rate} &= 10 \text{ M}/(2 \times 33) \\ &= 10000000/(2 \times 33) = 151515 \text{ [bps]} \end{aligned}$$

$$\begin{aligned} \text{Error} &= (151515/153600 - 1) \times 100 \\ &= -1.357 \text{ [%]} \end{aligned}$$



## (3) Example of setting baud rate

Table 12-4. Set Data of Baud Rate Generator

| Baud Rate<br>[bps] | $f_x = 10.0$ MHz  |     |                     |        | $f_x = 8.38$ MHz  |     |                     |        | $f_x = 4.19$ MHz  |     |                     |        |
|--------------------|-------------------|-----|---------------------|--------|-------------------|-----|---------------------|--------|-------------------|-----|---------------------|--------|
|                    | TPS63 to<br>TPS60 | k   | Calculated<br>Value | ERR[%] | TPS63 to<br>TPS60 | k   | Calculated<br>Value | ERR[%] | TPS63 to<br>TPS60 | k   | Calculated<br>Value | ERR[%] |
| 600                | 6H                | 130 | 601                 | 0.16   | 6H                | 109 | 601                 | 0.11   | 5H                | 109 | 601                 | 0.11   |
| 1200               | 5H                | 130 | 1202                | 0.16   | 5H                | 109 | 1201                | 0.11   | 4H                | 109 | 1201                | 0.11   |
| 2400               | 4H                | 130 | 2404                | 0.16   | 4H                | 109 | 2403                | 0.11   | 3H                | 109 | 2403                | 0.11   |
| 4800               | 3H                | 130 | 4808                | 0.16   | 3H                | 109 | 4805                | 0.11   | 2H                | 109 | 4805                | 0.11   |
| 9600               | 2H                | 130 | 9615                | 0.16   | 2H                | 109 | 9610                | 0.11   | 1H                | 109 | 9610                | 0.11   |
| 10400              | 2H                | 120 | 10417               | 0.16   | 2H                | 101 | 10371               | 0.28   | 1H                | 101 | 10475               | -0.28  |
| 19200              | 1H                | 130 | 19231               | 0.16   | 1H                | 109 | 19220               | 0.11   | 0H                | 109 | 19220               | 0.11   |
| 31250              | 1H                | 80  | 31250               | 0.00   | 0H                | 134 | 31268               | 0.06   | 0H                | 67  | 31268               | 0.06   |
| 38400              | 0H                | 130 | 38462               | 0.16   | 0H                | 109 | 38440               | 0.11   | 0H                | 55  | 38090               | -0.80  |
| 76800              | 0H                | 65  | 76923               | 0.16   | 0H                | 55  | 76182               | -0.80  | 0H                | 27  | 77593               | 1.03   |
| 115200             | 0H                | 43  | 116279              | 0.94   | 0H                | 36  | 116389              | 1.03   | 0H                | 18  | 116389              | 1.03   |
| 153600             | 0H                | 33  | 151515              | -1.36  | 0H                | 27  | 155185              | 1.03   | 0H                | 14  | 149643              | -2.58  |
| 230400             | 0H                | 22  | 227272              | -1.36  | 0H                | 18  | 232778              | 1.03   | 0H                | 9   | 232778              | 1.03   |

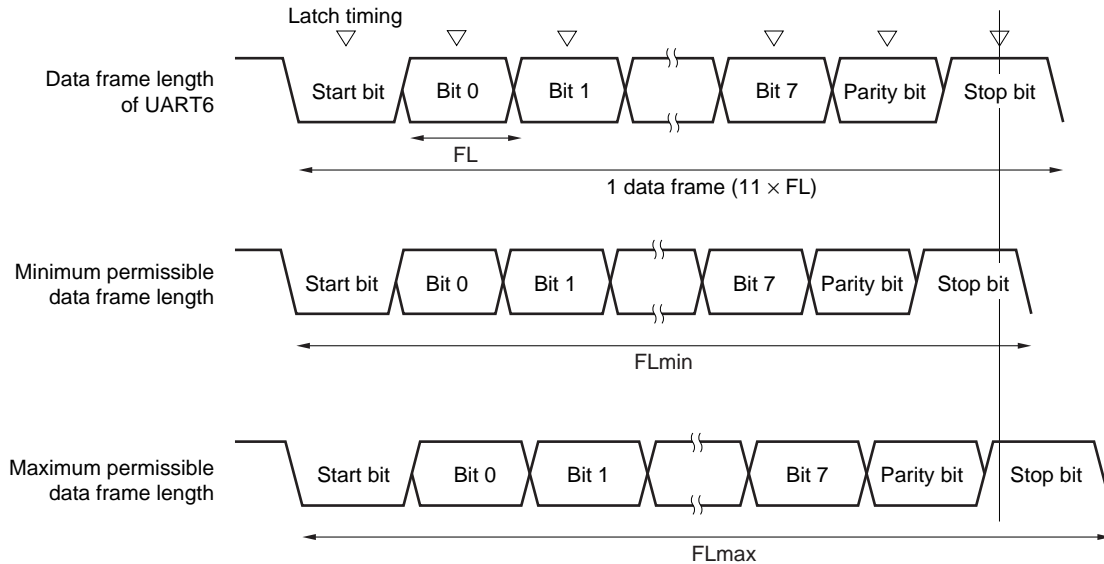
**Remark** TPS63 to TPS60: Bits 3 to 0 of clock selection register 6 (CKSR6) (setting of base clock ( $f_{CLK6}$ ))  
k: Value set by MDL67 to MDL60 bits of baud rate generator control register 6 (BRGC6) ( $k = 8, 9, 10, \dots, 255$ )  
 $f_x$ : X1 input clock oscillation frequency  
ERR: Baud rate error

**(4) Permissible baud rate range during reception**

The permissible error from the baud rate at the transmission destination during reception is shown below.

**Caution** Make sure that the baud rate error during reception is within the permissible error range, by using the calculation expression shown below.

**Figure 12-26. Permissible Baud Rate Range During Reception**



As shown in Figure 12-26, the latch timing of the receive data is determined by the counter set by baud rate generator control register 6 (BRGC6) after the start bit has been detected. If the last data (stop bit) meets this latch timing, the data can be correctly received.

Assuming that 11-bit data is received, the theoretical values can be calculated as follows.

$$FL = (\text{Brate})^{-1}$$

- Brate: Baud rate of UART6
- k: Set value of BRGC6
- FL: 1-bit data length
- Margin of latch timing: 2 clocks

$$\text{Minimum permissible data frame length: } FL_{\min} = 11 \times FL - \frac{k-2}{2k} \times FL = \frac{21k+2}{2k} FL$$

Therefore, the maximum receivable baud rate at the transmission destination is as follows.

$$BR_{max} = (FL_{min}/11)^{-1} = \frac{22k}{21k + 2} \text{ Brate}$$

Similarly, the maximum permissible data frame length can be calculated as follows.

$$\frac{10}{11} \times FL_{max} = 11 \times FL - \frac{k + 2}{2 \times k} \times FL = \frac{21k - 2}{2 \times k} FL$$

$$FL_{max} = \frac{21k - 2}{20k} FL \times 11$$

Therefore, the minimum receivable baud rate at the transmission destination is as follows.

$$BR_{min} = (FL_{max}/11)^{-1} = \frac{20k}{21k - 2} \text{ Brate}$$

The permissible baud rate error between UART6 and the transmission destination can be calculated from the above minimum and maximum baud rate expressions, as follows.

**Table 12-5. Maximum/Minimum Permissible Baud Rate Error**

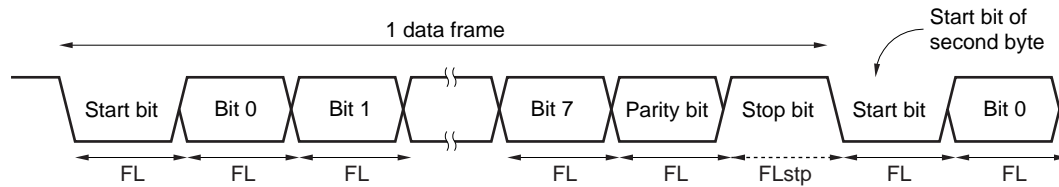
| Division Ratio (k) | Maximum Permissible Baud Rate Error | Minimum Permissible Baud Rate Error |
|--------------------|-------------------------------------|-------------------------------------|
| 8                  | +3.53%                              | -3.61%                              |
| 20                 | +4.26%                              | -4.31%                              |
| 50                 | +4.56%                              | -4.58%                              |
| 100                | +4.66%                              | -4.67%                              |
| 255                | +4.72%                              | -4.73%                              |

- Remarks**
1. The permissible error of reception depends on the number of bits in one frame, input clock frequency, and division ratio (k). The higher the input clock frequency and the higher the division ratio (k), the higher the permissible error.
  2. k: Set value of BRGC6

**(5) Data frame length during continuous transmission**

When data is continuously transmitted, the data frame length from a stop bit to the next start bit is extended by two clocks of base clock from the normal value. However, the result of communication is not affected because the timing is initialized on the reception side when the start bit is detected.

**Figure 12-27. Data Frame Length During Continuous Transmission**



Where the 1-bit data length is FL, the stop bit length is FLstp, and base clock frequency is  $f_{XCLK6}$ , the following expression is satisfied.

$$FL_{stp} = FL + 2/f_{XCLK6}$$

Therefore, the data frame length during continuous transmission is:

$$\text{Data frame length} = 11 \times FL + 2/f_{XCLK6}$$

## CHAPTER 13 SERIAL INTERFACE CSI10

### 13.1 Functions of Serial Interface CSI10

Serial interface CSI10 has the following two modes.

- Operation stop mode
- 3-wire serial I/O mode

#### (1) Operation stop mode

This mode is used when serial communication is not performed and can enable a reduction in the power consumption.

For details, see **13.4.1 Operation stop mode**.

#### (2) 3-wire serial I/O mode (MSB/LSB-first selectable)

This mode is used to communicate 8-bit data using three lines: a serial clock line ( $\overline{\text{SCK10}}$ ) and two serial data lines (SI10 and SO10).

The processing time of data communication can be shortened in the 3-wire serial I/O mode because transmission and reception can be simultaneously executed.

In addition, whether 8-bit data is communicated with the MSB or LSB first can be specified, so this interface can be connected to any device.

The 3-wire serial I/O mode can be used connecting peripheral ICs and display controllers with a clocked serial interface.

For details, see **13.4.2 3-wire serial I/O mode**.

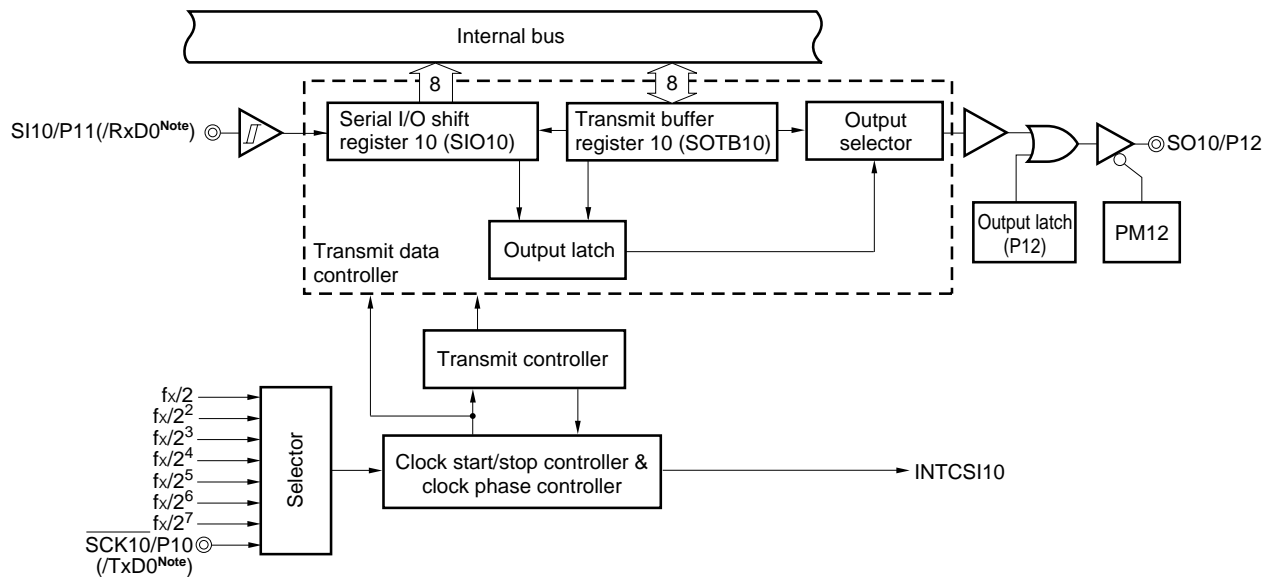
### 13.2 Configuration of Serial Interface CSI10

Serial interface CSI10 includes the following hardware.

**Table 13-1. Configuration of Serial Interface CSI10**

| Item              | Configuration   |
|-------------------|---|
| Registers         | Transmit buffer register 10 (SOTB10)<br>Serial I/O shift register 10 (SIO10)  |
| Control registers | Serial operation mode register 10 (CSIM10)<br>Serial clock selection register 10 (CSIC10)<br>Port mode register 1 (PM1)<br>Port register 1 (P1) |

Figure 13-1. Block Diagram of Serial Interface CSI10



**Note**  $\mu$ PD780102, 780103, 78F0103 only.

#### (1) Transmit buffer register 10 (SOTB10)

This register sets the transmit data.

Transmission/reception is started by writing data to SOTB10 when bit 7 (CSIE10) and bit 6 (TRMD10) of serial operation mode register 10 (CSIM10) are 1.

The data written to SOTB10 is converted from parallel data into serial data by serial I/O shift register 10, and output to the serial output pin (SO10).

SOTB10 can be written or read by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input makes this register undefined.

**Caution** Do not access SOTB10 when CSOT10 = 1 (during serial communication).

#### (2) Serial I/O shift register 10 (SIO10)

This is an 8-bit register that converts data from parallel data into serial data and vice versa.

This register can be read by an 8-bit memory manipulation instruction.

Reception is started by reading data from SIO10 if bit 6 (TRMD10) of serial operation mode register 10 (CSIM10) is 0.

During reception, the data is read from the serial input pin (SI10) to SIO10.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Caution** Do not access SIO10 when CSOT10 = 1 (during serial communication).

### 13.3 Registers Controlling Serial Interface CSI10

Serial interface CSI10 is controlled by the following four registers.

- Serial operation mode register 10 (CSIM10)
- Serial clock selection register 10 (CSIC10)
- Port mode register 1 (PM1)
- Port register 1 (P1)

#### (1) Serial operation mode register 10 (CSIM10)

CSIM10 is used to select the operation mode and enable or disable operation.

CSIM10 can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears this register to 00H.

**Figure 13-2. Format of Serial Operation Mode Register 10 (CSIM10)**

Address: FF80H After reset: 00H R/W<sup>Note 1</sup>

| Symbol                   | <7>   | 6      | 5 | 4     | 3 | 2 | 1 | 0      |
|--------------------------|---|--------|---|-------|---|---|---|--------|
| CSIM10                   | CSIE10  | TRMD10 | 0 | DIR10 | 0 | 0 | 0 | CSOT10 |
| CSIE10                   | Operation control in 3-wire serial I/O mode   |        |   |       |   |   |   |        |
| 0                        | Disables operation <sup>Note 2</sup> and asynchronously resets the internal circuit <sup>Note 3</sup> . |        |   |       |   |   |   |        |
| 1                        | Enables operation   |        |   |       |   |   |   |        |
| TRMD10 <sup>Note 4</sup> | Transmit/receive mode control   |        |   |       |   |   |   |        |
| 0 <sup>Note 5</sup>      | Receive mode (transmission disabled).   |        |   |       |   |   |   |        |
| 1                        | Transmit/receive mode   |        |   |       |   |   |   |        |
| DIR10 <sup>Note 6</sup>  | First bit specification   |        |   |       |   |   |   |        |
| 0                        | MSB   |        |   |       |   |   |   |        |
| 1                        | LSB   |        |   |       |   |   |   |        |
| CSOT10                   | Communication status flag   |        |   |       |   |   |   |        |
| 0                        | Communication is stopped.   |        |   |       |   |   |   |        |
| 1                        | Communication is in progress.   |        |   |       |   |   |   |        |

- Notes**
1. Bit 0 is a read-only bit.
  2. When using P10/SCK10(/TxD0<sup>Note 7</sup>), P11/SI10(/RxD0<sup>Note 7</sup>), or P12/SO10 as a general-purpose port, see **CHAPTER 4 PORT FUNCTIONS** and **Caution 3 of Figure 13-3**.
  3. Bit 0 (CSOT10) of CSIM10 and serial I/O shift register 10 (SIO10) are reset.
  4. Do not rewrite TRMD10 when CSOT10 = 1 (during serial communication).
  5. The SO10 output is fixed to the low level when TRMD10 is 0. Reception is started when data is read from SIO10.
  6. Do not rewrite DIR10 when CSOT10 = 1 (during serial communication).
  7.  $\mu$ PD780102, 780103, and 78F0103 only.

**Caution** Be sure to clear bit 5 to 0.

**(2) Serial clock selection register 10 (CSIC10)**

This register specifies the timing of the data transmission/reception and sets the serial clock.

CSIC10 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 13-3. Format of Serial Clock Selection Register 10 (CSIC10)**

Address: FF81H After reset: 00H R/W

|        |   |   |   |       |       |        |        |        |
|--------|---|---|---|-------|-------|--------|--------|--------|
| Symbol | 7 | 6 | 5 | 4     | 3     | 2      | 1      | 0      |
| CSIC10 | 0 | 0 | 0 | CKP10 | DAP10 | CKS102 | CKS101 | CKS100 |

| CKP10 | DAP10 | Specification of data transmission/reception timing | Type |
|-------|-------|---|------|
| 0     | 0     |   | 1    |
| 0     | 1     |   | 2    |
| 1     | 0     |   | 3    |
| 1     | 1     |   | 4    |

| CKS102 | CKS101 | CKS100 | CSI10 serial clock selection <sup>Note</sup>      | Mode        |
|--------|--------|--------|---|-------------|
| 0      | 0      | 0      | $f_x/2$ (5 MHz)                                   | Master mode |
| 0      | 0      | 1      | $f_x/2^2$ (2.5 MHz)                               | Master mode |
| 0      | 1      | 0      | $f_x/2^3$ (1.25 MHz)                              | Master mode |
| 0      | 1      | 1      | $f_x/2^4$ (625 kHz)                               | Master mode |
| 1      | 0      | 0      | $f_x/2^5$ (312.5 kHz)                             | Master mode |
| 1      | 0      | 1      | $f_x/2^6$ (156.25 kHz)                            | Master mode |
| 1      | 1      | 0      | $f_x/2^7$ (78.13 kHz)                             | Master mode |
| 1      | 1      | 1      | External clock input to $\overline{\text{SCK10}}$ | Slave mode  |

★ **Note** Be sure to set the serial clock so that the following condition is satisfied.

- $V_{DD} = 4.0$  to  $5.5$  V: Serial clock  $\leq 5$  MHz
- $V_{DD} = 3.3$  to  $4.0$  V: Serial clock  $\leq 4.19$  MHz
- $V_{DD} = 2.7$  to  $3.3$  V: Serial clock  $\leq 2.5$  MHz
- $V_{DD} = 2.5$  to  $2.7$  V: Serial clock  $\leq 1.25$  MHz



- Cautions**
1. When the Ring-OSC clock is selected as the clock supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the serial clock. At this time, the operation of serial interface CSI10 is not guaranteed.
  2. Do not write to CSIC10 while CSIE10 = 1 (operation enabled).
  3. Clear CKP10 to 0 to use P10/ $\overline{\text{SCK10}}$  (/TxD0<sup>Note</sup>), P11/SI10 (/RxD0<sup>Note</sup>), and P12/SO10 as general-purpose port pins.
  4. The phase type of the data clock is type 1 after reset.

**Note**  $\mu$ PD780102, 780103, 78F0103 only.

- Remarks**
1. Figures in parentheses are for operation with  $f_x = 10$  MHz
  2.  $f_x$ : X1 input clock oscillation frequency

**(3) Port mode register 1 (PM1)**

This register sets port 1 input/output in 1-bit units.

★ When using P10/ $\overline{\text{SCK10}}$ (/TxD0<sup>Note</sup>) as the clock output pin of the serial interface, clear PM10 to 0 and set the output latch of P10 to 1.

When using P12/SO10 as the data output pin of the serial interface, clear PM12 and the output latch of P12 to 0. When using P10/ $\overline{\text{SCK10}}$ (/TxD0<sup>Note</sup>) as the clock input pin of the serial interface, and P11/SI10(/RxD0<sup>Note</sup>) as the data input pin, set PM10 and PM11 to 1. At this time, the output latches of P10 and P11 may be 0 or 1.

PM1 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input sets this register to FFH.

**Note**  $\mu$ PD780102, 780103, 78F0103 only.

**Figure 13-4. Format of Port Mode Register 1 (PM1)**

Address: FF21H After reset: FFH R/W

|        |      |      |      |      |      |      |      |      |
|--------|------|------|------|------|------|------|------|------|
| Symbol | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PM1    | PM17 | PM16 | PM15 | PM14 | PM13 | PM12 | PM11 | PM10 |

|      |   |
|------|---|
| PM1n | P1n pin I/O mode selection (n = 0 to 7) |
| 0    | Output mode (output buffer on)          |
| 1    | Input mode (output buffer off)          |

## 13.4 Operation of Serial Interface CSI10

Serial interface CSI10 can be used in the following two modes.

- Operation stop mode
- 3-wire serial I/O mode

### 13.4.1 Operation stop mode

Serial communication is not executed in this mode. Therefore, the power consumption can be reduced. In addition, the P10/ $\overline{\text{SCK10}}$ (/TxD0<sup>Note</sup>), P11/SI10(/RxD0<sup>Note</sup>), and P12/SO10 pins can be used as ordinary I/O port pins in this mode.

**Note**  $\mu$ PD780102, 780103, and 78F0103 only.

#### (1) Register used

The operation stop mode is set by serial operation mode register 10 (CSIM10).

To set the operation stop mode, clear bit 7 (CSIE10) of CSIM10 to 0.

#### (a) Serial operation mode register 10 (CSIM10)

CSIM10 can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears CSIM10 to 00H.

Address: FF80H After reset: 00H R/W

| Symbol | <7>    | 6   | 5 | 4     | 3 | 2 | 1 | 0      |
|--------|--------|---|---|-------|---|---|---|--------|
| CSIM10 | CSIE10 | TRMD10  | 0 | DIR10 | 0 | 0 | 0 | CSOT10 |
|        | CSIE10 | Operation control in 3-wire serial I/O mode   |   |       |   |   |   |        |
|        | 0      | Disables operation <sup>Note 1</sup> and asynchronously resets the internal circuit <sup>Note 2</sup> . |   |       |   |   |   |        |

**Notes 1.** When using P10/ $\overline{\text{SCK10}}$ (/TxD0<sup>Note 3</sup>), P11/SI10(RxD0<sup>Note 3</sup>), or P12/SO10 as general-purpose port pins, see **CHAPTER 4 PORT FUNCTIONS, Caution 3 of Figure 13-3, and Table 13-2.**

**2.** Bit 0 (CSOT10) of CSIM10 and serial I/O shift register 10 (SIO10) are reset.

**3.**  $\mu$ PD780102, 780103, and 78F0103 only.

### 13.4.2 3-wire serial I/O mode

The 3-wire serial I/O mode can be used for connecting peripheral ICs and display controllers that have a clocked serial interface.

In this mode, communication is executed by using three lines: the serial clock ( $\overline{\text{SCK10}}$ ), serial output (SO10), and serial input (SI10) lines.

#### (1) Registers used

- Serial operation mode register 10 (CSIM10)
- Serial clock selection register 10 (CSIC10)
- Port mode register 1 (PM1)
- Port register 1 (P1)

The basic procedure of setting an operation in the 3-wire serial I/O mode is as follows.

- <1> Set the CSIC10 register (see **Figure 13-3**).
- <2> Set bits 0, 4, and 6 (CSOT10, DIR10, and TRMD10) of the CSIM10 register (see **Figure 13-2**).
- <3> Set bit 7 (CSIE10) of the CSIM10 register to 1. → Transmission/reception is enabled.
- <4> Write data to transmit buffer register 10 (SOTB10). → Data transmission/reception is started.  
Read data from serial I/O shift register 10 (SIO10). → Data reception is started.

**Caution** Take relationship with the other party of communication when setting the port mode register and port register.

The relationship between the register settings and pins is shown below.

**Table 13-2. Relationship Between Register Settings and Pins**

| CSIE10 | TRMD10 | PM11                | P11                 | PM12                | P12                 | PM10                | P10                 | CSI10 Operation                                | Pin Function                        |          |   |
|--------|--------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--|-------------------------------------|----------|---|
|        |        |                     |                     |                     |                     |                     |                     |  | P11/SI10 (/RxD0 <sup>Note 4</sup> ) | P12/SO10 | P10/ $\overline{\text{SCK10}}$ (/TxD0 <sup>Note 4</sup> ) |
| 0      | x      | x <sup>Note 1</sup> | x <sup>Note 1</sup> | x <sup>Note 1</sup> | x <sup>Note 1</sup> | x <sup>Note 1</sup> | x <sup>Note 1</sup> | Stop   | P11 (/RxD0 <sup>Note 4</sup> )      | P12      | P10 (/TxD0 <sup>Note 4</sup> ) <sup>Note 2</sup>          |
| 1      | 0      | 1                   | x                   | x <sup>Note 1</sup> | x <sup>Note 1</sup> | 1                   | x                   | Slave reception <sup>Note 3</sup>              | SI10                                | P12      | $\overline{\text{SCK10}}$ (input) <sup>Note 3</sup>       |
| 1      | 1      | x <sup>Note 1</sup> | x <sup>Note 1</sup> | 0                   | 0                   | 1                   | x                   | Slave transmission <sup>Note 3</sup>           | P11 (/RxD0 <sup>Note 4</sup> )      | SO10     | $\overline{\text{SCK10}}$ (input) <sup>Note 3</sup>       |
| 1      | 1      | 1                   | x                   | 0                   | 0                   | 1                   | x                   | Slave transmission/reception <sup>Note 3</sup> | SI10                                | SO10     | $\overline{\text{SCK10}}$ (input) <sup>Note 3</sup>       |
| 1      | 0      | 1                   | x                   | x <sup>Note 1</sup> | x <sup>Note 1</sup> | 0                   | 1                   | Master reception                               | SI10                                | P12      | $\overline{\text{SCK10}}$ (output)                        |
| 1      | 1      | x <sup>Note 1</sup> | x <sup>Note 1</sup> | 0                   | 0                   | 0                   | 1                   | Master transmission                            | P11 (/RxD0 <sup>Note 4</sup> )      | SO10     | $\overline{\text{SCK10}}$ (output)                        |
| 1      | 1      | 1                   | x                   | 0                   | 0                   | 0                   | 1                   | Master transmission/reception                  | SI10                                | SO10     | $\overline{\text{SCK10}}$ (output)                        |

- Notes**
1. Can be set as port function.
  2. To use P10/ $\overline{\text{SCK10}}$  (/TxD0<sup>Note 4</sup>) as port pins, clear CKP10 to 0.
  3. To use the slave mode, set CKS102, CKS101, and CKS100 to 1, 1, 1.
  4.  $\mu$ PD780102, 780103, and 78F0103 only.

**Remark**

x: don't care

CSIE10: Bit 7 of serial operation mode register 10 (CSIM10)

TRMD10: Bit 6 of CSIM10

CKP10: Bit 4 of serial clock selection register 10 (CSIC10)

CKS102, CKS101, CKS100: Bits 2 to 0 of CSIC10

PM1x: Port mode register

P1x: Port output latch

**(2) Communication operation**

In the 3-wire serial I/O mode, data is transmitted or received in 8-bit units. Each bit of the data is transmitted or received in synchronization with the serial clock.

Data can be transmitted or received if bit 6 (TRMD10) of serial operation mode register 10 (CSIM10) is 1. Transmission/reception is started when a value is written to transmit buffer register 10 (SOTB10). In addition, data can be received when bit 6 (TRMD10) of serial operation mode register 10 (CSIM10) is 0.

Reception is started when data is read from serial I/O shift register 10 (SIO10).

After communication has been started, bit 0 (CSOT10) of CSIM10 is set to 1. When communication of 8-bit data has been completed, a communication completion interrupt request flag (CSIF10) is set, and CSOT10 is cleared to 0. Then the next communication is enabled.

**Caution** Do not access the control register and data register when CSOT10 = 1 (during serial communication).

Figure 13-5. Timing in 3-Wire Serial I/O Mode (1/2)

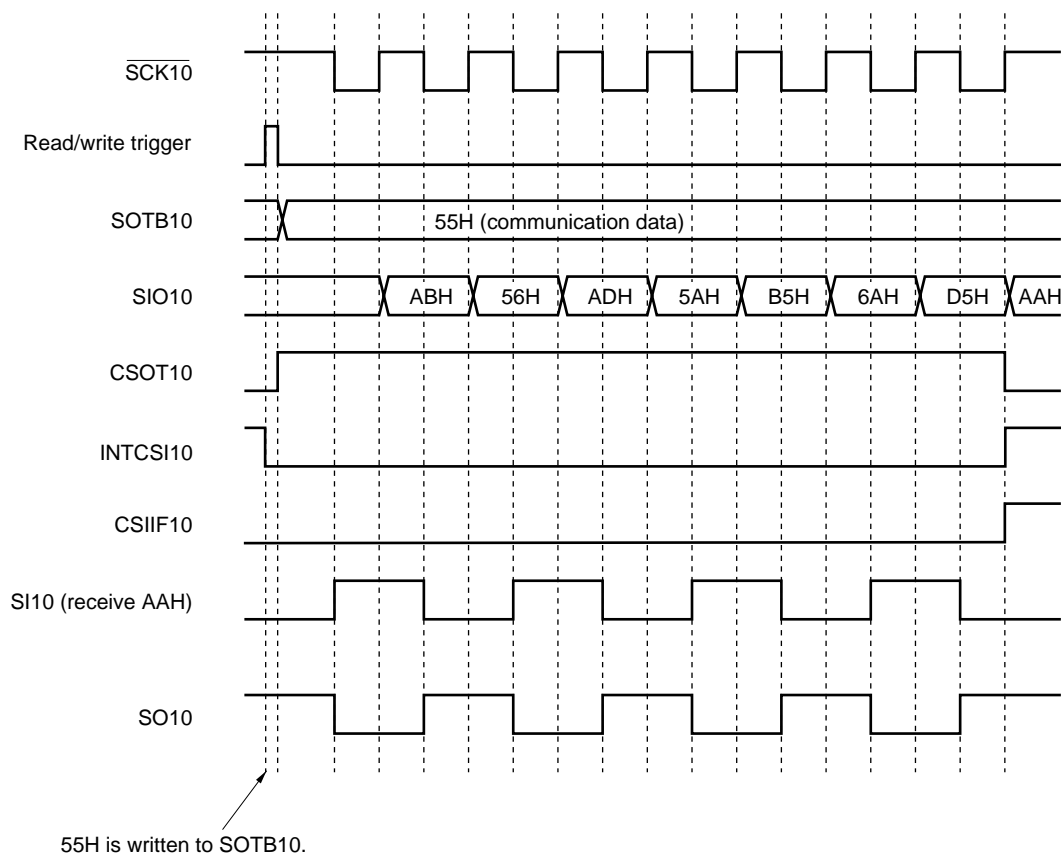
**(1) Transmission/reception timing (Type 1; TRMD10 = 1, DIR10 = 0, CKP10 = 0, DAP10 = 0)**

Figure 13-5. Timing in 3-Wire Serial I/O Mode (2/2)

(2) Transmission/reception timing (Type 2; TRMD10 = 1, DIR10 = 0, CKP10 = 0, DAP10 = 1)

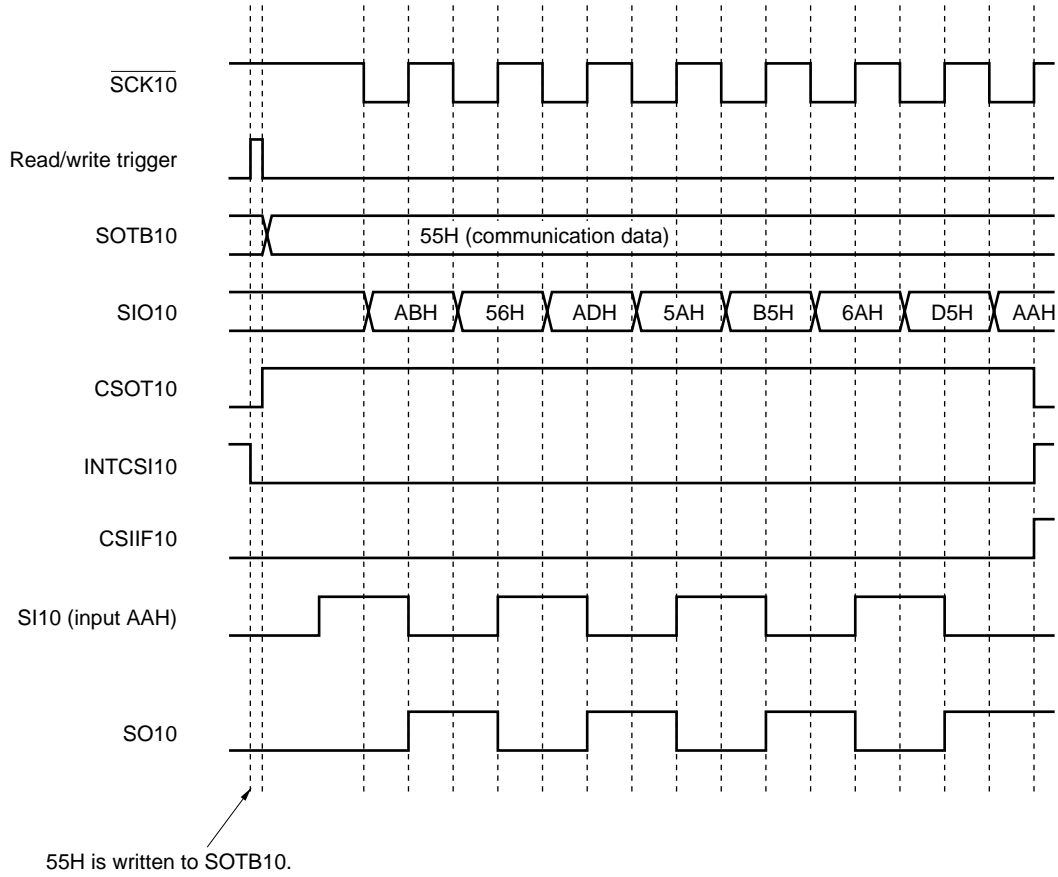
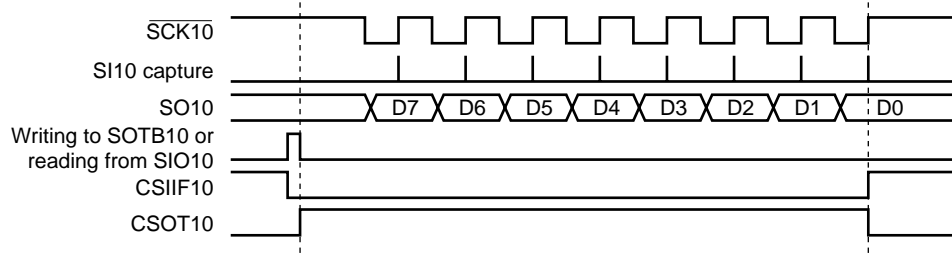
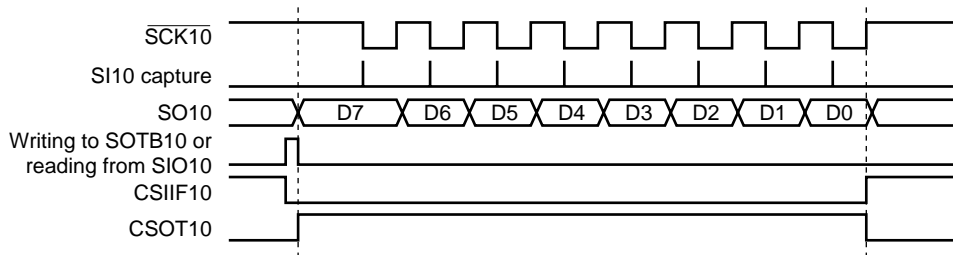


Figure 13-6. Timing of Clock/Data Phase

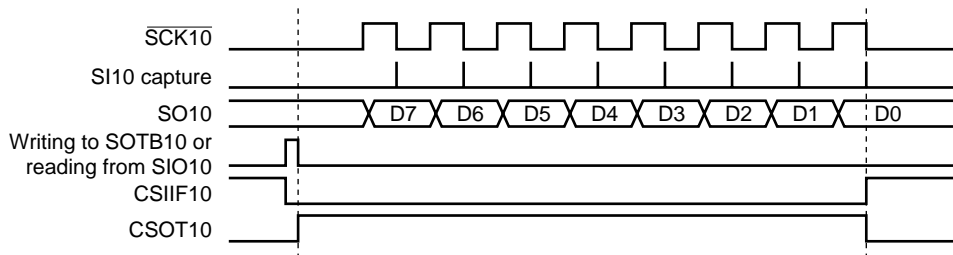
(a) Type 1; CKP10 = 0, DAP10 = 0



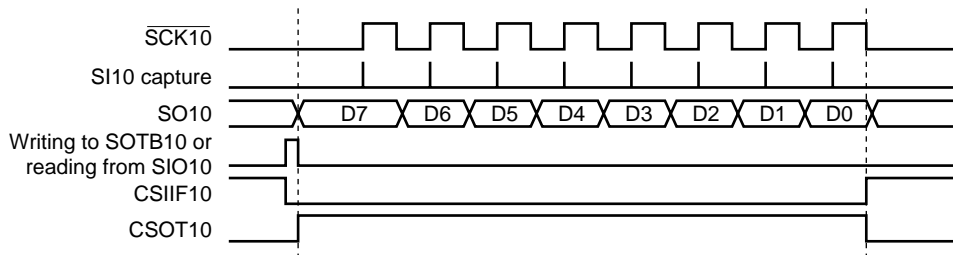
(b) Type 2; CKP10 = 0, DAP10 = 1



(c) Type 3; CKP10 = 1, DAP10 = 0

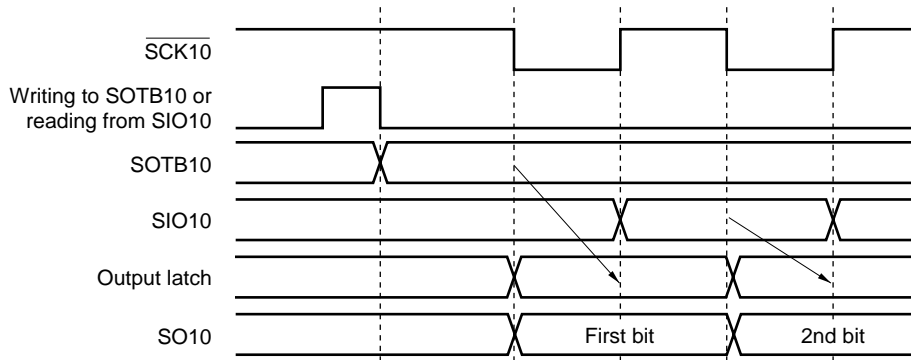


(d) Type 4; CKP10 = 1, DAP10 = 1



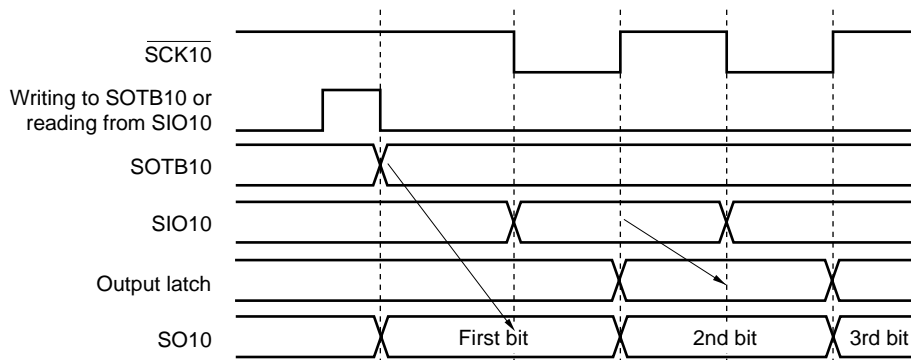
**(3) Timing of output to SO10 pin (first bit)**

When communication is started, the value of transmit buffer register 10 (SOTB10) is output from the SO10 pin. The output operation of the first bit at this time is described below.

**Figure 13-7. Output Operation of First Bit****(1) When CKP10 = 0, DAP10 = 0 (or CKP10 = 1, DAP10 = 0)**

The first bit is directly latched by the SOTB10 register to the output latch at the falling (or rising) edge of  $\overline{SCK10}$ , and output from the SO10 pin via an output selector. Then, the value of the SOTB10 register is transferred to the SIO10 register at the next rising (or falling) edge of  $\overline{SCK10}$ , and shifted one bit. At the same time, the first bit of the receive data is stored in the SIO10 register via the SI10 pin.

The second and subsequent bits are latched by the SIO10 register to the output latch at the next falling (or rising) edge of  $\overline{SCK10}$ , and the data is output from the SO10 pin.

**(2) When CKP10 = 0, DAP10 = 1 (or CKP10 = 1, DAP10 = 1)**

The first bit is directly latched by the SOTB10 register at the falling edge of the write signal of the SOTB10 register or the read signal of the SIO10 register, and output from the SO10 pin via an output selector. Then, the value of the SOTB10 register is transferred to the SIO10 register at the next falling (or rising) edge of  $\overline{SCK10}$ , and shifted one bit. At the same time, the first bit of the receive data is stored in the SIO10 register via the SI10 pin.

The second and subsequent bits are latched by the SIO10 register to the output latch at the next rising (or falling) edge of  $\overline{SCK10}$ , and the data is output from the SO10 pin.

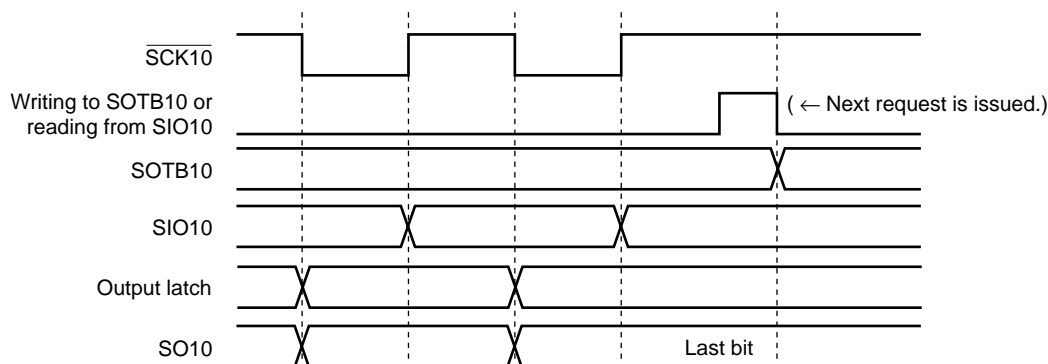


**(4) Output value of SO10 pin (last bit)**

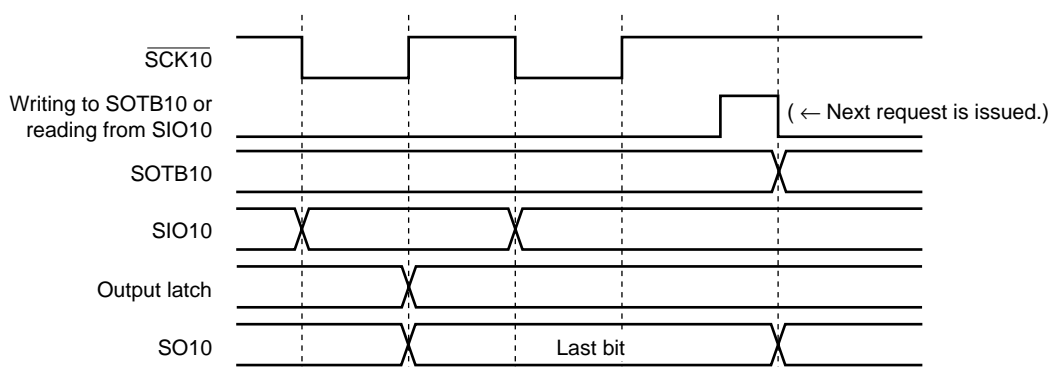
After communication has been completed, the SO10 pin holds the output value of the last bit.

**Figure 13-8. Output Value of SO10 Pin (Last Bit)**

**(1) Type 1; when CKP10 = 0 and DAP10 = 0 (or CKP10 = 1, DAP10 = 0)**



**(2) Type 2; when CKP10 = 0 and DAP10 = 1 (or CKP10 = 1, DAP10 = 1)**



**(5) SO10 output**

The status of the SO10 output is as follows if bit 7 (CSIE10) of serial operation mode register 10 (CSIM10) is cleared to 0.

**Table 13-3. SO10 Output Status**

| TRMD10                     | DAP10     | DIR10     | SO10 Output                            |
|----------------------------|-----------|-----------|--|
| TRMD10 = 0 <sup>Note</sup> | –         | –         | Outputs low level <sup>Note</sup> .    |
| TRMD10 = 1                 | DAP10 = 0 | –         | Value of SO10 latch (low-level output) |
|                            |           | –         | Value of bit 7 of SOTB10               |
|                            | DAP10 = 1 | DIR10 = 0 | Value of bit 0 of SOTB10               |

**Note** Status after reset

**Caution** If a value is written to TRMD10, DAP10, and DIR10, the output value of SO10 changes.

## CHAPTER 14 INTERRUPT FUNCTIONS

### 14.1 Interrupt Function Types

The following two types of interrupt functions are used.

#### (1) Maskable interrupts

These interrupts undergo mask control. Maskable interrupts can be divided into a high interrupt priority group and a low interrupt priority group by setting the priority specification flag registers (PR0L, PR0H, PR1L).

Multiple interrupt servicing of high-priority interrupts can be applied to low priority interrupts. If two or more interrupts with the same priority are simultaneously generated, each interrupt is serviced according to its predetermined priority (see **Table 14-1**).

A standby release signal is generated and the STOP mode and HALT mode are released by maskable interrupts. Six external interrupt requests and 12 internal interrupt requests are provided as maskable interrupts.

#### (2) Software interrupt

This is a vectored interrupt generated by executing the BRK instruction. It is acknowledged even when interrupts are disabled. The software interrupt does not undergo interrupt priority control.

### 14.2 Interrupt Sources and Configuration

A total of 19 interrupt sources exist for maskable and software interrupts. In addition, maximum total of 5 reset sources are also provided (see **Table 14-1**).

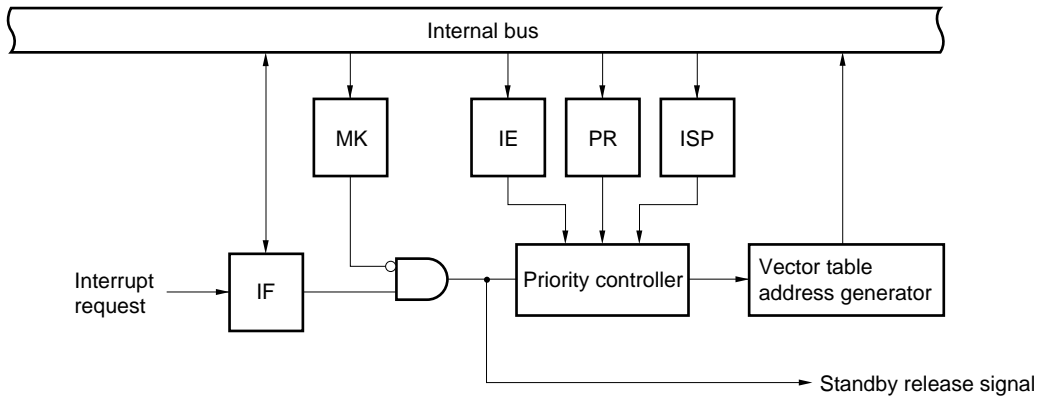
Table 14-1. Interrupt Source List

| Interrupt Type | Default Priority <sup>Note 1</sup> | Interrupt Source                      |  | Internal/ External | Vector Table Address | Basic Configuration Type <sup>Note 2</sup> |
|----------------|------------------------------------|---------------------------------------|--|--------------------|----------------------|--|
|                |                                    | Name                                  | Trigger  |                    |                      |  |
| Maskable       | 0                                  | INTLVI                                | Low-voltage detection <sup>Note 3</sup>                              | Internal           | 0004H                | (A)  |
|                | 1                                  | INTP0                                 | Pin input edge detection   | External           | 0006H                | (B)  |
|                | 2                                  | INTP1                                 |  |                    | 0008H                |  |
|                | 3                                  | INTP2                                 |  |                    | 000AH                |  |
|                | 4                                  | INTP3                                 |  |                    | 000CH                |  |
|                | 5                                  | INTP4                                 |  |                    | 000EH                |  |
|                | 6                                  | INTP5                                 |  |                    | 0010H                |  |
|                | 7                                  | INTSRE6                               | UART6 reception error generation                                     | Internal           | 0012H                | (A)  |
|                | 8                                  | INTSR6                                | End of UART6 reception   |                    | 0014H                |  |
|                | 9                                  | INTST6                                | End of UART6 transmission  |                    | 0016H                |  |
|                | 10                                 | INTCSI10/<br>INTST0 <sup>Note 4</sup> | End of CSI10 communication/end of UART0 transmission                 |                    | 0018H                |  |
|                | 11                                 | INTTMH1                               | Match between TMH1 and CMP01<br>(when compare register is specified) |                    | 001AH                |  |
|                | 12                                 | INTTMH0                               | Match between TMH0 and CMP00<br>(when compare register is specified) |                    | 001CH                |  |
|                | 13                                 | INTTM50                               | Match between TM50 and CR50<br>(when compare register is specified)  |                    | 001EH                |  |
|                | 14                                 | INTTM000                              | Match between TM00 and CR000<br>(when compare register is specified) |                    | 0020H                |  |
|                | 15                                 | INTTM010                              | Match between TM00 and CR010<br>(when compare register is specified) |                    | 0022H                |  |
|                | 16                                 | INTAD                                 | End of A/D conversion  |                    | 0024H                |  |
| 17             | INTSR0 <sup>Note 4</sup>           | End of UART0 reception                | 0026H  |                    |                      |  |
| Software       | –                                  | BRK                                   | BRK instruction execution  | –                  | 003EH                | (C)  |
| Reset          | –                                  | RESET                                 | Reset input  | –                  | 0000H                | –  |
|                |                                    | POC                                   | Power-on-clear <sup>Note 5</sup>                                     |                    |                      |  |
|                |                                    | LVI                                   | Low-voltage detection <sup>Note 6</sup>                              |                    |                      |  |
|                |                                    | Clock monitor                         | X1 input clock stop detection  |                    |                      |  |
|                |                                    | WDT                                   | WDT overflow   |                    |                      |  |

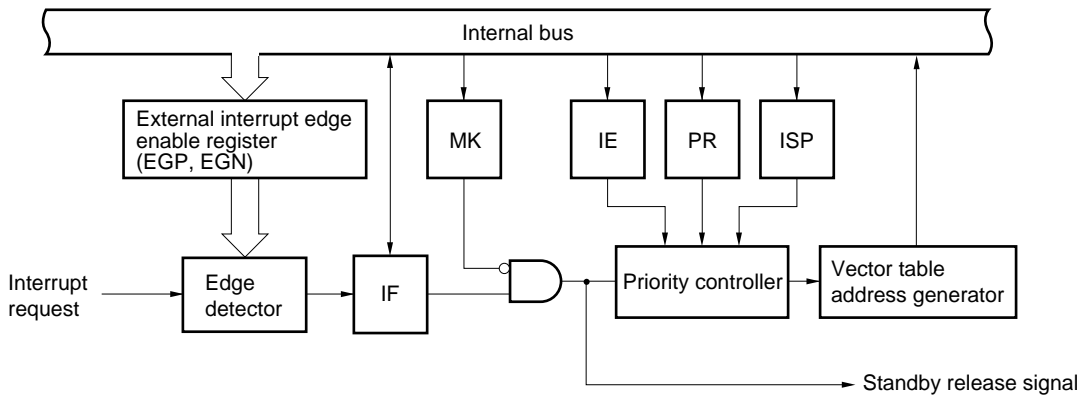
- Notes**
- The default priority is the priority applicable when two or more maskable interrupts are generated simultaneously. 0 is the highest priority, and 17 is the lowest.
  - Basic configuration types (A) to (C) correspond to (A) to (C) in Figure 14-1.
  - When bit 1 (LVIMD) = 0 is selected for the low-voltage detection register (LVIM).
  - The interrupt sources INTST0 and INTSR0 are available only in the  $\mu$ PD780102, 780103, and 78F0103.
  - When “POC used” is selected by mask option.
  - When LVIMD = 1 is selected.

Figure 14-1. Basic Configuration of Interrupt Function

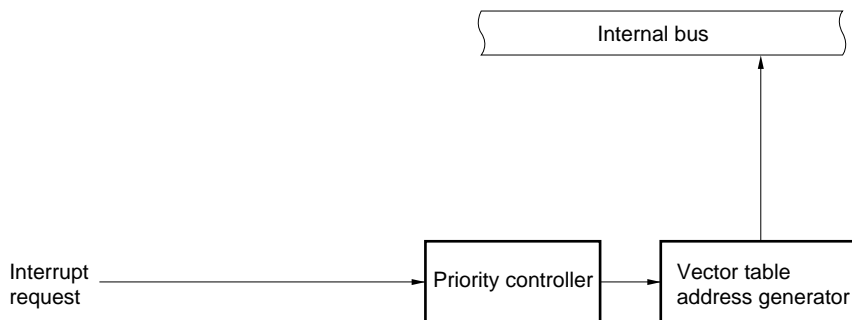
(A) Internal maskable interrupt



(B) External maskable interrupt (INTP0 to INTP5)



(C) Software interrupt



- IF: Interrupt request flag
- IE: Interrupt enable flag
- ISP: In-service priority flag
- MK: Interrupt mask flag
- PR: Priority specification flag

### 14.3 Registers Controlling Interrupt Function

The following 6 types of registers are used to control the interrupt functions.

- Interrupt request flag register (IF0L, IF0H, IF1L)
- Interrupt mask flag register (MK0L, MK0H, MK1L)
- Priority specification flag register (PR0L, PR0H, PR1L)
- External interrupt rising edge enable register (EGP)
- External interrupt falling edge enable register (EGN)
- Program status word (PSW)

Table 14-2 shows a list of interrupt request flags, interrupt mask flags, and priority specification flags corresponding to interrupt request sources.

**Table 14-2. Flags Corresponding to Interrupt Request Sources**

| Interrupt Request        | Interrupt Request Flag    |                         | Interrupt Mask Flag       |                         | Priority Specification Flag |          |
|--------------------------|---------------------------|-------------------------|---------------------------|-------------------------|-----------------------------|----------|
|                          | Register                  | Register                | Register                  | Register                | Register                    | Register |
| INTLVI                   | LVIIIF                    | IF0L                    | LVIMK                     | MK0L                    | LVIPR                       | PR0L     |
| INTP0                    | PIF0                      |                         | PMK0                      |                         | PPR0                        |          |
| INTP1                    | PIF1                      |                         | PMK1                      |                         | PPR1                        |          |
| INTP2                    | PIF2                      |                         | PMK2                      |                         | PPR2                        |          |
| INTP3                    | PIF3                      |                         | PMK3                      |                         | PPR3                        |          |
| INTP4                    | PIF4                      |                         | PMK4                      |                         | PPR4                        |          |
| INTP5                    | PIF5                      |                         | PMK5                      |                         | PPR5                        |          |
| INTSRE6                  | SREIF6                    |                         | SREMK6                    |                         | SREPR6                      |          |
| INTSR6                   | SRIF6                     | IF0H                    | SRMK6                     | MK0H                    | SRPR6                       | PR0H     |
| INTST6                   | STIF6                     |                         | STMK6                     |                         | STPR6                       |          |
| INTST0 <sup>Note 1</sup> | DUALIF0 <sup>Note 2</sup> |                         | DUALMK0 <sup>Note 4</sup> |                         | DUALPR0 <sup>Note 4</sup>   |          |
| INTCSI10                 | CSIIF10 <sup>Note 3</sup> |                         | CSIMK10 <sup>Note 3</sup> |                         | CSIPR10 <sup>Note 3</sup>   |          |
| INTTMH1                  | TMIFH1                    |                         | TMMKH1                    |                         | TMPRH1                      |          |
| INTTMH0                  | TMIFH0                    |                         | TMMKH0                    |                         | TMPRH0                      |          |
| INTTM50                  | TMIF50                    |                         | TMMK50                    |                         | TMPR50                      |          |
| INTTM000                 | TMIF000                   |                         | TMMK000                   |                         | TMPR000                     |          |
| INTTM010                 | TMIF010                   |                         | TMMK010                   |                         | TMPR010                     |          |
| INTAD                    | ADIF                      |                         | IF1L                      |                         | ADMK                        |          |
| INTSR0 <sup>Note 1</sup> | SRIF0 <sup>Note 1</sup>   | SRMK0 <sup>Note 1</sup> |                           | SRPR0 <sup>Note 1</sup> |                             |          |

**Notes** 1.  $\mu$ PD780102, 780103, and 78F0103 only.

2. Flag name in the  $\mu$ PD780102, 780103, and 78F0103. If either of the two types of interrupt sources is generated, these flags are set (1).
3. Flag name in the  $\mu$ PD780101
4. These are the flag names in the  $\mu$ PD780102, 780103, and 78F0103. These flags support two types of interrupt sources.

**(1) Interrupt request flag registers (IF0L, IF0H, IF1L)**

The interrupt request flags are set to 1 when the corresponding interrupt request is generated or an instruction is executed. They are cleared to 0 when an instruction is executed upon acknowledgment of an interrupt request or upon application of  $\overline{\text{RESET}}$  input.

When an interrupt is acknowledged, the interrupt request flag is automatically cleared and then the interrupt routine is entered.

IF0L, IF0H, and IF1L are set by a 1-bit or 8-bit memory manipulation instruction. When IF0L and IF0H are combined to form 16-bit register IF0, they are set by a 16-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears these registers to 00H.

**Figure 14-2. Format of Interrupt Request Flag Register (IF0L, IF0H, IF1L)**

Address: FFE0H After reset: 00H R/W

|        |        |      |      |      |      |      |      |      |
|--------|--------|------|------|------|------|------|------|------|
| Symbol | <7>    | <6>  | <5>  | <4>  | <3>  | <2>  | <1>  | <0>  |
| IF0L   | SREIF6 | PIF5 | PIF4 | PIF3 | PIF2 | PIF1 | PIF0 | LVIF |

Address: FFE1H After reset: 00H R/W

|        |         |         |        |        |        |                           |       |       |
|--------|---------|---------|--------|--------|--------|---------------------------|-------|-------|
| Symbol | <7>     | <6>     | <5>    | <4>    | <3>    | <2>                       | <1>   | <0>   |
| IF0H   | TMIF010 | TMIF000 | TMIF50 | TMIFH0 | TMIFH1 | DUALIF0 <sup>Note 1</sup> | STIF6 | SRIF6 |

Address: FFE2H After reset: 00H R/W

|        |   |   |   |   |   |   |                         |      |
|--------|---|---|---|---|---|---|-------------------------|------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2 | <1>                     | <0>  |
| IF1L   | 0 | 0 | 0 | 0 | 0 | 0 | SRIF0 <sup>Note 2</sup> | ADIF |

|       |  |
|-------|--|
| XXIFX | Interrupt request flag                                   |
| 0     | No interrupt request signal is generated                 |
| 1     | Interrupt request is generated, interrupt request status |

- Notes**
1. This is CSIF10 in the  $\mu\text{PD780101}$ .
  2.  $\mu\text{PD780102}$ , 780103, and 78F0103 only.

- Cautions**
1. Be sure to clear bits 2 to 7 of IF1L to 0.
  2. When operating a timer, serial interface, or A/D converter after standby release, operate it once after clearing the interrupt request flag. An interrupt request flag may be set by noise.
  3. When manipulating a flag of the interrupt request flag register, use a 1-bit memory manipulation instruction (CLR1). When describing in C language, use a bit manipulation instruction such as "IF0L.0 = 0;" or "\_asm("clr1 IF0L, 0");" because the compiled assembler must be a 1-bit memory manipulation instruction (CLR1).

If a program is described in C language using an 8-bit memory manipulation instruction such as "IF0L &= 0xfe;" and compiled, it becomes the assembler of three instructions.

```
mov a, IF0L
and a, #0FEH
mov IF0L, a
```

In this case, even if the request flag of another bit of the same interrupt request flag register (IF0L) is set to 1 at the timing between "mov a, IF0L" and "mov IF0L, a", the flag is cleared to 0 at "mov IF0L, a". Therefore, care must be exercised when using an 8-bit memory manipulation instruction in C language.

**(2) Interrupt mask flag registers (MK0L, MK0H, MK1L)**

The interrupt mask flags are used to enable/disable the corresponding maskable interrupt servicing. MK0L, MK0H, and MK1L are set by a 1-bit or 8-bit memory manipulation instruction. When MK0L and MK0H are combined to form a 16-bit register MK0, they are set with a 16-bit memory manipulation instruction.  $\overline{\text{RESET}}$  input sets these registers to FFH.

**Figure 14-3. Format of Interrupt Mask Flag Register (MK0L, MK0H, MK1L)**

Address: FFE4H After reset: FFH R/W

|        |        |      |      |      |      |      |      |       |
|--------|--------|------|------|------|------|------|------|-------|
| Symbol | <7>    | <6>  | <5>  | <4>  | <3>  | <2>  | <1>  | <0>   |
| MK0L   | SREMK6 | PMK5 | PMK4 | PMK3 | PMK2 | PMK1 | PMK0 | LVIMK |

Address: FFE5H After reset: FFH R/W

|        |         |         |        |        |        |                           |       |       |
|--------|---------|---------|--------|--------|--------|---------------------------|-------|-------|
| Symbol | <7>     | <6>     | <5>    | <4>    | <3>    | <2>                       | <1>   | <0>   |
| MK0H   | TMMK010 | TMMK000 | TMMK50 | TMMKH0 | TMMKH1 | DUALMK0 <sup>Note 1</sup> | STMK6 | SRMK6 |

Address: FFE6H After reset: FFH R/W

|        |   |   |   |   |   |   |                         |      |
|--------|---|---|---|---|---|---|-------------------------|------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2 | <1>                     | <0>  |
| MK1L   | 1 | 1 | 1 | 1 | 1 | 1 | SRMK0 <sup>Note 2</sup> | ADMK |

|       |                              |
|-------|------------------------------|
| XXMKX | Interrupt servicing control  |
| 0     | Interrupt servicing enabled  |
| 1     | Interrupt servicing disabled |

- Notes**
1. This is CSIMK10 in the  $\mu$ PD780101.
  2.  $\mu$ PD780102, 780103, and 78F0103 only.

**Caution** Be sure to set bits 2 to 7 of MK1L to 1.

**(3) Priority specification flag registers (PR0L, PR0H, PR1L)**

The priority specification flag registers are used to set the corresponding maskable interrupt priority order. PR0L, PR0H, and PR1L are set by a 1-bit or 8-bit memory manipulation instruction. If PR0L and PR0H are combined to form 16-bit register PR0, they are set with a 16-bit memory manipulation instruction.  $\overline{\text{RESET}}$  input sets these registers to FFH.

**Figure 14-4. Format of Priority Specification Flag Register (PR0L, PR0H, PR1L)**

Address: FFE8H After reset: FFH R/W

|        |        |      |      |      |      |      |      |       |
|--------|--------|------|------|------|------|------|------|-------|
| Symbol | <7>    | <6>  | <5>  | <4>  | <3>  | <2>  | <1>  | <0>   |
| PR0L   | SREPR6 | PPR5 | PPR4 | PPR3 | PPR2 | PPR1 | PPR0 | LVIPR |

Address: FFE9H After reset: FFH R/W

|        |         |         |        |        |        |                           |       |       |
|--------|---------|---------|--------|--------|--------|---------------------------|-------|-------|
| Symbol | <7>     | <6>     | <5>    | <4>    | <3>    | <2>                       | <1>   | <0>   |
| PR0H   | TMPR010 | TMPR000 | TMPR50 | TMPRH0 | TMPRH1 | DUALPR0 <sup>Note 1</sup> | STPR6 | SRPR6 |

Address: FFEAH After reset: FFH R/W

|        |   |   |   |   |   |   |                         |      |
|--------|---|---|---|---|---|---|-------------------------|------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2 | <1>                     | <0>  |
| PR1L   | 1 | 1 | 1 | 1 | 1 | 1 | SRPR0 <sup>Note 2</sup> | ADPR |

|       |                          |
|-------|--------------------------|
| XXPRX | Priority level selection |
| 0     | High priority level      |
| 1     | Low priority level       |

- Notes**
1. This is CSIPR10 in the  $\mu$ PD780101.
  2.  $\mu$ PD780102, 780103, and 78F0103 only.

**Caution** Be sure to set bits 2 to 7 of PR1L to 1.



**(4) External interrupt rising edge enable register (EGP), external interrupt falling edge enable register (EGN)**

These registers specify the valid edge for INTP0 to INTP5.

EGP and EGN are set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears these registers to 00H.

**Figure 14-5. Format of External Interrupt Rising Edge Enable Register (EGP) and External Interrupt Falling Edge Enable Register (EGN)**

Address: FF48H After reset: 00H R/W

|        |   |   |      |      |      |      |      |      |
|--------|---|---|------|------|------|------|------|------|
| Symbol | 7 | 6 | 5    | 4    | 3    | 2    | 1    | 0    |
| EGP    | 0 | 0 | EGP5 | EGP4 | EGP3 | EGP2 | EGP1 | EGP0 |

Address: FF49H After reset: 00H R/W

|        |   |   |      |      |      |      |      |      |
|--------|---|---|------|------|------|------|------|------|
| Symbol | 7 | 6 | 5    | 4    | 3    | 2    | 1    | 0    |
| EGN    | 0 | 0 | EGN5 | EGN4 | EGN3 | EGN2 | EGN1 | EGN0 |

| EGPn | EGNn | INTPn pin valid edge selection (n = 0 to 5) |
|------|------|---|
| 0    | 0    | Edge detection disabled                     |
| 0    | 1    | Falling edge                                |
| 1    | 0    | Rising edge                                 |
| 1    | 1    | Both rising and falling edges               |

Table 14-3 shows the ports corresponding to EGPn and EGNn.

**Table 14-3. Ports Corresponding to EGPn and EGNn**

| Detection Enable Register |      | Edge Detection Port | Interrupt Request Signal |
|---------------------------|------|---------------------|--------------------------|
| EGP0                      | EGN0 | P120                | INTP0                    |
| EGP1                      | EGN1 | P30                 | INTP1                    |
| EGP2                      | EGN2 | P31                 | INTP2                    |
| EGP3                      | EGN3 | P32                 | INTP3                    |
| EGP4                      | EGN4 | P33                 | INTP4                    |
| EGP5                      | EGN5 | P16                 | INTP5                    |

**Caution** Select the port mode by clearing EGPn and EGNn to 0 because an edge may be detected when the external interrupt function is switched to the port function.

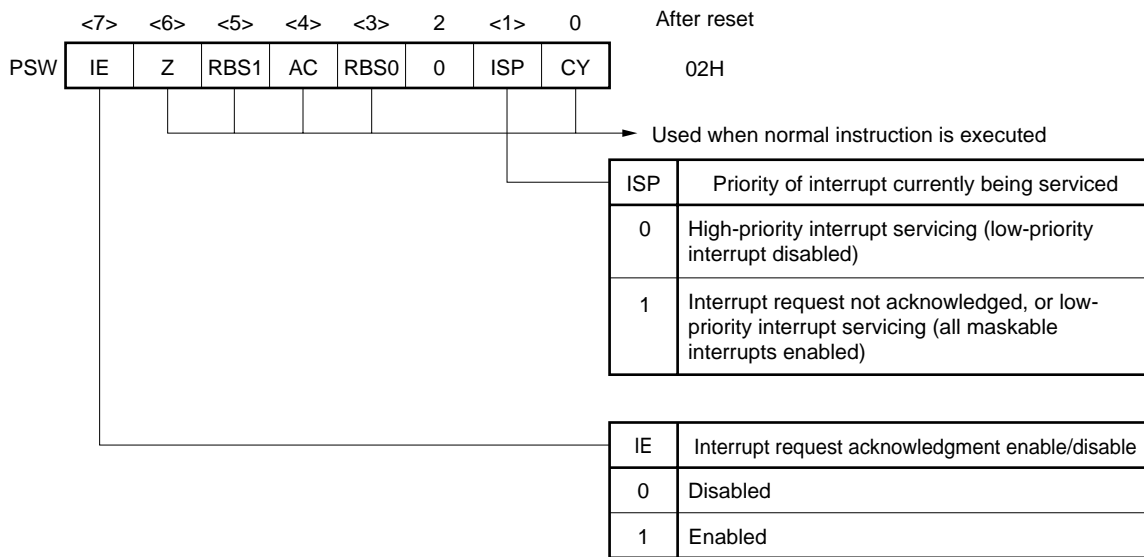
**Remark** n = 0 to 5

**(5) Program status word (PSW)**

The program status word is a register used to hold the instruction execution result and the current status for an interrupt request. The IE flag that sets maskable interrupt enable/disable and the ISP flag that controls multiple interrupt servicing are mapped to the PSW.

Besides 8-bit read/write, this register can carry out operations using bit manipulation instructions and dedicated instructions (EI and DI). When a vectored interrupt request is acknowledged, if the BRK instruction is executed, the contents of the PSW are automatically saved into a stack and the IE flag is reset to 0. If a maskable interrupt request is acknowledged, the contents of the priority specification flag of the acknowledged interrupt are transferred to the ISP flag. The PSW contents are also saved into the stack with the PUSH PSW instruction. They are restored from the stack with the RETI, RETB, and POP PSW instructions.  $\overline{\text{RESET}}$  input sets PSW to 02H.

**Figure 14-6. Format of Program Status Word**



## 14.4 Interrupt Servicing Operations

### 14.4.1 Maskable interrupt request acknowledgment

A maskable interrupt request becomes acknowledgeable when the interrupt request flag is set to 1 and the mask (MK) flag corresponding to that interrupt request is cleared to 0. A vectored interrupt request is acknowledged if interrupts are in the interrupt enabled state (when the IE flag is set to 1). However, a low-priority interrupt request is not acknowledged during servicing of a higher priority interrupt request (when the ISP flag is reset to 0).

The times from generation of a maskable interrupt request until interrupt servicing is performed are listed in Table 14-4 below.

For the interrupt request acknowledgment timing, see **Figures 14-8** and **14-9**.

**Table 14-4. Time from Generation of Maskable Interrupt Request Until Servicing**

|                                  | Minimum Time | Maximum Time <sup>Note</sup> |
|----------------------------------|--------------|------------------------------|
| When $\times\times\text{PR} = 0$ | 7 clocks     | 32 clocks                    |
| When $\times\times\text{PR} = 1$ | 8 clocks     | 33 clocks                    |

**Note** If an interrupt request is generated just before a divide instruction, the wait time becomes longer.

**Remark** 1 clock:  $1/f_{\text{CPU}}$  ( $f_{\text{CPU}}$ : CPU clock)

If two or more maskable interrupt requests are generated simultaneously, the request with a higher priority level specified in the priority specification flag is acknowledged first. If two or more interrupt requests have the same priority level, the request with the highest default priority is acknowledged first.

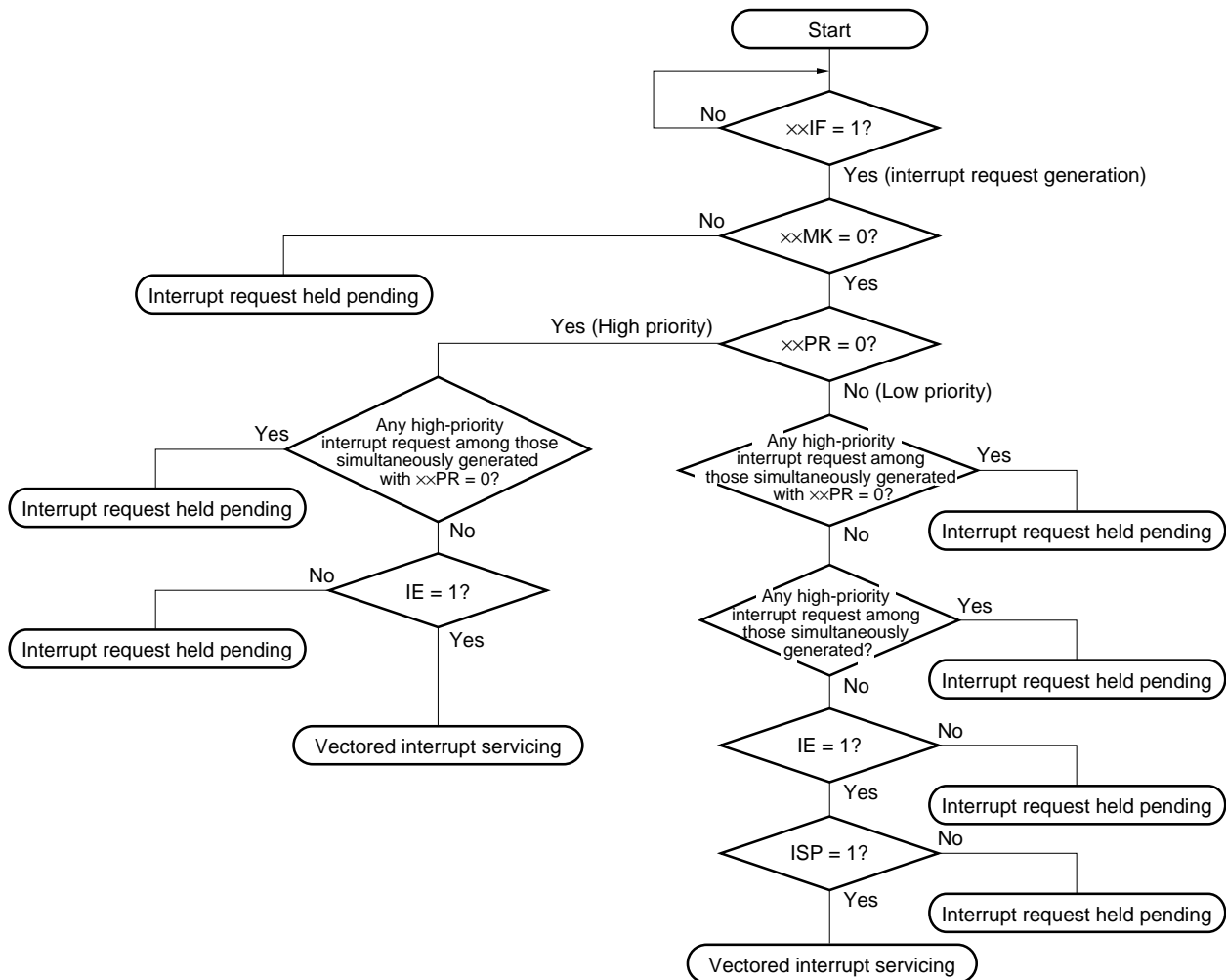
An interrupt request that is held pending is acknowledged when it becomes acknowledgeable.

Figure 14-7 shows the interrupt request acknowledgment algorithm.

If a maskable interrupt request is acknowledged, the contents are saved into the stacks in the order of PSW, then PC, the IE flag is reset (0), and the contents of the priority specification flag corresponding to the acknowledged interrupt are transferred to the ISP flag. The vector table data determined for each interrupt request is loaded into the PC and branched.

Restoring from an interrupt is possible by using the RETI instruction.

Figure 14-7. Interrupt Request Acknowledgment Processing Algorithm



xxIF: Interrupt request flag

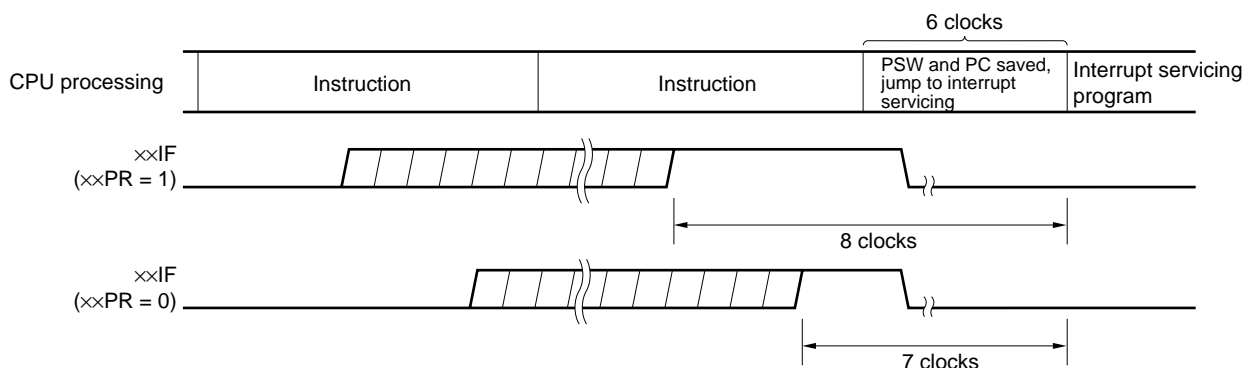
xxMK: Interrupt mask flag

xxPR: Priority specification flag

IE: Flag that controls acknowledgment of maskable interrupt request (1 = Enable, 0 = Disable)

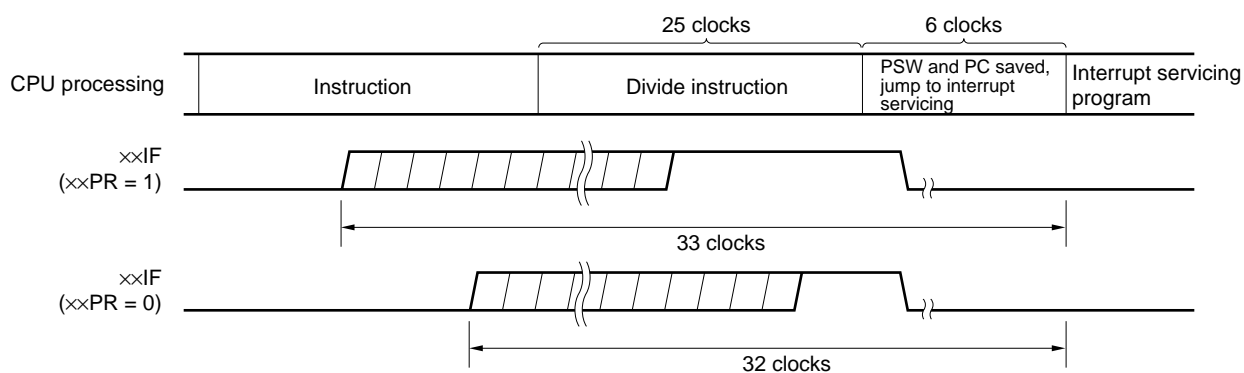
ISP: Flag that indicates the priority level of the interrupt currently being serviced (0 = High-priority interrupt servicing, 1 = No interrupt request acknowledged, or low-priority interrupt servicing)

Figure 14-8. Interrupt Request Acknowledgment Timing (Minimum Time)



**Remark** 1 clock:  $1/f_{CPU}$  ( $f_{CPU}$ : CPU clock)

Figure 14-9. Interrupt Request Acknowledgment Timing (Maximum Time)



**Remark** 1 clock:  $1/f_{CPU}$  ( $f_{CPU}$ : CPU clock)

#### 14.4.2 Software interrupt request acknowledgment

A software interrupt request is acknowledged by BRK instruction execution. Software interrupts cannot be disabled.

If a software interrupt request is acknowledged, the contents are saved into the stacks in the order of the program status word (PSW), then program counter (PC), the IE flag is reset (0), and the contents of the vector table (003EH, 003FH) are loaded into the PC and branched.

Restoring from a software interrupt is possible by using the RETB instruction.

**Caution** Do not use the RETI instruction for restoring from the software interrupt.

### 14.4.3 Multiple interrupt servicing

Multiple interrupt servicing occurs when another interrupt request is acknowledged during execution of an interrupt.

Multiple interrupt servicing does not occur unless the interrupt request acknowledgment enabled state is selected (IE = 1). When an interrupt request is acknowledged, interrupt request acknowledgment becomes disabled (IE = 0). Therefore, to enable multiple interrupt servicing, it is necessary to set (1) the IE flag with the EI instruction during interrupt servicing to enable interrupt acknowledgment.

Moreover, even if interrupts are enabled, multiple interrupt servicing may not be enabled, this being subject to interrupt priority control. Two types of priority control are available: default priority control and programmable priority control. Programmable priority control is used for multiple interrupt servicing.

In the interrupt enabled state, if an interrupt request with a priority equal to or higher than that of the interrupt currently being serviced is generated, it is acknowledged for multiple interrupt servicing. If an interrupt with a priority lower than that of the interrupt currently being serviced is generated during interrupt servicing, it is not acknowledged for multiple interrupt servicing.

Interrupt requests that are not enabled because interrupts are in the interrupt disabled state or because they have a lower priority are held pending. When servicing of the current interrupt ends, the pending interrupt request is acknowledged following execution of at least one main processing instruction execution.

Table 14-5 shows relationship between interrupt requests enabled for multiple interrupt servicing and Figure 14-10 shows multiple interrupt servicing examples.

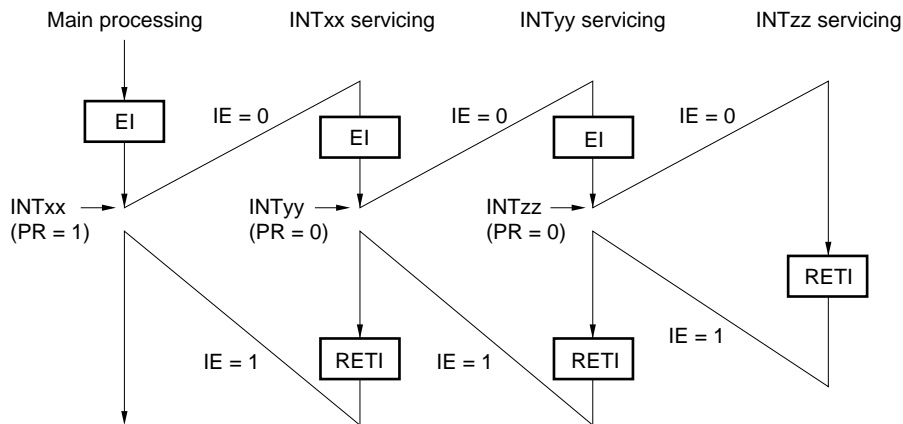
**Table 14-5. Relationship Between Interrupt Requests Enabled for Multiple Interrupt Servicing During Interrupt Servicing**

| Multiple Interrupt Request<br>Interrupt Being Serviced |         | Maskable Interrupt Request |        |        |        | Software<br>Interrupt<br>Request |
|--|---------|----------------------------|--------|--------|--------|----------------------------------|
|  |         | PR = 0                     |        | PR = 1 |        |                                  |
|  |         | IE = 1                     | IE = 0 | IE = 1 | IE = 0 |                                  |
| Maskable interrupt                                     | ISP = 0 | ○                          | ×      | ×      | ×      | ○                                |
|  | ISP = 1 | ○                          | ×      | ○      | ×      | ○                                |
| Software interrupt                                     |         | ○                          | ×      | ○      | ×      | ○                                |

- Remarks**
- : Multiple interrupt servicing enabled
  - ×: Multiple interrupt servicing disabled
  - The ISP and IE are flags contained in the PSW.
    - ISP = 0: An interrupt with higher priority is being serviced.
    - ISP = 1: No interrupt request has been acknowledged, or an interrupt with a lower priority is being serviced.
    - IE = 0: Interrupt request acknowledgment is disabled.
    - IE = 1: Interrupt request acknowledgment is enabled.
  - PR is a flag contained in PR0L, PR0H, and PR1L.
    - PR = 0: Higher priority level
    - PR = 1: Lower priority level

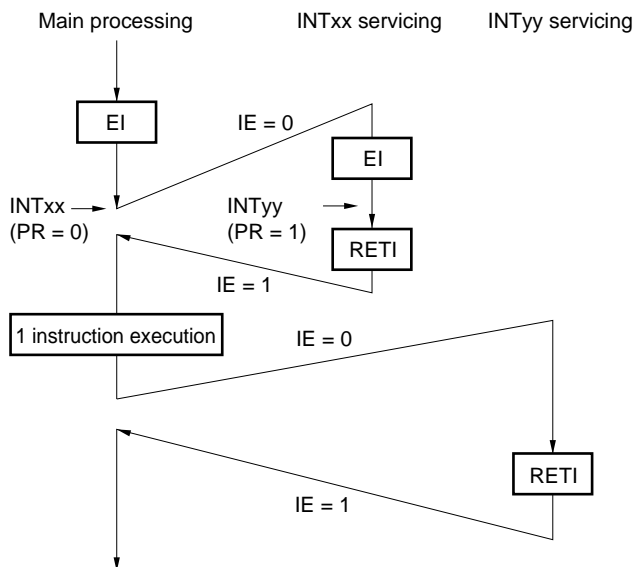
Figure 14-10. Examples of Multiple Interrupt Servicing (1/2)

**Example 1. Multiple interrupt servicing occurs twice**



During servicing of interrupt INTxx, two interrupt requests, INTyy and INTzz, are acknowledged, and multiple interrupt servicing takes place. Before each interrupt request is acknowledged, the EI instruction must always be issued to enable interrupt request acknowledgment.

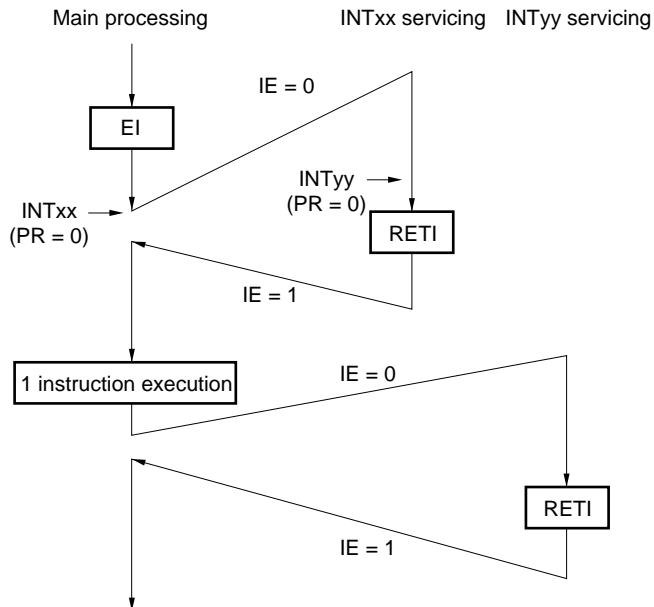
**Example 2. Multiple interrupt servicing does not occur due to priority control**



Interrupt request INTyy issued during servicing of interrupt INTxx is not acknowledged because its priority is lower than that of INTxx, and multiple interrupt servicing does not take place. The INTyy interrupt request is held pending, and is acknowledged following execution of one main processing instruction.

- PR = 0: Higher priority level
- PR = 1: Lower priority level
- IE = 0: Interrupt request acknowledgment disabled

Figure 14-10. Examples of Multiple Interrupt Servicing (2/2)

**Example 3. Multiple interrupt servicing does not occur because interrupts are not enabled**

Interrupts are not enabled during servicing of interrupt INTxx (EI instruction is not issued), therefore, interrupt request INTyy is not acknowledged and multiple interrupt servicing does not take place. The INTyy interrupt request is held pending, and is acknowledged following execution of one main processing instruction.

PR = 0: Higher priority level

IE = 0: Interrupt request acknowledgment disabled



#### 14.4.4 Interrupt request hold

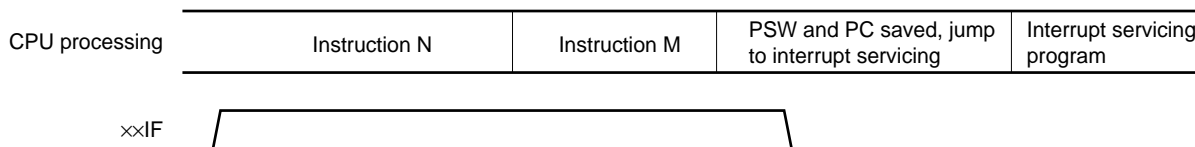
There are instructions where, even if an interrupt request is issued for them while another instruction is being executed, request acknowledgment is held pending until the end of execution of the next instruction. These instructions (interrupt request hold instructions) are listed below.

- MOV PSW, #byte
- MOV A, PSW
- MOV PSW, A
- MOV1 PSW. bit, CY
- MOV1 CY, PSW. bit
- AND1 CY, PSW. bit
- OR1 CY, PSW. bit
- XOR1 CY, PSW. bit
- SET1 PSW. bit
- CLR1 PSW. bit
- RETB
- RETI
- PUSH PSW
- POP PSW
- BT PSW. bit, \$addr16
- BF PSW. bit, \$addr16
- BTCLR PSW. bit, \$addr16
- EI
- DI
- Manipulation instructions for the IF0L, IF0H, IF1L, MK0L, MK0H, MK1L, PR0L, PR0H, and PR1L registers

**Caution** The BRK instruction is not one of the above-listed interrupt request hold instructions. However, the software interrupt activated by executing the BRK instruction causes the IE flag to be cleared to 0. Therefore, even if a maskable interrupt request is generated during execution of the BRK instruction, the interrupt request is not acknowledged.

Figure 14-11 shows the timing at which interrupt requests are held pending.

**Figure 14-11. Interrupt Request Hold**



- Remarks**
1. Instruction N: Interrupt request hold instruction
  2. Instruction M: Instruction other than interrupt request hold instruction
  3. The ××PR (priority level) values do not affect the operation of ××IF (interrupt request).

## CHAPTER 15 STANDBY FUNCTION

### 15.1 Standby Function and Configuration

#### 15.1.1 Standby function

**Table 15-1. Relationship Between Operation Clocks in Each Operation Status**

| Status<br>Operation<br>Mode | X1 Oscillator | Ring-OSC Oscillator |             |           | CPU Clock<br>After<br>Release | Prescaler Clock Supplied to<br>Peripherals |          |
|-----------------------------|---------------|---------------------|-------------|-----------|-------------------------------|--|----------|
|                             |               | Note 1              | Note 2      |           |                               | MCM0 = 0                                   | MCM0 = 1 |
|                             |               |                     | RSTOP = 0   | RSTOP = 1 |                               |  |          |
| Reset                       | Stopped       | Stopped             |             |           | Ring-OSC                      | Stopped                                    |          |
| STOP                        |               | Oscillating         | Oscillating | Stopped   | Note 3                        | Stopped                                    |          |
| HALT                        | Oscillating   |                     |             |           | Note 4                        | Ring-OSC                                   | X1       |

- Notes**
1. When “Cannot be stopped” is selected for Ring-OSC by a mask option.
  2. When “Can be stopped by software” is selected for Ring-OSC by a mask option.
  3. Operates using the CPU clock at STOP instruction execution.
  4. Operates using the CPU clock at HALT instruction execution.

**Caution** The RSTOP setting is valid only when “Can be stopped by software” is set for Ring-OSC by a mask option.

**Remark** RSTOP: Bit 0 of the Ring-OSC mode register (RCM)  
MCM0: Bit 0 of the main clock mode register (MCM)

The standby function is designed to reduce the operating current consumption of the system. The following two modes are available.

**(1) HALT mode**

HALT instruction execution sets the HALT mode. The HALT mode is intended to stop the CPU operation clock. If the X1 input clock and Ring-OSC clock oscillator are operating before the HALT mode is set, oscillation of the X1 input clock and Ring-OSC clock continues. In this mode, operating current is not decreased as much as in the STOP mode. However, the HALT mode is effective for restarting operation immediately upon interrupt request generation and carrying out intermittent operations.

**(2) STOP mode**

STOP instruction execution sets the STOP mode. In the STOP mode, the X1 oscillator stops, stopping the whole system, thereby considerably reducing the CPU operating current.

Because this mode can be cleared by an interrupt request, it enables intermittent operations to be carried out. However, because a wait time is required to secure the oscillation stabilization time after the STOP mode is released, select the HALT mode if it is necessary to start processing immediately upon interrupt request generation.

In either of these two modes, all the contents of registers, flags and data memory just before the standby mode is set are held. The I/O port output latches and output buffer statuses are also held.

- Cautions**
- 1. When shifting to the STOP mode, be sure to stop the peripheral hardware operation before executing STOP instruction.**
  - 2. The following sequence is recommended for operating current reduction of the A/D converter when the standby function is used: First clear bit 7 (ADCS) of the A/D converter mode register (ADM) to 0 to stop the A/D conversion operation, and then execute the HALT or STOP instruction.**
  - 3. If the Ring-OSC oscillator is operating before the STOP mode is set, oscillation of the Ring-OSC clock cannot be stopped in the STOP mode. However, when the Ring-OSC clock is used as the CPU clock, the CPU operation is stopped for  $17/f_R$  (s) after STOP mode is released.**

15.1.2 Registers controlling standby function

The standby function is controlled by the following two registers.

- Oscillation stabilization time counter status register (OSTC)
- Oscillation stabilization time select register (OSTS)

**Remark** For the registers that start, stop, or select the clock, see **CHAPTER 5 CLOCK GENERATOR**.

(1) Oscillation stabilization time counter status register (OSTC)

This is the status register of the X1 input clock oscillation stabilization time counter. If the Ring-OSC clock is used as the CPU clock, the X1 input clock oscillation stabilization time can be checked.

OSTC can be read by a 1-bit or 8-bit memory manipulation instruction.

When reset is released (reset by  $\overline{\text{RESET}}$  input, POC, LVI, clock monitor, and WDT), the STOP instruction, and MSTOP (bit 7 of MOC register) = 1 clear OSTC to 00H.

**Figure 15-1. Format of Oscillation Stabilization Time Counter Status Register (OSTC)**

Address: FFA3H After reset: 00H R

|        |   |   |   |        |        |        |        |        |
|--------|---|---|---|--------|--------|--------|--------|--------|
| Symbol | 7 | 6 | 5 | 4      | 3      | 2      | 1      | 0      |
| OSTC   | 0 | 0 | 0 | MOST11 | MOST13 | MOST14 | MOST15 | MOST16 |

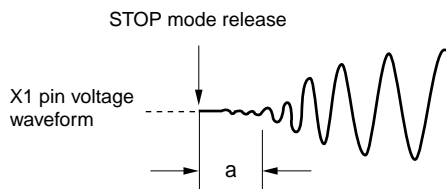
| ★ | MOST11 | MOST13 | MOST14 | MOST15 | MOST16 | Oscillation stabilization time status |   |                          |
|---|--------|--------|--------|--------|--------|---------------------------------------|---|--------------------------|
|   |        |        |        |        |        | $f_{XP} = 10 \text{ MHz}$             | $f_{XP} = 12 \text{ MHz}$ <sup>Note</sup> |                          |
|   | 1      | 0      | 0      | 0      | 0      | $2^{11}/f_{XP}$ min.                  | 204.8 $\mu\text{s}$ min.                  | 170.7 $\mu\text{s}$ min. |
|   | 1      | 1      | 0      | 0      | 0      | $2^{13}/f_{XP}$ min.                  | 819.2 $\mu\text{s}$ min.                  | 682.7 $\mu\text{s}$ min. |
|   | 1      | 1      | 1      | 0      | 0      | $2^{14}/f_{XP}$ min.                  | 1.64 ms min.                              | 1.37 ms min.             |
|   | 1      | 1      | 1      | 1      | 0      | $2^{15}/f_{XP}$ min.                  | 3.27 ms min.                              | 2.73 ms min.             |
|   | 1      | 1      | 1      | 1      | 1      | $2^{16}/f_{XP}$ min.                  | 6.55 ms min.                              | 5.46 ms min.             |

★ **Note** Expanded-specification products of standard products and (A) grade products only

- Cautions**
1. After the above time has elapsed, the bits are set to 1 in order from MOST11 and remain 1.
  2. If the STOP mode is entered and then released while the Ring-OSC clock is being used as the CPU clock, set the oscillation stabilization time as follows.
    - Desired OSTC oscillation stabilization time  $\leq$  Oscillation stabilization time set by OSTC

The X1 oscillation stabilization time counter counts only during the oscillation stabilization time set by OSTC. Therefore, note that only the statuses during the oscillation stabilization time set by OSTC are set to OSTC after STOP mode has been released.

3. The wait time when STOP mode is released does not include the time after STOP mode release until clock oscillation starts (“a” below) regardless of whether STOP mode is released by RESET input or interrupt generation.



**Remark** fx: X1 input clock oscillation frequency

**(2) Oscillation stabilization time select register (OSTS)**

This register is used to select the X1 oscillation stabilization wait time when STOP mode is released. The wait time set by OSTS is valid only after STOP mode is released when the X1 input clock is selected as the CPU clock. After STOP mode is released when the Ring-OSC clock is selected as the CPU clock, check the oscillation stabilization time using OSTC.

OSTS can be set by an 8-bit memory manipulation instruction.

RESET input sets OSTS to 05H.

**Figure 15-2. Format of Oscillation Stabilization Time Select Register (OSTS)**

Address: FFA4H After reset: 05H R/W

|        |   |   |   |   |   |       |       |       |
|--------|---|---|---|---|---|-------|-------|-------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2     | 1     | 0     |
| OSTS   | 0 | 0 | 0 | 0 | 0 | OSTS2 | OSTS1 | OSTS0 |

| OSTS2            | OSTS1 | OSTS0 | Oscillation stabilization time selection |                           |   |
|------------------|-------|-------|--|---------------------------|---|
|                  |       |       |  | $f_{XP} = 10 \text{ MHz}$ | $f_{XP} = 12 \text{ MHz}^{\text{Note}}$ |
| 0                | 0     | 1     | $2^{11}/f_{XP}$                          | 204.8 $\mu\text{s}$       | 170.7 $\mu\text{s}$                     |
| 0                | 1     | 0     | $2^{13}/f_{XP}$                          | 819.2 $\mu\text{s}$       | 682.7 $\mu\text{s}$                     |
| 0                | 1     | 1     | $2^{14}/f_{XP}$                          | 1.64 ms                   | 1.37 ms                                 |
| 1                | 0     | 0     | $2^{15}/f_{XP}$                          | 3.27 ms                   | 2.73 ms                                 |
| 1                | 0     | 1     | $2^{16}/f_{XP}$                          | 6.55 ms                   | 5.46 ms                                 |
| Other than above |       |       | Setting prohibited                       |                           |   |

★ **Note** Expanded-specification products of standard products and (A) grade products only

★ **Cautions 1.** To set the STOP mode when the X1 input clock is used as the CPU clock, set OSTS before executing the STOP instruction.

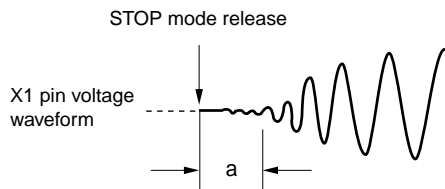
★ **2.** Execute the OSTS setting after confirming that the oscillation stabilization time has elapsed as expected in the OSTC.

★ **3.** If the STOP mode is entered and then released while the Ring-OSC clock is being used as the CPU clock, set the oscillation stabilization time as follows.

- Desired OSTC oscillation stabilization time  $\leq$  Oscillation stabilization time set by OSTS

The X1 oscillation stabilization time counter counts only during the oscillation stabilization time set by OSTS. Therefore, note that only the statuses during the oscillation stabilization time set by OSTS are set to OSTC after STOP mode has been released.

**4.** The wait time when STOP mode is released does not include the time after STOP mode release until clock oscillation starts (“a” below) regardless of whether STOP mode is released by RESET input or interrupt generation.



**Remark** fx: X1 input clock oscillation frequency

## 15.2 Standby Function Operation

### 15.2.1 HALT mode

#### (1) HALT mode

The HALT mode is set by executing the HALT instruction. HALT mode can be set when the CPU clock before the setting was the X1 input clock or Ring-OSC clock.

The operating statuses in the HALT mode are shown below.

**Table 15-2. Operating Statuses in HALT Mode**

| HALT Mode Setting                         |  | When HALT Instruction Is Executed While CPU Is Operating Using X1 Input Clock |  | When HALT Instruction Is Executed While CPU Is Operating Using Ring-OSC Clock   |                                    |
|---|--|---|--|---|------------------------------------|
|   |  | Ring-OSC Oscillation Continues  | Ring-OSC Oscillation Stopped <sup>Note 1</sup> | X1 Input Clock Oscillation Continues  | X1 Input Clock Oscillation Stopped |
| Item                                      |  |   |  |   |                                    |
| System clock                              |  | Clock supply to the CPU is stopped  |  |   |                                    |
| CPU                                       |  | Operation stopped   |  |   |                                    |
| Port (output latch)                       |  | Holds the status before HALT mode was set                                     |  |   |                                    |
| 16-bit timer/event counter 00             |  | Operable  |  | Operation not guaranteed  |                                    |
| 8-bit timer/event counter 50              |  | Operable  |  | Operation not guaranteed when count clock other than T150 is selected   |                                    |
| 8-bit timer H0                            |  | Operable  |  | Operation not guaranteed when count clock other than TM50 output is selected during 8-bit timer/event counter 50 operation  |                                    |
| 8-bit timer H1                            |  | Operable  |  | Operation not guaranteed when count clock other than $f_{R/2^7}$ is selected  |                                    |
| Watchdog timer                            | Ring-OSC cannot be stopped <sup>Note 2</sup> | Operable  | –  | Operable  |                                    |
|   | Ring-OSC can be stopped <sup>Note 2</sup>    | Operation stopped   |  |   |                                    |
| A/D converter                             |  | Operable  |  | Operation not guaranteed  |                                    |
| Serial interface                          | UART0 <sup>Note 3</sup>                      | Operable  |  | Operation not guaranteed when serial clock other than TM50 output is selected during 8-bit timer/event counter 50 operation |                                    |
|   | UART6  | Operable  |  |   |                                    |
|   | CSI10  | Operable  |  | Operation not guaranteed when serial clock other than external $\overline{\text{SCK10}}$ is selected                        |                                    |
| Clock monitor                             |  | Operable  | Operation stopped                              | Operable  | Operation stopped                  |
| Power-on-clear function <sup>Note 4</sup> |  | Operable  |  |   |                                    |
| Low-voltage detection function            |  | Operable  |  |   |                                    |
| External interrupt                        |  | Operable  |  |   |                                    |

- Notes**
1. When “Stopped by software” is selected for Ring-OSC by a mask option and Ring-OSC is stopped by software (for mask options, see **CHAPTER 20 MASK OPTIONS**).
  2. “Ring-OSC cannot be stopped” or “Ring-OSC can be stopped by software” can be selected by a mask option.
  3.  $\mu\text{PD780102}$ ,  $780103$ , and  $78F0103$  only.
  4. When “POC used” is selected by a mask option.

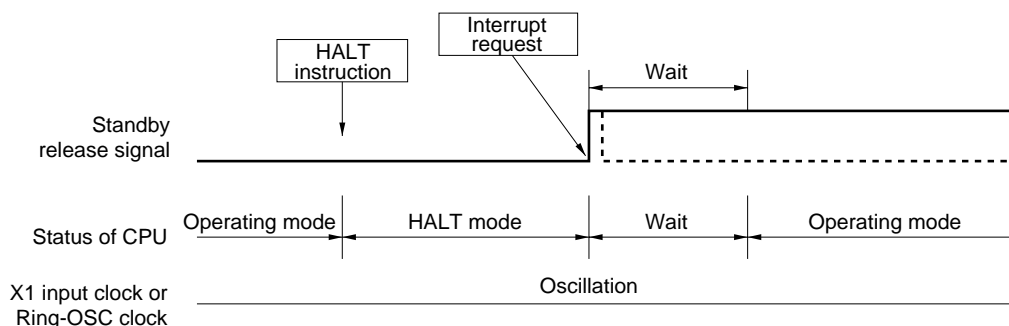
**(2) HALT mode release**

The HALT mode can be released by the following two sources.

**(a) Release by unmasked interrupt request**

When an unmasked interrupt request is generated, the HALT mode is released. If interrupt acknowledgement is enabled, vectored interrupt servicing is carried out. If interrupt acknowledgement is disabled, the next address instruction is executed.

**Figure 15-3. HALT Mode Release by Interrupt Request Generation**



**Remarks 1.** The broken lines indicate the case when the interrupt request which has released the standby mode is acknowledged.

**2.** The wait time is as follows:

- When vectored interrupt servicing is carried out: 8 or 9 clocks
- When vectored interrupt servicing is not carried out: 2 or 3 clocks

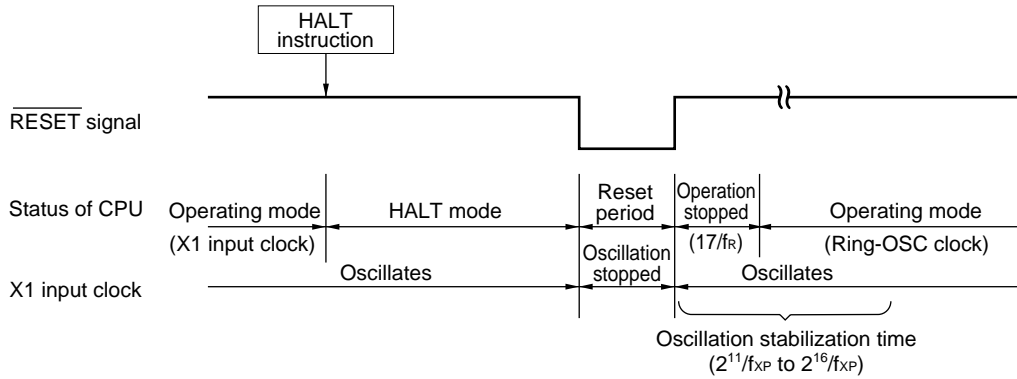


**(b) Release by  $\overline{\text{RESET}}$  input**

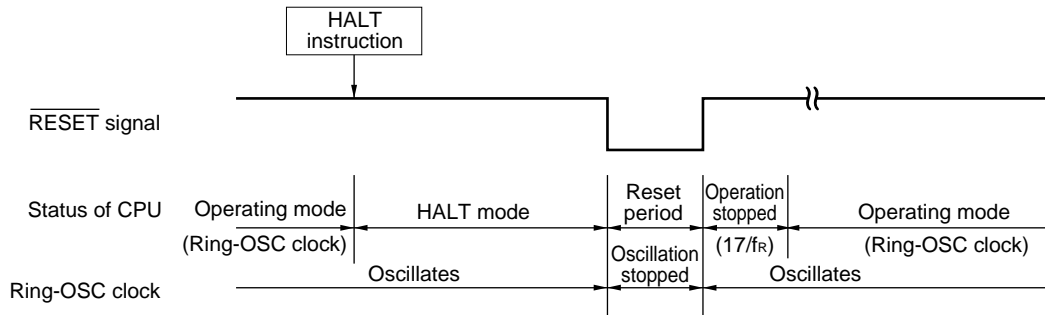
When the  $\overline{\text{RESET}}$  signal is input, HALT mode is released, and then, as in the case with a normal reset operation, the program is executed after branching to the reset vector address.

**Figure 15-4. HALT Mode Release by  $\overline{\text{RESET}}$  Input**

**(1) When X1 input clock is used as CPU clock**



**(2) When Ring-OSC clock is used as CPU clock**



- Remarks**
1.  $f_{XP}$ : X1 input clock oscillation frequency
  2.  $f_R$ : Ring-OSC clock oscillation frequency

**Table 15-3. Operation in Response to Interrupt Request in HALT Mode**

| Release Source                  | MK $\times\times$ | PR $\times\times$ | IE | ISP            | Operation                          |
|---------------------------------|-------------------|-------------------|----|----------------|------------------------------------|
| Maskable interrupt request      | 0                 | 0                 | 0  | ×              | Next address instruction execution |
|                                 | 0                 | 0                 | 1  | ×              | Interrupt servicing execution      |
|                                 | 0                 | 1                 | 0  | 1              | Next address instruction execution |
|                                 | 0                 | 1                 | ×  | 0              |                                    |
|                                 | 0                 | 1                 | 1  | 1              | Interrupt servicing execution      |
| 1                               | ×                 | ×                 | ×  | HALT mode held |                                    |
| $\overline{\text{RESET}}$ input | –                 | –                 | ×  | ×              | Reset processing                   |

×: Don't care

## 15.2.2 STOP mode

## (1) STOP mode setting and operating statuses

The STOP mode is set by executing the STOP instruction. It can be set when the CPU clock before the setting was the X1 input clock or Ring-OSC clock.

**Caution** Because the interrupt request signal is used to clear the standby mode, if there is an interrupt source with the interrupt request flag set and the interrupt mask flag reset, the standby mode is immediately cleared if set. Thus, the STOP mode is reset to the HALT mode immediately after execution of the STOP instruction and the system returns to the operating mode as soon as the wait time set using the oscillation stabilization time select register (OSTS) has elapsed.

The operating statuses in the STOP mode are shown below.

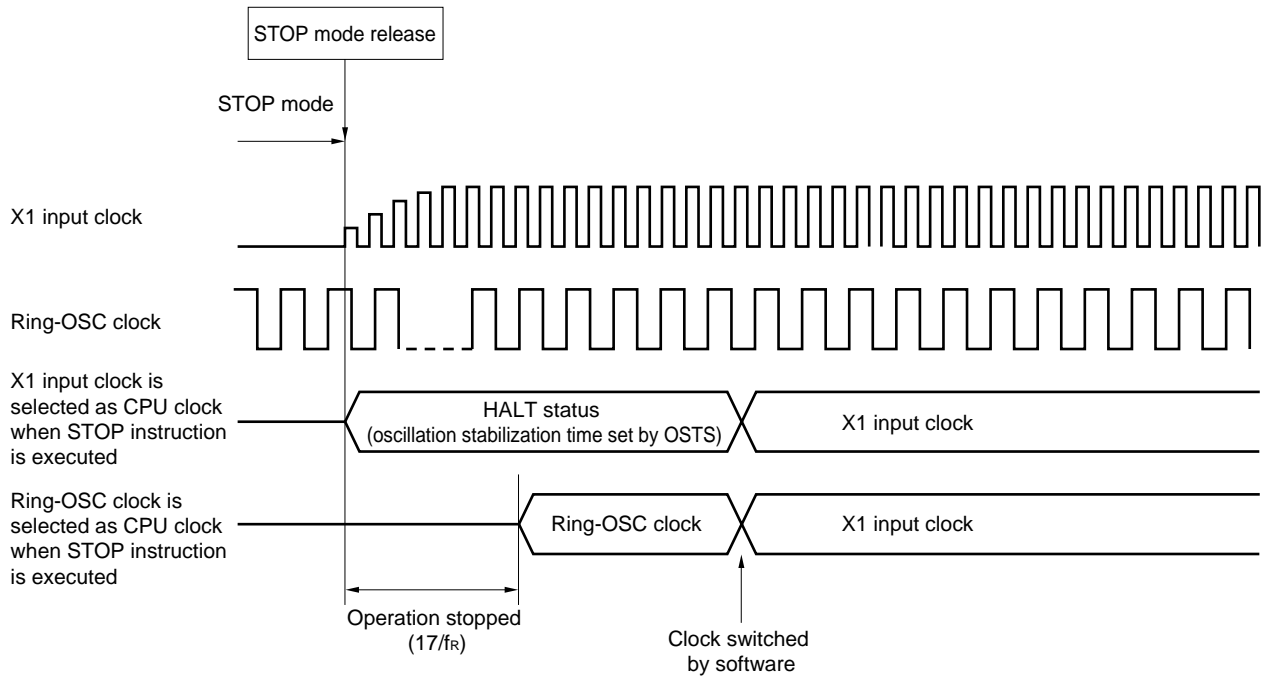
Table 15-4. Operating Statuses in STOP Mode

| HALT Mode Setting                         |  | When STOP Instruction Is Executed While CPU Is Operating Using X1 Input Clock                            |  | When STOP Instruction Is Executed While CPU Is Operating Using Ring-OSC Clock |
|---|--|--|--|---|
|   |  | Ring-OSC Oscillation Continues   | Ring-OSC Oscillation Stopped <sup>Note 1</sup> |   |
| Item                                      |  |  |  |   |
| System clock                              |  | Only X1 oscillator oscillation is stopped. Clock supply to the CPU is stopped.                           |  |   |
| CPU                                       |  | Operation stopped  |  |   |
| Port (output latch)                       |  | Holds the status before STOP mode was set  |  |   |
| 16-bit timer/event counter 00             |  | Operation stopped  |  |   |
| 8-bit timer/event counter 50              |  | Operable only when TI50 is selected as count clock   |  |   |
| 8-bit timer H0                            |  | Operable when TM50 output is selected as count clock during 8-bit timer/event counter 50 operation       |  |   |
| 8-bit timer H1                            |  | Operable <sup>Note 2</sup>   | Operation stopped                              | Operable <sup>Note 2</sup>  |
| Watchdog timer                            | Ring-OSC cannot be stopped <sup>Note 3</sup> | Operable   | –  | Operable  |
|   | Ring-OSC can be stopped <sup>Note 3</sup>    | Operation stopped  |  |   |
| A/D converter                             |  | Operation stopped  |  |   |
| Serial interface                          | UART0 <sup>Note 4</sup>                      | Operable only when TM50 output is selected as serial clock during 8-bit timer/event counter 50 operation |  |   |
|   | UART6  |  |  |   |
|   | CSI10  | Operable only when external $\overline{\text{SCK10}}$ is selected as serial clock                        |  |   |
| Clock monitor                             |  | Operation stopped  |  |   |
| Power-on-clear function <sup>Note 5</sup> |  | Operable   |  |   |
| Low-voltage detection function            |  | Operable   |  |   |
| External interrupt                        |  | Operable   |  |   |

- Notes**
1. When “Stopped by software” is selected for Ring-OSC by a mask option and Ring-OSC is stopped by software (for mask options, see **CHAPTER 20 MASK OPTIONS**).
  2. Operable only when  $f_{R/2^7}$  is selected as count clock.
  3. “Ring-OSC cannot be stopped” or “Ring-OSC can be stopped by software” can be selected by a mask option.
  4.  $\mu\text{PD780102}$ ,  $\text{780103}$ , and  $\text{78F0103}$  only.
  5. When “POC used” is selected by a mask option.

(2) STOP mode release

Figure 15-5. Operation Timing When STOP Mode Is Released

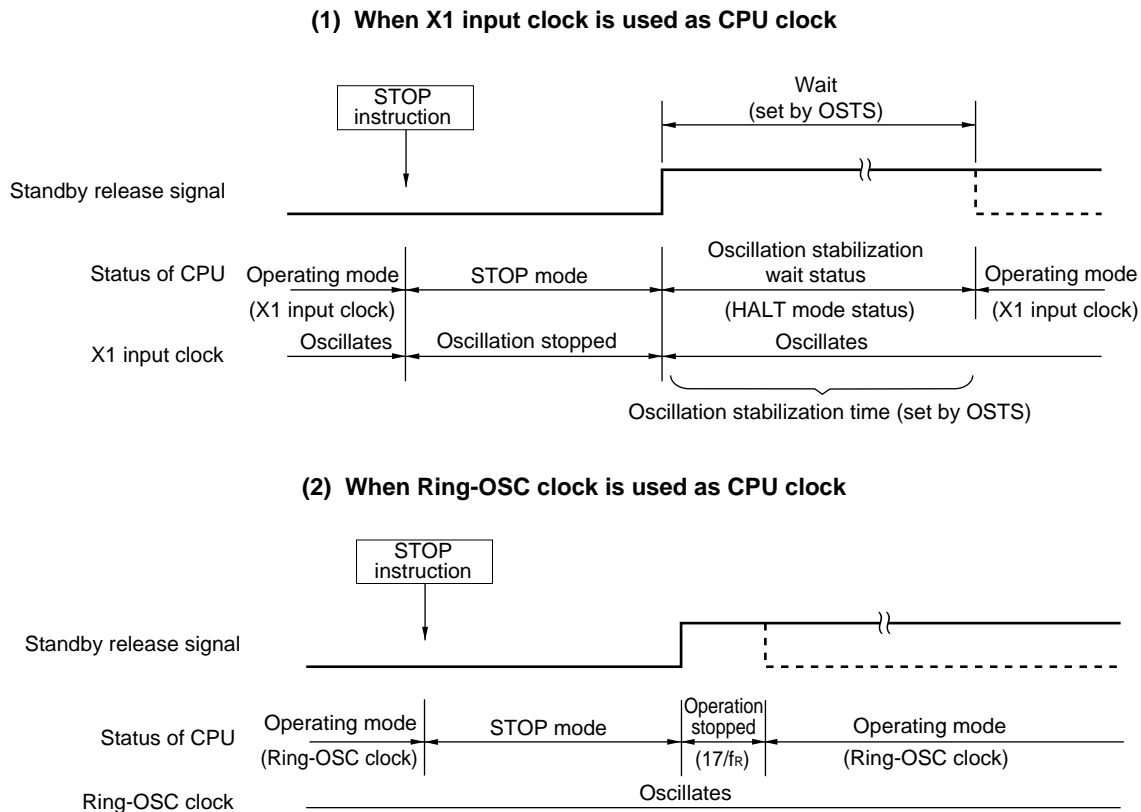


The STOP mode can be released by the following two sources.

**(a) Release by unmasked interrupt request**

When an unmasked interrupt request is generated, the STOP mode is released. After the oscillation stabilization time has elapsed, if interrupt acknowledgment is enabled, vectored interrupt servicing is carried out. If interrupt acknowledgment is disabled, the next address instruction is executed.

**Figure 15-6. STOP Mode Release by Interrupt Request Generation**



**Remarks 1.** The broken lines indicate the case when the interrupt request that has released the standby mode is acknowledged.

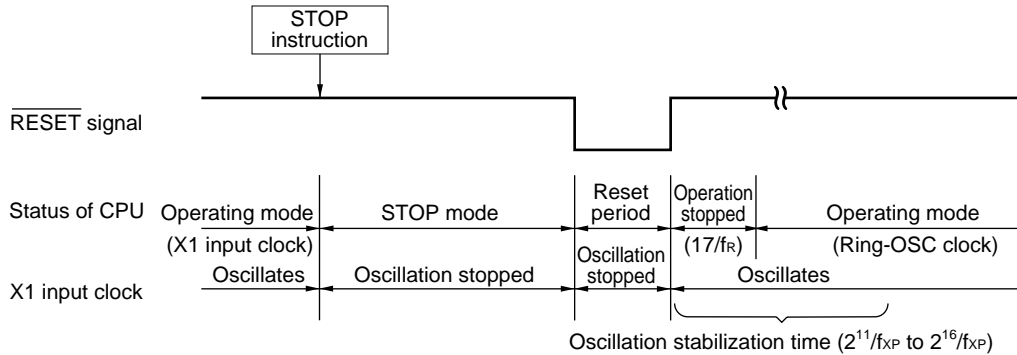
**2.** fr: Ring-OSC clock oscillation frequency

**(b) Release by  $\overline{\text{RESET}}$  input**

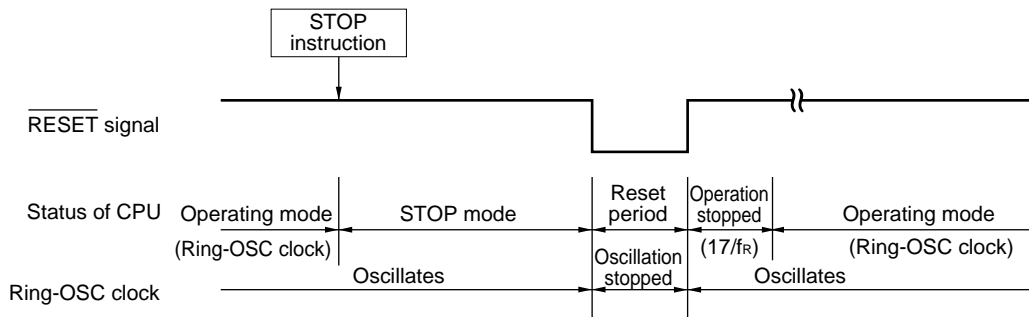
When the  $\overline{\text{RESET}}$  signal is input, STOP mode is released and a reset operation is performed after the oscillation stabilization time has elapsed.

**Figure 15-7. STOP Mode Release by  $\overline{\text{RESET}}$  Input**

**(1) When X1 input clock is used as CPU clock**



**(2) When Ring-OSC clock is used as CPU clock**



- Remarks 1.  $f_{XP}$ : X1 input clock oscillation frequency
- 2.  $f_R$ : Ring-OSC clock oscillation frequency

**Table 15-5. Operation in Response to Interrupt Request in STOP Mode**

| Release Source                  | MK $\times\times$ | PR $\times\times$ | IE | ISP | Operation                          |
|---------------------------------|-------------------|-------------------|----|-----|------------------------------------|
| Maskable interrupt request      | 0                 | 0                 | 0  | ×   | Next address instruction execution |
|                                 | 0                 | 0                 | 1  | ×   | Interrupt servicing execution      |
|                                 | 0                 | 1                 | 0  | 1   | Next address instruction execution |
|                                 | 0                 | 1                 | ×  | 0   |                                    |
|                                 | 0                 | 1                 | 1  | 1   | Interrupt servicing execution      |
|                                 | 1                 | ×                 | ×  | ×   | STOP mode held                     |
| $\overline{\text{RESET}}$ input | –                 | –                 | ×  | ×   | Reset processing                   |

×: Don't care

## CHAPTER 16 RESET FUNCTION

The following five operations are available to generate a reset signal.

- (1) External reset input via  $\overline{\text{RESET}}$  pin
- (2) Internal reset by watchdog timer program loop detection
- (3) Internal reset by clock monitor X1 input clock oscillation stop detection
- (4) Internal reset by comparison of supply voltage and detection voltage of power-on-clear (POC) circuit
- (5) Internal reset by comparison of supply voltage and detection voltage of low-power-supply detector (LVI)

External and internal resets have no functional differences. In both cases, program execution starts at the address at 0000H and 0001H when the reset signal is input.

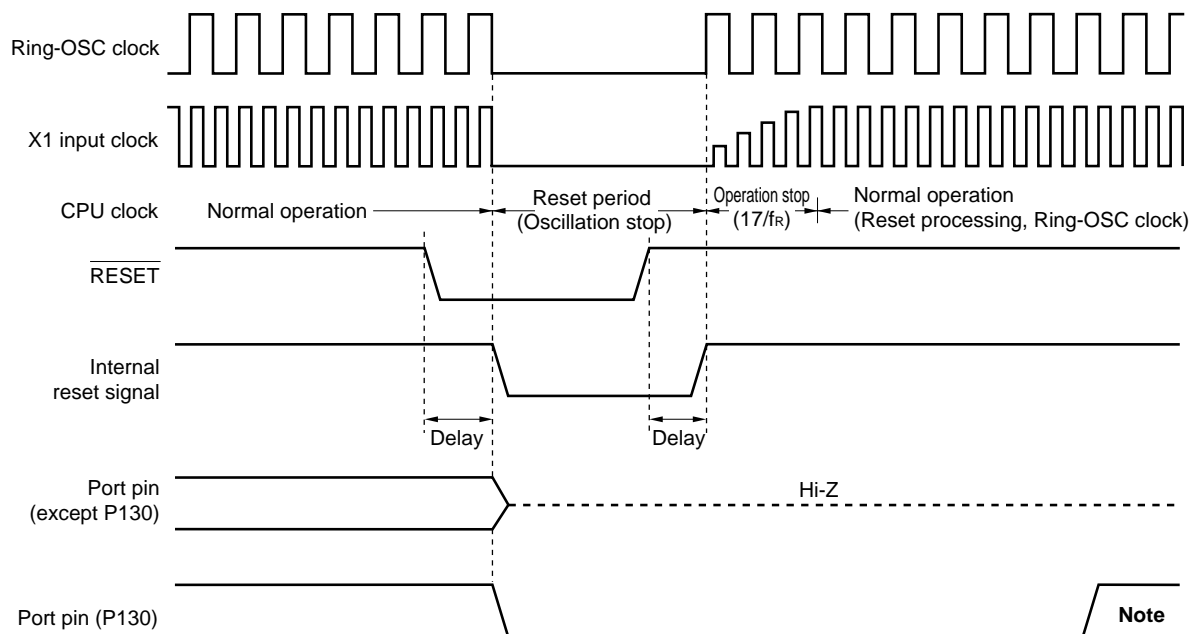
A reset is applied when a low level is input to the  $\overline{\text{RESET}}$  pin, the watchdog timer overflows, X1 clock oscillation stop is detected by the clock monitor, or by POC and LVI circuit voltage detection, and each item of hardware is set to the status shown in Table 16-1. Each pin is high impedance during reset input or during the oscillation stabilization time just after reset release, except for P130, which is low-level output.

When a high level is input to the  $\overline{\text{RESET}}$  pin, the reset is released and program execution starts using the Ring-OSC clock after the CPU clock operation has stopped for  $17/f_R$  (s). A reset generated by the watchdog timer and clock monitor sources is automatically released after the reset, and program execution starts using the Ring-OSC clock after the CPU clock operation has stopped for  $17/f_R$  (s) (see **Figures 16-2 to 16-4**). Reset by POC and LVI circuit power supply detection is automatically released when  $V_{DD} > V_{POC}$  or  $V_{DD} > V_{LVI}$  after the reset, and program execution starts using the Ring-OSC clock after the CPU clock operation has stopped for  $17/f_R$  (s) (see **CHAPTER 18 POWER-ON-CLEAR CIRCUIT** and **CHAPTER 19 LOW-VOLTAGE DETECTOR**).

- Cautions**
1. For an external reset, input a low level for 10  $\mu\text{s}$  or more to the  $\overline{\text{RESET}}$  pin.
  2. During reset input, the X1 input clock and Ring-OSC clock stop oscillating.
  3. When the STOP mode is released by a reset, the STOP mode contents are held during reset input. However, the port pins become high-impedance, except for P130, which is set to low-level output.



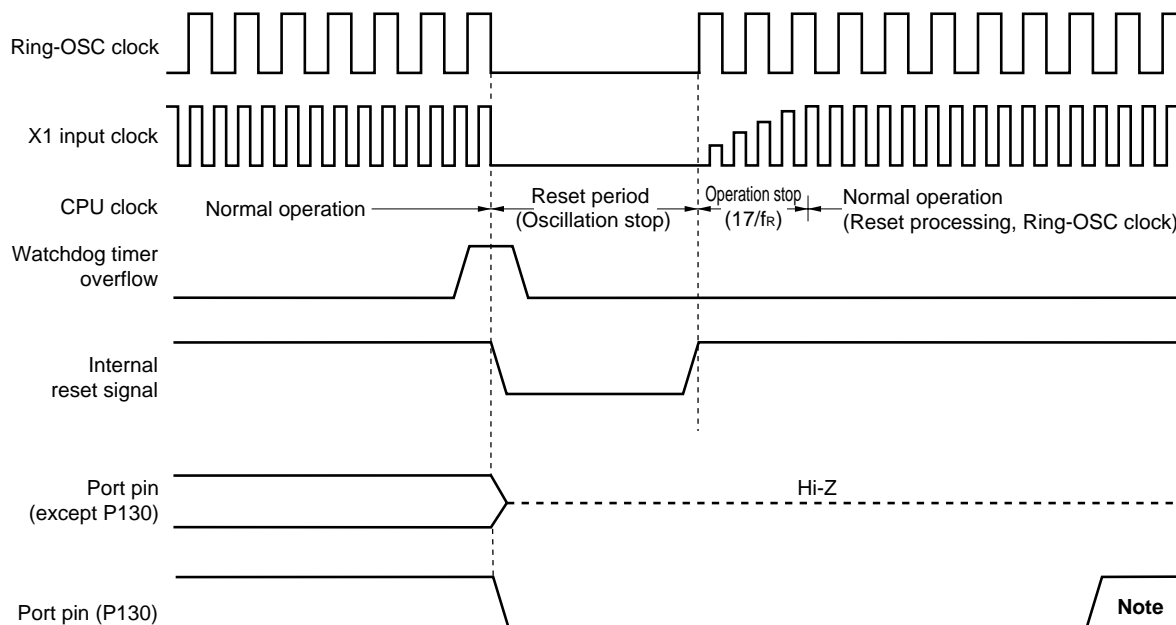
★ **Figure 16-2. Timing of Reset by RESET Input**



**Note** Set P130 to high-level output by software.

**Remark** When reset is effected, P130 outputs a low level. If P130 is set to output a high level before reset is effected, the output signal of P130 can be dummy-output as the reset signal to the CPU.

★ **Figure 16-3. Timing of Reset Due to Watchdog Timer Overflow**



**Note** Set P130 to high-level output by software.

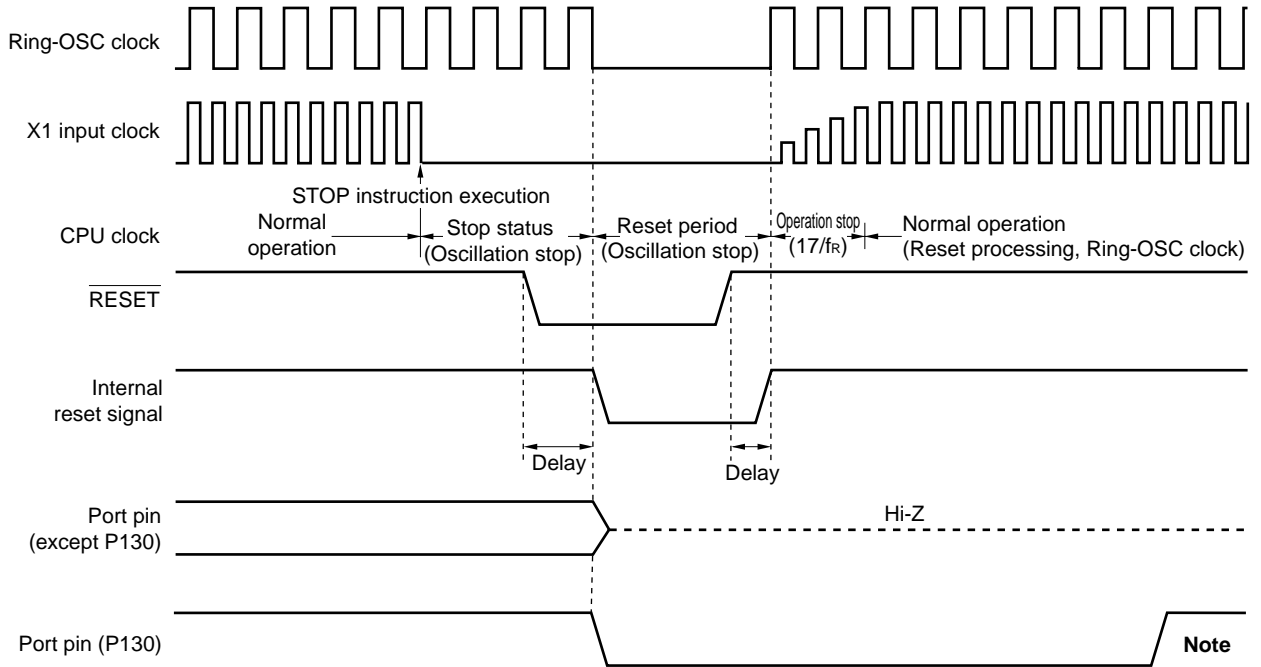
**Caution** A watchdog timer internal reset resets the watchdog timer.

**Remark** When reset is effected, P130 outputs a low level. If P130 is set to output a high level immediately after reset is effected, the output signal of P130 can be dummy-output as the reset signal to the CPU.



★

Figure 16-4. Timing of Reset in STOP Mode by  $\overline{\text{RESET}}$  Input



**Note** Set P130 to high-level output by software.

- Remarks**
1. When reset is effected, P130 outputs a low level. If P130 is set to output a high level immediately after reset is effected, the output signal of P130 can be dummy-output as the reset signal to the CPU.
  2. For the reset timing of the power-on-clear circuit and low-voltage detector, see **CHAPTER 18 POWER-ON-CLEAR CIRCUIT** and **CHAPTER 19 LOW-VOLTAGE DETECTOR**.

Table 16-1. Hardware Statuses After Reset Acknowledgment (1/2)

| Hardware  |   | Status After Reset Acknowledgment <sup>Note 1</sup>            |
|---|---|--|
| Program counter (PC)  |   | The contents of the reset vector table (0000H, 0001H) are set. |
| Stack pointer (SP)  |   | Undefined  |
| Program status word (PSW)                                     |   | 02H  |
| RAM   | Data memory   | Undefined <sup>Note 2</sup>                                    |
|   | General-purpose registers                                     | Undefined <sup>Note 2</sup>                                    |
| Port registers (P0 to P3, P12, P13) (output latches)          |   | 00H (undefined only for P2)                                    |
| Port mode registers (PM0, PM1, PM3, PM12)                     |   | FFH  |
| Pull-up resistor option registers (PU0, PU1, PU3, PU12)       |   | 00H  |
| Input switch control register (ISC)                           |   | 00H  |
| Internal memory size switching register (IMS)                 |   | CFH  |
| Internal expansion RAM size switching register (IXS)          |   | 0CH  |
| Processor clock control register (PCC)                        |   | 00H  |
| Ring-OSC mode register (RCM)                                  |   | 00H  |
| Main clock mode register (MCM)                                |   | 00H  |
| Main OSC control register (MOC)                               |   | 00H  |
| Oscillation stabilization time select register (OSTS)         |   | 05H  |
| Oscillation stabilization time counter status register (OSTC) |   | 00H  |
| 16-bit timer/event counter 00                                 | Timer counter 00 (TM00)                                       | 0000H  |
|   | Capture/compare registers 000, 010 (CR000, CR010)             | 0000H  |
|   | Mode control register 00 (TMC00)                              | 00H  |
|   | Prescaler mode register 00 (PRM00)                            | 00H  |
|   | Capture/compare control register 00 (CRC00)                   | 00H  |
|   | Timer output control register 00 (TOC00)                      | 00H  |
| 8-bit timer/event counter 50                                  | Timer counter 50 (TM50)                                       | 00H  |
|   | Compare register 50 (CR50)                                    | 00H  |
|   | Timer clock selection register 50 (TCL50)                     | 00H  |
|   | Mode control register 50 (TMC50)                              | 00H  |
| 8-bit timer/event counters H0, H1                             | Compare registers 00, 10, 01, 11 (CMP00, CMP10, CMP01, CMP11) | 00H  |
|   | Mode registers (TMHMD0, TMHMD1)                               | 00H  |
| Watchdog timer  | Mode register (WDTM)  | 67H  |
|   | Enable register (WDTE)  | 9AH  |
| A/D converter   | Conversion result register (ADCR)                             | Undefined  |
|   | Mode register (ADM)   | 00H  |
|   | Analog input channel specification register (ADS)             | 00H  |
|   | Power-fail comparison mode register (PFM)                     | 00H  |
|   | Power-fail comparison threshold register (PFT)                | 00H  |

**Notes** 1. During reset input or oscillation stabilization time wait, only the PC contents among the hardware statuses become undefined. All other hardware statuses remain unchanged after reset.

2. When a reset is executed in the standby mode, the pre-reset status is held even after reset.

**Table 16-1. Hardware Statuses After Reset Acknowledgment (2/2)**

| Hardware                                 |   | Status After Reset Acknowledgment |
|--|---|-----------------------------------|
| Serial interface UART0 <sup>Note 1</sup> | Receive buffer register 0 (RXB0)  | FFH                               |
|  | Transmit shift register 0 (TXS0)  | FFH                               |
|  | Asynchronous serial interface operation mode register 0 (ASIM0)         | 01H                               |
|  | Baud rate generator control register 0 (BRGC0)                          | 1FH                               |
| Serial interface UART6                   | Receive buffer register 6 (RXB6)  | FFH                               |
|  | Transmit buffer register 6 (TXB6)                                       | FFH                               |
|  | Asynchronous serial interface operation mode register 6 (ASIM6)         | 01H                               |
|  | Asynchronous serial interface reception error status register 6 (ASIS6) | 00H                               |
|  | Asynchronous serial interface transmission status register 6 (ASIF6)    | 00H                               |
|  | Clock selection register 6 (CKSR6)                                      | 00H                               |
|  | Baud rate generator control register 6 (BRGC6)                          | FFH                               |
|  | Asynchronous serial interface control register 6 (ASICL6)               | 16H                               |
| Serial interface CSI10                   | Transmit buffer register 10 (SOTB10)                                    | Undefined                         |
|  | Serial I/O shift register 10 (SIO10)                                    | 00H                               |
|  | Serial operation mode register 10 (CSIM10)                              | 00H                               |
|  | Serial clock selection register 10 (CSIC10)                             | 00H                               |
| Clock monitor                            | Mode register (CLM)   | 00H                               |
| Reset function                           | Reset control flag register (RESF)                                      | 00H <sup>Note 2</sup>             |
| Low-voltage detector                     | Low-voltage detection register (LVIM)                                   | 00H <sup>Note 2</sup>             |
|  | Low-voltage detection level selection register (LVIS)                   | 00H <sup>Note 2</sup>             |
| Interrupt                                | Request flag registers 0L, 0H, 1L (IF0L, IF0H, IF1L)                    | 00H                               |
|  | Mask flag registers 0L, 0H, 1L (MK0L, MK0H, MK1L)                       | FFH                               |
|  | Priority specification flag registers 0L, 0H, 1L (PR0L, PR0H, PR1L)     | FFH                               |
|  | External interrupt rising edge enable register (EGP)                    | 00H                               |
|  | External interrupt falling edge enable register (EGN)                   | 00H                               |

- Notes** 1.  $\mu$ PD780102, 780103, and 78F0103 only.  
 2. These values vary depending on the reset source.

| Reset Source \ Register | $\overline{\text{RESET}}$ Input | Reset by POC  | Reset by WDT  | Reset by CLM  | Reset by LVI |
|-------------------------|---------------------------------|---------------|---------------|---------------|--------------|
| RESF                    | See <b>Table 16-2</b> .         |               |               |               |              |
| LVIM                    | Cleared (00H)                   | Cleared (00H) | Cleared (00H) | Cleared (00H) | Held         |
| LVIS                    |                                 |               |               |               |              |

### 16.1 Register for Confirming Reset Source

Many internal reset generation sources exist in the 78K0/KB1. The reset control flag register (RESF) is used to store which source has generated the reset request.

RESF can be read by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input, reset input by power-on-clear (POC) circuit, and reading RESF clear RESF to 00H.

**Figure 16-5. Format of Reset Control Flag Register (RESF)**

Address: FFACH After reset: 00H<sup>Note</sup> R

|        |   |   |   |       |   |   |       |       |
|--------|---|---|---|-------|---|---|-------|-------|
| Symbol | 7 | 6 | 5 | 4     | 3 | 2 | 1     | 0     |
| RESF   | 0 | 0 | 0 | WDTRF | 0 | 0 | CLMRF | LVIRF |

|       |  |
|-------|--|
| WDTRF | Internal reset request by watchdog timer (WDT)               |
| 0     | Internal reset request is not generated, or RESF is cleared. |
| 1     | Internal reset request is generated.                         |

|       |  |
|-------|--|
| CLMRF | Internal reset request by clock monitor (CLM)                |
| 0     | Internal reset request is not generated, or RESF is cleared. |
| 1     | Internal reset request is generated.                         |

|       |  |
|-------|--|
| LVIRF | Internal reset request by low-voltage detector (LVI)         |
| 0     | Internal reset request is not generated, or RESF is cleared. |
| 1     | Internal reset request is generated.                         |

**Note** The value after reset varies depending on the reset source.

**Caution** Do not read data via a 1-bit memory manipulation instruction.

The status of RESF when a reset request is generated is shown in Table 16-2.

**Table 16-2. RESF Status When Reset Request Is Generated**

| Reset Source / Flag | $\overline{\text{RESET}}$ input | Reset by POC | Reset by WDT | Reset by CLM | Reset by LVI |
|---------------------|---------------------------------|--------------|--------------|--------------|--------------|
| WDTRF               | Cleared (0)                     | Cleared (0)  | Set (1)      | Held         | Held         |
| CLMRF               |                                 |              | Held         | Set (1)      | Held         |
| LVIRF               |                                 |              | Held         | Held         | Set (1)      |

## CHAPTER 17 CLOCK MONITOR

### 17.1 Functions of Clock Monitor

The clock monitor samples the X1 input clock using the on-chip Ring-OSC, and generates an internal reset signal when the X1 input clock is stopped.

When a reset signal is generated by the clock monitor, bit 1 (CLMRF) of the reset control flag register (RESF) is set to 1. For details of RESF, see **CHAPTER 16 RESET FUNCTION**.

The clock monitor automatically stops under the following conditions.

- Reset is released and during the oscillation stabilization time
- In STOP mode and during the oscillation stabilization time
- When the X1 input clock is stopped by software (MSTOP = 1) and during the oscillation stabilization time
- When the Ring-OSC clock is stopped

**Remark** MSTOP: Bit 7 of the main OSC control register (MOC)

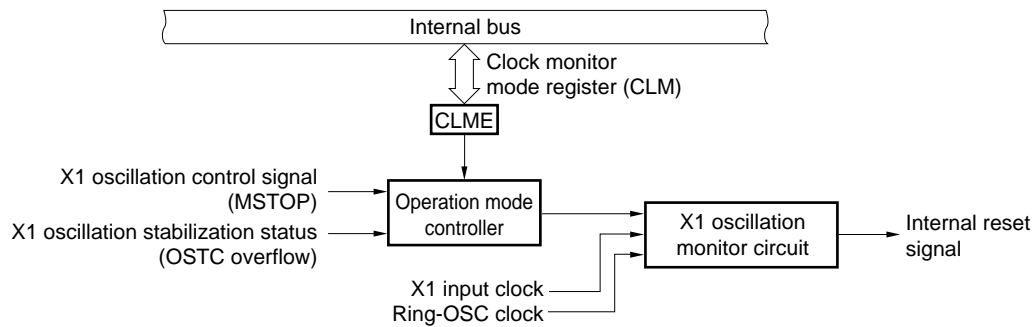
### 17.2 Configuration of Clock Monitor

The clock monitor includes the following hardware.

**Table 17-1. Configuration of Clock Monitor**

| Item             | Configuration                     |
|------------------|-----------------------------------|
| Control register | Clock monitor mode register (CLM) |

**Figure 17-1. Block Diagram of Clock Monitor**



**Remark** MSTOP: Bit 7 of the main OSC control register (MOC)

OSTC: Oscillation stabilization time counter status register (OSTC)

### 17.3 Register Controlling Clock Monitor

The clock monitor is controlled by the clock monitor mode register (CLM).

#### (1) Clock monitor mode register (CLM)

This register sets the operation mode of the clock monitor.

This register can be set by a 1-bit or 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$  input clears this register to 00H.

**Figure 17-2. Format of Clock Monitor Mode Register (CLM)**

Address: FFA9H    After reset: 00H    R/W

| Symbol | 7 | 6 | 5 | 4 | 3 | 2 | 1 | <0>  |
|--------|---|---|---|---|---|---|---|------|
| CLM    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | CLME |

| CLME | Enables/disables clock monitor operation |
|------|--|
| 0    | Disables clock monitor operation         |
| 1    | Enables clock monitor operation          |

- Cautions**
1. Once bit 0 (CLME) is set to 1, it cannot be cleared to 0 except by  $\overline{\text{RESET}}$  input or the internal reset signal.
  2. If the reset signal is generated by the clock monitor, CLME is cleared to 0 and bit 1 (CLMRF) of the reset control flag register (RESF) is set to 1.

## 17.4 Operation of Clock Monitor

This section explains the functions of the clock monitor. The monitor start and stop conditions are as follows.

<Monitor start condition>

When bit 0 (CLME) of the clock monitor mode register (CLM) is set to operation enabled (1).

< Monitor stop condition>

- Reset is released and during the oscillation stabilization time
- In STOP mode and during the oscillation stabilization time
- When the X1 input clock is stopped by software (MSTOP = 1) and during the oscillation stabilization time
- When the Ring-OSC clock is stopped

**Remark** MSTOP: Bit 7 of the main OSC control register (MOC)

**Table 17-2. Operation Status of Clock Monitor (When CLME = 1)**

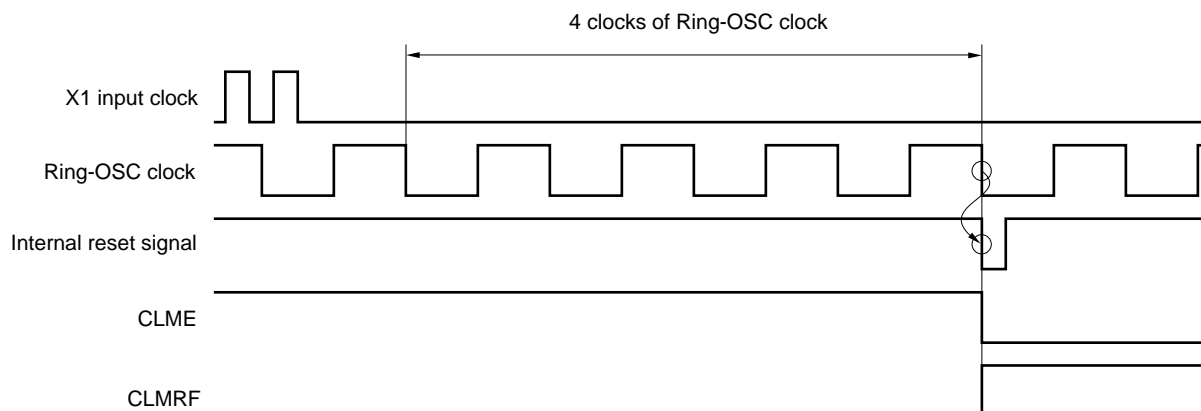
| CPU Operation Clock                | Operation Mode                     | X1 Input Clock Status   | Ring-OSC Clock Status   | Clock Monitor Status |
|------------------------------------|------------------------------------|-------------------------|-------------------------|----------------------|
| X1 input clock                     | STOP mode                          | Stopped                 | Oscillating             | Stopped              |
|                                    |                                    |                         | Stopped <sup>Note</sup> |                      |
|                                    | RESET input                        |                         | Oscillating             |                      |
|                                    | Stopped <sup>Note</sup>            |                         |                         |                      |
| Normal operation mode<br>HALT mode |                                    | Oscillating             | Oscillating             | Operating            |
|                                    |                                    | Stopped <sup>Note</sup> | Stopped                 |                      |
| Ring-OSC clock                     | STOP mode                          | Stopped                 | Oscillating             | Stopped              |
|                                    | RESET input                        |                         |                         |                      |
|                                    | Normal operation mode<br>HALT mode | Oscillating             |                         | Operating            |
|                                    |                                    | Stopped                 |                         | Stopped              |

**Note** The Ring-OSC clock is stopped only when the “Ring-OSC can be stopped by software” is selected by a mask option. If “Ring-OSC cannot be stopped” is selected, the Ring-OSC clock cannot be stopped.

The clock monitor timing is as shown in Figure 17-3.

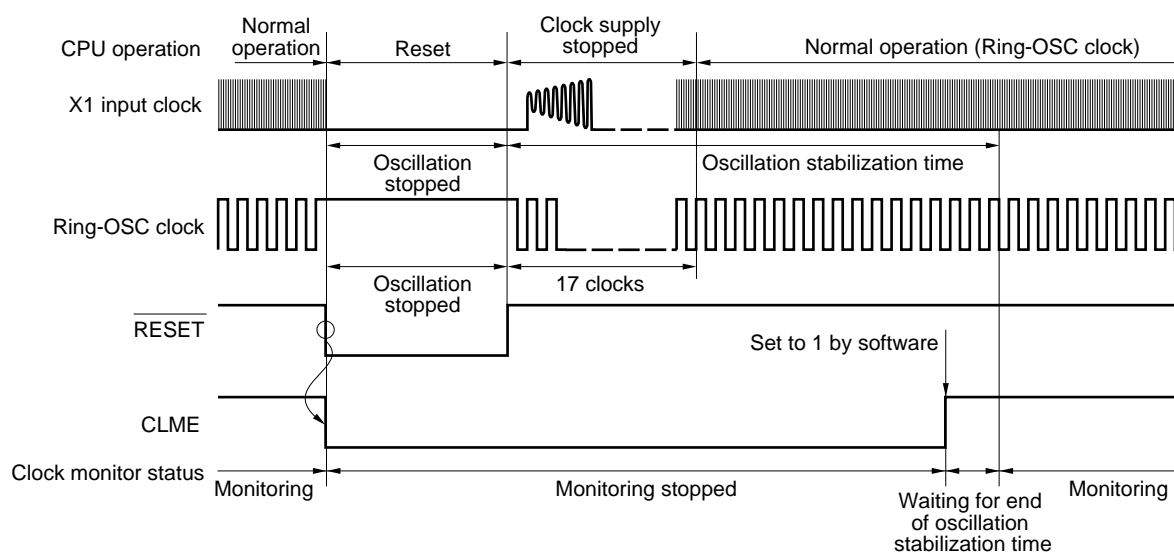
Figure 17-3. Timing of Clock Monitor (1/4)

(1) When internal reset is executed by oscillation stop of X1 input clock



(2) Clock monitor status after  $\overline{\text{RESET}}$  input

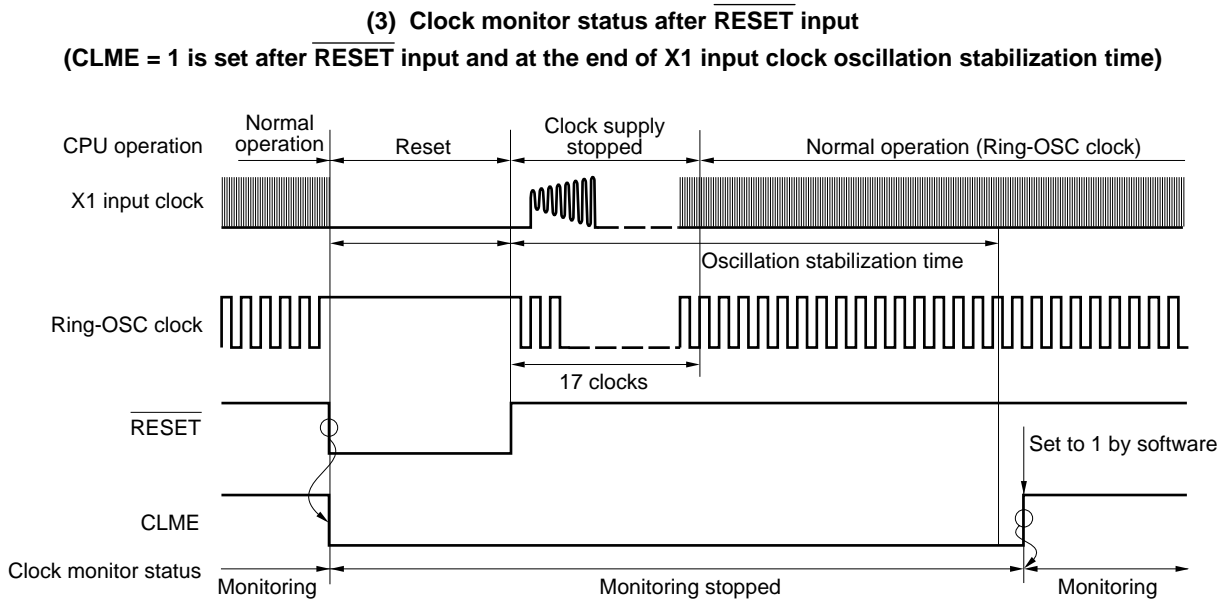
(CLME = 1 is set after  $\overline{\text{RESET}}$  input and during X1 input clock oscillation stabilization time)



$\overline{\text{RESET}}$  input clears bit 0 (CLME) of the clock monitor mode register (CLM) to 0 and stops the clock monitor operation. Even if CLME is set to 1 by software during the oscillation stabilization time (reset value of OSTS register is 05H ( $2^{16}/f_{XP}$ )) of the X1 input clock, monitoring is not performed until the oscillation stabilization time of the X1 input clock ends. Monitoring is automatically started at the end of the oscillation stabilization time.

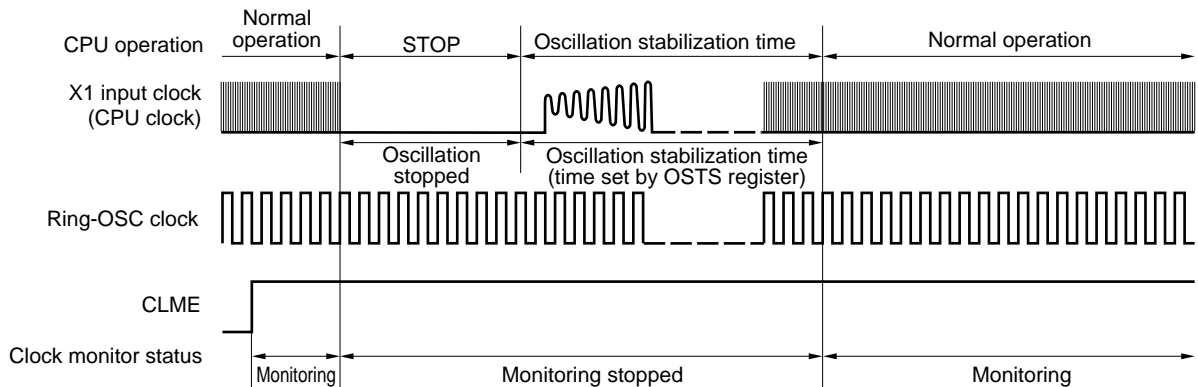


Figure 17-3. Timing of Clock Monitor (2/4)



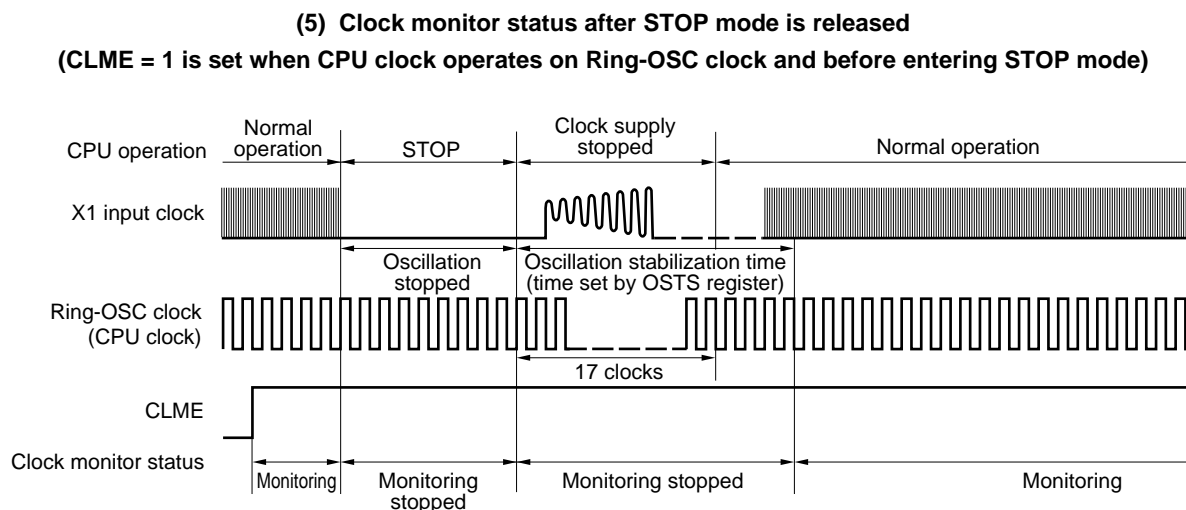
$\overline{\text{RESET}}$  input clears bit 0 (CLME) of the clock monitor mode register (CLM) to 0 and stops the clock monitor operation. When CLME is set to 1 by software at the end of the oscillation stabilization time (reset value of OSTC register is 05H ( $2^{16}/f_{XP}$ )) of the X1 input clock, monitoring is started.

**(4) Clock monitor status after STOP mode is released**  
**(CLME = 1 is set when CPU clock operates on X1 input clock and before entering STOP mode)**

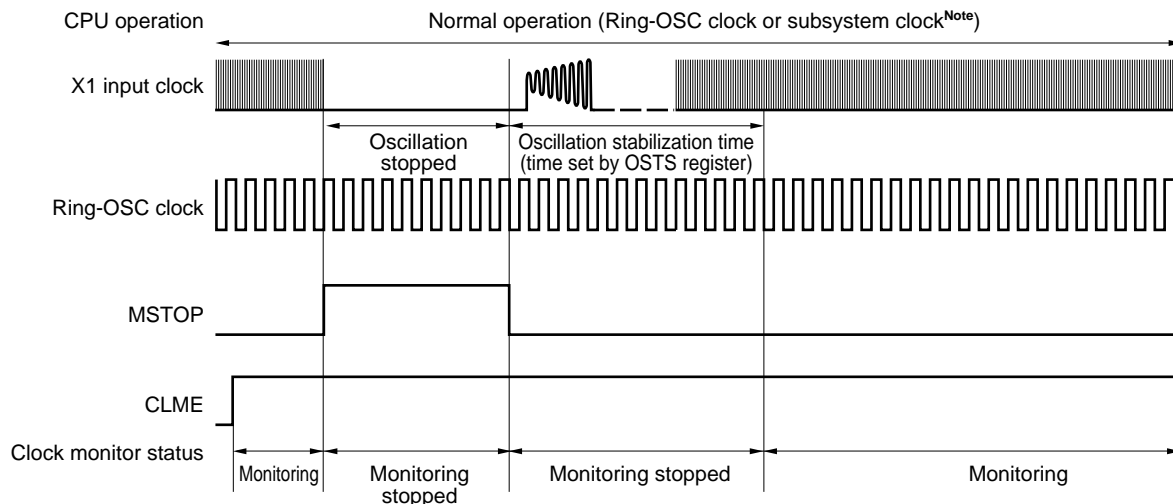


When bit 0 (CLME) of the clock monitor mode register (CLM) is set to 1 before entering STOP mode, monitoring automatically starts at the end of the X1 input clock oscillation stabilization time. Monitoring is stopped in STOP mode and during the oscillation stabilization time.

Figure 17-3. Timing of Clock Monitor (3/4)



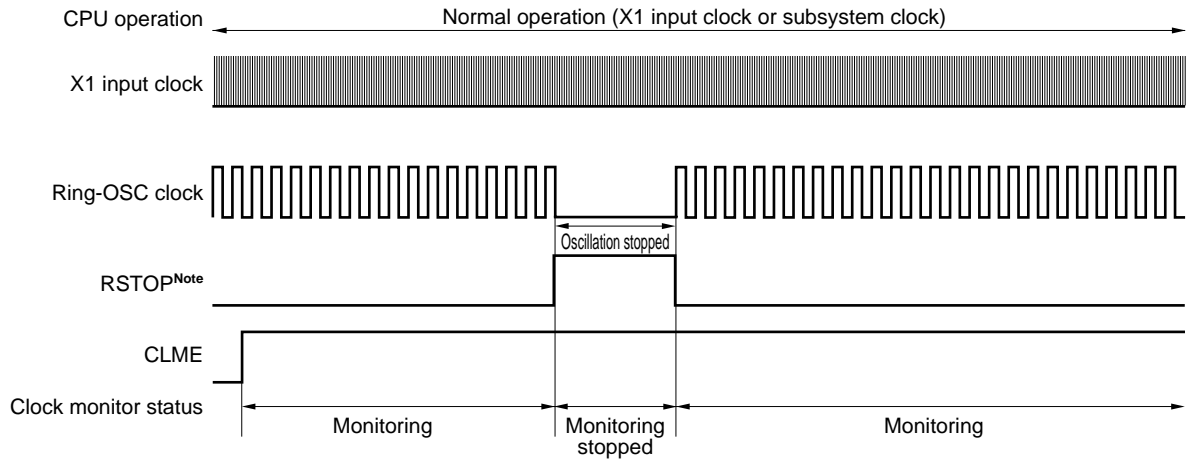
When bit 0 (CLME) of the clock monitor mode register (CLM) is set to 1 before entering STOP mode, monitoring automatically starts at the end of the X1 input clock oscillation stabilization time. Monitoring is stopped in STOP mode and during the oscillation stabilization time.

**(6) Clock monitor status after X1 input clock oscillation is stopped by software**

When bit 0 (CLME) of the clock monitor mode register (CLM) is set to 1 before or while oscillation of the X1 input clock is stopped, monitoring automatically starts at the end of the X1 input clock oscillation stabilization time. Monitoring is stopped when oscillation of the X1 input clock is stopped and during the oscillation stabilization time.

Figure 17-3. Timing of Clock Monitor (4/4)

## (7) Clock monitor status after Ring-OSC clock oscillation is stopped by software



When bit 0 (CLME) of the clock monitor mode register (CLM) is set to 1 before or while oscillation of the Ring-OSC clock is stopped, monitoring automatically starts after the Ring-OSC clock is stopped. Monitoring is stopped when oscillation of the Ring-OSC clock is stopped.

**Note** If it is specified by a mask option that Ring-OSC cannot be stopped, the setting of bit 0 (RSTOP) of the Ring-OSC mode register (RCM) is invalid. To set RSTOP, be sure to confirm that bit 1 (MCS) of the main clock mode register (MCM) is 1.

## CHAPTER 18 POWER-ON-CLEAR CIRCUIT

### 18.1 Functions of Power-on-Clear Circuit

The power-on-clear circuit (POC) has the following functions.

- Generates internal reset signal at power on.
- Compares supply voltage ( $V_{DD}$ ) and detection voltage ( $V_{POC}$ ), and generates internal reset signal when  $V_{DD} < V_{POC}$ .
- The following can be selected by a mask option.
  - POC disabled
  - POC used (detection voltage:  $V_{POC} = 2.85 \text{ V} \pm 0.15 \text{ V}$ )<sup>Note</sup>
  - POC used (detection voltage:  $V_{POC} = 3.5 \text{ V} \pm 0.2 \text{ V}$ )

**Note** This option cannot be selected in (A1) and (A2) grade products because the supply voltage  $V_{DD}$  is 3.3 to 5.5 V.

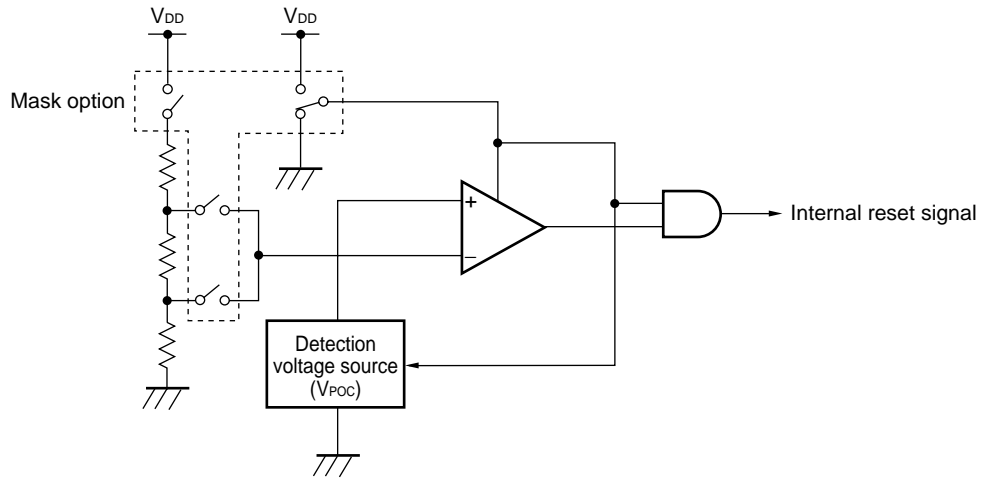
**Caution** If an internal reset signal is generated in the POC circuit, the reset control flag register (RESF) is cleared to 00H.

**Remark** This product incorporates multiple hardware functions that generate an internal reset signal. A flag that indicates the reset cause is located in the reset control flag register (RESF) for when an internal reset signal is generated by the watchdog timer (WDT), low-voltage-detection (LVI) circuit, or clock monitor. RESF is not cleared to 00H and the flag is set to 1 when an internal reset signal is generated by WDT, LVI, or the clock monitor.  
For details of the RESF, see **CHAPTER 16 RESET FUNCTION**.

## 18.2 Configuration of Power-on-Clear Circuit

A block diagram of the power-on-clear circuit is shown in Figure 18-1.

**Figure 18-1. Block Diagram of Power-on-Clear Circuit**

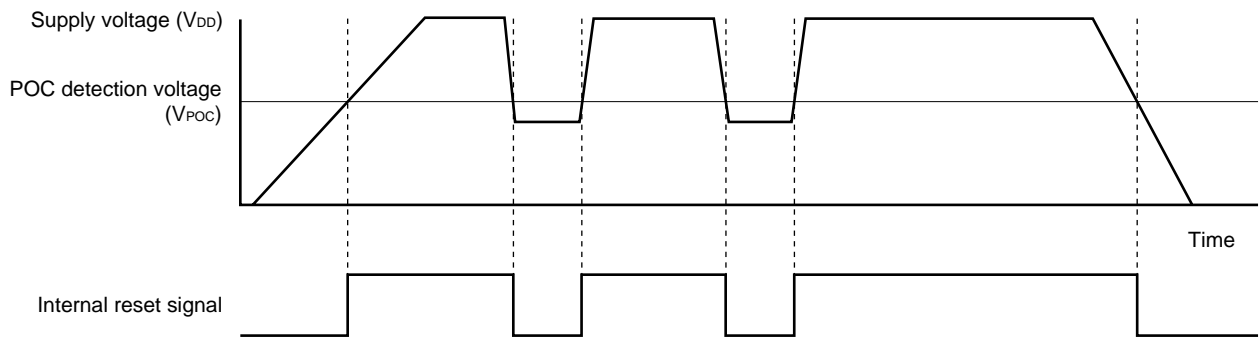


**Note** Selected by mask option.

## 18.3 Operation of Power-on-Clear Circuit

In the power-on-clear circuit, the supply voltage ( $V_{DD}$ ) and detection voltage ( $V_{POC}$ ) are compared, and when  $V_{DD} < V_{POC}$ , an internal reset signal is generated.

**Figure 18-2. Timing of Internal Reset Signal Generation in Power-on-Clear Circuit**



### 18.4 Cautions for Power-on-Clear Circuit

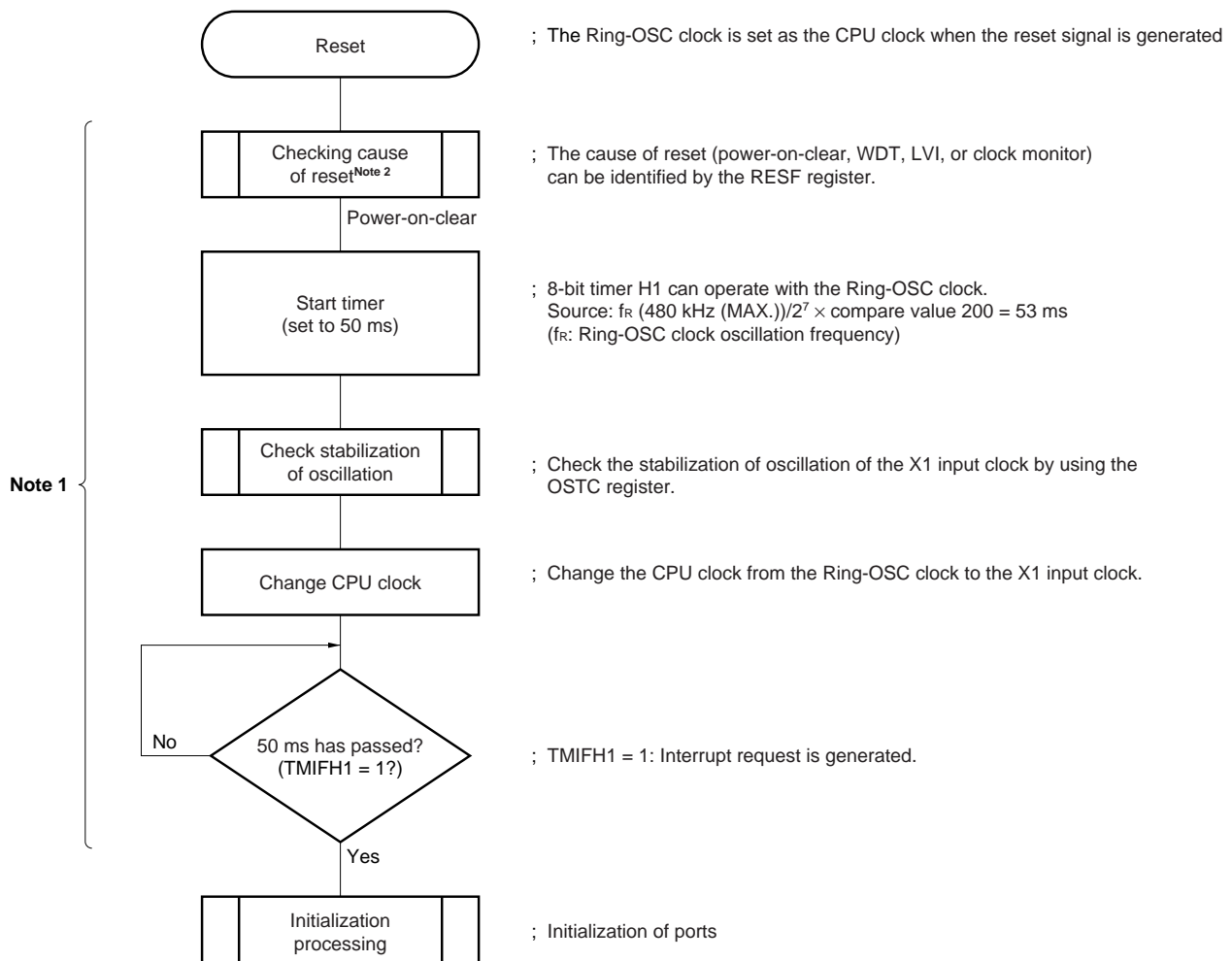
In a system where the supply voltage ( $V_{DD}$ ) fluctuates for a certain period in the vicinity of the POC detection voltage ( $V_{POC}$ ), the system may be repeatedly reset and released from the reset status. In this case, the time from release of reset to the start of the operation of the microcontroller can be arbitrarily set by taking the following action.

<Action>

After releasing the reset signal, wait for the supply voltage fluctuation period of each system by means of a software counter that uses a timer, and then initialize the ports.

**Figure 18-3. Example of Software Processing After Release of Reset (1/2)**

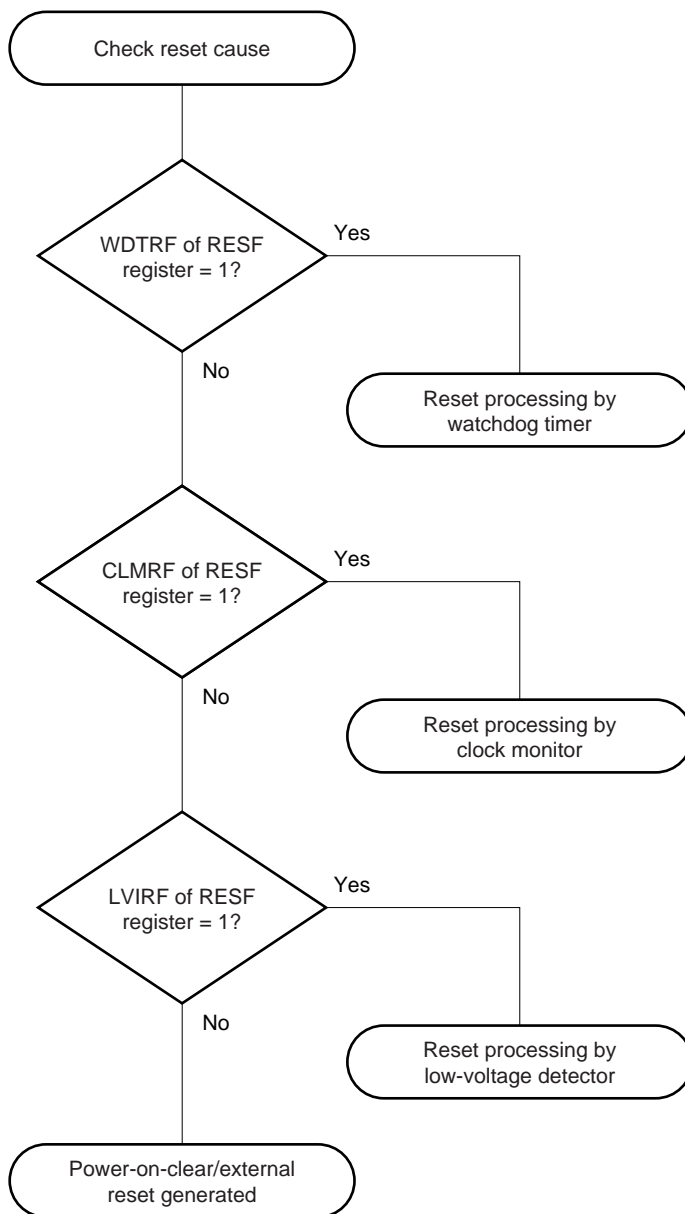
- If supply voltage fluctuation is 50 ms or less in vicinity of POC detection voltage



- Notes**
1. If reset is generated again during this period, initialization processing is not started.
  2. A flowchart is shown on the next page.

Figure 18-3. Example of Software Processing After Release of Reset (2/2)

- Checking reset cause



## CHAPTER 19 LOW-VOLTAGE DETECTOR

### 19.1 Functions of Low-Voltage Detector

The low-voltage detector (LVI) has following functions.

- Compares supply voltage ( $V_{DD}$ ) and detection voltage ( $V_{LVI}$ ), and generates an internal interrupt signal or internal reset signal when  $V_{DD} < V_{LVI}$ .
- Detection levels<sup>Note</sup> of supply voltage can be changed by software.
- Interrupt or reset function can be selected by software.
- Operable in STOP mode.

★ **Note** Detection levels of supply voltage differ as follows.

Expanded-specification product of standard products and (A) grade products: 8 levels

Conventional product of standard products and (A) grade products: 7 levels

(A1) grade products and (A2) grade products: 5 levels

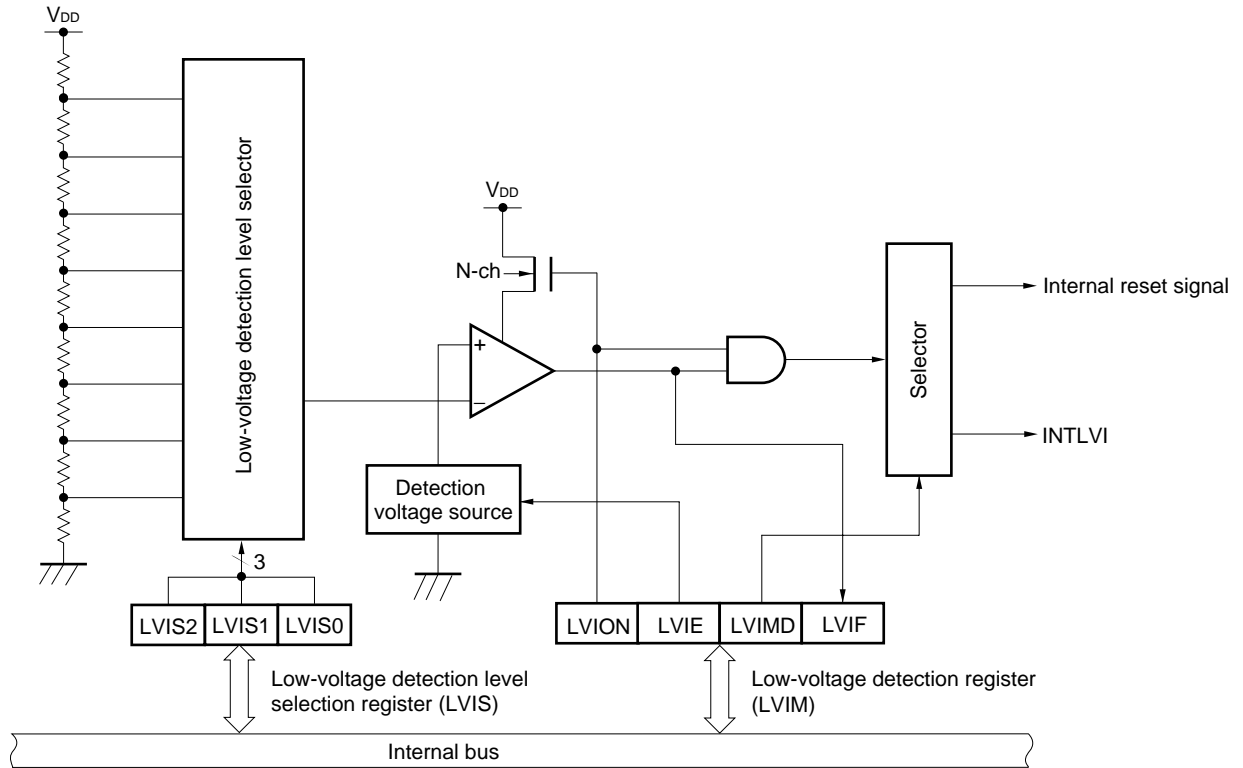
When the low-voltage detector is used to reset, bit 0 (LVIRF) of the reset control flag register (RESF) is set to 1 if reset occurs. For details of RESF, see **CHAPTER 16 RESET FUNCTION**.



## 19.2 Configuration of Low-Voltage Detector

A block diagram of the low-voltage detector is shown below.

Figure 19-1. Block Diagram of Low-Voltage Detector



## 19.3 Registers Controlling Low-Voltage Detector

The low-voltage detector is controlled by the following registers.

- Low-voltage detection register (LVIM)
- Low-voltage detection level selection register (LVIS)

**(1) Low-voltage detection register (LVIM)**

This register sets low-voltage detection and the operation mode.

This register can be set by a 1-bit or 8-bit memory manipulation instruction.

RESET input clears LVIM to 00H.

**Figure 19-2. Format of Low-Voltage Detection Register (LVIM)**

Address: FFBEH After reset: 00H R/W<sup>Note 1</sup>

|        |       |   |   |      |   |   |       |      |
|--------|-------|---|---|------|---|---|-------|------|
| Symbol | <7>   | 6 | 5 | <4>  | 3 | 2 | <1>   | <0>  |
| LVIM   | LVION | 0 | 0 | LVIE | 0 | 0 | LVIMD | LVIF |

|                             |   |
|-----------------------------|---|
| LVION <sup>Notes 2, 3</sup> | Enables low-voltage detection operation |
| 0                           | Disables operation                      |
| 1                           | Enables operation                       |

|                               |                                       |
|-------------------------------|---------------------------------------|
| LVIE <sup>Notes 2, 4, 5</sup> | Specifies reference voltage generator |
| 0                             | Disables operation                    |
| 1                             | Enables operation                     |

|                         |  |
|-------------------------|--|
| LVIMD <sup>Note 2</sup> | Low-voltage detection operation mode selection   |
| 0                       | Generates interrupt signal when supply voltage ( $V_{DD}$ ) < detection voltage ( $V_{LVI}$ )      |
| 1                       | Generates internal reset signal when supply voltage ( $V_{DD}$ ) < detection voltage ( $V_{LVI}$ ) |

|                        |  |
|------------------------|--|
| LVIF <sup>Note 6</sup> | Low-voltage detection flag   |
| 0                      | Supply voltage ( $V_{DD}$ ) > detection voltage ( $V_{LVI}$ ), or when operation is disabled |
| 1                      | Supply voltage ( $V_{DD}$ ) < detection voltage ( $V_{LVI}$ )                                |

- Notes**
1. Bit 0 is read-only.
  2. LVION, LVIE, and LVIMD are cleared to 0 in the case of a reset other than an LVI reset. These are not cleared to 0 in the case of an LVI reset.
  3. When LVION is set to 1, operation of the comparator in the LVI circuit is started. Use software to instigate a wait of at least 0.2 ms from when LVION is set to 1 until the voltage is confirmed at LVIF.
  4. If "POC cannot be used" is selected by a mask option, wait for 2 ms or more by software from when LVIE is set to 1 until LVION is set to 1.
  5. If "POC used" is selected by a mask option, setting of LVIE is invalid because the reference voltage generator in the LVI circuit always operates.
  6. The value of LVIF is output as the interrupt request signal INTLVI when LVION = 1 and LVIMD = 0.

**Caution To stop LVI, follow either of the procedures below.**

- When using 8-bit memory manipulation instruction: Write 00H to LVIM.
- When using 1-bit memory manipulation instruction: Clear LVION to 0 first and then clear LVIE to 0.

**(2) Low-voltage detection level selection register (LVIS)**

This register selects the low-voltage detection level.

This register can be set by an 8-bit memory manipulation instruction.

RESET input clears LVIS to 00H.

**Figure 19-3. Format of Low-Voltage Detection Level Selection Register (LVIS)**

Address: FFBFH After reset: 00H R/W

|        |   |   |   |   |   |       |       |       |
|--------|---|---|---|---|---|-------|-------|-------|
| Symbol | 7 | 6 | 5 | 4 | 3 | 2     | 1     | 0     |
| LVIS   | 0 | 0 | 0 | 0 | 0 | LVIS2 | LVIS1 | LVIS0 |

| LVIS2 | LVIS1 | LVIS0 | Detection level   |
|-------|-------|-------|---|
| 0     | 0     | 0     | $V_{LV10}$ (4.3 V $\pm$ 0.2 V)                            |
| 0     | 0     | 1     | $V_{LV11}$ (4.1 V $\pm$ 0.2 V)                            |
| 0     | 1     | 0     | $V_{LV12}$ (3.9 V $\pm$ 0.2 V)                            |
| 0     | 1     | 1     | $V_{LV13}$ (3.7 V $\pm$ 0.2 V)                            |
| 1     | 0     | 0     | $V_{LV14}$ (3.5 V $\pm$ 0.2 V) <sup>Note 1</sup>          |
| 1     | 0     | 1     | $V_{LV15}$ (3.3 V $\pm$ 0.15 V) <sup>Notes 1, 2</sup>     |
| 1     | 1     | 0     | $V_{LV16}$ (3.1 V $\pm$ 0.15 V) <sup>Notes 1, 2</sup>     |
| 1     | 1     | 1     | $V_{LV17}$ (2.85 V $\pm$ 0.15 V) <sup>Notes 1, 3, 4</sup> |

- ★
- Notes**
1. When the detection voltage of the POC circuit is specified as  $V_{POC} = 3.5\text{ V} \pm 0.2\text{ V}$  by a mask option, do not select  $V_{LV14}$  to  $V_{LV17}$  as the LVI detection voltage. Even if  $V_{LV14}$  to  $V_{LV17}$  are selected, the POC circuit has priority.
  2. This can be set only with the expanded-specification products and conventional products of standard products and (A) grade products.
  3. When the detection voltage of the POC circuit is specified as  $V_{POC} = 2.85\text{ V} \pm 0.15\text{ V}$  by a mask option, do not select  $V_{LV17}$  as the LVI detection voltage. Even if  $V_{LV17}$  is selected, the POC circuit has priority.
  4. This can be set only with the expanded-specification products of standard products and (A) grade products.
- ★
- ★

**Caution** Be sure to clear bits 3 to 7 to 0.

## 19.4 Operation of Low-Voltage Detector

The low-voltage detector can be used in the following two modes.

- Used as reset  
Compares the supply voltage ( $V_{DD}$ ) and detection voltage ( $V_{LVI}$ ), and generates an internal reset signal when  $V_{DD} < V_{LVI}$ .
- Used as interrupt  
Compares the supply voltage ( $V_{DD}$ ) and detection voltage ( $V_{LVI}$ ), and generates an interrupt signal (INTLVI) when  $V_{DD} < V_{LVI}$ .

The operation is set as follows.

### (1) When used as reset

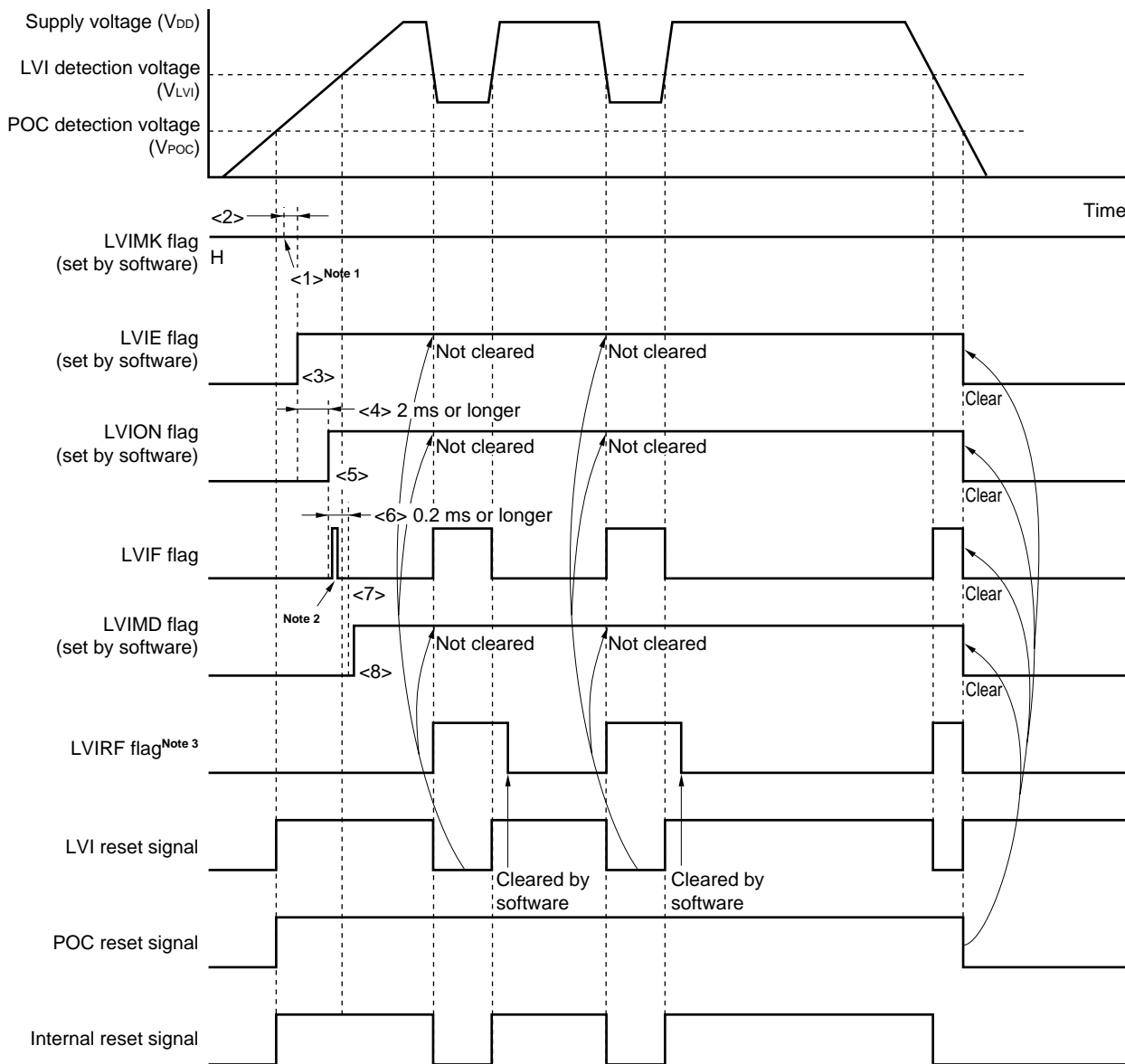
- When starting operation
  - <1> Mask the LVI interrupt ( $LVIMK = 1$ ).
  - <2> Set the detection voltage using bits 2 to 0 ( $LVIS2$  to  $LVIS0$ ) of the low-voltage detection level selection register ( $LVIS$ ).
  - <3> Set bit 4 ( $LVIE$ ) of the low-voltage detection register ( $LVIM$ ) to 1 (enables reference voltage generator operation).
  - <4> Use software to instigate a wait of at least 2 ms.
  - <5> Set bit 7 ( $LVION$ ) of  $LVIM$  to 1 (enables LVI operation).
  - <6> Use software to instigate a wait of at least 0.2 ms.
  - <7> Wait until it is checked that (supply voltage ( $V_{DD}$ ) > detection voltage ( $V_{LVI}$ )) by bit 0 ( $LVIF$ ) of  $LVIM$ .
  - <8> Set bit 1 ( $LVIMD$ ) of  $LVIM$  to 1 (generates internal reset signal when supply voltage ( $V_{DD}$ ) < detection voltage ( $V_{LVI}$ )).

Figure 19-4 shows the timing of the internal reset signal generated by the low-voltage detector. The numbers in this timing chart correspond to <1> to <8> above.

- Cautions**
1. <1> must always be executed. When  $LVIMK = 0$ , an interrupt may occur immediately after the processing in <5>.
  2. If “POC used” is selected by a mask option, procedures <3> and <4> are not required.
  3. If supply voltage ( $V_{DD}$ ) > detection voltage ( $V_{LVI}$ ) when  $LVIM$  is set to 1, an internal reset signal is not generated.

- When stopping operation  
Either of the following procedures must be executed.
  - When using 8-bit memory manipulation instruction:  
Write 00H to  $LVIM$ .
  - When using 1-bit memory manipulation instruction:  
Clear  $LVIMD$  to 0,  $LVION$  to 0, and  $LVIE$  to 0 in that order.

Figure 19-4. Timing of Low-Voltage Detector Internal Reset Signal Generation



- Notes**
1. The LVIMK flag is set to “1” by  $\overline{\text{RESET}}$  input.
  2. The LVIF flag may be set (1).
  3. LVIRF is bit 0 of the reset control flag register (RESF). For details of RESF, see **CHAPTER 16 RESET FUNCTION**.

**Remark** <1> to <8> in Figure 19-4 above correspond to <1> to <8> in the description of “when starting operation” in **19.4 (1) When used as reset**.

**(2) When used as interrupt**

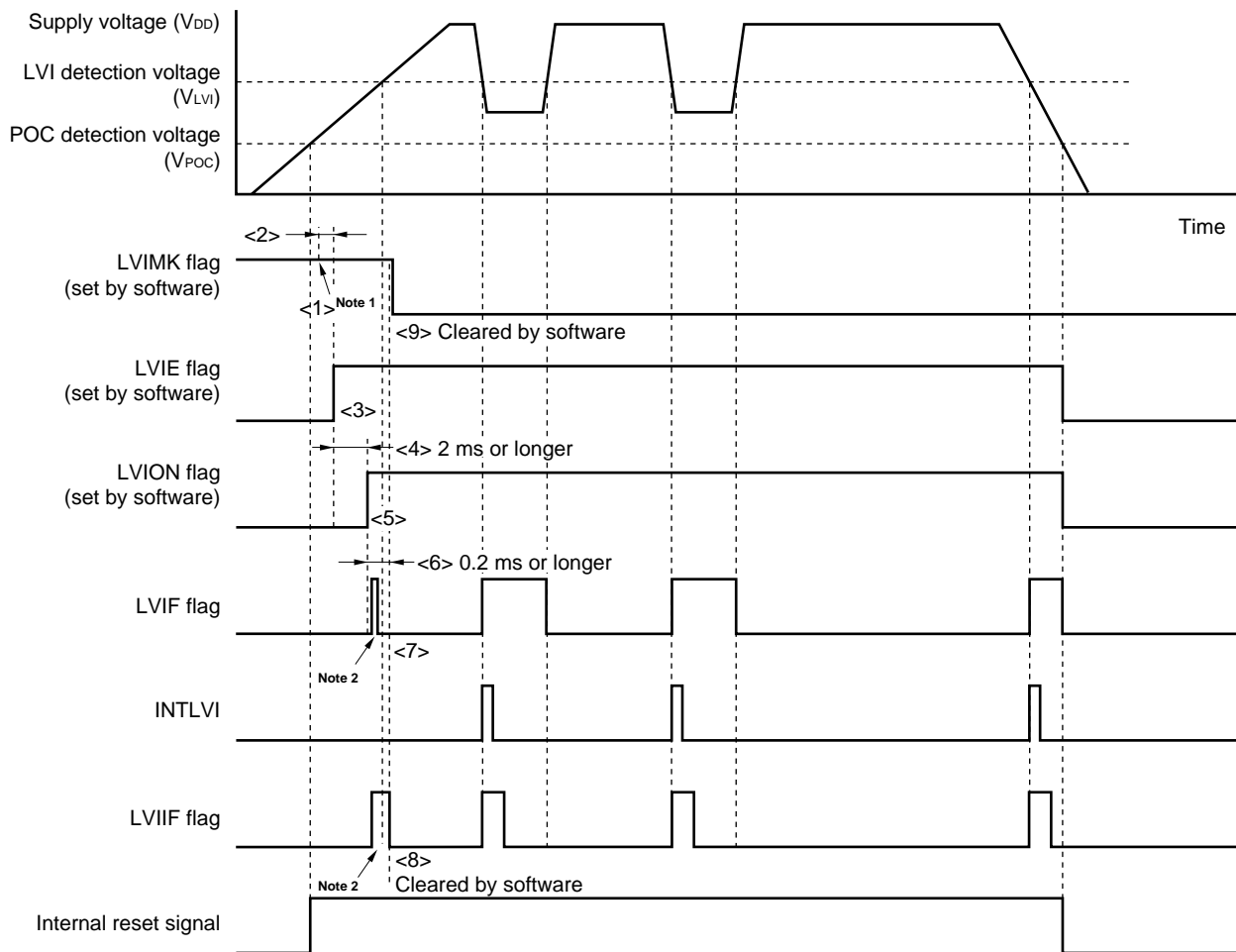
- When starting operation
  - <1> Mask the LVI interrupt (LVIMK = 1).
  - <2> Set the detection voltage using bits 2 to 0 (LVIS2 to LVIS0) of the low-voltage detection level selection register (LVIS).
  - <3> Set bit 4 (LVIE) of the low-voltage detection register (LVIM) to 1 (enables reference voltage generator operation).
  - <4> Use software to instigate a wait of at least 2 ms.
  - <5> Set bit 7 (LVION) of LVIM to 1 (enables LVI operation).
  - <6> Use software to instigate a wait of at least 0.2 ms.
  - <7> Wait until it is checked that (supply voltage ( $V_{DD}$ ) > detection voltage ( $V_{LVI}$ )) by bit 0 (LVIF) of LVIM.
  - <8> Clear the interrupt request flag of LVI (LVIIIF) to 0.
  - <9> Release the interrupt mask flag of LVI (LVIMK).
  - <10> Execute the EI instruction (when vectored interrupts are used).

Figure 19-5 shows the timing of the interrupt signal generated by the low-voltage detector. The numbers in this timing chart correspond to <1> to <9> above.

**Caution** If “POC used” is selected by a mask option, procedures <3> and <4> are not required.

- When stopping operation
  - Either of the following procedures must be executed.
  - When using 8-bit memory manipulation instruction:
    - Write 00H to LVIM.
  - When using 1-bit memory manipulation instruction:
    - Clear LVION to 0 first, and then clear LVIE to 0.

Figure 19-5. Timing of Low-Voltage Detector Interrupt Signal Generation



- Notes**
1. The LVIMK flag is set to "1" by  $\overline{\text{RESET}}$  input.
  2. The LVIF and LVIIF flags may be set (1).

**Remark** <1> to <9> in Figure 19-5 above correspond to <1> to <9> in the description of "when starting operation" in **19.4 (2) When used as interrupt**.

## 19.5 Cautions for Low-Voltage Detector

In a system where the supply voltage ( $V_{DD}$ ) fluctuates for a certain period in the vicinity of the LVI detection voltage ( $V_{LVI}$ ), the operation is as follows depending on how the low-voltage detector is used.

### (1) When used as reset

The system may be repeatedly reset and released from the reset status.

In this case, the time from release of reset to the start of the operation of the microcontroller can be arbitrarily set by taking action (a) below.

### (2) When used as interrupt

Interrupt requests may be frequently generated. Take action (b) below.

In this system, take the following actions.

<Action>

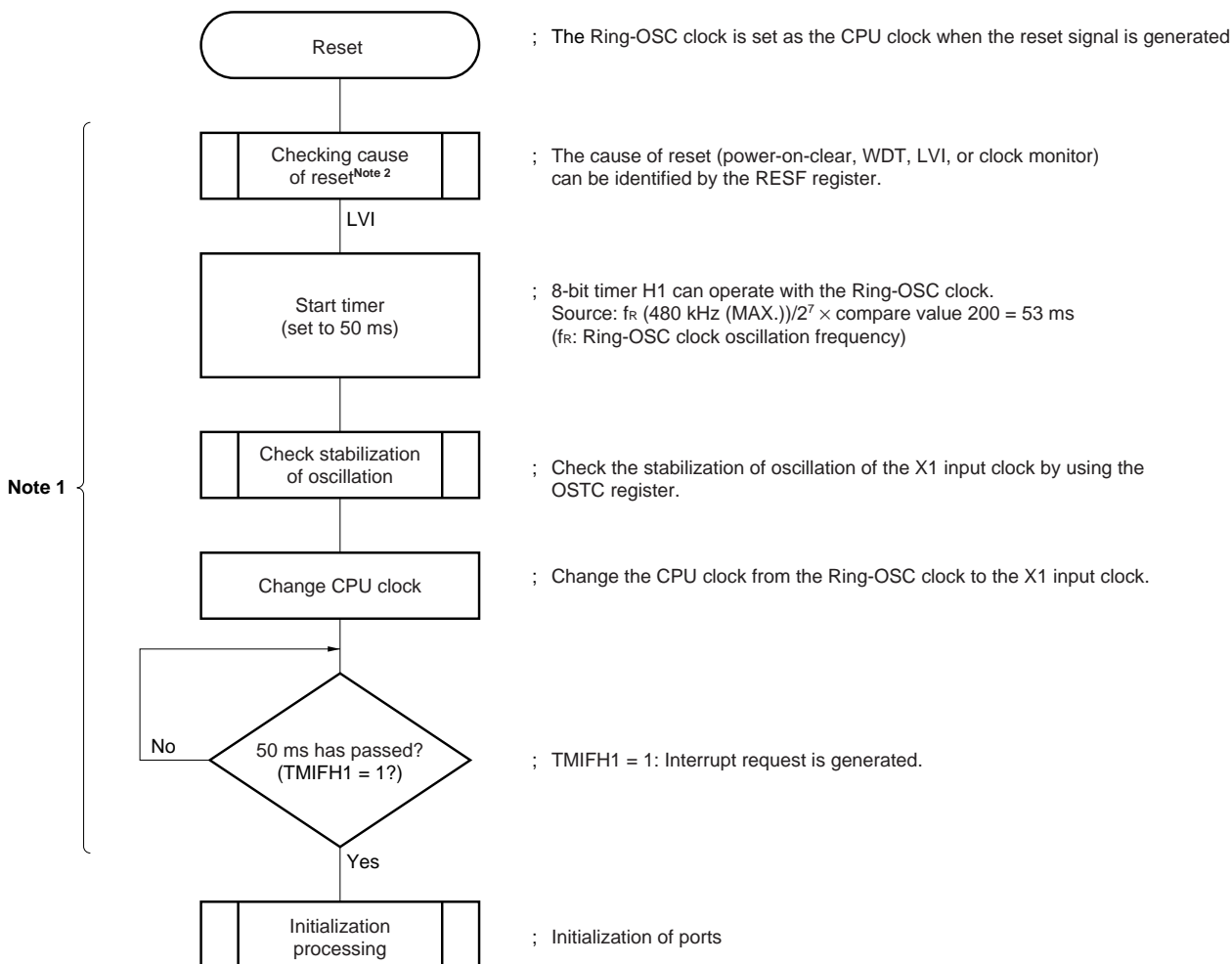
#### (a) When used as reset

After releasing the reset signal, wait for the supply voltage fluctuation period of each system by means of a software counter that uses a timer, and then initialize the ports.



Figure 19-6. Example of Software Processing After Release of Reset (1/2)

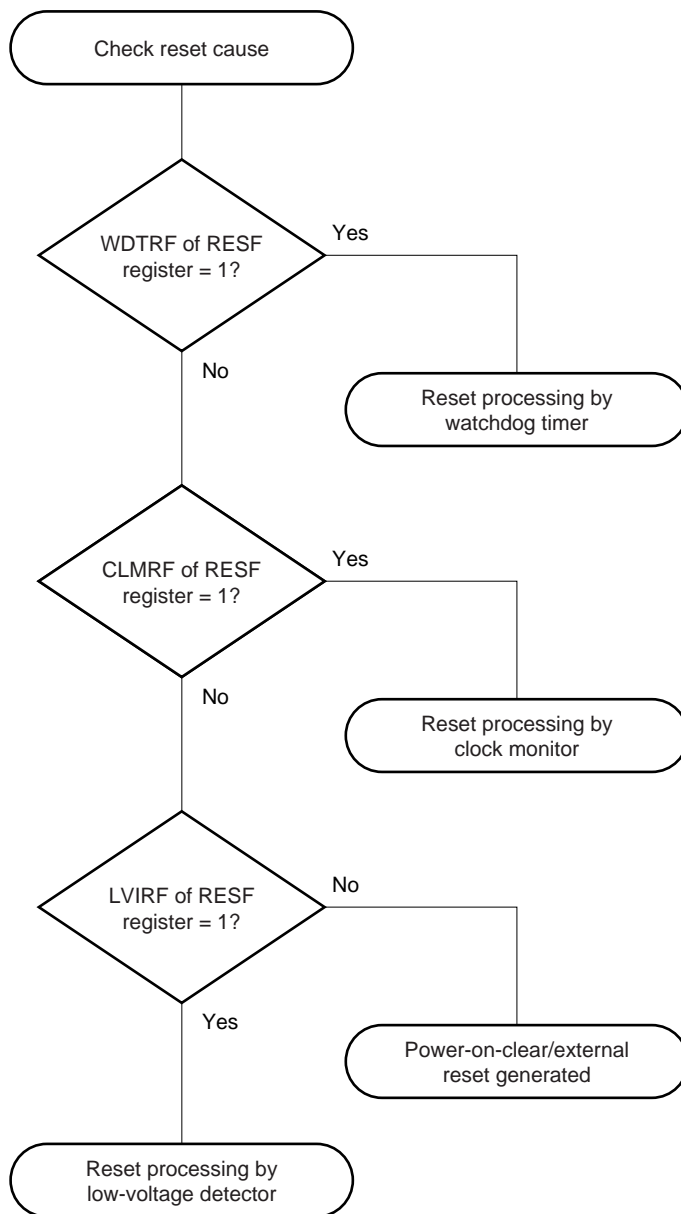
- If supply voltage fluctuation is 50 ms or less in vicinity of LVI detection voltage



- Notes**
1. If reset is generated again during this period, initialization processing is not started.
  2. A flowchart is shown on the next page.

Figure 19-6. Example of Software Processing After Release of Reset (2/2)

- Checking reset cause



**(b) When used as interrupt**

Check that "supply voltage ( $V_{DD}$ ) > detection voltage ( $V_{LVI}$ )" in the servicing routine of the LVI interrupt by using bit 0 (LVIF) of the low-voltage detection register (LVIM). Clear bit 0 (LVIF) of interrupt request flag register 0L (IF0L) to 0 and enable interrupts (EI).

In a system where the supply voltage fluctuation period is long in the vicinity of the LVI detection voltage, wait for the supply voltage fluctuation period, check that "supply voltage ( $V_{DD}$ ) > detection voltage ( $V_{LVI}$ )" using the LVIF flag, and then enable interrupts (EI).

## CHAPTER 20 MASK OPTIONS

Mask ROM versions are provided with the following mask options.

1. Power-on-clear (POC) circuit
  - POC cannot be used
  - POC used (detection voltage:  $V_{POC} = 2.85\text{ V} \pm 0.15\text{ V}$ )<sup>Note</sup>
  - POC used (detection voltage:  $V_{POC} = 3.5\text{ V} \pm 0.2\text{ V}$ )
2. Ring-OSC
  - Cannot be stopped
  - Can be stopped by software

**Note** This option cannot be selected in (A1) and (A2) grade products because the supply voltage  $V_{DD}$  is 3.3 to 5.5 V.

Flash memory versions that support the mask options of the mask ROM versions are as follows.

**Table 20-1. Flash Memory Versions Supporting Mask Options of Mask ROM Versions**

| Mask Option   |                            | Flash Memory Version                           |
|---|----------------------------|--|
| POC Circuit   | Ring-OSC                   |  |
| POC cannot be used  | Cannot be stopped          | $\mu$ PD78F0103M1, 78F0103M1(A), 78F0103M1(A1) |
|   | Can be stopped by software | $\mu$ PD78F0103M2, 78F0103M2(A), 78F0103M2(A1) |
| POC used<br>( $V_{POC} = 2.85\text{ V} \pm 0.15\text{ V}$ ) | Cannot be stopped          | $\mu$ PD78F0103M3, 78F0103M3(A)                |
|   | Can be stopped by software | $\mu$ PD78F0103M4, 78F0103M4(A)                |
| POC used<br>( $V_{POC} = 3.5\text{ V} \pm 0.2\text{ V}$ )   | Cannot be stopped          | $\mu$ PD78F0103M5, 78F0103M5(A), 78F0103M5(A1) |
|   | Can be stopped by software | $\mu$ PD78F0103M6, 78F0103M6(A), 78F0103M6(A1) |

## CHAPTER 21 $\mu$ PD78F0103

The  $\mu$ PD78F0103 is provided as the flash memory version of the 78K0/KB1.

The  $\mu$ PD78F0103 replaces the internal mask ROM of the  $\mu$ PD780103 with flash memory to which a program can be written, erased, and overwritten while mounted on the board. Table 21-1 lists the differences between the  $\mu$ PD78F0103 and the mask ROM versions.

**Table 21-1. Differences Between  $\mu$ PD78F0103 and Mask ROM Versions**

| Item  | $\mu$ PD78F0103   | Mask ROM Versions   |
|---|---|---|
| Internal ROM configuration                                  | Flash memory  | Mask ROM  |
| Internal ROM capacity                                       | 24 KB <sup>Note</sup>   | $\mu$ PD780101: 8 KB<br>$\mu$ PD780102: 16 KB<br>$\mu$ PD780103: 24 KB              |
| Internal high-speed RAM capacity                            | 768 bytes <sup>Note</sup>   | $\mu$ PD780101: 512 bytes<br>$\mu$ PD780102: 768 bytes<br>$\mu$ PD780103: 768 bytes |
| IC pin  | None  | Available   |
| V <sub>PP</sub> pin   | Available   | None  |
| Electrical specifications, recommended soldering conditions | Refer to the description of electrical specifications and recommended soldering conditions. |   |

**Note** The same capacity as the mask ROM versions can be specified by means of the internal memory size switching register (IMS).

**Caution** There are differences in noise immunity and noise radiation between the flash memory and mask ROM versions. When pre-producing an application set with the flash memory version and then mass-producing it with the mask ROM version, be sure to conduct sufficient evaluations for the commercial samples (not engineering samples) of the mask ROM versions.

## 21.1 Internal Memory Size Switching Register

The  $\mu$ PD78F0103 allows users to select the internal memory capacity using the internal memory size switching register (IMS) so that the same memory map as that of the mask ROM versions with a different internal memory capacity can be achieved.

IMS is set by an 8-bit memory manipulation instruction.

RESET input sets IMS to CFH.

**Caution** The initial value of IMS is “setting prohibited (CFH)”. Be sure to set the value of the relevant mask ROM version at initialization.

**Figure 21-1. Format of Internal Memory Size Switching Register (IMS)**

Address: FFF0H After reset: CFH R/W

|        |      |      |      |   |      |      |      |      |
|--------|------|------|------|---|------|------|------|------|
| Symbol | 7    | 6    | 5    | 4 | 3    | 2    | 1    | 0    |
| IMS    | RAM2 | RAM1 | RAM0 | 0 | ROM3 | ROM2 | ROM1 | ROM0 |

| RAM2             | RAM1 | RAM0 | Internal high-speed RAM capacity selection |
|------------------|------|------|--|
| 0                | 0    | 0    | 768 bytes                                  |
| 0                | 1    | 0    | 512 bytes                                  |
| Other than above |      |      | Setting prohibited                         |

| ROM3             | ROM2 | ROM1 | ROM0 | Internal ROM capacity selection |
|------------------|------|------|------|---------------------------------|
| 0                | 0    | 1    | 0    | 8 KB                            |
| 0                | 1    | 0    | 0    | 16 KB                           |
| 0                | 1    | 1    | 0    | 24 KB                           |
| Other than above |      |      |      | Setting prohibited              |

The IMS settings required to obtain the same memory map as mask ROM versions are shown in Table 21-2.

**Table 21-2. Internal Memory Size Switching Register Settings**

| Target Mask ROM Versions | IMS Setting |
|--------------------------|-------------|
| $\mu$ PD780101           | 42H         |
| $\mu$ PD780102           | 04H         |
| $\mu$ PD780103           | 06H         |

**Caution** When using a mask ROM version, be sure to set IMS to the value indicated in Table 21-2.

## 21.2 Writing with Flash Programmer

Data can be written to the flash memory on-board or off-board, by using a dedicated flash programmer.

### (1) On-board programming

The contents of the flash memory can be rewritten after the  $\mu$ PD78F0103 has been mounted on the target system. The connectors that connect the dedicated flash programmer must be mounted on the target system.

### (2) Off-board programming

Data can be written to the flash memory with a dedicated program adapter (FA series) before the  $\mu$ PD78F0103 is mounted on the target system.

**Remark** The FA series is a product of Naito Densai Machida Mfg. Co., Ltd.

**Table 21-3. Wiring Between  $\mu$ PD78F0103 and Dedicated Flash Programmer (1/2)**

### (1) 3-wire serial I/O (CSI10)

| Pin Configuration of Dedicated Flash Programmer |        |  | With CSI10                         |            | With CSI10+HS                      |         |
|---|--------|--|------------------------------------|------------|------------------------------------|---------|
| Signal Name                                     | I/O    | Pin Function                                       | Pin Name                           | Pin No.    | Pin Name                           | Pin No. |
| SI/RxD  | Input  | Receive signal                                     | SO10/P12                           | 17         | SO10/P12                           | 17      |
| SO/TxD  | Output | Transmit signal                                    | SI10/RxD0/P11                      | 16         | SI10/RxD0/P11                      | 16      |
| SCK   | Output | Transfer clock                                     | $\overline{\text{SCK10/TxD0/P10}}$ | 15         | $\overline{\text{SCK10/TxD0/P10}}$ | 15      |
| CLK   | Output | Clock to $\mu$ PD78F0103                           | X1                                 | 8          | X1                                 | 8       |
|   |        |  | X2 <sup>Note</sup>                 | 9          | X2 <sup>Note</sup>                 | 9       |
| /RESET  | Output | Reset signal                                       | $\overline{\text{RESET}}$          | 10         | $\overline{\text{RESET}}$          | 10      |
| V <sub>PP</sub>                                 | Output | Write voltage                                      | V <sub>PP</sub>                    | 5          | V <sub>PP</sub>                    | 5       |
| H/S   | Input  | Handshake signal                                   | Not needed                         | Not needed | HS/P15/TOH0                        | 20      |
| V <sub>DD</sub>                                 | I/O    | V <sub>DD</sub> voltage generation/voltage monitor | V <sub>DD</sub>                    | 7          | V <sub>DD</sub>                    | 7       |
|   |        |  | AV <sub>REF</sub>                  | 28         | AV <sub>REF</sub>                  | 28      |
| GND   | -      | Ground   | V <sub>SS</sub>                    | 6          | V <sub>SS</sub>                    | 6       |
|   |        |  | AV <sub>SS</sub>                   | 29         | AV <sub>SS</sub>                   | 29      |

**Note** When using the clock out of the flash programmer, connect CLK of the programmer to X1, and connect its inverse signal to X2.

Table 21-3. Wiring Between  $\mu$ PD78F0103 and Dedicated Flash Programmer (2/2)

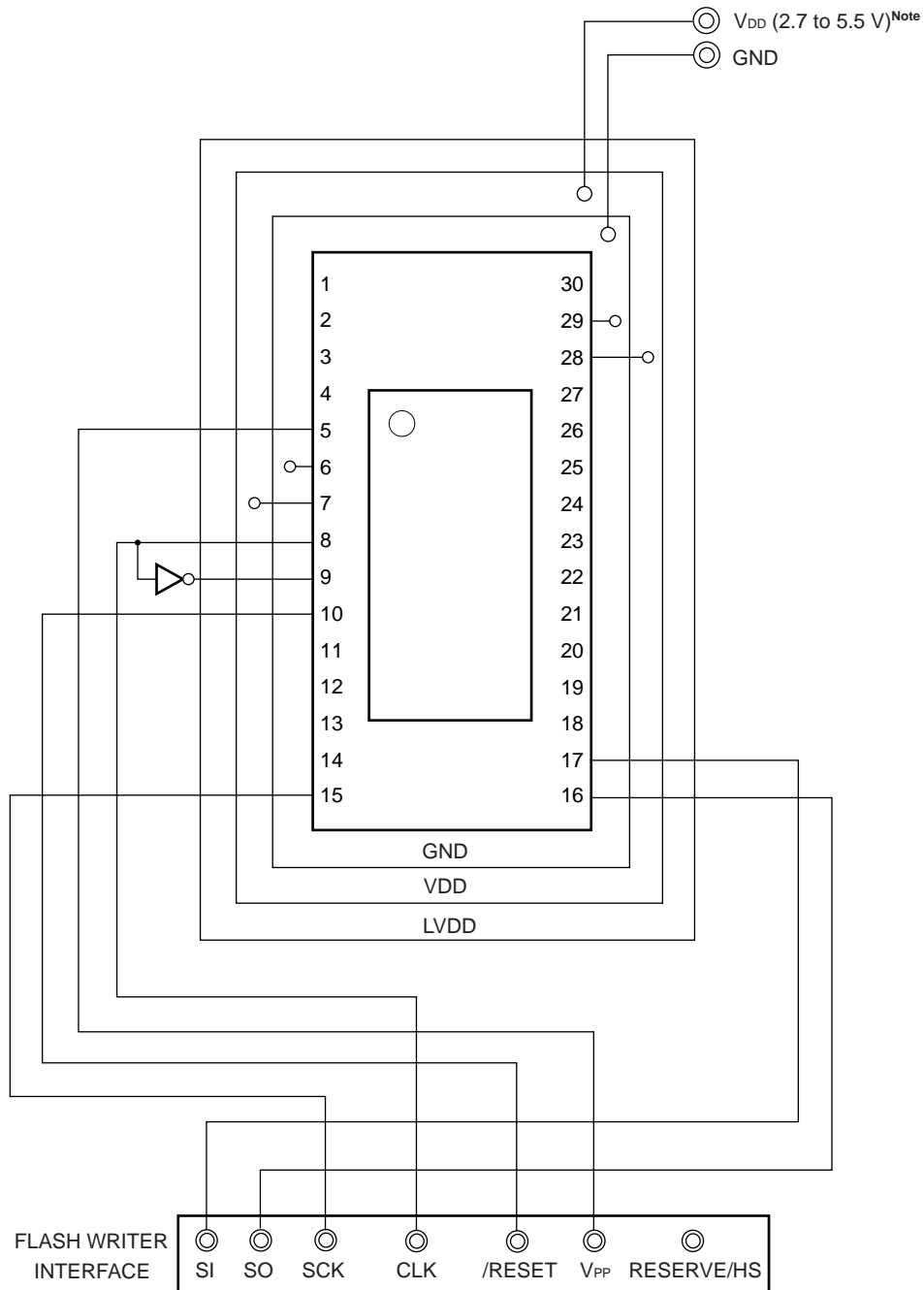
## (2) UART (UART0, UART6)

| Pin Configuration of Dedicated Flash Programmer |        |  | With UART0         |            | With UART0+HS      |            | With UART6         |            |
|---|--------|--|--------------------|------------|--------------------|------------|--------------------|------------|
| Signal Name                                     | I/O    | Pin Function                                       | Pin Name           | Pin No.    | Pin Name           | Pin No.    | Pin Name           | Pin No.    |
| SI/RxD  | Input  | Receive signal                                     | TxD0/<br>SCK10/P10 | 15         | TxD0/<br>SCK10/P10 | 15         | TxD6/P13           | 18         |
| SO/TxD  | Output | Transmit signal                                    | RxD0/SI10/<br>P11  | 16         | RxD0/SI10/<br>P11  | 16         | RxD6/P14           | 19         |
| SCK   | Output | Transfer clock                                     | Not needed         | Not needed | Not needed         | Not needed | Not needed         | Not needed |
| CLK   | Output | Clock to $\mu$ PD78F0103                           | X1                 | 8          | X1                 | 8          | X1                 | 8          |
|   |        |  | X2 <sup>Note</sup> | 9          | X2 <sup>Note</sup> | 9          | X2 <sup>Note</sup> | 9          |
| /RESET  | Output | Reset signal                                       | RESET              | 10         | RESET              | 10         | RESET              | 10         |
| V <sub>PP</sub>                                 | Output | Write voltage                                      | V <sub>PP</sub>    | 5          | V <sub>PP</sub>    | 5          | V <sub>PP</sub>    | 5          |
| H/S   | Input  | Handshake signal                                   | Not needed         | Not needed | HS/P15/TOH0        | 20         | Not needed         | Not needed |
| V <sub>DD</sub>                                 | I/O    | V <sub>DD</sub> voltage generation/voltage monitor | V <sub>DD</sub>    | 7          | V <sub>DD</sub>    | 7          | V <sub>DD</sub>    | 7          |
|   |        |  | AV <sub>REF</sub>  | 28         | AV <sub>REF</sub>  | 28         | AV <sub>REF</sub>  | 28         |
| GND   | -      | Ground   | V <sub>SS</sub>    | 6          | V <sub>SS</sub>    | 6          | V <sub>SS</sub>    | 6          |
|   |        |  | AV <sub>SS</sub>   | 29         | AV <sub>SS</sub>   | 29         | AV <sub>SS</sub>   | 29         |

**Note** When using the clock out of the flash programmer, connect CLK of the programmer to X1, and connect its inverse signal to X2.

Examples of the recommended connection when using the adapter for flash memory writing are shown below.

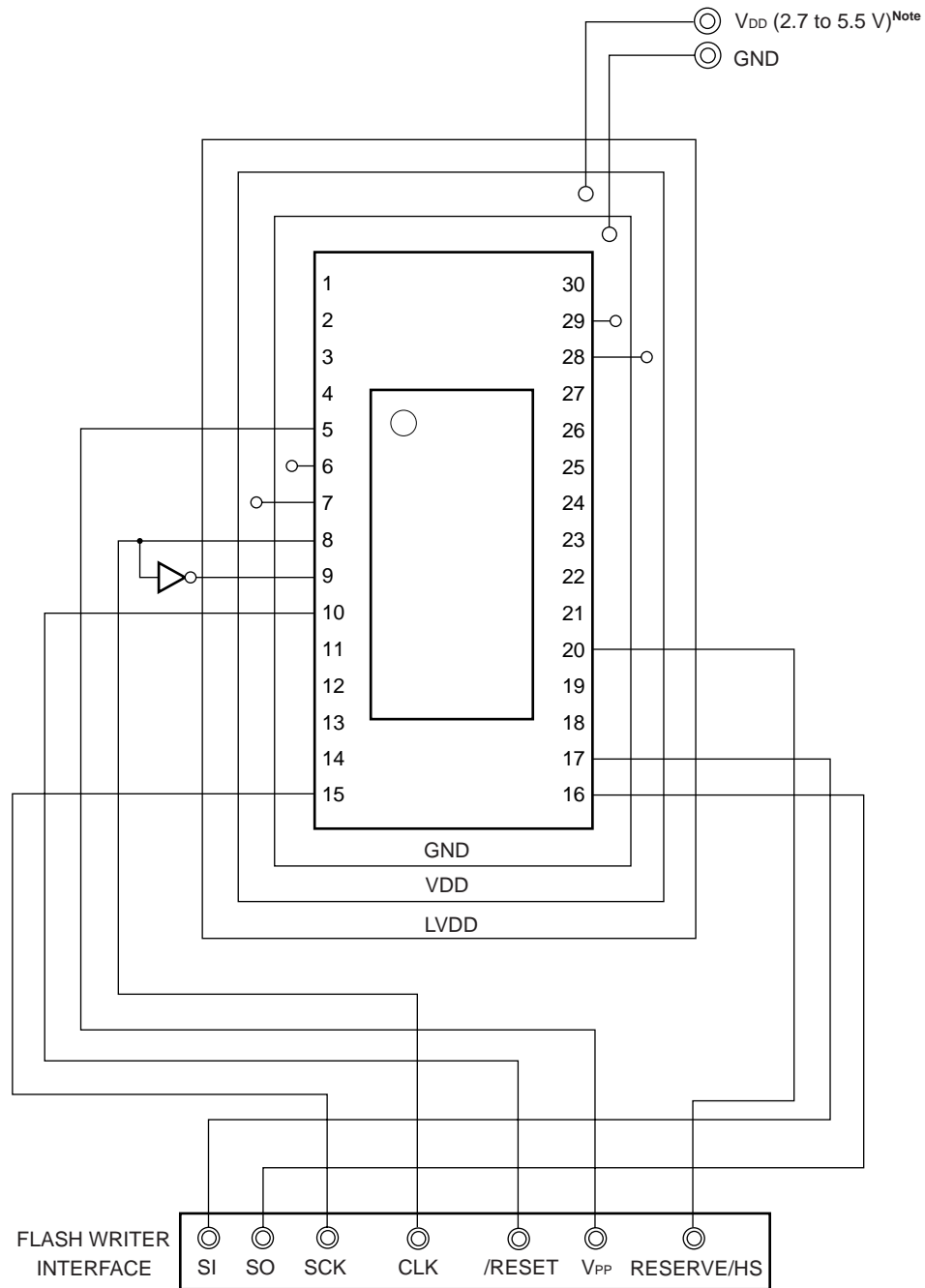
**Figure 21-2. Example of Wiring Adapter for Flash Memory Writing in 3-Wire Serial I/O (CSI10) Mode**



**Note**  $\mu$ PD78F0103, 78F0103(A): 2.7 to 5.5 V  
 $\mu$ PD78F0103(A1): 3.3 to 5.5 V

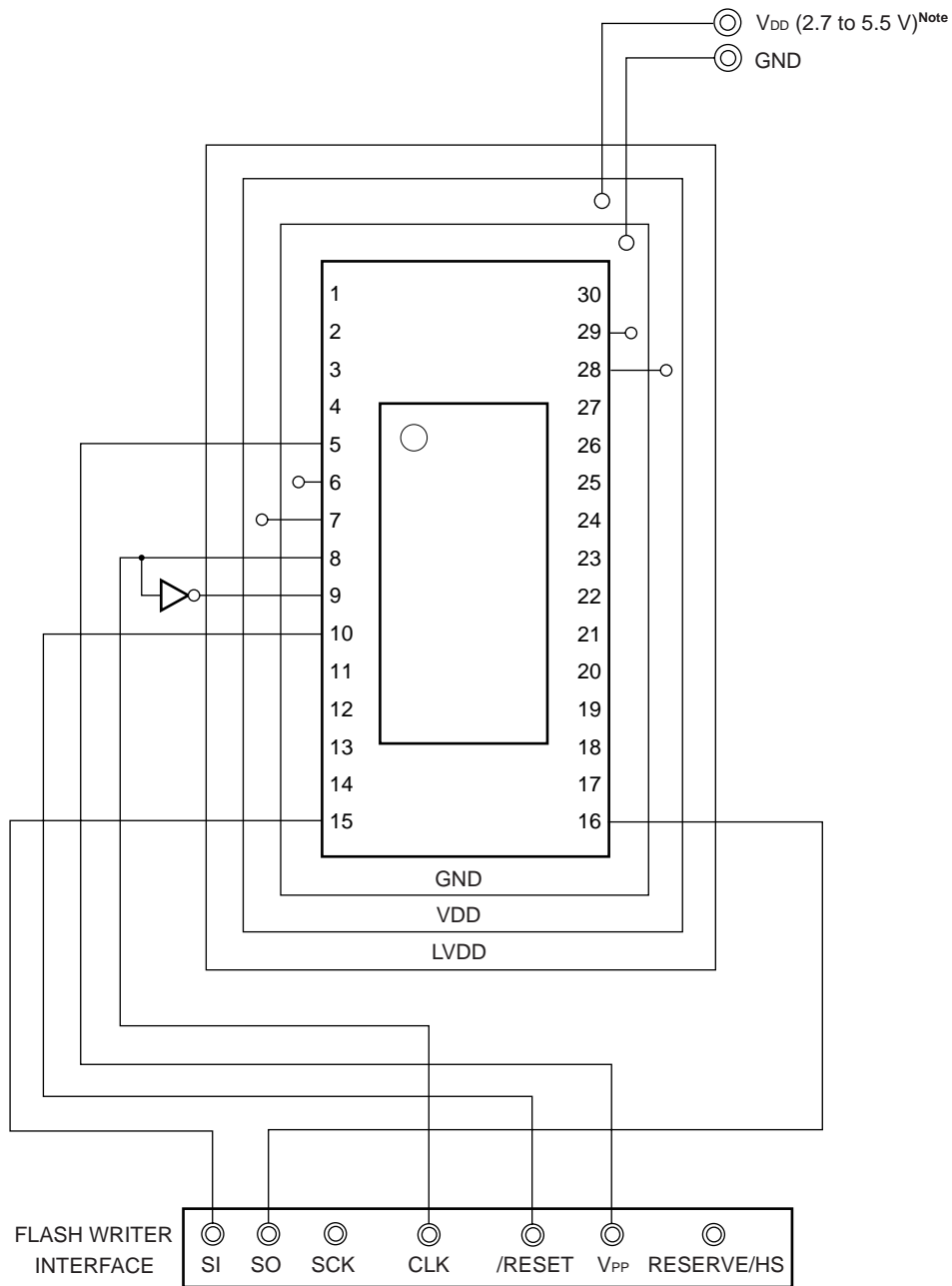


Figure 21-3. Example of Wiring Adapter for Flash Memory Writing in 3-Wire Serial I/O (CSI10 + HS) Mode



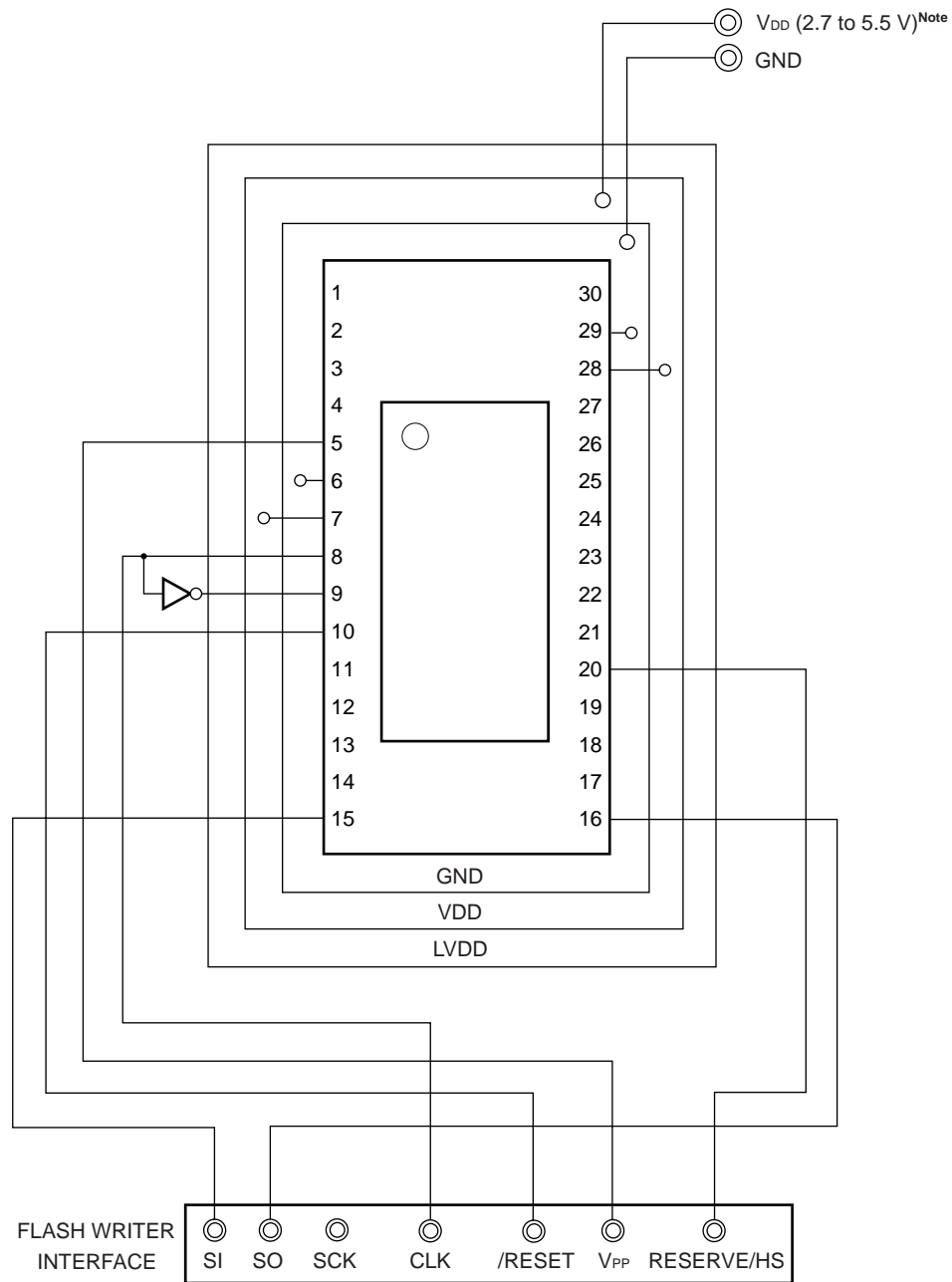
**Note**  $\mu$ PD78F0103, 78F0103(A): 2.7 to 5.5 V  
 $\mu$ PD78F0103(A1): 3.3 to 5.5 V

Figure 21-4. Example of Wiring Adapter for Flash Memory Writing in UART (UART0) Mode



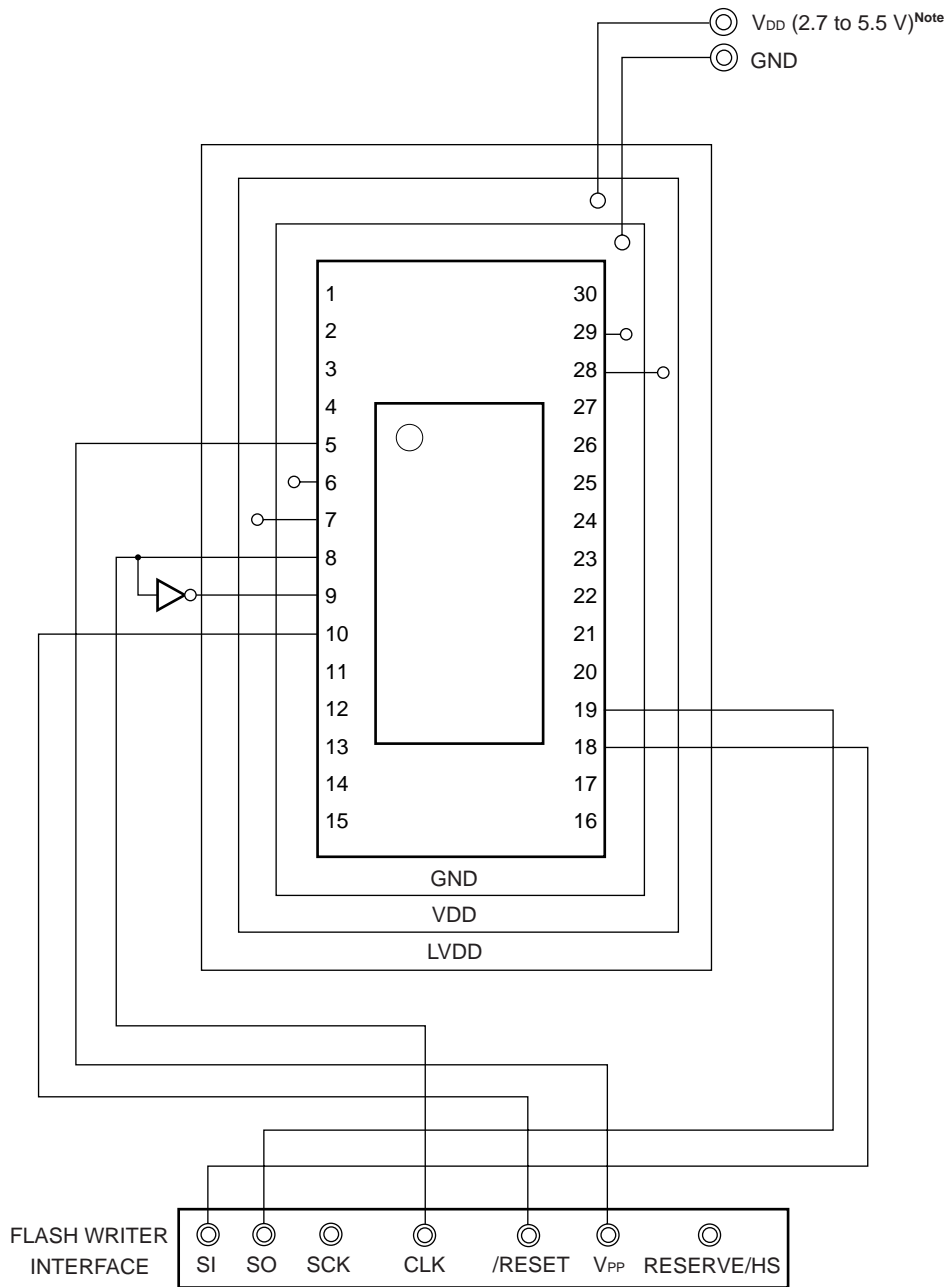
**Note**  $\mu$ PD78F0103, 78F0103(A): 2.7 to 5.5 V  
 $\mu$ PD78F0103(A1): 3.3 to 5.5 V

Figure 21-5. Example of Wiring Adapter for Flash Memory Writing in UART (UART0 + HS) Mode



**Note**  $\mu$ PD78F0103, 78F0103(A): 2.7 to 5.5 V  
 $\mu$ PD78F0103(A1): 3.3 to 5.5 V

Figure 21-6. Example of Wiring Adapter for Flash Memory Writing in UART (UART6) Mode

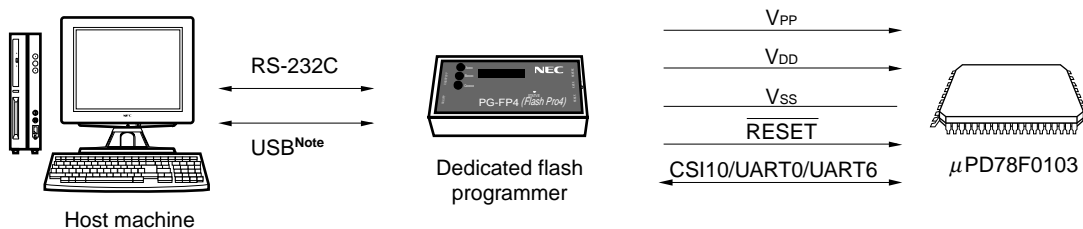


**Note**  $\mu$ PD78F0103, 78F0103(A): 2.7 to 5.5 V  
 $\mu$ PD78F0103(A1): 3.3 to 5.5 V

## 21.3 Programming Environment

The environment required for writing a program to the flash memory of the  $\mu$ PD78F0103 is illustrated below.

**Figure 21-7. Environment for Writing Program to Flash Memory**



**Note** Flashpro IV only

A host machine that controls the dedicated flash programmer is necessary.

To interface between the dedicated flash programmer and the  $\mu$ PD78F0103, CSI10, UART0, or UART6 is used for manipulation such as writing and erasing. To write the flash memory off-board, a dedicated program adapter (FA series) is necessary.

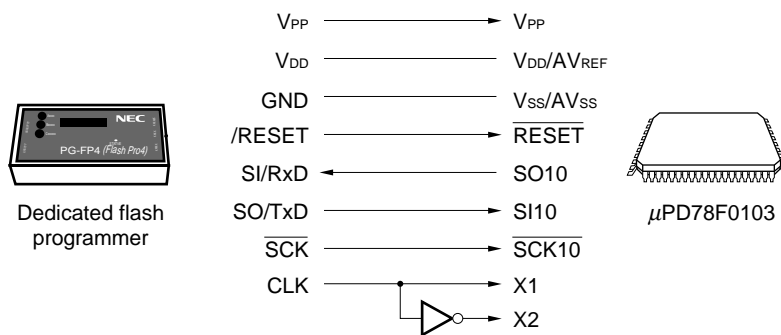
## 21.4 Communication Mode

Communication between the dedicated flash programmer and the  $\mu$ PD78F0103 is established by serial communication via CSI10, UART0, or UART6 of the  $\mu$ PD78F0103.

### (1) CSI10

Transfer rate: 200 kHz to 2 MHz

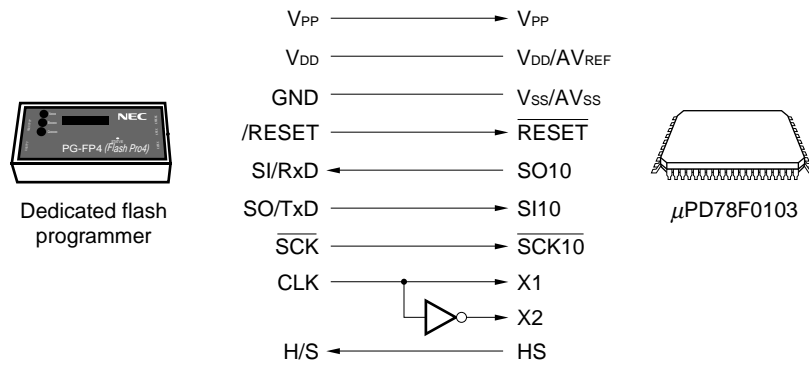
**Figure 21-8. Communication with Dedicated Flash Programmer (CSI10)**



**(2) CSI communication mode supporting handshake**

Transfer rate: 200 kHz to 2 MHz

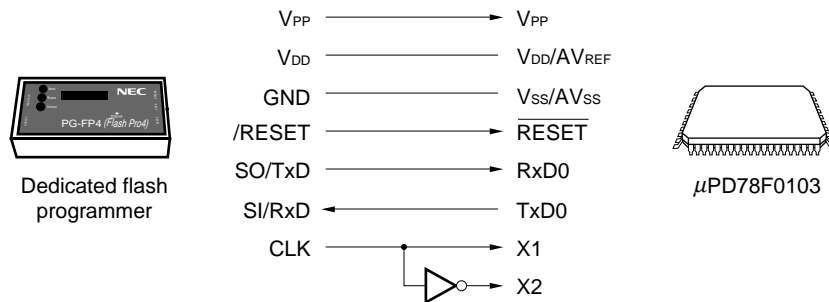
**Figure 21-9. Communication with Dedicated Flash Programmer (CSI10 + HS)**



**(3) UART0**

Transfer rate: 4800 to 38400 bps

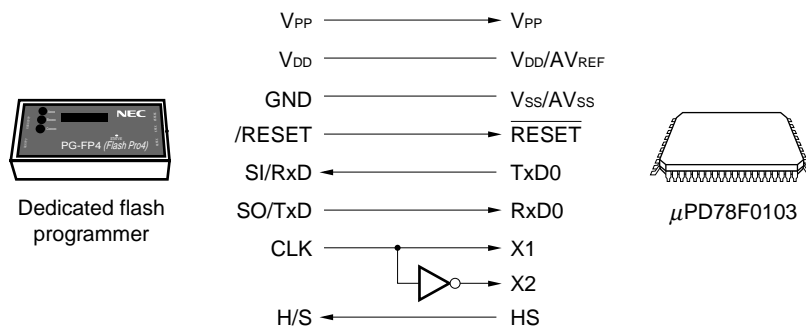
**Figure 21-10. Communication with Dedicated Flash Programmer (UART0)**



**(4) UART communication mode supporting handshake**

Transfer rate: 4800 to 38400 bps

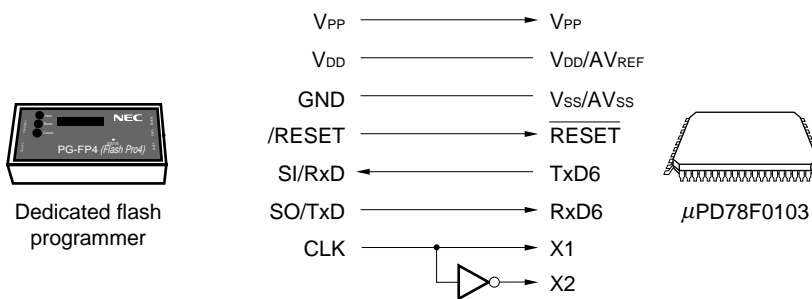
**Figure 21-11. Communication with Dedicated Flash Programmer (UART0 + HS)**



**(5) UART6**

Transfer rate: 4800 to 76800 bps

**Figure 21-12. Communication with Dedicated Flash Programmer (UART6)**



If Flashpro III/Flashpro IV is used as the dedicated flash programmer, Flashpro III/Flashpro IV generates the following signal for the  $\mu$ PD78F0103. For details, refer to the Flashpro III/Flashpro IV Manual.

**Table 21-4. Pin Connection**

| Flashpro III/Flashpro IV |        |  | $\mu$ PD78F0103                     | Connection |       |       |
|--------------------------|--------|--|-------------------------------------|------------|-------|-------|
| Signal Name              | I/O    | Pin Function                                       | Pin Name                            | CSI10      | UART0 | UART6 |
| V <sub>PP</sub>          | Output | Write voltage                                      | V <sub>PP</sub>                     | ⊙          | ⊙     | ⊙     |
| V <sub>DD</sub>          | I/O    | V <sub>DD</sub> voltage generation/voltage monitor | V <sub>DD</sub> , AV <sub>REF</sub> | ⊙          | ⊙     | ⊙     |
| GND                      | –      | Ground   | V <sub>SS</sub> , AV <sub>SS</sub>  | ⊙          | ⊙     | ⊙     |
| CLK                      | Output | Clock output to $\mu$ PD78F0103                    | X1, X2 <sup>Note</sup>              | ○          | ○     | ○     |
| /RESET                   | Output | Reset signal                                       | RESET                               | ⊙          | ⊙     | ⊙     |
| SI/RxD                   | Input  | Receive signal                                     | SO10/TxD0/TxD6                      | ⊙          | ⊙     | ⊙     |
| SO/TxD                   | Output | Transmit signal                                    | SI10/RxD0/RxD6                      | ⊙          | ⊙     | ⊙     |
| SCK                      | Output | Transfer clock                                     | SCK10                               | ⊙          | ×     | ×     |
| H/S                      | Input  | Handshake signal                                   | HS                                  | △          | △     | ×     |

**Note** When using the clock out of the flash programmer, connect CLK of the programmer to X1, and connect its inverse signal to X2.

**Remark** ⊙: Be sure to connect the pin.

○: The pin does not have to be connected if the signal is generated on the target board.

×: The pin does not have to be connected.

△: In handshake mode



## 21.5 Handling of Pins on Board

To write the flash memory on-board, connectors that connect the dedicated flash programmer must be provided on the target system. First provide a function that selects the normal operation mode or flash memory programming mode on the board.

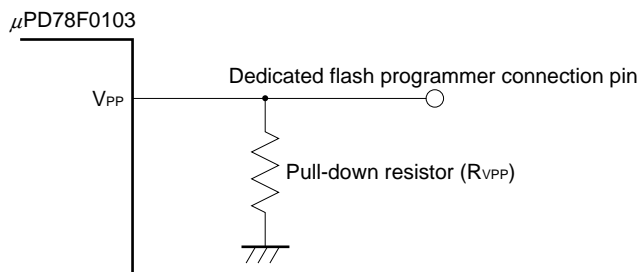
When the flash memory programming mode is set, all the pins not used for programming the flash memory are in the same status as immediately after reset. Therefore, if the external device does not recognize the state immediately after reset, the pins must be handled as described below.

### 21.5.1 $V_{PP}$ pin

In the normal operation mode, connect the  $V_{PP}$  pin to  $V_{SS}$ . In addition, a write voltage of 10.0 V (TYP.) is supplied to the  $V_{PP}$  pin in the flash memory programming mode. Perform the following pin handling.

- (1) Connect pull-down resistor  $R_{VPP} = 10\text{ k}\Omega$  to the  $V_{PP}$  pin.
- (2) Switch the input of the  $V_{PP}$  pin to the programmer side by using a jumper on the board or to GND directly.

**Figure 21-13. Example of Connection of  $V_{PP}$  Pin**



### 21.5.2 Serial interface pins

The pins used by each serial interface are listed below.

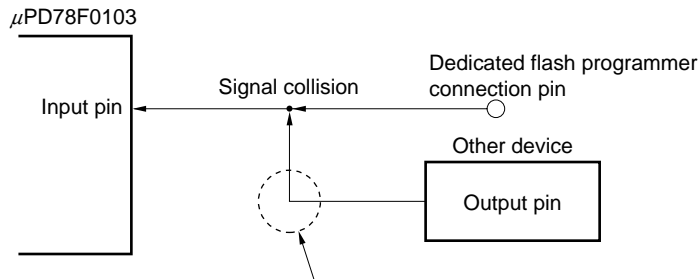
**Table 21-5. Pins Used by Each Serial Interface**

| Serial Interface | Pins Used                                      |
|------------------|--|
| CSI10            | SO10, SI10, $\overline{\text{SCK10}}$          |
| CSI10 + HS       | SO10, SI10, $\overline{\text{SCK10}}$ , HS/P15 |
| UART0            | TxD0, RxD0                                     |
| UART0 + HS       | TxD0, RxD0, HS/P15                             |
| UART6            | TxD6, RxD6                                     |

To connect the dedicated flash programmer to the pins of a serial interface that is connected to another device on the board, care must be exercised so that signals do not collide or that the other device does not malfunction.

**(1) Signal collision**

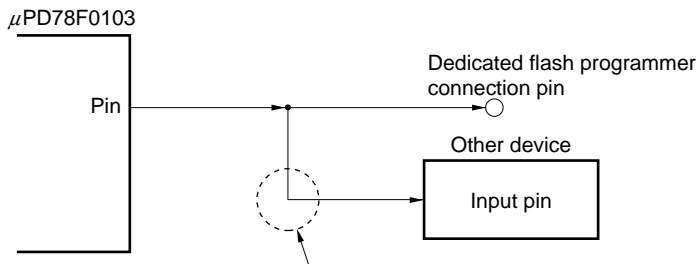
If the dedicated flash programmer (output) is connected to a pin (input) of a serial interface connected to another device (output), signal collision takes place. To avoid this collision, either isolate the connection with the other device, or make the other device go into an output high-impedance state.

**Figure 21-14. Signal Collision (Input Pin of Serial Interface)**

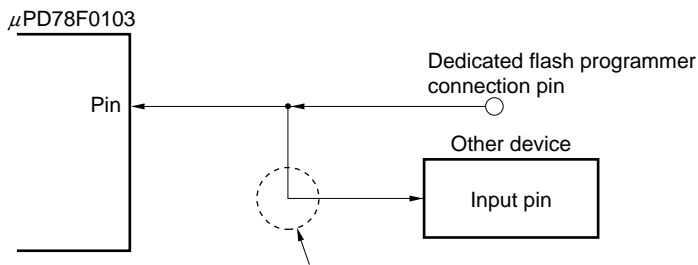
In the flash memory programming mode, the signal output by the device collides with the signal sent from the dedicated flash programmer. Therefore, isolate the signal of the other device.

**(2) Malfunction of other device**

If the dedicated flash programmer (output or input) is connected to a pin (input or output) of a serial interface connected to another device (input), a signal may be output to the other device, causing the device to malfunction. To avoid this malfunction, either isolate the connection with the other device.

**Figure 21-15. Malfunction of Other Device**

If the signal output by the  $\mu$ PD78F0103 in the flash memory programming mode affects the other device, isolate the signal of the other device.



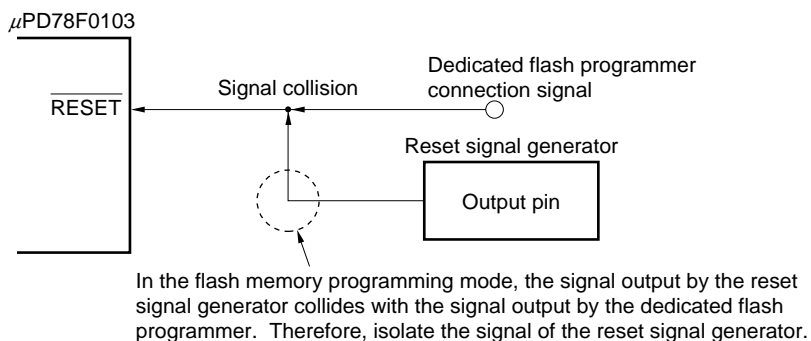
If the signal output by the dedicated flash programmer in the flash memory programming mode affects the other device, isolate the signal of the other device.

### 21.5.3 $\overline{\text{RESET}}$ pin

If the reset signal of the dedicated flash programmer is connected to the  $\overline{\text{RESET}}$  pin that is connected to the reset signal generator on the board, signal collision takes place. To prevent this collision, isolate the connection with the reset signal generator.

If the reset signal is input from the user system while the flash memory programming mode is set, the flash memory will not be correctly programmed. Do not input any signal other than the reset signal of the dedicated flash programmer.

Figure 21-16. Signal Collision ( $\overline{\text{RESET}}$  Pin)



### 21.5.4 Port pins

When the flash memory programming mode is set, all the pins not used for flash memory programming enter the same status as that immediately after reset. If external devices connected to the ports do not recognize the port status immediately after reset, the port pin must be connected to  $V_{DD}$  or  $V_{SS}$  via a resistor.

### 21.5.5 Other signal pins

Connect X1 and X2 in the same status as in the normal operation mode when using the on-board clock.

To input the operating clock from the programmer, however, connect the clock out of the programmer to X1, and its inverse signal to X2.

### 21.5.6 Power supply

To use the supply voltage output of the flash programmer, connect the  $V_{DD}$  pin to  $V_{DD}$  of the flash programmer, and the  $V_{SS}$  pin to  $V_{SS}$  of the flash programmer.

To use the on-board supply voltage, connect in compliance with the normal operation mode.

However, be sure to connect the  $V_{DD}$  and  $V_{SS}$  pins to  $V_{DD}$  and GND of the flash programmer to use the power monitor function with the flash programmer.

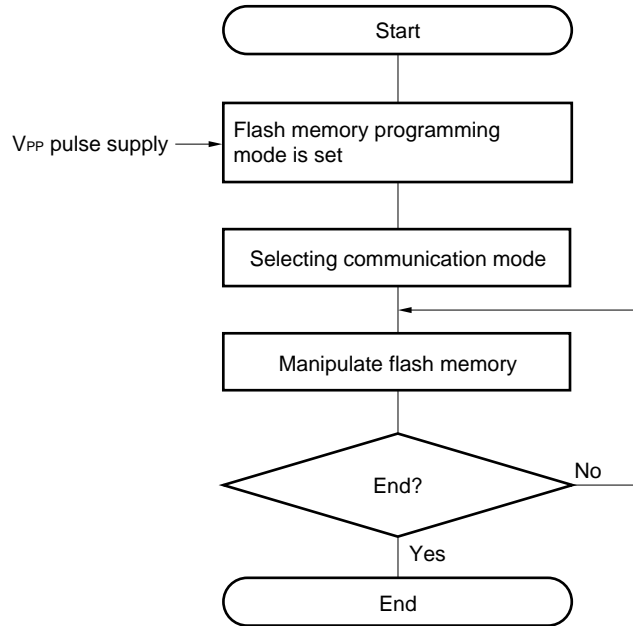
Supply the same other power supplies ( $AV_{REF}$  and  $AV_{SS}$ ) as those in the normal operation mode.

## 21.6 Programming Method

### 21.6.1 Controlling flash memory

The following figure illustrates the procedure to manipulate the flash memory.

**Figure 21-17. Flash Memory Manipulation Procedure**

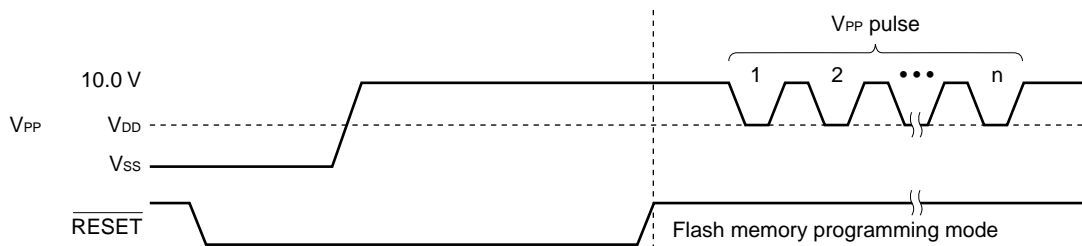


### 21.6.2 Flash memory programming mode

To rewrite the contents of the flash memory by using the dedicated flash programmer, set the  $\mu$ PD78F0103 in the flash memory programming mode. To set the mode, set the V<sub>PP</sub> pin and clear the reset signal.

Change the mode by using a jumper when writing the flash memory on-board.

**Figure 21-18. Flash Memory Programming Mode**



| V <sub>PP</sub> | Operation mode                |
|-----------------|-------------------------------|
| V <sub>SS</sub> | Normal operation mode         |
| 10.0 V          | Flash memory programming mode |

### 21.6.3 Selecting communication mode

In the  $\mu$ PD78F0103 a communication mode is selected by inputting pulses (up to 11 pulses) to the  $V_{PP}$  pin after the dedicated flash memory programming mode is entered. These  $V_{PP}$  pulses are generated by the flash programmer.

The following table shows the relationship between the number of pulses and communication modes.

**Table 21-6. Communication Modes**

| Communication Mode                                      | Standard (TYPE) Setting <sup>Note 1</sup> |  |                       |                            |                               | Pins Used                 | Number of $V_{PP}$ Pulses |
|---|---|--|-----------------------|----------------------------|-------------------------------|---------------------------|---------------------------|
|   | Port (COMM PORT)                          | Speed (SIO CLOCK)                      | On Target (CPU CLOCK) | Frequency (Flashpro Clock) | Multiply Rate (Multiple Rate) |                           |                           |
| 3-wire serial I/O (CSI10)                               | SIO-ch0 (SIO ch-0)                        | 200 kHz to 2 MHz <sup>Note 2</sup>     | Arbitrary             | 2 to 10 MHz                | 1.0                           | SO10, SI10, SCK10         | 0                         |
| 3-wire serial I/O with handshake supported (CSI10 + HS) | SIO-H/S (SIO ch-3 + handshake)            | 200 kHz to 2 MHz <sup>Note 2</sup>     |                       |                            |                               | SO10, SI10, SCK10, HS/P15 | 3                         |
| UART (UART0)  | UART-ch0 (UART ch-0)                      | 4800 to 38400 bps <sup>Notes 2,3</sup> |                       |                            |                               | TxD0, RxD0                | 8                         |
| UART (UART6)  | UART-ch1 (UART ch-1)                      | 4800 to 76800 bps <sup>Notes 2,3</sup> |                       |                            |                               | TxD6, RxD6                | 9                         |
| UART with handshake supported (UART0 + HS)              | UART-ch3 (UART ch-3)                      | 4800 to 38400 bps <sup>Notes 2,3</sup> |                       |                            |                               | TxD0, RxD0, HS/P15        | 11                        |

- Notes**
1. Selection items for Standard settings on Flashpro IV (TYPE settings on Flashpro III).
  2. The possible setting range differs depending on the voltage. For details, refer to the chapters of electrical specifications.
  3. Because factors other than the baud rate error, such as the signal waveform slew, also affect UART communication, thoroughly evaluate the slew as well as the baud rate error.

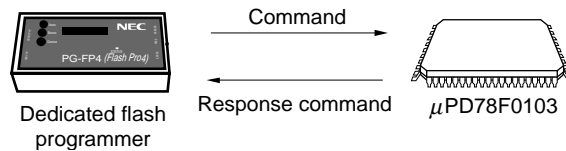
**Caution** When UART0 or UART6 is selected, the receive clock is calculated based on the reset command sent from the dedicated flash programmer after the  $V_{PP}$  pulse has been received.

**Remark** Items enclosed in parentheses in the setting item column are the set value and set item when they differ from those of Flashpro IV.

### 21.6.4 Communication commands

The  $\mu$ PD78F0103 communicates with the dedicated flash programmer by using commands. The signals sent from the flash programmer to the  $\mu$ PD78F0103 are called commands, and the commands sent from the  $\mu$ PD78F0103 to the dedicated flash programmer are called response commands.

**Figure 21-19. Communication Commands**



The flash memory control commands of the  $\mu$ PD78F0103 are listed in the table below. All these commands are issued from the programmer and the  $\mu$ PD78F0103 performs processing corresponding to the respective commands.

**Table 21-7. Flash Memory Control Commands**

| Classification          | Command Name                          | Function  |
|-------------------------|---------------------------------------|---|
| Verify                  | Batch verify command                  | Compares the contents of the entire memory with the input data.   |
| Erase                   | Batch erase command                   | Erases the contents of the entire memory.   |
| Blank check             | Batch blank check command             | Checks the erasure status of the entire memory.   |
| Data write              | High-speed write command              | Writes data by specifying the write address and number of bytes to be written, and executes a verify check.                           |
|                         | Successive write command              | Writes data from the address following that of the high-speed write command executed immediately before, and executes a verify check. |
| System setting, control | Status read command                   | Obtains the operation status  |
|                         | Oscillation frequency setting command | Sets the oscillation frequency  |
|                         | Erase time setting command            | Sets the erase time for batch erase   |
|                         | Write time setting command            | Sets the write time for writing data  |
|                         | Baud rate setting command             | Sets the baud rate when UART is used  |
|                         | Silicon signature command             | Reads the silicon signature information   |
|                         | Reset command                         | Escapes from each status  |

The  $\mu$ PD78F0103 return a response command for the command issued by the dedicated flash programmer. The response commands sent from the  $\mu$ PD78F0103 are listed below.

**Table 21-8. Response Commands**

| Command Name | Function                           |
|--------------|------------------------------------|
| ACK          | Acknowledges command/data.         |
| NAK          | Acknowledges illegal command/data. |

## CHAPTER 22 INSTRUCTION SET

This chapter lists each instruction set of the 78K0/KB1 in table form. For details of each operation and operation code, refer to the separate document **78K0 Series Instructions User's Manual (U12326E)**.

### 22.1 Conventions Used in Operation List

#### 22.1.1 Operand identifiers and specification methods

Operands are written in the "Operand" column of each instruction in accordance with the specification method of the instruction operand identifier (refer to the assembler specifications for details). When there are two or more methods, select one of them. Uppercase letters and the symbols #, !, \$ and [ ] are keywords and must be written as they are. Each symbol has the following meaning.

- #: Immediate data specification
- !: Absolute address specification
- \$: Relative address specification
- [ ]: Indirect address specification

In the case of immediate data, describe an appropriate numeric value or a label. When using a label, be sure to write the #, !, \$, and [ ] symbols.

For operand register identifiers r and rp, either function names (X, A, C, etc.) or absolute names (names in parentheses in the table below, R0, R1, R2, etc.) can be used for specification.

**Table 22-1. Operand Identifiers and Specification Methods**

| Identifier | Specification Method   |
|------------|--|
| r          | X (R0), A (R1), C (R2), B (R3), E (R4), D (R5), L (R6), H (R7)   |
| rp         | AX (RP0), BC (RP1), DE (RP2), HL (RP3)   |
| sfr        | Special function register symbol <sup>Note</sup>   |
| sfrp       | Special function register symbol (16-bit manipulatable register even addresses only) <sup>Note</sup>   |
| saddr      | FE20H to FF1FH Immediate data or labels  |
| saddrp     | FE20H to FF1FH Immediate data or labels (even address only)  |
| addr16     | 0000H to FFFFH Immediate data or labels<br>(Only even addresses for 16-bit data transfer instructions) |
| addr11     | 0800H to 0FFFH Immediate data or labels  |
| addr5      | 0040H to 007FH Immediate data or labels (even address only)  |
| word       | 16-bit immediate data or label   |
| byte       | 8-bit immediate data or label  |
| bit        | 3-bit immediate data or label  |
| RBn        | RB0 to RB3   |

**Note** Addresses from FFD0H to FFDFH cannot be accessed with these operands.

**Remark** For special function register symbols, see **Table 3-5 Special Function Register List**.

**22.1.2 Description of operation column**

|                                   |  |
|-----------------------------------|--|
| A:                                | A register; 8-bit accumulator  |
| X:                                | X register   |
| B:                                | B register   |
| C:                                | C register   |
| D:                                | D register   |
| E:                                | E register   |
| H:                                | H register   |
| L:                                | L register   |
| AX:                               | AX register pair; 16-bit accumulator                                     |
| BC:                               | BC register pair   |
| DE:                               | DE register pair   |
| HL:                               | HL register pair   |
| PC:                               | Program counter  |
| SP:                               | Stack pointer  |
| PSW:                              | Program status word  |
| CY:                               | Carry flag   |
| AC:                               | Auxiliary carry flag   |
| Z:                                | Zero flag  |
| RBS:                              | Register bank select flag  |
| IE:                               | Interrupt request enable flag  |
| ( ):                              | Memory contents indicated by address or register contents in parentheses |
| X <sub>H</sub> , X <sub>L</sub> : | Higher 8 bits and lower 8 bits of 16-bit register                        |
| ∧:                                | Logical product (AND)  |
| ∨:                                | Logical sum (OR)   |
| ⊕:                                | Exclusive logical sum (exclusive OR)                                     |
| —:                                | Inverted data  |
| addr16:                           | 16-bit immediate data or label   |
| jdisp8:                           | Signed 8-bit data (displacement value)                                   |

**22.1.3 Description of flag operation column**

|          |                                     |
|----------|-------------------------------------|
| (Blank): | Not affected                        |
| 0:       | Cleared to 0                        |
| 1:       | Set to 1                            |
| ×:       | Set/cleared according to the result |
| R:       | Previously saved value is restored  |



## 22.2 Operation List

| Instruction Group   | Mnemonic    | Operands                   | Bytes | Clocks       |              | Operation       | Flag |    |    |   |
|---------------------|-------------|----------------------------|-------|--------------|--------------|-----------------|------|----|----|---|
|                     |             |                            |       | Note 1       | Note 2       |                 | Z    | AC | CY |   |
| 8-bit data transfer | <b>MOV</b>  | r, #byte                   | 2     | 4            | –            | r ← byte        |      |    |    |   |
|                     |             | saddr, #byte               | 3     | 6            | 7            | (saddr) ← byte  |      |    |    |   |
|                     |             | sfr, #byte                 | 3     | –            | 7            | sfr ← byte      |      |    |    |   |
|                     |             | A, r <small>Note 3</small> | 1     | 2            | –            | A ← r           |      |    |    |   |
|                     |             | r, A <small>Note 3</small> | 1     | 2            | –            | r ← A           |      |    |    |   |
|                     |             | A, saddr                   | 2     | 4            | 5            | A ← (saddr)     |      |    |    |   |
|                     |             | saddr, A                   | 2     | 4            | 5            | (saddr) ← A     |      |    |    |   |
|                     |             | A, sfr                     | 2     | –            | 5            | A ← sfr         |      |    |    |   |
|                     |             | sfr, A                     | 2     | –            | 5            | sfr ← A         |      |    |    |   |
|                     |             | A, !addr16                 | 3     | 8            | 9            | A ← (addr16)    |      |    |    |   |
|                     |             | !addr16, A                 | 3     | 8            | 9            | (addr16) ← A    |      |    |    |   |
|                     |             | PSW, #byte                 | 3     | –            | 7            | PSW ← byte      |      | x  | x  | x |
|                     |             | A, PSW                     | 2     | –            | 5            | A ← PSW         |      |    |    |   |
|                     |             | PSW, A                     | 2     | –            | 5            | PSW ← A         |      | x  | x  | x |
|                     |             | A, [DE]                    | 1     | 4            | 5            | A ← (DE)        |      |    |    |   |
|                     |             | [DE], A                    | 1     | 4            | 5            | (DE) ← A        |      |    |    |   |
|                     |             | A, [HL]                    | 1     | 4            | 5            | A ← (HL)        |      |    |    |   |
|                     |             | [HL], A                    | 1     | 4            | 5            | (HL) ← A        |      |    |    |   |
|                     |             | A, [HL + byte]             | 2     | 8            | 9            | A ← (HL + byte) |      |    |    |   |
|                     |             | [HL + byte], A             | 2     | 8            | 9            | (HL + byte) ← A |      |    |    |   |
|                     | A, [HL + B] | 1                          | 6     | 7            | A ← (HL + B) |                 |      |    |    |   |
|                     | [HL + B], A | 1                          | 6     | 7            | (HL + B) ← A |                 |      |    |    |   |
|                     | A, [HL + C] | 1                          | 6     | 7            | A ← (HL + C) |                 |      |    |    |   |
|                     | [HL + C], A | 1                          | 6     | 7            | (HL + C) ← A |                 |      |    |    |   |
|                     | <b>XCH</b>  | A, r <small>Note 3</small> | 1     | 2            | –            | A ↔ r           |      |    |    |   |
|                     |             | A, saddr                   | 2     | 4            | 6            | A ↔ (saddr)     |      |    |    |   |
|                     |             | A, sfr                     | 2     | –            | 6            | A ↔ sfr         |      |    |    |   |
|                     |             | A, !addr16                 | 3     | 8            | 10           | A ↔ (addr16)    |      |    |    |   |
|                     |             | A, [DE]                    | 1     | 4            | 6            | A ↔ (DE)        |      |    |    |   |
|                     |             | A, [HL]                    | 1     | 4            | 6            | A ↔ (HL)        |      |    |    |   |
|                     |             | A, [HL + byte]             | 2     | 8            | 10           | A ↔ (HL + byte) |      |    |    |   |
|                     |             | A, [HL + B]                | 2     | 8            | 10           | A ↔ (HL + B)    |      |    |    |   |
| A, [HL + C]         | 2           | 8                          | 10    | A ↔ (HL + C) |              |                 |      |    |    |   |

- Notes**
1. When the internal high-speed RAM area is accessed or for an instruction with no data access
  2. When an area except the internal high-speed RAM area is accessed
  3. Except “r = A”

- Remarks**
1. One instruction clock cycle is one cycle of the CPU clock ( $f_{CPU}$ ) selected by the processor clock control register (PCC).
  2. This clock cycle applies to the internal ROM program.

| Instruction Group    | Mnemonic    | Operands                     | Bytes | Clocks |                           | Operation                         | Flag |    |    |
|----------------------|-------------|------------------------------|-------|--------|---------------------------|-----------------------------------|------|----|----|
|                      |             |                              |       | Note 1 | Note 2                    |                                   | Z    | AC | CY |
| 16-bit data transfer | <b>MOVW</b> | rp, #word                    | 3     | 6      | –                         | rp ← word                         |      |    |    |
|                      |             | saddrp, #word                | 4     | 8      | 10                        | (saddrp) ← word                   |      |    |    |
|                      |             | sfrp, #word                  | 4     | –      | 10                        | sfrp ← word                       |      |    |    |
|                      |             | AX, saddrp                   | 2     | 6      | 8                         | AX ← (saddrp)                     |      |    |    |
|                      |             | saddrp, AX                   | 2     | 6      | 8                         | (saddrp) ← AX                     |      |    |    |
|                      |             | AX, sfrp                     | 2     | –      | 8                         | AX ← sfrp                         |      |    |    |
|                      |             | sfrp, AX                     | 2     | –      | 8                         | sfrp ← AX                         |      |    |    |
|                      |             | AX, rp <small>Note 3</small> | 1     | 4      | –                         | AX ← rp                           |      |    |    |
|                      |             | rp, AX <small>Note 3</small> | 1     | 4      | –                         | rp ← AX                           |      |    |    |
|                      |             | AX, !addr16                  | 3     | 10     | 12                        | AX ← (addr16)                     |      |    |    |
|                      |             | !addr16, AX                  | 3     | 10     | 12                        | (addr16) ← AX                     |      |    |    |
|                      | <b>XCHW</b> | AX, rp <small>Note 3</small> | 1     | 4      | –                         | AX ↔ rp                           |      |    |    |
| 8-bit operation      | <b>ADD</b>  | A, #byte                     | 2     | 4      | –                         | A, CY ← A + byte                  | x    | x  | x  |
|                      |             | saddr, #byte                 | 3     | 6      | 8                         | (saddr), CY ← (saddr) + byte      | x    | x  | x  |
|                      |             | A, r <small>Note 4</small>   | 2     | 4      | –                         | A, CY ← A + r                     | x    | x  | x  |
|                      |             | r, A                         | 2     | 4      | –                         | r, CY ← r + A                     | x    | x  | x  |
|                      |             | A, saddr                     | 2     | 4      | 5                         | A, CY ← A + (saddr)               | x    | x  | x  |
|                      |             | A, !addr16                   | 3     | 8      | 9                         | A, CY ← A + (addr16)              | x    | x  | x  |
|                      |             | A, [HL]                      | 1     | 4      | 5                         | A, CY ← A + (HL)                  | x    | x  | x  |
|                      |             | A, [HL + byte]               | 2     | 8      | 9                         | A, CY ← A + (HL + byte)           | x    | x  | x  |
|                      |             | A, [HL + B]                  | 2     | 8      | 9                         | A, CY ← A + (HL + B)              | x    | x  | x  |
|                      | A, [HL + C] | 2                            | 8     | 9      | A, CY ← A + (HL + C)      | x                                 | x    | x  |    |
|                      | <b>ADDC</b> | A, #byte                     | 2     | 4      | –                         | A, CY ← A + byte + CY             | x    | x  | x  |
|                      |             | saddr, #byte                 | 3     | 6      | 8                         | (saddr), CY ← (saddr) + byte + CY | x    | x  | x  |
|                      |             | A, r <small>Note 4</small>   | 2     | 4      | –                         | A, CY ← A + r + CY                | x    | x  | x  |
|                      |             | r, A                         | 2     | 4      | –                         | r, CY ← r + A + CY                | x    | x  | x  |
|                      |             | A, saddr                     | 2     | 4      | 5                         | A, CY ← A + (saddr) + CY          | x    | x  | x  |
|                      |             | A, !addr16                   | 3     | 8      | 9                         | A, CY ← A + (addr16) + CY         | x    | x  | x  |
|                      |             | A, [HL]                      | 1     | 4      | 5                         | A, CY ← A + (HL) + CY             | x    | x  | x  |
|                      |             | A, [HL + byte]               | 2     | 8      | 9                         | A, CY ← A + (HL + byte) + CY      | x    | x  | x  |
|                      |             | A, [HL + B]                  | 2     | 8      | 9                         | A, CY ← A + (HL + B) + CY         | x    | x  | x  |
| A, [HL + C]          |             | 2                            | 8     | 9      | A, CY ← A + (HL + C) + CY | x                                 | x    | x  |    |

- Notes**
1. When the internal high-speed RAM area is accessed or for an instruction with no data access
  2. When an area except the internal high-speed RAM area is accessed
  3. Only when rp = BC, DE or HL
  4. Except “r = A”

- Remarks**
1. One instruction clock cycle is one cycle of the CPU clock (f<sub>CPU</sub>) selected by the processor clock control register (PCC).
  2. This clock cycle applies to the internal ROM program.

| Instruction Group | Mnemonic    | Operands                   | Bytes | Clocks |                           | Operation                         | Flag |    |    |
|-------------------|-------------|----------------------------|-------|--------|---------------------------|-----------------------------------|------|----|----|
|                   |             |                            |       | Note 1 | Note 2                    |                                   | Z    | AC | CY |
| 8-bit operation   | <b>SUB</b>  | A, #byte                   | 2     | 4      | –                         | A, CY ← A – byte                  | x    | x  | x  |
|                   |             | saddr, #byte               | 3     | 6      | 8                         | (saddr), CY ← (saddr) – byte      | x    | x  | x  |
|                   |             | A, r <small>Note 3</small> | 2     | 4      | –                         | A, CY ← A – r                     | x    | x  | x  |
|                   |             | r, A                       | 2     | 4      | –                         | r, CY ← r – A                     | x    | x  | x  |
|                   |             | A, saddr                   | 2     | 4      | 5                         | A, CY ← A – (saddr)               | x    | x  | x  |
|                   |             | A, !addr16                 | 3     | 8      | 9                         | A, CY ← A – (addr16)              | x    | x  | x  |
|                   |             | A, [HL]                    | 1     | 4      | 5                         | A, CY ← A – (HL)                  | x    | x  | x  |
|                   |             | A, [HL + byte]             | 2     | 8      | 9                         | A, CY ← A – (HL + byte)           | x    | x  | x  |
|                   |             | A, [HL + B]                | 2     | 8      | 9                         | A, CY ← A – (HL + B)              | x    | x  | x  |
|                   | A, [HL + C] | 2                          | 8     | 9      | A, CY ← A – (HL + C)      | x                                 | x    | x  |    |
|                   | <b>SUBC</b> | A, #byte                   | 2     | 4      | –                         | A, CY ← A – byte – CY             | x    | x  | x  |
|                   |             | saddr, #byte               | 3     | 6      | 8                         | (saddr), CY ← (saddr) – byte – CY | x    | x  | x  |
|                   |             | A, r <small>Note 3</small> | 2     | 4      | –                         | A, CY ← A – r – CY                | x    | x  | x  |
|                   |             | r, A                       | 2     | 4      | –                         | r, CY ← r – A – CY                | x    | x  | x  |
|                   |             | A, saddr                   | 2     | 4      | 5                         | A, CY ← A – (saddr) – CY          | x    | x  | x  |
|                   |             | A, !addr16                 | 3     | 8      | 9                         | A, CY ← A – (addr16) – CY         | x    | x  | x  |
|                   |             | A, [HL]                    | 1     | 4      | 5                         | A, CY ← A – (HL) – CY             | x    | x  | x  |
|                   |             | A, [HL + byte]             | 2     | 8      | 9                         | A, CY ← A – (HL + byte) – CY      | x    | x  | x  |
|                   |             | A, [HL + B]                | 2     | 8      | 9                         | A, CY ← A – (HL + B) – CY         | x    | x  | x  |
|                   | A, [HL + C] | 2                          | 8     | 9      | A, CY ← A – (HL + C) – CY | x                                 | x    | x  |    |
|                   | <b>AND</b>  | A, #byte                   | 2     | 4      | –                         | A ← A ∧ byte                      | x    |    |    |
|                   |             | saddr, #byte               | 3     | 6      | 8                         | (saddr) ← (saddr) ∧ byte          | x    |    |    |
|                   |             | A, r <small>Note 3</small> | 2     | 4      | –                         | A ← A ∧ r                         | x    |    |    |
|                   |             | r, A                       | 2     | 4      | –                         | r ← r ∧ A                         | x    |    |    |
|                   |             | A, saddr                   | 2     | 4      | 5                         | A ← A ∧ (saddr)                   | x    |    |    |
|                   |             | A, !addr16                 | 3     | 8      | 9                         | A ← A ∧ (addr16)                  | x    |    |    |
|                   |             | A, [HL]                    | 1     | 4      | 5                         | A ← A ∧ (HL)                      | x    |    |    |
|                   |             | A, [HL + byte]             | 2     | 8      | 9                         | A ← A ∧ (HL + byte)               | x    |    |    |
|                   |             | A, [HL + B]                | 2     | 8      | 9                         | A ← A ∧ (HL + B)                  | x    |    |    |
|                   | A, [HL + C] | 2                          | 8     | 9      | A ← A ∧ (HL + C)          | x                                 |      |    |    |

- Notes**
1. When the internal high-speed RAM area is accessed or for an instruction with no data access
  2. When an area except the internal high-speed RAM area is accessed
  3. Except “r = A”

- Remarks**
1. One instruction clock cycle is one cycle of the CPU clock (f<sub>cpu</sub>) selected by the processor clock control register (PCC).
  2. This clock cycle applies to the internal ROM program.

| Instruction Group | Mnemonic   | Operands                   | Bytes | Clocks |        | Operation   | Flag |    |    |
|-------------------|------------|----------------------------|-------|--------|--------|---|------|----|----|
|                   |            |                            |       | Note 1 | Note 2 |   | Z    | AC | CY |
| 8-bit operation   | <b>OR</b>  | A, #byte                   | 2     | 4      | –      | $A \leftarrow A \vee \text{byte}$                             |      | x  |    |
|                   |            | saddr, #byte               | 3     | 6      | 8      | $(\text{saddr}) \leftarrow (\text{saddr}) \vee \text{byte}$   |      | x  |    |
|                   |            | A, r <small>Note 3</small> | 2     | 4      | –      | $A \leftarrow A \vee r$                                       |      | x  |    |
|                   |            | r, A                       | 2     | 4      | –      | $r \leftarrow r \vee A$                                       |      | x  |    |
|                   |            | A, saddr                   | 2     | 4      | 5      | $A \leftarrow A \vee (\text{saddr})$                          |      | x  |    |
|                   |            | A, !addr16                 | 3     | 8      | 9      | $A \leftarrow A \vee (\text{addr16})$                         |      | x  |    |
|                   |            | A, [HL]                    | 1     | 4      | 5      | $A \leftarrow A \vee (\text{HL})$                             |      | x  |    |
|                   |            | A, [HL + byte]             | 2     | 8      | 9      | $A \leftarrow A \vee (\text{HL} + \text{byte})$               |      | x  |    |
|                   |            | A, [HL + B]                | 2     | 8      | 9      | $A \leftarrow A \vee (\text{HL} + B)$                         |      | x  |    |
|                   |            | A, [HL + C]                | 2     | 8      | 9      | $A \leftarrow A \vee (\text{HL} + C)$                         |      | x  |    |
|                   | <b>XOR</b> | A, #byte                   | 2     | 4      | –      | $A \leftarrow A \nabla \text{byte}$                           |      | x  |    |
|                   |            | saddr, #byte               | 3     | 6      | 8      | $(\text{saddr}) \leftarrow (\text{saddr}) \nabla \text{byte}$ |      | x  |    |
|                   |            | A, r <small>Note 3</small> | 2     | 4      | –      | $A \leftarrow A \nabla r$                                     |      | x  |    |
|                   |            | r, A                       | 2     | 4      | –      | $r \leftarrow r \nabla A$                                     |      | x  |    |
|                   |            | A, saddr                   | 2     | 4      | 5      | $A \leftarrow A \nabla (\text{saddr})$                        |      | x  |    |
|                   |            | A, !addr16                 | 3     | 8      | 9      | $A \leftarrow A \nabla (\text{addr16})$                       |      | x  |    |
|                   |            | A, [HL]                    | 1     | 4      | 5      | $A \leftarrow A \nabla (\text{HL})$                           |      | x  |    |
|                   |            | A, [HL + byte]             | 2     | 8      | 9      | $A \leftarrow A \nabla (\text{HL} + \text{byte})$             |      | x  |    |
|                   |            | A, [HL + B]                | 2     | 8      | 9      | $A \leftarrow A \nabla (\text{HL} + B)$                       |      | x  |    |
|                   |            | A, [HL + C]                | 2     | 8      | 9      | $A \leftarrow A \nabla (\text{HL} + C)$                       |      | x  |    |
|                   | <b>CMP</b> | A, #byte                   | 2     | 4      | –      | $A - \text{byte}$   | x    | x  | x  |
|                   |            | saddr, #byte               | 3     | 6      | 8      | $(\text{saddr}) - \text{byte}$                                | x    | x  | x  |
|                   |            | A, r <small>Note 3</small> | 2     | 4      | –      | $A - r$   | x    | x  | x  |
|                   |            | r, A                       | 2     | 4      | –      | $r - A$   | x    | x  | x  |
|                   |            | A, saddr                   | 2     | 4      | 5      | $A - (\text{saddr})$  | x    | x  | x  |
|                   |            | A, !addr16                 | 3     | 8      | 9      | $A - (\text{addr16})$   | x    | x  | x  |
|                   |            | A, [HL]                    | 1     | 4      | 5      | $A - (\text{HL})$   | x    | x  | x  |
|                   |            | A, [HL + byte]             | 2     | 8      | 9      | $A - (\text{HL} + \text{byte})$                               | x    | x  | x  |
|                   |            | A, [HL + B]                | 2     | 8      | 9      | $A - (\text{HL} + B)$   | x    | x  | x  |
|                   |            | A, [HL + C]                | 2     | 8      | 9      | $A - (\text{HL} + C)$   | x    | x  | x  |

- Notes**
1. When the internal high-speed RAM area is accessed or for an instruction with no data access
  2. When an area except the internal high-speed RAM area is accessed
  3. Except “r = A”

- Remarks**
1. One instruction clock cycle is one cycle of the CPU clock ( $f_{\text{CPU}}$ ) selected by the processor clock control register (PCC).
  2. This clock cycle applies to the internal ROM program.

| Instruction Group   | Mnemonic     | Operands      | Bytes | Clocks                          |        | Operation  | Flag |    |    |
|---------------------|--------------|---------------|-------|---------------------------------|--------|--|------|----|----|
|                     |              |               |       | Note 1                          | Note 2 |  | Z    | AC | CY |
| 16-bit operation    | <b>ADDW</b>  | AX, #word     | 3     | 6                               | –      | $AX, CY \leftarrow AX + \text{word}$   | x    | x  | x  |
|                     | <b>SUBW</b>  | AX, #word     | 3     | 6                               | –      | $AX, CY \leftarrow AX - \text{word}$   | x    | x  | x  |
|                     | <b>CMPW</b>  | AX, #word     | 3     | 6                               | –      | $AX - \text{word}$   | x    | x  | x  |
| Multiply/divide     | <b>MULU</b>  | X             | 2     | 16                              | –      | $AX \leftarrow A \times X$   |      |    |    |
|                     | <b>DIVUW</b> | C             | 2     | 25                              | –      | $AX \text{ (Quotient)}, C \text{ (Remainder)} \leftarrow AX \div C$                              |      |    |    |
| Increment/decrement | <b>INC</b>   | r             | 1     | 2                               | –      | $r \leftarrow r + 1$   | x    | x  |    |
|                     |              | saddr         | 2     | 4                               | 6      | $(\text{saddr}) \leftarrow (\text{saddr}) + 1$   | x    | x  |    |
|                     | <b>DEC</b>   | r             | 1     | 2                               | –      | $r \leftarrow r - 1$   | x    | x  |    |
|                     |              | saddr         | 2     | 4                               | 6      | $(\text{saddr}) \leftarrow (\text{saddr}) - 1$   | x    | x  |    |
|                     | <b>INCW</b>  | rp            | 1     | 4                               | –      | $rp \leftarrow rp + 1$   |      |    |    |
|                     | <b>DECW</b>  | rp            | 1     | 4                               | –      | $rp \leftarrow rp - 1$   |      |    |    |
| Rotate              | <b>ROR</b>   | A, 1          | 1     | 2                               | –      | $(CY, A_7 \leftarrow A_0, A_{m-1} \leftarrow A_m) \times 1 \text{ time}$                         |      |    | x  |
|                     | <b>ROL</b>   | A, 1          | 1     | 2                               | –      | $(CY, A_0 \leftarrow A_7, A_{m+1} \leftarrow A_m) \times 1 \text{ time}$                         |      |    | x  |
|                     | <b>RORC</b>  | A, 1          | 1     | 2                               | –      | $(CY \leftarrow A_0, A_7 \leftarrow CY, A_{m-1} \leftarrow A_m) \times 1 \text{ time}$           |      |    | x  |
|                     | <b>ROLC</b>  | A, 1          | 1     | 2                               | –      | $(CY \leftarrow A_7, A_0 \leftarrow CY, A_{m+1} \leftarrow A_m) \times 1 \text{ time}$           |      |    | x  |
|                     | <b>ROR4</b>  | [HL]          | 2     | 10                              | 12     | $A_{3-0} \leftarrow (HL)_{3-0}, (HL)_{7-4} \leftarrow A_{3-0}, (HL)_{3-0} \leftarrow (HL)_{7-4}$ |      |    |    |
|                     | <b>ROL4</b>  | [HL]          | 2     | 10                              | 12     | $A_{3-0} \leftarrow (HL)_{7-4}, (HL)_{3-0} \leftarrow A_{3-0}, (HL)_{7-4} \leftarrow (HL)_{3-0}$ |      |    |    |
| BCD adjustment      | <b>ADJBA</b> |               | 2     | 4                               | –      | Decimal Adjust Accumulator after Addition  | x    | x  | x  |
|                     | <b>ADJBS</b> |               | 2     | 4                               | –      | Decimal Adjust Accumulator after Subtract  | x    | x  | x  |
| Bit manipulate      | <b>MOV1</b>  | CY, saddr.bit | 3     | 6                               | 7      | $CY \leftarrow (\text{saddr.bit})$   |      |    | x  |
|                     |              | CY, sfr.bit   | 3     | –                               | 7      | $CY \leftarrow \text{sfr.bit}$   |      |    | x  |
|                     |              | CY, A.bit     | 2     | 4                               | –      | $CY \leftarrow A.\text{bit}$   |      |    | x  |
|                     |              | CY, PSW.bit   | 3     | –                               | 7      | $CY \leftarrow \text{PSW.bit}$   |      |    | x  |
|                     |              | CY, [HL].bit  | 2     | 6                               | 7      | $CY \leftarrow (HL).\text{bit}$  |      |    | x  |
|                     |              | saddr.bit, CY | 3     | 6                               | 8      | $(\text{saddr.bit}) \leftarrow CY$   |      |    |    |
|                     |              | sfr.bit, CY   | 3     | –                               | 8      | $\text{sfr.bit} \leftarrow CY$   |      |    |    |
|                     |              | A.bit, CY     | 2     | 4                               | –      | $A.\text{bit} \leftarrow CY$   |      |    |    |
|                     |              | PSW.bit, CY   | 3     | –                               | 8      | $\text{PSW.bit} \leftarrow CY$   |      |    | x  |
| [HL].bit, CY        | 2            | 6             | 8     | $(HL).\text{bit} \leftarrow CY$ |        |  |      |    |    |

- Notes**
1. When the internal high-speed RAM area is accessed or for an instruction with no data access
  2. When an area except the internal high-speed RAM area is accessed

- Remarks**
1. One instruction clock cycle is one cycle of the CPU clock ( $f_{CPU}$ ) selected by the processor clock control register (PCC).
  2. This clock cycle applies to the internal ROM program.

| Instruction Group | Mnemonic    | Operands      | Bytes | Clocks |        | Operation  | Flag |    |    |
|-------------------|-------------|---------------|-------|--------|--------|--|------|----|----|
|                   |             |               |       | Note 1 | Note 2 |  | Z    | AC | CY |
| Bit manipulate    | <b>AND1</b> | CY, saddr.bit | 3     | 6      | 7      | $CY \leftarrow CY \wedge (\text{saddr.bit})$     |      |    | ×  |
|                   |             | CY, sfr.bit   | 3     | –      | 7      | $CY \leftarrow CY \wedge \text{sfr.bit}$         |      |    | ×  |
|                   |             | CY, A.bit     | 2     | 4      | –      | $CY \leftarrow CY \wedge A.\text{bit}$           |      |    | ×  |
|                   |             | CY, PSW.bit   | 3     | –      | 7      | $CY \leftarrow CY \wedge \text{PSW.bit}$         |      |    | ×  |
|                   |             | CY, [HL].bit  | 2     | 6      | 7      | $CY \leftarrow CY \wedge (\text{HL}).\text{bit}$ |      |    | ×  |
|                   | <b>OR1</b>  | CY, saddr.bit | 3     | 6      | 7      | $CY \leftarrow CY \vee (\text{saddr.bit})$       |      |    | ×  |
|                   |             | CY, sfr.bit   | 3     | –      | 7      | $CY \leftarrow CY \vee \text{sfr.bit}$           |      |    | ×  |
|                   |             | CY, A.bit     | 2     | 4      | –      | $CY \leftarrow CY \vee A.\text{bit}$             |      |    | ×  |
|                   |             | CY, PSW.bit   | 3     | –      | 7      | $CY \leftarrow CY \vee \text{PSW.bit}$           |      |    | ×  |
|                   |             | CY, [HL].bit  | 2     | 6      | 7      | $CY \leftarrow CY \vee (\text{HL}).\text{bit}$   |      |    | ×  |
|                   | <b>XOR1</b> | CY, saddr.bit | 3     | 6      | 7      | $CY \leftarrow CY \oplus (\text{saddr.bit})$     |      |    | ×  |
|                   |             | CY, sfr.bit   | 3     | –      | 7      | $CY \leftarrow CY \oplus \text{sfr.bit}$         |      |    | ×  |
|                   |             | CY, A.bit     | 2     | 4      | –      | $CY \leftarrow CY \oplus A.\text{bit}$           |      |    | ×  |
|                   |             | CY, PSW.bit   | 3     | –      | 7      | $CY \leftarrow CY \oplus \text{PSW.bit}$         |      |    | ×  |
|                   |             | CY, [HL].bit  | 2     | 6      | 7      | $CY \leftarrow CY \oplus (\text{HL}).\text{bit}$ |      |    | ×  |
|                   | <b>SET1</b> | saddr.bit     | 2     | 4      | 6      | $(\text{saddr.bit}) \leftarrow 1$                |      |    |    |
|                   |             | sfr.bit       | 3     | –      | 8      | $\text{sfr.bit} \leftarrow 1$                    |      |    |    |
|                   |             | A.bit         | 2     | 4      | –      | $A.\text{bit} \leftarrow 1$                      |      |    |    |
|                   |             | PSW.bit       | 2     | –      | 6      | $\text{PSW.bit} \leftarrow 1$                    | ×    | ×  | ×  |
|                   |             | [HL].bit      | 2     | 6      | 8      | $(\text{HL}).\text{bit} \leftarrow 1$            |      |    |    |
|                   | <b>CLR1</b> | saddr.bit     | 2     | 4      | 6      | $(\text{saddr.bit}) \leftarrow 0$                |      |    |    |
|                   |             | sfr.bit       | 3     | –      | 8      | $\text{sfr.bit} \leftarrow 0$                    |      |    |    |
|                   |             | A.bit         | 2     | 4      | –      | $A.\text{bit} \leftarrow 0$                      |      |    |    |
|                   |             | PSW.bit       | 2     | –      | 6      | $\text{PSW.bit} \leftarrow 0$                    | ×    | ×  | ×  |
|                   |             | [HL].bit      | 2     | 6      | 8      | $(\text{HL}).\text{bit} \leftarrow 0$            |      |    |    |
|                   | <b>SET1</b> | CY            | 1     | 2      | –      | $CY \leftarrow 1$                                |      |    | 1  |
|                   | <b>CLR1</b> | CY            | 1     | 2      | –      | $CY \leftarrow 0$                                |      |    | 0  |
|                   | <b>NOT1</b> | CY            | 1     | 2      | –      | $CY \leftarrow \overline{CY}$                    |      |    | ×  |

- Notes**
1. When the internal high-speed RAM area is accessed or for an instruction with no data access
  2. When an area except the internal high-speed RAM area is accessed

- Remarks**
1. One instruction clock cycle is one cycle of the CPU clock ( $f_{\text{CPU}}$ ) selected by the processor clock control register (PCC).
  2. This clock cycle applies to the internal ROM program.

| Instruction Group    | Mnemonic     | Operands  | Bytes | Clocks |                    | Operation   | Flag |    |    |
|----------------------|--------------|-----------|-------|--------|--------------------|---|------|----|----|
|                      |              |           |       | Note 1 | Note 2             |   | Z    | AC | CY |
| Call/return          | <b>CALL</b>  | !addr16   | 3     | 7      | –                  | $(SP - 1) \leftarrow (PC + 3)_H, (SP - 2) \leftarrow (PC + 3)_L,$<br>$PC \leftarrow \text{addr16}, SP \leftarrow SP - 2$  |      |    |    |
|                      | <b>CALLF</b> | !addr11   | 2     | 5      | –                  | $(SP - 1) \leftarrow (PC + 2)_H, (SP - 2) \leftarrow (PC + 2)_L,$<br>$PC_{15-11} \leftarrow 00001, PC_{10-0} \leftarrow \text{addr11},$<br>$SP \leftarrow SP - 2$                             |      |    |    |
|                      | <b>CALLT</b> | [addr5]   | 1     | 6      | –                  | $(SP - 1) \leftarrow (PC + 1)_H, (SP - 2) \leftarrow (PC + 1)_L,$<br>$PC_H \leftarrow (00000000, \text{addr5} + 1),$<br>$PC_L \leftarrow (00000000, \text{addr5}),$<br>$SP \leftarrow SP - 2$ |      |    |    |
|                      | <b>BRK</b>   |           | 1     | 6      | –                  | $(SP - 1) \leftarrow PSW, (SP - 2) \leftarrow (PC + 1)_H,$<br>$(SP - 3) \leftarrow (PC + 1)_L, PC_H \leftarrow (003FH),$<br>$PC_L \leftarrow (003EH), SP \leftarrow SP - 3, IE \leftarrow 0$  |      |    |    |
|                      | <b>RET</b>   |           | 1     | 6      | –                  | $PC_H \leftarrow (SP + 1), PC_L \leftarrow (SP),$<br>$SP \leftarrow SP + 2$   |      |    |    |
|                      | <b>RETI</b>  |           | 1     | 6      | –                  | $PC_H \leftarrow (SP + 1), PC_L \leftarrow (SP),$<br>$PSW \leftarrow (SP + 2), SP \leftarrow SP + 3$  | R    | R  | R  |
|                      | <b>RETB</b>  |           | 1     | 6      | –                  | $PC_H \leftarrow (SP + 1), PC_L \leftarrow (SP),$<br>$PSW \leftarrow (SP + 2), SP \leftarrow SP + 3$  | R    | R  | R  |
| Stack manipulate     | <b>PUSH</b>  | PSW       | 1     | 2      | –                  | $(SP - 1) \leftarrow PSW, SP \leftarrow SP - 1$   |      |    |    |
|                      |              | rp        | 1     | 4      | –                  | $(SP - 1) \leftarrow rp_H, (SP - 2) \leftarrow rp_L,$<br>$SP \leftarrow SP - 2$   |      |    |    |
|                      | <b>POP</b>   | PSW       | 1     | 2      | –                  | $PSW \leftarrow (SP), SP \leftarrow SP + 1$   | R    | R  | R  |
|                      |              | rp        | 1     | 4      | –                  | $rp_H \leftarrow (SP + 1), rp_L \leftarrow (SP),$<br>$SP \leftarrow SP + 2$   |      |    |    |
|                      | <b>MOVW</b>  | SP, #word | 4     | –      | 10                 | $SP \leftarrow \text{word}$   |      |    |    |
|                      |              | SP, AX    | 2     | –      | 8                  | $SP \leftarrow AX$  |      |    |    |
| AX, SP               |              | 2         | –     | 8      | $AX \leftarrow SP$ |   |      |    |    |
| Unconditional branch | <b>BR</b>    | !addr16   | 3     | 6      | –                  | $PC \leftarrow \text{addr16}$   |      |    |    |
|                      |              | \$addr16  | 2     | 6      | –                  | $PC \leftarrow PC + 2 + \text{jdisp8}$  |      |    |    |
|                      |              | AX        | 2     | 8      | –                  | $PC_H \leftarrow A, PC_L \leftarrow X$  |      |    |    |
| Conditional branch   | <b>BC</b>    | \$addr16  | 2     | 6      | –                  | $PC \leftarrow PC + 2 + \text{jdisp8}$ if CY = 1  |      |    |    |
|                      | <b>BNC</b>   | \$addr16  | 2     | 6      | –                  | $PC \leftarrow PC + 2 + \text{jdisp8}$ if CY = 0  |      |    |    |
|                      | <b>BZ</b>    | \$addr16  | 2     | 6      | –                  | $PC \leftarrow PC + 2 + \text{jdisp8}$ if Z = 1   |      |    |    |
|                      | <b>BNZ</b>   | \$addr16  | 2     | 6      | –                  | $PC \leftarrow PC + 2 + \text{jdisp8}$ if Z = 0   |      |    |    |

- Notes**
1. When the internal high-speed RAM area is accessed or for an instruction with no data access
  2. When an area except the internal high-speed RAM area is accessed

- Remarks**
1. One instruction clock cycle is one cycle of the CPU clock ( $f_{CPU}$ ) selected by the processor clock control register (PCC).
  2. This clock cycle applies to the internal ROM program.

| Instruction Group  | Mnemonic     | Operands            | Bytes | Clocks |        | Operation   | Flag |    |    |
|--------------------|--------------|---------------------|-------|--------|--------|---|------|----|----|
|                    |              |                     |       | Note 1 | Note 2 |   | Z    | AC | CY |
| Conditional branch | <b>BT</b>    | saddr.bit, \$addr16 | 3     | 8      | 9      | PC ← PC + 3 + jdisp8 if (saddr.bit) = 1                         |      |    |    |
|                    |              | sfr.bit, \$addr16   | 4     | –      | 11     | PC ← PC + 4 + jdisp8 if sfr.bit = 1                             |      |    |    |
|                    |              | A.bit, \$addr16     | 3     | 8      | –      | PC ← PC + 3 + jdisp8 if A.bit = 1                               |      |    |    |
|                    |              | PSW.bit, \$addr16   | 3     | –      | 9      | PC ← PC + 3 + jdisp8 if PSW.bit = 1                             |      |    |    |
|                    |              | [HL].bit, \$addr16  | 3     | 10     | 11     | PC ← PC + 3 + jdisp8 if (HL).bit = 1                            |      |    |    |
|                    | <b>BF</b>    | saddr.bit, \$addr16 | 4     | 10     | 11     | PC ← PC + 4 + jdisp8 if (saddr.bit) = 0                         |      |    |    |
|                    |              | sfr.bit, \$addr16   | 4     | –      | 11     | PC ← PC + 4 + jdisp8 if sfr.bit = 0                             |      |    |    |
|                    |              | A.bit, \$addr16     | 3     | 8      | –      | PC ← PC + 3 + jdisp8 if A.bit = 0                               |      |    |    |
|                    |              | PSW.bit, \$addr16   | 4     | –      | 11     | PC ← PC + 4 + jdisp8 if PSW.bit = 0                             |      |    |    |
|                    |              | [HL].bit, \$addr16  | 3     | 10     | 11     | PC ← PC + 3 + jdisp8 if (HL).bit = 0                            |      |    |    |
|                    | <b>BTCLR</b> | saddr.bit, \$addr16 | 4     | 10     | 12     | PC ← PC + 4 + jdisp8 if (saddr.bit) = 1 then reset (saddr.bit)  |      |    |    |
|                    |              | sfr.bit, \$addr16   | 4     | –      | 12     | PC ← PC + 4 + jdisp8 if sfr.bit = 1 then reset sfr.bit          |      |    |    |
|                    |              | A.bit, \$addr16     | 3     | 8      | –      | PC ← PC + 3 + jdisp8 if A.bit = 1 then reset A.bit              |      |    |    |
|                    |              | PSW.bit, \$addr16   | 4     | –      | 12     | PC ← PC + 4 + jdisp8 if PSW.bit = 1 then reset PSW.bit          | ×    | ×  | ×  |
|                    |              | [HL].bit, \$addr16  | 3     | 10     | 12     | PC ← PC + 3 + jdisp8 if (HL).bit = 1 then reset (HL).bit        |      |    |    |
|                    | <b>DBNZ</b>  | B, \$addr16         | 2     | 6      | –      | B ← B – 1, then PC ← PC + 2 + jdisp8 if B ≠ 0                   |      |    |    |
|                    |              | C, \$addr16         | 2     | 6      | –      | C ← C – 1, then PC ← PC + 2 + jdisp8 if C ≠ 0                   |      |    |    |
|                    |              | saddr, \$addr16     | 3     | 8      | 10     | (saddr) ← (saddr) – 1, then PC ← PC + 3 + jdisp8 if (saddr) ≠ 0 |      |    |    |
| CPU control        | <b>SEL</b>   | RBn                 | 2     | 4      | –      | RBS1, 0 ← n   |      |    |    |
|                    | <b>NOP</b>   |                     | 1     | 2      | –      | No Operation  |      |    |    |
|                    | <b>EI</b>    |                     | 2     | –      | 6      | IE ← 1 (Enable Interrupt)                                       |      |    |    |
|                    | <b>DI</b>    |                     | 2     | –      | 6      | IE ← 0 (Disable Interrupt)                                      |      |    |    |
|                    | <b>HALT</b>  |                     | 2     | 6      | –      | Set HALT Mode   |      |    |    |
|                    | <b>STOP</b>  |                     | 2     | 6      | –      | Set STOP Mode   |      |    |    |

- Notes**
1. When the internal high-speed RAM area is accessed or for an instruction with no data access
  2. When an area except the internal high-speed RAM area is accessed

- Remarks**
1. One instruction clock cycle is one cycle of the CPU clock ( $f_{CPU}$ ) selected by the processor clock control register (PCC).
  2. This clock cycle applies to the internal ROM program.



### 22.3 Instructions Listed by Addressing Type

(1) 8-bit instructions

MOV, XCH, ADD, ADDC, SUB, SUBC, AND, OR, XOR, CMP, MULU, DIVUW, INC, DEC, ROR, ROL, RORC, ROLC, ROR4, ROL4, PUSH, POP, DBNZ

| Second Operand<br>First Operand     | #byte  | A  | r <sup>Note</sup>   | sfr        | saddr   | !addr16   | PSW | [DE]       | [HL]  | [HL+byte]<br>[HL + B]<br>[HL + C]                                   | \$saddr16 | 1                          | None         |
|-------------------------------------|--|--|---|------------|---|---|-----|------------|---|---|-----------|----------------------------|--------------|
| A                                   | ADD<br>ADDC<br>SUB<br>SUBC<br>AND<br>OR<br>XOR<br>CMP        |  | MOV<br>XCH<br>ADD<br>ADDC<br>SUB<br>SUBC<br>AND<br>OR<br>XOR<br>CMP | MOV<br>XCH | MOV<br>XCH<br>ADD<br>ADDC<br>SUB<br>SUBC<br>AND<br>OR<br>XOR<br>CMP | MOV<br>XCH<br>ADD<br>ADDC<br>SUB<br>SUBC<br>AND<br>OR<br>XOR<br>CMP | MOV | MOV<br>XCH | MOV<br>XCH<br>ADD<br>ADDC<br>SUB<br>SUBC<br>AND<br>OR<br>XOR<br>CMP | MOV<br>XCH<br>ADD<br>ADDC<br>SUB<br>SUBC<br>AND<br>OR<br>XOR<br>CMP |           | ROR<br>ROL<br>RORC<br>ROLC |              |
| r                                   | MOV  | MOV<br>ADD<br>ADDC<br>SUB<br>SUBC<br>AND<br>OR<br>XOR<br>CMP |   |            |   |   |     |            |   |   |           |                            | INC<br>DEC   |
| B, C                                |  |  |   |            |   |   |     |            |   |   | DBNZ      |                            |              |
| sfr                                 | MOV  | MOV  |   |            |   |   |     |            |   |   |           |                            |              |
| saddr                               | MOV<br>ADD<br>ADDC<br>SUB<br>SUBC<br>AND<br>OR<br>XOR<br>CMP | MOV  |   |            |   |   |     |            |   |   | DBNZ      |                            | INC<br>DEC   |
| !addr16                             |  | MOV  |   |            |   |   |     |            |   |   |           |                            |              |
| PSW                                 | MOV  | MOV  |   |            |   |   |     |            |   |   |           |                            | PUSH<br>POP  |
| [DE]                                |  | MOV  |   |            |   |   |     |            |   |   |           |                            |              |
| [HL]                                |  | MOV  |   |            |   |   |     |            |   |   |           |                            | ROR4<br>ROL4 |
| [HL + byte]<br>[HL + B]<br>[HL + C] |  | MOV  |   |            |   |   |     |            |   |   |           |                            |              |
| X                                   |  |  |   |            |   |   |     |            |   |   |           |                            | MULU         |
| C                                   |  |  |   |            |   |   |     |            |   |   |           |                            | DIVUW        |

**Note** Except r = A

**(2) 16-bit instructions**

MOVW, XCHW, ADDW, SUBW, CMPW, PUSH, POP, INCW, DECW

| Second Operand<br>First Operand | #word                | AX                   | rp <sup>Note</sup> | sfrp | saddrp | !addr16 | SP   | None                        |
|---------------------------------|----------------------|----------------------|--------------------|------|--------|---------|------|-----------------------------|
| AX                              | ADDW<br>SUBW<br>CMPW |                      | MOVW<br>XCHW       | MOVW | MOVW   | MOVW    | MOVW |                             |
| rp                              | MOVW                 | MOVW <sup>Note</sup> |                    |      |        |         |      | INCW<br>DECW<br>PUSH<br>POP |
| sfrp                            | MOVW                 | MOVW                 |                    |      |        |         |      |                             |
| saddrp                          | MOVW                 | MOVW                 |                    |      |        |         |      |                             |
| !addr16                         |                      | MOVW                 |                    |      |        |         |      |                             |
| SP                              | MOVW                 | MOVW                 |                    |      |        |         |      |                             |

**Note** Only when rp = BC, DE, HL

**(3) Bit manipulation instructions**

MOV1, AND1, OR1, XOR1, SET1, CLR1, NOT1, BT, BF, BTCLR

| Second Operand<br>First Operand | A.bit                       | sfr.bit                     | saddr.bit                   | PSW.bit                     | [HL].bit                    | CY   | \$addr16          | None                 |
|---------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------|-------------------|----------------------|
| A.bit                           |                             |                             |                             |                             |                             | MOV1 | BT<br>BF<br>BTCLR | SET1<br>CLR1         |
| sfr.bit                         |                             |                             |                             |                             |                             | MOV1 | BT<br>BF<br>BTCLR | SET1<br>CLR1         |
| saddr.bit                       |                             |                             |                             |                             |                             | MOV1 | BT<br>BF<br>BTCLR | SET1<br>CLR1         |
| PSW.bit                         |                             |                             |                             |                             |                             | MOV1 | BT<br>BF<br>BTCLR | SET1<br>CLR1         |
| [HL].bit                        |                             |                             |                             |                             |                             | MOV1 | BT<br>BF<br>BTCLR | SET1<br>CLR1         |
| CY                              | MOV1<br>AND1<br>OR1<br>XOR1 | MOV1<br>AND1<br>OR1<br>XOR1 | MOV1<br>AND1<br>OR1<br>XOR1 | MOV1<br>AND1<br>OR1<br>XOR1 | MOV1<br>AND1<br>OR1<br>XOR1 |      |                   | SET1<br>CLR1<br>NOT1 |

**(4) Call instructions/branch instructions**

CALL, CALLF, CALLT, BR, BC, BNC, BZ, BNZ, BT, BF, BTCLR, DBNZ

| Second Operand<br>First Operand | AX | !addr16    | !addr11 | [addr5] | \$addr16                     |
|---------------------------------|----|------------|---------|---------|------------------------------|
| Basic instruction               | BR | CALL<br>BR | CALLF   | CALLT   | BR<br>BC<br>BNC<br>BZ<br>BNZ |
| Compound instruction            |    |            |         |         | BT<br>BF<br>BTCLR<br>DBNZ    |

**(5) Other instructions**

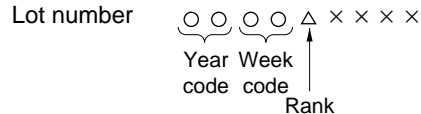
ADJBA, ADJBS, BRK, RET, RETI, RETB, SEL, NOP, EI, DI, HALT, STOP

★ **CHAPTER 23 ELECTRICAL SPECIFICATIONS (STANDARD PRODUCTS, (A) GRADE PRODUCTS) (EXPANDED-SPECIFICATION PRODUCTS)**

Target products (expanded-specification products): Products with a rank<sup>Note</sup> E or after

- $\mu$ PD780101, 780102, 780103, 780101(A), 780102(A), and 780103(A) for which orders were received on or after mid-March, 2004
- $\mu$ PD78F0103 and 78F0103(A) for which orders were received on or after mid-July, 2004

**Note** The rank is indicated by the 5th digit from the left in the 3rd column (lot number) marked on the package.



**Absolute Maximum Ratings (T<sub>A</sub> = 25°C)**

| Parameter                     | Symbol            | Conditions  | Ratings  | Unit |    |
|-------------------------------|-------------------|---|--|------|----|
| Supply voltage                | V <sub>DD</sub>   |   | -0.3 to +6.5   | V    |    |
|                               | V <sub>SS</sub>   |   | -0.3 to +0.3   | V    |    |
|                               | AV <sub>REF</sub> |   | -0.3 to V <sub>DD</sub> + 0.3 <sup>Note 1</sup>  | V    |    |
|                               | AV <sub>SS</sub>  |   | -0.3 to +0.3   | V    |    |
|                               | V <sub>PP</sub>   | $\mu$ PD78F0103, 78F0103(A) only <b>Note 2</b>                                | -0.3 to +10.5  | V    |    |
| Input voltage                 | V <sub>I1</sub>   | P00 to P03, P10 to P17, P20 to P23, P30 to P33, P120, X1, X2, RESET           | -0.3 to V <sub>DD</sub> + 0.3 <sup>Note 1</sup>  | V    |    |
|                               | V <sub>I2</sub>   | V <sub>PP</sub> in flash programming mode ( $\mu$ PD78F0103, 78F0103(A) only) | -0.3 to +10.5  | V    |    |
| Output voltage                | V <sub>O</sub>    |   | -0.3 to V <sub>DD</sub> + 0.3 <sup>Note 1</sup>  | V    |    |
| Analog input voltage          | V <sub>AN</sub>   |   | AV <sub>SS</sub> - 0.3 to AV <sub>REF</sub> + 0.3 <sup>Note 1</sup><br>and -0.3 to V <sub>DD</sub> + 0.3 <sup>Note 1</sup> | V    |    |
| Output current, high          | I <sub>OH</sub>   | Per pin   | -10  | mA   |    |
|                               |                   | Total of pins   | P30 to P33, P120   | -30  | mA |
|                               |                   |   | P00 to P03, P10 to P17, P130   | -30  | mA |
|                               |                   | Total of all pins   | -50  | mA   |    |
| Output current, low           | I <sub>OL</sub>   | Per pin   | 20   | mA   |    |
|                               |                   | Total of pins   | P30 to P33, P120   | 35   | mA |
|                               |                   |   | P00 to P03, P10 to P17, P130   | 35   | mA |
|                               |                   | Total of all pins   | 60   | mA   |    |
| Operating ambient temperature | T <sub>A</sub>    | In normal operation mode  | -40 to +85   | °C   |    |
|                               |                   | In flash memory programming   | -10 to +85   |      |    |
| Storage temperature           | T <sub>stg</sub>  | $\mu$ PD780101, 780102, 780103, 780101(A), 780102(A), 780103(A)               | -65 to +150  | °C   |    |
|                               |                   | $\mu$ PD78F0103, 78F0103(A)   | -40 to +125  |      |    |

**Note 1.** Must be 6.5 V or lower.  
(Refer to **Note 2** on the next page.)

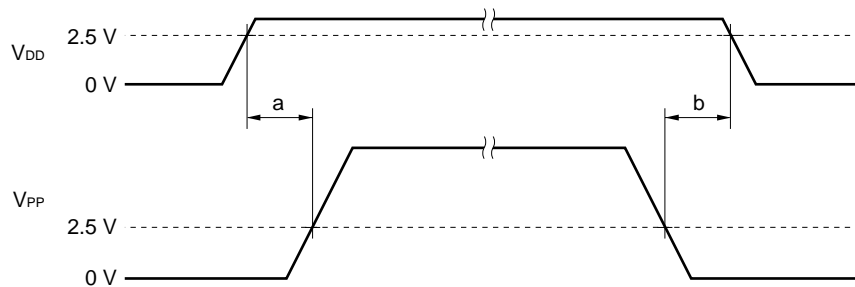
**Note 2.** Make sure that the following conditions of the  $V_{PP}$  voltage application timing are satisfied when the flash memory is written.

- **When supply voltage rises**

$V_{PP}$  must exceed  $V_{DD}$  10  $\mu\text{s}$  or more after  $V_{DD}$  has reached the lower-limit value (2.5 V) of the operating voltage range (see a in the figure below).

- **When supply voltage drops**

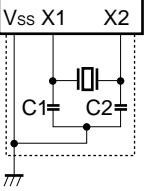
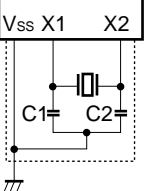
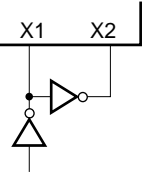
$V_{DD}$  must be lowered 10  $\mu\text{s}$  or more after  $V_{PP}$  falls below the lower-limit value (2.5 V) of the operating voltage range of  $V_{DD}$  (see b in the figure below).



**Caution** Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**X1 Oscillator Characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.5\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Resonator         | Recommended Circuit   | Parameter  | Conditions                                   | MIN. | TYP. | MAX. | Unit |
|-------------------|---|--|--|------|------|------|------|
| Ceramic resonator |  | Oscillation frequency ( $f_{XP}$ ) <sup>Note</sup>       | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 12   | MHz  |
|                   |   |  | $3.5\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 10   |      |
|                   |   |  | $3.0\text{ V} \leq V_{DD} < 3.5\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |   |  | $2.5\text{ V} \leq V_{DD} < 3.0\text{ V}$    | 2.0  |      | 5.0  |      |
| Crystal resonator |  | Oscillation frequency ( $f_{XP}$ ) <sup>Note</sup>       | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 12   | MHz  |
|                   |   |  | $3.5\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 10   |      |
|                   |   |  | $3.0\text{ V} \leq V_{DD} < 3.5\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |   |  | $2.5\text{ V} \leq V_{DD} < 3.0\text{ V}$    | 2.0  |      | 5.0  |      |
| External clock    |  | X1 input frequency ( $f_{XP}$ ) <sup>Note</sup>          | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 12   | MHz  |
|                   |   |  | $3.5\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 10   |      |
|                   |   |  | $3.0\text{ V} \leq V_{DD} < 3.5\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |   |  | $2.5\text{ V} \leq V_{DD} < 3.0\text{ V}$    | 2.0  |      | 5.0  |      |
|                   |   | X1 input high-/low-level width ( $t_{XPH}$ , $t_{XPL}$ ) | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 38   |      | 500  | ns   |
|                   |   |  | $3.5\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 46   |      | 500  |      |
|                   |   |  | $3.0\text{ V} \leq V_{DD} < 3.5\text{ V}$    | 56   |      | 500  |      |
|                   |   |  | $2.5\text{ V} \leq V_{DD} < 3.0\text{ V}$    | 96   |      | 500  |      |

**Note** Indicates only oscillator characteristics. Refer to **AC Characteristics** for instruction execution time.

**Cautions 1.** When using the X1 oscillator, wire as follows in the area enclosed by the broken lines in the above figures to avoid an adverse effect from wiring capacitance.

- Keep the wiring length as short as possible.
- Do not cross the wiring with the other signal lines.
- Do not route the wiring near a signal line through which a high fluctuating current flows.
- Always make the ground point of the oscillator capacitor the same potential as V<sub>SS</sub>.
- Do not ground the capacitor to a ground pattern through which a high current flows.
- Do not fetch signals from the oscillator.

2. Since the CPU is started by the Ring-OSC after reset is released, check the oscillation stabilization time of the X1 input clock using the oscillation stabilization time counter status register (OSTC). Determine the oscillation stabilization time of the OSTC register and oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.

**Ring-OSC Oscillator Characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.5\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Resonator                   | Parameter                       | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------|---------------------------------|------------|------|------|------|------|
| On-chip Ring-OSC oscillator | Oscillation frequency ( $f_R$ ) |            | 120  | 240  | 480  | kHz  |

## Recommended Oscillator Constants

**Caution** For the resonator selection of the  $\mu$ PD780101(A), 780102(A), and 780103(A) and oscillator constants, users are required to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation.

(a)  $\mu$ PD780101, 780102, 780103

X1 oscillation: Ceramic resonator ( $T_A = -40$  to  $+85^\circ\text{C}$ )

| Manufacturer     | Part Number      | SMD/Lead | Frequency (MHz) | Recommended Circuit Constants |               | Oscillation Voltage Range |          |
|------------------|------------------|----------|-----------------|-------------------------------|---------------|---------------------------|----------|
|                  |                  |          |                 | C1 (pF)                       | C2 (pF)       | MIN. (V)                  | MAX. (V) |
| Murata Mfg.      | CSTCC2M00G56-R0  | SMD      | 2.00            | Internal (47)                 | Internal (47) | 2.5                       | 5.5      |
|                  | CSTCR4M00G55-R0  | SMD      | 4.00            | Internal (39)                 | Internal (39) |                           |          |
|                  | CSTCR4M00G55U-R0 |          |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS4M00G56-B0  | Lead     |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS4M00G56U-B0 |          |                 | Internal (39)                 | Internal (39) |                           |          |
|                  | CSTCR4M19G55-R0  | SMD      | 4.194           | Internal (39)                 | Internal (39) |                           |          |
|                  | CSTCR4M19G55U-R0 |          |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS4M19G56-B0  | Lead     |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS4M19G56U-B0 |          |                 | Internal (39)                 | Internal (39) |                           |          |
|                  | CSTCR4M91G55-R0  | SMD      | 4.915           | Internal (39)                 | Internal (39) |                           |          |
|                  | CSTCR4M91G55U-R0 |          |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS4M91G56-B0  | Lead     |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS4M91G56U-B0 |          |                 | Internal (39)                 | Internal (39) | 2.5                       |          |
|                  | CSTCR5M00G55-R0  | SMD      | 5.00            | Internal (39)                 | Internal (39) | 2.6                       |          |
|                  | CSTCR5M00G55U-R0 |          |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS5M00G56-B0  | Lead     |                 | Internal (47)                 | Internal (47) | 2.5                       |          |
|                  | CSTLS5M00G56U-B0 |          |                 | Internal (39)                 | Internal (39) | 2.7                       |          |
|                  | CSTCR6M00G55-R0  | SMD      | 6.00            | Internal (39)                 | Internal (39) | 2.5                       |          |
|                  | CSTCR6M00G55U-R0 |          |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS6M00G56-B0  | Lead     |                 | Internal (47)                 | Internal (47) |                           |          |
|                  | CSTLS6M00G56U-B0 |          |                 | Internal (10)                 | Internal (10) |                           |          |
|                  | CSTCE8M00G52-R0  | SMD      | 8.00            | Internal (15)                 | Internal (15) |                           |          |
|                  | CSTLS8M00G53-B0  |          |                 | Internal (10)                 | Internal (10) |                           |          |
|                  | CSTLS8M00G53U-B0 | Lead     |                 | Internal (15)                 | Internal (15) |                           |          |
| CSTCE10M0G52-R0  | Internal (10)    |          |                 | Internal (10)                 |               |                           |          |
| CSTLS10M0G53-B0  | SMD              | 10.0     | Internal (15)   | Internal (15)                 |               |                           |          |
| CSTLS10M0G53U-B0 |                  |          | Internal (10)   | Internal (10)                 |               |                           |          |
| CSTCE12M0G52-R0  | SMD              | 12.0     | Internal (10)   | Internal (10)                 |               |                           |          |

**Caution** The oscillator constants shown above are reference values based on evaluation in a specific environment by the resonator manufacturer. If it is necessary to optimize the oscillator characteristics in the actual application, apply to the resonator manufacturer for evaluation on the implementation circuit. The oscillation voltage and oscillation frequency only indicate the oscillator characteristic. Use the 78K0/KB1 so that the internal operation conditions are within the specifications of the DC and AC characteristics.

(b)  $\mu$ PD78F0103X1 oscillation: Ceramic resonator ( $T_A = -40$  to  $+85^\circ\text{C}$ )

| Manufacturer    | Part Number        | SMD/Lead | Frequency (MHz) | Recommended Circuit Constants |               | Oscillation Voltage Range |          |
|-----------------|--------------------|----------|-----------------|-------------------------------|---------------|---------------------------|----------|
|                 |                    |          |                 | C1 (pF)                       | C2 (pF)       | MIN. (V)                  | MAX. (V) |
| Murata Mfg.     | CSTCC2M00G56-R0    | SMD      | 2.00            | Internal (47)                 | Internal (47) | 2.5                       | 5.5      |
|                 | CSTCC2M45G56-R0    | SMD      | 2.457           | Internal (47)                 | Internal (47) |                           |          |
|                 | CSTCR4M00G53-R0    | SMD      | 4.00            | Internal (15)                 | Internal (15) |                           |          |
|                 | CSTCR4M00G53093-R0 |          |                 |                               |               |                           |          |
|                 | CSTLS4M00G53-B0    | Lead     |                 | Internal (15)                 | Internal (15) |                           |          |
|                 | CSTLS4M00G53093-B0 |          |                 |                               |               |                           |          |
|                 | CSTCR5M00G53-R0    | SMD      | 5.00            | Internal (15)                 | Internal (15) |                           |          |
|                 | CSTCR5M00G53093-R0 |          |                 |                               |               |                           |          |
|                 | CSTLS5M00G53-B0    | Lead     |                 | Internal (15)                 | Internal (15) |                           |          |
|                 | CSTLS5M00G53093-B0 |          |                 |                               |               |                           |          |
|                 | CSTCR6M00G53-R0    | SMD      | 6.00            | Internal (15)                 | Internal (15) |                           |          |
|                 | CSTCR6M00G53U-R0   |          |                 |                               |               |                           |          |
|                 | CSTLS6M00G53-B0    | Lead     |                 | Internal (15)                 | Internal (15) |                           |          |
|                 | CSTLS6M00G53U-B0   |          |                 |                               |               |                           |          |
|                 | CSTCE8M38G52-R0    | SMD      | 8.388           | Internal (10)                 | Internal (10) |                           |          |
|                 | CSTLS8M38G53-B0    | Lead     |                 |                               |               |                           |          |
|                 | CSTLS8M38G53093-B0 |          |                 |                               |               |                           |          |
|                 | CSTCE10M0G52-R0    | SMD      | 10.0            | Internal (10)                 | Internal (10) |                           |          |
|                 | CSTLS10M0G53-B0    | Lead     |                 |                               |               |                           |          |
|                 | CSTLS10M0G53093-B0 |          |                 |                               |               |                           |          |
| CSTCE12M0G52-R0 | SMD                | 12.0     | Internal (10)   | Internal (10)                 |               |                           |          |

**Caution** The oscillator constants shown above are reference values based on evaluation in a specific environment by the resonator manufacturer. If it is necessary to optimize the oscillator characteristics in the actual application, apply to the resonator manufacturer for evaluation on the implementation circuit. The oscillation voltage and oscillation frequency only indicate the oscillator characteristic. Use the 78K0/KB1 so that the internal operation conditions are within the specifications of the DC and AC characteristics.



(c)  $\mu$ PD78F0103(A)X1 oscillation: Ceramic resonator ( $T_A = -40$  to  $+85^\circ\text{C}$ )

| Manufacturer | Part Number      | SMD/Lead | Frequency (MHz) | Recommended Circuit Constants |               | Oscillation Voltage Range |          |
|--------------|------------------|----------|-----------------|-------------------------------|---------------|---------------------------|----------|
|              |                  |          |                 | C1 (pF)                       | C2 (pF)       | MIN. (V)                  | MAX. (V) |
| Murata Mfg.  | CSTCC2M00G56A-R0 | SMD      | 2.00            | Internal (47)                 | Internal (47) | 2.5                       | 5.5      |
|              | CSTCC2M45G56A-R0 |          | 2.457           | Internal (47)                 | Internal (47) |                           |          |
|              | CSTCR4M00G53A-R0 |          | 4.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCR5M00G53A-R0 |          | 5.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCR6M00G53A-R0 |          | 6.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCE8M38G52A-R0 |          | 8.388           | Internal (10)                 | Internal (10) |                           |          |
|              | CSTCE10M0G52A-R0 |          | 10.0            | Internal (10)                 | Internal (10) |                           |          |
|              | CSTCE12M0G52A-R0 |          | 12.0            | Internal (10)                 | Internal (10) |                           |          |

**Caution** The oscillator constants shown above are reference values based on evaluation in a specific environment by the resonator manufacturer. If it is necessary to optimize the oscillator characteristics in the actual application, apply to the resonator manufacturer for evaluation on the implementation circuit. The oscillation voltage and oscillation frequency only indicate the oscillator characteristic. Use the 78K0/KB1 so that the internal operation conditions are within the specifications of the DC and AC characteristics.

DC Characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.5\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ ) (1/4)

| Parameter            | Symbol    | Conditions   | MIN.  | TYP.           | MAX. | Unit          |    |
|----------------------|-----------|--|---|----------------|------|---------------|----|
| Output current, high | $I_{OH}$  | Per pin  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | -5            | mA |
|                      |           | Total of P30 to P33, P120  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | -25           | mA |
|                      |           | Total of P00 to P03, P10 to P17, P130                                  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | -25           | mA |
|                      |           | Total of all pins  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | -40           | mA |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |                |      | -10           | mA |
| Output current, low  | $I_{OL}$  | Per pin  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | 10            | mA |
|                      |           | Total of P30 to P33, P120  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | 30            | mA |
|                      |           | Total of P00 to P03, P10 to P17, P130                                  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | 30            | mA |
|                      |           | Total of all pins  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | 50            | mA |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |                |      | 10            | mA |
| Input voltage, high  | $V_{IH1}$ | P12, P13, P15  | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              | $0.7V_{DD}$    |      | $V_{DD}$      | V  |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$                                 | $0.8V_{DD}$    |      | $V_{DD}$      | V  |
|                      | $V_{IH2}$ | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET           | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              | $0.8V_{DD}$    |      | $V_{DD}$      | V  |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$                                 | $0.85V_{DD}$   |      | $V_{DD}$      | V  |
|                      | $V_{IH3}$ | P20 to P23 <sup>Note</sup>   | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              | $0.7AV_{REF}$  |      | $AV_{REF}$    | V  |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$                                 | $0.8AV_{REF}$  |      | $AV_{REF}$    | V  |
|                      | $V_{IH4}$ | X1, X2   | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              | $V_{DD} - 0.5$ |      | $V_{DD}$      | V  |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$                                 | $V_{DD} - 0.2$ |      | $V_{DD}$      | V  |
| Input voltage, low   | $V_{IL1}$ | P12, P13, P15  | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              | 0              |      | $0.3V_{DD}$   | V  |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$                                 | 0              |      | $0.2V_{DD}$   | V  |
|                      | $V_{IL2}$ | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET           | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              | 0              |      | $0.2V_{DD}$   | V  |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$                                 | 0              |      | $0.15V_{DD}$  | V  |
|                      | $V_{IL3}$ | P20 to P23 <sup>Note</sup>   | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              | 0              |      | $0.3AV_{REF}$ | V  |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$                                 | 0              |      | $0.2AV_{REF}$ | V  |
|                      | $V_{IL4}$ | X1, X2   | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              | 0              |      | 0.4           | V  |
|                      |           |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$                                 | 0              |      | 0.2           | V  |
| Output voltage, high | $V_{OH}$  | Total of P30 to P33, P120 pins<br>$I_{OH} = -25\text{ mA}$             | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OH} = -5\text{ mA}$ | $V_{DD} - 1.0$ |      |               | V  |
|                      |           | Total of P00 to P03, P10 to P17, P130 pins<br>$I_{OH} = -25\text{ mA}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OH} = -5\text{ mA}$ | $V_{DD} - 1.0$ |      |               | V  |
|                      |           | $I_{OH} = -100\text{ }\mu\text{A}$                                     | $2.5\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 | $V_{DD} - 0.5$ |      |               | V  |
| Output voltage, low  | $V_{OL}$  | Total of P30 to P33, P120 pins<br>$I_{OL} = 30\text{ mA}$              | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OL} = 10\text{ mA}$ |                |      | 1.3           | V  |
|                      |           | Total of P00 to P03, P10 to P17, P130 pins<br>$I_{OL} = 30\text{ mA}$  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OL} = 10\text{ mA}$ |                |      | 1.3           | V  |
|                      |           | $I_{OL} = 400\text{ }\mu\text{A}$                                      | $2.5\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |                |      | 0.4           | V  |

**Note** When used as a digital input port, set  $AV_{REF} = V_{DD}$ .

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**DC Characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.5\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ ) (2/4)**

| Parameter  | Symbol            | Conditions               |   | MIN. | TYP. | MAX.               | Unit          |
|--|-------------------|--------------------------|---|------|------|--------------------|---------------|
| Input leakage current, high  | I <sub>LIH1</sub> | $V_I = V_{DD}$           | P00 to P03, P10 to P17, P30 to P33, P120, RESET             |      |      | 3                  | $\mu\text{A}$ |
|  |                   | $V_I = AV_{REF}$         | P20 to P23  |      |      | 3                  | $\mu\text{A}$ |
|  | I <sub>LIH2</sub> | $V_I = V_{DD}$           | X1, X2 <sup>Note</sup>                                      |      |      | 20                 | $\mu\text{A}$ |
| Input leakage current, low   | I <sub>LIL1</sub> | $V_I = 0\text{ V}$       | P00 to P03, P10 to P17, P20 to P23, P30 to P33, P120, RESET |      |      | -3                 | $\mu\text{A}$ |
|  | I <sub>LIL2</sub> |                          | X1, X2 <sup>Note</sup>                                      |      |      | -20                | $\mu\text{A}$ |
| Output leakage current, high   | I <sub>LOH</sub>  | $V_O = V_{DD}$           |   |      |      | 3                  | $\mu\text{A}$ |
| Output leakage current, low  | I <sub>LOL</sub>  | $V_O = 0\text{ V}$       |   |      |      | -3                 | $\mu\text{A}$ |
| Pull-up resistance value   | R                 | $V_I = 0\text{ V}$       |   | 10   | 30   | 100                | k $\Omega$    |
| V <sub>PP</sub> supply voltage<br>( $\mu\text{PD78F0103}$ , 78F0103(A) only) | V <sub>PP1</sub>  | In normal operation mode |   | 0    |      | 0.2V <sub>DD</sub> | V             |

**Note** When the inverse level of X1 is input to X2.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

DC Characteristics (3/4):  $\mu$ PD78F0103, 78F0103(A)(T<sub>A</sub> = -40 to +85°C, 2.5 V ≤ V<sub>DD</sub> ≤ 5.5 V, 2.5 V ≤ AV<sub>REF</sub> ≤ V<sub>DD</sub>, V<sub>SS</sub> = AV<sub>SS</sub> = 0 V)

| Parameter                        | Symbol                               | Conditions  |   | MIN.  | TYP. | MAX. | Unit |    |
|----------------------------------|--------------------------------------|---|---|---|------|------|------|----|
| Supply current <sup>Note 1</sup> | I <sub>DD1</sub>                     | X1 crystal oscillation operating mode <sup>Note 2</sup> | f <sub>XP</sub> = 12 MHz,<br>V <sub>DD</sub> = 5.0 V ±10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 14   | 23.4 | mA |
|                                  |                                      |   |   | When A/D converter is operating <sup>Note 4</sup> |      | 15   | 25.4 | mA |
|                                  |                                      |   | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V ±10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 11.6 | 19.5 | mA |
|                                  |                                      |   |   | When A/D converter is operating <sup>Note 4</sup> |      | 12.6 | 21.5 | mA |
|                                  |                                      |   | f <sub>XP</sub> = 5 MHz,<br>V <sub>DD</sub> = 3.0 V ±10% <sup>Note 3</sup>  | When A/D converter is stopped                     |      | 4    | 6.4  | mA |
|                                  |                                      |   |   | When A/D converter is operating <sup>Note 4</sup> |      | 4.6  | 7.6  | mA |
|                                  | I <sub>DD2</sub>                     | X1 crystal oscillation HALT mode                        | f <sub>XP</sub> = 12 MHz,<br>V <sub>DD</sub> = 5.0 V ±10%                   | When peripheral functions are stopped             |      | 1.6  | 3.2  | mA |
|                                  |                                      |   |   | When peripheral functions are operating           |      |      | 6.4  | mA |
|                                  |                                      |   | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V ±10%                   | When peripheral functions are stopped             |      | 1.4  | 2.8  | mA |
|                                  |                                      |   |   | When peripheral functions are operating           |      |      | 5.5  | mA |
|                                  |                                      |   | f <sub>XP</sub> = 5 MHz,<br>V <sub>DD</sub> = 3.0 V ±10%                    | When peripheral functions are stopped             |      | 0.32 | 0.64 | mA |
|                                  |                                      |   |   | When peripheral functions are operating           |      |      | 1.9  | mA |
|                                  | I <sub>DD3</sub>                     | Ring-OSC operating mode <sup>Note 5</sup>               | V <sub>DD</sub> = 5.0 V ±10%  |   |      | 0.37 | 1.51 | mA |
|                                  |                                      |   | V <sub>DD</sub> = 3.0 V ±10%  |   |      | 0.29 | 1.16 | mA |
| I <sub>DD4</sub>                 | Ring-OSC HALT mode <sup>Note 5</sup> | V <sub>DD</sub> = 5.0 V ±10%                            |   |   | 0.19 | 0.76 | mA   |    |
|                                  |                                      | V <sub>DD</sub> = 3.0 V ±10%                            |   |   | 0.16 | 0.64 | mA   |    |
| I <sub>DD5</sub>                 | STOP mode                            | V <sub>DD</sub> = 5.0 V ±10%                            | POC: OFF, RING: OFF   |   |      | 0.1  | 30   | μA |
|                                  |                                      |   | POC: OFF, RING: ON  |   |      | 14   | 58   | μA |
|                                  |                                      |   | POC: ON <sup>Note 6</sup> , RING: OFF                                       |   |      | 3.5  | 35.5 | μA |
|                                  |                                      |   | POC: ON <sup>Note 6</sup> , RING: ON  |   |      | 17.5 | 63.5 | μA |
|                                  |                                      | V <sub>DD</sub> = 3.0 V ±10%                            | POC: OFF, RING: OFF   |   |      | 0.05 | 10   | μA |
|                                  |                                      |   | POC: OFF, RING: ON  |   |      | 7.5  | 25   | μA |
|                                  |                                      |   | POC: ON <sup>Note 6</sup> , RING: OFF                                       |   |      | 3.5  | 15.5 | μA |
|                                  |                                      |   | POC: ON <sup>Note 6</sup> , RING: ON  |   |      | 11   | 30.5 | μA |

**Notes** 1. Total current flowing through the internal power supply (V<sub>DD</sub>). Peripheral operation current is included (however, the current that flows through the pull-up resistors of ports is not included).

2. I<sub>DD1</sub> includes peripheral operation current.

3. When PCC = 00H.

4. Total current flowing through V<sub>DD</sub> and AV<sub>REF</sub> pins.

5. When X1 oscillator is stopped.

6. Including when LVIE (bit 4 of LVIM) = 1 in the  $\mu$ PD78F0103M1, 78F0103M2, 78F0103M1(A), and 78F0103M2(A).

**DC Characteristics (4/4):  $\mu$ PD780101, 780102, 780103, 780101(A), 780102(A), 780103(A)**  
**( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.5\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Parameter                        | Symbol  | Conditions  |  | MIN.  | TYP. | MAX. | Unit    |    |
|----------------------------------|---|---|--|---|------|------|---------|----|
| Supply current <sup>Note 1</sup> | I <sub>DD1</sub>  | X1 crystal oscillation operating mode <sup>Note 2</sup> | f <sub>XP</sub> = 12 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 7.2  | 13.1    | mA |
|                                  |   |   |  | When A/D converter is operating <sup>Note 4</sup> |      | 8.2  | 15.1    | mA |
|                                  |   |   | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 6    | 10.9    | mA |
|                                  |   |   |  | When A/D converter is operating <sup>Note 4</sup> |      | 7    | 12.9    | mA |
|                                  | f <sub>XP</sub> = 5 MHz,<br>V <sub>DD</sub> = 3.0 V $\pm$ 10% <sup>Note 3</sup> | When A/D converter is stopped                           |  | 1.7   | 3.1  | mA   |         |    |
|                                  |   | When A/D converter is operating <sup>Note 4</sup>       |  | 2.3   | 4.3  | mA   |         |    |
|                                  | I <sub>DD2</sub>  | X1 crystal oscillation HALT mode                        | f <sub>XP</sub> = 12 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10%                   | When peripheral functions are stopped             |      | 1.5  | 3.0     | mA |
|                                  |   |   |  | When peripheral functions are operating           |      |      | 5.5     | mA |
|                                  |   |   | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10%                   | When peripheral functions are stopped             |      | 1.3  | 2.6     | mA |
|                                  |   |   |  | When peripheral functions are operating           |      |      | 4.8     | mA |
|                                  | f <sub>XP</sub> = 5 MHz,<br>V <sub>DD</sub> = 3.0 V $\pm$ 10%                   | When peripheral functions are stopped                   |  | 0.25  | 0.5  | mA   |         |    |
|                                  |   | When peripheral functions are operating                 |  |   | 1.1  | mA   |         |    |
|                                  | I <sub>DD3</sub>  | Ring-OSC operating mode <sup>Note 5</sup>               | V <sub>DD</sub> = 5.0 V $\pm$ 10%  |   |      | 0.18 | 0.72    | mA |
|                                  |   |   | V <sub>DD</sub> = 3.0 V $\pm$ 10%  |   |      | 0.11 | 0.44    | mA |
|                                  | I <sub>DD4</sub>  | Ring-OSC HALT mode <sup>Note 5</sup>                    | V <sub>DD</sub> = 5.0 V $\pm$ 10%  |   |      | 0.05 | 0.20    | mA |
|                                  |   |   | V <sub>DD</sub> = 3.0 V $\pm$ 10%  |   |      | 0.03 | 0.12    | mA |
| I <sub>DD5</sub>                 | STOP mode   | V <sub>DD</sub> = 5.0 V $\pm$ 10%                       | POC: OFF, RING: OFF  |   | 0.1  | 30   | $\mu$ A |    |
|                                  |   |   | POC: OFF, RING: ON   |   | 14   | 58   | $\mu$ A |    |
|                                  |   |   | POC: ON <sup>Note 6</sup> , RING: OFF  |   | 3.5  | 35.5 | $\mu$ A |    |
|                                  |   |   | POC: ON <sup>Note 6</sup> , RING: ON   |   | 17.5 | 63.5 | $\mu$ A |    |
|                                  |   | V <sub>DD</sub> = 3.0 V $\pm$ 10%                       | POC: OFF, RING: OFF  |   | 0.05 | 10   | $\mu$ A |    |
|                                  |   |   | POC: OFF, RING: ON   |   | 7.5  | 25   | $\mu$ A |    |
|                                  |   |   | POC: ON <sup>Note 6</sup> , RING: OFF  |   | 3.5  | 15.5 | $\mu$ A |    |
|                                  |   |   | POC: ON <sup>Note 6</sup> , RING: ON   |   | 11   | 30.5 | $\mu$ A |    |

- Notes**
- Total current flowing through the internal power supply (V<sub>DD</sub>). Peripheral operation current is included (however, the current that flows through the pull-up resistors of ports is not included).
  - I<sub>DD1</sub> includes peripheral operation current.
  - When PCC = 00H.
  - Total current flowing through V<sub>DD</sub> and AV<sub>REF</sub> pins.
  - When X1 oscillator is stopped.
  - Including when LVIE (bit 4 of LVIM) = 1 with POC-OFF selected by a mask option.

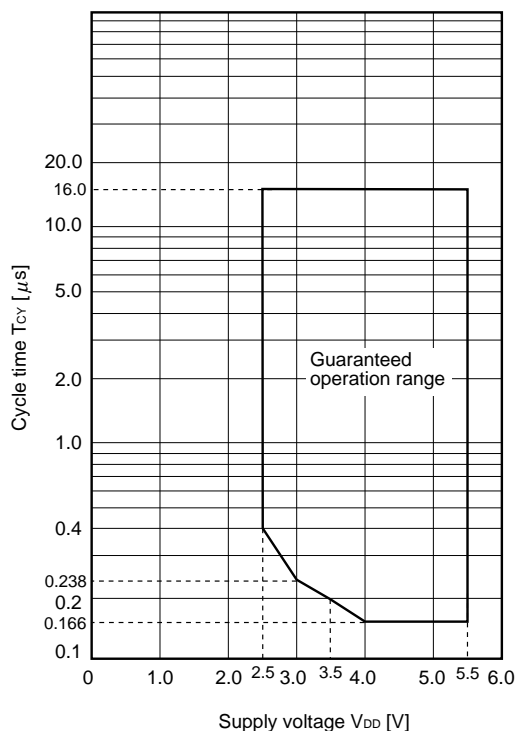
### AC Characteristics

(1) Basic operation ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.5\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter  | Symbol                  | Conditions                                   | MIN.   | TYP.  | MAX. | Unit          |               |
|--|-------------------------|--|--|-------|------|---------------|---------------|
| Instruction cycle (minimum instruction execution time) | $T_{CY}$                | X1 input clock                               | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 0.166 |      | 16            | $\mu\text{s}$ |
|  |                         |  | $3.5\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 0.2   |      | 16            | $\mu\text{s}$ |
|  |                         |  | $3.0\text{ V} \leq V_{DD} < 3.5\text{ V}$    | 0.238 |      | 16            | $\mu\text{s}$ |
|  |                         |  | $2.5\text{ V} \leq V_{DD} < 3.0\text{ V}$    | 0.4   |      | 16            | $\mu\text{s}$ |
|  |                         | Ring-OSC clock                               | 4.17   | 8.33  | 33.3 | $\mu\text{s}$ |               |
| TI000, TI010 input high-level width, low-level width   | $t_{TI0}$ , $t_{TILO}$  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | $2/f_{sam} + 0.1$ <sup>Note</sup>            |       |      | $\mu\text{s}$ |               |
|  |                         | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$    | $2/f_{sam} + 0.2$ <sup>Note</sup>            |       |      | $\mu\text{s}$ |               |
|  |                         | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | $2/f_{sam} + 0.5$ <sup>Note</sup>            |       |      | $\mu\text{s}$ |               |
| TI50 input frequency                                   | $f_{TI5}$               | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |  |       | 10   | MHz           |               |
|  |                         | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$    |  |       | 5    | MHz           |               |
|  |                         | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    |  |       | 2.5  | MHz           |               |
| TI50 input high-level width, low-level width           | $t_{TIH5}$ , $t_{TIL5}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 50   |       |      | ns            |               |
|  |                         | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 100  |       |      | ns            |               |
|  |                         | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | 200  |       |      | ns            |               |
| Interrupt input high-level width, low-level width      | $t_{INTH}$ , $t_{INTL}$ | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 1  |       |      | $\mu\text{s}$ |               |
|  |                         | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | 2  |       |      | $\mu\text{s}$ |               |
| RESET low-level width                                  | $t_{RSL}$               | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 10   |       |      | $\mu\text{s}$ |               |
|  |                         | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | 20   |       |      | $\mu\text{s}$ |               |

**Note** Selection of  $f_{sam} = f_{XP}$ ,  $f_{XP}/4$ ,  $f_{XP}/256$  is possible using bits 0 and 1 (PRM000, PRM001) of prescaler mode register 00 (PRM00). Note that when selecting the TI000 valid edge as the count clock,  $f_{sam} = f_{XP}$ .

**$T_{CY}$  vs.  $V_{DD}$  (X1 Input Clock Operation)**



**(2) Serial interface ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.5\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )****(a) UART mode (UART6, dedicated baud rate generator output)**

| Parameter     | Symbol | Conditions | MIN. | TYP. | MAX.  | Unit |
|---------------|--------|------------|------|------|-------|------|
| Transfer rate |        |            |      |      | 312.5 | kbps |

**(b) UART mode (UART0, dedicated baud rate generator output):  $\mu\text{PD780102}$ ,  $780103$ ,  $78F0103$ ,  $780102(\text{A})$ ,  $780103(\text{A})$ , and  $78F0103(\text{A})$  only**

| Parameter     | Symbol | Conditions | MIN. | TYP. | MAX.  | Unit |
|---------------|--------|------------|------|------|-------|------|
| Transfer rate |        |            |      |      | 312.5 | kbps |

**(c) 3-wire serial I/O mode (master mode,  $\overline{\text{SCK10}}$ ... internal clock output)**

| Parameter  | Symbol             | Conditions                                   | MIN.   | TYP. | MAX. | Unit |
|--|--------------------|--|--|------|------|------|
| $\overline{\text{SCK10}}$ cycle time                               | $t_{\text{KCY1}}$  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 200  |      |      | ns   |
|  |                    | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 240  |      |      | ns   |
|  |                    | $2.7\text{ V} \leq V_{DD} < 3.3\text{ V}$    | 400  |      |      | ns   |
|  |                    | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | 800  |      |      | ns   |
| $\overline{\text{SCK10}}$ high-/low-level width                    | $t_{\text{KH1}}$ , | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | $t_{\text{KCY1}}/2-10$                       |      |      | ns   |
|  | $t_{\text{KL1}}$   | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | $t_{\text{KCY1}}/2-50$                       |      |      | ns   |
| SI10 setup time (to $\overline{\text{SCK10}}\uparrow$ )            | $t_{\text{SIK1}}$  | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 30   |      |      | ns   |
|  |                    | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | 70   |      |      | ns   |
| SI10 hold time (from $\overline{\text{SCK10}}\uparrow$ )           | $t_{\text{KSI1}}$  | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 30   |      |      | ns   |
|  |                    | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | 70   |      |      | ns   |
| Delay time from $\overline{\text{SCK10}}\downarrow$ to SO10 output | $t_{\text{KSO1}}$  | $C = 100\text{ pF}^{\text{Note}}$            | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | 30   | ns   |
|  |                    |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    |      | 120  | ns   |

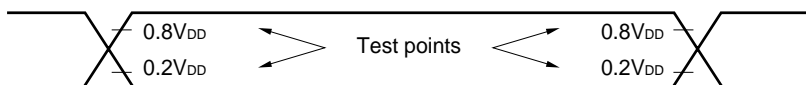
**Note** C is the load capacitance of the  $\overline{\text{SCK10}}$  and SO10 output lines.

**(d) 3-wire serial I/O mode (slave mode,  $\overline{\text{SCK10}}$ ... external clock input)**

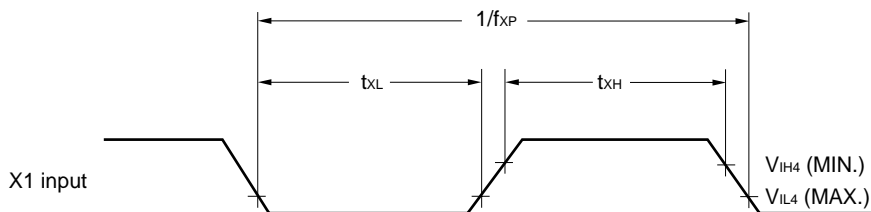
| Parameter  | Symbol                                 | Conditions                                   | MIN.                | TYP. | MAX. | Unit |
|--|--|--|---------------------|------|------|------|
| $\overline{\text{SCK10}}$ cycle time                               | $t_{\text{KCY2}}$                      | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 400                 |      |      | ns   |
|  |  | $2.5\text{ V} \leq V_{DD} < 2.7\text{ V}$    | 800                 |      |      | ns   |
| $\overline{\text{SCK10}}$ high-/low-level width                    | $t_{\text{KH2}}$ ,<br>$t_{\text{KL2}}$ |  | $t_{\text{KCY2}}/2$ |      |      | ns   |
| SI10 setup time (to $\overline{\text{SCK10}}\uparrow$ )            | $t_{\text{SIK2}}$                      |  | 80                  |      |      | ns   |
| SI10 hold time (from $\overline{\text{SCK10}}\uparrow$ )           | $t_{\text{KSI2}}$                      |  | 50                  |      |      | ns   |
| Delay time from $\overline{\text{SCK10}}\downarrow$ to SO10 output | $t_{\text{KSO2}}$                      | $C = 100\text{ pF}^{\text{Note}}$            |                     |      | 120  | ns   |

**Note** C is the load capacitance of the SO10 output line.

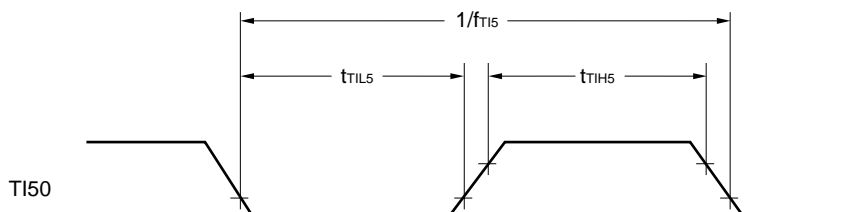
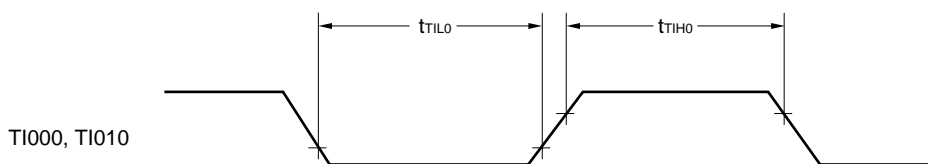
**AC Timing Test Points (Excluding X1 Input)**



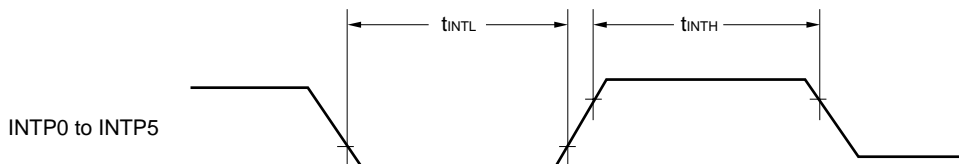
**Clock Timing**



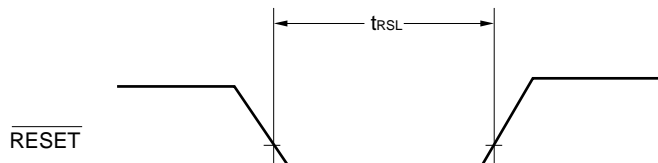
**TI Timing**



**Interrupt Request Input Timing**



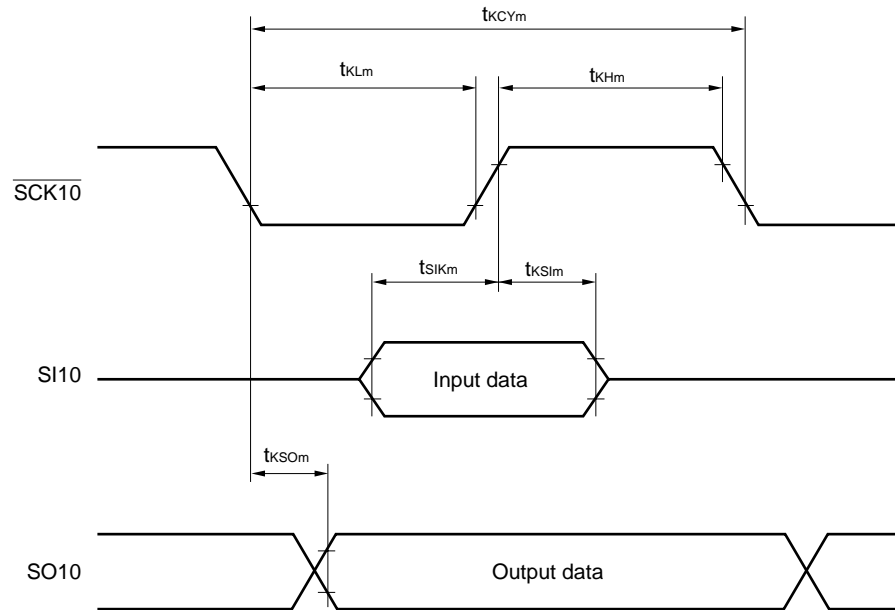
**RESET Input Timing**





## Serial Transfer Timing

### 3-wire serial I/O mode:



**Remark**  $m = 1, 2$

### A/D Converter Characteristics ( $T_A = -40$ to $+85^\circ\text{C}$ , $2.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ , $2.5\text{ V} \leq AV_{REF} \leq V_{DD}$ , $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter  | Symbol     | Conditions                                     | MIN.      | TYP.      | MAX.       | Unit          |
|--|------------|--|-----------|-----------|------------|---------------|
| Resolution   |            |  | 10        | 10        | 10         | bit           |
| Overall error <sup>Notes 1, 2</sup>                |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           | $\pm 0.2$ | $\pm 0.4$  | %FSR          |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           | $\pm 0.3$ | $\pm 0.6$  | %FSR          |
|  |            | $2.5\text{ V} \leq AV_{REF} < 2.7\text{ V}$    |           | $\pm 0.6$ | $\pm 1.2$  | %FSR          |
| Conversion time                                    | $t_{CONV}$ | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ | 14        |           | 100        | $\mu\text{s}$ |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    | 17        |           | 100        | $\mu\text{s}$ |
|  |            | $2.5\text{ V} \leq AV_{REF} < 2.7\text{ V}$    | 48        |           | 100        | $\mu\text{s}$ |
| Zero-scale error <sup>Notes 1, 2</sup>             |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 0.4$  | %FSR          |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 0.6$  | %FSR          |
|  |            | $2.5\text{ V} \leq AV_{REF} < 2.7\text{ V}$    |           |           | $\pm 1.2$  | %FSR          |
| Full-scale error <sup>Notes 1, 2</sup>             |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 0.4$  | %FSR          |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 0.6$  | %FSR          |
|  |            | $2.5\text{ V} \leq AV_{REF} < 2.7\text{ V}$    |           |           | $\pm 1.2$  | %FSR          |
| Integral non-linearity error <sup>Note 1</sup>     |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 2.5$  | LSB           |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 4.5$  | LSB           |
|  |            | $2.5\text{ V} \leq AV_{REF} < 2.7\text{ V}$    |           |           | $\pm 8.5$  | LSB           |
| Differential non-linearity error <sup>Note 1</sup> |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 1.5$  | LSB           |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 2.0$  | LSB           |
|  |            | $2.5\text{ V} \leq AV_{REF} < 2.7\text{ V}$    |           |           | $\pm 3.5$  | LSB           |
| Analog input voltage                               | $V_{AIN}$  |  | $AV_{SS}$ |           | $AV_{REF}$ | V             |

**Notes** 1. Excludes quantization error ( $\pm 1/2$  LSB).

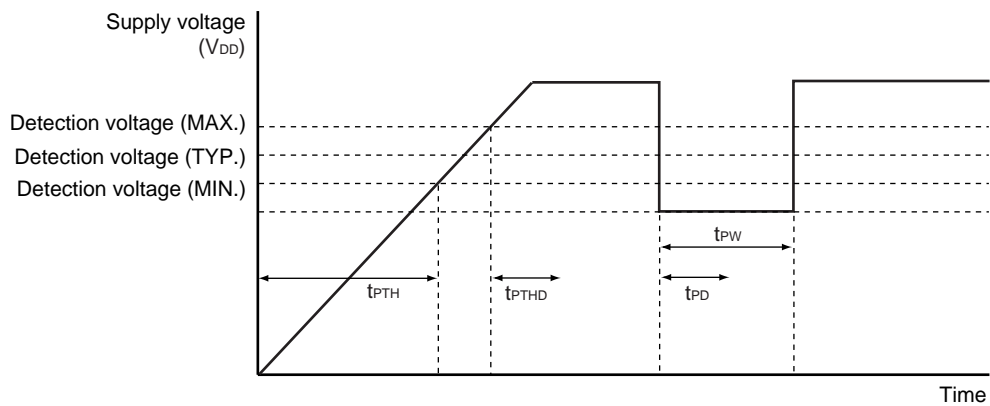
2. This value is indicated as a ratio (%FSR) to the full-scale value.

**POC Circuit Characteristics (T<sub>A</sub> = -40 to +85°C)**

| Parameter                               | Symbol            | Conditions   | MIN.   | TYP. | MAX. | Unit |
|---|-------------------|--|--------|------|------|------|
| Detection voltage                       | V <sub>POC0</sub> | Mask option = 3.5 V <sup>Note 1</sup>                            | 3.3    | 3.5  | 3.7  | V    |
|   | V <sub>POC1</sub> | Mask option = 2.85 V <sup>Note 2</sup>                           | 2.7    | 2.85 | 3.0  | V    |
| Power supply rise time                  | t <sub>PTH</sub>  | V <sub>DD</sub> : 0 V → 2.7 V                                    | 0.0015 |      |      | ms   |
|   |                   | V <sub>DD</sub> : 0 V → 3.3 V                                    | 0.002  |      |      | ms   |
| Response delay time 1 <sup>Note 3</sup> | t <sub>PTHD</sub> | When power supply rises, after reaching detection voltage (MAX.) |        |      | 3.0  | ms   |
| Response delay time 2 <sup>Note 4</sup> | t <sub>PD</sub>   | When V <sub>DD</sub> falls                                       |        |      | 1.0  | ms   |
| Minimum pulse width                     | t <sub>PW</sub>   |  | 0.2    |      |      | ms   |

- Notes**
1. When flash memory version  $\mu$ PD78F0103M5, 78F0103M6, 78F0103M5(A), or 78F0103M6(A) is used
  2. When flash memory version  $\mu$ PD78F0103M3, 78F0103M4, 78F0103M3(A), or 78F0103M4(A) is used
  3. Time required from voltage detection to reset release.
  4. Time required from voltage detection to internal reset output.

**POC Circuit Timing**

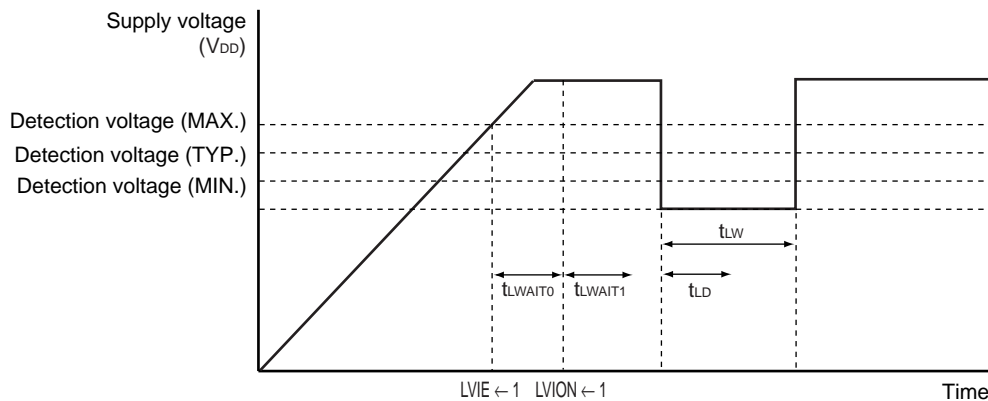


**LVI Circuit Characteristics (T<sub>A</sub> = -40 to +85°C)**

| Parameter   | Symbol              | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---------------------|------------|------|------|------|------|
| Detection voltage   | V <sub>LV10</sub>   |            | 4.1  | 4.3  | 4.5  | V    |
|   | V <sub>LV11</sub>   |            | 3.9  | 4.1  | 4.3  | V    |
|   | V <sub>LV12</sub>   |            | 3.7  | 3.9  | 4.1  | V    |
|   | V <sub>LV13</sub>   |            | 3.5  | 3.7  | 3.9  | V    |
|   | V <sub>LV14</sub>   |            | 3.3  | 3.5  | 3.7  | V    |
|   | V <sub>LV15</sub>   |            | 3.15 | 3.3  | 3.45 | V    |
|   | V <sub>LV16</sub>   |            | 2.95 | 3.1  | 3.25 | V    |
|   | V <sub>LV17</sub>   |            | 2.7  | 2.85 | 3.0  | V    |
| Response time <sup>Note 1</sup>                             | t <sub>LD</sub>     |            |      | 0.2  | 2.0  | ms   |
| Minimum pulse width   | t <sub>LW</sub>     |            | 0.2  |      |      | ms   |
| Reference voltage stabilization wait time <sup>Note 2</sup> | t <sub>LWAIT0</sub> |            |      | 0.5  | 2.0  | ms   |
| Operation stabilization wait time <sup>Note 3</sup>         | t <sub>LWAIT1</sub> |            |      | 0.1  | 0.2  | ms   |

- Notes**
1. Time required from voltage detection to interrupt output or internal reset output.
  2. Time required from setting LVIE to 1 to reference voltage stabilization when POC-OFF is selected by mask option (for the flash memory version, when the  $\mu$ PD78F0103M1, 78F0103M2, 78F0103M1(A), or 78F0103M2(A) is used).
  3. Time required from setting LVION to 1 to operation stabilization.

- Remarks**
1. V<sub>LV10</sub> > V<sub>LV11</sub> > V<sub>LV12</sub> > V<sub>LV13</sub> > V<sub>LV14</sub> > V<sub>LV15</sub> > V<sub>LV16</sub> > V<sub>LV17</sub>
  2. V<sub>POCn</sub> < V<sub>LVIm</sub> (n = 0 or 1, m = 0 to 7)

**LVI Circuit Timing**

**Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics (T<sub>A</sub> = -40 to +85°C)**

| Parameter                     | Symbol            | Conditions  | MIN. | TYP. | MAX. | Unit    |
|-------------------------------|-------------------|---|------|------|------|---------|
| Data retention supply voltage | V <sub>DDDR</sub> | When POC-OFF is selected by mask option <sup>Note</sup> | 1.6  |      | 5.5  | V       |
| Release signal set time       | t <sub>SREL</sub> |   | 0    |      |      | $\mu$ s |

**Note** When flash memory version  $\mu$ PD78F0103M1, 78F0103M2, 78F0103M1(A), or 78F0103M2(A) is used

**Flash Memory Programming Characteristics:  $\mu$ PD78F0103, 78F0103(A)****( $T_A = +10$  to  $+60^\circ\text{C}$ ,  $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )****(1) Write erase characteristics**

| Parameter  | Symbol     | Conditions   | MIN.  | TYP. | MAX.  | Unit          |
|--|------------|--|-------|------|-------|---------------|
| $V_{PP}$ supply voltage  | $V_{PP2}$  | During flash memory programming  | 9.7   | 10.0 | 10.3  | V             |
| $V_{DD}$ supply current  | $I_{DD}$   | When $V_{PP} = V_{PP2}$ , $f_{XP} = 10\text{ MHz}$ , $V_{DD} = 5.5\text{ V}$ |       |      | 37    | mA            |
| $V_{PP}$ supply current  | $I_{PP}$   | $V_{PP} = V_{PP2}$   |       |      | 100   | mA            |
| Step erase time <sup>Note 1</sup>                              | $T_{er}$   |  | 0.199 | 0.2  | 0.201 | s             |
| Overall erase time <sup>Note 2</sup>                           | $T_{era}$  | When step erase time = 0.2 s   |       |      | 20    | s/chip        |
| Writeback time <sup>Note 3</sup>                               | $T_{wb}$   |  | 49.4  | 50   | 50.6  | ms            |
| Number of writebacks per 1 writeback command <sup>Note 4</sup> | $C_{wb}$   | When writeback time = 50 ms  |       |      | 60    | Times         |
| Number of erases/writebacks                                    | $C_{erwb}$ |  |       |      | 16    | Times         |
| Step write time <sup>Note 5</sup>                              | $T_{wr}$   |  | 48    | 50   | 52    | $\mu\text{s}$ |
| Overall write time per word <sup>Note 6</sup>                  | $T_{wrw}$  | When step write time = 50 $\mu\text{s}$ (1 word = 1 byte)                    | 48    |      | 520   | $\mu\text{s}$ |
| Number of rewrites per chip <sup>Note 7</sup>                  | $C_{erwr}$ | 1 erase + 1 write after erase = 1 rewrite                                    |       |      | 20    | Times/area    |

- Notes**
- The recommended setting value of the step erase time is 0.2 s.
  - The prewrite time before erasure and the erase verify time (writeback time) are not included.
  - The recommended setting value of the writeback time is 50 ms.
  - Writeback is executed once by the issuance of the writeback command. Therefore, the number of retries must be the maximum value minus the number of commands issued.
  - The recommended setting value of the step write time is 50  $\mu\text{s}$ .
  - The actual write time per word is 100  $\mu\text{s}$  longer. The internal verify time during or after a write is not included.
  - When a product is first written after shipment, "erase  $\rightarrow$  write" and "write only" are both taken as one rewrite.

Example: P: Write, E: Erase

Shipped product  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P: 3 rewrites

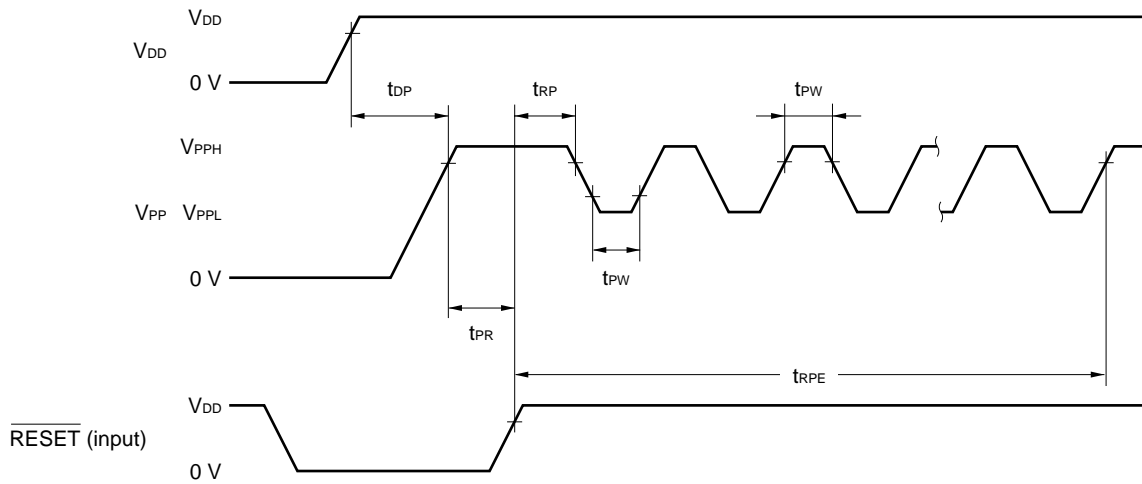
Shipped product  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P: 3 rewrites

**Remark** The range of the operating clock during flash memory programming is the same as the range during normal operation.

(2) Serial write operation characteristics

| Parameter  | Symbol    | Conditions | MIN.        | TYP. | MAX.        | Unit    |
|--|-----------|------------|-------------|------|-------------|---------|
| Set time from $V_{DD}\uparrow$ to $V_{PP}\uparrow$               | $t_{DP}$  |            | 10          |      |             | $\mu s$ |
| Release time from $V_{PP}\uparrow$ to $\overline{RESET}\uparrow$ | $t_{PR}$  |            | 10          |      |             | $\mu s$ |
| $V_{PP}$ pulse input start time from $\overline{RESET}\uparrow$  | $t_{RP}$  |            | 2           |      |             | ms      |
| $V_{PP}$ pulse high-/low-level width                             | $t_{PW}$  |            | 8           |      |             | $\mu s$ |
| $V_{PP}$ pulse input end time from $\overline{RESET}\uparrow$    | $t_{RPE}$ |            |             |      | 14          | ms      |
| $V_{PP}$ pulse low-level input voltage                           | $V_{PPL}$ |            | $0.8V_{DD}$ |      | $1.2V_{DD}$ | V       |
| $V_{PP}$ pulse high-level input voltage                          | $V_{PPH}$ |            | 9.7         | 10.0 | 10.3        | V       |

Flash Write Mode Setting Timing





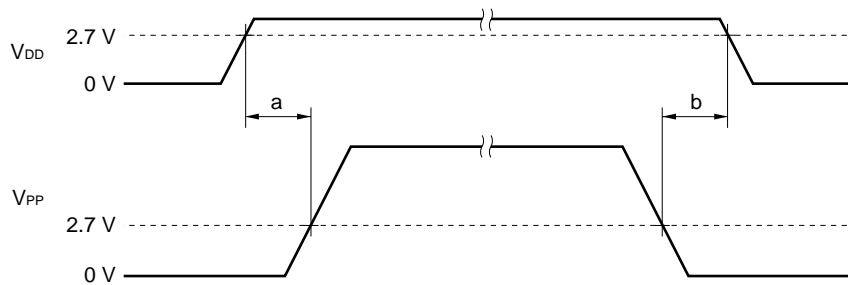
**Note 2.** Make sure that the following conditions of the  $V_{PP}$  voltage application timing are satisfied when the flash memory is written.

- **When supply voltage rises**

$V_{PP}$  must exceed  $V_{DD}$  10  $\mu\text{s}$  or more after  $V_{DD}$  has reached the lower-limit value (2.7 V) of the operating voltage range (see a in the figure below).

- **When supply voltage drops**

$V_{DD}$  must be lowered 10  $\mu\text{s}$  or more after  $V_{PP}$  falls below the lower-limit value (2.7 V) of the operating voltage range of  $V_{DD}$  (see b in the figure below).



**Caution** Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**X1 Oscillator Characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Resonator         | Recommended Circuit | Parameter  | Conditions                                   | MIN. | TYP. | MAX. | Unit |
|-------------------|---------------------|--|--|------|------|------|------|
| Ceramic resonator |                     | Oscillation frequency ( $f_{XP}$ ) <sup>Note</sup>       | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 10   | MHz  |
|                   |                     |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |                     |  | $2.7\text{ V} \leq V_{DD} < 3.3\text{ V}$    | 2.0  |      | 5.0  |      |
| Crystal resonator |                     | Oscillation frequency ( $f_{XP}$ ) <sup>Note</sup>       | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 10   | MHz  |
|                   |                     |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |                     |  | $2.7\text{ V} \leq V_{DD} < 3.3\text{ V}$    | 2.0  |      | 5.0  |      |
| External clock    |                     | X1 input frequency ( $f_{XP}$ ) <sup>Note</sup>          | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 10   | MHz  |
|                   |                     |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |                     |  | $2.7\text{ V} \leq V_{DD} < 3.3\text{ V}$    | 2.0  |      | 5.0  |      |
|                   |                     | X1 input high-/low-level width ( $t_{XPH}$ , $t_{XPL}$ ) | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 46   |      | 500  | ns   |
|                   |                     |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 56   |      | 500  |      |
|                   |                     |  | $2.7\text{ V} \leq V_{DD} < 3.3\text{ V}$    | 96   |      | 500  |      |

**Note** Indicates only oscillator characteristics. Refer to **AC Characteristics** for instruction execution time.

**Cautions 1.** When using the X1 oscillator, wire as follows in the area enclosed by the broken lines in the above figures to avoid an adverse effect from wiring capacitance.

- Keep the wiring length as short as possible.
- Do not cross the wiring with the other signal lines.
- Do not route the wiring near a signal line through which a high fluctuating current flows.
- Always make the ground point of the oscillator capacitor the same potential as V<sub>ss</sub>.
- Do not ground the capacitor to a ground pattern through which a high current flows.
- Do not fetch signals from the oscillator.

- ★ 2. Since the CPU is started by the Ring-OSC after reset is released, check the oscillation stabilization time of the X1 input clock using the oscillation stabilization time counter status register (OSTC). Determine the oscillation stabilization time of the OSTC register and oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.

**Ring-OSC Oscillator Characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Resonator                   | Parameter                       | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------|---------------------------------|------------|------|------|------|------|
| On-chip Ring-OSC oscillator | Oscillation frequency ( $f_R$ ) |            | 120  | 240  | 480  | kHz  |



## Recommended Oscillator Constants

**Caution** For the resonator selection of the  $\mu$ PD780101(A), 780102(A), and 780103(A) and oscillator constants, users are required to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation.

(a)  $\mu$ PD780101, 780102, 780103

X1 oscillation: Ceramic resonator ( $T_A = -40$  to  $+85^\circ\text{C}$ )

| Manufacturer     | Part Number      | SMD/Lead | Frequency (MHz) | Recommended Circuit Constants |               | Oscillation Voltage Range |          |
|------------------|------------------|----------|-----------------|-------------------------------|---------------|---------------------------|----------|
|                  |                  |          |                 | C1 (pF)                       | C2 (pF)       | MIN. (V)                  | MAX. (V) |
| Murata Mfg.      | CSTCC2M00G56-R0  | SMD      | 2.00            | Internal (47)                 | Internal (47) | 2.7                       | 5.5      |
|                  | CSTCR4M00G55-R0  | SMD      | 4.00            | Internal (39)                 | Internal (39) |                           |          |
|                  | CSTCR4M00G55U-R0 |          |                 | Lead                          | Internal (47) |                           |          |
|                  | CSTLS4M00G56-B0  | SMD      | 4.194           |                               | Internal (39) |                           |          |
|                  | CSTLS4M00G56U-B0 |          |                 | Lead                          | Internal (47) |                           |          |
|                  | CSTCR4M19G55-R0  | SMD      | 4.915           |                               | Internal (39) |                           |          |
|                  | CSTCR4M19G55U-R0 |          |                 | Lead                          | Internal (47) |                           |          |
|                  | CSTLS4M19G56-B0  | SMD      | 5.00            |                               | Internal (39) |                           |          |
|                  | CSTLS4M19G56U-B0 |          |                 | Lead                          | Internal (47) |                           |          |
|                  | CSTCR4M91G55-R0  | SMD      | 6.00            |                               | Internal (39) |                           |          |
|                  | CSTCR4M91G55U-R0 |          |                 | Lead                          | Internal (47) |                           |          |
|                  | CSTLS4M91G56-B0  | SMD      | 8.00            |                               | Internal (10) |                           |          |
|                  | CSTLS4M91G56U-B0 |          |                 | Lead                          | Internal (15) |                           |          |
|                  | CSTCR5M00G55-R0  | SMD      | 10.0            |                               | Internal (10) |                           |          |
|                  | CSTCR5M00G55U-R0 |          |                 | Lead                          | Internal (15) |                           |          |
|                  | CSTLS5M00G56-B0  | SMD      | 10.0            |                               | Internal (10) |                           |          |
|                  | CSTLS5M00G56U-B0 |          |                 | Lead                          | Internal (15) |                           |          |
|                  | CSTCR6M00G55-R0  | SMD      | 10.0            |                               | Internal (10) |                           |          |
|                  | CSTCR6M00G55U-R0 |          |                 | Lead                          | Internal (15) |                           |          |
|                  | CSTLS6M00G56-B0  | SMD      | 10.0            |                               | Internal (10) |                           |          |
|                  | CSTLS6M00G56U-B0 |          |                 | Lead                          | Internal (15) |                           |          |
|                  | CSTCE8M00G52-R0  | SMD      | 10.0            |                               | Internal (10) |                           |          |
|                  | CSTLS8M00G53-B0  |          |                 | Lead                          | Internal (15) |                           |          |
|                  | CSTLS8M00G53U-B0 | SMD      | 10.0            |                               | Internal (10) |                           |          |
| CSTCE10M0G52-R0  | Lead             |          |                 | Internal (15)                 | Internal (15) |                           |          |
| CSTLS10M0G53-B0  |                  | SMD      | 10.0            | Internal (10)                 | Internal (10) |                           |          |
| CSTLS10M0G53U-B0 | Lead             |          |                 | Internal (15)                 | Internal (15) |                           |          |

**Caution** The oscillator constants shown above are reference values based on evaluation in a specific environment by the resonator manufacturer. If it is necessary to optimize the oscillator characteristics in the actual application, apply to the resonator manufacturer for evaluation on the implementation circuit. The oscillation voltage and oscillation frequency only indicate the oscillator characteristic. Use the 78K0/KB1 so that the internal operation conditions are within the specifications of the DC and AC characteristics.

(b)  $\mu$ PD78F0103X1 oscillation: Ceramic resonator ( $T_A = -40$  to  $+85^\circ\text{C}$ )

| Manufacturer | Part Number        | SMD/Lead | Frequency (MHz) | Recommended Circuit Constants |               | Oscillation Voltage Range |          |
|--------------|--------------------|----------|-----------------|-------------------------------|---------------|---------------------------|----------|
|              |                    |          |                 | C1 (pF)                       | C2 (pF)       | MIN. (V)                  | MAX. (V) |
| Murata Mfg.  | CSTCC2M00G56-R0    | SMD      | 2.00            | Internal (47)                 | Internal (47) | 2.7                       | 5.5      |
|              | CSTCC2M45G56-R0    | SMD      | 2.457           | Internal (47)                 | Internal (47) |                           |          |
|              | CSTCR4M00G53-R0    | SMD      | 4.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCR4M00G53093-R0 |          |                 |                               |               |                           |          |
|              | CSTLS4M00G53-B0    | Lead     |                 | Internal (15)                 | Internal (15) |                           |          |
|              | CSTLS4M00G53093-B0 |          |                 |                               |               |                           |          |
|              | CSTCR5M00G53-R0    | SMD      | 5.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCR5M00G53093-R0 |          |                 |                               |               |                           |          |
|              | CSTLS5M00G53-B0    | Lead     |                 | Internal (15)                 | Internal (15) |                           |          |
|              | CSTLS5M00G53093-B0 |          |                 |                               |               |                           |          |
|              | CSTCR6M00G53-R0    | SMD      | 6.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCR6M00G53U-R0   |          |                 |                               |               |                           |          |
|              | CSTLS6M00G53-B0    | Lead     |                 | Internal (15)                 | Internal (15) |                           |          |
|              | CSTLS6M00G53U-B0   |          |                 |                               |               |                           |          |
|              | CSTCE8M38G52-R0    | SMD      | 8.388           | Internal (10)                 | Internal (10) |                           |          |
|              | CSTLS8M38G53-B0    | Lead     |                 |                               |               |                           |          |
|              | CSTLS8M38G53093-B0 |          |                 |                               |               |                           |          |
|              | CSTCE10M0G52-R0    | SMD      | 10.0            | Internal (10)                 | Internal (10) |                           |          |
|              | CSTLS10M0G53-B0    | Lead     |                 |                               |               |                           |          |
|              | CSTLS10M0G53093-B0 |          |                 |                               |               |                           |          |

**Caution** The oscillator constants shown above are reference values based on evaluation in a specific environment by the resonator manufacturer. If it is necessary to optimize the oscillator characteristics in the actual application, apply to the resonator manufacturer for evaluation on the implementation circuit. The oscillation voltage and oscillation frequency only indicate the oscillator characteristic. Use the 78K0/KB1 so that the internal operation conditions are within the specifications of the DC and AC characteristics.

(c)  $\mu$ PD78F0103(A)X1 oscillation: Ceramic resonator ( $T_A = -40$  to  $+85^\circ\text{C}$ )

| Manufacturer | Part Number      | SMD/Lead | Frequency (MHz) | Recommended Circuit Constants |               | Oscillation Voltage Range |          |
|--------------|------------------|----------|-----------------|-------------------------------|---------------|---------------------------|----------|
|              |                  |          |                 | C1 (pF)                       | C2 (pF)       | MIN. (V)                  | MAX. (V) |
| Murata Mfg.  | CSTCC2M00G56A-R0 | SMD      | 2.00            | Internal (47)                 | Internal (47) | 2.7                       | 5.5      |
|              | CSTCC2M45G56A-R0 |          | 2.457           | Internal (47)                 | Internal (47) |                           |          |
|              | CSTCR4M00G53A-R0 |          | 4.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCR5M00G53A-R0 |          | 5.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCR6M00G53A-R0 |          | 6.00            | Internal (15)                 | Internal (15) |                           |          |
|              | CSTCE8M38G52A-R0 |          | 8.388           | Internal (10)                 | Internal (10) |                           |          |
|              | CSTCE10M0G52A-R0 |          | 10.0            | Internal (10)                 | Internal (10) |                           |          |

**Caution** The oscillator constants shown above are reference values based on evaluation in a specific environment by the resonator manufacturer. If it is necessary to optimize the oscillator characteristics in the actual application, apply to the resonator manufacturer for evaluation on the implementation circuit. The oscillation voltage and oscillation frequency only indicate the oscillator characteristic. Use the 78K0/KB1 so that the internal operation conditions are within the specifications of the DC and AC characteristics.

DC Characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ ) (1/3)

| Parameter  | Symbol     | Conditions   |   | MIN.           | TYP. | MAX.          | Unit          |
|--|------------|--|---|----------------|------|---------------|---------------|
| Output current, high   | $I_{OH}$   | Per pin  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | -5            | mA            |
|  |            | Total of P30 to P33, P120  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | -25           | mA            |
|  |            | Total of P00 to P03, P10 to P17, P130                                  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | -25           | mA            |
|  |            | Total of all pins  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | -40           | mA            |
|  |            |  | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |                |      | -10           | mA            |
| Output current, low  | $I_{OL}$   | Per pin  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | 10            | mA            |
|  |            | Total of P30 to P33, P120  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | 30            | mA            |
|  |            | Total of P00 to P03, P10 to P17, P130                                  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | 30            | mA            |
|  |            | Total of all pins  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |                |      | 50            | mA            |
|  |            |  | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |                |      | 10            | mA            |
| Input voltage, high  | $V_{IH1}$  | P12, P13, P15  |   | $0.7V_{DD}$    |      | $V_{DD}$      | V             |
|  | $V_{IH2}$  | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET           |   | $0.8V_{DD}$    |      | $V_{DD}$      | V             |
|  | $V_{IH3}$  | P20 to P23 <sup>Note 1</sup>   |   | $0.7AV_{REF}$  |      | $AV_{REF}$    | V             |
|  | $V_{IH4}$  | X1, X2   |   | $V_{DD} - 0.5$ |      | $V_{DD}$      | V             |
| Input voltage, low   | $V_{IL1}$  | P12, P13, P15  |   | 0              |      | $0.3V_{DD}$   | V             |
|  | $V_{IL2}$  | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET           |   | 0              |      | $0.2V_{DD}$   | V             |
|  | $V_{IL3}$  | P20 to P23 <sup>Note 1</sup>   |   | 0              |      | $0.3AV_{REF}$ | V             |
|  | $V_{IL4}$  | X1, X2   |   | 0              |      | 0.4           | V             |
| Output voltage, high   | $V_{OH}$   | Total of P30 to P33, P120 pins<br>$I_{OH} = -25\text{ mA}$             | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OH} = -5\text{ mA}$ | $V_{DD} - 1.0$ |      |               | V             |
|  |            | Total of P00 to P03, P10 to P17, P130 pins<br>$I_{OH} = -25\text{ mA}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OH} = -5\text{ mA}$ | $V_{DD} - 1.0$ |      |               | V             |
|  |            | $I_{OH} = -100\text{ }\mu\text{A}$                                     | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 | $V_{DD} - 0.5$ |      |               | V             |
| Output voltage, low  | $V_{OL}$   | Total of P30 to P33, P120 pins<br>$I_{OL} = 30\text{ mA}$              | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OL} = 10\text{ mA}$ |                |      | 1.3           | V             |
|  |            | Total of P00 to P03, P10 to P17, P130 pins<br>$I_{OL} = 30\text{ mA}$  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OL} = 10\text{ mA}$ |                |      | 1.3           | V             |
|  |            | $I_{OL} = 400\text{ }\mu\text{A}$                                      | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |                |      | 0.4           | V             |
| Input leakage current, high  | $I_{LIH1}$ | $V_i = V_{DD}$   | P00 to P03, P10 to P17, P30 to P33, P120, RESET                           |                |      | 3             | $\mu\text{A}$ |
|  |            | $V_i = AV_{REF}$   | P20 to P23  |                |      | 3             | $\mu\text{A}$ |
|  | $I_{LIH2}$ | $V_i = V_{DD}$   | X1, X2 <sup>Note 2</sup>  |                |      | 20            | $\mu\text{A}$ |
| Input leakage current, low   | $I_{LIL1}$ | $V_i = 0\text{ V}$   | P00 to P03, P10 to P17, P20 to P23, P30 to P33, P120, RESET               |                |      | -3            | $\mu\text{A}$ |
|  | $I_{LIL2}$ |  | X1, X2 <sup>Note 2</sup>  |                |      | -20           | $\mu\text{A}$ |
| Output leakage current, high                                       | $I_{LOH}$  | $V_o = V_{DD}$   |   |                |      | 3             | $\mu\text{A}$ |
| Output leakage current, low  | $I_{LOL}$  | $V_o = 0\text{ V}$   |   |                |      | -3            | $\mu\text{A}$ |
| Pull-up resistance value   | R          | $V_i = 0\text{ V}$   |   | 10             | 30   | 100           | k $\Omega$    |
| $V_{PP}$ supply voltage ( $\mu\text{PD78F0103}$ , 78F0103(A) only) | $V_{PP1}$  | In normal operation mode   |   | 0              |      | $0.2V_{DD}$   | V             |

**Notes** 1. When used as a digital input port, set  $AV_{REF} = V_{DD}$ .

2. When the inverse level of X1 is input to X2.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**DC Characteristics (2/3):  $\mu$ PD78F0103, 78F0103(A)****( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Parameter                             | Symbol           | Conditions  |  | MIN.  | TYP. | MAX. | Unit    |         |         |
|---------------------------------------|------------------|---|--|---|------|------|---------|---------|---------|
| Supply current <sup>Note 1</sup>      | I <sub>DD1</sub> | X1 crystal oscillation operating mode <sup>Note 2</sup>                         | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 11.6 | 19.5    | mA      |         |
|                                       |                  |   |  | When A/D converter is operating <sup>Note 4</sup> |      | 12.6 | 21.5    | mA      |         |
|                                       |                  | f <sub>XP</sub> = 5 MHz,<br>V <sub>DD</sub> = 3.0 V $\pm$ 10% <sup>Note 3</sup> | When A/D converter is stopped  |   | 4    | 6.4  | mA      |         |         |
|                                       |                  |   | When A/D converter is operating <sup>Note 4</sup>                                |   | 4.6  | 7.6  | mA      |         |         |
|                                       | I <sub>DD2</sub> | X1 crystal oscillation HALT mode  | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10%                   | When peripheral functions are stopped             |      | 1.4  | 2.8     | mA      |         |
|                                       |                  |   |  | When peripheral functions are operating           |      |      | 5.5     | mA      |         |
|                                       |                  | f <sub>XP</sub> = 5 MHz,<br>V <sub>DD</sub> = 3.0 V $\pm$ 10%                   | When peripheral functions are stopped  |   | 0.32 | 0.64 | mA      |         |         |
|                                       |                  |   | When peripheral functions are operating  |   |      | 1.9  | mA      |         |         |
|                                       | I <sub>DD3</sub> | Ring-OSC operating mode <sup>Note 5</sup>                                       | V <sub>DD</sub> = 5.0 V $\pm$ 10%  |   |      | 0.37 | 1.51    | mA      |         |
|                                       |                  |   | V <sub>DD</sub> = 3.0 V $\pm$ 10%  |   |      | 0.29 | 1.16    | mA      |         |
|                                       | I <sub>DD4</sub> | STOP mode   | V <sub>DD</sub> = 5.0 V $\pm$ 10%  | POC: OFF, RING: OFF                               |      |      | 0.1     | 30      | $\mu$ A |
|                                       |                  |   |  | POC: OFF, RING: ON                                |      |      | 14      | 58      | $\mu$ A |
| POC: ON <sup>Note 6</sup> , RING: OFF |                  |   |  |   | 3.5  | 35.5 | $\mu$ A |         |         |
| POC: ON <sup>Note 6</sup> , RING: ON  |                  |   |  |   | 17.5 | 63.5 | $\mu$ A |         |         |
| V <sub>DD</sub> = 3.0 V $\pm$ 10%     |                  |   | POC: OFF, RING: OFF  |   |      | 0.05 | 10      | $\mu$ A |         |
|                                       |                  |   | POC: OFF, RING: ON   |   |      | 7.5  | 25      | $\mu$ A |         |
|                                       |                  |   | POC: ON <sup>Note 6</sup> , RING: OFF  |   |      | 3.5  | 15.5    | $\mu$ A |         |
|                                       |                  |   | POC: ON <sup>Note 6</sup> , RING: ON   |   |      | 11   | 30.5    | $\mu$ A |         |

- Notes**
- Total current flowing through the internal power supply (V<sub>DD</sub>). Peripheral operation current is included (however, the current that flows through the pull-up resistors of ports is not included).
  - I<sub>DD1</sub> includes peripheral operation current.
  - When PCC = 00H.
  - Total current flowing through V<sub>DD</sub> and AV<sub>REF</sub> pins.
  - When X1 oscillator is stopped.
  - Including when LVIE (bit 4 of LVIM) = 1 in the  $\mu$ PD78F0103M1, 78F0103M2, 78F0103M1(A), and 78F0103M2(A).

**DC Characteristics (3/3):  $\mu$ PD780101, 780102, 780103, 780101(A), 780102(A), 780103(A)**
**( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Parameter                             | Symbol           | Conditions  |   | MIN.  | TYP. | MAX. | Unit |    |    |
|---------------------------------------|------------------|---|---|---|------|------|------|----|----|
| Supply current <sup>Note 1</sup>      | I <sub>DD1</sub> | X1 crystal oscillation operating mode <sup>Note 2</sup> | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V ±10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 6    | 10.9 | mA |    |
|                                       |                  |   |   | When A/D converter is operating <sup>Note 4</sup> |      | 7    | 12.9 | mA |    |
|                                       |                  |   | f <sub>XP</sub> = 5 MHz,<br>V <sub>DD</sub> = 3.0 V ±10% <sup>Note 3</sup>  | When A/D converter is stopped                     |      | 1.7  | 3.1  | mA |    |
|                                       |                  |   |   | When A/D converter is operating <sup>Note 4</sup> |      | 2.3  | 4.3  | mA |    |
|                                       | I <sub>DD2</sub> | X1 crystal oscillation HALT mode                        | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V ±10%                   | When peripheral functions are stopped             |      | 1.3  | 2.6  | mA |    |
|                                       |                  |   |   | When peripheral functions are operating           |      |      | 4.8  | mA |    |
|                                       |                  |   | f <sub>XP</sub> = 5 MHz,<br>V <sub>DD</sub> = 3.0 V ±10%                    | When peripheral functions are stopped             |      | 0.25 | 0.5  | mA |    |
|                                       |                  |   |   | When peripheral functions are operating           |      |      | 1.1  | mA |    |
|                                       | I <sub>DD3</sub> | Ring-OSC operating mode <sup>Note 5</sup>               | V <sub>DD</sub> = 5.0 V ±10%  |   |      | 0.18 | 0.72 | mA |    |
|                                       |                  |   | V <sub>DD</sub> = 3.0 V ±10%  |   |      | 0.11 | 0.44 | mA |    |
|                                       | I <sub>DD4</sub> | STOP mode   | V <sub>DD</sub> = 5.0 V ±10%  | POC: OFF, RING: OFF                               |      |      | 0.1  | 30 | μA |
|                                       |                  |   |   | POC: OFF, RING: ON                                |      |      | 14   | 58 | μA |
| POC: ON <sup>Note 6</sup> , RING: OFF |                  |   |   |   | 3.5  | 35.5 | μA   |    |    |
| POC: ON <sup>Note 6</sup> , RING: ON  |                  |   |   |   | 17.5 | 63.5 | μA   |    |    |
| V <sub>DD</sub> = 3.0 V ±10%          |                  |   | POC: OFF, RING: OFF   |   |      | 0.05 | 10   | μA |    |
|                                       |                  |   | POC: OFF, RING: ON  |   |      | 7.5  | 25   | μA |    |
|                                       |                  |   | POC: ON <sup>Note 6</sup> , RING: OFF                                       |   |      | 3.5  | 15.5 | μA |    |
|                                       |                  |   | POC: ON <sup>Note 6</sup> , RING: ON  |   |      | 11   | 30.5 | μA |    |

- Notes**
- Total current flowing through the internal power supply ( $V_{DD}$ ). Peripheral operation current is included (however, the current that flows through the pull-up resistors of ports is not included).
  - I<sub>DD1</sub> includes peripheral operation current.
  - When PCC = 00H.
  - Total current flowing through  $V_{DD}$  and  $AV_{REF}$  pins.
  - When X1 oscillator is stopped.
  - Including when LVIE (bit 4 of LVIM) = 1 with POC-OFF selected by a mask option.

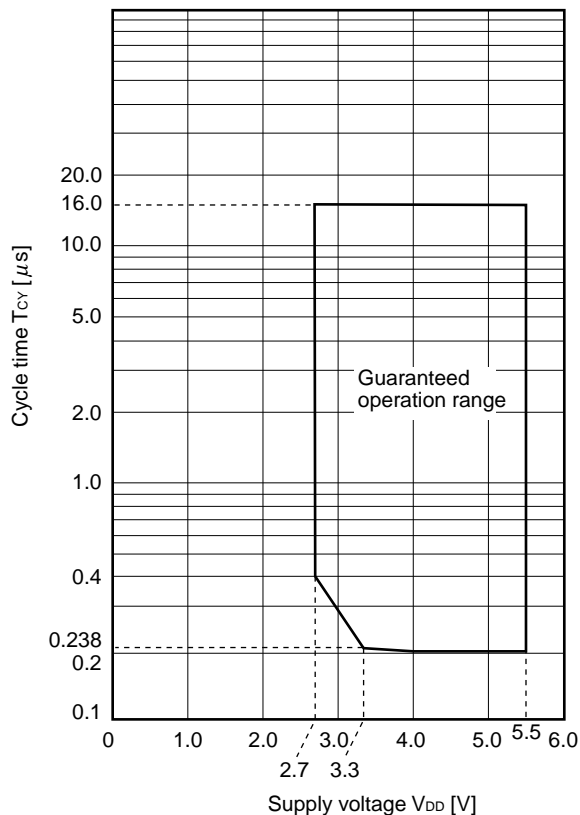
## AC Characteristics

### (1) Basic operation ( $T_A = -40$ to $+85^\circ\text{C}$ , $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ , $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ , $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter  | Symbol                     | Conditions                                   | MIN.   | TYP.  | MAX.  | Unit          |               |
|--|----------------------------|--|--|-------|-------|---------------|---------------|
| Instruction cycle (minimum instruction execution time) | $T_{CY}$                   | X1 input clock                               | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 0.2   |       | 16            | $\mu\text{s}$ |
|  |                            |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 0.238 |       | 16            | $\mu\text{s}$ |
|  |                            |  | $2.7\text{ V} \leq V_{DD} < 3.3\text{ V}$    | 0.4   |       | 16            | $\mu\text{s}$ |
|  |                            | Ring-OSC clock                               | 4.17   | 8.33  | 16.67 | $\mu\text{s}$ |               |
| TI000, TI010 input high-level width, low-level width   | $t_{TIH0}$ ,<br>$t_{TIL0}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | $2/f_{sam} + 0.1$ <sup>Note</sup>            |       |       | $\mu\text{s}$ |               |
|  |                            | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$    | $2/f_{sam} + 0.2$ <sup>Note</sup>            |       |       | $\mu\text{s}$ |               |
| TI50 input frequency                                   | $f_{TI5}$                  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |  |       | 10    | MHz           |               |
|  |                            | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$    |  |       | 5     | MHz           |               |
| TI50 input high-level width, low-level width           | $t_{TIH5}$ ,<br>$t_{TIL5}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 50   |       |       | ns            |               |
|  |                            | $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 100  |       |       | ns            |               |
| Interrupt input high-level width, low-level width      | $t_{INTH}$ ,<br>$t_{INTL}$ |  | 1  |       |       | $\mu\text{s}$ |               |
| RESET low-level width                                  | $t_{RSL}$                  |  | 10   |       |       | $\mu\text{s}$ |               |

**Note** Selection of  $f_{sam} = f_{XP}$ ,  $f_{XP}/4$ ,  $f_{XP}/256$  is possible using bits 0 and 1 (PRM000, PRM001) of prescaler mode register 00 (PRM00). Note that when selecting the TI000 valid edge as the count clock,  $f_{sam} = f_{XP}$ .

**$T_{CY}$  vs.  $V_{DD}$  (X1 Input Clock Operation)**



**(2) Serial interface ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )****(a) UART mode (UART6, dedicated baud rate generator output)**

| Parameter     | Symbol | Conditions | MIN. | TYP. | MAX.  | Unit |
|---------------|--------|------------|------|------|-------|------|
| Transfer rate |        |            |      |      | 312.5 | kbps |

**(b) UART mode (UART0, dedicated baud rate generator output):  $\mu\text{PD780102}$ , **780103**, **78F0103**, **780102(A)**, **780103(A)**, and **78F0103(A)** only**

| Parameter     | Symbol | Conditions | MIN. | TYP. | MAX.  | Unit |
|---------------|--------|------------|------|------|-------|------|
| Transfer rate |        |            |      |      | 312.5 | kbps |

**(c) 3-wire serial I/O mode (master mode,  $\overline{\text{SCK10}}$ ... internal clock output)**

| Parameter  | Symbol                                 | Conditions                                   | MIN.                   | TYP. | MAX. | Unit |
|--|--|--|------------------------|------|------|------|
| $\overline{\text{SCK10}}$ cycle time                               | $t_{\text{KCY1}}$                      | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 200                    |      |      | ns   |
|  |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 240                    |      |      | ns   |
|  |  | $2.7\text{ V} \leq V_{DD} < 3.3\text{ V}$    | 400                    |      |      | ns   |
| $\overline{\text{SCK10}}$ high-/low-level width                    | $t_{\text{KH1}}$ ,<br>$t_{\text{KL1}}$ |  | $t_{\text{KCY1}}/2-10$ |      |      | ns   |
| SI10 setup time (to $\overline{\text{SCK10}}\uparrow$ )            | $t_{\text{SIK1}}$                      |  | 30                     |      |      | ns   |
| SI10 hold time (from $\overline{\text{SCK10}}\uparrow$ )           | $t_{\text{KSI1}}$                      |  | 30                     |      |      | ns   |
| Delay time from $\overline{\text{SCK10}}\downarrow$ to SO10 output | $t_{\text{KSO1}}$                      | $C = 100\text{ pF}^{\text{Note}}$            |                        |      | 30   | ns   |

**Note** C is the load capacitance of the  $\overline{\text{SCK10}}$  and SO10 output lines.

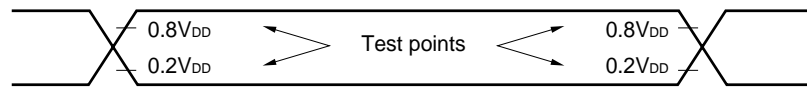
**(d) 3-wire serial I/O mode (slave mode,  $\overline{\text{SCK10}}$ ... external clock input)**

| Parameter  | Symbol                                 | Conditions                        | MIN.                | TYP. | MAX. | Unit |
|--|--|-----------------------------------|---------------------|------|------|------|
| $\overline{\text{SCK10}}$ cycle time                               | $t_{\text{KCY2}}$                      |                                   | 400                 |      |      | ns   |
| $\overline{\text{SCK10}}$ high-/low-level width                    | $t_{\text{KH2}}$ ,<br>$t_{\text{KL2}}$ |                                   | $t_{\text{KCY2}}/2$ |      |      | ns   |
| SI10 setup time (to $\overline{\text{SCK10}}\uparrow$ )            | $t_{\text{SIK2}}$                      |                                   | 80                  |      |      | ns   |
| SI10 hold time (from $\overline{\text{SCK10}}\uparrow$ )           | $t_{\text{KSI2}}$                      |                                   | 50                  |      |      | ns   |
| Delay time from $\overline{\text{SCK10}}\downarrow$ to SO10 output | $t_{\text{KSO2}}$                      | $C = 100\text{ pF}^{\text{Note}}$ |                     |      | 120  | ns   |

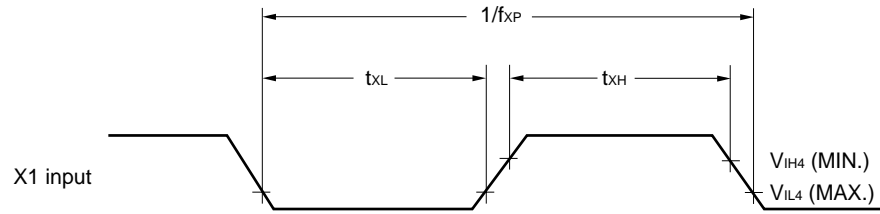
**Note** C is the load capacitance of the SO10 output line.



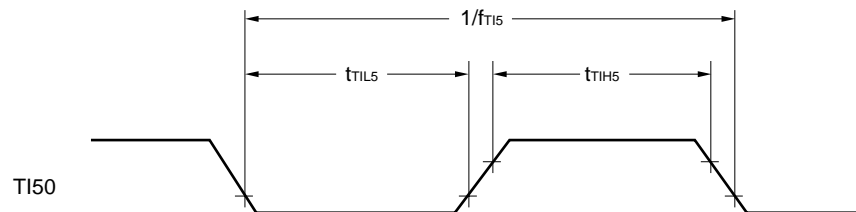
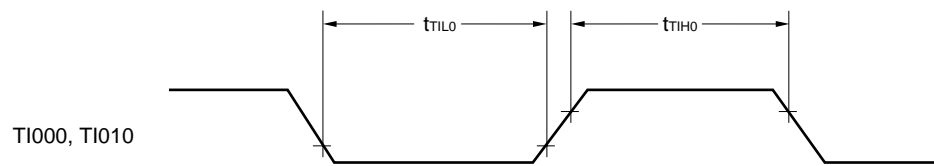
**AC Timing Test Points (Excluding X1 Input)**



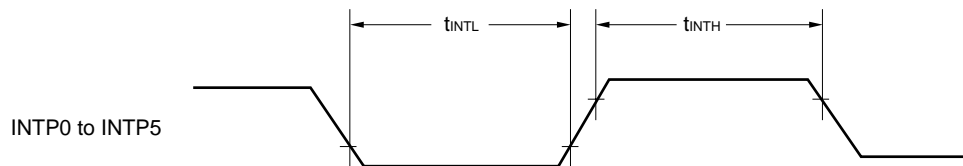
**Clock Timing**



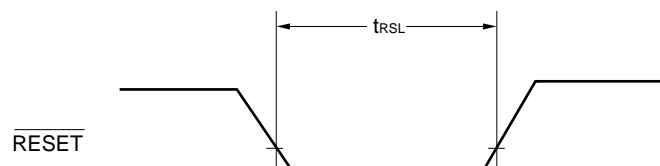
**TI Timing**



**Interrupt Request Input Timing**

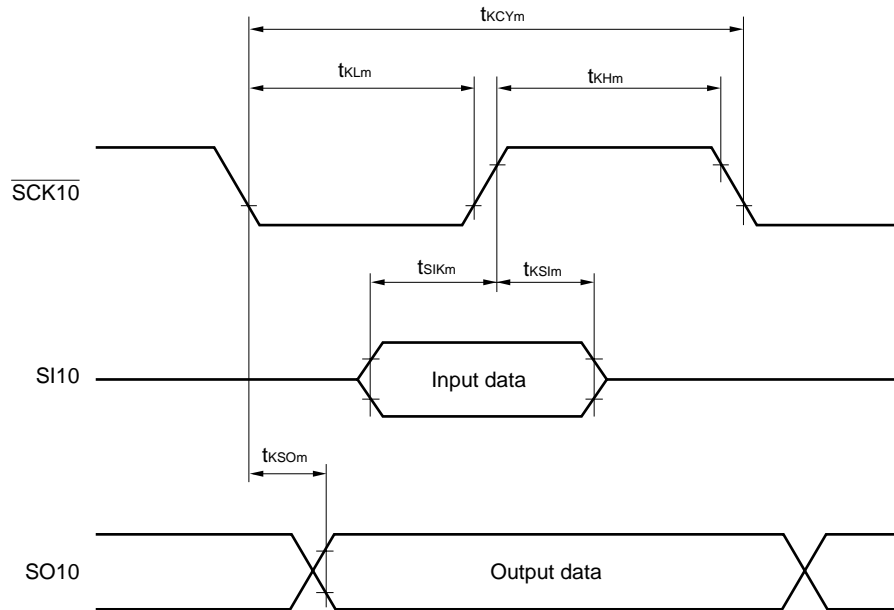


**RESET Input Timing**



## Serial Transfer Timing

### 3-wire serial I/O mode:



**Remark**  $m = 1, 2$

### A/D Converter Characteristics ( $T_A = -40$ to $+85^\circ\text{C}$ , $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ , $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ , $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter  | Symbol     | Conditions                                     | MIN.      | TYP.      | MAX.       | Unit          |
|--|------------|--|-----------|-----------|------------|---------------|
| Resolution   |            |  | 10        | 10        | 10         | bit           |
| Overall error <sup>Notes 1, 2</sup>                |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           | $\pm 0.2$ | $\pm 0.4$  | %FSR          |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           | $\pm 0.3$ | $\pm 0.6$  | %FSR          |
| Conversion time                                    | $t_{CONV}$ | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ | 14        |           | 100        | $\mu\text{s}$ |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    | 17        |           | 100        | $\mu\text{s}$ |
| Zero-scale error <sup>Notes 1, 2</sup>             |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 0.4$  | %FSR          |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 0.6$  | %FSR          |
| Full-scale error <sup>Notes 1, 2</sup>             |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 0.4$  | %FSR          |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 0.6$  | %FSR          |
| Integral non-linearity error <sup>Note 1</sup>     |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 2.5$  | LSB           |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 4.5$  | LSB           |
| Differential non-linearity error <sup>Note 1</sup> |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 1.5$  | LSB           |
|  |            | $2.7\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 2.0$  | LSB           |
| Analog input voltage                               | $V_{AIN}$  |  | $AV_{SS}$ |           | $AV_{REF}$ | V             |

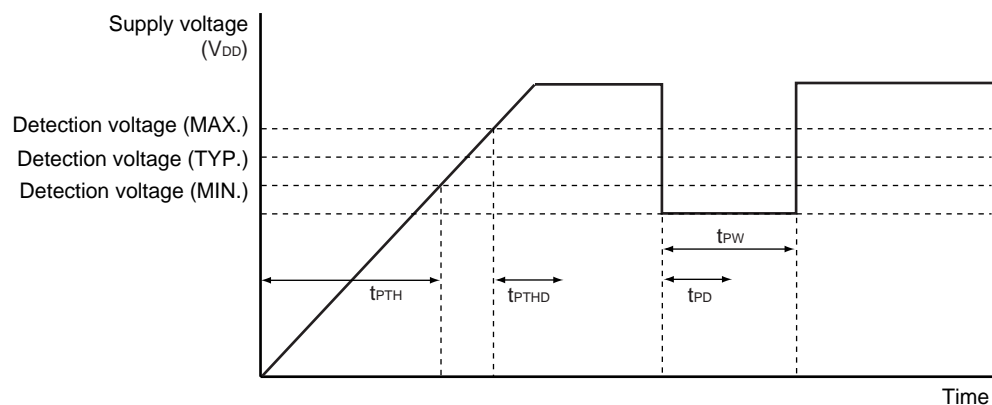
- Notes**
1. Excludes quantization error ( $\pm 1/2$  LSB).
  2. This value is indicated as a ratio (%FSR) to the full-scale value.

**POC Circuit Characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ )**

| Parameter                               | Symbol     | Conditions   | MIN.   | TYP. | MAX. | Unit |
|---|------------|--|--------|------|------|------|
| Detection voltage                       | $V_{POC0}$ | Mask option = $3.5\text{ V}^{\text{Note 1}}$                     | 3.3    | 3.5  | 3.7  | V    |
|   | $V_{POC1}$ | Mask option = $2.85\text{ V}^{\text{Note 2}}$                    | 2.7    | 2.85 | 3.0  | V    |
| Power supply rise time                  | $t_{PTH}$  | $V_{DD}: 0\text{ V} \rightarrow 2.7\text{ V}$                    | 0.0015 |      |      | ms   |
|   |            | $V_{DD}: 0\text{ V} \rightarrow 3.3\text{ V}$                    | 0.002  |      |      | ms   |
| Response delay time 1 <sup>Note 3</sup> | $t_{PTHD}$ | When power supply rises, after reaching detection voltage (MAX.) |        |      | 3.0  | ms   |
| Response delay time 2 <sup>Note 4</sup> | $t_{PD}$   | When $V_{DD}$ falls  |        |      | 1.0  | ms   |
| Minimum pulse width                     | $t_{PW}$   |  | 0.2    |      |      | ms   |

- Notes**
- When flash memory version  $\mu\text{PD78F0103M5}$ ,  $78\text{F0103M6}$ ,  $78\text{F0103M5(A)}$ , or  $78\text{F0103M6(A)}$  is used
  - When flash memory version  $\mu\text{PD78F0103M3}$ ,  $78\text{F0103M4}$ ,  $78\text{F0103M3(A)}$ , or  $78\text{F0103M4(A)}$  is used
  - Time required from voltage detection to reset release.
  - Time required from voltage detection to internal reset output.

★

**POC Circuit Timing**


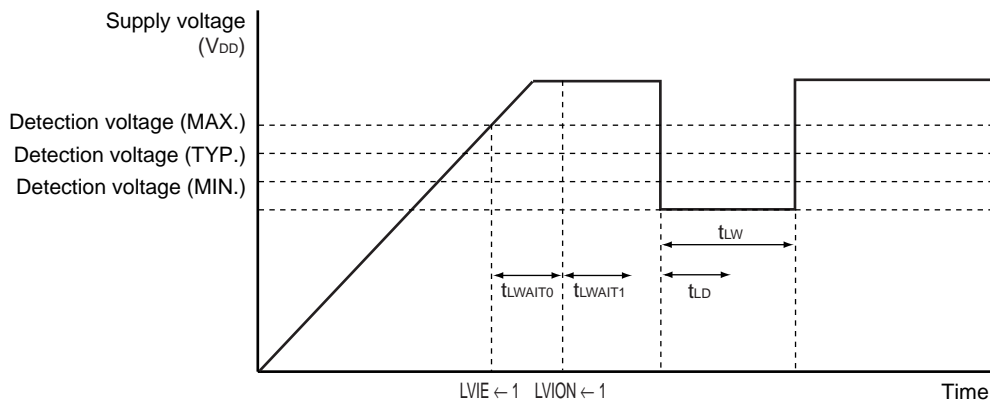
**LVI Circuit Characteristics (T<sub>A</sub> = -40 to +85°C)**

| Parameter   | Symbol              | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---------------------|------------|------|------|------|------|
| Detection voltage   | V <sub>LV10</sub>   |            | 4.1  | 4.3  | 4.5  | V    |
|   | V <sub>LV11</sub>   |            | 3.9  | 4.1  | 4.3  | V    |
|   | V <sub>LV12</sub>   |            | 3.7  | 3.9  | 4.1  | V    |
|   | V <sub>LV13</sub>   |            | 3.5  | 3.7  | 3.9  | V    |
|   | V <sub>LV14</sub>   |            | 3.3  | 3.5  | 3.7  | V    |
|   | V <sub>LV15</sub>   |            | 3.15 | 3.3  | 3.45 | V    |
|   | V <sub>LV16</sub>   |            | 2.95 | 3.1  | 3.25 | V    |
| Response time <sup>Note 1</sup>                             | t <sub>LD</sub>     |            |      | 0.2  | 2.0  | ms   |
| Minimum pulse width   | t <sub>LW</sub>     |            | 0.2  |      |      | ms   |
| Reference voltage stabilization wait time <sup>Note 2</sup> | t <sub>LWAIT0</sub> |            |      | 0.5  | 2.0  | ms   |
| Operation stabilization wait time <sup>Note 3</sup>         | t <sub>LWAIT1</sub> |            |      | 0.1  | 0.2  | ms   |

- Notes**
- Time required from voltage detection to interrupt output or internal reset output.
  - Time required from setting LVIE to 1 to reference voltage stabilization when POC-OFF is selected by mask option (for the flash memory version, when the  $\mu$ PD78F0103M1, 78F0103M2, 78F0103M1(A), or 78F0103M2(A) is used).
  - Time required from setting LVION to 1 to operation stabilization.

**Remarks 1.** V<sub>LV10</sub> > V<sub>LV11</sub> > V<sub>LV12</sub> > V<sub>LV13</sub> > V<sub>LV14</sub> > V<sub>LV15</sub> > V<sub>LV16</sub>

**2.** V<sub>POCn</sub> < V<sub>LVIm</sub> (n = 0 or 1, m = 0 to 6)

**LVI Circuit Timing**

**Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics (T<sub>A</sub> = -40 to +85°C)**

| Parameter                     | Symbol            | Conditions  | MIN. | TYP. | MAX. | Unit    |
|-------------------------------|-------------------|---|------|------|------|---------|
| Data retention supply voltage | V <sub>DDDR</sub> | When POC-OFF is selected by mask option <sup>Note</sup> | 1.6  |      | 5.5  | V       |
| Release signal set time       | t <sub>SREL</sub> |   | 0    |      |      | $\mu$ s |

**Note** When flash memory version  $\mu$ PD78F0103M1, 78F0103M2, 78F0103M1(A), or 78F0103M2(A) is used

**Flash Memory Programming Characteristics:  $\mu$ PD78F0103, 78F0103(A)**  
**( $T_A = +10$  to  $+60^\circ\text{C}$ ,  $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $2.7\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

**(1) Write erase characteristics**

| Parameter  | Symbol     | Conditions   | MIN.  | TYP. | MAX.  | Unit          |
|--|------------|--|-------|------|-------|---------------|
| $V_{PP}$ supply voltage  | $V_{PP2}$  | During flash memory programming  | 9.7   | 10.0 | 10.3  | V             |
| $V_{DD}$ supply current  | $I_{DD}$   | When $V_{PP} = V_{PP2}$ , $f_{XP} = 10\text{ MHz}$ , $V_{DD} = 5.5\text{ V}$ |       |      | 37    | mA            |
| $V_{PP}$ supply current  | $I_{PP}$   | $V_{PP} = V_{PP2}$   |       |      | 100   | mA            |
| Step erase time <sup>Note 1</sup>                              | $T_{er}$   |  | 0.199 | 0.2  | 0.201 | s             |
| Overall erase time <sup>Note 2</sup>                           | $T_{era}$  | When step erase time = 0.2 s   |       |      | 20    | s/chip        |
| Writeback time <sup>Note 3</sup>                               | $T_{wb}$   |  | 49.4  | 50   | 50.6  | ms            |
| Number of writebacks per 1 writeback command <sup>Note 4</sup> | $C_{wb}$   | When writeback time = 50 ms  |       |      | 60    | Times         |
| Number of erases/writebacks                                    | $C_{erwb}$ |  |       |      | 16    | Times         |
| Step write time <sup>Note 5</sup>                              | $T_{wr}$   |  | 48    | 50   | 52    | $\mu\text{s}$ |
| Overall write time per word <sup>Note 6</sup>                  | $T_{wrw}$  | When step write time = 50 $\mu\text{s}$ (1 word = 1 byte)                    | 48    |      | 520   | $\mu\text{s}$ |
| Number of rewrites per chip <sup>Note 7</sup>                  | $C_{erwr}$ | 1 erase + 1 write after erase = 1 rewrite                                    |       |      | 20    | Times/area    |

- Notes**
- The recommended setting value of the step erase time is 0.2 s.
  - The prewrite time before erasure and the erase verify time (writeback time) are not included.
  - The recommended setting value of the writeback time is 50 ms.
  - Writeback is executed once by the issuance of the writeback command. Therefore, the number of retries must be the maximum value minus the number of commands issued.
  - The recommended setting value of the step write time is 50  $\mu\text{s}$ .
  - The actual write time per word is 100  $\mu\text{s}$  longer. The internal verify time during or after a write is not included.
  - When a product is first written after shipment, "erase  $\rightarrow$  write" and "write only" are both taken as one rewrite.

Example: P: Write, E: Erase

Shipped product  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P: 3 rewrites

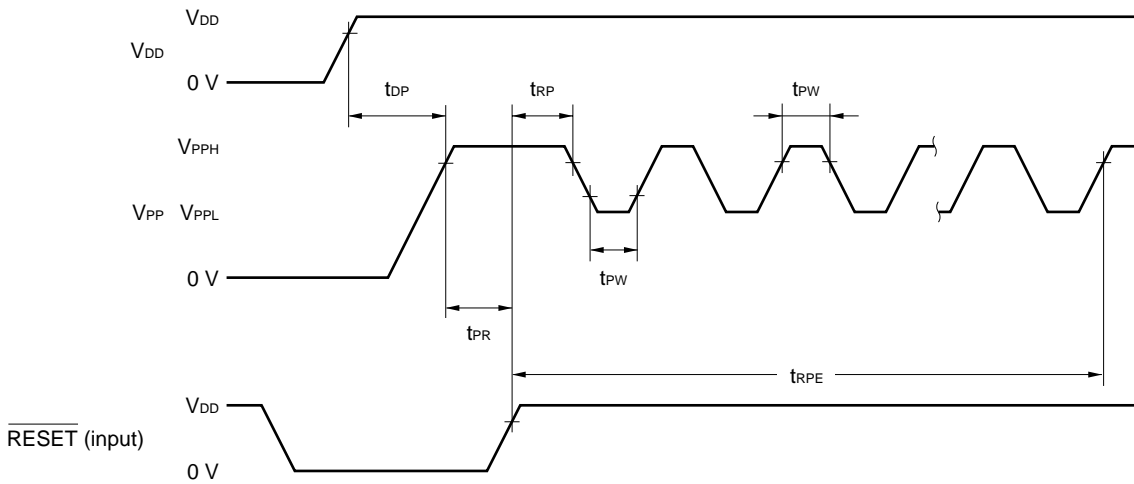
Shipped product  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P: 3 rewrites

**Remark** The range of the operating clock during flash memory programming is the same as the range during normal operation.

**(2) Serial write operation characteristics**

| Parameter   | Symbol    | Conditions | MIN.        | TYP. | MAX.        | Unit          |
|---|-----------|------------|-------------|------|-------------|---------------|
| Set time from $V_{DD}\uparrow$ to $V_{PP}\uparrow$                      | $t_{DP}$  |            | 10          |      |             | $\mu\text{s}$ |
| Release time from $V_{PP}\uparrow$ to $\overline{\text{RESET}}\uparrow$ | $t_{PR}$  |            | 10          |      |             | $\mu\text{s}$ |
| $V_{PP}$ pulse input start time from $\overline{\text{RESET}}\uparrow$  | $t_{RP}$  |            | 2           |      |             | ms            |
| $V_{PP}$ pulse high-/low-level width                                    | $t_{PW}$  |            | 8           |      |             | $\mu\text{s}$ |
| $V_{PP}$ pulse input end time from $\overline{\text{RESET}}\uparrow$    | $t_{RPE}$ |            |             |      | 14          | ms            |
| $V_{PP}$ pulse low-level input voltage                                  | $V_{PPL}$ |            | $0.8V_{DD}$ |      | $1.2V_{DD}$ | V             |
| $V_{PP}$ pulse high-level input voltage                                 | $V_{PPH}$ |            | 9.7         | 10.0 | 10.3        | V             |

**Flash Write Mode Setting Timing**



## CHAPTER 25 ELECTRICAL SPECIFICATIONS ((A1) GRADE PRODUCTS)

Target products:  $\mu$ PD780101(A1), 780102(A1), 780103(A1), 78F0103(A1)

### Absolute Maximum Ratings (T<sub>A</sub> = 25°C)

| Parameter                     | Symbol            | Conditions  | Ratings  | Unit |             |
|-------------------------------|-------------------|---|--|------|-------------|
| Supply voltage                | V <sub>DD</sub>   |   | -0.3 to +6.5   | V    |             |
|                               | V <sub>SS</sub>   |   | -0.3 to +0.3   | V    |             |
|                               | AV <sub>REF</sub> |   | -0.3 to V <sub>DD</sub> + 0.3 <sup>Note 1</sup>  | V    |             |
|                               | AV <sub>SS</sub>  |   | -0.3 to +0.3   | V    |             |
|                               | V <sub>PP</sub>   | $\mu$ PD78F0103(A1) only <b>Note 2</b>                                | -0.3 to +10.5  | V    |             |
| Input voltage                 | V <sub>I1</sub>   | P00 to P03, P10 to P17, P20 to P23, P30 to P33, P120, X1, X2, RESET   | -0.3 to V <sub>DD</sub> + 0.3 <sup>Note 1</sup>  | V    |             |
|                               | V <sub>I2</sub>   | V <sub>PP</sub> in flash programming mode ( $\mu$ PD78F0103(A1) only) | -0.3 to +10.5  | V    |             |
| Output voltage                | V <sub>O</sub>    |   | -0.3 to V <sub>DD</sub> + 0.3 <sup>Note 1</sup>  | V    |             |
| Analog input voltage          | V <sub>AN</sub>   |   | AV <sub>SS</sub> - 0.3 to AV <sub>REF</sub> + 0.3 <sup>Note 1</sup><br>and -0.3 to V <sub>DD</sub> + 0.3 <sup>Note 1</sup> | V    |             |
| Output current, high          | I <sub>OH</sub>   | Per pin   | -8   | mA   |             |
|                               |                   | Total of pins   | P30 to P33, P120   | -24  | mA          |
|                               |                   |   | P00 to P03, P10 to P17, P130   | -24  | mA          |
|                               |                   | Total of all pins   | -40  | mA   |             |
| Output current, low           | I <sub>OL</sub>   | Per pin   | 16   | mA   |             |
|                               |                   | Total of pins   | P30 to P33, P120   | 28   | mA          |
|                               |                   |   | P00 to P03, P10 to P17, P130   | 28   | mA          |
|                               |                   | Total of all pins   | 48   | mA   |             |
| Operating ambient temperature | T <sub>A</sub>    | $\mu$ PD780101(A1), 780102(A1), 780103(A1)                            | -40 to +110  | °C   |             |
|                               |                   | $\mu$ PD78F0103(A1)   | In normal operation mode   |      | -40 to +105 |
|                               |                   |   | In flash memory programming  |      | -10 to +85  |
| Storage temperature           | T <sub>stg</sub>  | $\mu$ PD780101(A1), 780102(A1), 780103(A1)                            | -65 to +150  | °C   |             |
|                               |                   | $\mu$ PD78F0103(A1)   | -40 to +125  |      |             |

**Note 1.** Must be 6.5 V or lower.  
(Refer to **Note 2** on the next page.)

**Caution** Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

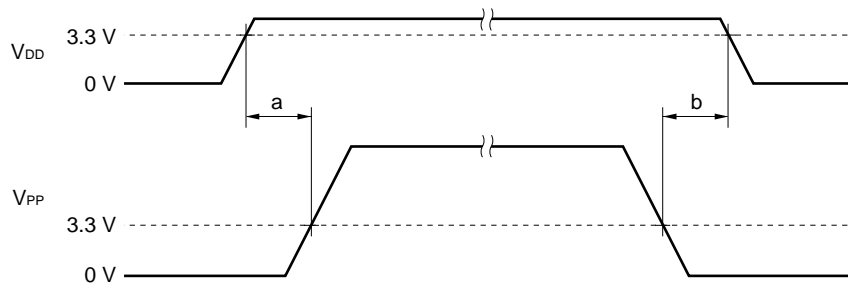
**Note 2.** Make sure that the following conditions of the  $V_{PP}$  voltage application timing are satisfied when the flash memory is written.

- **When supply voltage rises**

$V_{PP}$  must exceed  $V_{DD}$  10  $\mu\text{s}$  or more after  $V_{DD}$  has reached the lower-limit value (3.3 V) of the operating voltage range (see a in the figure below).

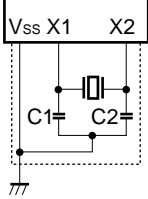
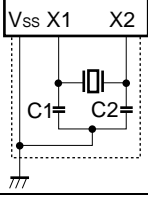
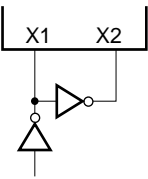
- **When supply voltage drops**

$V_{DD}$  must be lowered 10  $\mu\text{s}$  or more after  $V_{PP}$  falls below the lower-limit value (3.3 V) of the operating voltage range of  $V_{DD}$  (see b in the figure below).





**X1 Oscillator Characteristics ( $T_A = -40$  to  $+110^\circ\text{C}$ <sup>Note 1</sup>,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Resonator         | Recommended Circuit   | Parameter  | Conditions                                   | MIN. | TYP. | MAX. | Unit |
|-------------------|---|--|--|------|------|------|------|
| Ceramic resonator |  | Oscillation frequency ( $f_{XP}$ ) <sup>Note 2</sup>   | $4.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 10   | MHz  |
|                   |   |  | $4.0\text{ V} \leq V_{DD} < 4.5\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |   |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 5.0  |      |
| Crystal resonator |  | Oscillation frequency ( $f_{XP}$ ) <sup>Note 2</sup>   | $4.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 10   | MHz  |
|                   |   |  | $4.0\text{ V} \leq V_{DD} < 4.5\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |   |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 5.0  |      |
| External clock    |  | X1 input frequency ( $f_{XP}$ ) <sup>Note 2</sup>      | $4.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 10   | MHz  |
|                   |   |  | $4.0\text{ V} \leq V_{DD} < 4.5\text{ V}$    | 2.0  |      | 8.38 |      |
|                   |   |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 5.0  |      |
|                   |   | X1 input high-/low-level width ( $t_{xH}$ , $t_{xL}$ ) | $4.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 46   |      | 500  | ns   |
|                   |   |  | $4.0\text{ V} \leq V_{DD} < 4.5\text{ V}$    | 56   |      | 500  |      |
|                   |   |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 96   |      | 500  |      |

**Notes** 1.  $T_A = -40$  to  $+110^\circ\text{C}$ :  $\mu\text{PD780101(A1)}$ ,  $780102(A1)$ ,  $780103(A1)$

$T_A = -40$  to  $+105^\circ\text{C}$ :  $\mu\text{PD78F0103(A1)}$

2. Indicates only oscillator characteristics. Refer to **AC Characteristics** for instruction execution time.

**Cautions** 1. When using the X1 oscillator, wire as follows in the area enclosed by the broken lines in the above figures to avoid an adverse effect from wiring capacitance.

- Keep the wiring length as short as possible.
- Do not cross the wiring with the other signal lines.
- Do not route the wiring near a signal line through which a high fluctuating current flows.
- Always make the ground point of the oscillator capacitor the same potential as  $V_{SS}$ .
- Do not ground the capacitor to a ground pattern through which a high current flows.
- Do not fetch signals from the oscillator.

- ★ 2. Since the CPU is started by the Ring-OSC after reset is released, check the oscillation stabilization time of the X1 input clock using the oscillation stabilization time counter status register (OSTC). Determine the oscillation stabilization time of the OSTC register and oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.

**Remark** For the resonator selection and oscillator constant, users are required to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation.

**Ring-OSC Oscillator Characteristics**

( $T_A = -40$  to  $+110^\circ\text{C}$ <sup>Note</sup>,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Resonator                   | Parameter                       | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------|---------------------------------|------------|------|------|------|------|
| On-chip Ring-OSC oscillator | Oscillation frequency ( $f_R$ ) |            | 120  | 240  | 490  | kHz  |

**Note**  $T_A = -40$  to  $+110^\circ\text{C}$ :  $\mu\text{PD780101(A1)}$ ,  $780102(A1)$ ,  $780103(A1)$

$T_A = -40$  to  $+105^\circ\text{C}$ :  $\mu\text{PD78F0103(A1)}$

**DC Characteristics (1/4):  $\mu$ PD78F0103(A1)**
**( $T_A = -40$  to  $+105^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Parameter                      | Symbol     | Conditions   |   | MIN.  | TYP. | MAX.           | Unit             |
|--------------------------------|------------|--|---|---|------|----------------|------------------|
| Output current, high           | $I_{OH}$   | Per pin  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |      | -4             | mA               |
|                                |            | Total of P30 to P33, P120  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |      | -20            | mA               |
|                                |            | Total of P00 to P03, P10 to P17, P130                                  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |      | -20            | mA               |
|                                |            | Total of all pins  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |      | -25            | mA               |
|                                |            |  |   | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |      | -8             | mA               |
| Output current, low            | $I_{OL}$   | Per pin  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |      | 8              | mA               |
|                                |            | Total of P30 to P33, P120  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |      | 24             | mA               |
|                                |            | Total of P00 to P03, P10 to P17, P130                                  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |      | 24             | mA               |
|                                |            | Total of all pins  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$                              |      | 30             | mA               |
|                                |            |  |   | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |      | 8              | mA               |
| Input voltage, high            | $V_{IH1}$  | P12, P13, P15  |   | $0.7V_{DD}$   |      | $V_{DD}$       | V                |
|                                | $V_{IH2}$  | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET           |   | $0.8V_{DD}$   |      | $V_{DD}$       | V                |
|                                | $V_{IH3}$  | P20 to P23 <sup>Note 1</sup>   |   | $0.7AV_{REF}$   |      | $AV_{REF}$     | V                |
|                                | $V_{IH4}$  | X1, X2   |   | $V_{DD} - 0.5$  |      | $V_{DD}$       | V                |
| Input voltage, low             | $V_{IL1}$  | P12, P13, P15  |   | 0   |      | $0.3V_{DD}$    | V                |
|                                | $V_{IL2}$  | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET           |   | 0   |      | $0.2V_{DD}$    | V                |
|                                | $V_{IL3}$  | P20 to P23 <sup>Note 1</sup>   |   | 0   |      | $0.3AV_{REF}$  | V                |
|                                | $V_{IL4}$  | X1, X2   |   | 0   |      | 0.4            | V                |
| Output voltage, high           | $V_{OH}$   | Total of P30 to P33, P120 pins<br>$I_{OH} = -20\text{ mA}$             |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OH} = -4\text{ mA}$ |      | $V_{DD} - 1.0$ | V                |
|                                |            | Total of P00 to P03, P10 to P17, P130 pins<br>$I_{OH} = -20\text{ mA}$ |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OH} = -4\text{ mA}$ |      | $V_{DD} - 1.0$ | V                |
|                                |            | $I_{OH} = -100\ \mu\text{A}$   |   | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |      | $V_{DD} - 0.5$ | V                |
| Output voltage, low            | $V_{OL}$   | Total of P30 to P33, P120 pins<br>$I_{OL} = 24\text{ mA}$              |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OL} = 8\text{ mA}$  |      | 1.3            | V                |
|                                |            | Total of P00 to P03, P10 to P17, P130 pins<br>$I_{OL} = 24\text{ mA}$  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OL} = 8\text{ mA}$  |      | 1.3            | V                |
|                                |            | $I_{OL} = 400\ \mu\text{A}$  |   | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |      | 0.4            | V                |
| Input leakage current, high    | $I_{LIH1}$ | $V_i = V_{DD}$   | P00 to P03, P10 to P17, P30 to P33, P120, RESET             |   |      | 10             | $\mu\text{A}$    |
|                                |            | $V_i = AV_{REF}$   | P20 to P23  |   |      | 10             | $\mu\text{A}$    |
|                                | $I_{LIH2}$ | $V_i = V_{DD}$   | X1, X2 <sup>Note 2</sup>                                    |   |      | 20             | $\mu\text{A}$    |
| Input leakage current, low     | $I_{LIL1}$ | $V_i = 0\text{ V}$   | P00 to P03, P10 to P17, P20 to P23, P30 to P33, P120, RESET |   |      | -10            | $\mu\text{A}$    |
|                                |            |  | X1, X2 <sup>Note 2</sup>                                    |   |      | -20            | $\mu\text{A}$    |
| Output leakage current, high   | $I_{LOH}$  | $V_o = V_{DD}$   |   |   |      | 10             | $\mu\text{A}$    |
| Output leakage current, low    | $I_{LOL}$  | $V_o = 0\text{ V}$   |   |   |      | -10            | $\mu\text{A}$    |
| Pull-up resistance value       | R          | $V_i = 0\text{ V}$   |   | 10  | 30   | 120            | $\text{k}\Omega$ |
| V <sub>PP</sub> supply voltage | $V_{PP1}$  | In normal operation mode   |   | 0   |      | $0.2V_{DD}$    | V                |

**Notes** 1. When used as a digital input port, set  $AV_{REF} = V_{DD}$ .

2. When the inverse level of X1 is input to X2.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**DC Characteristics (2/4):  $\mu$ PD780101(A1), 780102(A1), 780103(A1)**  
 ( $T_A = -40$  to  $+110^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter                    | Symbol     | Conditions   |   | MIN.   | TYP. | MAX.          | Unit          |
|------------------------------|------------|--|---|--|------|---------------|---------------|
| Output current, high         | $I_{OH}$   | Per pin  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | -4            | mA            |
|                              |            | Total of P30 to P33, P120  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | -20           | mA            |
|                              |            | Total of P00 to P03, P10 to P17, P130                                  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | -20           | mA            |
|                              |            | Total of all pins  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | -32           | mA            |
|                              |            |  |   | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    |      | -8            | mA            |
| Output current, low          | $I_{OL}$   | Per pin  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | 8             | mA            |
|                              |            | Total of P30 to P33, P120  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | 24            | mA            |
|                              |            | Total of P00 to P03, P10 to P17, P130                                  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | 24            | mA            |
|                              |            | Total of all pins  |   | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |      | 40            | mA            |
|                              |            |  |   | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    |      | 8             | mA            |
| Input voltage, high          | $V_{IH1}$  | P12, P13, P15  |   | $0.7V_{DD}$                                  |      | $V_{DD}$      | V             |
|                              | $V_{IH2}$  | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET           |   | $0.8V_{DD}$                                  |      | $V_{DD}$      | V             |
|                              | $V_{IH3}$  | P20 to P23 <sup>Note 1</sup>   |   | $0.7AV_{REF}$                                |      | $AV_{REF}$    | V             |
|                              | $V_{IH4}$  | X1, X2   |   | $V_{DD} - 0.5$                               |      | $V_{DD}$      | V             |
| Input voltage, low           | $V_{IL1}$  | P12, P13, P15  |   | 0  |      | $0.3V_{DD}$   | V             |
|                              | $V_{IL2}$  | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET           |   | 0  |      | $0.2V_{DD}$   | V             |
|                              | $V_{IL3}$  | P20 to P23 <sup>Note 1</sup>   |   | 0  |      | $0.3AV_{REF}$ | V             |
|                              | $V_{IL4}$  | X1, X2   |   | 0  |      | 0.4           | V             |
| Output voltage, high         | $V_{OH}$   | Total of P30 to P33, P120 pins<br>$I_{OH} = -20\text{ mA}$             | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OH} = -4\text{ mA}$ | $V_{DD} - 1.0$                               |      |               | V             |
|                              |            | Total of P00 to P03, P10 to P17, P130 pins<br>$I_{OH} = -20\text{ mA}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OH} = -4\text{ mA}$ | $V_{DD} - 1.0$                               |      |               | V             |
|                              |            | $I_{OH} = -100\text{ }\mu\text{A}$                                     | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 | $V_{DD} - 0.5$                               |      |               | V             |
| Output voltage, low          | $V_{OL}$   | Total of P30 to P33, P120 pins<br>$I_{OL} = 24\text{ mA}$              | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OL} = 8\text{ mA}$  |  |      | 1.3           | V             |
|                              |            | Total of P00 to P03, P10 to P17, P130 pins<br>$I_{OL} = 24\text{ mA}$  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,<br>$I_{OL} = 8\text{ mA}$  |  |      | 1.3           | V             |
|                              |            | $I_{OL} = 400\text{ }\mu\text{A}$                                      | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$                                 |  |      | 0.4           | V             |
| Input leakage current, high  | $I_{LIH1}$ | $V_i = V_{DD}$   | P00 to P03, P10 to P17, P30 to P33, P120, RESET                           |  |      | 10            | $\mu\text{A}$ |
|                              |            | $V_i = AV_{REF}$   | P20 to P23  |  |      | 10            | $\mu\text{A}$ |
|                              | $I_{LIH2}$ | $V_i = V_{DD}$   | X1, X2 <sup>Note 2</sup>  |  |      | 20            | $\mu\text{A}$ |
| Input leakage current, low   | $I_{LIL1}$ | $V_i = 0\text{ V}$   | P00 to P03, P10 to P17, P20 to P23, P30 to P33, P120, RESET               |  |      | -10           | $\mu\text{A}$ |
|                              | $I_{LIL2}$ |  | X1, X2 <sup>Note 2</sup>  |  |      | -20           | $\mu\text{A}$ |
| Output leakage current, high | $I_{LOH}$  | $V_o = V_{DD}$   |   |  |      | 10            | $\mu\text{A}$ |
| Output leakage current, low  | $I_{LOL}$  | $V_o = 0\text{ V}$   |   |  |      | -10           | $\mu\text{A}$ |
| Pull-up resistance value     | R          | $V_i = 0\text{ V}$   |   | 10   | 30   | 120           | k $\Omega$    |

- Notes**
- When used as a digital input port, set  $AV_{REF} = V_{DD}$ .
  - When the inverse level of X1 is input to X2.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**DC Characteristics (3/4):  $\mu$ PD78F0103(A1)**
**( $T_A = -40$  to  $+105^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Parameter                        | Symbol           | Conditions  |  | MIN.  | TYP. | MAX. | Unit |         |
|----------------------------------|------------------|---|--|---|------|------|------|---------|
| Supply current <sup>Note 1</sup> | I <sub>DD1</sub> | X1 crystal oscillation operating mode <sup>Note 2</sup> | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 11.6 | 20.6 | mA      |
|                                  |                  |   |  | When A/D converter is operating <sup>Note 4</sup> |      | 12.6 | 22.6 | mA      |
|                                  | I <sub>DD2</sub> | X1 crystal oscillation HALT mode                        | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10%                   | When peripheral functions are stopped             |      | 1.4  | 3.9  | mA      |
|                                  |                  |   |  | When peripheral functions are operating           |      |      | 6.6  | mA      |
|                                  | I <sub>DD3</sub> | Ring-OSC operating mode <sup>Note 5</sup>               | V <sub>DD</sub> = 5.0 V $\pm$ 10%  |   |      | 0.37 | 2.61 | mA      |
|                                  | I <sub>DD4</sub> | Ring-OSC HALT mode <sup>Note 5</sup>                    | V <sub>DD</sub> = 5.0 V $\pm$ 10%  |   |      | 0.19 | 1.86 | mA      |
|                                  | I <sub>DD5</sub> | STOP mode   | V <sub>DD</sub> = 5.0 V $\pm$ 10%  | POC: OFF, RING: OFF                               |      | 0.1  | 1100 | $\mu$ A |
|                                  |                  |   |  | POC: OFF, RING: ON                                |      | 14   | 1200 | $\mu$ A |
|                                  |                  |   |  | POC: ON <sup>Note 6</sup> , RING: OFF             |      | 3.5  | 1100 | $\mu$ A |
|                                  |                  |   |  | POC: ON <sup>Note 6</sup> , RING: ON              |      | 17.5 | 1200 | $\mu$ A |

**Notes** 1. Total current flowing through the internal power supply (V<sub>DD</sub>). Peripheral operation current is included (however, the current that flows through the pull-up resistors of ports is not included).

2. I<sub>DD1</sub> includes peripheral operation current.

3. When PCC = 00H.

4. Total current flowing through V<sub>DD</sub> and AV<sub>REF</sub> pins.

5. When X1 oscillator is stopped.

6. Including when LVIE (bit 4 of LVIM) = 1 in the  $\mu$ PD78F0103M1(A1) and 78F0103M2(A1).

**DC Characteristics (4/4):  $\mu$ PD780101(A1), 780102(A1), 780103(A1)**

( $T_A = -40$  to  $+110^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter                        | Symbol           | Conditions  |  | MIN.  | TYP. | MAX. | Unit |         |
|----------------------------------|------------------|---|--|---|------|------|------|---------|
| Supply current <sup>Note 1</sup> | I <sub>DD1</sub> | X1 crystal oscillation operating mode <sup>Note 2</sup> | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 6    | 11.7 | mA      |
|                                  |                  |   |  | When A/D converter is operating <sup>Note 4</sup> |      | 7    | 13.7 | mA      |
|                                  | I <sub>DD2</sub> | X1 crystal oscillation HALT mode                        | f <sub>XP</sub> = 10 MHz,<br>V <sub>DD</sub> = 5.0 V $\pm$ 10%                   | When peripheral functions are stopped             |      | 1.3  | 3.4  | mA      |
|                                  |                  |   |  | When peripheral functions are operating           |      |      | 5.6  | mA      |
|                                  | I <sub>DD3</sub> | Ring-OSC operating mode <sup>Note 5</sup>               | V <sub>DD</sub> = 5.0 V $\pm$ 10%  |   | 0.18 | 1.52 | mA   |         |
|                                  | I <sub>DD4</sub> | Ring-OSC HALT mode <sup>Note 5</sup>                    | V <sub>DD</sub> = 5.0 V $\pm$ 10%  |   | 0.05 | 1.00 | mA   |         |
|                                  | I <sub>DD5</sub> | STOP mode   | V <sub>DD</sub> = 5.0 V $\pm$ 10%  | POC: OFF, RING: OFF                               |      | 0.1  | 800  | $\mu$ A |
|                                  |                  |   |  | POC: OFF, RING: ON                                |      | 14   | 900  | $\mu$ A |
|                                  |                  |   |  | POC: ON <sup>Note 6</sup> , RING: OFF             |      | 3.5  | 800  | $\mu$ A |
|                                  |                  |   |  | POC: ON <sup>Note 6</sup> , RING: ON              |      | 17.5 | 900  | $\mu$ A |

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- Notes**
1. Total current flowing through the internal power supply (V<sub>DD</sub>). Peripheral operation current is included (however, the current that flows through the pull-up resistors of ports is not included).
  2. I<sub>DD1</sub> includes peripheral operation current.
  3. When PCC = 00H.
  4. Total current flowing through V<sub>DD</sub> and AV<sub>REF</sub> pins.
  5. When X1 oscillator is stopped.
  6. Including when LVIE (bit 4 of LVIM) = 1 with POC-OFF selected by a mask option.

## AC Characteristics

 (1) Basic operation ( $T_A = -40$  to  $+110^\circ\text{C}$ <sup>Note 1</sup>,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )

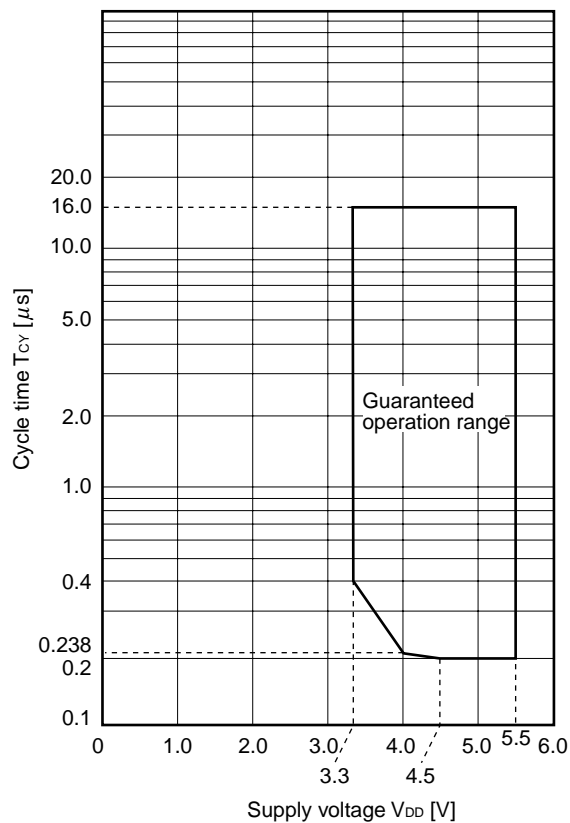
| Parameter  | Symbol                     | Conditions                                   | MIN.   | TYP.  | MAX.  | Unit          |               |
|--|----------------------------|--|--|-------|-------|---------------|---------------|
| Instruction cycle (minimum instruction execution time) | $T_{CY}$                   | X1 input clock                               | $4.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 0.2   |       | 16            | $\mu\text{s}$ |
|  |                            |  | $4.0\text{ V} \leq V_{DD} < 4.5\text{ V}$    | 0.238 |       | 16            | $\mu\text{s}$ |
|  |                            |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 0.4   |       | 16            | $\mu\text{s}$ |
|  |                            | Ring-OSC clock                               | 4.09   | 8.33  | 16.67 | $\mu\text{s}$ |               |
| TI000, TI010 input high-level width, low-level width   | $t_{TIH0}$ ,<br>$t_{TIL0}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | $2/f_{sam} + 0.1$ <sup>Note 2</sup>          |       |       | $\mu\text{s}$ |               |
|  |                            | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | $2/f_{sam} + 0.2$ <sup>Note 2</sup>          |       |       | $\mu\text{s}$ |               |
| TI50 input frequency                                   | $f_{TI5}$                  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |  |       | 10    | MHz           |               |
|  |                            | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    |  |       | 5     | MHz           |               |
| TI50 input high-level width, low-level width           | $t_{TIH5}$ ,<br>$t_{TIL5}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 50   |       |       | ns            |               |
|  |                            | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 100  |       |       | ns            |               |
| Interrupt input high-level width, low-level width      | $t_{INTH}$ ,<br>$t_{INTL}$ |  | 1  |       |       | $\mu\text{s}$ |               |
|  |                            |  |  |       |       |               |               |
| RESET low-level width                                  | $t_{RSL}$                  |  | 10   |       |       | $\mu\text{s}$ |               |

**Notes 1.**  $T_A = -40$  to  $+110^\circ\text{C}$ :  $\mu\text{PD780101(A1)}$ ,  $780102(A1)$ ,  $780103(A1)$

$T_A = -40$  to  $+105^\circ\text{C}$ :  $\mu\text{PD78F0103(A1)}$

- 2.** Selection of  $f_{sam} = f_{XP}$ ,  $f_{XP}/4$ ,  $f_{XP}/256$  is possible using bits 0 and 1 (PRM000, PRM001) of prescaler mode register 00 (PRM00). Note that when selecting the TI000 valid edge as the count clock,  $f_{sam} = f_{XP}$ .

**$T_{CY}$  vs.  $V_{DD}$  (X1 Input Clock Operation)**



**(2) Serial interface ( $T_A = -40$  to  $+110^\circ\text{C}^{\text{Note}}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

**Note**  $T_A = -40$  to  $+110^\circ\text{C}$ :  $\mu\text{PD780101(A1)}$ ,  $780102(A1)$ ,  $780103(A1)$

$T_A = -40$  to  $+105^\circ\text{C}$ :  $\mu\text{PD78F0103(A1)}$

**(a) UART mode (UART6, dedicated baud rate generator output)**

| Parameter     | Symbol | Conditions | MIN. | TYP. | MAX.  | Unit |
|---------------|--------|------------|------|------|-------|------|
| Transfer rate |        |            |      |      | 312.5 | kbps |

**(b) UART mode (UART0, dedicated baud rate generator output):**

$\mu\text{PD780102(A1)}$ ,  $780103(A1)$ , and  $78F0103(A1)$  only

| Parameter     | Symbol | Conditions | MIN. | TYP. | MAX.  | Unit |
|---------------|--------|------------|------|------|-------|------|
| Transfer rate |        |            |      |      | 312.5 | kbps |

**(c) 3-wire serial I/O mode (master mode,  $\overline{\text{SCK10}}$ ... internal clock output)**

| Parameter  | Symbol                                 | Conditions                                   | MIN.                  | TYP. | MAX. | Unit |
|--|--|--|-----------------------|------|------|------|
| $\overline{\text{SCK10}}$ cycle time                               | $t_{\text{CY1}}$                       | $4.5\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 200                   |      |      | ns   |
|  |  | $4.0\text{ V} \leq V_{DD} < 4.5\text{ V}$    | 240                   |      |      | ns   |
|  |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 400                   |      |      | ns   |
| $\overline{\text{SCK10}}$ high-/low-level width                    | $t_{\text{KH1}}$ ,<br>$t_{\text{KL1}}$ |  | $t_{\text{CY1}}/2-10$ |      |      | ns   |
| SI10 setup time (to $\overline{\text{SCK10}}\uparrow$ )            | $t_{\text{SIK1}}$                      |  | 30                    |      |      | ns   |
| SI10 hold time (from $\overline{\text{SCK10}}\uparrow$ )           | $t_{\text{KSI1}}$                      |  | 30                    |      |      | ns   |
| Delay time from $\overline{\text{SCK10}}\downarrow$ to SO10 output | $t_{\text{KSO1}}$                      | $C = 100\text{ pF}^{\text{Note}}$            |                       |      | 30   | ns   |

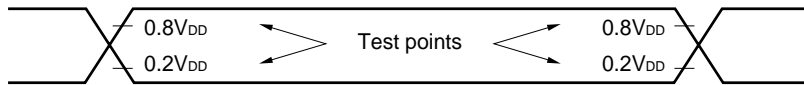
**Note** C is the load capacitance of the  $\overline{\text{SCK10}}$  and SO10 output lines.

**(d) 3-wire serial I/O mode (slave mode,  $\overline{\text{SCK10}}$ ... external clock input)**

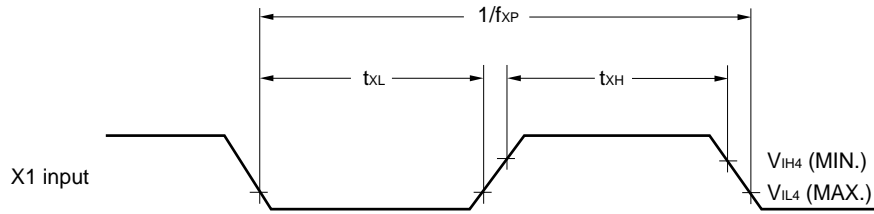
| Parameter  | Symbol                                 | Conditions                        | MIN.               | TYP. | MAX. | Unit |
|--|--|-----------------------------------|--------------------|------|------|------|
| $\overline{\text{SCK10}}$ cycle time                               | $t_{\text{CY2}}$                       |                                   | 400                |      |      | ns   |
| $\overline{\text{SCK10}}$ high-/low-level width                    | $t_{\text{KH2}}$ ,<br>$t_{\text{KL2}}$ |                                   | $t_{\text{CY2}}/2$ |      |      | ns   |
| SI10 setup time (to $\overline{\text{SCK10}}\uparrow$ )            | $t_{\text{SIK2}}$                      |                                   | 80                 |      |      | ns   |
| SI10 hold time (from $\overline{\text{SCK10}}\uparrow$ )           | $t_{\text{KSI2}}$                      |                                   | 50                 |      |      | ns   |
| Delay time from $\overline{\text{SCK10}}\downarrow$ to SO10 output | $t_{\text{KSO2}}$                      | $C = 100\text{ pF}^{\text{Note}}$ |                    |      | 120  | ns   |

**Note** C is the load capacitance of the SO10 output line.

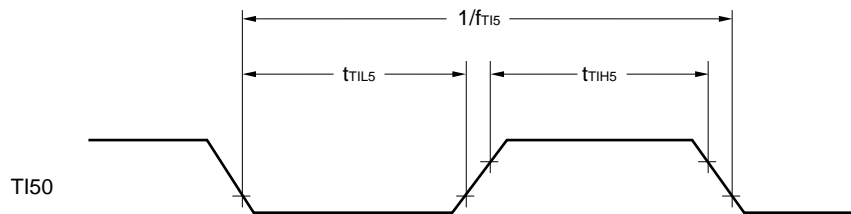
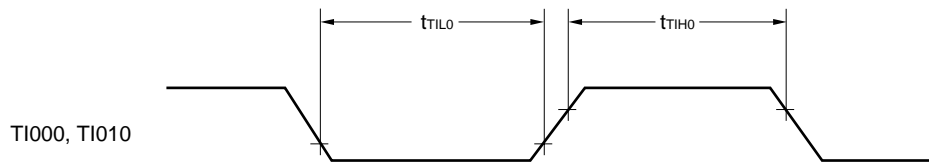
**AC Timing Test Points (Excluding X1 Input)**



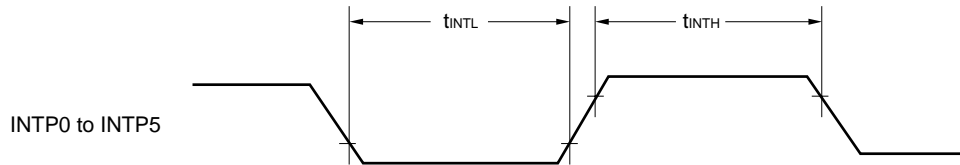
**Clock Timing**



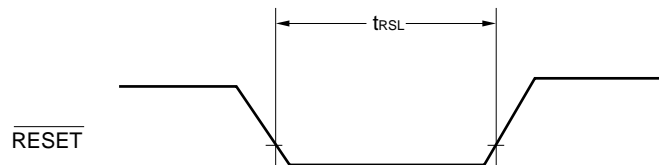
**TI Timing**



**Interrupt Request Input Timing**



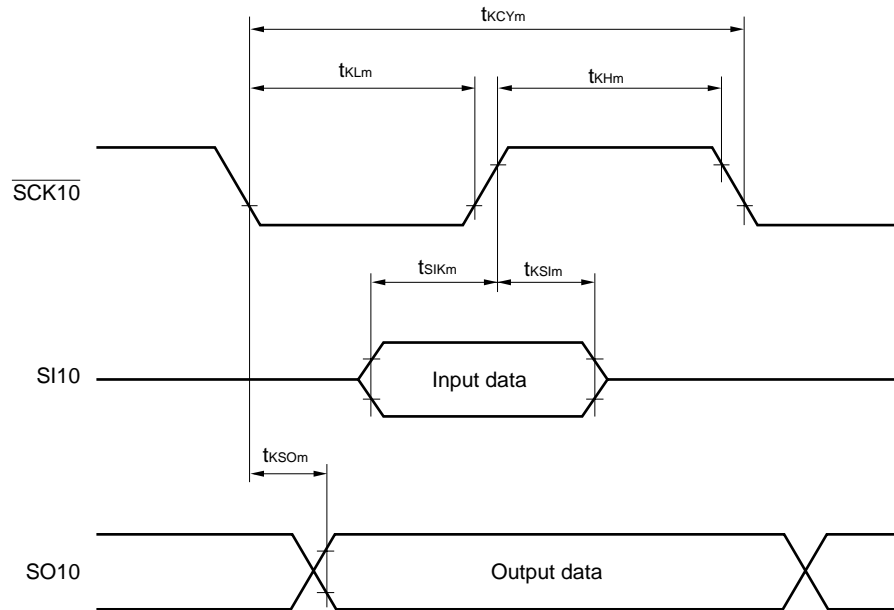
**RESET Input Timing**





## Serial Transfer Timing

3-wire serial I/O mode:


 Remark  $m = 1, 2$ 
**A/D Converter Characteristics ( $T_A = -40$  to  $+110^\circ\text{C}$ <sup>Note 1</sup>,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Parameter  | Symbol     | Conditions                                     | MIN.      | TYP.      | MAX.       | Unit          |
|--|------------|--|-----------|-----------|------------|---------------|
| Resolution   |            |  | 10        | 10        | 10         | bit           |
| Overall error <sup>Notes 2, 3</sup>                |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           | $\pm 0.2$ | $\pm 0.6$  | %FSR          |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           | $\pm 0.3$ | $\pm 0.8$  | %FSR          |
| Conversion time                                    | $t_{CONV}$ | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ | 14        |           | 60         | $\mu\text{s}$ |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    | 19        |           | 60         | $\mu\text{s}$ |
| Zero-scale error <sup>Notes 2, 3</sup>             |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 0.6$  | %FSR          |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 0.8$  | %FSR          |
| Full-scale error <sup>Notes 2, 3</sup>             |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 0.6$  | %FSR          |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 0.8$  | %FSR          |
| Integral non-linearity error <sup>Note 2</sup>     |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 4.5$  | LSB           |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 6.5$  | LSB           |
| Differential non-linearity error <sup>Note 2</sup> |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 2.0$  | LSB           |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 2.5$  | LSB           |
| Analog input voltage                               | $V_{AIN}$  |  | $AV_{SS}$ |           | $AV_{REF}$ | V             |

**Notes** 1.  $T_A = -40$  to  $+110^\circ\text{C}$ :  $\mu\text{PD780101(A1)}$ ,  $780102(A1)$ ,  $780103(A1)$ 
 $T_A = -40$  to  $+105^\circ\text{C}$ :  $\mu\text{PD78F0103(A1)}$ 

 2. Excludes quantization error ( $\pm 1/2$  LSB).

3. This value is indicated as a ratio (%FSR) to the full-scale value.

**POC Circuit Characteristics ( $T_A = -40$  to  $+110^\circ\text{C}$ <sup>Note 1</sup>)**

| Parameter                               | Symbol     | Conditions   | MIN.  | TYP. | MAX. | Unit |
|---|------------|--|-------|------|------|------|
| Detection voltage                       | $V_{POCO}$ | Mask option = 3.5 V <sup>Note 2</sup>                            | 3.3   | 3.5  | 3.72 | V    |
| Power supply rise time                  | $t_{PTH}$  | $V_{DD}: 0\text{ V} \rightarrow 3.3\text{ V}$                    | 0.002 |      |      | ms   |
| Response delay time 1 <sup>Note 3</sup> | $t_{PTHD}$ | When power supply rises, after reaching detection voltage (MAX.) |       |      | 3.0  | ms   |
| Response delay time 2 <sup>Note 4</sup> | $t_{PD}$   | When $V_{DD}$ falls  |       |      | 1.0  | ms   |
| Minimum pulse width                     | $t_{PW}$   |  | 0.2   |      |      | ms   |

**Notes** 1.  $T_A = -40$  to  $+110^\circ\text{C}$ :  $\mu\text{PD780101(A1)}$ ,  $780102(A1)$ ,  $780103(A1)$

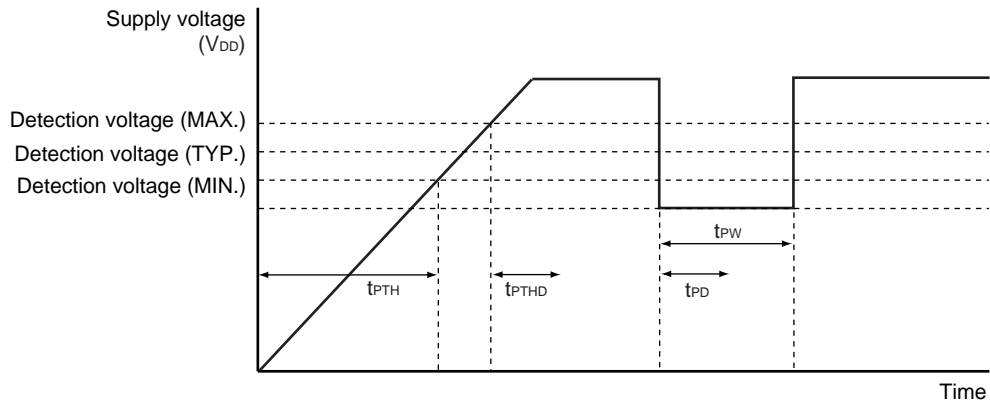
$T_A = -40$  to  $+105^\circ\text{C}$ :  $\mu\text{PD78F0103(A1)}$

2. When flash memory version  $\mu\text{PD78F0103M5(A1)}$  or  $78F0103M6(A1)$  is used

3. Time required from voltage detection to reset release.

★ 4. Time required from voltage detection to internal reset output.

**POC Circuit Timing**

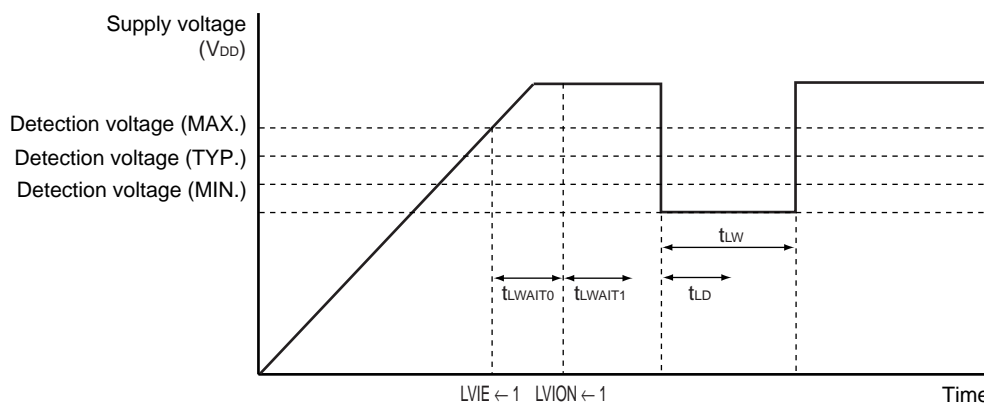


**LVI Circuit Characteristics ( $T_A = -40$  to  $+110^\circ\text{C}$ <sup>Note 1</sup>)**

| Parameter   | Symbol       | Conditions | MIN. | TYP. | MAX. | Unit |
|---|--------------|------------|------|------|------|------|
| Detection voltage   | $V_{LV10}$   |            | 4.1  | 4.3  | 4.52 | V    |
|   | $V_{LV11}$   |            | 3.9  | 4.1  | 4.32 | V    |
|   | $V_{LV12}$   |            | 3.7  | 3.9  | 4.12 | V    |
|   | $V_{LV13}$   |            | 3.5  | 3.7  | 3.92 | V    |
|   | $V_{LV14}$   |            | 3.3  | 3.5  | 3.72 | V    |
| Response time <sup>Note 2</sup>                             | $t_{LD}$     |            |      | 0.2  | 2.0  | ms   |
| Minimum pulse width   | $t_{LW}$     |            | 0.2  |      |      | ms   |
| Reference voltage stabilization wait time <sup>Note 3</sup> | $t_{LWAIT0}$ |            |      | 0.5  | 2.0  | ms   |
| Operation stabilization wait time <sup>Note 4</sup>         | $t_{LWAIT1}$ |            |      | 0.1  | 0.2  | ms   |

- Notes**
- $T_A = -40$  to  $+110^\circ\text{C}$ :  $\mu\text{PD780101(A1)}$ ,  $780102(A1)$ ,  $780103(A1)$   
 $T_A = -40$  to  $+105^\circ\text{C}$ :  $\mu\text{PD78F0103(A1)}$
  - Time required from voltage detection to interrupt output or internal reset output.
  - Time required from setting LVIE to 1 to reference voltage stabilization when POC-OFF is selected by mask option (for the flash memory version, when the  $\mu\text{PD78F0103M1(A1)}$  or  $78F0103M2(A1)$  is used).
  - Time required from setting LVION to 1 to operation stabilization.

- Remarks**
- $V_{LV10} > V_{LV11} > V_{LV12} > V_{LV13} > V_{LV14}$
  - $V_{POC0} < V_{LV1m}$  ( $m = 0$  to  $4$ )

**LVI Circuit Timing**

**Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics ( $T_A = -40$  to  $+110^\circ\text{C}$ <sup>Note 1</sup>)**

| Parameter                     | Symbol     | Conditions  | MIN. | TYP. | MAX. | Unit          |
|-------------------------------|------------|---|------|------|------|---------------|
| Data retention supply voltage | $V_{DDDR}$ | When POC-OFF is selected by mask option <sup>Note 2</sup> | 2.0  |      | 5.5  | V             |
| Release signal set time       | $t_{SREL}$ |   | 0    |      |      | $\mu\text{s}$ |

- Notes**
- $T_A = -40$  to  $+110^\circ\text{C}$ :  $\mu\text{PD780101(A1)}$ ,  $780102(A1)$ ,  $780103(A1)$   
 $T_A = -40$  to  $+105^\circ\text{C}$ :  $\mu\text{PD78F0103(A1)}$
  - When flash memory version  $\mu\text{PD78F0103M1(A1)}$  or  $78F0103M2(A1)$  is used

**Flash Memory Programming Characteristics:  $\mu$ PD78F0103(A1)****( $T_A = +10$  to  $+60^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )****(1) Write erase characteristics**

| Parameter  | Symbol     | Conditions   | MIN.  | TYP. | MAX.  | Unit          |
|--|------------|--|-------|------|-------|---------------|
| $V_{PP}$ supply voltage  | $V_{PP2}$  | During flash memory programming  | 9.7   | 10.0 | 10.3  | V             |
| $V_{DD}$ supply current  | $I_{DD}$   | When $V_{PP} = V_{PP2}$ , $f_{XP} = 10\text{ MHz}$ , $V_{DD} = 5.5\text{ V}$ |       |      | 37    | mA            |
| $V_{PP}$ supply current  | $I_{PP}$   | $V_{PP} = V_{PP2}$   |       |      | 100   | mA            |
| Step erase time <sup>Note 1</sup>                              | $T_{er}$   |  | 0.199 | 0.2  | 0.201 | s             |
| Overall erase time <sup>Note 2</sup>                           | $T_{era}$  | When step erase time = 0.2 s   |       |      | 20    | s/chip        |
| Writeback time <sup>Note 3</sup>                               | $T_{wb}$   |  | 49.4  | 50   | 50.6  | ms            |
| Number of writebacks per 1 writeback command <sup>Note 4</sup> | $C_{wb}$   | When writeback time = 50 ms  |       |      | 60    | Times         |
| Number of erases/writebacks                                    | $C_{erwb}$ |  |       |      | 16    | Times         |
| Step write time <sup>Note 5</sup>                              | $T_{wr}$   |  | 48    | 50   | 52    | $\mu\text{s}$ |
| Overall write time per word <sup>Note 6</sup>                  | $T_{wrw}$  | When step write time = 50 $\mu\text{s}$ (1 word = 1 byte)                    | 48    |      | 520   | $\mu\text{s}$ |
| Number of rewrites per chip <sup>Note 7</sup>                  | $C_{erwr}$ | 1 erase + 1 write after erase = 1 rewrite                                    |       |      | 20    | Times/area    |

- Notes**
- The recommended setting value of the step erase time is 0.2 s.
  - The prewrite time before erasure and the erase verify time (writeback time) are not included.
  - The recommended setting value of the writeback time is 50 ms.
  - Writeback is executed once by the issuance of the writeback command. Therefore, the number of retries must be the maximum value minus the number of commands issued.
  - The recommended setting value of the step write time is 50  $\mu\text{s}$ .
  - The actual write time per word is 100  $\mu\text{s}$  longer. The internal verify time during or after a write is not included.
  - When a product is first written after shipment, "erase  $\rightarrow$  write" and "write only" are both taken as one rewrite.

Example: P: Write, E: Erase

Shipped product  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P: 3 rewrites

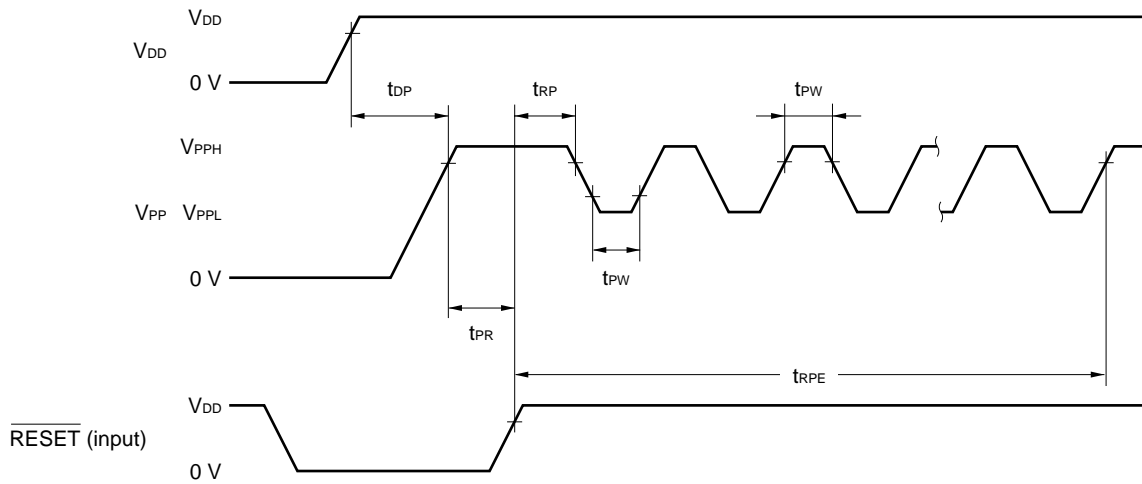
Shipped product  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P  $\rightarrow$  E  $\rightarrow$  P: 3 rewrites

**Remark** The range of the operating clock during flash memory programming is the same as the range during normal operation.

(2) Serial write operation characteristics

| Parameter  | Symbol    | Conditions | MIN.        | TYP. | MAX.        | Unit    |
|--|-----------|------------|-------------|------|-------------|---------|
| Set time from $V_{DD}\uparrow$ to $V_{PP}\uparrow$               | $t_{DP}$  |            | 10          |      |             | $\mu s$ |
| Release time from $V_{PP}\uparrow$ to $\overline{RESET}\uparrow$ | $t_{PR}$  |            | 10          |      |             | $\mu s$ |
| $V_{PP}$ pulse input start time from $\overline{RESET}\uparrow$  | $t_{RP}$  |            | 2           |      |             | ms      |
| $V_{PP}$ pulse high-/low-level width                             | $t_{PW}$  |            | 8           |      |             | $\mu s$ |
| $V_{PP}$ pulse input end time from $\overline{RESET}\uparrow$    | $t_{RPE}$ |            |             |      | 14          | ms      |
| $V_{PP}$ pulse low-level input voltage                           | $V_{PPL}$ |            | $0.8V_{DD}$ |      | $1.2V_{DD}$ | V       |
| $V_{PP}$ pulse high-level input voltage                          | $V_{PPH}$ |            | 9.7         | 10.0 | 10.3        | V       |

Flash Write Mode Setting Timing



## CHAPTER 26 ELECTRICAL SPECIFICATIONS ((A2) GRADE PRODUCTS)

Target products:  $\mu$ PD780101(A2), 780102(A2), 780103(A2)

### Absolute Maximum Ratings ( $T_A = 25^\circ\text{C}$ )

| Parameter                     | Symbol     | Conditions  | Ratings   | Unit             |    |
|-------------------------------|------------|---|---|------------------|----|
| Supply voltage                | $V_{DD}$   |   | -0.3 to +6.5  | V                |    |
|                               | $V_{SS}$   |   | -0.3 to +0.3  | V                |    |
|                               | $AV_{REF}$ |   | -0.3 to $V_{DD} + 0.3^{\text{Note}}$  | V                |    |
|                               | $AV_{SS}$  |   | -0.3 to +0.3  | V                |    |
| Input voltage                 | $V_{I1}$   | P00 to P03, P10 to P17, P20 to P23, P30 to P33, P120, X1, X2, $\overline{\text{RESET}}$ | -0.3 to $V_{DD} + 0.3^{\text{Note}}$  | V                |    |
| Output voltage                | $V_O$      |   | -0.3 to $V_{DD} + 0.3^{\text{Note}}$  | V                |    |
| Analog input voltage          | $V_{AN}$   |   | $AV_{SS} - 0.3$ to $AV_{REF} + 0.3^{\text{Note}}$<br>and -0.3 to $V_{DD} + 0.3^{\text{Note}}$ | V                |    |
| Output current, high          | $I_{OH}$   | Per pin   | -7  | mA               |    |
|                               |            | Total of pins   | P30 to P33, P120  | -21              | mA |
|                               |            |   | P00 to P03, P10 to P17, P130  | -21              | mA |
|                               |            | Total of all pins   | -35   | mA               |    |
| Output current, low           | $I_{OL}$   | Per pin   | 14  | mA               |    |
|                               |            | Total of pins   | P30 to P33, P120  | 24.5             | mA |
|                               |            |   | P00 to P03, P10 to P17, P130  | 24.5             | mA |
|                               |            | Total of all pins   | 42  | mA               |    |
| Operating ambient temperature | $T_A$      | In normal operation mode  | -40 to +125   | $^\circ\text{C}$ |    |
| Storage temperature           | $T_{stg}$  |   | -65 to +150   | $^\circ\text{C}$ |    |

**Note** Must be 6.5 V or lower.

**Caution** Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**X1 Oscillator Characteristics ( $T_A = -40$  to  $+125^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

| Resonator         | Recommended Circuit | Parameter  | Conditions                                   | MIN. | TYP. | MAX. | Unit |
|-------------------|---------------------|--|--|------|------|------|------|
| Ceramic resonator |                     | Oscillation frequency ( $f_{XP}$ ) <sup>Note</sup>     | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 8.38 | MHz  |
|                   |                     |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 5.0  |      |
| Crystal resonator |                     | Oscillation frequency ( $f_{XP}$ ) <sup>Note</sup>     | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 8.38 | MHz  |
|                   |                     |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 5.0  |      |
| External clock    |                     | X1 input frequency ( $f_{XP}$ ) <sup>Note</sup>        | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.0  |      | 8.38 | MHz  |
|                   |                     |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 2.0  |      | 5.0  |      |
|                   |                     | X1 input high-/low-level width ( $t_{XH}$ , $t_{XL}$ ) | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 56   |      | 500  | ns   |
|                   |                     |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 96   |      | 500  |      |

**Note** Indicates only oscillator characteristics. Refer to **AC Characteristics** for instruction execution time.

**Cautions 1.** When using the X1 oscillator, wire as follows in the area enclosed by the broken lines in the above figures to avoid an adverse effect from wiring capacitance.

- Keep the wiring length as short as possible.
- Do not cross the wiring with the other signal lines.
- Do not route the wiring near a signal line through which a high fluctuating current flows.
- Always make the ground point of the oscillator capacitor the same potential as  $V_{SS}$ .
- Do not ground the capacitor to a ground pattern through which a high current flows.
- Do not fetch signals from the oscillator.

- ★ 2. Since the CPU is started by the Ring-OSC after reset is released, check the oscillation stabilization time of the X1 input clock using the oscillation stabilization time counter status register (OSTC). Determine the oscillation stabilization time of the OSTC register and oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.

**Remark** For the resonator selection and oscillator constant, users are required to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation.

**Ring-OSC Oscillator Characteristics**

( $T_A = -40$  to  $+125^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Resonator                   | Parameter                       | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------|---------------------------------|------------|------|------|------|------|
| On-chip Ring-OSC oscillator | Oscillation frequency ( $f_R$ ) |            | 120  | 240  | 495  | kHz  |

**DC Characteristics (1/2)**

 (T<sub>A</sub> = -40 to +125°C, 3.3 V ≤ V<sub>DD</sub> ≤ 5.5 V, 3.3 V ≤ AV<sub>REF</sub> ≤ V<sub>DD</sub>, V<sub>SS</sub> = AV<sub>SS</sub> = 0 V)

| Parameter                    | Symbol            | Conditions   | MIN.   | TYP.                  | MAX.                 | Unit  |    |
|------------------------------|-------------------|--|--|-----------------------|----------------------|-------|----|
| Output current, high         | I <sub>OH</sub>   | Per pin  | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V                                |                       |                      | -3.5  | mA |
|                              |                   | Total of P30 to P33, P120  | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V                                |                       |                      | -17.5 | mA |
|                              |                   | Total of P00 to P03, P10 to P17, P130                                    | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V                                |                       |                      | -17.5 | mA |
|                              |                   | Total of all pins  | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V                                |                       |                      | -28   | mA |
|                              |                   |  | 3.3 V ≤ V <sub>DD</sub> < 4.0 V                                |                       |                      | -7    | mA |
| Output current, low          | I <sub>OL</sub>   | Per pin  | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V                                |                       |                      | 7     | mA |
|                              |                   | Total of P30 to P33, P120  | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V                                |                       |                      | 21    | mA |
|                              |                   | Total of P00 to P03, P10 to P17, P130                                    | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V                                |                       |                      | 21    | mA |
|                              |                   | Total of all pins  | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V                                |                       |                      | 35    | mA |
|                              |                   |  | 3.3 V ≤ V <sub>DD</sub> < 4.0 V                                |                       |                      | 7     | mA |
| Input voltage, high          | V <sub>IH1</sub>  | P12, P13, P15  | 0.7V <sub>DD</sub>   |                       | V <sub>DD</sub>      | V     |    |
|                              | V <sub>IH2</sub>  | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET             | 0.8V <sub>DD</sub>   |                       | V <sub>DD</sub>      | V     |    |
|                              | V <sub>IH3</sub>  | P20 to P23 <sup>Note 1</sup>   | 0.7AV <sub>REF</sub>   |                       | AV <sub>REF</sub>    | V     |    |
|                              | V <sub>IH4</sub>  | X1, X2   | V <sub>DD</sub> - 0.5  |                       | V <sub>DD</sub>      | V     |    |
| Input voltage, low           | V <sub>IL1</sub>  | P12, P13, P15  | 0  |                       | 0.3V <sub>DD</sub>   | V     |    |
|                              | V <sub>IL2</sub>  | P00 to P03, P10, P11, P14, P16, P17, P30 to P33, P120, RESET             | 0  |                       | 0.2V <sub>DD</sub>   | V     |    |
|                              | V <sub>IL3</sub>  | P20 to P23 <sup>Note 1</sup>   | 0  |                       | 0.3AV <sub>REF</sub> | V     |    |
|                              | V <sub>IL4</sub>  | X1, X2   | 0  |                       | 0.4                  | V     |    |
| Output voltage, high         | V <sub>OH</sub>   | Total of P30 to P33, P120 pins<br>I <sub>OH</sub> = -17.5 mA             | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V,<br>I <sub>OH</sub> = -3.5 mA  | V <sub>DD</sub> - 1.0 |                      | V     |    |
|                              |                   | Total of P00 to P03, P10 to P17,<br>P130 pins I <sub>OH</sub> = -17.5 mA | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V,<br>I <sub>OH</sub> = -3.5 mA  | V <sub>DD</sub> - 1.0 |                      | V     |    |
|                              |                   | I <sub>OH</sub> = -100 μA  | 3.3 V ≤ V <sub>DD</sub> < 4.0 V                                | V <sub>DD</sub> - 0.5 |                      | V     |    |
| Output voltage, low          | V <sub>OL</sub>   | Total of P30 to P33, P120 pins<br>I <sub>OL</sub> = 21 mA                | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V,<br>I <sub>OL</sub> = 7 mA     |                       |                      | 1.3   | V  |
|                              |                   | Total of P00 to P03, P10 to P17,<br>P130 pins I <sub>OL</sub> = 21 mA    | 4.0 V ≤ V <sub>DD</sub> ≤ 5.5 V,<br>I <sub>OL</sub> = 7 mA     |                       |                      | 1.3   | V  |
|                              |                   | I <sub>OL</sub> = 400 μA   | 3.3 V ≤ V <sub>DD</sub> < 4.0 V                                |                       |                      | 0.4   | V  |
| Input leakage current, high  | I <sub>LIH1</sub> | V <sub>I</sub> = V <sub>DD</sub>   | P00 to P03, P10 to P17, P30 to P33,<br>P120, RESET             |                       |                      | 10    | μA |
|                              |                   | V <sub>I</sub> = AV <sub>REF</sub>                                       | P20 to P23   |                       |                      | 10    | μA |
|                              | I <sub>LIH2</sub> | V <sub>I</sub> = V <sub>DD</sub>   | X1, X2 <sup>Note 2</sup>                                       |                       |                      | 20    | μA |
| Input leakage current, low   | I <sub>LIL1</sub> | V <sub>I</sub> = 0 V   | P00 to P03, P10 to P17, P20 to P23,<br>P30 to P33, P120, RESET |                       |                      | -10   | μA |
|                              | I <sub>LIL2</sub> |  | X1, X2 <sup>Note 2</sup>                                       |                       |                      | -20   | μA |
| Output leakage current, high | I <sub>LOH</sub>  | V <sub>O</sub> = V <sub>DD</sub>   |  |                       |                      | 10    | μA |
| Output leakage current, low  | I <sub>LOL</sub>  | V <sub>O</sub> = 0 V   |  |                       |                      | -10   | μA |
| Pull-up resistance value     | R                 | V <sub>I</sub> = 0 V   |  | 10                    | 30                   | 120   | kΩ |

- Notes**
- When used as a digital input port, set AV<sub>REF</sub> = V<sub>DD</sub>.
  - When the inverse level of X1 is input to X2.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.



**DC Characteristics (2/2)**

( $T_A = -40$  to  $+125^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter                        | Symbol           | Conditions  |   | MIN.  | TYP. | MAX. | Unit |    |
|----------------------------------|------------------|---|---|---|------|------|------|----|
| Supply current <sup>Note 1</sup> | I <sub>DD1</sub> | X1 crystal oscillation operating mode <sup>Note 2</sup> | f <sub>XP</sub> = 8.38 MHz,<br>V <sub>DD</sub> = 5.0 V ±10% <sup>Note 3</sup> | When A/D converter is stopped                     |      | 5.2  | 10.6 | mA |
|                                  |                  |   |   | When A/D converter is operating <sup>Note 4</sup> |      | 6.2  | 12.6 | mA |
|                                  | I <sub>DD2</sub> | X1 crystal oscillation HALT mode                        | f <sub>XP</sub> = 8.38 MHz,<br>V <sub>DD</sub> = 5.0 V ±10%                   | When peripheral functions are stopped             |      | 1.2  | 3.6  | mA |
|                                  |                  |   |   | When peripheral functions are operating           |      |      | 5.5  | mA |
|                                  | I <sub>DD3</sub> | Ring-OSC operating mode <sup>Note 5</sup>               | V <sub>DD</sub> = 5.0 V ±10%  |   |      | 0.18 | 1.92 | mA |
|                                  | I <sub>DD4</sub> | Ring-OSC HALT mode <sup>Note 5</sup>                    | V <sub>DD</sub> = 5.0 V ±10%  |   |      | 0.05 | 1.4  | mA |
|                                  | I <sub>DD5</sub> | STOP mode   | V <sub>DD</sub> = 5.0 V ±10%  | POC: OFF, RING: OFF                               |      | 0.1  | 1200 | μA |
|                                  |                  |   |   | POC: OFF, RING: ON                                |      | 14   | 1300 | μA |
|                                  |                  |   |   | POC: ON <sup>Note 6</sup> , RING: OFF             |      | 3.5  | 1200 | μA |
|                                  |                  |   |   | POC: ON <sup>Note 6</sup> , RING: ON              |      | 17.5 | 1300 | μA |

★

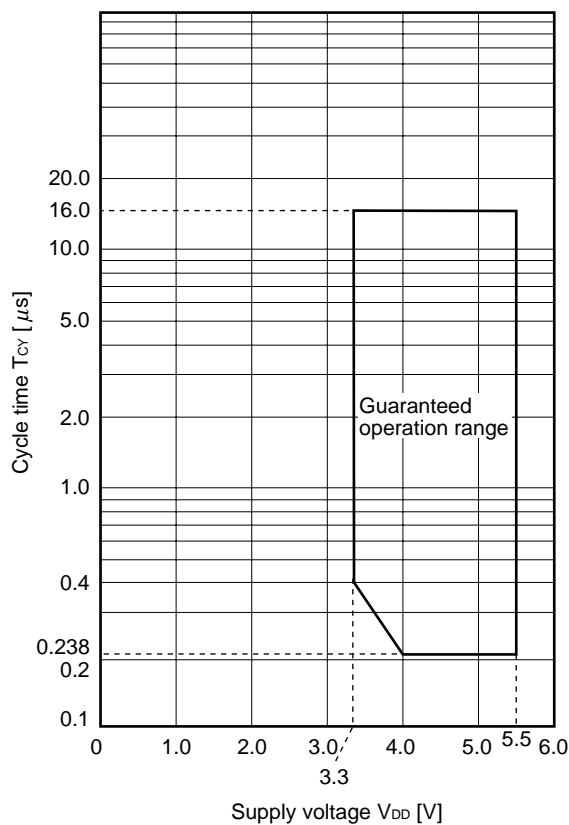
- Notes**
1. Total current flowing through the internal power supply (V<sub>DD</sub>). Peripheral operation current is included (however, the current that flows through the pull-up resistors of ports is not included).
  2. I<sub>DD1</sub> includes peripheral operation current.
  3. When PCC = 00H.
  4. Total current flowing through V<sub>DD</sub> and AV<sub>REF</sub> pins.
  5. When X1 oscillator is stopped.
  6. Including when LVIE (bit 4 of LVIM) = 1 with POC-OFF selected by a mask option.

## AC Characteristics

 (1) Basic operation ( $T_A = -40$  to  $+125^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter  | Symbol                     | Conditions                                   | MIN.   | TYP.  | MAX. | Unit          |               |
|--|----------------------------|--|--|-------|------|---------------|---------------|
| Instruction cycle (minimum instruction execution time) | $T_{CY}$                   | X1 input clock                               | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 0.238 |      | 16            | $\mu\text{s}$ |
|  |                            |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 0.4   |      | 16            | $\mu\text{s}$ |
|  |                            | Ring-OSC clock                               |  | 4.04  | 8.33 | 16.67         | $\mu\text{s}$ |
| TI000, TI010 input high-level width, low-level width   | $t_{TIH0}$ ,<br>$t_{TIL0}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | $2/f_{sam} + 0.1$ <sup>Note</sup>            |       |      | $\mu\text{s}$ |               |
|  |                            | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | $2/f_{sam} + 0.2$ <sup>Note</sup>            |       |      | $\mu\text{s}$ |               |
| TI50 input frequency                                   | $f_{TI5}$                  | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ |  |       | 8.38 | MHz           |               |
|  |                            | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    |  |       | 5    | MHz           |               |
| TI50 input high-level width, low-level width           | $t_{TIH5}$ ,<br>$t_{TIL5}$ | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 59.6   |       |      | ns            |               |
|  |                            | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 100  |       |      | ns            |               |
| Interrupt input high-level width, low-level width      | $t_{INTH}$ ,<br>$t_{INTL}$ |  | 1  |       |      | $\mu\text{s}$ |               |
| RESET low-level width                                  | $t_{RSL}$                  |  | 10   |       |      | $\mu\text{s}$ |               |

**Note** Selection of  $f_{sam} = f_{XP}$ ,  $f_{XP}/4$ ,  $f_{XP}/256$  is possible using bits 0 and 1 (PRM000, PRM001) of prescaler mode register 00 (PRM00). Note that when selecting the TI000 valid edge as the count clock,  $f_{sam} = f_{XP}$ .

 **$T_{CY}$  vs.  $V_{DD}$  (X1 Input Clock Operation)**


**(2) Serial interface ( $T_A = -40$  to  $+125^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**
**(a) UART mode (UART6, dedicated baud rate generator output)**

| Parameter     | Symbol | Conditions | MIN. | TYP. | MAX.  | Unit |
|---------------|--------|------------|------|------|-------|------|
| Transfer rate |        |            |      |      | 261.9 | kbps |

**(b) UART mode (UART0, dedicated baud rate generator output):  $\mu\text{PD780102(A2)}$  and  $780103(A2)$  only**

| Parameter     | Symbol | Conditions | MIN. | TYP. | MAX.  | Unit |
|---------------|--------|------------|------|------|-------|------|
| Transfer rate |        |            |      |      | 261.9 | kbps |

**(c) 3-wire serial I/O mode (master mode,  $\overline{\text{SCK10}}$ ... internal clock output)**

| Parameter  | Symbol                                 | Conditions                                   | MIN.                  | TYP. | MAX. | Unit |
|--|--|--|-----------------------|------|------|------|
| $\overline{\text{SCK10}}$ cycle time                               | $t_{\text{CY1}}$                       | $4.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 240                   |      |      | ns   |
|  |  | $3.3\text{ V} \leq V_{DD} < 4.0\text{ V}$    | 400                   |      |      | ns   |
| $\overline{\text{SCK10}}$ high-/low-level width                    | $t_{\text{KH1}}$ ,<br>$t_{\text{KL1}}$ |  | $t_{\text{CY1}}/2-10$ |      |      | ns   |
| SI10 setup time (to $\overline{\text{SCK10}}\uparrow$ )            | $t_{\text{SIK1}}$                      |  | 30                    |      |      | ns   |
| SI10 hold time (from $\overline{\text{SCK10}}\uparrow$ )           | $t_{\text{KSI1}}$                      |  | 30                    |      |      | ns   |
| Delay time from $\overline{\text{SCK10}}\downarrow$ to SO10 output | $t_{\text{KSO1}}$                      | $C = 100\text{ pF}^{\text{Note}}$            |                       |      | 30   | ns   |

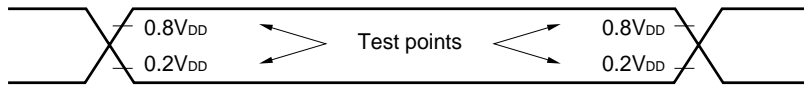
**Note** C is the load capacitance of the  $\overline{\text{SCK10}}$  and SO10 output lines.

**(d) 3-wire serial I/O mode (slave mode,  $\overline{\text{SCK10}}$ ... external clock input)**

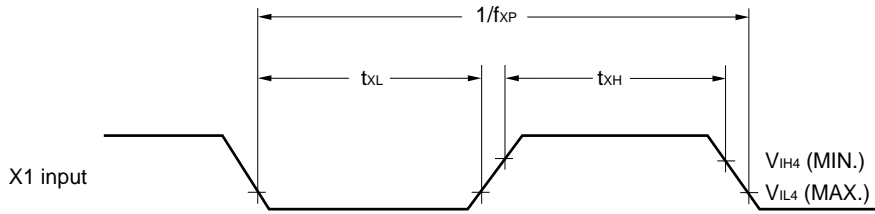
| Parameter  | Symbol                                 | Conditions                        | MIN.               | TYP. | MAX. | Unit |
|--|--|-----------------------------------|--------------------|------|------|------|
| $\overline{\text{SCK10}}$ cycle time                               | $t_{\text{CY2}}$                       |                                   | 400                |      |      | ns   |
| $\overline{\text{SCK10}}$ high-/low-level width                    | $t_{\text{KH2}}$ ,<br>$t_{\text{KL2}}$ |                                   | $t_{\text{CY2}}/2$ |      |      | ns   |
| SI10 setup time (to $\overline{\text{SCK10}}\uparrow$ )            | $t_{\text{SIK2}}$                      |                                   | 80                 |      |      | ns   |
| SI10 hold time (from $\overline{\text{SCK10}}\uparrow$ )           | $t_{\text{KSI2}}$                      |                                   | 50                 |      |      | ns   |
| Delay time from $\overline{\text{SCK10}}\downarrow$ to SO10 output | $t_{\text{KSO2}}$                      | $C = 100\text{ pF}^{\text{Note}}$ |                    |      | 120  | ns   |

**Note** C is the load capacitance of the SO10 output line.

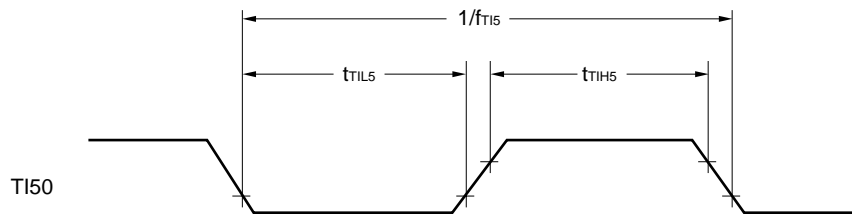
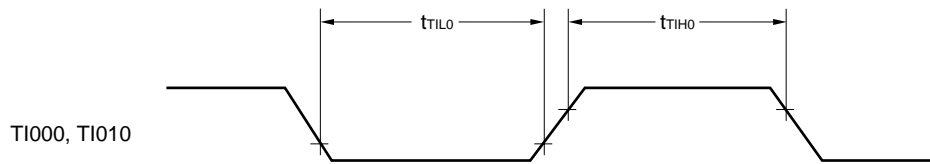
**AC Timing Test Points (Excluding X1 Input)**



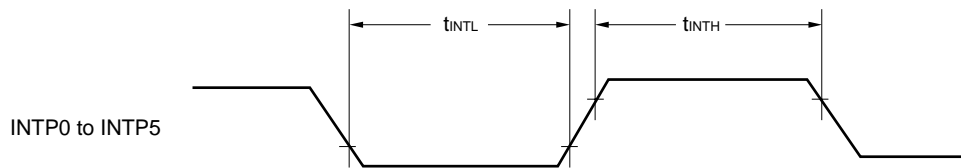
**Clock Timing**



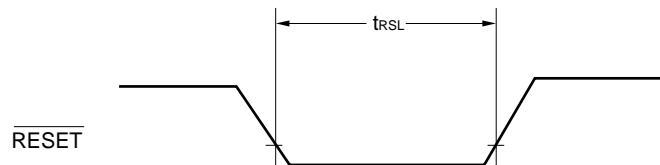
**TI Timing**



**Interrupt Request Input Timing**

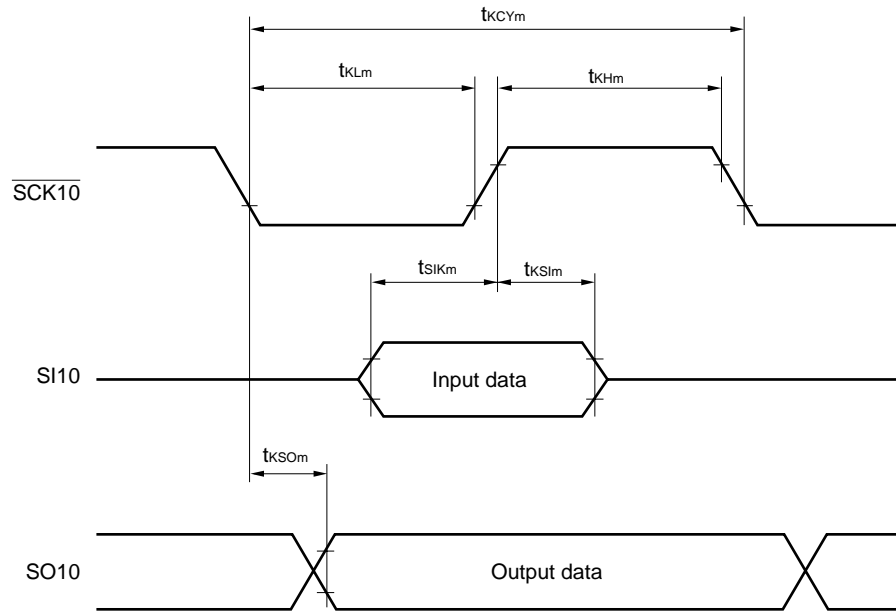


**RESET Input Timing**



Serial Transfer Timing

3-wire serial I/O mode:



Remark  $m = 1, 2$

**A/D Converter Characteristics ( $T_A = -40$  to  $+125^\circ\text{C}$ ,  $3.3\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ ,  $3.3\text{ V} \leq AV_{REF} \leq V_{DD}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ )**

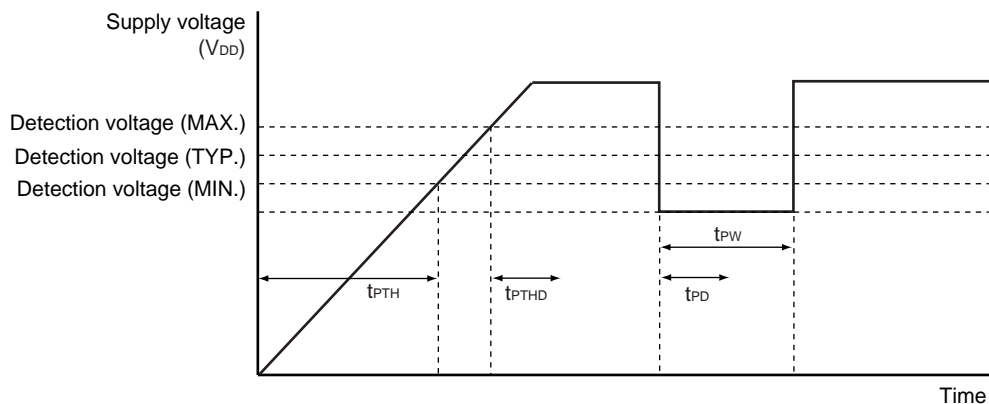
| Parameter  | Symbol     | Conditions                                     | MIN.      | TYP.      | MAX.       | Unit          |
|--|------------|--|-----------|-----------|------------|---------------|
| Resolution   |            |  | 10        | 10        | 10         | bit           |
| Overall error <sup>Notes 1, 2</sup>                |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           | $\pm 0.2$ | $\pm 0.7$  | %FSR          |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           | $\pm 0.3$ | $\pm 0.9$  | %FSR          |
| Conversion time                                    | $t_{CONV}$ | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ | 16        |           | 48         | $\mu\text{s}$ |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    | 19        |           | 48         | $\mu\text{s}$ |
| Zero-scale error <sup>Notes 1, 2</sup>             |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 0.7$  | %FSR          |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 0.9$  | %FSR          |
| Full-scale error <sup>Notes 1, 2</sup>             |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 0.7$  | %FSR          |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 0.9$  | %FSR          |
| Integral non-linearity error <sup>Note 1</sup>     |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 5.5$  | LSB           |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 7.5$  | LSB           |
| Differential non-linearity error <sup>Note 1</sup> |            | $4.0\text{ V} \leq AV_{REF} \leq 5.5\text{ V}$ |           |           | $\pm 2.5$  | LSB           |
|  |            | $3.3\text{ V} \leq AV_{REF} < 4.0\text{ V}$    |           |           | $\pm 3.0$  | LSB           |
| Analog input voltage                               | $V_{AIN}$  |  | $AV_{SS}$ |           | $AV_{REF}$ | V             |

- Notes**
1. Excludes quantization error ( $\pm 1/2$  LSB).
  2. This value is indicated as a ratio (%FSR) to the full-scale value.

**POC Circuit Characteristics ( $T_A = -40$  to  $+125^\circ\text{C}$ )**

| Parameter                               | Symbol     | Conditions   | MIN.  | TYP. | MAX. | Unit |
|---|------------|--|-------|------|------|------|
| Detection voltage                       | $V_{POC0}$ | Mask option = 3.5 V  | 3.3   | 3.5  | 3.76 | V    |
| Power supply rise time                  | $t_{PTH}$  | $V_{DD}: 0\text{ V} \rightarrow 3.3\text{ V}$                    | 0.002 |      |      | ms   |
| Response delay time 1 <sup>Note 1</sup> | $t_{PTHd}$ | When power supply rises, after reaching detection voltage (MAX.) |       |      | 3.0  | ms   |
| Response delay time 2 <sup>Note 2</sup> | $t_{PD}$   | When $V_{DD}$ falls  |       |      | 1.0  | ms   |
| Minimum pulse width                     | $t_{PW}$   |  | 0.2   |      |      | ms   |

- Notes**
1. Time required from voltage detection to reset release.
  2. Time required from voltage detection to internal reset output.

**POC Circuit Timing**


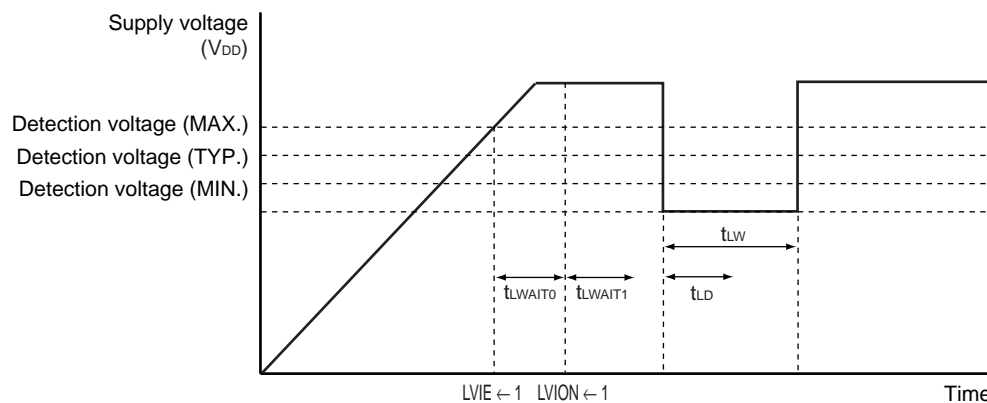
**LVI Circuit Characteristics (T<sub>A</sub> = -40 to +125°C)**

| Parameter   | Symbol              | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---------------------|------------|------|------|------|------|
| Detection voltage   | V <sub>LV10</sub>   |            | 4.1  | 4.3  | 4.56 | V    |
|   | V <sub>LV11</sub>   |            | 3.9  | 4.1  | 4.36 | V    |
|   | V <sub>LV12</sub>   |            | 3.7  | 3.9  | 4.16 | V    |
|   | V <sub>LV13</sub>   |            | 3.5  | 3.7  | 3.96 | V    |
|   | V <sub>LV14</sub>   |            | 3.3  | 3.5  | 3.76 | V    |
| Response time <sup>Note 1</sup>                             | t <sub>LD</sub>     |            |      | 0.2  | 2.0  | ms   |
| Minimum pulse width   | t <sub>LW</sub>     |            | 0.2  |      |      | ms   |
| Reference voltage stabilization wait time <sup>Note 2</sup> | t <sub>LWAIT0</sub> |            |      | 0.5  | 2.0  | ms   |
| Operation stabilization wait time <sup>Note 3</sup>         | t <sub>LWAIT1</sub> |            |      | 0.1  | 0.2  | ms   |

- Notes**
1. Time required from voltage detection to interrupt output or internal reset output.
  2. Time required from setting LVIE to 1 to reference voltage stabilization when POC-OFF is selected by mask option.
  3. Time required from setting LVION to 1 to operation stabilization.

- Remarks**
1. V<sub>LV10</sub> > V<sub>LV11</sub> > V<sub>LV12</sub> > V<sub>LV13</sub> > V<sub>LV14</sub>
  2. V<sub>POC0</sub> < V<sub>LV1m</sub> (m = 0 to 4)

**LVI Circuit Timing**

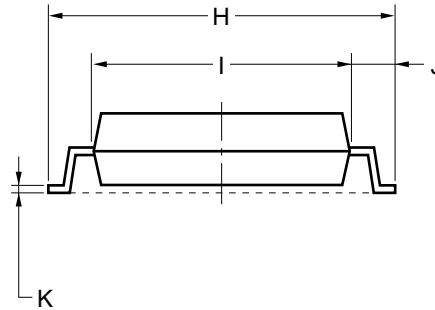
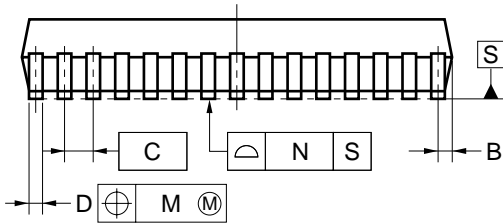
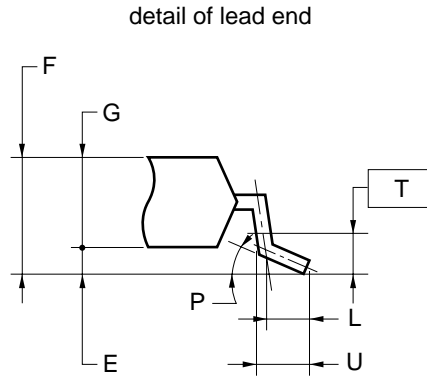
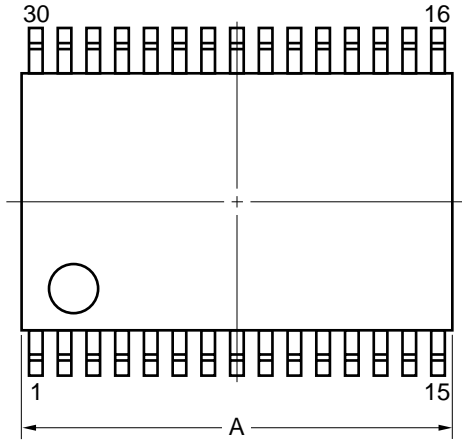


**Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics (T<sub>A</sub> = -40 to +125°C)**

| Parameter                     | Symbol            | Conditions                              | MIN. | TYP. | MAX. | Unit |
|-------------------------------|-------------------|---|------|------|------|------|
| Data retention supply voltage | V <sub>DDDR</sub> | When POC-OFF is selected by mask option | 2.0  |      | 5.5  | V    |
| Release signal set time       | t <sub>SREL</sub> |   | 0    |      |      | μs   |

## CHAPTER 27 PACKAGE DRAWING

### 30-PIN PLASTIC SSOP (7.62 mm (300))



**NOTE**

Each lead centerline is located within 0.13 mm of its true position (T.P.) at maximum material condition.

| ITEM | MILLIMETERS                            |
|------|--|
| A    | 9.85±0.15                              |
| B    | 0.45 MAX.                              |
| C    | 0.65 (T.P.)                            |
| D    | 0.24 <sup>+0.08</sup> <sub>-0.07</sub> |
| E    | 0.1±0.05                               |
| F    | 1.3±0.1                                |
| G    | 1.2                                    |
| H    | 8.1±0.2                                |
| I    | 6.1±0.2                                |
| J    | 1.0±0.2                                |
| K    | 0.17±0.03                              |
| L    | 0.5                                    |
| M    | 0.13                                   |
| N    | 0.10                                   |
| P    | 3° <sup>+5°</sup> <sub>-3°</sub>       |
| T    | 0.25                                   |
| U    | 0.6±0.15                               |

**S30MC-65-5A4-2**



## CHAPTER 28 RECOMMENDED SOLDERING CONDITIONS

These products should be soldered and mounted under the following recommended conditions.

For soldering methods and conditions other than those recommended below, please contact an NEC Electronics sales representative.

For technical information, see the following website.

Semiconductor Device Mount Manual (<http://www.necel.com/pkg/en/mount/index.html>)

**Table 28-1. Surface Mounting Type Soldering Conditions (1/2)**

**(1) 30-pin plastic SSOP (7.62 mm (300))**

$\mu$ PD780101MC-xxx-5A4, 780102MC-xxx-5A4, 780103MC-xxx-5A4,

$\mu$ PD780101MC(A)-xxx-5A4, 780102MC(A)-xxx-5A4, 780103MC(A)-xxx-5A4,

$\mu$ PD780101MC(A1)-xxx-5A4, 780102MC(A1)-xxx-5A4, 780103MC(A1)-xxx-5A4,

$\mu$ PD780101MC(A2)-xxx-5A4, 780102MC(A2)-xxx-5A4, 780103MC(A2)-xxx-5A4

| Soldering Method | Soldering Conditions  | Recommended Condition Symbol |
|------------------|---|------------------------------|
| Infrared reflow  | Package peak temperature: 235°C, Time: 30 seconds max. (at 210°C or higher), Count: 3 times or less, Exposure limit: 7 days <sup>Note</sup> (after that, prebake at 125°C for 10 hours)                                       | IR35-107-3                   |
| VPS              | Package peak temperature: 215°C, Time: 40 seconds max. (at 200°C or higher), Count: 3 times or less, Exposure limit: 7 days <sup>Note</sup> (after that, prebake at 125°C for 10 hours)                                       | VP15-107-3                   |
| Wave soldering   | Solder bath temperature: 260°C max., Time: 10 seconds max., Count: Once, Preheating temperature: 120°C max. (package surface temperature), Exposure limit: 7 days <sup>Note</sup> (after that, prebake at 125°C for 10 hours) | WS60-107-1                   |
| Partial heating  | Pin temperature: 300°C max., Time: 3 seconds max. (per pin row)   | -                            |

**Note** After opening the dry pack, store it at 25°C or less and 65% RH or less for the allowable storage period.

**Caution** Do not use different soldering methods together (except for partial heating).

Table 28-1. Surface Mounting Type Soldering Conditions (2/2)

**(2) 30-pin plastic SSOP (7.62 mm (300))**

$\mu$ PD78F0103M1MC-5A4, 78F0103M2MC-5A4, 78F0103M3MC-5A4, 78F0103M4MC-5A4,  
 $\mu$ PD78F0103M5MC-5A4, 78F0103M6MC-5A4, 78F0103M1MC(A)-5A4, 78F0103M2MC(A)-5A4,  
 $\mu$ PD78F0103M3MC(A)-5A4, 78F0103M4MC(A)-5A4, 78F0103M5MC(A)-5A4,  
 $\mu$ PD78F0103M6MC(A)-5A4, 78F0103M1MC(A1)-5A4, 78F0103M2MC(A1)-5A4,  
 $\mu$ PD78F0103M5MC(A1)-5A4, 78F0103M6MC(A1)-5A4

| Soldering Method | Soldering Conditions  | Recommended Condition Symbol |
|------------------|---|------------------------------|
| Infrared reflow  | Package peak temperature: 235°C, Time: 30 seconds max. (at 210°C or higher), Count: 2 times or less, Exposure limit: 3 days <sup>Note</sup> (after that, prebake at 125°C for 10 hours)                                       | IR35-103-2                   |
| VPS              | Package peak temperature: 215°C, Time: 40 seconds max. (at 200°C or higher), Count: 2 times or less, Exposure limit: 3 days <sup>Note</sup> (after that, prebake at 125°C for 10 hours)                                       | VP15-103-2                   |
| Wave soldering   | Solder bath temperature: 260°C max., Time: 10 seconds max., Count: Once, Preheating temperature: 120°C Max. (package surface temperature), Exposure limit: 3 days <sup>Note</sup> (after that, prebake at 125°C for 10 hours) | WS60-103-1                   |
| Partial heating  | Pin temperature: 300°C max., Time: 3 seconds max. (per pin row)   | –                            |

**Note** After opening the dry pack, store it at 25°C or less and 65% RH or less for the allowable storage period.

**Caution** Do not use different soldering methods together (except for partial heating).

## CHAPTER 29 CAUTIONS FOR WAIT

### 29.1 Cautions for Wait

This product has two internal system buses.

One is a CPU bus and the other is a peripheral bus that interfaces with the low-speed peripheral hardware.

Because the clock of the CPU bus and the clock of the peripheral bus are asynchronous, unexpected illegal data may be passed if an access to the CPU conflicts with an access to the peripheral hardware.

When accessing the peripheral hardware that may cause a conflict, therefore, the CPU repeatedly executes processing, until the correct data is passed.

As a result, the CPU does not start the next instruction processing but waits. If this happens, the number of execution clocks of an instruction increases by the number of wait clocks (for the number of wait clocks, see **Table 29-1**). This must be noted when real-time processing is performed.

## 29.2 Peripheral Hardware That Generates Wait

Table 29-1 lists the registers that issue a wait request when accessed by the CPU, and the number of CPU wait clocks.

**Table 29-1. Registers That Generate Wait and Number of CPU Wait Clocks**

| Peripheral Hardware   | Register | Access | Number of Wait Clocks  |
|---|----------|--------|--|
| Watchdog timer  | WDTM     | Write  | 3 clocks (fixed)   |
| Serial interface UART0  | ASIS0    | Read   | 1 clock (fixed)  |
| Serial interface UART6  | ASIS6    | Read   | 1 clock (fixed)  |
| A/D converter   | ADM      | Write  | 2 to 5 clocks <sup>Note</sup><br>(when ADM.5 flag = "1")                             |
|   | ADS      | Write  | 2 to 9 clocks <sup>Note</sup><br>(when ADM.5 flag = "0")                             |
|   | PFM      | Write  |  |
|   | PFT      | Write  |  |
|   | ADCR     | Read   | 1 to 5 clocks<br>(when ADM.5 flag = "1")<br>1 to 9 clocks<br>(when ADM.5 flag = "0") |
| <p>&lt;Calculating maximum number of wait clocks&gt;</p> $\{(1/f_{\text{MACRO}}) \times 2/(1/f_{\text{CPU}})\} + 1$ <p>*The result after the decimal point is truncated if it is less than <math>t_{\text{CPUL}}</math> after it has been multiplied by <math>(1/f_{\text{CPU}})</math>, and is rounded up if it exceeds <math>t_{\text{CPUL}}</math>.</p> <p><math>f_{\text{MACRO}}</math>: Macro operating frequency<br/>(When bit 5 (FR2) of ADM = "1": <math>f_x/2</math>, when bit 5 (FR2) of ADM = "0": <math>f_x/2^2</math>)</p> <p><math>f_{\text{CPU}}</math>: CPU clock frequency</p> <p><math>t_{\text{CPUL}}</math>: Low-level width of CPU clock</p> |          |        |  |

**Note** No wait cycle is generated for the CPU if the number of wait clocks calculated by the above expression is 1.

**Remark** The clock is the CPU clock ( $f_{\text{CPU}}$ ).

### 29.3 Example of Wait Occurrence

<1> Watchdog timer

<On execution of MOV WDTM, A>

Number of execution clocks: 8

(5 clocks when data is written to a register that does not issue a wait (MOV sfr, A).)

<On execution of MOV WDTM, #byte>

Number of execution clocks: 10

(7 clocks when data is written to a register that does not issue a wait (MOV sfr, #byte).)

<2> Serial interface UART6

<On execution of MOV A, ASIS6>

Number of execution clocks: 6

(5 clocks when data is read from a register that does not issue a wait (MOV A, sfr).)

<3> A/D converter

**Table 29-2. Number of Wait Clocks and Number of Execution Clocks on Occurrence of Wait (A/D Converter)**

<On execution of MOV ADM, A; MOV ADS, A; or MOV A, ADCR>

- When  $f_x = 10\text{ MHz}$ ,  $t_{\text{CPUL}} = 50\text{ ns}$

| Value of Bit 5 (FR2) of ADM Register | $f_{\text{CPU}}$ | Number of Wait Clocks               | Number of Execution Clocks           |
|--------------------------------------|------------------|-------------------------------------|--------------------------------------|
| 0                                    | $f_x$            | 9 clocks                            | 14 clocks                            |
|                                      | $f_x/2$          | 5 clocks                            | 10 clocks                            |
|                                      | $f_x/2^2$        | 3 clocks                            | 8 clocks                             |
|                                      | $f_x/2^3$        | 2 clocks                            | 7 clocks                             |
|                                      | $f_x/2^4$        | 0 clocks (1 clock <sup>Note</sup> ) | 5 clocks (6 clocks <sup>Note</sup> ) |
| 1                                    | $f_x$            | 5 clocks                            | 10 clocks                            |
|                                      | $f_x/2$          | 3 clocks                            | 8 clocks                             |
|                                      | $f_x/2^2$        | 2 clocks                            | 7 clocks                             |
|                                      | $f_x/2^3$        | 0 clocks (1 clock <sup>Note</sup> ) | 5 clocks (6 clocks <sup>Note</sup> ) |
|                                      | $f_x/2^4$        | 0 clocks (1 clock <sup>Note</sup> ) | 5 clocks (6 clocks <sup>Note</sup> ) |

**Note** On execution of MOV A, ADCR

**Remark** The clock is the CPU clock ( $f_{\text{CPU}}$ ).

$f_x$ : X1 input clock oscillation frequency

$t_{\text{CPUL}}$ : Low-level width of CPU clock

## APPENDIX A DEVELOPMENT TOOLS

The following development tools are available for the development of systems that employ the 78K0/KB1. Figure A-1 shows the development tool configuration.

- **Support for PC98-NX series**

Unless otherwise specified, products supported by IBM PC/AT™ compatibles are compatible with PC98-NX series computers. When using PC98-NX series computers, refer to the explanation for IBM PC/AT compatibles.

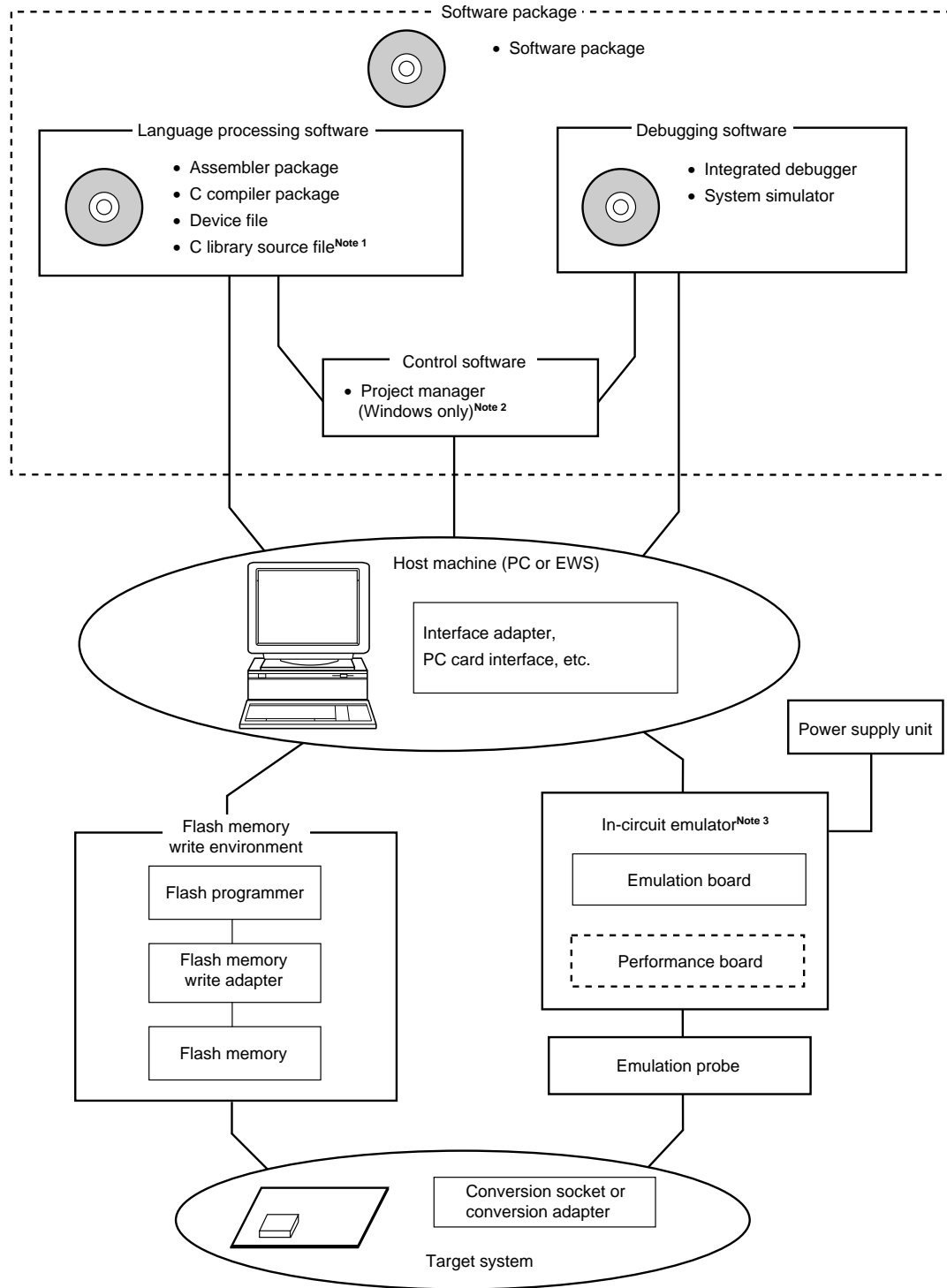
- **Windows**

Unless otherwise specified, "Windows" means the following OSs.

- Windows 3.1
- Windows 95
- Windows 98
- Windows NT™ Ver. 4.0
- Windows 2000
- Windows XP

Figure A-1. Development Tool Configuration (1/3)

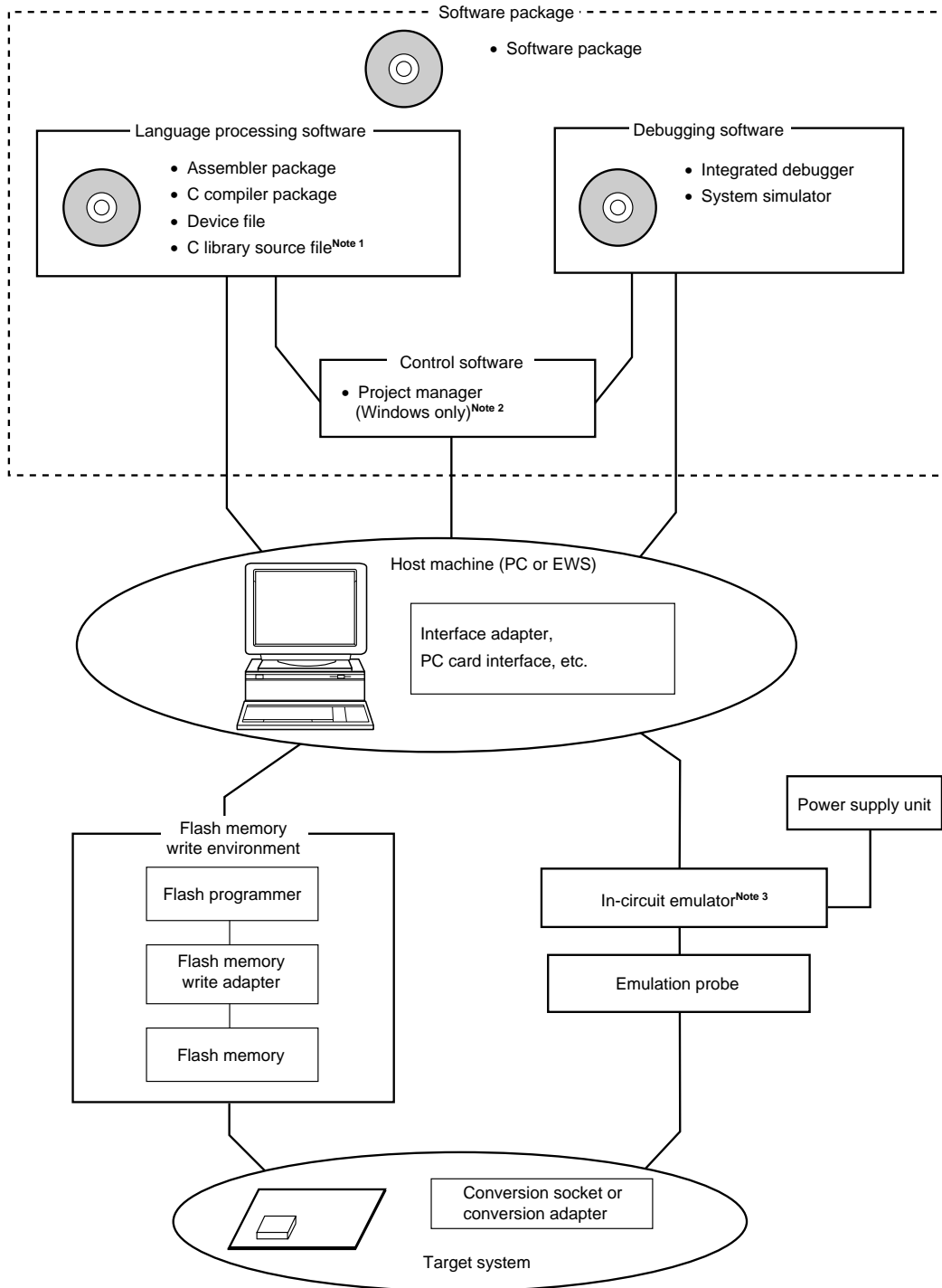
(1) When using the in-circuit emulators IE-78K0-NS, IE-78K0-NS-A



- Notes**
1. The C library source file is not included in the software package.
  2. The project manager PM plus is included in the assembler package. The PM plus is only used for Windows.
  3. Products other than in-circuit emulators IE-78K0-NS and IE-78K0-NS-A are all sold separately.

Figure A-1. Development Tool Configuration (2/3)

(2) When using the in-circuit emulator IE-78K0K1-ET



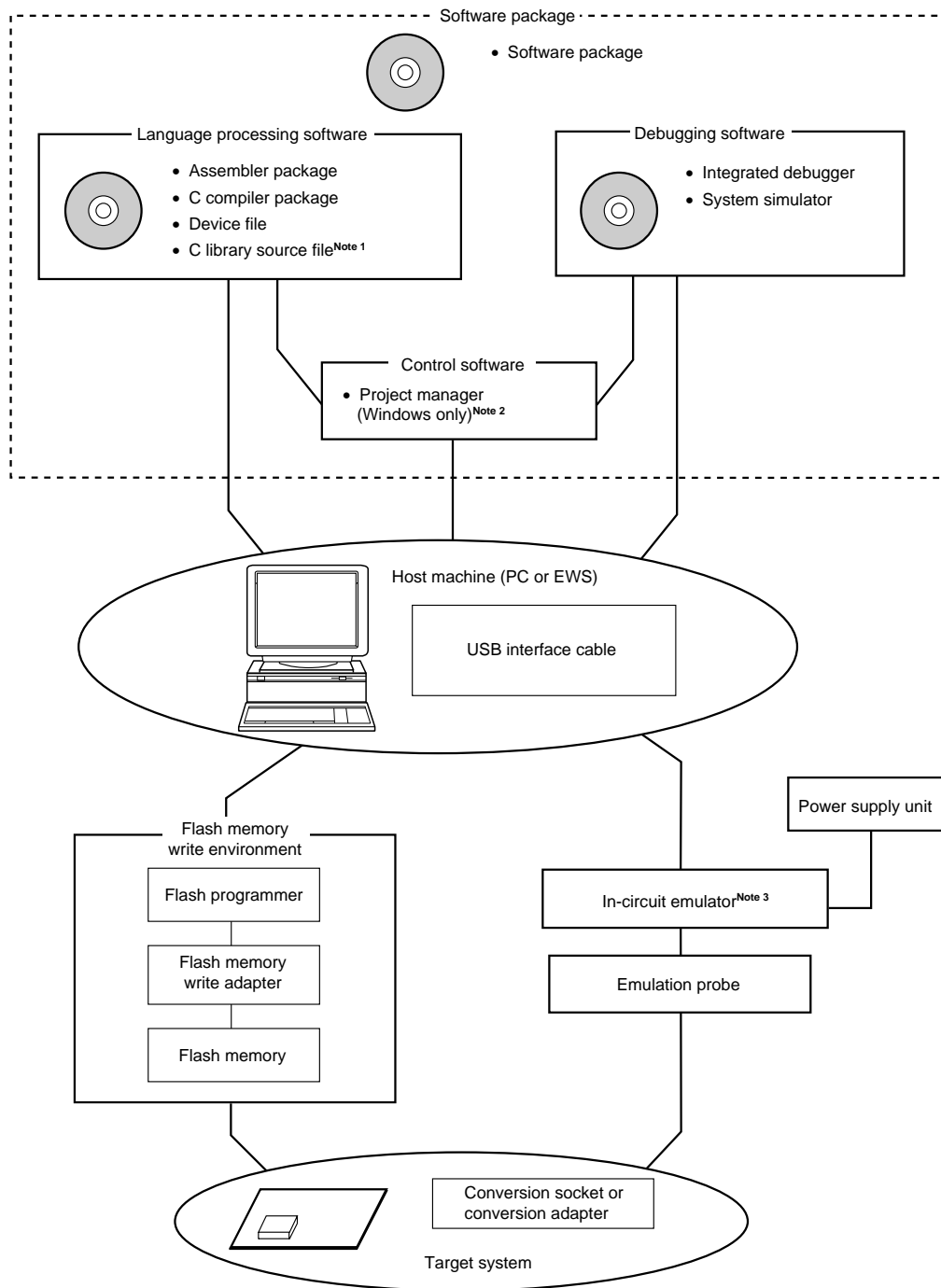
- Notes**
1. The C library source file is not included in the software package.
  2. The project manager PM plus is included in the assembler package. The PM plus is only used for Windows.
  3. In-circuit emulator IE-78K0K1-ET is supplied with integrated debugger ID78K0-NS, a device file, power supply unit, and PCI bus interface adapter IE-70000-PCI-IF-A. Any other products are sold separately.



★

Figure A-1. Development Tool Configuration (3/3)

(3) When using the in-circuit emulator QB-78K0KX1H



- Notes**
1. The C library source file is not included in the software package.
  2. The project manager PM plus is included in the assembler package. The PM plus is only used for Windows.
  3. In-circuit emulator QB-78K0KX1H is supplied with integrated debugger ID78K0-QB, flash memory programmer PG-FPL (78K0/Kx1 products are not supported), power supply unit, and USB interface cable. Any other products are sold separately.

## A.1 Software Package

|   |   |
|---|---|
| SP78K0<br>78K/0 Series software package | Development tools (software) common to the 78K/0 Series are combined in this package. |
|   | Part number: $\mu$ SxxxxSP78K0  |

**Remark** xxxx in the part number differs depending on the host machine and OS used.

$\mu$ SxxxxSP78K0

| xxxx | Host Machine          | OS                         | Supply Medium |
|------|-----------------------|----------------------------|---------------|
| AB17 | PC-9800 series,       | Windows (Japanese version) | CD-ROM        |
| BB17 | IBM PC/AT compatibles | Windows (English version)  |               |

## A.2 Language Processing Software

|   |  |
|---|--|
| RA78K0<br>Assembler package                         | <p>This assembler converts programs written in mnemonics into object codes executable with a microcontroller.</p> <p>This assembler is also provided with functions capable of automatically creating symbol tables and branch instruction optimization.</p> <p>This assembler should be used in combination with a device file (DF780103) (sold separately).</p> <p><b>&lt;Precaution when using RA78K0 in PC environment&gt;</b></p> <p>This assembler package is a DOS-based application. It can also be used in Windows, however, by using the project manager (included in assembler package) on Windows.</p> |
|   | Part number: $\mu$ SxxxxRA78K0   |
| CC78K0<br>C compiler package                        | <p>This compiler converts programs written in C language into object codes executable with a microcontroller.</p> <p>This compiler should be used in combination with an assembler package and device file (both sold separately).</p> <p><b>&lt;Precaution when using CC78K0 in PC environment&gt;</b></p> <p>This C compiler package is a DOS-based application. It can also be used in Windows, however, by using the project manager (included in assembler package) on Windows.</p>   |
|   | Part number: $\mu$ SxxxxCC78K0   |
| DF780103 <sup>Note 1</sup><br>Device file           | <p>This file contains information peculiar to the device.</p> <p>This device file should be used in combination with a tool (RA78K0, CC78K0, SM78K0, ID78K0-NS, ID78K0, and ID78K0-QB) (all sold separately).</p> <p>The corresponding OS and host machine differ depending on the tool to be used.</p>  |
|   | Part number: $\mu$ SxxxxDF780103   |
| CC78K0-L <sup>Note 2</sup><br>C library source file | <p>This is a source file of the functions that configure the object library included in the C compiler package.</p> <p>This file is required to match the object library included in the C compiler package to the user's specifications.</p> <p>Since this is a source file, its working environment does not depend on any particular operating system.</p>  |
|   | Part number: $\mu$ SxxxxCC78K0-L   |

- Notes**
1. The DF780103 can be used in common with the RA78K0, CC78K0, SM78K0, ID78K0-NS, ID78K0, and ID78K0-QB.
  2. The CC78K0-L is not included in the software package (SP78K0).

**Remark** xxxx in the part number differs depending on the host machine and OS used.

μSxxxxRA78K0  
 μSxxxxCC78K0  
 μSxxxxCC78K0-L

| xxxx | Host Machine                             | OS  | Supply Medium |
|------|--|---|---------------|
| AB17 | PC-9800 series,<br>IBM PC/AT compatibles | Windows (Japanese version)                    | CD-ROM        |
| BB17 |  | Windows (English version)                     |               |
| 3P17 | HP9000 series 700™                       | HP-UX™ (Rel. 10.10)                           |               |
| 3K17 | SPARCstation™                            | SunOS™ (Rel. 4.1.4),<br>Solaris™ (Rel. 2.5.1) |               |

μSxxxxDF780103

| xxxx | Host Machine                             | OS                         | Supply Medium   |
|------|--|----------------------------|-----------------|
| AB13 | PC-9800 series,<br>IBM PC/AT compatibles | Windows (Japanese version) | 3.5-inch 2HD FD |
| BB13 |  | Windows (English version)  |                 |

### A.3 Control Software

|                            |  |
|----------------------------|--|
| PM plus<br>Project manager | This is control software designed to enable efficient user program development in the Windows environment. All operations used in development of a user program, such as starting the editor, building, and starting the debugger, can be performed from the PM plus.<br><b>&lt;Caution&gt;</b><br>The PM plus is included in the assembler package (RA78K0).<br>It can only be used in Windows. |
|----------------------------|--|

### A.4 Flash Memory Writing Tools

|   |  |
|---|--|
| Flashpro III<br>(part number: FL-PR3, PG-FP3)<br>Flashpro IV<br>(part number: FL-PR4, PG-FP4)<br>Flash programmer | Flash programmer dedicated to microcontrollers with on-chip flash memory.  |
| FA-30MC<br>Flash memory writing adapter   | Flash memory writing adapter used connected to the Flashpro III/Flashpro IV.<br>• FA-30MC: For 30-pin plastic SSOP (MC-5A4 type) |

**Remark** FL-PR3, FL-PR4, and FA-30MC are products of Naito Densai Machida Mfg. Co., Ltd.  
 TEL: +81-45-475-4191 Naito Densai Machida Mfg. Co., Ltd.

## A.5 Debugging Tools (Hardware)

### A.5.1 When using in-circuit emulators IE-78K0-NS and IE-78K0-NS-A

- ★ **Remark** Operations where the oscillation frequencies exceed 10 MHz can only be supported by the versions of the IE-78K0-NS with post N administrative symbols, IE-78K0-NS-A with post G administrative symbols, and IE-780148-NS-EM1 with post E administrative symbols.

|   |  |
|---|--|
| IE-78K0-NS<br>In-circuit emulator                                       | The in-circuit emulator serves to debug hardware and software when developing application systems using a 78K/0 Series product. It corresponds to the integrated debugger (ID78K0-NS). This emulator should be used in combination with a power supply unit, emulation probe, and the interface adapter required to connect this emulator to the host machine. |
| IE-78K0-NS-PA<br>Performance board                                      | This board is connected to the IE-78K0-NS to expand its functions. Adding this board adds a coverage function and enhances debugging functions such as tracer and timer functions.   |
| IE-78K0-NS-A<br>In-circuit emulator                                     | Product that combines the IE-78K0-NS and IE-78K0-NS-PA   |
| IE-70000-MC-PS-B<br>Power supply unit                                   | This adapter is used for supplying power from a 100 V to 240 V AC outlet.  |
| IE-70000-98-IF-C<br>Interface adapter                                   | This adapter is required when using a PC-9800 series computer (except notebook type) as the host machine (C bus compatible).   |
| IE-70000-CD-IF-A<br>PC card interface                                   | This is PC card and interface cable required when using a notebook-type computer as the host machine (PCMCIA socket compatible).   |
| IE-70000-PC-IF-C<br>Interface adapter                                   | This adapter is required when using an IBM PC/AT compatible computer as the host machine (ISA bus compatible).   |
| IE-70000-PCI-IF-A<br>Interface adapter                                  | This adapter is required when using a computer with a PCI bus as the host machine.   |
| IE-780148-NS-EM1<br>Emulation board                                     | This board emulates the operations of the peripheral hardware peculiar to a device. It should be used in combination with an in-circuit emulator.  |
| NP-30MC<br>Emulation probe  | This probe is used to connect the in-circuit emulator to the target system and is designed for use with a 30-pin plastic SSOP (MC-5A4 type).   |
| NSPACK30BK<br>YSPACK30BK<br>HSPACK30BK<br>YQ-Guide<br>Conversion socket | This conversion socket connects the NP-30MC to a target system board designed to mount a 30-pin plastic SSOP (MC-5A4 type). <ul style="list-style-type: none"> <li>• NSPACK30BK: Socket for connecting target</li> <li>• YSPACK30BK: Socket for connecting emulator</li> <li>• HSPACK30BK: Cover for mounting device</li> <li>• YQ-Guide: Guide pin</li> </ul> |

- Remarks**
- NP-30MC is a product of Naito Densai Machida Mfg. Co., Ltd.  
TEL: +81-45-475-4191 Naito Densai Machida Mfg. Co., Ltd.
  - NSPACK30BK, YSPACK30BK, HSPACK30BK, and YQ-Guide are products of TOKYO ELETECH CORPORATION.  
For further information, contact Daimaru Kogyo Co., Ltd.  
Tokyo Electronics Department (TEL: +81-3-3820-7112)  
Osaka Electronics Department (TEL: +81-6-6244-6672)

**A.5.2 When using in-circuit emulator IE-78K0K1-ET**

- ★ **Remark** Operations where the oscillation frequencies exceed 10 MHz can only be supported by the versions of the IE-78K0K1-ET with post C administrative symbols.

|   |  |
|---|--|
| IE-78K0K1-ET <sup>Note</sup><br>In-circuit emulator                     | The in-circuit emulator serves to debug hardware and software when developing application systems using a 78K0/Kx1 product. It corresponds to the integrated debugger (ID78K0-NS). This emulator should be used in combination with a power supply unit, emulation probe, and the interface adapter required to connect this emulator to the host machine.     |
| IE-70000-98-IF-C<br>Interface adapter                                   | This adapter is required when using a PC-9800 series computer (except notebook type) as the host machine (C bus compatible).   |
| IE-70000-CD-IF-A<br>PC card interface                                   | This is PC card and interface cable required when using a notebook-type computer as the host machine (PCMCIA socket compatible).   |
| IE-70000-PC-IF-C<br>Interface adapter                                   | This adapter is required when using an IBM PC/AT compatible computer as the host machine (ISA bus compatible).   |
| IE-70000-PCI-IF-A<br>Interface adapter                                  | This adapter is required when using a computer with a PCI bus as the host machine. This is supplied with IE-78K0K1-ET.   |
| NP-30MC<br>Emulation probe  | This probe is used to connect the in-circuit emulator to the target system and is designed for use with a 30-pin plastic SSOP (MC-5A4 type).   |
| NSPACK30BK<br>YSPACK30BK<br>HSPACK30BK<br>YQ-Guide<br>Conversion socket | This conversion socket connects the NP-30MC to a target system board designed to mount a 30-pin plastic SSOP (MC-5A4 type). <ul style="list-style-type: none"> <li>• NSPACK30BK: Socket for connecting target</li> <li>• YSPACK30BK: Socket for connecting emulator</li> <li>• HSPACK30BK: Cover for mounting device</li> <li>• YQ-Guide: Guide pin</li> </ul> |

**Note** IE-78K0K1-ET is supplied with a power supply unit and PCI bus interface adapter IE-70000-PCI-IF-A. It is also supplied with integrated debugger ID78K0-NS and a device file as control software.

- Remarks**
1. NP-30MC is a product of Naito Densai Machida Mfg. Co., Ltd.  
TEL: +81-45-475-4191 Naito Densai Machida Mfg. Co., Ltd.
  2. NSPACK30BK, YSPACK30BK, HSPACK30BK, and YQ-Guide are products of TOKYO ELETECH CORPORATION.  
For further information, contact Daimaru Kogyo Co., Ltd.  
Tokyo Electronics Department (TEL: +81-3-3820-7112)  
Osaka Electronics Department (TEL: +81-6-6244-6672)

**A.5.3 When using in-circuit emulator QB-78K0KX1H**

|  |   |
|--|---|
| QB-78K0KX1H <sup>Note 1</sup><br>In-circuit emulator | This in-circuit emulator serves to debug hardware and software when developing application systems using the 78K0/Kx1 and 78K0/Kx1+. It corresponds to the integrated debugger (ID78K0-QB). This emulator should be used in combination with a power supply unit and emulation probe, and the USB is used to connect this emulator to the host machine. |
| QB-144-CA-01 <sup>Note 2</sup><br>Check pin adapter  | This check pin adapter is used in waveform monitoring using the oscilloscope, etc.  |
| QB-80-EP-01T<br>Emulation probe                      | This emulation probe is flexible type and used to connect the in-circuit emulator and target system.  |
| QB-30MC-EA-01T<br>Exchange adapter                   | This exchange adapter is used to perform pin conversion from the in-circuit emulator to target connector.   |
| QB-30MC-YS-01T<br>Space adapter                      | This space adapter is used to adjust the height between the target system and in-circuit emulator.  |
| QB-30MC-YQ-01T<br>YQ connector                       | This YQ connector is used to connect the target connector and exchange adapter.   |
| QB-30MC-HQ-01T<br>Mount adapter                      | This mount adapter is used to mount the target device with socket.  |
| QB-30MC-NQ-01T<br>Target connector                   | This target connector is used to mount on the target system.  |

- Notes**
1. The QB-78K0KX1H is supplied with a power supply unit, USB interface cable, and flash memory programmer PG-FPL (78K0/Kx1 products are not supported). As control software, integrated debugger ID78K0-QB is supplied.
  2. Under development

**Remark** The packed contents differ depending on the part number, as follows.

- QB-78K0KX1H-ZZZ: In-circuit emulator only
- QB-78K0KX1H-T30MC: In-circuit emulator and supplied products (emulation probe, exchange adapter, YQ connector, and target connector)

**A.6 Debugging Tools (Software)**

|  |  |
|--|--|
| <p>SM78K0<br/>System simulator</p>   | <p>This is a system simulator for the 78K/0 Series. The SM78K0 is Windows-based software.<br/>It is used to perform debugging at the C source level or assembler level while simulating the operation of the target system on a host machine.<br/>Use of the SM78K0 allows the execution of application logical testing and performance testing on an independent basis from hardware development, thereby providing higher development efficiency and software quality.<br/>The SM78K0 should be used in combination with the device file (DF780103) (sold separately).</p> |
| <p>Part number: <math>\mu S_{xxxx}</math>SM78K0</p>  |  |
| <p>ID78K0-NS<br/>(supporting in-circuit emulator<br/>IE-78K0-NS, IE-78K0-NS-A,<br/>IE-78K0K1-ET),<br/>ID78K0-QB<br/>(supporting in-circuit emulator<br/>QB-78K0KX1H)<br/>Integrated debugger</p> | <p>This debugger supports the in-circuit emulators for the 78K/0 Series. The ID78K0-NS and ID78K0-QB are Windows-based software.<br/>It has improved C-compatible debugging functions and can be display the results of tracing with the source program using an integrating window function that associates the source program, disassemble display, and memory display with the trace result. It should be used in combination with the device file (sold separately).</p>   |
| <p>Part number: <math>\mu S_{xxxx}</math>ID78K0-NS, <math>\mu S_{xxxx}</math>ID78K0-QB</p>   |  |

★

**Remark** xxxx in the part number differs depending on the host machine and OS used.

$\mu S_{xxxx}$ SM78K0  
 $\mu S_{xxxx}$ ID78K0-NS  
 $\mu S_{xxxx}$ ID78K0-QB

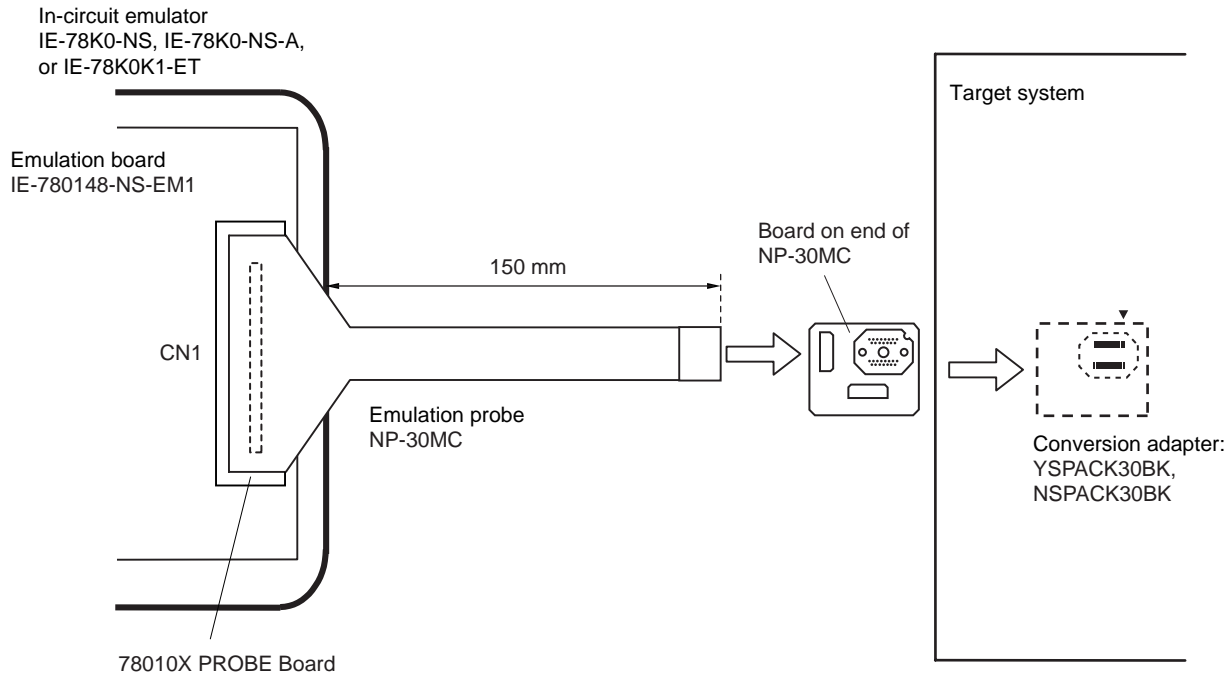
| xxxx | Host Machine          | OS                         | Supply Medium |
|------|-----------------------|----------------------------|---------------|
| AB17 | PC-9800 series,       | Windows (Japanese version) | CD-ROM        |
| BB17 | IBM PC/AT compatibles | Windows (English version)  |               |

## APPENDIX B NOTES ON TARGET SYSTEM DESIGN

### B.1 When Using IE-78K0-NS, IE-78K0-NS-A, or IE-78K0K1-ET

The following show the conditions when connecting the emulation probe to the conversion adapter. Follow the configuration below and consider the shape of parts to be mounted on the target system when designing a system.

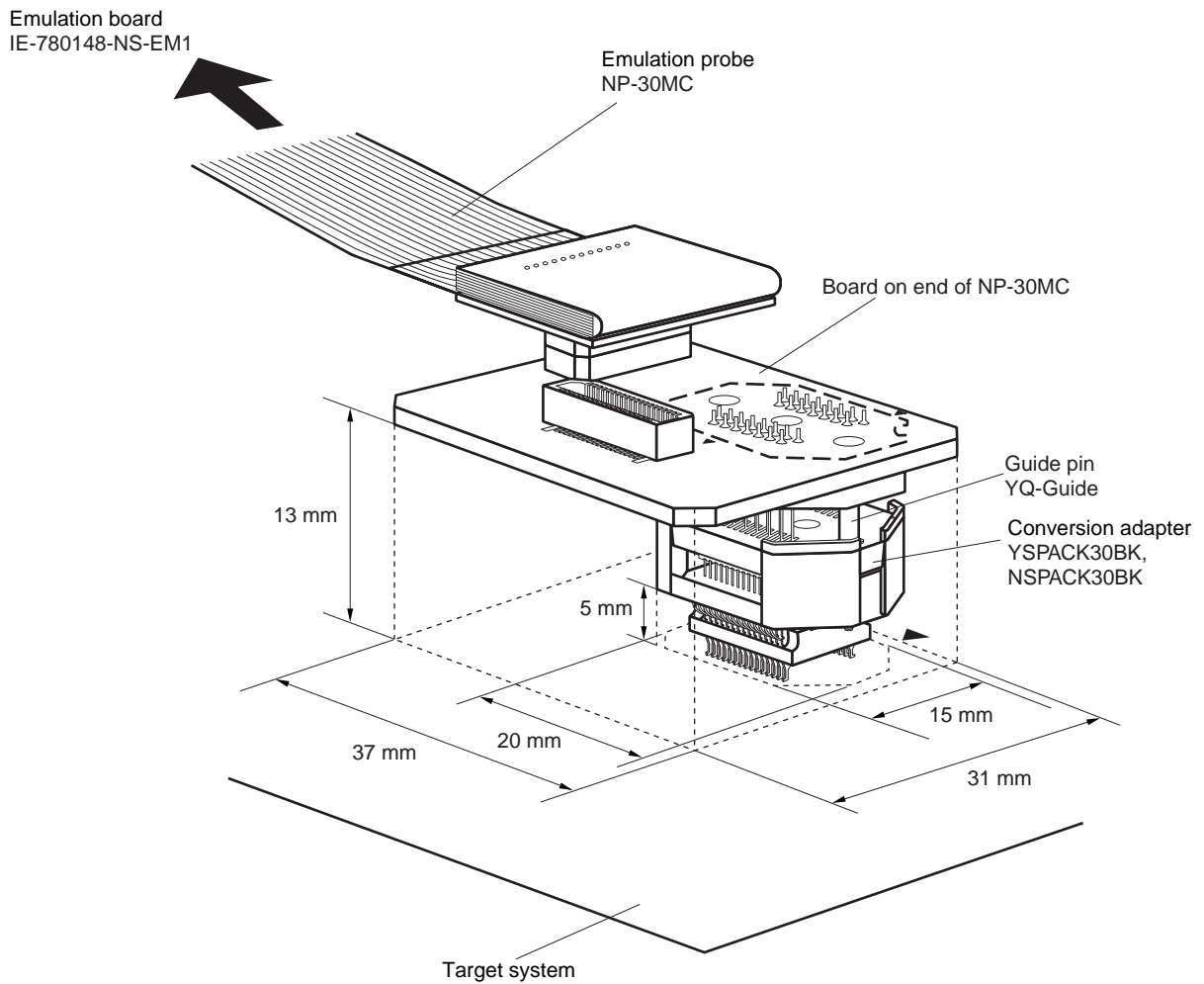
**Figure B-1. Distance Between In-Circuit Emulator and Conversion Adapter**



- Remarks**
1. The NP-30MC is a product of Naito Densai Machida Mfg. Co., Ltd.
  2. The YSPACK30BK and NSPACK30BK are products of TOKYO ELETECH CORPORATION.



Figure B-2. Connection Condition of Target System

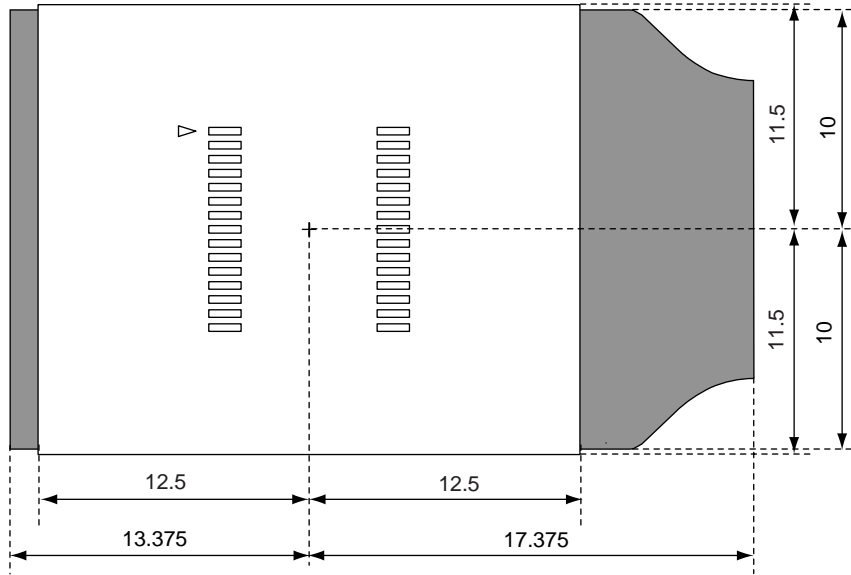


- Remarks**
1. NP-30MC is a product of Naito Densai Machida Mfg. Co., Ltd.
  2. YSPACK30BK, NSPACK30BK, and YQ-Guide are products of TOKYO ELETECH CORPORATION.

★ B.2 When Using QB-78K0KX1H

This section shows areas on the target system where component mounting is prohibited and areas where there are component mounting height restrictions.

Figure B-3. Restriction Area on Target System



□: Exchange adapter area: Components up to 17.45 mm in height can be mounted<sup>Note</sup>

■: Emulation probe tip area: Components up to 24.45 mm in height can be mounted<sup>Note</sup>

**Note** Height can be regulated by using space adapters (each adds 2.4 mm)

## APPENDIX C REGISTER INDEX

### C.1 Register Index (In Alphabetical Order with Respect to Register Names)

#### [A]

|  |     |
|--|-----|
| A/D conversion result register (ADCR) .....                                  | 194 |
| A/D converter mode register (ADM) .....                                      | 192 |
| Analog input channel specification register (ADS) .....                      | 194 |
| Asynchronous serial interface control register 6 (ASICL6).....               | 243 |
| Asynchronous serial interface operation mode register 0 (ASIM0) .....        | 213 |
| Asynchronous serial interface operation mode register 6 (ASIM6) .....        | 237 |
| Asynchronous serial interface reception error status register 0 (ASIS0)..... | 215 |
| Asynchronous serial interface reception error status register 6 (ASIS6)..... | 239 |
| Asynchronous serial interface transmission status register 6 (ASIF6) .....   | 240 |

#### [B]

|   |     |
|---|-----|
| Baud rate generator control register 0 (BRGC0)..... | 216 |
| Baud rate generator control register 6 (BRGC6)..... | 242 |

#### [C]

|  |     |
|--|-----|
| Capture/compare control register 00 (CRC00)..... | 117 |
| Clock monitor mode register (CLM) .....          | 316 |
| Clock selection register 6 (CKSR6).....          | 241 |

#### [E]

|  |     |
|--|-----|
| 8-bit timer compare register 50 (CR50).....                | 150 |
| 8-bit timer counter 50 (TM50).....                         | 149 |
| 8-bit timer H compare register 00 (CMP00) .....            | 164 |
| 8-bit timer H compare register 01 (CMP01) .....            | 164 |
| 8-bit timer H compare register 10 (CMP10) .....            | 164 |
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| 8-bit timer mode control register 50 (TMC50) .....         | 152 |
| External interrupt falling edge enable register (EGN)..... | 287 |
| External interrupt rising edge enable register (EGP).....  | 287 |

#### [I]

|   |     |
|---|-----|
| Input switch control register (ISC) .....           | 244 |
| Internal memory size switching register (IMS) ..... | 339 |
| Interrupt mask flag register 0H (MK0H) .....        | 285 |
| Interrupt mask flag register 0L (MK0L).....         | 285 |
| Interrupt mask flag register 1L (MK1L).....         | 285 |
| Interrupt request flag register 0H (IF0H) .....     | 284 |
| Interrupt request flag register 0L (IF0L) .....     | 284 |
| Interrupt request flag register 1L (IF1L) .....     | 284 |

**[L]**

|  |     |
|--|-----|
| Low-voltage detection level selection register (LVIS)..... | 329 |
| Low-voltage detection register (LVIM).....                 | 328 |

**[M]**

|                                       |    |
|---------------------------------------|----|
| Main clock mode register (MCM) .....  | 93 |
| Main OSC control register (MOC) ..... | 94 |

**[O]**

|  |         |
|--|---------|
| Oscillation stabilization time counter status register (OSTC)..... | 95, 298 |
| Oscillation stabilization time select register (OSTS).....         | 96, 300 |

**[P]**

|   |                             |
|---|-----------------------------|
| Port mode register 0 (PM0).....                     | 84, 120                     |
| Port mode register 1 (PM1).....                     | 84, 153, 168, 217, 244, 271 |
| Port mode register 3 (PM3).....                     | 84                          |
| Port mode register 12 (PM12).....                   | 84                          |
| Port register 0 (P0).....                           | 86                          |
| Port register 1 (P1).....                           | 86                          |
| Port register 2 (P2).....                           | 86                          |
| Port register 3 (P3).....                           | 86                          |
| Port register 12 (P12).....                         | 86                          |
| Port register 13 (P13).....                         | 86                          |
| Power-fail comparison mode register (PFM).....      | 195                         |
| Power-fail comparison threshold register (PFT)..... | 195                         |
| Prescaler mode register 00 (PRM00).....             | 119                         |
| Priority specification flag register 0H (PR0H)..... | 286                         |
| Priority specification flag register 0L (PR0L)..... | 286                         |
| Priority specification flag register 1L (PR1L)..... | 286                         |
| Processor clock control register (PCC).....         | 91                          |
| Pull-up resistor option register 0 (PU0).....       | 87                          |
| Pull-up resistor option register 1 (PU1).....       | 87                          |
| Pull-up resistor option register 3 (PU3).....       | 87                          |
| Pull-up resistor option register 12 (PU12).....     | 87                          |

**[R]**

|   |     |
|---|-----|
| Receive buffer register 0 (RXB0).....   | 212 |
| Receive buffer register 6 (RXB6).....   | 236 |
| Reset control flag register (RESF)..... | 314 |
| Ring-OSC mode register (RCM).....       | 92  |

**[S]**

|  |     |
|--|-----|
| Serial clock selection register 10 (CSIC10).....       | 270 |
| Serial I/O shift register 10 (SIO10).....              | 268 |
| Serial operation mode register 10 (CSIM10).....        | 269 |
| 16-bit timer capture/compare register 000 (CR000)..... | 112 |
| 16-bit timer capture/compare register 010 (CR010)..... | 114 |
| 16-bit timer counter 00 (TM00).....                    | 112 |
| 16-bit timer mode control register 00 (TMC00).....     | 115 |

16-bit timer output control register 00 (TOC00)..... 117

**[T]**

Timer clock selection register 50 (TCL50) ..... 151

Transmit buffer register 10 (SOTB10)..... 268

Transmit buffer register 6 (TXB6)..... 236

Transmit shift register 0 (TXS0) ..... 212

**[W]**

Watchdog timer enable register (WDTE) ..... 182

Watchdog timer mode register (WDTM) ..... 181

**C.2 Register Index (In Alphabetical Order with Respect to Register Symbol)****[A]**

|         |  |     |
|---------|--|-----|
| ADCR:   | A/D conversion result register .....                                 | 194 |
| ADM:    | A/D converter mode register.....                                     | 192 |
| ADS:    | Analog input channel specification register .....                    | 194 |
| ASICL6: | Asynchronous serial interface control register 6.....                | 243 |
| ASIF6:  | Asynchronous serial interface transmission status register 6.....    | 240 |
| ASIM0:  | Asynchronous serial interface operation mode register 0.....         | 213 |
| ASIM6:  | Asynchronous serial interface operation mode register 6.....         | 237 |
| ASIS0:  | Asynchronous serial interface reception error status register 0..... | 215 |
| ASIS6:  | Asynchronous serial interface reception error status register 6..... | 239 |

**[B]**

|        |   |     |
|--------|---|-----|
| BRGC0: | Baud rate generator control register 0..... | 216 |
| BRGC6: | Baud rate generator control register 6..... | 242 |

**[C]**

|         |  |     |
|---------|--|-----|
| CKSR6:  | Clock selection register 6 .....               | 241 |
| CLM:    | Clock monitor mode register.....               | 316 |
| CMP00:  | 8-bit timer H compare register 00 .....        | 164 |
| CMP01:  | 8-bit timer H compare register 01 .....        | 164 |
| CMP10:  | 8-bit timer H compare register 10 .....        | 164 |
| CMP11:  | 8-bit timer H compare register 11 .....        | 164 |
| CR000:  | 16-bit timer capture/compare register 000..... | 112 |
| CR010:  | 16-bit timer capture/compare register 010..... | 114 |
| CR50:   | 8-bit timer compare register 50.....           | 150 |
| CRC00:  | Capture/compare control register 00 .....      | 117 |
| CSIC10: | Serial clock selection register 10.....        | 270 |
| CSIM10: | Serial operation mode register 10.....         | 269 |

**[E]**

|      |   |     |
|------|---|-----|
| EGN: | External interrupt falling edge enable register ..... | 287 |
| EGP: | External interrupt rising edge enable register .....  | 287 |

**[I]**

|       |  |     |
|-------|--|-----|
| IF0H: | Interrupt request flag register 0H.....      | 284 |
| IF0L: | Interrupt request flag register 0L .....     | 284 |
| IF1L: | Interrupt request flag register 1L .....     | 284 |
| IMS:  | Internal memory size switching register..... | 339 |
| ISC:  | Input switch control register.....           | 244 |

**[L]**

|       |  |     |
|-------|--|-----|
| LVIM: | Low-voltage detection register.....                  | 328 |
| LVIS: | Low-voltage detection level selection register ..... | 329 |

**[M]**

|      |                               |    |
|------|-------------------------------|----|
| MCM: | Main clock mode register..... | 93 |
|------|-------------------------------|----|

|            |  |                             |
|------------|--|-----------------------------|
| MK0H:      | Interrupt mask flag register 0H .....                        | 285                         |
| MK0L:      | Interrupt mask flag register 0L.....                         | 285                         |
| MK1L:      | Interrupt mask flag register 1L.....                         | 285                         |
| MOC:       | Main OSC control register .....                              | 94                          |
| <b>[O]</b> |  |                             |
| OSTC:      | Oscillation stabilization time counter status register ..... | 95, 298                     |
| OSTS:      | Oscillation stabilization time select register .....         | 96, 300                     |
| <b>[P]</b> |  |                             |
| P0:        | Port register 0.....   | 86                          |
| P1:        | Port register 1.....   | 86                          |
| P2:        | Port register 2.....   | 86                          |
| P3:        | Port register 3.....   | 86                          |
| P12:       | Port register 12.....  | 86                          |
| P13:       | Port register 13.....  | 86                          |
| PCC:       | Processor clock control register .....                       | 91                          |
| PFM:       | Power-fail comparison mode register .....                    | 195                         |
| PFT:       | Power-fail comparison threshold register .....               | 195                         |
| PM0:       | Port mode register 0.....                                    | 84, 120                     |
| PM1:       | Port mode register 1.....                                    | 84, 153, 168, 217, 244, 271 |
| PM3:       | Port mode register 3.....                                    | 84                          |
| PM12:      | Port mode register 12.....                                   | 84                          |
| PR0H:      | Priority specification flag register 0H .....                | 286                         |
| PR0L:      | Priority specification flag register 0L.....                 | 286                         |
| PR1L:      | Priority specification flag register 1L.....                 | 286                         |
| PRM00:     | Prescaler mode register 00 .....                             | 119                         |
| PU0:       | Pull-up resistor option register 0.....                      | 87                          |
| PU1:       | Pull-up resistor option register 1.....                      | 87                          |
| PU3:       | Pull-up resistor option register 3.....                      | 87                          |
| PU12:      | Pull-up resistor option register 12.....                     | 87                          |
| <b>[R]</b> |  |                             |
| RCM:       | Ring-OSC mode register .....                                 | 92                          |
| RESF:      | Reset control flag register .....                            | 314                         |
| RXB0:      | Receive buffer register 0 .....                              | 212                         |
| RXB6:      | Receive buffer register 6 .....                              | 236                         |
| <b>[S]</b> |  |                             |
| SIO10:     | Serial I/O shift register 10.....                            | 268                         |
| SOTB10:    | Transmit buffer register 10 .....                            | 268                         |
| <b>[T]</b> |  |                             |
| TCL50:     | Timer clock selection register 50.....                       | 151                         |
| TM00:      | 16-bit timer counter 00 .....                                | 112                         |
| TM50:      | 8-bit timer counter 50 .....                                 | 149                         |
| TMC00:     | 16-bit timer mode control register 00.....                   | 115                         |
| TMC50:     | 8-bit timer mode control register 50.....                    | 152                         |
| TMHMD0:    | 8-bit timer H mode register 0.....                           | 165                         |

|         |   |     |
|---------|---|-----|
| TMHMD1: | 8-bit timer H mode register 1 .....           | 165 |
| TOC00:  | 16-bit timer output control register 00 ..... | 117 |
| TXB6:   | Transmit buffer register 6 .....              | 236 |
| TXS0:   | Transmit shift register 0 .....               | 212 |

**[W]**

|       |                                      |     |
|-------|--------------------------------------|-----|
| WDTE: | Watchdog timer enable register ..... | 182 |
| WDTM: | Watchdog timer mode register .....   | 181 |



## APPENDIX D LIST OF CAUTIONS

This appendix lists cautions described in this document.

“Classification (hard/soft)” in table is as follows.

Hard: Cautions for microcontroller internal/external hardware

Soft: Cautions for software such as register settings or programs

(1/20)

| Chapter   | Classification | Function                   | Details of Function  | Cautions   | Page                          |
|-----------|----------------|----------------------------|--|--|-------------------------------|
| Chapter 1 | Hard           | Operating frequency rating | Peripheral function: Count clock, base clock                     | The specifications of the peripheral functions (such as the timer, serial interface, and A/D converter) at $V_{DD} = 2.7$ to $5.5$ V remain unchanged. Consequently when selecting the count clock or base clock of a peripheral function, set to satisfy the following conditions. <ul style="list-style-type: none"> <li>• <math>V_{DD} = 4.0</math> to <math>5.5</math> V: Count clock or base clock <math>\leq 10</math> MHz</li> <li>• <math>V_{DD} = 3.3</math> to <math>4.0</math> V: Count clock or base clock <math>\leq 8.38</math> MHz</li> <li>• <math>V_{DD} = 2.7</math> to <math>3.3</math> V: Count clock or base clock <math>\leq 5</math> MHz</li> <li>• <math>V_{DD} = 2.5</math> to <math>2.7</math> V: Count clock or base clock <math>\leq 2.5</math> MHz</li> </ul> | p.17 <input type="checkbox"/> |
|           |                |                            | Flash memory   | Rewrite the flash memory within the ranges of $f_x = 2$ to $10$ MHz and $V_{DD} = 2.7$ to $5.5$ V as before.   | p.17 <input type="checkbox"/> |
|           | Pin processing | -                          | Connect the IC (Internally Connected) pin directly to $V_{SS}$ . | p.22 <input type="checkbox"/>  |                               |
|           |                |                            | Connect the $AV_{SS}$ pin to $V_{SS}$ .                          | p.22 <input type="checkbox"/>  |                               |
|           |                |                            | Connect the $V_{PP}$ pin to $V_{SS}$ during normal operation.    | p.22 <input type="checkbox"/>  |                               |
| Chapter 3 | Soft           | Memory space               | IMS: Internal memory size switching register                     | Regardless of the internal memory capacity, the initial values of internal memory size switching register (IMS) of all products in the 78K0/KB1 are fixed (IMS = CFH). Therefore, set the value corresponding to each product as indicated below. <ul style="list-style-type: none"> <li><math>\mu</math>PD780101: 42H</li> <li><math>\mu</math>PD780102: 04H</li> <li><math>\mu</math>PD780103: 06H</li> <li><math>\mu</math>PD78F0103: Value corresponding to mask ROM version</li> </ul>  | p.39 <input type="checkbox"/> |
|           |                |                            | SFR area: Special function register                              | Do not access addresses to which SFRs are not assigned.  | p.45 <input type="checkbox"/> |
|           |                |                            | SP: Stack pointer  | Since $\overline{RESET}$ input makes the SP contents undefined, be sure to initialize the SP before use.   | p.51 <input type="checkbox"/> |
| Chapter 4 | Soft           | Port function              | P10, P11, P12  | When using P10/ $\overline{SCK10}$ (/TxD0), P11/SI10 (/RxD0), and P12/SO10 as general-purpose ports, do not write to serial clock selection register 10 (CSIC10).  | p.76 <input type="checkbox"/> |
|           |                |                            | -  | In the case of a 1-bit memory manipulation instruction, although a single bit is manipulated, the port is accessed as an 8-bit unit. Therefore, on a port with a mixture of input and output pins, the output latch contents for pins specified as input are undefined, even for bits other than the manipulated bit.  | p.88 <input type="checkbox"/> |
| Chapter 5 | Soft           | Ring-OSC                   | RCM: Ring-OSC mode register                                      | Make sure that bit 1 (MCS) of the main clock mode register (MCM) is 1 before setting RSTOP.  | p.92 <input type="checkbox"/> |

| Chapter   | Classification | Function   | Details of Function  | Cautions  | Page   |  |                               |
|-----------|----------------|------------|--|---|--|--|-------------------------------|
| Chapter 5 | Hard           | Main clock | MCM: Main clock mode register                                | When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the divided clock of the Ring-OSC oscillator output (fx) is supplied to the peripheral hardware (fx = 240 kHz (TYP.)). Operation of the peripheral hardware with the Ring-OSC clock cannot be guaranteed. Therefore, when the Ring-OSC clock is selected as the clock supplied to the CPU, do not use peripheral hardware. In addition, stop the peripheral hardware before switching the clock supplied to the CPU from the X1 input clock to the Ring-OSC clock. Note, however, that the following peripheral hardware can be used when the CPU operates on the Ring-OSC clock. <ul style="list-style-type: none"> <li>• Watchdog timer</li> <li>• Clock monitor</li> <li>• 8-bit timer H1 when <math>f_R/2^7</math> is selected as the count clock</li> <li>• Peripheral hardware with an external clock selected as the clock source (Except when the external count clock of TM00 is selected (TI000 valid edge))</li> </ul> | p.93 <input type="checkbox"/>                        |  |                               |
|           |                |            | MOC: Main OSC control register                               | Make sure that bit 1 (MCS) of the main clock mode register (MCM) is 0 before setting MSTOP.   | p.94 <input type="checkbox"/>                        |  |                               |
|           |                |            | OSTC: Oscillation stabilization time counter status register | After the above time has elapsed, the bits are set to 1 in order from MOST11 and remain 1.  | p.95 <input type="checkbox"/>                        |  |                               |
|           |                |            |  | If the STOP mode is entered and then released while the Ring-OSC clock is being used as the CPU clock, set the oscillation stabilization time as follows. <ul style="list-style-type: none"> <li>• Desired OSTC oscillation stabilization time ≤ Oscillation stabilization time set by OSTC</li> </ul> The X1 oscillation stabilization time counter counts up to the oscillation stabilization time set by OSTC. Note, therefore, that only the status up to the oscillation stabilization time set by OSTC is set to OSTC after STOP mode is released.  | p.95 <input type="checkbox"/>                        |  |                               |
|           |                |            | Soft   | Hard  | OSTS: Oscillation stabilization time select register | The wait time when STOP mode is released does not include the time after STOP mode release until clock oscillation starts ("a" below) regardless of whether STOP mode is released by $\overline{\text{RESET}}$ input or interrupt generation.  | p.95 <input type="checkbox"/> |
|           |                |            |  |   |  | To set the STOP mode when the X1 input clock is used as the CPU clock, set OSTC before executing the STOP instruction.   | p.96 <input type="checkbox"/> |
|           |                |            |  |   |  | Execute the OSTC setting after confirming that the oscillation stabilization time has elapsed as expected in the OSTC.   | p.96 <input type="checkbox"/> |
|           |                |            |  |   |  | If the STOP mode is entered and then released while the Ring-OSC clock is being used as the CPU clock, set the oscillation stabilization time as follows. <ul style="list-style-type: none"> <li>• Desired OSTC oscillation stabilization time ≤ Oscillation stabilization time set by OSTC</li> </ul> The X1 oscillation stabilization time counter counts up to the oscillation stabilization time set by OSTC. Note, therefore, that only the status up to the oscillation stabilization time set by OSTC is set to OSTC after STOP mode is released. | p.96 <input type="checkbox"/> |
|           |                |            | Soft   | Hard  | OSTS: Oscillation stabilization time select register | The wait time when STOP mode is released does not include the time after STOP mode release until clock oscillation starts ("a" below) regardless of whether STOP mode is released by $\overline{\text{RESET}}$ input or interrupt generation.  | p.96 <input type="checkbox"/> |
|           |                |            |  |   |  |  |                               |

| Chapter   | Classification | Function                             | Details of Function                              | Cautions   | Page   |
|-----------|----------------|--------------------------------------|--|--|--|
| Chapter 5 | Hard           | X1 oscillator                        | –  | When using the X1 oscillator, wire as follows in the area enclosed by the broken lines in the Figure 5-8 to avoid an adverse effect from wiring capacitance. <ul style="list-style-type: none"> <li>• Keep the wiring length as short as possible.</li> <li>• Do not cross the wiring with the other signal lines.</li> <li>• Do not route the wiring near a signal line through which a high fluctuating current flows.</li> <li>• Always make the ground point of the oscillator capacitor the same potential as V<sub>SS</sub>. Do not ground the capacitor to a ground pattern through which a high current flows.</li> <li>• Do not fetch signals from the oscillator.</li> </ul> | p.97 <input type="checkbox"/>                                    |
|           |                | Prescaler                            | –  | When the Ring-OSC clock is selected as the clock supplied to the CPU, the prescaler generates various clocks by dividing the Ring-OSC oscillator output (f <sub>x</sub> = 240 kHz (TYP.)).   | p.99 <input type="checkbox"/>                                    |
|           | Soft           | Ring-OSC                             | –  | The RSTOP setting is valid only when “Can be stopped by software” is set for Ring-OSC by a mask option.<br>To calculate the maximum time, set f <sub>R</sub> = 120 kHz.  | p.104 <input type="checkbox"/><br>p.105 <input type="checkbox"/> |
|           |                |                                      | –  | Setting the following values is prohibited when the CPU operates on the Ring-OSC clock. <ul style="list-style-type: none"> <li>• PCC2, PCC1, PCC0 = 0, 0, 1 (settable only for standard products and (A) grade products)</li> <li>• PCC2, PCC1, PCC0 = 0, 1, 0</li> <li>• PCC2, PCC1, PCC0 = 0, 1, 1</li> <li>• PCC2, PCC1, PCC0 = 1, 0, 0</li> </ul>  | p.106 <input type="checkbox"/>                                   |
|           |                | CPU clock                            | –  | Setting the following values is prohibited when the CPU operates on the Ring-OSC clock. <ul style="list-style-type: none"> <li>• PCC2, PCC1, PCC0 = 0, 0, 1 (settable only for standard products and (A) grade products)</li> <li>• PCC2, PCC1, PCC0 = 0, 1, 0</li> <li>• PCC2, PCC1, PCC0 = 0, 1, 1</li> <li>• PCC2, PCC1, PCC0 = 1, 0, 0</li> </ul>  | p.106 <input type="checkbox"/>                                   |
| Chapter 6 | Soft           | 16-bit timer/event counter 00 (TM00) | CR000: 16-bit timer capture/compare register 000 | Set a value other than 0000H in CR000 in the mode in which clear & start occurs on a match of TM00 and CR000.  | p.113 <input type="checkbox"/>                                   |
|           |                |                                      |  | If CR000 is set to 0000H in the free-running mode and in the clear mode using the valid edge of the TI000 pin, an interrupt request (INTTM000) is generated when the value of CR000 changes from 0000H to 0001H following TM00 overflow (FFFFH). Moreover, INTTM000 is generated after a match of TM00 and CR000 is detected, a valid edge of the TI010 pin is detected, and the timer is cleared by a one-shot trigger.   | p.113 <input type="checkbox"/>                                   |
|           |                |                                      |  | Do not rewrite CR000 during TM00 operation.  | pp.113, 121, 126, 138 <input type="checkbox"/>                   |
|           | Hard           |                                      |  | When P01 is used as the valid edge input pin of TI010, it cannot be used as the timer output (TO00). Moreover, when P01 is used as TO00, it cannot be used as the valid edge input pin of TI010.   | p.113 <input type="checkbox"/>                                   |
|           |                |                                      |  | When CR000 is used as a capture register, read data is undefined if the register read time and capture trigger input conflict (the capture data itself is the correct value). If timer count stop and capture trigger input conflict, the captured data is undefined.  | p.113 <input type="checkbox"/>                                   |
| Soft      |                |                                      | CR010: 16-bit timer capture/compare register 010 | If the CR010 register is cleared to 0000H, an interrupt request (INTTM010) is generated when the value of CR010 changes from 0000H to 0001H following TM00 overflow (FFFFH). Moreover, INTTM010 is generated after a match of TM00 and CR010 is detected, a valid edge of the TI000 pin is detected, and the timer is cleared by a one-shot trigger.   | p.114 <input type="checkbox"/>                                   |

| Chapter   | Classification   | Function                             | Details of Function   | Cautions  | Page  |
|-----------|--|--------------------------------------|---|---|---|
| Chapter 6 | Hard   | 16-bit timer/event counter 00 (TM00) | CR010: 16-bit timer capture/compare register 010  | When CR010 is used as a capture register, read data is undefined if the register read time and capture trigger input conflict (the capture data itself is the correct value). If count stop input and capture trigger input conflict, the captured data is undefined.   | p.114 <input type="checkbox"/>                                    |
|           |  |                                      |   | CR010 can be rewritten during TM00 operation. For details, see Caution 2 in Figure 6-15.  | p.114 <input type="checkbox"/>                                    |
|           |  |                                      | TMC00: 16-bit timer mode control register 00  | 16-bit timer counter 00 (TM00) starts operation at the moment TMC002 and TMC003 are set to values other than 0, 0 (operation stop mode), respectively. Clear TMC002 and TMC003 to 0, 0 to stop operation.   | p.115 <input type="checkbox"/>                                    |
|           |  |                                      |   | Timer operation must be stopped before writing to bits other than the OVF00 flag.   | p.116 <input type="checkbox"/>                                    |
|           |  |                                      |   | Set the valid edge of the TI000/P00 pin using prescaler mode register 00 (PRM00).   | p.116 <input type="checkbox"/>                                    |
|           |  |                                      |   | If any of the following modes: the mode in which clear & start occurs on match between TM00 and CR000, the mode in which clear & start occurs at the TI000 valid edge, or free-running mode is selected, when the set value of CR000 is FFFFH and the TM00 value changes from FFFFH to 0000H, the OVF00 flag is set to 1. | p.116 <input type="checkbox"/>                                    |
|           |  |                                      | CRC00: Capture/compare control register 00  | Timer operation must be stopped before setting CRC00.   | p.117 <input type="checkbox"/>                                    |
|           |  |                                      |   | When the mode in which clear & start occurs on a match between TM00 and CR000 is selected with 16-bit timer mode control register 00 (TMC00), CR000 should not be specified as a capture register.  | p.117 <input type="checkbox"/>                                    |
|           |  |                                      |   | To ensure that the capture operation is performed properly, the capture trigger requires a pulse two cycles longer than the count clock selected by prescaler mode register 00 (PRM00).   | p.117 <input type="checkbox"/>                                    |
|           |  |                                      | Soft  | TOC00: 16-bit timer output control register 00  | Timer operation must be stopped before setting other than TOC004. |
|           | LVS00 and LVR00 are 0 when they are read.  | p.118 <input type="checkbox"/>       |   |   |   |
|           | OSPT00 is automatically cleared after data is set, so 0 is read.   | p.118 <input type="checkbox"/>       |   |   |   |
|           | Do not set OSPT00 to 1 other than in one-shot pulse output mode.   | p.118 <input type="checkbox"/>       |   |   |   |
|           | A write interval of two cycles or more of the count clock selected by prescaler mode register 00 (PRM00) is required to write to OSPT00 successively.  | p.118 <input type="checkbox"/>       |   |   |   |
|           | Do not set LVS00 to 1 before TOE00, and do not set LVS00 and TOE00 to 1 simultaneously.  | p.118 <input type="checkbox"/>       |   |   |   |
|           | Do not make settings <1> and <2> below simultaneously. In addition, follow the setting procedure shown below.<br><1> Setting of TOC001, TOC004, TOE00, and OSPE00:<br>Setting of timer output operation<br><2> Setting of LVS00 and LVR00: Setting of timer output F/F | p.118 <input type="checkbox"/>       |   |   |   |
|           | Hard   | PRM00: Prescaler mode register 00    | When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the count clock is the Ring-OSC clock, the operation of 16-bit timer/event counter 00 is not guaranteed. When an external clock is used and when the Ring-OSC clock is selected and supplied to the CPU, the operation of 16-bit timer/event counter 00 is not guaranteed, either, because the Ring-OSC clock is supplied as the sampling clock to eliminate noise. | p.119 <input type="checkbox"/>  |   |

| Chapter   | Classification | Function                             | Details of Function               | Cautions  | Page  |   |                                |   |  |                                |
|-----------|----------------|--------------------------------------|-----------------------------------|---|---|---|--------------------------------|---|--|--------------------------------|
| Chapter 6 | Soft           | 16-bit timer/event counter 00 (TM00) | PRM00: Prescaler mode register 00 | Always set data to PRM00 after stopping the timer operation.  | p.119 <input type="checkbox"/>                                |   |                                |   |  |                                |
|           |                |                                      |                                   | If the valid edge of TI000 is to be set for the count clock, do not set the clear & start mode using the valid edge of TI000 and the capture trigger.   | p.119 <input type="checkbox"/>                                |   |                                |   |  |                                |
|           |                |                                      |                                   | If the TI000 or TI010 pin is high level immediately after system reset, the rising edge is immediately detected after the rising edge or both the rising and falling edges are set as the valid edge(s) of the TI000 pin or TI010 pin to enable the operation of 16-bit timer counter 00 (TM00). Care is therefore required when pulling up the TI000 or TI010 pin. However, when the TI000 or TI010 pin is high level and re-enabling operation after the operation has been stopped, the rising edge is not detected. | p.120 <input type="checkbox"/>                                |   |                                |   |  |                                |
|           |                |                                      |                                   | When P01 is used as the TI010 valid edge input pin, it cannot be used as the timer output (TO00), and when used as TO00, it cannot be used as the TI010 valid edge input pin.   | p.120 <input type="checkbox"/>                                |   |                                |   |  |                                |
|           | Hard           |                                      |                                   |   |   |   |                                |   |  |                                |
|           |                |                                      |                                   |   |   |   |                                |   |  |                                |
|           | Soft           |                                      |                                   |   | CR010: 16-bit timer capture/compare register 010              | To change the value of the duty factor (the value of the CR010 register) during operation, see Caution 2 in Figure 6-15 PPG Output Operation Timing.  | p.124 <input type="checkbox"/> |   |  |                                |
|           |                |                                      |                                   |   | CR000, CR010: 16-bit timer capture/compare registers 000, 010 | Values in the following range should be set in CR000 and CR010:<br>$0000H \leq CR010 < CR000 \leq FFFFH$  | p.125 <input type="checkbox"/> |   |  |                                |
|           |                |                                      |                                   |   |   | The cycle of the pulse generated through PPG output (CR000 setting value + 1) has a duty of $(CR010 \text{ setting value} + 1) / (CR000 \text{ setting value} + 1)$ .   | p.125 <input type="checkbox"/> |   |  |                                |
|           |                |                                      |                                   |   | PPG output  | In the PPG output operation, change the pulse width (rewrite CR010) during TM00 operation using the following procedure.<br><1> Disable the timer output inversion operation by match of TM00 and CR010 (TOC004 = 0)<br><2> Disable the INTTM010 interrupt (TMMK010 = 1)<br><3> Rewrite CR010<br><4> Wait for 1 cycle of the TM00 count clock<br><5> Enable the timer output inversion operation by match of TM00 and CR010 (TOC004 = 1)<br><6> Clear the interrupt request flag of INTTM010 (TMIF010 = 0)<br><7> Enable the INTTM010 interrupt (TMMK010 = 0) | p.126 <input type="checkbox"/> |   |  |                                |
|           |                |                                      |                                   |   | Pulse width measurement                                       | To use two capture registers, set the TI000 and TI010 pins.   | p.127 <input type="checkbox"/> |   |  |                                |
|           |                |                                      |                                   |   | External event counter  | When reading the external event counter count value, TM00 should be read.   | p.137 <input type="checkbox"/> |   |  |                                |
| Hard      |                |                                      |                                   |   |   |   |                                | One-shot pulse output: Software trigger | Do not set the OSPT00 bit to 1 while the one-shot pulse is being output. To output the one-shot pulse again, wait until the current one-shot pulse output is completed.  | p.140 <input type="checkbox"/> |
|           |                |                                      |                                   |   |   |   |                                |   | When using the one-shot pulse output of 16-bit timer/event counter 00 with a software trigger, do not change the level of the TI000 pin or its alternate-function port pin.<br>Because the external trigger is valid even in this case, the timer is cleared and started even at the level of the TI000 pin or its alternate-function port pin, resulting in the output of a pulse at an undesired timing. | p.140 <input type="checkbox"/> |

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| Chapter 6 | Soft           | 16-bit timer/<br>event<br>counter 00<br>(TM00) | One-shot pulse<br>output: Software<br>trigger | Do not set the CR000 and CR010 registers to 0000H.   | p.141 <input type="checkbox"/>  |  |   |                                |
|           |                |  |   | 16-bit timer counter 00 starts operating as soon as the TMC003 and TMC002 bits are set to a value other than 00 (operation stop mode). | p.142 <input type="checkbox"/>  |  |   |                                |
|           | Hard           |  | One-shot pulse<br>output: External<br>trigger | Even if the external trigger is generated again while the one-shot pulse is being output, it is ignored.                               | p.142 <input type="checkbox"/>  |  |   |                                |
|           |                |  |   | Do not set the CR000 and CR010 registers to 0000H.   | p.143 <input type="checkbox"/>  |  |   |                                |
|           | Soft           |  | One-shot pulse<br>output: External<br>trigger | 16-bit timer counter 00 starts operating as soon as the TMC002 and TMC003 bits are set to a value other than 00 (operation stop mode). | p.144 <input type="checkbox"/>  |  |   |                                |
|           |                |  |   | Timer start errors   | An error of up to one clock may occur in the time required for a match signal to be generated after timer start. This is because 16-bit timer counter 00 (TM00) is started asynchronously to the count clock.         | p.145 <input type="checkbox"/>   |   |                                |
|           | Hard           |  | Soft  | 16-bit timer<br>capture/compare<br>registers 000,<br>010 setting   | 16-bit timer capture/compare registers 000, 010 (CR000, CR010) to other than 0000H. This means a 1-pulse count operation cannot be performed when 16-bit timer/event counter 00 is used as an external event counter. | p.145 <input type="checkbox"/>   |   |                                |
|           |                |  |   |  | Capture register data retention timing  | The values of 16-bit timer capture/compare registers 000 and 010 (CR000 and CR010) are not guaranteed after 16-bit timer/event counter 00 has been stopped.  | p.145 <input type="checkbox"/>  |                                |
|           |                |  |   |  | Valid edge setting  | Set the valid edge of the TI000 pin after setting bits 2 and 3 (TMC002 and TMC003) of 16-bit timer mode control register 00 (TMC00) to 0, 0, respectively, and then stopping timer operation. The valid edge is set using bits 4 and 5 (ES000 and ES001) of prescaler mode register 00 (PRM00).  | p.145 <input type="checkbox"/>  |                                |
|           |                |  |   |  | One-shot pulse output: Software trigger   | When a one-shot pulse is output, do not set the OSPT00 bit to 1. Do not output the one-shot pulse again until INTTM000, which occurs upon a match with the CR000 register, or INTTM010, which occurs upon a match with the CR010 register, occurs.   | p.145 <input type="checkbox"/>  |                                |
|           |                |  |   |  | One-shot pulse output: External trigger   | If the external trigger occurs again while a one-shot pulse is output, it is ignored.  | p.145 <input type="checkbox"/>  |                                |
|           |                |  |   |  | One-shot pulse output function  | When using the one-shot pulse output of 16-bit timer/event counter 00 with a software trigger, do not change the level of the TI000 pin or its alternate function port pin.<br>Because the external trigger is valid even in this case, the timer is cleared and started even at the level of the TI000 pin or its alternate function port pin, resulting in the output of a pulse at an undesired timing. | p.145 <input type="checkbox"/>  |                                |
|           |                |  |   |  | Soft  | Operation of<br>OVF00 flag   | The OVF00 flag is also set to 1 in the following case.<br>If any of the following modes: the mode in which clear & start occurs on a match between TM00 and CR000, the mode in which clear & start occurs on a TI000 valid edge, or the free-running mode, is selected<br>→ CR000 is set to FFFFH.<br>→ TM00 is counted up from FFFFH to 0000H. | p.146 <input type="checkbox"/> |
|           |                |  |   |  |   |  | Even if the OVF00 flag is cleared before the next count clock (before TM00 becomes 0001H) after the occurrence of TM00 overflow, the OVF00 flag is re-set newly and clear is disabled.  | p.146 <input type="checkbox"/> |

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|--|---|--|---|--|---|
| Chapter 6  | Soft  | 16-bit timer/<br>event<br>counter 00<br>(TM00) | Conflicting operations  | When the read period of the 16-bit timer capture/compare register (CR000/CR010) and capture trigger input (CR000/CR010 used as capture register) conflict, capture trigger input has priority. The data read from CR000/CR010 is undefined.  | p.146 <input type="checkbox"/>              |
|  |   |  | Timer operation   | Even if 16-bit timer counter 00 (TM00) is read, the value is not captured by 16-bit timer capture/compare register 010 (CR010).  | p.147 <input type="checkbox"/>              |
|  |   |  |   | Regardless of the CPU's operation mode, when the timer stops, the input signals to the TI000/TI010 pins are not acknowledged.  | p.147 <input type="checkbox"/>              |
|  |   |  |   | The one-shot pulse output mode operates correctly only in the free-running mode and the mode in which clear & start occurs at the TI000 valid edge. In the mode in which clear & start occurs on a match between the TM00 register and CR000 register, one-shot pulse output is not possible because an overflow does not occur. | p.147 <input type="checkbox"/>              |
|  |   |  | Capture operation   | If TI000 valid edge is specified as the count clock, a capture operation by the capture register specified as the trigger for TI000 is not possible.   | p.147 <input type="checkbox"/>              |
|  |   |  |   | To ensure the reliability of the capture operation, the capture trigger requires a pulse two cycles longer than the count clock selected by prescaler mode register 00 (PRM00).  | p.147 <input type="checkbox"/>              |
|  | The capture operation is performed at the falling edge of the count clock. An interrupt request input (INTTM000/INTTM010), however, is generated at the rise of the next count clock. |  |   | p.147 <input type="checkbox"/>   |   |
|  | Compare operation   |  | A capture operation may not be performed for CR000/CR010 set in compare mode even if a capture trigger has been input.  | p.147 <input type="checkbox"/>   |   |
|  | Edge detection  |  | If the TI000 or TI010 pin is high level immediately after system reset and the rising edge or both the rising and falling edges are specified as the valid edge of the TI000 or TI010 pin to enable the 16-bit timer counter 00 (TM00) operation, a rising edge is detected immediately after the operation is enabled. Be careful therefore when pulling up the TI000 or TI010 pin. However, when the TI000 or TI010 pin is high level, the rising edge is not detected at restart after the operation has been stopped. | p.147 <input type="checkbox"/>   |   |
|  |   |  | The sampling clock used to eliminate noise differs when the TI000 valid edge is used as the count clock and when it is used as a capture trigger. In the former case, the count clock is $f_x$ , and in the latter case the count clock is selected by prescaler mode register 00 (PRM00). The capture operation is started only after a valid level is detected twice by sampling the valid edge, thus eliminating noise with a short pulse width.   | p.147 <input type="checkbox"/>   |   |
|  |   |  |   |  |   |
|  | Chapter 7   |  | Soft  | 8-bit timer/<br>event<br>counter 50<br>(TM50)  | CR50: 8-bit timer<br>compare register<br>50 |
| In PWM mode, make the CR50 rewrite period 3 count clocks of the count clock (clock selected by TCL50) or more. |   | p.150 <input type="checkbox"/>                 |   |  |   |
| Hard   |   | TCL50: Timer<br>clock selection<br>register 50 | When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the count clock is the Ring-OSC clock, the operation of 8-bit timer/event counter 50 is not guaranteed.   |  | p.151 <input type="checkbox"/>              |
|  |   |  | When rewriting TCL50 to other than the same data, stop the timer operation beforehand.  |  | p.151 <input type="checkbox"/>              |

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|-----------|---|---|--|---|---|--------------------------------|
| Chapter 7 | Soft  | 8-bit timer/<br>event<br>counter 50<br>(TM50) | TCL50: Timer<br>clock selection<br>register 50       | Be sure to clear bits 3 to 7 to 0.  | p.151 <input type="checkbox"/>  |                                |
|           |   |   | TMC50: 8-bit<br>timer mode<br>control register<br>50 | The settings of LVS50 and LVR50 are valid in other than PWM mode.   | p.153 <input type="checkbox"/>  |                                |
|           |   |   |  | Do not make settings <1> to <4> below simultaneously. In addition, follow the setting procedure shown below.<br><1> Setting of TMC501 and TMC506: Setting of operation mode<br><2> Setting of TOE50 if enabling output: Enabling timer output<br><3> Setting of LVS50 and LVR50 (see Caution 1): Setting of timer F/F<br><4> Setting of TCE50 | p.153 <input type="checkbox"/>  |                                |
|           |   |   |  | Stop operation before rewriting TMC506.   | p.153 <input type="checkbox"/>  |                                |
|           |   |   | Interval timer/<br>square-wave<br>output             | Do not write other values to CR50 during operation.   | pp.154, <input type="checkbox"/><br>157   |                                |
|           |   |   | PWM output   | In PWM mode, make the CR50 rewrite period 3 count clocks of the count clock (clock selected by TCL50) or more.  | p.158 <input type="checkbox"/>  |                                |
|           | When reading from CR50 between <1> and <2> in Figure 7-11, the value read differs from the actual value (read value: M, actual value of CR50: N). | p.160 <input type="checkbox"/>                |  |   |   |                                |
|           | Hard  |   | Timer start error                                    | An error of up to one clock may occur in the time required for a match signal to be generated after timer start. This is because 8-bit timer counter 50 (TM50) is started asynchronously to the count clock.  | p.160 <input type="checkbox"/>  |                                |
|           | Chapter 8   | Soft  | 8-bit timers<br>H0, H1<br>(TMH0,<br>TMH1)            | CMP0n: 8-bit<br>timer H compare<br>register 0n  | CMP0n cannot be rewritten during timer count operation.   | p.164 <input type="checkbox"/> |
|           |   |   |  | CMP1n: 8-bit<br>timer H compare<br>register 1n  | In the PWM output mode be sure to set CMP1n when starting the timer count operation (TMHE <sub>n</sub> = 1) after the timer count operation was stopped (TMHE <sub>n</sub> = 0) (be sure to set again even if setting the same value to CMP1n). | p.164 <input type="checkbox"/> |
| Hard      |   |   | TMHMD0: 8-bit<br>timer H mode<br>register 0          | When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the count clock is the Ring-OSC clock, the operation of 8-bit timer H0 is not guaranteed.   | p.167 <input type="checkbox"/>  |                                |
|           |   |   |  | When TMHE0 = 1, setting the other bits of TMHMD0 is prohibited.   | p.167 <input type="checkbox"/>  |                                |
|           |   |   |  | In the PWM output mode, be sure to set 8-bit timer H compare register 10 (CMP10) when starting the timer count operation (TMHE0 = 1) after the timer count operation was stopped (TMHE0 = 0) (be sure to set again even if setting the same value to CMP10).  | p.167 <input type="checkbox"/>  |                                |
| Soft      |   |   | TMHMD1: 8-bit<br>timer H mode<br>register 1          | When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the count clock is the Ring-OSC clock, the operation of 8-bit timer H1 is not guaranteed (except when CKS12, CKS11, CKS10 = 1, 0, 1 ( $f_{R/2^7}$ )).                         | p.168 <input type="checkbox"/>  |                                |
|           |   |   |  | When TMHE1 = 1, setting the other bits of TMHMD1 is prohibited.   | p.168 <input type="checkbox"/>  |                                |
|           |   |   |  | In the PWM output mode, be sure to set 8-bit timer H compare register 11 (CMP11) when starting the timer count operation (TMHE1 = 1) after the timer count operation was stopped (TMHE1 = 0) (be sure to set again even if setting the same value to CMP11).  | p.168 <input type="checkbox"/>  |                                |



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| Chapter 8 | Hard                   | 8-bit timers H0, H1 (TMH0, TMH1) | PWM output                         | In PWM output mode, three operation clocks (signal selected using the CKSn2 to CKSn0 bits of the TMHMDn register) are required to transfer the CMP1n register value after rewriting the register.   | p.173 <input type="checkbox"/>  |   |  |
|           |                        |                                  |                                    | Be sure to set the CMP1n register when starting the timer count operation (TMHEn = 1) after the timer count operation was stopped (TMHEn = 0) (be sure to set again even if setting the same value to the CMP1n register).  | p.173 <input type="checkbox"/>  |   |  |
|           |                        |                                  |                                    | Make sure that the CMP1n register setting value (M) and CMP0n register setting value (N) are within the following range.<br>00H ≤ CMP1n (M) < CMP0n (N) ≤ FFH   | p.174 <input type="checkbox"/>  |   |  |
| Chapter 9 | Soft                   | Watchdog timer                   | WDTM: Watchdog timer mode register | If data is written to WDTM, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.   | p.181 <input type="checkbox"/>  |   |  |
|           |                        |                                  |                                    | Set bits 7, 6, and 5 to 0, 1, and 1, respectively (when "Ring-OSC cannot be stopped" is selected by a mask option, other values are ignored).   | p.181 <input type="checkbox"/>  |   |  |
|           |                        |                                  |                                    | After reset is released, WDTM can be written only once by an 8-bit memory manipulation instruction. If writing is attempted a second time, an internal reset signal is generated. If the source clock to the watchdog timer is stopped, however, an internal reset signal is generated when the source clock to the watchdog timer resumes operation. | p.182 <input type="checkbox"/>  |   |  |
|           |                        |                                  |                                    | WDTM cannot be set by a 1-bit memory manipulation instruction.  | p.182 <input type="checkbox"/>  |   |  |
|           |                        |                                  |                                    | If "Ring-OSC can be stopped by software" is selected by the mask option and the watchdog timer is stopped by setting WDCS4 to 1, the watchdog timer does not resume operation even if WDCS4 is cleared to 0. In addition, the internal reset signal is not generated.   | p.182 <input type="checkbox"/>  |   |  |
|           |                        |                                  |                                    | WDTE: Watchdog timer enable register  | If a value other than ACH is written to WDTE, an internal reset signal is generated. If the source clock to the watchdog timer is stopped, however, an internal reset signal is generated when the source clock to the watchdog timer resumes operation.                    | p.182 <input type="checkbox"/>  |  |
|           |                        |                                  |                                    |   | If a 1-bit memory manipulation instruction is executed for WDTE, an internal reset signal is generated. If the source clock to the watchdog timer is stopped, however, an internal reset signal is generated when the source clock to the watchdog timer resumes operation. | p.182 <input type="checkbox"/>  |  |
|           |                        |                                  |                                    |   | The value read from WDTE is 9AH (this differs from the written value (ACH)).  | p.182 <input type="checkbox"/>  |  |
|           |                        |                                  |                                    | Hard  | Watchdog timer operation when "Ring-OSC cannot be stopped" is selected by mask option   | In this mode, operation of the watchdog timer absolutely cannot be stopped even during STOP instruction execution. For 8-bit timer H1 (TMH1), a division of the Ring-OSC can be selected as the count source, so after STOP instruction execution, clear the watchdog timer using the interrupt request of TMH1 before the watchdog timer overflows. If this processing is not performed, an internal reset signal is generated when the watchdog timer overflows after STOP instruction execution. | p.184 <input type="checkbox"/>   |
|           |                        |                                  |                                    |   |   | Watchdog timer operation when "Ring-OSC can be stopped by software" is selected by mask option  | In this mode, watchdog timer operation is stopped during HALT/STOP instruction execution. After HALT/STOP mode is released, counting is started again using the operation clock of the watchdog timer set before HALT/STOP instruction execution by WDTM. At this time, the counter is not cleared to 0 but holds its value. |

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| Chapter 10                  | Soft  | A/D converter   | ADM: A/D converter mode register   | A/D conversion must be stopped before rewriting bits FR0 to FR2 to values other than the identical data.   | p.193 <input type="checkbox"/> |
|                             |   |   |  | For the sampling time of the A/D converter and the A/D conversion start delay time, see (11) in 10.6 Cautions for A/D Converter.   | p.193 <input type="checkbox"/> |
|                             |   |   |  | If data is written to ADM, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.   | p.193 <input type="checkbox"/> |
|                             |   |   | ADS: Analog input channel specification register   | Be sure to clear bits 2 to 7 of ADS to 0.  | p.194 <input type="checkbox"/> |
|                             |   |   |  | If data is written to ADS, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.   | p.194 <input type="checkbox"/> |
|                             |   |   | ADCR: A/D conversion result register   | When writing to the A/D converter mode register (ADM) and analog input channel specification register (ADS), the contents of ADCR may become undefined. Read the conversion result following conversion completion before writing to ADM and ADS. Using timing other than the above may cause an incorrect conversion result to be read. | p.194 <input type="checkbox"/> |
|                             |   |   |  | If data is read from ADCR, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.   | p.194 <input type="checkbox"/> |
|                             |   |   | PFM: Power-fail comparison mode register   | If data is written to PFM, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.   | p.195 <input type="checkbox"/> |
|                             |   |   | PFT: Power-fail comparison threshold register  | If data is written to PFT, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.   | p.195 <input type="checkbox"/> |
|                             |   |   | A/D conversion operation   | Make sure the period of <1> to <3> is 14 $\mu$ s or more.  | p.201 <input type="checkbox"/> |
|                             |   |   |  | It is no problem if the order of <1> and <2> is reversed.  | p.201 <input type="checkbox"/> |
|                             |   |   |  | <1> can be omitted. However, do not use the first conversion result after <3> in this case.  | p.201 <input type="checkbox"/> |
|                             | The period from <4> to <7> differs from the conversion time set using bits 5 to 3 (FR2 to FR0) of ADM.<br>The period from <6> to <7> is the conversion time set using FR2 to FR0. | p.201 <input type="checkbox"/>  |  |  |                                |
|                             | Power-fail detection function   | Make sure the period of <3> to <6> is 14 $\mu$ s or more.   | p.201 <input type="checkbox"/>   |  |                                |
|                             |   | It is no problem if the order of <3>, <4>, and <5> is changed.  | p.201 <input type="checkbox"/>   |  |                                |
|                             |   | <3> must not be omitted if the power-fail function is used.   | p.201 <input type="checkbox"/>   |  |                                |
|                             |   | The period from <7> to <11> differs from the conversion time set using bits 5 to 3 (FR2 to FR0) of ADM.<br>The period from <9> to <11> is the conversion time set using FR2 to FR0. | p.201 <input type="checkbox"/>   |  |                                |
|                             | Hard  |   | Operating current in standby mode  | The A/D converter stops operating in the standby mode. At this time, the operating current can be reduced by clearing bit 7 (ADCS) of the A/D converter mode register (ADM) to 0 (see Figure 10-2).  | p.204 <input type="checkbox"/> |
| Input range of ANI0 to ANI3 |   |   | Observe the rated range of the ANI0 to ANI3 input voltage. If a voltage of AVREF or higher and AVSS or lower (even in the range of absolute maximum ratings) is input to an analog input channel, the converted value of that channel becomes undefined. In addition, the converted values of the other channels may also be affected. | p.204 <input type="checkbox"/>   |                                |

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| Chapter 10 | Soft           | A/D converter | Conflicting operations               | ADCR read has priority. After the read operation, the new conversion result is written to ADCR.  | p.204 <input type="checkbox"/>   |                                |
|            |                |               |                                      | ADM or ADS write has priority. ADCR write is not performed, nor is the conversion end interrupt signal (INTAD) generated.  | p.204 <input type="checkbox"/>   |                                |
|            | Hard           |               | Noise countermeasures                | To maintain the 10-bit resolution, attention must be paid to noise input to the AVREF and ANI0 to ANI3 pins. Because the effect increases in proportion to the output impedance of the analog input source, it is recommended that a capacitor be connected externally, as shown in Figure 10-19, to reduce noise.   | p.205 <input type="checkbox"/>   |                                |
|            |                |               | ANI0/P20 to ANI3/P23                 | The analog input pins (ANI0 to ANI3) are also used as input port pins (P20 to P23).<br>When A/D conversion is performed with any of ANI0 to ANI3 selected, do not access port 2 while conversion is in progress; otherwise the conversion resolution may be degraded.  | p.205 <input type="checkbox"/>   |                                |
|            |                |               |                                      | If a digital pulse is applied to the pins adjacent to the pins currently being used for A/D conversion, the expected value of the A/D conversion may not be obtained due to coupling noise. Therefore, do not apply a pulse to the pins adjacent to the pin undergoing A/D conversion.   | p.205 <input type="checkbox"/>   |                                |
|            |                |               | Input impedance of ANI0 to ANI3 pins | In this A/D converter, the internal sampling capacitor is charged and sampling is performed for approx. one sixth of the conversion time.<br>Since only the leakage current flows other than during sampling and the current for charging the capacitor also flows during sampling, the input impedance fluctuates and has no meaning.<br>To perform sufficient sampling, however, it is recommended to make the output impedance of the analog input source 10 kΩ or lower, or attach a capacitor of around 100 pF to the ANI0 to ANI3 pins (see Figure 10-19). | p.205 <input type="checkbox"/>   |                                |
|            |                |               | AVREF pin input impedance            | A series resistor string of several tens of kΩ is connected between the AVREF and AVSS pins.<br>Therefore, if the output impedance of the reference voltage source is high, this will result in a series connection to the series resistor string between the AVREF and AVSS pins, resulting in a large reference voltage error.   | p.205 <input type="checkbox"/>   |                                |
|            |                |               | Soft                                 | Interrupt request flag (ADIF)  | The interrupt request flag (ADIF) is not cleared even if the analog input channel specification register (ADS) is changed.<br>Therefore, if an analog input pin is changed during A/D conversion, the A/D conversion result and ADIF for the pre-change analog input may be set just before the ADS rewrite. Caution is therefore required since, at this time, when ADIF is read immediately after the ADS rewrite, ADIF is set despite the fact A/D conversion for the post-change analog input has not finished.<br>When A/D conversion is stopped and then resumed, clear ADIF before the A/D conversion operation is resumed. | p.206 <input type="checkbox"/> |
|            |                |               |                                      | Conversion results just after A/D conversion start   | The first A/D conversion value immediately after A/D conversion starts may not fall within the rating range if the ADCS bit is set to 1 within 14 μs after the ADCE bit was set to 1, or if the ADCS bit is set to 1 with the ADCE bit = 0. Take measures such as polling the A/D conversion end interrupt request (INTAD) and removing the first conversion result.   | p.206 <input type="checkbox"/> |

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| Chapter 10                 | Soft                           | A/D converter          | A/D conversion result register (ADCR) read operation            | When a write operation is performed to the A/D converter mode register (ADM) and analog input channel specification register (ADS), the contents of ADCR may become undefined. Read the conversion result following conversion completion before writing to ADM and ADS. Using a timing other than the above may cause an incorrect conversion result to be read.  | p.206 <input type="checkbox"/>   |                                |
|                            | Hard                           |                        | A/D converter sampling time and A/D conversion start delay time | The A/D converter sampling time differs depending on the set value of the A/D converter mode register (ADM). A delay time exists until actual sampling is started after A/D converter operation is enabled.<br>When using a set in which the A/D conversion time must be strictly observed, care is required regarding the contents shown in Figure 10-21 and Table 10-3.  | p.207 <input type="checkbox"/>   |                                |
| Chapter 11                 | Soft                           | Serial interface UART0 | UART mode   | If clock supply to serial interface UART0 is not stopped (e.g., in the HALT mode), normal operation continues. If clock supply to serial interface UART0 is stopped (e.g., in the STOP mode), each register stops operating, and holds the value immediately before clock supply was stopped. The TxD0 pin also holds the value immediately before clock supply was stopped and outputs it. However, the operation is not guaranteed after clock supply is resumed. Therefore, reset the circuit so that POWER0 = 0, RXE0 = 0, and TXE0 = 0. | p.209 <input type="checkbox"/>   |                                |
|                            |                                |                        |   | Set POWER0 = 1 and then set TXE0 = 1 (transmission) or RXE0 = 1 (reception) to start communication.  | p.209 <input type="checkbox"/>   |                                |
|                            |                                |                        |   | TXE0 and RXE0 are synchronized by the base clock (f <sub>CLK0</sub> ) set by BRGC0. To enable transmission or reception again, set TXE0 or RXE0 to 1 at least two clocks of base clock after TXE0 or RXE0 has been cleared to 0. If TXE0 or RXE0 is set within two clocks of base clock, the transmission circuit or reception circuit may not be initialized.   | p.209 <input type="checkbox"/>   |                                |
|                            |                                |                        |   | TXS0: Transmit shift register 0  | Do not write the next transmit data to TXS0 before the transmission completion interrupt signal (INTST0) is generated.   | p.212 <input type="checkbox"/> |
|                            |                                |                        |   | ASIM0: Asynchronous serial interface operation mode register 0   | At startup, set POWER0 to 1 and then set TXE0 to 1. To stop the operation, clear TXE0 to 0, and then clear POWER0 to 0.  | p.214 <input type="checkbox"/> |
|                            |                                |                        |   |  | At startup, set POWER0 to 1 and then set RXE0 to 1. To stop the operation, clear RXE0 to 0, and then clear POWER0 to 0.  | p.214 <input type="checkbox"/> |
|                            |                                |                        |   |  | Set POWER0 to 1 and then set RXE0 to 1 while a high level is input to the RxD0 pin. If POWER0 is set to 1 and RXE0 is set to 1 while a low level is input, reception is started.   | p.214 <input type="checkbox"/> |
|                            |                                |                        |   |  | TXE0 and RXE0 are synchronized by the base clock (f <sub>CLK0</sub> ) set by BRGC0. To enable transmission or reception again, set TXE0 or RXE0 to 1 at least two clocks of base clock after TXE0 or RXE0 has been cleared to 0. If TXE0 or RXE0 is set within two clocks of base clock, the transmission circuit or reception circuit may not be initialized. | p.214 <input type="checkbox"/> |
|                            |                                |                        |   |  | Clear the TXE0 and RXE0 bits to 0 before rewriting the PS01, PS00, and CL0 bits.   | p.214 <input type="checkbox"/> |
|                            |                                |                        |   |  | Make sure that TXE0 = 0 when rewriting the SL0 bit. Reception is always performed with "number of stop bits = 1", and therefore, is not affected by the set value of the SL0 bit.  | p.214 <input type="checkbox"/> |
| Be sure to set bit 0 to 1. | p.214 <input type="checkbox"/> |                        |   |  |  |                                |

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|------------|----------------|--|--|--|--|--|--------------------------------|
| Chapter 11 | Soft           | Serial interface UART0   | ASIS0: Asynchronous serial interface reception error status register 0 | The operation of the PE0 bit differs depending on the set values of the PS01 and PS00 bits of asynchronous serial interface operation mode register 0 (ASIM0).   | p.215 <input type="checkbox"/>   |  |                                |
|            |                |  |  | Only the first bit of the receive data is checked as the stop bit, regardless of the number of stop bits.  | p.215 <input type="checkbox"/>   |  |                                |
|            |                |  |  | If an overrun error occurs, the next receive data is not written to receive buffer register 0 (RXB0) but discarded.  | p.215 <input type="checkbox"/>   |  |                                |
|            |                |  |  | If data is read from ASIS0, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.  | p.215 <input type="checkbox"/>   |  |                                |
|            | Hard           |  | BRGC0: Baud rate generator control register 0                          | When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the base clock is the Ring-OSC clock, the operation of serial interface UART0 is not guaranteed. | p.217 <input type="checkbox"/>   |  |                                |
|            |                |  |  | Make sure that bit 6 (TXE0) and bit 5 (RXE0) of the ASIM0 register = 0 when rewriting the MDL04 to MDL00 bits.   | p.217 <input type="checkbox"/>   |  |                                |
|            |                |  |  | The baud rate value is the output clock of the 5-bit counter divided by 2.   | p.217 <input type="checkbox"/>   |  |                                |
|            | Soft           |  |  | POWER0, TXE0, RXE0: Bits 7, 6, 5 of ASIM0  | Clear POWER0 to 0 after clearing TXE0 and RXE0 to 0 to set the operation stop mode.<br>To start the operation, set POWER0 to 1, and then set TXE0 and RXE0 to 1. | p.218 <input type="checkbox"/>   |                                |
|            | H              |  |  | UART mode  | Take relationship with the other party of communication when setting the port mode register and port register.   | p.219 <input type="checkbox"/>   |                                |
|            | Soft           |  |  | UART transmission  | After transmit data is written to TXS0, do not write the next transmit data before the transmission completion interrupt signal (INTST0) is generated.           | p.222 <input type="checkbox"/>   |                                |
|            |                |  |  |  | UART reception   | Be sure to read receive buffer register 0 (RXB0) even if a reception error occurs. Otherwise, an overrun error will occur when the next data is received, and the reception error status will persist. | p.223 <input type="checkbox"/> |
|            |                |  |  |  |  | Reception is always performed with the "number of stop bits = 1". The second stop bit is ignored.  | p.223 <input type="checkbox"/> |
|            |                |  |  |  |  | Be sure to read asynchronous serial interface reception error status register 0 (ASIS0) before reading RXB0.   | p.223 <input type="checkbox"/> |
|            |                |  |  |  | Error of baud rate   | Keep the baud rate error during transmission to within the permissible error range at the reception destination.   | p.226 <input type="checkbox"/> |
|            |                |  |  |  |  | Make sure that the baud rate error during reception satisfies the range shown in (4) Permissible baud rate range during reception.   | p.226 <input type="checkbox"/> |
|            |                |  |  |  | Permissible baud rate range during reception   | Make sure that the baud rate error during reception is within the permissible error range, by using the calculation expression shown below.  | p.228 <input type="checkbox"/> |
| Chapter 12 |                |  |  |  | Hard   | Serial interface UART6   | UART mode                      |
|            | Soft           | If clock supply to serial interface UART6 is not stopped (e.g., in the HALT mode), normal operation continues. If clock supply to serial interface UART6 is stopped (e.g., in the STOP mode), each register stops operating, and holds the value immediately before clock supply was stopped. The TxD6 pin also holds the value immediately before clock supply was stopped and outputs it. However, the operation is not guaranteed after clock supply is resumed. Therefore, reset the circuit so that POWER6 = 0, RXE6 = 0, and TXE6 = 0. | p.230 <input type="checkbox"/>   |  |  |  |                                |

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|------------|----------------|------------------------|--|---|--|--------------------------------|
| Chapter 12 | Soft           | Serial interface UART6 | UART mode  | If data is continuously transmitted, the communication timing from the stop bit to the next start bit is extended two operating clocks of the macro. However, this does not affect the result of communication because the reception side initializes the timing when it has detected a start bit. Do not use the continuous transmission function if the interface is incorporated in LIN. | p.230 <input type="checkbox"/>   |                                |
|            |                |                        | TXB6: Transmit buffer register 6                                       | Do not write data to TXB6 when bit 1 (TXBF6) of asynchronous serial interface transmission status register 6 (ASIF6) is 1.  | p.236 <input type="checkbox"/>   |                                |
|            |                |                        |  | Do not refresh (write the same value to) TXB6 by software during a communication operation (when bit 7 (POWER6) and bit 6 (TXE6) of asynchronous serial interface operation mode register 6 (ASIM6) are 1 or when bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 are 1).  | p.236 <input type="checkbox"/>   |                                |
|            |                |                        | ASIM6: Asynchronous serial interface operation mode register 6         | At startup, set POWER6 to 1 and then set TXE6 to 1. To stop the operation, clear TXE6 to 0 and then clear POWER6 to 0.  | p.238 <input type="checkbox"/>   |                                |
|            |                |                        |  | At startup, set POWER6 to 1 and then set RXE6 to 1. To stop the operation, clear RXE6 to 0 and then clear POWER6 to 0.  | p.238 <input type="checkbox"/>   |                                |
|            |                |                        |  | Set POWER6 to 1 and then set RXE6 to 1 while a high level is input to the RxD6 pin. If POWER6 is set to 1 and RXE6 is set to 1 while a low level is input, reception is started.  | p.238 <input type="checkbox"/>   |                                |
|            |                |                        |  | Clear the TXE6 and RXE6 bits to 0 before rewriting the PS61, PS60, and CL6 bits.  | p.238 <input type="checkbox"/>   |                                |
|            |                |                        |  | Fix the PS61 and PS60 bits to 0 when mounting the device on LIN.  | p.238 <input type="checkbox"/>   |                                |
|            |                |                        |  | Make sure that TXE6 = 0 when rewriting the SL6 bit. Reception is always performed with "the number of stop bits = 1", and therefore, is not affected by the set value of the SL6 bit.   | p.238 <input type="checkbox"/>   |                                |
|            |                |                        |  | Make sure that RXE6 = 0 when rewriting the ISRM6 bit.   | p.238 <input type="checkbox"/>   |                                |
|            |                |                        | ASIS6: Asynchronous serial interface reception error status register 6 | The operation of the PE6 bit differs depending on the set values of the PS61 and PS60 bits of asynchronous serial interface operation mode register 6 (ASIM6).  | p.239 <input type="checkbox"/>   |                                |
|            |                |                        |  | The first bit of the receive data is checked as the stop bit, regardless of the number of stop bits.  | p.239 <input type="checkbox"/>   |                                |
|            |                |                        |  | If an overrun error occurs, the next receive data is not written to receive buffer register 6 (RXB6) but discarded.   | p.239 <input type="checkbox"/>   |                                |
|            |                |                        |  | If data is read from ASIS6, a wait cycle is generated. For details, see CHAPTER 29 CAUTIONS FOR WAIT.   | p.239 <input type="checkbox"/>   |                                |
|            |                |                        | ASIF6: Asynchronous serial interface transmission status register 6    | To transmit data continuously, write the first transmit data (first byte) to the TXB6 register. Be sure to check that the TXBF6 flag is "0". If so, write the next transmit data (second byte) to the TXB6 register. If data is written to the TXB6 register while the TXBF6 flag is "1", the transmit data cannot be guaranteed.   | p.240 <input type="checkbox"/>   |                                |
|            |                |                        |  | To initialize the transmission unit upon completion of continuous transmission, be sure to check that the TXSF6 flag is "0" after generation of the transmission completion interrupt, and then execute initialization. If initialization is executed while the TXSF6 flag is "1", the transmit data cannot be guaranteed.  | p.240 <input type="checkbox"/>   |                                |
|            |                |                        | Hard   | CKSR6: Clock selection register 6   | When the Ring-OSC clock is selected as the clock to be supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the count clock. If the base clock is the Ring-OSC clock, the operation of serial interface UART6 is not guaranteed. | p.241 <input type="checkbox"/> |

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|            |  |                        |  |  |  |
| Chapter 12 | Soft   | Serial interface UART6 | CKSR6: Clock selection register 6  | Make sure POWER6 = 0 when rewriting TPS63 to TPS60.  | p.241 <input type="checkbox"/>   |
|            |  |                        | BRGC6: Baud rate generator control register 6  | Make sure that bit 6 (TXE6) and bit 5 (RXE6) of the ASIM6 register = 0 when rewriting the MDL67 to MDL60 bits.   | p.242 <input type="checkbox"/>   |
|            | The baud rate value is the output clock of the 8-bit counter divided by 2. |                        |  | p.242 <input type="checkbox"/>   |  |
|            | Soft   |                        | ASICL6: Asynchronous serial interface control register 6   | ASICL6 can be refreshed (the same value is written) by software during a communication operation (when bit 7 (POWER6) and bit 6 (TXE6) of ASIM6 = 1 or bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 = 1). Note, however, that communication is started by the refresh operation because bit 6 (SBRT6) of ASICL6 is cleared to 0 when communication is completed (when an interrupt signal is generated). | p.243 <input type="checkbox"/>   |
|            |  |                        |  | In the case of an SBF reception error, return the mode to the SBF reception mode again. The status of the SBRF6 flag is held (1).  | p.243 <input type="checkbox"/>   |
|            |  |                        |  | Before setting the SBRT6 bit, make sure that bit 7 (POWER6) and bit 5 (RXE6) of ASIM6 = 1.   | p.243 <input type="checkbox"/>   |
|            |  |                        |  | The read value of the SBRT6 bit is always 0. SBRT6 is automatically cleared to 0 after SBF reception has been correctly completed.   | p.243 <input type="checkbox"/>   |
|            |  |                        |  | Before rewriting the DIR6 and TXDLV6 bits, clear the TXE6 and RXE6 bits to 0.  | p.243 <input type="checkbox"/>   |
|            |  |                        |  | POWER6, TXE6, RXE6: Bits 7, 6, 5 of ASIM6  | Clear POWER6 to 0 after clearing TXE6 and RXE6 to 0 to set the operation stop mode.<br>To start the operation, set POWER6 to 1, and then set TXE6 and RXE6 to 1. |
|            | UART mode  |                        | Take relationship with the other party of communication when setting the port mode register and port register.   | p.246 <input type="checkbox"/>   |  |
|            | Parity types and operation   |                        | Fix the PS61 and PS60 bits to 0 when the device is incorporated in LIN.  | p.249 <input type="checkbox"/>   |  |
|            | Continuous transmission  |                        | The TXBF6 and TXSF6 flags of the ASIF6 register change from "10" to "11", and to "01" during continuous transmission. To check the status, therefore, do not use a combination of the TXBF6 and TXSF6 flags for judgment. Read only the TXBF6 flag when executing continuous transmission.   | p.251 <input type="checkbox"/>   |  |
|            |  |                        | When the device is incorporated in a LIN, the continuous transmission function cannot be used. Make sure that asynchronous serial interface transmission status register 6 (ASIF6) is 00H before writing transmit data to transmit buffer register 6 (TXB6).   | p.251 <input type="checkbox"/>   |  |
|            | TXBF6 during continuous transmission: Bit 1 of ASIF6                       |                        | To transmit data continuously, write the first transmit data (first byte) to the TXB6 register. Be sure to check that the TXBF6 flag is "0". If so, write the next transmit data (second byte) to the TXB6 register. If data is written to the TXB6 register while the TXBF6 flag is "1", the transmit data cannot be guaranteed.            | p.251 <input type="checkbox"/>   |  |
|            | TXSF6 during continuous transmission: Bit 1 of ASIF6                       |                        | To initialize the transmission unit upon completion of continuous transmission, be sure to check that the TXSF6 flag is "0" after generation of the transmission completion interrupt, and then execute initialization. If initialization is executed while the TXSF6 flag is "1", the transmit data cannot be guaranteed.                   | p.251 <input type="checkbox"/>   |  |
|            |  |                        | During continuous transmission, an overrun error may occur, which means that the next transmission was completed before execution of INTST6 interrupt servicing after transmission of one data frame. An overrun error can be detected by developing a program that can count the number of transmit data and by referencing the TXSF6 flag. | p.251 <input type="checkbox"/>   |  |

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| Chapter 12 | Soft  | Serial interface UART6 | Normal reception   | Be sure to read receive buffer register 6 (RXB6) even if a reception error occurs. Otherwise, an overrun error will occur when the next data is received, and the reception error status will persist.                           | p.255 <input type="checkbox"/> |
|            |   |                        |  | Reception is always performed with the "number of stop bits = 1". The second stop bit is ignored.  | p.255 <input type="checkbox"/> |
|            |   |                        |  | Be sure to read asynchronous serial interface reception error status register 6 (ASIS6) before reading RXB6.   | p.255 <input type="checkbox"/> |
|            |   |                        | Generation of serial clock   | Keep the baud rate error during transmission to within the permissible error range at the reception destination.   | p.262 <input type="checkbox"/> |
|            |   |                        |  | Make sure that the baud rate error during reception satisfies the range shown in (4) Permissible baud rate range during reception.   | p.262 <input type="checkbox"/> |
|            |   |                        | Permissible baud rate range during reception   | Make sure that the baud rate error during reception is within the permissible error range, by using the calculation expression shown below.  | p.264 <input type="checkbox"/> |
| Chapter 13 | Soft  | Serial interface CSI10 | SOTB10: Transmit buffer register 10  | Do not access SOTB10 when CSOT10 = 1 (during serial communication).  | p.268 <input type="checkbox"/> |
|            |   |                        | SIO10: Serial I/O shift register 10  | Do not access SIO10 when CSOT10 = 1 (during serial communication).   | p.268 <input type="checkbox"/> |
|            |   |                        | CSIM10: Serial operation mode register 10  | Be sure to clear bit 5 to 0.   | p.269 <input type="checkbox"/> |
|            | Hard  |                        | CSIC10: Serial clock selection register 10   | When the Ring-OSC clock is selected as the clock supplied to the CPU, the clock of the Ring-OSC oscillator is divided and supplied as the serial clock. At this time, the operation of serial interface CSI10 is not guaranteed. | p.271 <input type="checkbox"/> |
|            |   |                        |  | Do not write to CSIC10 while CSIE10 = 1 (operation enabled).   | p.271 <input type="checkbox"/> |
|            |   |                        |  | Clear CKP10 to 0 to use P10/ $\overline{\text{SCK10}}$ (/TxD0), P11/SI10 (/RxD0), and P12/SO10 as general-purpose port pins.   | p.271 <input type="checkbox"/> |
|            | The phase type of the data clock is type 1 after reset. |                        |  | p.271 <input type="checkbox"/>   |                                |
|            | 3-wire serial I/O mode                                  |                        | Take relationship with the other party of communication when setting the port mode register and port register. | p.273 <input type="checkbox"/>   |                                |
|            | Communication operation                                 |                        | Do not access the control register and data register when CSOT10 = 1 (during serial communication).            | p.275 <input type="checkbox"/>   |                                |
|            | SO10 output   |                        | If a value is written to TRMD10, DAP10, and DIR10, the output value of SO10 changes.                           | p.279 <input type="checkbox"/>   |                                |
| Chapter 14 | Soft  | Interrupt              | IF1L: Interrupt request flag register  | Be sure to clear bits 2 to 7 of IF1L to 0.   | p.284 <input type="checkbox"/> |
|            |   |                        | IF0L, IF0H, IF1L: Interrupt request flag registers   | When operating a timer, serial interface, or A/D converter after standby release, operate it once after clearing the interrupt request flag. An interrupt request flag may be set by noise.                                      | p.284 <input type="checkbox"/> |



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| Chapter 14 | Soft           | Interrupt        | IF0L, IF0H, IF1L: Interrupt request flag registers                | When manipulating a flag of the interrupt request flag register, use a 1-bit memory manipulation instruction (CLR1). When describing in C language, use a bit manipulation instruction such as "IF0L.0 = 0;" or "_asm("clr1 IF0L, 0");" because the compiled assembler must be a 1-bit memory manipulation instruction (CLR1).<br>If a program is described in C language using an 8-bit memory manipulation instruction such as "IF0L &= 0xfe;" and compiled, it becomes the assembler of three instructions.<br>mov a, IF0L<br>and a, #0FEH<br>mov IF0L, a<br>In this case, even if the request flag of another bit of the same interrupt request flag register (IF0L) is set to 1 at the timing between "mov a, IF0L" and "mov IF0L, a", the flag is cleared to 0 at "mov IF0L, a". Therefore, care must be exercised when using an 8-bit memory manipulation instruction in C language. | p.284 <input type="checkbox"/> |
|            |                |                  | MK1L: Interrupt mask flag register                                | Be sure to set bits 2 to 7 of MK1L to 1.  | p.285 <input type="checkbox"/> |
|            |                |                  | PR1L: Priority specification flag register                        | Be sure to set bits 2 to 7 of PR1L to 1.  | p.286 <input type="checkbox"/> |
|            |                |                  | EGP, EGN: External interrupt rising, falling edge enable register | Select the port mode by clearing EGPn and EGNn to 0 because an edge may be detected when the external interrupt function is switched to the port function.  | p.287 <input type="checkbox"/> |
|            |                |                  | Software interrupt request acknowledgment                         | Do not use the RETI instruction for restoring from the software interrupt.  | p.291 <input type="checkbox"/> |
|            |                |                  | Interrupt request hold  | The BRK instruction is not one of the above-listed interrupt request hold instructions. However, the software interrupt activated by executing the BRK instruction causes the IE flag to be cleared to 0. Therefore, even if a maskable interrupt request is generated during execution of the BRK instruction, the interrupt request is not acknowledged.  | p.295 <input type="checkbox"/> |
| Chapter 15 | Soft           | Standby function | –   | The RSTOP setting is valid only when "Can be stopped by software" is set for Ring-OSC by a mask option.   | p.296 <input type="checkbox"/> |
|            |                |                  | –   | When shifting to the STOP mode, be sure to stop the peripheral hardware operation before executing STOP instruction.  | p.297 <input type="checkbox"/> |
|            | Hard           |                  | STOP mode, HALT mode  | The following sequence is recommended for operating current reduction of the A/D converter when the standby function is used: First clear bit 7 (ADCS) of the A/D converter mode register (ADM) to 0 to stop the A/D conversion operation, and then execute the HALT or STOP instruction.   | p.297 <input type="checkbox"/> |
|            | Hard           |                  | STOP mode   | If the Ring-OSC oscillator is operating before the STOP mode is set, oscillation of the Ring-OSC clock cannot be stopped in the STOP mode. However, when the Ring-OSC clock is used as the CPU clock, the CPU operation is stopped for 17/f <sub>R</sub> (s) after STOP mode is released.   | p.297 <input type="checkbox"/> |

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| Chapter 15 | Soft           | Standby function | OSTC: Oscillation stabilization time counter status register | After the above time has elapsed, the bits are set to 1 in order from MOST11 and remain 1.  | p.299 <input type="checkbox"/> |
|            |                |                  |  | If the STOP mode is entered and then released while the Ring-OSC clock is being used as the CPU clock, set the oscillation stabilization time as follows. <ul style="list-style-type: none"> <li>Desired OSTC oscillation stabilization time ≤ Oscillation stabilization time set by OSTC</li> </ul> The X1 oscillation stabilization time counter counts only during the oscillation stabilization time set by OSTC. Therefore, note that only the statuses during the oscillation stabilization time set by OSTC are set to OSTC after STOP mode has been released. | p.299 <input type="checkbox"/> |
|            |                |                  |  | The wait time when STOP mode is released does not include the time after STOP mode release until clock oscillation starts ("a" below) regardless of whether STOP mode is released by $\overline{\text{RESET}}$ input or interrupt generation.   | p.299 <input type="checkbox"/> |
|            | Soft           |                  | OSTS: Oscillation stabilization time select register         | To set the STOP mode when the X1 input clock is used as the CPU clock, set OSTC before executing the STOP instruction.  | p.300 <input type="checkbox"/> |
|            |                |                  |  | Execute the OSTC setting after confirming that the oscillation stabilization time has elapsed as expected in the OSTC.  | p.300 <input type="checkbox"/> |
|            |                |                  |  | If the STOP mode is entered and then released while the Ring-OSC clock is being used as the CPU clock, set the oscillation stabilization time as follows. <ul style="list-style-type: none"> <li>Desired OSTC oscillation stabilization time ≤ Oscillation stabilization time set by OSTC</li> </ul> The X1 oscillation stabilization time counter counts only during the oscillation stabilization time set by OSTC. Therefore, note that only the statuses during the oscillation stabilization time set by OSTC are set to OSTC after STOP mode has been released. | p.300 <input type="checkbox"/> |
|            | Hard           |                  |  | The wait time when STOP mode is released does not include the time after STOP mode release until clock oscillation starts ("a" below) regardless of whether STOP mode is released by $\overline{\text{RESET}}$ input or interrupt generation.   | p.300 <input type="checkbox"/> |
|            |                |                  |  |   |                                |
|            | Soft           |                  | STOP mode setting and operating statuses                     | Because the interrupt request signal is used to clear the standby mode, if there is an interrupt source with the interrupt request flag set and the interrupt mask flag reset, the standby mode is immediately cleared if set. Thus, the STOP mode is reset to the HALT mode immediately after execution of the STOP instruction and the system returns to the operating mode as soon as the wait time set using the oscillation stabilization time select register (OSTC) has elapsed.   | p.304 <input type="checkbox"/> |
|            |                |                  |  |   |                                |
| Chapter 16 | Hard           | Reset function   | -  | For an external reset, input a low level for 10 $\mu\text{s}$ or more to the $\overline{\text{RESET}}$ pin.   | p.308 <input type="checkbox"/> |
|            |                |                  |  | During reset input, the X1 input clock and Ring-OSC clock stop oscillating.   | p.308 <input type="checkbox"/> |
|            |                |                  |  | When the STOP mode is released by a reset, the STOP mode contents are held during reset input. However, the port pins become high-impedance, except for P130, which is set to low-level output.   | p.308 <input type="checkbox"/> |
|            | Soft           |                  | LVI circuit internal reset                                   | An LVI circuit internal reset does not reset the LVI circuit.   | p.309 <input type="checkbox"/> |
|            |                |                  | Reset timing due to watchdog timer overflow                  | A watchdog timer internal reset resets the watchdog timer.  | p.310 <input type="checkbox"/> |
|            | Soft           |                  | RESF: Reset control flag register                            | Do not read data via a 1-bit memory manipulation instruction.   | p.314 <input type="checkbox"/> |

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| Chapter 17 | Soft           | Clock monitor                | CLM: Clock monitor mode register                     | Once bit 0 (CLME) is set to 1, it cannot be cleared to 0 except by $\overline{\text{RESET}}$ input or the internal reset signal.  | p.316 <input type="checkbox"/> |
|            |                |                              |  | If the reset signal is generated by the clock monitor, CLME is cleared to 0 and bit 1 (CLMRF) of the reset control flag register (RESF) is set to 1.  | p.316 <input type="checkbox"/> |
| Chapter 18 | Soft           | Power-on-clear circuit (POC) | Functions of power-on-clear circuit                  | If an internal reset signal is generated in the POC circuit, the reset control flag register (RESF) is cleared to 00H.  | p.322 <input type="checkbox"/> |
|            |                |                              | Cautions for power-on-clear circuit                  | In a system where the supply voltage ( $V_{DD}$ ) fluctuates for a certain period in the vicinity of the POC detection voltage ( $V_{POC}$ ), the system may be repeatedly reset and released from the reset status. In this case, the time from release of reset to the start of the operation of the microcontroller can be arbitrarily set by taking the following action.   | p.324 <input type="checkbox"/> |
| Chapter 19 | Soft           | Low-voltage detector (LVI)   | LVIM: Low-voltage detection register                 | To stop LVI, follow either of the procedures below.<br><ul style="list-style-type: none"> <li>• When using 8-bit memory manipulation instruction: Write 00H to LVIM.</li> <li>• When using 1-bit memory manipulation instruction: Clear LVION to 0 first and then clear LVIE to 0.</li> </ul>   | p.328 <input type="checkbox"/> |
|            |                |                              | LVIS: Low-voltage detection level selection register | Be sure to clear bits 3 to 7 to 0.  | p.329 <input type="checkbox"/> |
|            |                |                              | When used as reset                                   | <1> must always be executed. When LVIMK = 0, an interrupt may occur immediately after the processing in <5>.  | p.330 <input type="checkbox"/> |
|            |                |                              |  | If "POC used" is selected by a mask option, procedures <3> and <4> are not required.  | p.330 <input type="checkbox"/> |
|            |                |                              |  | If supply voltage ( $V_{DD}$ ) > detection voltage ( $V_{LVI}$ ) when LVIM is set to 1, an internal reset signal is not generated.  | p.330 <input type="checkbox"/> |
|            |                |                              | When used as interrupt                               | If "POC used" is selected by a mask option, procedures <3> and <4> are not required.  | p.332 <input type="checkbox"/> |
|            |                |                              | Cautions for low-voltage detector                    | In a system where the supply voltage ( $V_{DD}$ ) fluctuates for a certain period in the vicinity of the LVI detection voltage ( $V_{LVI}$ ), the operation is as follows depending on how the low-voltage detector is used.<br>(1) When used as reset<br>The system may be repeatedly reset and released from the reset status. In this case, the time from release of reset to the start of the operation of the microcontroller can be arbitrarily set by taking action (a) below.<br>(2) When used as interrupt<br>Interrupt requests may be frequently generated. Take action (b) below. | p.334 <input type="checkbox"/> |
| Chapter 21 | Hard           | $\mu$ PD78F0103              | –  | There are differences in noise immunity and noise radiation between the flash memory and mask ROM versions. When pre-producing an application set with the flash memory version and then mass-producing it with the mask ROM version, be sure to conduct sufficient evaluations for the commercial samples (not engineering samples) of the mask ROM versions.  | p.338 <input type="checkbox"/> |
|            |                |                              | IMS: Internal memory size switching register         | The initial value of IMS is "setting prohibited (CFH)". Be sure to set the value of the relevant mask ROM version at initialization.  | p.339 <input type="checkbox"/> |
|            |                |                              |  | When using a mask ROM version, be sure to set IMS to the value indicated in Table 21-2.   | p.339 <input type="checkbox"/> |
|            | Soft           |                              | UART0, UART6   | When UART0 or UART6 is selected, the receive clock is calculated based on the reset command sent from the dedicated flash programmer after the $V_{PP}$ pulse has been received.  | p.355 <input type="checkbox"/> |

| Chapter                 | Classification | Function                         | Details of Function   | Cautions   | Page   |
|-------------------------|----------------|----------------------------------|---|--|--|
| Chapters 23, 24, 25, 26 | Hard           | Electrical specifications        | Absolute maximum ratings  | Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.  | pp.371, <input type="checkbox"/><br>389, 405, 420  |
|                         |                |                                  | X1 oscillator   | When using the X1 oscillator, wire as follows in the area enclosed by the broken lines in the above figures to avoid an adverse effect from wiring capacitance. <ul style="list-style-type: none"> <li>• Keep the wiring length as short as possible.</li> <li>• Do not cross the wiring with the other signal lines.</li> <li>• Do not route the wiring near a signal line through which a high fluctuating current flows.</li> <li>• Always make the ground point of the oscillator capacitor the same potential as V<sub>SS</sub>.</li> <li>• Do not ground the capacitor to a ground pattern through which a high current flows.</li> <li>• Do not fetch signals from the oscillator.</li> </ul> | pp.372, <input type="checkbox"/><br>390, 407, 421  |
|                         |                |                                  |   | Since the CPU is started by the Ring-OSC after reset is released, check the oscillation stabilization time of the X1 input clock using the oscillation stabilization time counter status register (OSTC). Determine the oscillation stabilization time of the OSTC register and oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.  | pp.372, <input type="checkbox"/><br>390, 407, 421  |
|                         |                |                                  |   | Recommended oscillator constants   | For the resonator selection of the $\mu$ PD780101(A), 780102(A), and 780103(A) and oscillator constants, users are required to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation. |
|                         |                |                                  | The oscillator constants shown above are reference values based on evaluation in a specific environment by the resonator manufacturer. If it is necessary to optimize the oscillator characteristics in the actual application, apply to the resonator manufacturer for evaluation on the implementation circuit. The oscillation voltage and oscillation frequency only indicate the oscillator characteristic. Use the 78K0/KB1 so that the internal operation conditions are within the specifications of the DC and AC characteristics. |  | pp.373, <input type="checkbox"/><br>374, 375, 391, 392, 393  |
| Chapter 28              | Hard           | Recommended soldering conditions | –   | Do not use different soldering methods together (except for partial heating).  | pp.431, <input type="checkbox"/><br>432  |

## APPENDIX E REVISION HISTORY

### ★ E.1 Major Revisions in This Edition

(1/2)

| Page       | Description  |
|------------|--|
| Throughout | Addition of description for expanded-specification products of standard products and (A) grade products  |
| p. 9       | Addition of <b>Differences Between 78K0/KB1 and 78K0/KB1+ to INTRODUCTION</b>  |
| p. 17      | Addition of <b>1.1 Expanded-Specification Products and Conventional Products (Standard Products, (A) Grade Products Only)</b>  |
| p. 23      | Modification of <b>1.6 Kx1 Series Lineup</b>   |
| p. 91      | Addition of <b>Note to Figure 5-2 Format of Processor Clock Control Register (PCC)</b>   |
| p. 92      | Addition of minimum instruction execution time with X1 input clock (at 12 MHz operation) and <b>Notes 2 and 3 to Table 5-2 Relationship Between CPU Clock and Minimum Instruction Execution Time</b> |
| p. 95      | Addition of oscillation stabilization time status ( $f_{XP} = 12$ MHz) to <b>Figure 5-6 Format of Oscillation Stabilization Time Counter Status Register (OSTC)</b>                                  |
| p. 96      | Addition of oscillation stabilization time ( $f_{XP} = 12$ MHz) and <b>Cautions 1 and 2 to Figure 5-7 Format of Oscillation Stabilization Time Select Register (OSTS)</b>                            |
| p. 105     | Modification of <b>Table 5-5 Maximum Time Required to Switch Between Ring-OSC Clock and X1 Input Clock</b> and addition of <b>Note</b>   |
| p. 106     | Addition of <b>Caution to Table 5-6 Maximum Time Required for CPU Clock Switchover</b>   |
| p. 116     | Addition of description of <When used as capture register> at interrupt request generation to <b>Figure 6-5 Format of 16-Bit Timer Mode Control Register 00 (TMC00)</b>                              |
| p. 118     | Addition of <b>Caution 7 to Figure 6-7 Format of 16-Bit Timer Output Control Register 00 (TOC00)</b>   |
| p. 119     | Addition of <b>Note 1 to Figure 6-8 Format of Prescaler Mode Register 00 (PRM00)</b>   |
| p. 142     | Modification of TMC00 set value in <b>Figure 6-32 Timing of One-Shot Pulse Output Operation with Software Trigger</b>  |
| p. 151     | Addition of <b>Note to Figure 7-4 Format of Timer Clock Selection Register 50 (TCL50)</b>  |
| p. 153     | Modification of <b>Caution 2 in Figure 7-5 Format of 8-Bit Timer Mode Control Register 50 (TMC50)</b>  |
| p. 166     | Addition of <b>Note 1</b> and modification of <b>Note 2 in Figure 8-5 Format of 8-Bit Timer H Mode Register 0 (TMHMD0)</b>   |
| p. 168     | Addition of <b>Note to Figure 8-6 Format of 8-Bit Timer H Mode Register 1 (TMHMD1)</b>   |
| p. 182     | Modification of <b>Caution 3</b> and addition of <b>Caution 5 in Figure 9-2 Format of Watchdog Timer Mode Register (WDTM)</b>  |
| p. 182     | Modification of <b>Cautions 1 and 2 in Figure 9-3 Format of Watchdog Timer Enable Register (WDTE)</b>  |
| p. 183     | Addition of <b>Table 9-4 Relationship Between Watchdog Timer Operation and Internal Reset Signal Generated by Watchdog Timer</b>   |
| p. 216     | Addition of <b>Note 1</b> and modification of <b>Note 2 in Figure 11-4 Format of Baud Rate Generator Control Register 0 (BRGC0)</b>  |
| p. 241     | Addition of <b>Note 1</b> and modification of <b>Note 2 in Figure 12-8 Format of Clock Selection Register 6 (CKSR6)</b>  |
| p. 270     | Addition of <b>Note to Figure 13-3 Format of Serial Clock Selection Register 10 (CSIC10)</b>   |
| p. 284     | Modification of <b>Caution 3 in Figure 14-2 Format of Interrupt Request Flag Register (IF0L, IF0H, IF1L)</b>   |
| p. 298     | Addition of oscillation stabilization time status ( $f_{XP} = 12$ MHz) to <b>Figure 15-1 Format of Oscillation Stabilization Time Counter Status Register (OSTC)</b>                                 |
| p. 300     | Addition of oscillation stabilization time ( $f_{XP} = 12$ MHz) and <b>Cautions 1 and 2 to Figure 15-2 Format of Oscillation Stabilization Time Select Register (OSTS)</b>                           |

| Page                   | Description   |
|------------------------|---|
| p. 310                 | Modification of <b>Figure 16-2 Timing of Reset by <math>\overline{\text{RESET}}</math> Input</b>  |
| p. 310                 | Modification of <b>Figure 16-3 Timing of Reset Due to Watchdog Timer Overflow</b>   |
| p. 311                 | Modification of <b>Figure 16-4 Timing of Reset in STOP Mode by <math>\overline{\text{RESET}}</math> Input</b>   |
| p. 326                 | Modification of <b>Note in 19.1 Functions of Low-Voltage Detector</b>   |
| p. 329                 | Addition of <b>Notes 3 and 4 to Figure 19-3 Format of Low-Voltage Detection Level Selection Register (LVIS)</b>   |
| p. 370                 | Addition of <b>CHAPTER 23 ELECTRICAL SPECIFICATIONS (STANDARD PRODUCTS, (A) GRADE PRODUCTS) (EXPANDED-SPECIFICATION PRODUCTS)</b>   |
| p. 388<br>p. 390       | <b>CHAPTER 24 ELECTRICAL SPECIFICATIONS (STANDARD PRODUCTS, (A) GRADE PRODUCTS) (CONVENTIONAL PRODUCTS)</b> <ul style="list-style-type: none"> <li>• Modification of description of target products</li> <li>• Addition of <b>Caution 2 to X1 Oscillator Characteristics</b></li> </ul>                       |
| p. 407<br>pp. 410, 411 | <b>CHAPTER 25 ELECTRICAL SPECIFICATIONS ((A1) GRADE PRODUCTS)</b> <ul style="list-style-type: none"> <li>• Addition of <b>Caution 2 to X1 Oscillator Characteristics</b></li> <li>• Addition of value of supply current (<math>I_{DD4}</math>) in Ring-OSC, HALT mode to <b>DC Characteristics</b></li> </ul> |
| p. 421<br>p. 423       | <b>CHAPTER 26 ELECTRICAL SPECIFICATIONS ((A2) GRADE PRODUCTS)</b> <ul style="list-style-type: none"> <li>• Addition of <b>Caution 2 to X1 Oscillator Characteristics</b></li> <li>• Addition of value of supply current (<math>I_{DD4}</math>) in Ring-OSC, HALT mode to <b>DC Characteristics</b></li> </ul> |
| p. 439                 | Addition of <b>(3) When using the in-circuit emulator QB-78K0KX1H to Figure A-1 Development Tool Configuration</b>  |
| p. 444                 | Addition of <b>A.5.3 When using in-circuit emulator QB-78K0KX1H</b>   |
| p. 448                 | Addition of <b>B.2 When Using QB-78K0KX1H</b>   |
| p. 455                 | Addition of <b>APPENDIX D LIST OF CAUTIONS</b>  |

## E.2 Revision History of Previous Editions

A history of the revisions up to this edition is shown below. “Applied to:” indicates the chapters to which the revision was applied.

(1/9)

| Edition  | Description  | Applied to:                      |
|--|--|----------------------------------|
| 2nd  | X1 input clock oscillation stabilization time<br>$2^{12}/f_x, 2^{14}/f_x, 2^{15}/f_x, 2^{16}/f_x, 2^{17}/f_x \rightarrow 2^{11}/f_x, 2^{13}/f_x, 2^{14}/f_x, 2^{15}/f_x, 2^{16}/f_x$   | Throughout                       |
|  | Modification of <b>Figure 4-5 Block Diagram of P10</b>   | CHAPTER 4                        |
|  | Modification of <b>Table 4-3 Settings of Port Mode Register and Output Latch When Alternate-Function Is Used</b>   | PORT FUNCTIONS                   |
|  | Modification of <b>Figure 5-6 Format of Oscillation Stabilization Time Counter Status Register (OSTC)</b>  | CHAPTER 5                        |
|  | Modification of <b>Figure 5-7 Format of Oscillation Stabilization Time Select Register (OSTS)</b>  | CLOCK GENERATOR                  |
|  | Addition of <b>5.7 Clock Selection Flowchart and Register Settings</b>   |                                  |
|  | Addition of <b>Remark to 12.1 Functions of Serial Interface UART6</b>  | CHAPTER 12                       |
|  | Addition of Reset to <b>Table 14-1 Interrupt Source List</b>   | SERIAL INTERFACE UART6           |
|  | Modification of <b>Figure 15-2 Format of Oscillation Stabilization Time Counter Status Register (OSTC)</b>   | CHAPTER 14                       |
|  | Modification of <b>Figure 15-3 Format of Oscillation Stabilization Time Select Register (OSTS)</b>   | INTERRUPT FUNCTIONS              |
| 2nd<br>(corrected edition)   | Modification of reset value of the following register in <b>Table 3-5 Special Function Register List</b><br>• Serial I/O shift register 10 (SIO10)   | CHAPTER 15                       |
|  | Modification of manipulatable bit unit of the following registers in <b>Table 3-5 Special Function Register List</b><br>• Oscillation stabilization time counter status register (OSTC)<br>• Interrupt request flag register 1L (IF1L)<br>• Interrupt mask flag register 1L (MK1L)<br>• Priority specification flag register 1L (PR1L) | CHAPTER 15                       |
|  | Modification of manipulatable bit unit in <b>5.3 (5) Oscillation stabilization time counter status register (OSTC)</b>   | CHAPTER 15                       |
|  | Modification of <b>Figure 5-11 Status Transition Diagram</b>   | CHAPTER 5                        |
|  | Modification of <b>Table 5-3 Relationship Between Operation Clocks in Each Operation Status</b>  | CLOCK GENERATOR                  |
|  | Modification of <b>Table 5-4 Oscillation Control Flags and Clock Oscillation Status</b>  |                                  |
|  | Modification of <b>Table 5-6 Clock and Register Settings</b>   |                                  |
|  | Modification of reset value in <b>6.2 (2) 16-bit timer capture/compare register 000 (CR000)</b> and <b>(3) 16-bit timer capture/compare register 010 (CR010)</b>   | CHAPTER 6                        |
|  | Modification of manipulatable bit unit in <b>6.3 (4) Prescaler mode register 00 (PRM00)</b>  | 16-BIT<br>TIMER/EVENT COUNTER 00 |
|  | Modification of <b>Caution in 9.4.2 Watchdog timer operation when “Ring-OSC can be stopped by software” is selected by mask option</b>   | CHAPTER 9                        |
| Modification of <b>9.4.3 Watchdog timer operation in STOP mode (when “Ring-OSC can be stopped by software” is selected by mask option)</b> | WATCHDOG<br>TIMER  |                                  |

| Edition                    | Description  | Applied to:  |
|----------------------------|--|--|
| 2nd<br>(corrected edition) | Addition of <b>9.4.4 Watchdog timer operation in HALT mode (when “Ring-OSC can be stopped by software” is selected by mask option)</b>   | CHAPTER 9 WATCHDOG TIMER                             |
|                            | Addition of <b>(11) A/D converter sampling time and A/D conversion start delay time in 10.6 Cautions for A/D Converter</b>   | CHAPTER 10 A/D CONVERTER                             |
|                            | Modification of reset value in <b>13.2 (2) Serial I/O shift register 10 (SIO10)</b>  | CHAPTER 13 SERIAL INTERFACE CSI10                    |
|                            | Modification of manipulatable bit unit in <b>15.1.2 (1) Oscillation stabilization time counter status register (OSTC)</b>  | CHAPTER 15 STANDBY FUNCTION                          |
|                            | Modification of A/D converter item in <b>Table 15-2 Operating Statuses in HALT mode</b>  |  |
|                            | Addition of <b>18.4 Cautions for Power-on-Clear Circuit</b>  | CHAPTER 18 POWER-ON-CLEAR CIRCUIT                    |
|                            | Modification of <b>Figure 19-3 Format of Low-Voltage Detection Level Selection Register (LVIS)</b>   | CHAPTER 19 LOW-VOLTAGE DETECTOR                      |
|                            | Addition of <b>19.5 Cautions for Low-Voltage Detector</b>  |  |
|                            | Modification of the following contents in <b>CHAPTER 23 ELECTRICAL SPECIFICATIONS (TARGET VALUES)</b> <ul style="list-style-type: none"> <li>• <b>Absolute Maximum Ratings</b></li> <li>• <b>X1 Oscillator Characteristics</b></li> <li>• <b>DC Characteristics</b></li> <li>• <b>A/D Converter Characteristics</b></li> <li>• <b>POC Circuit Characteristics</b></li> <li>• <b>LVI Circuit Characteristics</b></li> <li>• <b>Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics</b> (deletion of data retention supply current)</li> <li>• Deletion of <b>Ring-OSC Characteristics</b></li> <li>• <b>Flash Memory Programming Characteristics</b></li> </ul> | CHAPTER 23 ELECTRICAL SPECIFICATIONS (TARGET VALUES) |
|                            | Modification from <b>CHAPTER 25 RETRY</b> to <b>CHAPTER 25 CAUTIONS FOR WAIT</b>   | CHAPTER 25 CAUTIONS FOR WAIT                         |
| 3rd                        | Deletion of following products. <ul style="list-style-type: none"> <li>• <math>\mu</math>PD780101(A2), 780102(A2), 780103(A2)</li> <li>• <math>\mu</math>PD78F0103M3MC(A1)-5A4, 78F0103M4MC(A1)-5A4</li> </ul>   | Throughout   |
|                            | Modification of supply voltage range of (A1) product and ambient operating temperature of flash memory version of (A1) product   |  |
|                            | Modification of reset value of A/D conversion result register (ADCR) (0000H → undefined)   |  |
|                            | Update of <b>1.6 78K0/K1 Series Lineup</b>   |  |
|                            | Modification of <b>Figure 3-12 Data to Be Saved to Stack Memory</b>  | CHAPTER 3 CPU ARCHITECTURE                           |
|                            | Modification of <b>Figure 3-13 Data to Be Restored from Stack Memory</b>   |  |
|                            | Modification of [Description example] in <b>3.4.4 Short direct addressing</b>  |  |
|                            | Addition of [Illustration] to <b>3.4.7 Based addressing, 3.4.8 Based indexed addressing, and 3.4.9 Stack addressing</b>  | CHAPTER 4 PORT FUNCTIONS                             |
|                            | Modification of <b>Figure 4-10 Block Diagram of P20 to P23</b>   |  |
|                            | Addition of <b>Remark</b> to <b>Figure 4-13 Block Diagram of P130</b>  |  |
|                            | Addition of condition (set value of MCM0) to <b>Figure 5-2 Format of Processor Clock Control Register (PCC)</b>  | CHAPTER 5 CLOCK GENERATOR                            |
|                            | Partial modification of description in <b>5.5 Clock Generator Operation</b>  |  |
|                            | Addition of <b>5.7 Changing System Clock and CPU Clock Settings</b>  |  |



| Edition   | Description  | Applied to:                                |
|---|--|--|
| 3rd   | Modification of <b>Figure 6-1 Block Diagram of 16-Bit Timer/Event Counter 00</b>   | CHAPTER 6 16-BIT<br>TIMER/EVENT COUNTER 00 |
|   | Modification of <b>Cautions 1 and 2 in 6.2 (2) 16-bit timer capture/compare register 000 (CR000)</b> , and modification of <b>Caution 1 in (3) 16-bit timer capture/compare register 010 (CR010)</b>   |  |
|   | Addition of <b>Caution 1 to Figure 6-5 Format of Prescaler Mode Register 00 (PRM00)</b>  |  |
|   | Addition of <b>Note to Figure 6-8 Interval Timer Configuration Diagram</b>   |  |
|   | Modification of <b>Caution 1 of Figure 6-10 Control Register Settings for PPG Output Operation</b>   |  |
|   | Addition of <b>Figure 6-11 Configuration of PPG Output and Figure 6-12 PPG Output Operation Timing</b>   |  |
|   | Addition of <b>Note to Figure 6-15 Timing of Pulse Width Measurement Operation with Free-Running Counter and One Capture Register (with Both Edges Specified)</b> , <b>Figure 6-18 Timing of Pulse Width Measurement Operation with Free-Running Counter (with Both Edges Specified)</b> , and <b>Figure 6-20 Timing of Pulse Width Measurement Operation with Free-Running Counter and Two Capture Registers (with Rising Edge Specified)</b> |  |
|   | Modification of <b>Figure 6-24 Configuration Diagram of External Event Counter</b>   |  |
|   | Addition of <b>6.4.6 One-shot pulse output operation</b>   |  |
|   | Modification of <b>Figure 6-34 Capture Register Data Retention Timing</b>  |  |
|   | Addition of description <2> to <b>6.5 (4) Capture register data retention timing</b>   |  |
|   | Deletion of <b>6.5 (7) Conflicting operations</b> from old edition   |  |
|   | 3rd  |  |
| Addition of <b>Caution 1 to Figure 7-2 Format of Timer Clock Selection Register 50 (TCL50)</b>  |  |  |
| Deletion of <b>Caution 1</b> of old edition and modification of <b>Caution 2 of Figure 7-3 Format of 8-Bit Timer Mode Control Register 50 (TMC50)</b> |  |  |
| Addition of <b>Remark to Figure 7-8 PWM Output Operation Timing</b>   |  |  |
| 3rd   | Addition of square-wave output to <b>8.1 Functions of 8-Bit Timers H0 and H1</b> , and modification of PWM pulse generator mode to PWM output  | CHAPTER 8 8-BIT TIMERS<br>H0 AND H1        |
|   | Modification of <b>Figure 8-1 Block Diagram of 8-Bit Timer H0</b>  |  |
|   | Modification of <b>Figure 8-2 Block Diagram of 8-Bit Timer H1</b>  |  |
|   | Addition of <b>Note and Caution 1 to Figure 8-3 Format of 8-Bit Timer H Mode Register 0 (TMHMD0)</b>   |  |
|   | Addition of <b>Figure 8-5 Format of Port Mode Register 1 (PM1)</b>   |  |
|   | Modification of <b>8.4.1 Operation as interval timer</b> of old edition to <b>8.4.1 Operation as interval timer/square-wave output</b>   |  |
|   | Modification of <b>(a) Basic operation of Figure 8-7 Timing of Interval Timer/Square-Wave Output Operation</b>   |  |
|   | Modification of description of duty ratio in <b>8.4.2 (1) Usage</b>  |  |
|   | 3rd  |  |
| Modification of <b>Note 1 of Figure 10-4 Format of A/D Converter Mode Register (ADM)</b>  |  |  |

| Edition   | Description  | Applied to:  |  |                                   |
|---|--|--|--|-----------------------------------|
| 3rd   | Modification of <b>Figure 10-6 Format of Analog Input Channel Specification Register (ADS)</b>   | CHAPTER 10 A/D CONVERTER   |  |                                   |
|   | Addition of description to <b>10.3 (3) Power-fail comparison mode register (PFM)</b> , and modification of <b>Figure 10-7 Format of Power-Fail Comparison Mode Register (PFM)</b>  |  |  |                                   |
|   | Modification of expressions in <b>10.4.2 Input voltage and conversion results</b>  |  |  |                                   |
|   | Partial modification of description in <b>10.6 (5) ANI0/P20 to ANI3/P23</b>  |  |  |                                   |
|   | Addition of description to <b>10.6 (9) Conversion results just after A/D conversion start</b>  |  |  |                                   |
| 3rd   | Modification of <b>Caution 3</b> of <b>11.1 Functions of Serial Interface UART0</b>  | CHAPTER 11 SERIAL INTERFACE UART0<br>( $\mu$ PD780102, 780103, 78F0103 ONLY) |  |                                   |
|   | Modification of <b>Figure 11-1 Block Diagram of Serial Interface UART0</b>   |  |  |                                   |
|   | Modification of <b>Caution 3</b> in <b>Figure 11-2 Format of Asynchronous Serial Interface Operation Mode Register 0 (ASIM0)</b> and <b>11.4.2 (1) (a) Asynchronous serial interface operation mode register 0 (ASIM0)</b> |  |  |                                   |
|   | Addition of <b>Note</b> and <b>Caution 1</b> to <b>Figure 11-4 Format of Baud Rate Generator Control Register 0 (BRGC0)</b> and <b>11.4.3 (2) (a) Baud rate generator control register 0 (BRGC0)</b>                       |  |  |                                   |
|   | Addition of <b>Figure 11-5 Format of Port Mode Register 1 (PM1)</b> and <b>11.4.2 (1) (c) Port mode register 1 (PM1)</b>   |  |  |                                   |
|   | Modification of <b>Figure 11-11 Configuration of Baud Rate Generator</b>   |  |  |                                   |
|   | Modification of term in <b>11.4.3 (4) Permissible baud rate range during reception</b> and <b>12.4.3 (4) Permissible baud rate range during reception</b> as follows<br>Transfer rate → Data frame length                  |  |  |                                   |
|   | Modification of <b>Remark 1</b> in <b>Table 11-4 Maximum/Minimum Permissible Baud Rate Error</b>   |  |  |                                   |
|   | 3rd  |  | Addition of <b>Figure 12-4 Format of Input Switch Control Register (ISC)</b> | CHAPTER 12 SERIAL INTERFACE UART6 |
|   |  |  | Modification of <b>Figure 12-5 Block Diagram of Serial Interface UART6</b>   |                                   |
| Addition of <b>Note</b> and <b>Caution 1</b> to <b>Figure 12-9 Format of Clock Selection Register 6 (CKSR6)</b> and <b>12.4.3 (2) (a) Clock selection register 6 (CKSR6)</b>                |  |  |  |                                   |
| Modification of <b>Figure 12-11 Format of Asynchronous Serial Interface Control Register 6 (ASICL6)</b> and <b>12.4.2 (1) (d) Asynchronous serial interface control register 6 (ASICL6)</b> |  |  |  |                                   |
| Addition of <b>Figure 12-12 Format of Port Mode Register 1 (PM1)</b> and <b>12.4.2 (1) (e) Port mode register 1 (PM1)</b>   |  |  |  |                                   |
| Modification of description of <b>12.4.2 (2) (h) SBF transmission</b> and addition of <b>Figure 12-22 Example of Setting Procedure of SBF Transmission (Flowchart)</b>                      |  |  |  |                                   |
| Modification of <b>Figure 12-25 Configuration of Baud Rate Generator</b>  |  |  |  |                                   |
| 3rd   | Modification of <b>Figure 13-1 Block Diagram of Serial Interface CSI10</b>   | CHAPTER 13 SERIAL INTERFACE CSI10  |  |                                   |
|   | Addition of <b>Figure 13-4 Format of Port Mode Register 1 (PM1)</b> and <b>13.4.2 (1) (c) Port mode register 1 (PM1)</b>   |  |  |                                   |
| 3rd   | Modification of <b>(C) Software interrupt</b> in <b>Figure 14-1 Basic Configuration of Interrupt Function</b>  | CHAPTER 14 INTERRUPT FUNCTIONS   |  |                                   |
|   | Addition of <b>Note 4</b> to <b>Table 14-2 Flag Corresponding to Interrupt Request Sources</b>   |  |  |                                   |
|   | Deletion of <b>Caution 1</b> from <b>Figure 14-3 Format of Interrupt Mask Flag Register (MK0L, MK0H, MK1L)</b> of old edition  |  |  |                                   |
|   | Addition of <b>Table 14-3 Ports Corresponding to EGPn and EGNn</b>   |  |  |                                   |

| Edition   | Description   | Applied to:                                 |
|---|---|---|
| 3rd   | Addition of items of software interrupt requests to <b>Table 14-5 Interrupt Request Enabled for Multiple Interrupt Servicing During Interrupt Servicing</b>   | CHAPTER 14 INTERRUPT FUNCTIONS              |
|   | Modification of <b>Table 15-1 Relationship Between HALT and STOP Modes and Clock</b>  | CHAPTER 15 STANDBY FUNCTION                 |
|   | Modification of following items in <b>Table 15-2 Operating Statuses in HALT Mode</b> and <b>Table 15-4 Operating Statuses in STOP Mode</b> <ul style="list-style-type: none"> <li>• System clock</li> <li>• 16-bit timer/event counter 00 (<b>Table 15-2</b> only)</li> <li>• 8-bit timer H0</li> <li>• Watchdog timer</li> <li>• Serial interface UART0</li> <li>• Serial interface UART6</li> </ul> |   |
|   | Modification of <b>Figure 16-1 Block Diagram of Reset Function</b>  | CHAPTER 16 RESET FUNCTION                   |
|   | Addition of description to (4) and (5) of <b>Figure 17-3 Timing of Clock Monitor</b>  | CHAPTER 17 CLOCK MONITOR                    |
|   | Addition of <b>Note</b> to description of <b>18.1 Functions of Power-on-Clear Circuit</b>   | CHAPTER 18 POWER-ON-CLEAR CIRCUIT           |
|   | Modification of <b>Figure 18-1 Block Diagram of Power-on-Clear Circuit</b>  |   |
|   | Addition of <b>Note</b> to description of <b>19.1 Functions of Low-Voltage Detector</b>   | CHAPTER 19 LOW-VOLTAGE DETECTOR             |
|   | Modification of <b>Figure 19-1 Block Diagram of Low-Voltage Detector</b>  |   |
|   | Addition of <b>Note 2</b> to <b>Figure 19-3 Format of Low-Voltage Detection Level Selection Register (LVIS)</b>   |   |
|   | Modification of <b>Figure 19-7 Example of Software Processing of LVI Interrupt</b>  |   |
|   | Addition of <b>Note</b> to description of <b>CHAPTER 20 MASK OPTIONS</b>  | CHAPTER 20 MASK OPTIONS                     |
|   | Revision of <b>CHAPTER 21 <math>\mu</math>PD78F0103</b> (no change to <b>21.1 Internal Memory Size Switching Register</b> )   | CHAPTER 21 $\mu$ PD78F0103                  |
|   | Revision of <b>CHAPTER 23 ELECTRICAL SPECIFICATIONS</b>   | CHAPTER 23 ELECTRICAL SPECIFICATIONS        |
|   | Addition of <b>CHAPTER 25 RECOMMENDED SOLDERING CONDITIONS</b>  | CHAPTER 25 RECOMMENDED SOLDERING CONDITIONS |
|   | Addition of <b>A.3 Control Software</b>   | APPENDIX A DEVELOPMENT TOOLS                |
|   | Deletion of 'NP-36GS' and 'NGS-30' from <b>A.5 Debugging Tools (Hardware)</b> of old edition, and addition of in-circuit emulator 'IE-78K0K1-ET'  |   |
| Modification of ordering name of RX78K0 in <b>A.7 Embedded Software</b> |   |   |
| Addition of <b>APPENDIX B NOTES ON TARGET SYSTEM DESIGN</b>             | APPENDIX B NOTES ON TARGET SYSTEM DESIGN  |   |
| 4th   | Addition of products<br>$\mu$ PD780101(A2), 780102(A2), 780103(A2)  | Throughout                                  |
|   | Modification of names of the following special function registers (SFRs) <ul style="list-style-type: none"> <li>• Ports 0 to 3, 12, and 13 → Port registers 0 to 3, 12, and 13</li> </ul>   |   |
|   | Addition of <b>Caution 3</b> to <b>1.4 Pin Configuration (Top View)</b>   | CHAPTER 1 OUTLINE                           |
|   | Modification of <b>1.5 K1 Family Lineup</b>   |   |
|   | Modification of outline of timer in <b>1.7 Outline of Functions</b>   |   |
| Addition of <b>Table 2-1 Pin I/O Buffer Power Supplies</b>              | CHAPTER 2 PIN FUNCTIONS   |   |

| Edition | Description   | Applied to:                             |
|---------|---|---|
| 4th     | Addition of <b>Table 4-1 Pin I/O Buffer Power Supplies</b>  | CHAPTER 4 PORT FUNCTIONS                |
|         | Modification of <b>Table 4-3 Port Configuration</b>   |   |
|         | Deletion of input switch control register (ISC) from and addition of port registers (P0 to P3, P12, and P13) to <b>4.3 Registers Controlling Port Function</b>  |   |
|         | Modification of <b>Figure 5-1 Block Diagram of Clock Generator</b>  | CHAPTER 5 CLOCK GENERATOR               |
|         | Addition of <b>Cautions 2 and 3 to Figure 5-6 Format of Oscillation Stabilization Time Counter Status Register (OSTC)</b>   |   |
|         | Modification of <b>Figure 5-8 External Circuit of X1 Oscillator and Figure 5-9 Examples of Incorrect Resonator Connection</b>   |   |
|         | Modification of <b>Note in Figure 5-12 Switching from Ring-OSC Clock to X1 Input Clock (Flowchart)</b>  |   |
|         | Addition of figures <ul style="list-style-type: none"> <li>• <b>Figure 6-2 Format of 16-Bit Timer Counter 00 (TM00)</b></li> <li>• <b>Figure 6-3 Format of 16-Bit Timer Capture/Compare Register 000 (CR000)</b></li> <li>• <b>Figure 6-4 Format of 16-Bit Timer Capture/Compare Register 010 (CR010)</b></li> </ul>  | CHAPTER 6 16-BIT TIMER/EVENT COUNTER 00 |
|         | Modification of tables <ul style="list-style-type: none"> <li>• <b>Table 6-2 CR000 Capture Trigger and Valid Edges of TI000 and TI010 Pins</b></li> <li>• <b>Table 6-3 CR010 Capture Trigger and Valid Edge of TI000 Pin (CRC002 = 1)</b></li> </ul>  |   |
|         | Modification of <b>Caution 1 in 6.2 (3) 16-bit timer capture/compare register 010 (CR010)</b>   |   |
|         | Modification of <b>Caution 3 to Figure 6-6 Format of Capture/Compare Control Register 00 (CRC00)</b>  |   |
|         | Addition of description to <b>Caution 5</b> and addition of <b>Caution 6</b> in <b>Figure 6-7 Format of 16-Bit Timer Output Control Register 00 (TOC00)</b>   |   |
|         | Addition of register settings <ul style="list-style-type: none"> <li>• <b>6.4.1 Interval timer operation</b></li> <li>• <b>6.4.2 PPG output operations</b></li> <li>• <b>6.4.3 Pulse width measurement operations</b></li> <li>• <b>6.4.4 External event counter operation</b></li> <li>• <b>6.4.5 Square-wave output operation</b></li> <li>• <b>6.4.6 One-shot pulse output operation</b></li> </ul>  |   |
|         | Addition of setting of prescaler mode register 00 (PRM00) <ul style="list-style-type: none"> <li>• <b>Figure 6-10 Control Register Settings for Interval Timer Operation</b></li> <li>• <b>Figure 6-13 Control Register Settings for PPG Output Operation</b></li> <li>• <b>Figure 6-17 Control Register Settings for Pulse Width Measurement with Free-Running Counter and One Capture Register (When TI000 and CR010 Are Used)</b></li> <li>• <b>Figure 6-20 Control Register Settings for Measurement of Two Pulse Widths with Free-Running Counter</b></li> <li>• <b>Figure 6-22 Control Register Settings for Pulse Width Measurement with Free-Running Counter and Two Capture Registers (with Rising Edge Specified)</b></li> <li>• <b>Figure 6-24 Control Register Settings for Pulse Width Measurement by Means of Restart (with Rising Edge Specified)</b></li> <li>• <b>Figure 6-26 Control Register Settings in External Event Counter Mode (with Rising Edge Specified)</b></li> <li>• <b>Figure 6-29 Control Register Settings in Square-Wave Output Mode</b></li> <li>• <b>Figure 6-31 Control Register Settings for One-Shot Pulse Output with Software Trigger</b></li> <li>• <b>Figure 6-33 Control Register Settings for One-Shot Pulse Output with External Trigger (with Rising Edge Specified)</b></li> </ul> |   |

| Edition | Description  | Applied to:                             |
|---------|--|---|
| 4th     | Modification of figures <ul style="list-style-type: none"> <li>• <b>Figure 6-12 Timing of Interval Timer Operation</b></li> <li>• <b>Figure 6-15 PPG Output Operation Timing</b></li> <li>• <b>Figure 6-34 Timing of One-Shot Pulse Output Operation with External Trigger (with Rising Edge Specified)</b></li> </ul>             | CHAPTER 6 16-BIT TIMER/EVENT COUNTER 00 |
|         | Addition of figures <ul style="list-style-type: none"> <li>• <b>Figure 7-2 Format of 8-Bit Timer Counter 50 (TM50)</b></li> <li>• <b>Figure 7-3 Format of 8-Bit Timer Compare Register 50 (CR50)</b></li> </ul>  | CHAPTER 7 8-BIT TIMER/EVENT COUNTER 50  |
|         | Modification of <b>Figure 7-7 Interval Timer Operation Timing</b>  |   |
|         | Modification of description of frequency in <b>7.4.3 Operation as square-wave output</b>   |   |
|         | Addition of description of cycle, active level width, and duty to <b>7.4.4 (1) PWM output basic operation</b>  |   |
|         | Modification of <b>Figure 8-11 Operation Timing in PWM Output Mode</b>   | CHAPTER 8 8-BIT TIMERS H0 AND H1        |
|         | Modification of <b>Figure 10-1 Block Diagram of A/D Converter</b>  | CHAPTER 10 A/D CONVERTER                |
|         | Partial modification of description of <b>10.2 Configuration of A/D Converter</b>  |   |
|         | Addition of description of A/D conversion result register (ADCR) to <b>10.3 Registers Used in A/D Converter</b>  |   |
|         | Partial modification of description of <b>10.4.1 Basic operations of A/D converter</b>   |   |
|         | Addition of description of successive approximation register (SAR) to <b>10.4.2 Input voltage and conversion results</b>   |   |
|         | Modification of <b>Caution 3</b> in “When used as power-fail function” in <b>10.4.3 A/D converter operation mode</b>   |   |
|         | Modification of <b>Figure 10-21 Timing of A/D Converter Sampling and A/D Conversion Start Delay</b>  |   |
|         | Addition of description of <b>(12) Internal equivalent circuit</b> to <b>10.6 Cautions for A/D Converter</b>   |   |
|         | Modification of <b>Cautions 1, 2, 4</b> and addition of <b>Note 2</b> and <b>Caution 3</b> to <b>Figure 11-2 Format of Asynchronous Serial Interface Operation Mode Register 0 (ASIM0)</b>   | CHAPTER 11 SERIAL INTERFACE UART0       |
|         | Modification of description of <b>11.4.1 Operation stop mode</b>   | ( $\mu$ PD780102, 780103, 78F0103 ONLY) |
|         | Modification of description of <b>11.4.2 Asynchronous serial interface (UART) mode (1) Registers used</b>  |   |
|         | Modification of <b>Table 11-3 Cause of Reception Error</b>   |   |
|         | Modification of figures <ul style="list-style-type: none"> <li>• <b>Figure 12-1 LIN Transmission Operation</b></li> <li>• <b>Figure 12-2 LIN Reception Operation</b></li> <li>• <b>Figure 12-3 Port Configuration for LIN Reception Operation</b></li> <li>• <b>Figure 12-4 Block Diagram of Serial Interface UART6</b></li> </ul> | CHAPTER 12 SERIAL INTERFACE UART6       |
|         | Modification of <b>Cautions 1, 2</b> and addition of <b>Note 2</b> and <b>Caution 3</b> to <b>Figure 12-5 Format of Asynchronous Serial Interface Operation Mode Register 6 (ASIM6)</b>  |   |
|         | Addition of input switch control register (ISC) to <b>12.3 Registers Controlling Serial Interface UART6</b>  |   |
|         | Modification of description of <b>12.4.1 Operation stop mode</b>   |   |
|         | Modification of description of <b>12.4.2 Asynchronous serial interface (UART) mode (1) Registers used</b>  |   |
|         | Modification of description of <b>12.4.2 (2) (d) Continuous transmission</b>   |   |
|         | Modification of <b>Table 12-3 Cause of Reception Error</b>   |   |

| Edition | Description   | Applied to:                       |
|---------|---|-----------------------------------|
| 4th     | Modification of <b>Figure 13-1 Block Diagram of Serial Interface CSI10</b>  | CHAPTER 13 SERIAL INTERFACE CSI10 |
|         | Addition of <b>Notes 2 and 3 to Figure 13-2 Format of Serial Operation Mode Register 10 (CSIM10)</b>  |                                   |
|         | Modification of <b>Caution 2</b> and addition of <b>Caution 3 to Figure 13-3 Format of Serial Clock Selection Register 10 (CSIC10)</b>  |                                   |
|         | Modification of description of <b>13.4.1 Operation stop mode</b>  |                                   |
|         | Modification of description of <b>13.4.2 3-wire serial I/O mode (1) Registers used</b>  |                                   |
|         | Addition of <b>(5) SO10 output to 13.4.2 3-wire serial I/O mode</b>   |                                   |
|         | Addition of <b>Caution 3 to Figure 14-2 Format of Interrupt Request Flag Register (IF0L, IF0H, IF1L)</b>  | CHAPTER 14 INTERRUPT FUNCTIONS    |
|         | Modification of <b>Table 15-1 Relationship Between HALT and STOP Modes and Clock</b> in old edition to <b>Table 15-1 Relationship Between Operation Clocks in Each Operation Status</b>   | CHAPTER 15 STANDBY FUNCTION       |
|         | Addition of <b>Cautions 2 and 3 to Figure 15-1 Format of Oscillation Stabilization Time Counter Status Register (OSTC)</b>  |                                   |
|         | Modification of <b>Table 15-2 Operating Statuses in HALT Mode</b>   |                                   |
|         | Modification of figures <ul style="list-style-type: none"> <li>• <b>Figure 16-1 Block Diagram of Reset Function</b></li> <li>• <b>Figure 16-2 Timing of Reset by <math>\overline{\text{RESET}}</math> Input</b></li> <li>• <b>Figure 16-3 Timing of Reset Due to Watchdog Timer Overflow</b></li> <li>• <b>Figure 16-4 Timing of Reset in STOP Mode by <math>\overline{\text{RESET}}</math> Input</b></li> </ul>  | CHAPTER 16 RESET FUNCTION         |
|         | Modification of <b>Figure 17-1 Block Diagram of Clock Monitor</b>   | CHAPTER 17 CLOCK MONITOR          |
|         | Addition of normal operation mode to <b>Table 17-2 Operation Status of Clock Monitor (When CLME = 1)</b>  |                                   |
|         | Addition of <b>(6) Clock monitor status after X1 input clock oscillation is stopped by software</b> and <b>(7) Clock monitor status after Ring-OSC clock oscillation is stopped by software</b> to <b>Figure 17-3 Timing of Clock Monitor</b>   |                                   |
|         | Modification of <b>Figure 18-1 Block Diagram of Power-on-Clear Circuit</b>  | CHAPTER 18 POWER-ON-CLEAR CIRCUIT |
|         | Modification of <b>Figure 19-1 Block Diagram of Low-Voltage Detector</b>  | CHAPTER 19 LOW-VOLTAGE DETECTOR   |
|         | Addition of <b>Caution</b> to <b>Figure 19-3 Format of Low-Voltage Detection Level Selection Register (LVIS)</b>  |                                   |
|         | Modification of <b>Figure 19-4 Timing of Low-Voltage Detector Internal Reset Signal Generation</b> and <b>Figure 19-5 Timing of Low-Voltage Detector Interrupt Signal Generation</b>  |                                   |
|         | Partial modification of description of <b>(2) When used as interrupt under &lt;Action&gt;</b> in <b>19.5 Cautions for Low-Voltage Detector</b>  |                                   |
|         | Addition of <b>Note 2 to Table 21-3 Wiring Between <math>\mu\text{PD78F0103}</math> and Dedicated Flash Programmer</b>  |                                   |
|         | Addition of <b>Note</b> to <b>Figure 21-7 Environment for Writing Program to Flash Memory</b>   | CHAPTER 21 $\mu\text{PD78F0103}$  |
|         | Modification of figures <ul style="list-style-type: none"> <li>• <b>Figure 21-8 Communication with Dedicated Flash Programmer (CSI10)</b></li> <li>• <b>Figure 21-9 Communication with Dedicated Flash Programmer (CSI10 + HS)</b></li> <li>• <b>Figure 21-10 Communication with Dedicated Flash Programmer (UART0)</b></li> <li>• <b>Figure 21-11 Communication with Dedicated Flash Programmer (UART0 + HS)</b></li> <li>• <b>Figure 21-12 Communication with Dedicated Flash Programmer (UART6)</b></li> </ul> |                                   |

| Edition  | Description  | Applied to:  |
|--|--|--|
| 4th  | Partial modification of description of <b>21.5.2 (2) Malfunction of other device</b>   | CHAPTER 21 $\mu$ PD78F0103   |
|  | Modification of description of <b>21.5.4 Port pins</b>   |  |
|  | Partial modification of <b>Caution</b> to <b>21.5.6 Power supply</b>   |  |
|  | Modification of followings <ul style="list-style-type: none"> <li>• Modification of <b>Note 2</b> of <b>DC Characteristics</b></li> <li>• Addition of <b>Notes 1</b> and <b>2</b> to <b>POC Circuit Characteristics</b></li> <li>• Modification of <b>Note 1</b> of <b>LVI Circuit Characteristics</b></li> <li>• Addition of condition for data retention supply voltage and <b>Note</b> to <b>Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics</b></li> </ul>   | CHAPTER 23 ELECTRICAL SPECIFICATIONS (STANDARD PRODUCTS, (A) GRADE PRODUCTS) |
|  | Modification of followings <ul style="list-style-type: none"> <li>• Modification of <b>Note 2</b> of <b>DC Characteristics</b></li> <li>• Modification of values for overall error and conversion time in <b>A/D Converter Characteristics</b></li> <li>• Addition of <b>Note 2</b> to <b>POC Circuit Characteristics</b></li> <li>• Modification of <b>Note 2</b> of <b>LVI Circuit Characteristics</b></li> <li>• Addition of condition for data retention supply voltage and <b>Note 2</b> to <b>Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics</b></li> </ul> | CHAPTER 24 ELECTRICAL SPECIFICATIONS ((A1) GRADE PRODUCTS)                   |
|  | Addition of chapter  | CHAPTER 25 ELECTRICAL SPECIFICATIONS ((A2) GRADE PRODUCTS)                   |
| Modification of <b>Table 27-1 Surface Mounting Type Soldering Conditions</b> | CHAPTER 27 RECOMMENDED SOLDERING CONDITIONS  |  |