

**NEC**

# Preliminary User's Manual

## **V850ES/JJ3**

### **32-bit Single-Chip Microcontrollers**

#### **Hardware**

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***μ*PD70F3743**

***μ*PD70F3744**

***μ*PD70F3745**

***μ*PD70F3746**

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[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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## PREFACE

- Readers** This manual is intended for users who wish to understand the functions of the V850ES/JJ3 and design application systems using the V850ES/JJ3.
- Purpose** This manual is intended to give users an understanding of the hardware functions of the V850ES/JJ3 shown in the **Organization** below.
- Organization** This manual is divided into two parts: Hardware (this manual) and Architecture (**V850ES Architecture User's Manual**).

|          |
|----------|
| Hardware |
|----------|

- Pin functions
- CPU function
- On-chip peripheral functions
- Flash memory programming
- Electrical specifications (target)

|              |
|--------------|
| Architecture |
|--------------|

- Data types
- Register set
- Instruction format and instruction set
- Interrupts and exceptions
- Pipeline operation

- How to Read This Manual** It is assumed that the readers of this manual have general knowledge in the fields of electrical engineering, logic circuits, and microcontrollers.

To understand the overall functions of the V850ES/JJ3

→ Read this manual according to the **CONTENTS**.

To find the details of a register where the name is known

→ Use **APPENDIX C REGISTER INDEX**.

Register format

→ The name of the bit whose number is in angle brackets (<>) in the figure of the register format of each register is defined as a reserved word in the device file.

To understand the details of an instruction function

→ Refer to the **V850ES Architecture User's Manual** available separately.

To know the electrical specifications of the V850ES/JJ3

→ See **CHAPTER 29 ELECTRICAL SPECIFICATIONS (TARGET)**

The "yyy bit of the xxx register" is described as the "xxx.yyy bit" in this manual. Note with caution that if "xxx.yyy" is described as is in a program, however, the compiler/assembler cannot recognize it correctly.

The mark <R> shows major revised points. The revised points can be easily searched by copying an "<R>" in the PDF file and specifying it in the "Find what:" field.

## Conventions

|  |  |
|--|--|
| Data significance:   | Higher digits on the left and lower digits on the right                                    |
| Active low representation:   | $\overline{\text{xxx}}$ (overscore over pin or signal name)                                |
| Memory map address:  | Higher addresses on the top and lower addresses on the bottom                              |
| <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  |
| Numeric representation:  | Binary ... xxxx or xxxxB<br>Decimal ... xxxx<br>Hexadecimal ... xxxxH                      |
| Prefix indicating power of 2<br>(address space, memory<br>capacity): | K (kilo): $2^{10} = 1,024$<br>M (mega): $2^{20} = 1,024^2$<br>G (giga): $2^{30} = 1,024^3$ |

## Related Documents

The related documents indicated in this publication may include preliminary versions. However, preliminary versions are not marked as such.

### Documents related to V850ES/JJ3

| Document Name                     | Document No. |
|-----------------------------------|--------------|
| V850ES Architecture User's Manual | U15943E      |
| V850ES/JJ3 Hardware User's Manual | This manual  |

### Documents related to development tools

| Document Name   | Document No.                                    |         |
|---|---|---------|
| QB-V850ESSX2 In-Circuit Emulator                          | U17091E   |         |
| QB-V850MINI On-Chip Debug Emulator                        | U17638E   |         |
| QB-MINI2 On-Chip Debug Emulator with Programming Function | U18371E   |         |
| CA850 Ver. 3.00 C Compiler Package                        | Operation                                       | U17293E |
|   | C Language                                      | U17291E |
|   | Assembly Language                               | U17292E |
|   | Link Directives                                 | U17294E |
| PM+ Ver. 6.20 Project Manager                             | U17990E   |         |
| ID850QB Ver. 3.20 Integrated Debugger                     | Operation                                       | U17964E |
| SM850 Ver. 2.50 System Simulator                          | Operation                                       | U16218E |
| SM850 Ver. 2.00 or Later System Simulator                 | External Part User Open Interface Specification | U14873E |
| SM+ System Simulator                                      | Operation                                       | U17246E |
|   | User Open Interface                             | U17247E |
| RX850 Ver. 3.20 Real-Time OS                              | Basics  | U13430E |
|   | Installation                                    | U17419E |
|   | Technical                                       | U13431E |
|   | Task Debugger                                   | U17420E |
| RX850 Pro Ver. 3.20 Real-Time OS                          | Basics  | U13773E |
|   | Installation                                    | U17421E |
|   | Technical                                       | U13772E |
|   | Task Debugger                                   | U17422E |
| AZ850 Ver. 3.30 System Performance Analyzer               | U17423E   |         |
| PG-FP4 Flash Memory Programmer                            | U15260E   |         |



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## CHAPTER 1 INTRODUCTION

The V850ES/JJ3 is one of the products in the NEC Electronics V850 single-chip microcontrollers designed for low-power operation for real-time control applications.

### 1.1 General

The V850ES/JJ3 is a 32-bit single-chip microcontroller that includes the V850ES CPU core and peripheral functions such as ROM/RAM, a timer/counter, serial interfaces, an A/D converter, and a D/A converter.

In addition to high real-time response characteristics and 1-clock-pitch basic instructions, the V850ES/JJ3 features multiply instructions, saturated operation instructions, bit manipulation instructions, etc., realized by a hardware multiplier, as optimum instructions for digital servo control applications. Moreover, as a real-time control system, the V850ES/JJ3 enables an extremely high cost-performance for applications that require low power consumption, such as home audio, printers, and digital home electronics.

Table 1-1 lists the products of the V850ES/JJ3.

Table 1-1. V850ES/JJ3 Product List

| Part Number       |                                    | $\mu$ PD70F3743      | $\mu$ PD70F3744  | $\mu$ PD70F3745 | $\mu$ PD70F3746 |         |
|-------------------|------------------------------------|----------------------|--|-----------------|-----------------|---------|
| <R><br><R><br><R> | Internal memory                    | Flash memory         | 384 KB   | 512 KB          | 768 KB          | 1024 KB |
|                   |                                    | RAM                  | 32 KB  | 40 KB           | 60 KB           | 60 KB   |
|                   | Memory space                       | Logical space        | 64 MB  |                 |                 |         |
|                   |                                    | External memory area | 16 MB  |                 |                 |         |
|                   | External bus interface             |                      | Address bus: 24 bits<br>Data bus: 8/16 bits<br>Multiplex bus mode/separate bus mode<br>Chip select signal: 4   |                 |                 |         |
|                   | General-purpose register           |                      | 32 bits $\times$ 32 registers  |                 |                 |         |
|                   | Main clock (oscillation frequency) |                      | Ceramic/crystal<br>(in PLL mode: $f_x = 2.5$ to 5 MHz (multiplied by 4) or $f_x = 2.5$ to 4 MHz (multiplied by 8),<br>in clock through mode: $f_x = 2.5$ to 10 MHz)  |                 |                 |         |
|                   | Subclock (oscillation frequency)   |                      | Crystal ( $f_{XT} = 32.768$ kHz)   |                 |                 |         |
|                   | Internal oscillator                |                      | $f_R = 220$ kHz (TYP.)   |                 |                 |         |
|                   | Minimum instruction execution time |                      | 31.25 ns (main clock ( $f_{XX}$ ) = 32 MHz)  |                 |                 |         |
|                   | DSP function                       |                      | 32 $\times$ 32 = 64: 125 to 156.25 ns (at 32 MHz)<br>32 $\times$ 32 + 32 = 32: 187.5 ns (at 32 MHz)<br>16 $\times$ 16 = 32: 31.25 to 62.5 ns (at 32 MHz)<br>16 $\times$ 16 + 32 = 32: 93.75 ns (at 32 MHz) |                 |                 |         |
|                   | I/O port                           |                      | I/O: 128 (5 V tolerant/N-ch open-drain output selectable: 60)  |                 |                 |         |
|                   | Timer                              |                      | 16-bit timer/event counter P: 9 channels<br>16-bit timer/event counter Q: 1 channel<br>16-bit interval timer M: 1 channel<br>Watch timer: 1 channel<br>Watchdog timer: 1 channel                           |                 |                 |         |
|                   | Real-time output port              |                      | 6 bits $\times$ 2 channels   |                 |                 |         |
|                   | A/D converter                      |                      | 10-bit resolution $\times$ 16 channels   |                 |                 |         |
|                   | D/A converter                      |                      | 8-bit resolution $\times$ 2 channels   |                 |                 |         |
|                   | Serial interface                   |                      | UART: 1 channel<br>UART/CSI: 1 channel<br>UART/I <sup>2</sup> C bus: 2 channels<br>CSI: 4 channels<br>CSI/I <sup>2</sup> C bus: 1 channel  |                 |                 |         |
|                   | DMA controller                     |                      | 4 channels (transfer target: on-chip peripheral I/O, internal RAM, external memory)  |                 |                 |         |
|                   | Interrupt source                   |                      | External: 10 (10) <sup>Note</sup> , internal: 61   |                 |                 |         |
|                   | Power save function                |                      | HALT/IDLE1/IDLE2/STOP/subclock/sub-IDLE mode   |                 |                 |         |
|                   | Reset                              |                      | $\overline{\text{RESET}}$ pin input, watchdog timer 2 (WDT2), clock monitor (CLM), low-voltage detector (LVI)  |                 |                 |         |
|                   | DCU                                |                      | Provided (RUN/break)   |                 |                 |         |
|                   | Operating power supply voltage     |                      | 2.85 to 3.6 V  |                 |                 |         |
|                   | Operating ambient temperature      |                      | -40 to +85°C   |                 |                 |         |
|                   | Package                            |                      | 144-pin plastic LQFP (fine pitch) (20 $\times$ 20 mm)  |                 |                 |         |

**Note** The figure in parentheses indicates the number of external interrupts that can release the STOP mode.

## 1.2 Features

- Minimum instruction execution time: 31.25 ns (operating with main clock ( $f_{xx}$ ) of 32 MHz)
- General-purpose registers: 32 bits  $\times$  32 registers
- CPU features:
  - Signed multiplication ( $16 \times 16 \rightarrow 32$ ): 1 to 2 clocks
  - Signed multiplication ( $32 \times 32 \rightarrow 64$ ): 1 to 5 clocks
  - Saturated operations (overflow and underflow detection functions included)
  - 32-bit shift instruction: 1 clock
  - Bit manipulation instructions
  - Load/store instructions with long/short format
- Memory space: 64 MB of linear address space (for programs and data)  
External expansion: Up to 16 MB (including 1 MB used as internal ROM/RAM)
  - Internal memory:
    - RAM: 32 KB/40 KB/60 KB (see **Table 1-1**)
    - Flash memory: 384 KB/512 KB/768 KB/1024 KB (see **Table 1-1**)
  - External bus interface: Separate bus/multiplexed bus output selectable
    - 8-/16-bit data bus sizing function
    - Wait function
      - Programmable wait function
      - External wait function
    - Idle state function
    - Bus hold function
- Interrupts and exceptions:
  - Non-maskable interrupts: 2 sources
  - Maskable interrupts: 60 sources
  - Software exceptions: 32 sources
  - Exception trap: 2 sources
- I/O lines: I/O ports: 128
- Timer function:
  - 16-bit interval timer M (TMM): 1 channel
  - 16-bit timer/event counter P (TMP): 9 channels
  - 16-bit timer/event counter Q (TMQ): 1 channel
  - Watch timer: 1 channel
  - Watchdog timer: 1 channel
- Real-time output port: 6 bits  $\times$  2 channels
- Serial interface:
  - Asynchronous serial interface A (UARTA)
  - 3-wire variable-length serial interface B (CSIB)
  - I<sup>2</sup>C bus interface (I<sup>2</sup>C)
    - UARTA/CSIB: 1 channel
    - UARTA/I<sup>2</sup>C: 2 channels
    - CSIB/I<sup>2</sup>C: 1 channel
    - CSIB: 4 channels
    - UARTA: 1 channel
- A/D converter: 10-bit resolution: 16 channels
- D/A converter: 8-bit resolution: 2 channels
- DMA controller: 4 channels
- CRC function: 16-bit error detection code for data in 8-bit units can be generated
- DCU (debug control unit): JTAG interface
- Clock generator:
  - During main clock or subclock operation
  - 7-level CPU clock ( $f_{xx}$ ,  $f_{xx}/2$ ,  $f_{xx}/4$ ,  $f_{xx}/8$ ,  $f_{xx}/16$ ,  $f_{xx}/32$ ,  $f_{XT}$ )
  - Clock-through mode/PLL mode selectable

- Internal oscillation clock: 220 kHz (TYP)
- Power-save functions: HALT/IDLE1/IDLE2/STOP/subclock/sub-IDLE mode
- Package: 144-pin plastic LQFP (fine pitch) (20 × 20)

### 1.3 Application Fields

Home audio, printers, digital home electronics, other consumer devices

### 1.4 Ordering Information

|     | Part Number         | Package                                     | Internal Flash Memory |
|-----|---------------------|---|-----------------------|
| <R> | μPD70F3743GJ-GAE-AX | 144-pin plastic LQFP (fine pitch) (20 × 20) | 384 KB                |
| <R> | μPD70F3744GJ-GAE-AX | 144-pin plastic LQFP (fine pitch) (20 × 20) | 512 KB                |
|     | μPD70F3745GJ-GAE-AX | 144-pin plastic LQFP (fine pitch) (20 × 20) | 768 KB                |
|     | μPD70F3746GJ-GAE-AX | 144-pin plastic LQFP (fine pitch) (20 × 20) | 1024 KB               |

**Remark** The V850ES/JJ3 microcontrollers are lead-free products.

### 1.5 Pin Configuration (Top View)

144-pin plastic LQFP (fine pitch) (20 × 20)

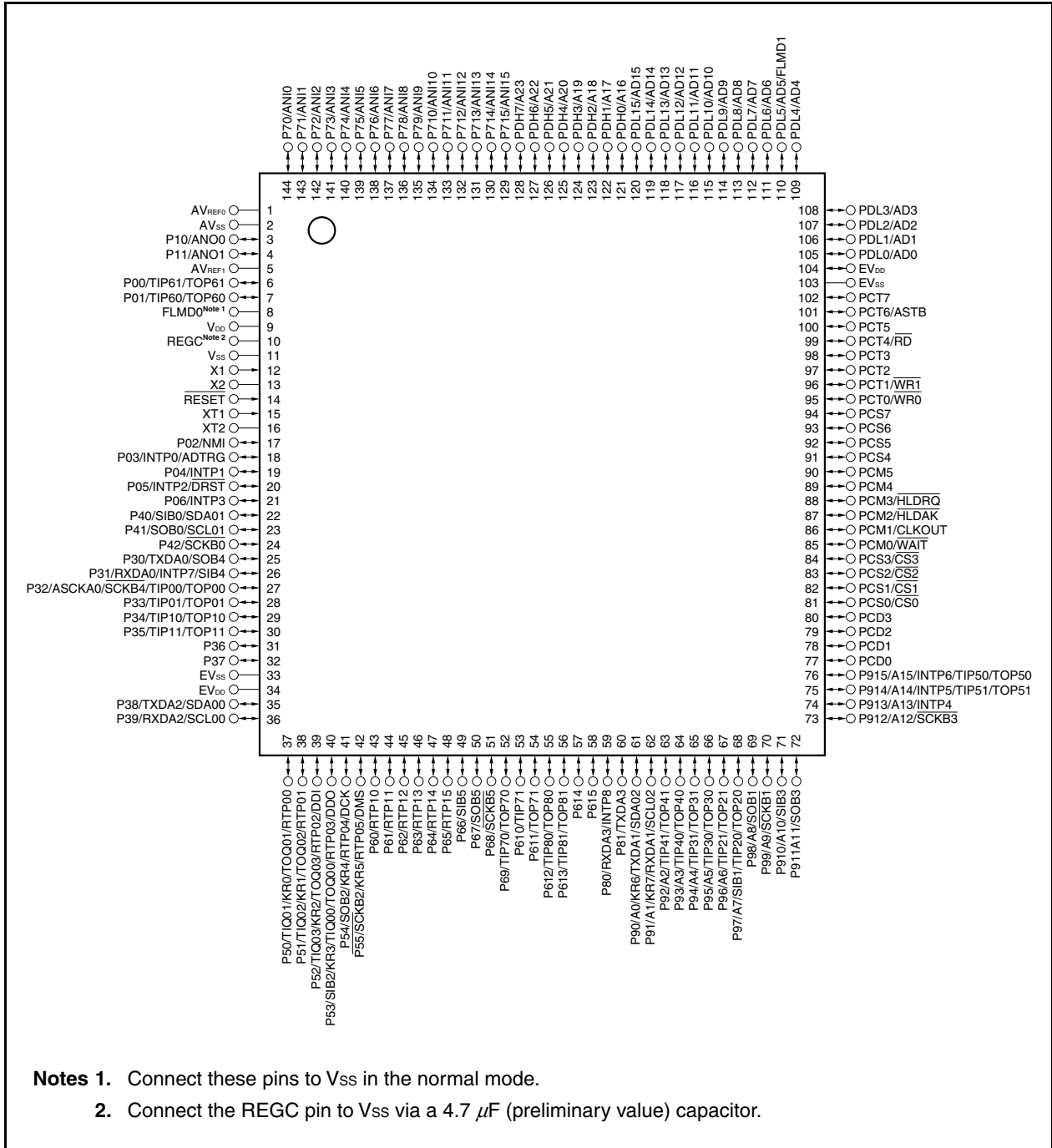
<R>

μPD70F3743GJ-GAE-AX

μPD70F3744GJ-GAE-AX

μPD70F3745GJ-GAE-AX

μPD70F3746GJ-GAE-AX



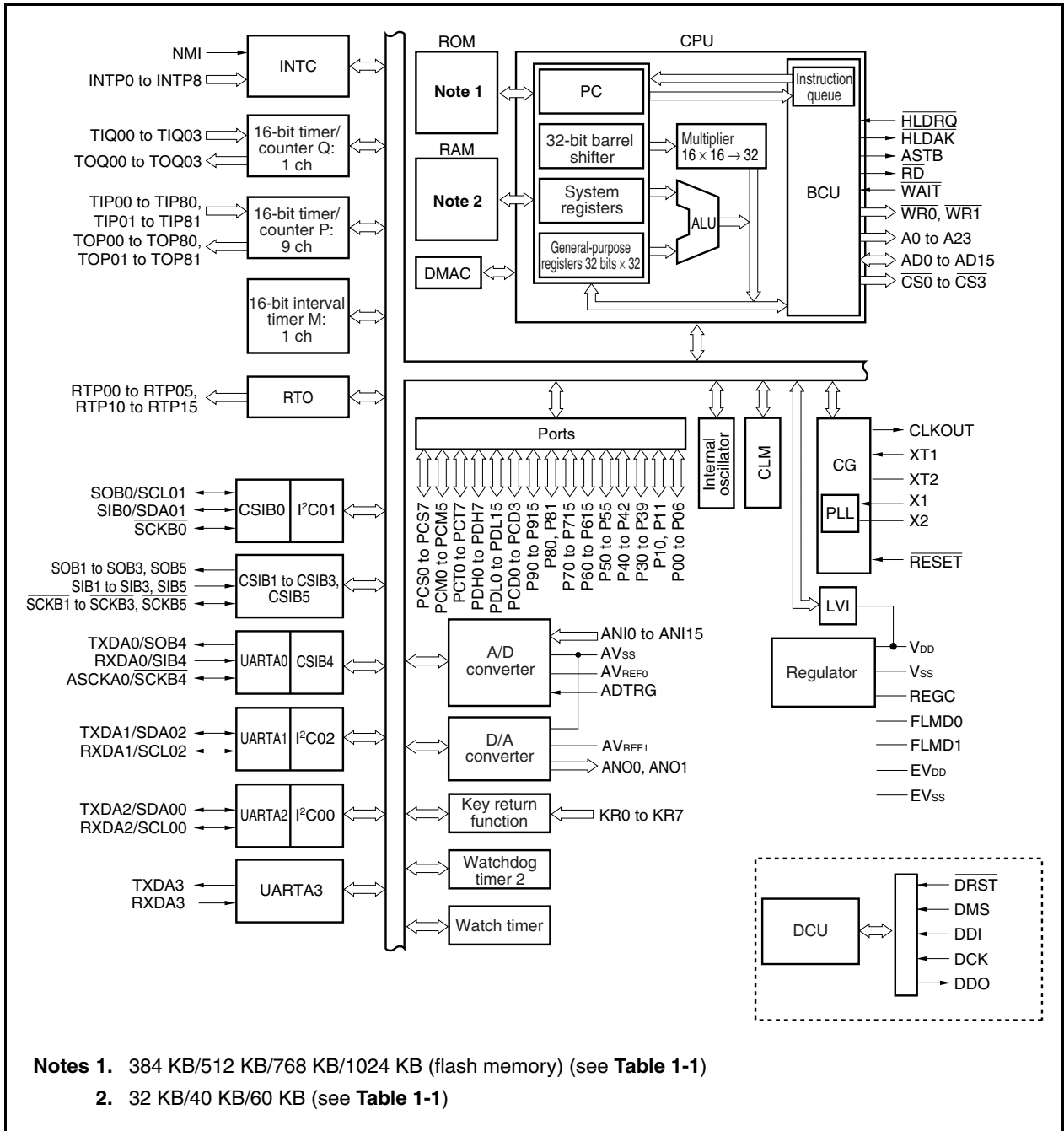
**Pin names**

|   |                                |  |                         |
|---|--------------------------------|--|-------------------------|
| A0 to A23:                                | Address bus                    | $\overline{RD}$ :                          | Read strobe             |
| AD0 to AD15:                              | Address/data bus               | REGC:                                      | Regulator control       |
| ADTRG:                                    | A/D trigger input              | $\overline{RESET}$ :                       | Reset                   |
| ANI0 to ANI15:                            | Analog input                   | RTP00 to RTP05,                            |                         |
| ANO0, ANO1:                               | Analog output                  | RTP10 to RTP15:                            | Real-time output port   |
| ASCKA0:                                   | Asynchronous serial clock      | $\overline{RXDA0}$ to $\overline{RXDA3}$ : | Receive data            |
| ASTB:                                     | Address strobe                 | $\overline{SCKB0}$ to $\overline{SCKB5}$ : | Serial clock            |
| AV <sub>REF0</sub> , AV <sub>REF1</sub> : | Analog reference voltage       | SCL00 to SCL02:                            | Serial clock            |
| AV <sub>SS</sub> :                        | Analog V <sub>SS</sub>         | SDA00 to SDA02:                            | Serial data             |
| CLKOUT:                                   | Clock output                   | SIB0 to SIB5:                              | Serial input            |
| $\overline{CS0}$ to $\overline{CS3}$ :    | Chip select                    | SOB0 to SOB5:                              | Serial output           |
| DCK:                                      | Debug clock                    | TIP00, TIP01,                              |                         |
| DDI:                                      | Debug data input               | TIP10, TIP11,                              |                         |
| DDO:                                      | Debug data output              | TIP20, TIP21,                              |                         |
| DMS:                                      | Debug mode select              | TIP30, TIP31,                              |                         |
| $\overline{DRST}$ :                       | Debug reset                    | TIP40, TIP41,                              |                         |
| EV <sub>DD</sub> :                        | Power supply for external pin  | TIP50, TIP51,                              |                         |
| EV <sub>SS</sub> :                        | Ground for external pin        | TIP60, TIP61,                              |                         |
| FLMD0, FLMD1:                             | Flash programming mode         | TIP70, TIP71,                              |                         |
| $\overline{HLDAK}$ :                      | Hold acknowledge               | TIP80, TIP81,                              |                         |
| $\overline{HLDRQ}$ :                      | Hold request                   | TIQ00 to TIQ03:                            | Timer input             |
| INTP0 to INTP8:                           | External interrupt input       | TOP00, TOP01,                              |                         |
| KR0 to KR7:                               | Key return                     | TOP10, TOP11,                              |                         |
| NMI:                                      | Non-maskable interrupt request | TOP20, TOP21,                              |                         |
| P00 to P06:                               | Port 0                         | TOP30, TOP31,                              |                         |
| P10, P11:                                 | Port 1                         | TOP40, TOP41,                              |                         |
| P30 to P39:                               | Port 3                         | TOP50, TOP51,                              |                         |
| P40 to P42:                               | Port 4                         | TOP60, TOP61,                              |                         |
| P50 to P55:                               | Port 5                         | TOP70, TOP71,                              |                         |
| P60 to P615:                              | Port 6                         | TOP80, TOP81,                              |                         |
| P70 to P715:                              | Port 7                         | TOQ00 to TOQ03:                            | Timer output            |
| P80, P81:                                 | Port 8                         | TXDA0 to TXDA3:                            | Transmit data           |
| P90 to P915:                              | Port 9                         | V <sub>DD</sub> :                          | Power supply            |
| PCD0 to PCD3:                             | Port CD                        | V <sub>SS</sub> :                          | Ground                  |
| PCM0 to PCM5:                             | Port CM                        | $\overline{WAIT}$ :                        | Wait                    |
| PCS0 to PCS7:                             | Port CS                        | $\overline{WR0}$ :                         | Lower byte write strobe |
| PCT0 to PCT7:                             | Port CT                        | $\overline{WR1}$ :                         | Upper byte write strobe |
| PDH0 to PDH7:                             | Port DH                        | X1, X2:                                    | Crystal for main clock  |
| PDL0 to PDL15:                            | Port DL                        | XT1, XT2:                                  | Crystal for subclock    |



## 1.6 Function Block Configuration

### 1.6.1 Internal block diagram



<R>  
<R>

## 1.6.2 Internal units

### (1) CPU

The CPU uses five-stage pipeline control to enable single-clock execution of address calculations, arithmetic logic operations, data transfers, and almost all other instruction processing.

Other dedicated on-chip hardware, such as a multiplier (16 bits  $\times$  16 bits  $\rightarrow$  32 bits) and a barrel shifter (32 bits) contribute to faster complex processing.

### (2) Bus control unit (BCU)

The BCU starts a required external bus cycle based on the physical address obtained by the CPU. When an instruction is fetched from external memory space and the CPU does not send a bus cycle start request, the BCU generates a prefetch address and prefetches the instruction code. The prefetched instruction code is stored in an instruction queue.

### (3) ROM

<R> This is a 1024/768/512/384 KB flash memory mapped to addresses 0000000H to 00FFFFFFH/0000000H to 00BFFFFFFH/0000000H to 007FFFFFFH/0000000H to 005FFFFFFH. It can be accessed from the CPU in one clock during instruction fetch.

### (4) RAM

<R> This is a 60/40/32 KB RAM mapped to addresses 3FF0000H to 3FFFFFFFFH/3FF5000H to 3FFFFFFFFH/3FF7000H to 3FFFFFFFFH. It can be accessed from the CPU in one clock during data access.

### (5) Interrupt controller (INTC)

This controller handles hardware interrupt requests (NMI, INTP0 to INTP8) from on-chip peripheral hardware and external hardware. Eight levels of interrupt priorities can be specified for these interrupt requests, and multiple servicing control can be performed.

### (6) Clock generator (CG)

A main clock oscillator that generates the main clock oscillation frequency ( $f_x$ ) and a subclock oscillator that generates the subclock oscillation frequency ( $f_{XT}$ ) are available. As the main clock frequency ( $f_{XX}$ ),  $f_x$  is used as is in the clock-through mode and is multiplied by four or eight in the PLL mode.

The CPU clock frequency ( $f_{CPU}$ ) can be selected from seven types:  $f_{XX}$ ,  $f_{XX}/2$ ,  $f_{XX}/4$ ,  $f_{XX}/8$ ,  $f_{XX}/16$ ,  $f_{XX}/32$ , and  $f_{XT}$ .

### (7) Internal oscillator

An internal oscillator is provided on chip. The oscillation frequency is 220 kHz (TYP.). An internal oscillator supplies the clock for watchdog timer 2 and timer M.

### (8) Timer/counter

Nine-channel 16-bit timer/event counter P (TMP), one-channel 16-bit timer/event counter Q (TMQ), and one-channel 16-bit interval timer M (TMM) are provided on chip.

### (9) Watch timer

This timer counts the reference time period (0.5 s) for counting the clock (the 32.768 kHz from the subclock or the 32.768 kHz  $f_{BRG}$  from prescaler 3). The watch timer can also be used as an interval timer for the main clock.

**(10) Watchdog timer 2**

A watchdog timer is provided on chip to detect inadvertent program loops, system abnormalities, etc.

The internal oscillation clock, the main clock, or the subclock can be selected as the source clock.

Watchdog timer 2 generates a non-maskable interrupt request signal (INTWDT2) or a system reset signal (WDT2RES) after an overflow occurs.

**(11) Serial interface**

The V850ES/JJ3 includes three kinds of serial interfaces: asynchronous serial interface A (UARTA), 3-wire variable-length serial interface B (CSIB), and an I<sup>2</sup>C bus interface (I<sup>2</sup>C).

In the case of UARTA, data is transferred via the TXDA0 to TXDA3 pins and RXDA0 to RXDA3 pins.

In the case of CSIB, data is transferred via the SOB0 to SOB5 pins, SIB0 to SIB5 pins, and  $\overline{\text{SCKB0}}$  to  $\overline{\text{SCKB5}}$  pins.

In the case of I<sup>2</sup>C, data is transferred via the SDA00 to SDA02 and SCL00 to SCL02 pins.

**(12) A/D converter**

This 10-bit A/D converter includes 16 analog input pins. Conversion is performed using the successive approximation method.

**(13) D/A converter**

A two-channel, 8-bit-resolution D/A converter that uses the R-2R ladder method is provided on chip.

**(14) DMA controller**

A 4-channel DMA controller is provided on chip. This controller transfers data between the internal RAM and on-chip peripheral I/O devices in response to interrupt requests sent by on-chip peripheral I/O.

**(15) Key interrupt function**

A key interrupt request signal (INTKR) can be generated by inputting a falling edge to key input pins (8 channels).

**(16) Real-time output function**

The real-time output function transfers preset 6-bit data to output latches upon the occurrence of a timer compare register match signal.

**(17) CRC function**

A CRC operation circuit that generates 16-bit CRC (cyclic redundancy check) codes for data in 8-bit units is provided.

**(18) DCU (debug control unit)**

An on-chip debug function that uses the JTAG (Joint Test Action Group) communication specifications is provided. Switching between the normal port function and on-chip debugging function is done with the control pin input level and the OCDM register.

**(19) Ports**

The general-purpose port functions and control pin functions are listed below.

| Port | I/O        | Alternate Function   |
|------|------------|--|
| P0   | 7-bit I/O  | Timer I/O, NMI, external interrupt, A/D converter trigger, debug reset                     |
| P1   | 2-bit I/O  | D/A converter analog output  |
| P3   | 10-bit I/O | External interrupt, serial interface, timer I/O  |
| P4   | 3-bit I/O  | Serial interface   |
| P5   | 6-bit I/O  | Timer I/O, real-time output, key interrupt input, serial interface, debug I/O              |
| P6   | 16-bit I/O | Real-time output, serial interface, timer I/O  |
| P7   | 16-bit I/O | A/D converter analog input   |
| P8   | 2-bit I/O  | Serial interface, external interrupt   |
| P9   | 16-bit I/O | External address bus, serial interface, key interrupt input, timer I/O, external interrupt |
| PCD  | 4-bit I/O  | –  |
| PCM  | 6-bit I/O  | External control signal  |
| PCS  | 8-bit I/O  | Chip select output   |
| PCT  | 8-bit I/O  | External control signal  |
| PDH  | 8-bit I/O  | External address bus   |
| PDL  | 16-bit I/O | External address/data bus  |

## CHAPTER 2 PIN FUNCTIONS

### 2.1 List of Pin Functions

The names and functions of the pins of the V850ES/JJ3 are described below.

There are three types of pin I/O buffer power supplies:  $AV_{REF0}$ ,  $AV_{REF1}$ , and  $EV_{DD}$ . The relationship between these power supplies and the pins is described below.

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

| Power Supply | Corresponding Pins   |
|--------------|--|
| $AV_{REF0}$  | Port 7   |
| $AV_{REF1}$  | Port 1   |
| $EV_{DD}$    | $\overline{RESET}$ , ports 0, 3 to 6, 8, 9, CD, CM, CS, CT, DH, DL |

## (1) Port pins

(1/4)

| Pin Name            | Pin No. | I/O                       | Function   | Alternate Function                             |
|---------------------|---------|---------------------------|--|--|
| P00                 | 6       | I/O                       | Port 0<br>7-bit I/O port<br>Input/output can be specified in 1-bit units.<br>N-ch open-drain output can be specified in 1-bit units.<br>5 V tolerant.  | TIP61/TOP61                                    |
| P01                 | 7       |                           |  | TIP60/TOP60                                    |
| P02                 | 17      |                           |  | NMI  |
| P03                 | 18      |                           |  | INTP0/ADTRG                                    |
| P04                 | 19      |                           |  | INTP1  |
| P05 <sup>Note</sup> | 20      |                           |  | INTP2/ $\overline{\text{DRST}}$                |
| P06                 | 21      |                           |  | INTP3  |
| P10                 | 3       | I/O                       | Port 1<br>2-bit I/O port<br>Input/output can be specified in 1-bit units.  | ANO0   |
| P11                 | 4       |                           |  | ANO1   |
| P30                 | 25      | I/O                       | Port 3<br>10-bit I/O port<br>Input/output can be specified in 1-bit units.<br>N-ch open-drain output can be specified in 1-bit units.<br>5 V tolerant. | TXDA0/SOB4                                     |
| P31                 | 26      |                           |  | RXDA0/INTP7/SIB4                               |
| P32                 | 27      |                           |  | ASCKA0/ $\overline{\text{SCKB4}}$ /TIP00/TOP00 |
| P33                 | 28      |                           |  | TIP01/TOP01                                    |
| P34                 | 29      |                           |  | TIP10/TOP10                                    |
| P35                 | 30      |                           |  | TIP11/TOP11                                    |
| P36                 | 31      |                           |  | –  |
| P37                 | 32      |                           |  | –  |
| P38                 | 35      |                           |  | TXDA2/SDA00                                    |
| P39                 | 36      |                           |  | RXDA2/SCL00                                    |
| P40                 | 22      |                           |  | I/O  |
| P41                 | 23      | SOB0/SCL01                |  |  |
| P42                 | 24      | $\overline{\text{SCKB0}}$ |  |  |
| P50                 | 37      | I/O                       | Port 5<br>6-bit I/O port<br>Input/output can be specified in 1-bit units.<br>N-ch open-drain output can be specified in 1-bit units.<br>5 V tolerant.  | TIQ01/KR0/TOQ01/RTP00                          |
| P51                 | 38      |                           |  | TIQ02/KR1/TOQ02/RTP01                          |
| P52                 | 39      |                           |  | TIQ03/KR2/TOQ03/RTP02/DDI                      |
| P53                 | 40      |                           |  | SIB2/KR3/TIQ00/TOQ00/RTP03/<br>DDO             |
| P54                 | 41      |                           |  | SOB2/KR4/RTP04/DCK                             |
| P55                 | 42      |                           |  | $\overline{\text{SCKB2}}$ /KR5/RTP05/DMS       |

**Note** Incorporates a pull-down resistor. It can be disconnected by clearing the OCDM.OCDM0 bit.

| Pin Name | Pin No. | I/O   | Function   | Alternate Function |
|----------|---------|-------|--|--------------------|
| P60      | 43      | I/O   | Port 6<br>16-bit I/O port<br>Input/output can be specified in 1-bit units.<br>N-ch open-drain output can be specified in 1-bit units.<br>5 V tolerant. | RTP10              |
| P61      | 44      |       |  | RTP11              |
| P62      | 45      |       |  | RTP12              |
| P63      | 46      |       |  | RTP13              |
| P64      | 47      |       |  | RTP14              |
| P65      | 48      |       |  | RTP15              |
| P66      | 49      |       |  | SIB5               |
| P67      | 50      |       |  | SOB5               |
| P68      | 51      |       |  | SCKB5              |
| P69      | 52      |       |  | TIP70/TOP70        |
| P610     | 53      |       |  | TIP71              |
| P611     | 54      |       |  | TOP71              |
| P612     | 55      |       |  | TIP80/TOP80        |
| P613     | 56      |       |  | TIP81/TOP81        |
| P614     | 57      |       |  | –                  |
| P615     | 58      | –     |  |                    |
| P70      | 144     | I/O   | Port 7<br>16-bit I/O port<br>Input/output can be specified in 1-bit units.   | ANI0               |
| P71      | 143     |       |  | ANI1               |
| P72      | 142     |       |  | ANI2               |
| P73      | 141     |       |  | ANI3               |
| P74      | 140     |       |  | ANI4               |
| P75      | 139     |       |  | ANI5               |
| P76      | 138     |       |  | ANI6               |
| P77      | 137     |       |  | ANI7               |
| P78      | 136     |       |  | ANI8               |
| P79      | 135     |       |  | ANI9               |
| P710     | 134     |       |  | ANI10              |
| P711     | 133     |       |  | ANI11              |
| P712     | 132     |       |  | ANI12              |
| P713     | 131     |       |  | ANI13              |
| P714     | 130     |       |  | ANI14              |
| P715     | 129     | ANI15 |  |                    |
| P80      | 59      | I/O   | Port 8<br>2-bit I/O port<br>Input/output can be specified in 1-bit units.<br>N-ch open-drain output can be specified in 1-bit units.<br>5 V tolerant.  | RXDA3/INTP8        |
| P81      | 60      |       |  | TXDA3              |

| Pin Name | Pin No. | I/O                   | Function   | Alternate Function    |
|----------|---------|-----------------------|--|-----------------------|
| P90      | 61      | I/O                   | Port 9<br>16-bit I/O port<br>Input/output can be specified in 1-bit units.<br>N-ch open-drain output can be specified in 1-bit units.<br>5 V tolerant. | A0/KR6/TXDA1/SDA02    |
| P91      | 62      |                       |  | A1/KR7/RXDA1/SCL02    |
| P92      | 63      |                       |  | A2/TIP41/TOP41        |
| P93      | 64      |                       |  | A3/TIP40/TOP40        |
| P94      | 65      |                       |  | A4/TIP31/TOP31        |
| P95      | 66      |                       |  | A5/TIP30/TOP30        |
| P96      | 67      |                       |  | A6/TIP21/TOP21        |
| P97      | 68      |                       |  | A7/SIB1/TIP20/TOP20   |
| P98      | 69      |                       |  | A8/SOB1               |
| P99      | 70      |                       |  | A9/SCKB1              |
| P910     | 71      |                       |  | A10/SIB3              |
| P911     | 72      |                       |  | A11/SOB3              |
| P912     | 73      |                       |  | A12/SCKB3             |
| P913     | 74      |                       |  | A13/INTP4             |
| P914     | 75      |                       |  | A14/INTP5/TIP51/TOP51 |
| P915     | 76      | A15/INTP6/TIP50/TOP50 |  |                       |
| PCD0     | 77      | I/O                   | Port CD<br>4-bit I/O port<br>Input/output can be specified in 1-bit units.   | –                     |
| PCD1     | 78      |                       |  | –                     |
| PCD2     | 79      |                       |  | –                     |
| PCD3     | 80      |                       |  | –                     |
| PCM0     | 85      | I/O                   | Port CM<br>6-bit I/O port<br>Input/output can be specified in 1-bit units.   | WAIT                  |
| PCM1     | 86      |                       |  | CLKOUT                |
| PCM2     | 87      |                       |  | HLDK                  |
| PCM3     | 88      |                       |  | HLDRQ                 |
| PCM4     | 89      |                       |  | –                     |
| PCM5     | 90      |                       |  | –                     |
| PCS0     | 81      | I/O                   | Port CS<br>8-bit I/O port<br>Input/output can be specified in 1-bit units.   | CS0                   |
| PCS1     | 82      |                       |  | CS1                   |
| PCS2     | 83      |                       |  | CS2                   |
| PCS3     | 84      |                       |  | CS3                   |
| PCS4     | 91      |                       |  | –                     |
| PCS5     | 92      |                       |  | –                     |
| PCS6     | 93      |                       |  | –                     |
| PCS7     | 94      |                       |  | –                     |



| Pin Name | Pin No. | I/O | Function  | Alternate Function |
|----------|---------|-----|---|--------------------|
| PCT0     | 95      | I/O | Port CT<br>8-bit I/O port<br>Input/output can be specified in 1-bit units.  | $\overline{WR0}$   |
| PCT1     | 96      |     |   | $\overline{WR1}$   |
| PCT2     | 97      |     |   | –                  |
| PCT3     | 98      |     |   | –                  |
| PCT4     | 99      |     |   | $\overline{RD}$    |
| PCT5     | 100     |     |   | –                  |
| PCT6     | 101     |     |   | ASTB               |
| PCT7     | 102     |     |   | –                  |
| PDH0     | 121     | I/O | Port DH<br>8-bit I/O port<br>Input/output can be specified in 1-bit units.  | A16                |
| PDH1     | 122     |     |   | A17                |
| PDH2     | 123     |     |   | A18                |
| PDH3     | 124     |     |   | A19                |
| PDH4     | 125     |     |   | A20                |
| PDH5     | 126     |     |   | A21                |
| PDH6     | 127     |     |   | A22                |
| PDH7     | 128     |     |   | A23                |
| PDL0     | 105     | I/O | Port DL<br>16-bit I/O port<br>Input/output can be specified in 1-bit units. | AD0                |
| PDL1     | 106     |     |   | AD1                |
| PDL2     | 107     |     |   | AD2                |
| PDL3     | 108     |     |   | AD3                |
| PDL4     | 109     |     |   | AD4                |
| PDL5     | 110     |     |   | AD5/FLMD1          |
| PDL6     | 111     |     |   | AD6                |
| PDL7     | 112     |     |   | AD7                |
| PDL8     | 113     |     |   | AD8                |
| PDL9     | 114     |     |   | AD9                |
| PDL10    | 115     |     |   | AD10               |
| PDL11    | 116     |     |   | AD11               |
| PDL12    | 117     |     |   | AD12               |
| PDL13    | 118     |     |   | AD13               |
| PDL14    | 119     |     |   | AD14               |
| PDL15    | 120     |     |   | AD15               |

(2) Non-port pins

(1/6)

| Pin Name | Pin No. | I/O                    | Function   | Alternate Function     |
|----------|---------|------------------------|--|------------------------|
| A0       | 61      | Output                 | Address bus for external memory<br>(when using separate bus)<br>N-ch open-drain output selectable<br>5 V tolerant. | P90/KR6/TXDA1/SDA02    |
| A1       | 62      |                        |  | P91/KR7/RXDA1/SCL02    |
| A2       | 63      |                        |  | P92/TIP41/TOP41        |
| A3       | 64      |                        |  | P93/TIP40/TOP40        |
| A4       | 65      |                        |  | P94/TIP31/TOP31        |
| A5       | 66      |                        |  | P95/TIP30/TOP30        |
| A6       | 67      |                        |  | P96/TIP21/TOP21        |
| A7       | 68      |                        |  | P97/SIB1/TIP20/TOP20   |
| A8       | 69      |                        |  | P98/SOB1               |
| A9       | 70      |                        |  | P99/SCKB1              |
| A10      | 71      |                        |  | P910/SIB3              |
| A11      | 72      |                        |  | P911/SOB3              |
| A12      | 73      |                        |  | P912/SCKB3             |
| A13      | 74      |                        |  | P913/INTP4             |
| A14      | 75      |                        |  | P914/INTP5/TIP51/TOP51 |
| A15      | 76      | P915/INTP6/TIP50/TOP50 |  |                        |
| A16      | 121     | Output                 | Address bus for external memory  | PDH0                   |
| A17      | 122     |                        |  | PDH1                   |
| A18      | 123     |                        |  | PDH2                   |
| A19      | 124     |                        |  | PDH3                   |
| A20      | 125     |                        |  | PDH4                   |
| A21      | 126     |                        |  | PDH5                   |
| A22      | 127     |                        |  | PDH6                   |
| A23      | 128     |                        |  | PDH7                   |
| AD0      | 105     | I/O                    | Address bus/data bus for external memory   | PDL0                   |
| AD1      | 106     |                        |  | PDL1                   |
| AD2      | 107     |                        |  | PDL2                   |
| AD3      | 108     |                        |  | PDL3                   |
| AD4      | 109     |                        |  | PDL4                   |
| AD5      | 110     |                        |  | PDL5/FLMD1             |
| AD6      | 111     |                        |  | PDL6                   |
| AD7      | 112     |                        |  | PDL7                   |
| AD8      | 113     |                        |  | PDL8                   |
| AD9      | 114     |                        |  | PDL9                   |
| AD10     | 115     |                        |  | PDL10                  |
| AD11     | 116     |                        |  | PDL11                  |
| AD12     | 117     |                        |  | PDL12                  |
| AD13     | 118     |                        |  | PDL13                  |
| AD14     | 119     |                        |  | PDL14                  |
| AD15     | 120     | PDL15                  |  |                        |
| ADTRG    | 18      | Input                  | A/D converter external trigger input, 5 V tolerant   | P03/INTP0              |

| Pin Name            | Pin No. | I/O    | Function  | Alternate Function                 |
|---------------------|---------|--------|---|------------------------------------|
| ANI0                | 144     | Input  | Analog voltage input for A/D converter  | P70                                |
| ANI1                | 143     |        |   | P71                                |
| ANI2                | 142     |        |   | P72                                |
| ANI3                | 141     |        |   | P73                                |
| ANI4                | 140     |        |   | P74                                |
| ANI5                | 139     |        |   | P75                                |
| ANI6                | 138     |        |   | P76                                |
| ANI7                | 137     |        |   | P77                                |
| ANI8                | 136     |        |   | P78                                |
| ANI9                | 135     |        |   | P79                                |
| ANI10               | 134     |        |   | P710                               |
| ANI11               | 133     |        |   | P711                               |
| ANI12               | 132     |        |   | P712                               |
| ANI13               | 131     |        |   | P713                               |
| ANI14               | 130     |        |   | P714                               |
| ANI15               | 129     | P715   |   |                                    |
| ANO0                | 3       | Output | Analog voltage output for D/A converter   | P10                                |
| ANO1                | 4       |        |   | P11                                |
| ASCKA0              | 27      | Input  | UARTA0 baud rate clock input, 5 V tolerant  | P32/SCKB4/TIP00/TOP00              |
| ASTB                | 101     | Output | Address strobe signal output for external memory  | PCT6                               |
| AV <sub>REF0</sub>  | 1       | –      | Reference voltage input for A/D converter,<br>positive power supply for alternate-function port 7 | –                                  |
| AV <sub>REF1</sub>  | 5       |        | Reference voltage input for D/A converter,<br>positive power supply for alternate-function port 1 | –                                  |
| AV <sub>SS</sub>    | 2       | –      | Ground potential for A/D and D/A converters<br>(same potential as V <sub>SS</sub> )               | –                                  |
| CLKOUT              | 86      | Output | Internal system clock output  | PCM1                               |
| $\overline{CS0}$    | 81      | Output | Chip select output  | PCS0                               |
| $\overline{CS1}$    | 82      |        |   | PCS1                               |
| $\overline{CS2}$    | 83      |        |   | PCS2                               |
| $\overline{CS3}$    | 84      |        |   | PCS3                               |
| DCK                 | 41      | Input  | Debug clock input, 5 V tolerant   | P54/SOB2/KR4/RTP04                 |
| DDI                 | 39      | Input  | Debug data input, 5 V tolerant  | P52/TIQ03/KR2/TOQ03/RTP02          |
| DDO <sup>Note</sup> | 40      | Output | Debug data output<br>N-ch open-drain output selectable, 5 V tolerant                              | P53/SIB2/KR3/TIQ00/TOQ00/<br>RTP03 |
| DMS                 | 42      | Input  | Debug mode select input, 5 V tolerant   | P55/SCKB2/KR5/RTP05                |
| $\overline{DRST}$   | 20      | Input  | Debug reset input, 5 V tolerant   | P05/INTP2                          |
| EV <sub>DD</sub>    | 34, 104 | –      | Positive power supply for external (same potential as V <sub>DD</sub> )                           | –                                  |
| EV <sub>SS</sub>    | 33, 103 | –      | Ground potential for external (same potential as V <sub>SS</sub> )                                | –                                  |
| FLMD0               | 8       | Input  | Flash memory programming mode setting pin   | –                                  |
| FLMD1               | 110     |        |   | PDL5/AD5                           |

**Note** In the on-chip debug mode, high-level output is forcibly set.

| Pin Name                   | Pin No. | I/O    | Function  | Alternate Function                        |
|----------------------------|---------|--------|---|---|
| H $\overline{\text{LDAK}}$ | 87      | Output | Bus hold acknowledge output   | PCM2                                      |
| H $\overline{\text{LDRQ}}$ | 88      | Input  | Bus hold request input  | PCM3                                      |
| INTP0                      | 18      | Input  | External interrupt request input (maskable, analog noise elimination). Analog noise elimination/digital noise elimination selectable for the INTP3 pin.<br>5 V tolerant | P03/ADTRG                                 |
| INTP1                      | 19      |        |   | P04                                       |
| INTP2                      | 20      |        |   | P05/ $\overline{\text{DRST}}$             |
| INTP3                      | 21      |        |   | P06                                       |
| INTP4                      | 74      |        |   | P913/A13                                  |
| INTP5                      | 75      |        |   | P914/A14/TIP51/TOP51                      |
| INTP6                      | 76      |        |   | P915/A15/TIP50/TOP50                      |
| INTP7                      | 26      |        |   | P31/RXDA0/SIB4                            |
| INTP8                      | 59      |        |   | P80/RXDA3                                 |
| KR0 <sup>Note 1</sup>      | 37      | Input  | Key interrupt input (on-chip analog noise eliminator)<br>5 V tolerant   | P50/TIQ01/TOQ01/RTP00                     |
| KR1 <sup>Note 1</sup>      | 38      |        |   | P51/TIQ02/TOQ02/RTP01                     |
| KR2 <sup>Note 1</sup>      | 39      |        |   | P52/TIQ03/TOQ03/RTP02/DDI                 |
| KR3 <sup>Note 1</sup>      | 40      |        |   | P53/SIB2/TIQ00/TOQ00/RTP03/DDO            |
| KR4 <sup>Note 1</sup>      | 41      |        |   | P54/SOB2/RTP04/DCK                        |
| KR5 <sup>Note 1</sup>      | 42      |        |   | P55/ $\overline{\text{SCKB2}}$ /RTP05/DMS |
| KR6 <sup>Note 1</sup>      | 61      |        |   | P90/A0/TXDA1/SDA02                        |
| KR7 <sup>Note 1</sup>      | 62      |        |   | P91/A1/RXDA1/SCL02                        |
| NMI <sup>Note 2</sup>      | 17      | Input  | External interrupt input (non-maskable, analog noise elimination)<br>5 V tolerant   | P02                                       |
| R $\overline{\text{D}}$    | 99      | Output | Read strobe signal output for external memory   | PCT4                                      |
| REGC                       | 10      | –      | Connection of regulator output stabilization capacitance (4.7 $\mu\text{F}$ (preliminary value))  | –   |
| R $\overline{\text{ESET}}$ | 14      | Input  | System reset input  | –   |
| RTP00                      | 37      | Output | Real-time output port<br>N-ch open-drain output selectable<br>5 V tolerant  | P50/TIQ01/KR0/TOQ01                       |
| RTP01                      | 38      |        |   | P51/TIQ02/KR1/TOQ02                       |
| RTP02                      | 39      |        |   | P52/TIQ03/KR2/TOQ03/DDI                   |
| RTP03                      | 40      |        |   | P53/SIB2/KR3/TIQ00/TOQ00/DDO              |
| RTP04                      | 41      |        |   | P54/SOB2/KR4/DCK                          |
| RTP05                      | 42      |        |   | P55/ $\overline{\text{SCKB2}}$ /KR5/DMS   |
| RTP10                      | 43      |        |   | P60                                       |
| RTP11                      | 44      |        |   | P61                                       |
| RTP12                      | 45      |        |   | P62                                       |
| RTP13                      | 46      |        |   | P63                                       |
| RTP14                      | 47      |        |   | P64                                       |
| RTP15                      | 48      |        |   | P65                                       |

**Notes 1.** Connect a pull-up resistor externally.

- 2.** The NMI pin alternately functions as the P02 pin. It functions as the P02 pin after reset. To enable the NMI pin, set the PMC0.PMC02 bit to 1. The initial setting of the NMI pin is "No edge detected". Select the NMI pin valid edge using INTF0 and INTR0 registers.

| Pin Name | Pin No. | I/O    | Function   | Alternate Function                |
|----------|---------|--------|--|-----------------------------------|
| RXDA0    | 26      | Input  | Serial receive data input (UARTA0 to UARTA3)<br>5 V tolerant   | P31/INTP7/SIB4                    |
| RXDA1    | 62      |        |  | P91/A1/KR7/SCL02                  |
| RXDA2    | 36      |        |  | P39/SCL00                         |
| RXDA3    | 59      |        |  | P80/INTP8                         |
| SCKB0    | 24      | I/O    | Serial clock I/O (CSIB0 to CSIB5)<br>N-ch open-drain output selectable<br>5 V tolerant   | P42                               |
| SCKB1    | 70      |        |  | P99/A9                            |
| SCKB2    | 42      |        |  | P55/KR5/RTP05/DMS                 |
| SCKB3    | 73      |        |  | P912/A12                          |
| SCKB4    | 27      |        |  | P32/ASCKA0/TIP00/TOP00            |
| SCKB5    | 51      |        |  | P68                               |
| SCL00    | 36      | I/O    | Serial clock I/O (I <sup>2</sup> C00 to I <sup>2</sup> C02)<br>N-ch open-drain output selectable<br>5 V tolerant                 | P39/RXDA2                         |
| SCL01    | 23      |        |  | P41/SOB0                          |
| SCL02    | 62      |        |  | P91/A1/KR7/RXDA1                  |
| SDA00    | 35      | I/O    | Serial transmit/receive data I/O (I <sup>2</sup> C00 to I <sup>2</sup> C02)<br>N-ch open-drain output selectable<br>5 V tolerant | P38/TXDA2                         |
| SDA01    | 22      |        |  | P40/SIB0                          |
| SDA02    | 61      |        |  | P90/A0/KR6/TXDA1                  |
| SIB0     | 22      | Input  | Serial receive data input (CSIB0 to CSIB5)<br>5 V tolerant   | P40/SDA01                         |
| SIB1     | 68      |        |  | P97/A7/TIP20/TOP20                |
| SIB2     | 40      |        |  | P53/KR3/TIQ00/TOQ00/RTP03/<br>DDO |
| SIB3     | 71      |        |  | P910/A10                          |
| SIB4     | 26      |        |  | P31/RXDA0/INTP7                   |
| SIB5     | 49      |        |  | P66                               |
| SOB0     | 23      | Output | Serial transmit data output (CSIB0 to CSIB5)<br>N-ch open-drain output selectable<br>5 V tolerant                                | P41/SCL01                         |
| SOB1     | 69      |        |  | P98/A8                            |
| SOB2     | 41      |        |  | P54/KR4/RTP04/DCK                 |
| SOB3     | 72      |        |  | P911/A11                          |
| SOB4     | 25      |        |  | P30/TXDA0                         |
| SOB5     | 50      |        |  | P67                               |
| TIP00    | 27      | Input  | External event count input/capture trigger input/external<br>trigger input (TMP0), 5 V tolerant                                  | P32/ASCKA0/SCKB4/TOP00            |
| TIP01    | 28      |        |  | P33/TOP01                         |
| TIP10    | 29      |        |  | P34/TOP10                         |
| TIP11    | 30      |        |  | P35/TOP11                         |
| TIP20    | 68      |        |  | P97/A7/SIB1/TOP20                 |
| TIP21    | 67      |        |  | P96/A6/TOP21                      |
| TIP30    | 66      |        |  | P95/A5/TOP30                      |
| TIP31    | 65      |        |  | P94/A4/TOP31                      |
| TIP40    | 64      |        |  | P93/A3/TOP40                      |

| Pin Name | Pin No. | I/O  | Function  | Alternate Function   |
|----------|---------|--|---|--|
| TIP41    | 63      | Input  | Capture trigger input (TMP4), 5 V tolerant  | P92/A2/TOP41   |
| TIP50    | 76      |  | External event count input/capture trigger input/external trigger input (TMP5), 5 V tolerant        | P915/A15/INTP6/TOP50   |
| TIP51    | 75      |  | Capture trigger input (TMP5), 5 V tolerant  | P914/A14/INTP5/TOP51   |
| TIP60    | 7       |  | External event count input/capture trigger input/external trigger input (TMP6), 5 V tolerant        | P01/TOP60  |
| TIP61    | 6       |  | Capture trigger input (TMP6), 5 V tolerant  | P00/TOP61  |
| TIP70    | 52      |  | External event count input/capture trigger input/external trigger input (TMP7), 5 V tolerant        | P69/TOP70  |
| TIP71    | 53      |  | Capture trigger input (TMP7), 5 V tolerant  | P610   |
| TIP80    | 55      |  | External event count input/capture trigger input/external trigger input (TMP8), 5 V tolerant        | P612/TOP80   |
| TIP81    | 56      |  | Capture trigger input (TMP8), 5 V tolerant  | P613/TOP81   |
| TIQ00    | 40      |  | External event count input/capture trigger input/external trigger input (TMQ0), 5 V tolerant        | P53/SIB2/KR3/TOQ00/RTP03/DDO   |
| TIQ01    | 37      |  | Capture trigger input (TMQ0), 5V tolerant   | P50/KR0/TOQ01/RTP00  |
| TIQ02    | 38      |  |   | P51/KR1/TOQ02/RTP01  |
| TIQ03    | 39      |  |   | P52/KR2/TOQ03/RTP02/DDI  |
| TOP00    | 27      |  | Output  | Timer output (TMP0)<br>N-ch open-drain output selectable, 5 V tolerant |
| TOP01    | 28      | P33/TIP01  |   |  |
| TOP10    | 29      | Timer output (TMP1)<br>N-ch open-drain output selectable, 5 V tolerant |   | P34/TIP10  |
| TOP11    | 30      | P35/TIP11  |   |  |
| TOP20    | 68      | Timer output (TMP2)<br>N-ch open-drain output selectable, 5 V tolerant |   | P97/A7/SIB1/TIP20  |
| TOP21    | 67      | P96/A6/TIP21   |   |  |
| TOP30    | 66      | Timer output (TMP3)<br>N-ch open-drain output selectable, 5 V tolerant |   | P95/A5/TIP30   |
| TOP31    | 65      | P94/A4/TIP31   |   |  |
| TOP40    | 64      | Timer output (TMP4)<br>N-ch open-drain output selectable, 5 V tolerant |   | P93/A3/TIP40   |
| TOP41    | 63      | P92/A2/TIP41   |   |  |
| TOP50    | 76      | Timer output (TMP5)<br>N-ch open-drain output selectable, 5 V tolerant |   | P915/A15/INTP6/TIP50   |
| TOP51    | 75      | P914/A14/INTP5/TIP51   |   |  |
| TOP60    | 7       | Timer output (TMP6)<br>N-ch open-drain output selectable, 5 V tolerant |   | P01/TIP60  |
| TOP61    | 6       | P00/TIP61  |   |  |
| TOP70    | 52      | Timer output (TMP7)<br>N-ch open-drain output selectable, 5 V tolerant |   | P69/TIP70  |
| TOP71    | 54      | P611   |   |  |
| TOP80    | 55      | Timer output (TMP8)<br>N-ch open-drain output selectable, 5 V tolerant |   | P612/TIP80   |
| TOP81    | 56      | P613/TIP81   |   |  |
| TOQ00    | 40      | Output   | Timer output (TMQ0)<br>N-ch open-drain output selectable<br>5 V tolerant                            | P53/SIB2/KR3/TOQ00/RTP03/DDO   |
| TOQ01    | 37      |  | P50/TOQ01/KR0/RTP00   |  |
| TOQ02    | 38      |  | P51/RTP01/KR1/TOQ02   |  |
| TOQ03    | 39      |  | P52/TOQ03/KR2/RTP02/DDI   |  |
| TXDA0    | 25      | Output   | Serial transmit data output (UARTA0 to UARTA3)<br>N-ch open-drain output selectable<br>5 V tolerant | P30/SOB4   |
| TXDA1    | 61      |  | P90/A0/KR6/SDA02  |  |
| TXDA2    | 35      |  | P38/SDA00   |  |
| TXDA3    | 60      |  | P81   |  |

| Pin Name                 | Pin No. | I/O    | Function   | Alternate Function |
|--------------------------|---------|--------|--|--------------------|
| V <sub>DD</sub>          | 9       | –      | Positive power supply pin for internal           | –                  |
| V <sub>SS</sub>          | 11      | –      | Ground potential for internal                    | –                  |
| $\overline{\text{WAIT}}$ | 85      | Input  | External wait input                              | PCM0               |
| $\overline{\text{WR0}}$  | 95      | Output | Write strobe for external memory (lower 8 bits)  | PCT0               |
| $\overline{\text{WR1}}$  | 96      |        | Write strobe for external memory (higher 8 bits) | PCT1               |
| X1                       | 12      | Input  | Connection of resonator for main clock           | –                  |
| X2                       | 13      | –      |  | –                  |
| XT1                      | 15      | Input  | Connection of resonator for subclock             | –                  |
| XT2                      | 16      |        |  | –                  |

## 2.2 Pin States

The operation states of pins in the various modes are described below.

**Table 2-2. Pin Operation States in Various Modes**

| Pin Name           | When Power Is Turned On <sup>Note 1</sup> | During Reset (Except When Power Is Turned On) | HALT Mode <sup>Note 2</sup>     | IDLE1, IDLE2, Sub-IDLE Mode <sup>Note 2</sup> | STOP Mode <sup>Note 2</sup> | Idle State <sup>Note 3</sup> | Bus Hold |   |   |           |           |
|--------------------|---|---|---------------------------------|---|-----------------------------|------------------------------|----------|---|---|-----------|-----------|
| P05/DRST           | Pulled down                               | Pulled down <sup>Note 4</sup>                 | Held                            | Held  | Held                        | Held                         | Held     |   |   |           |           |
| P10/ANO0, P11/ANO1 | Hi-Z                                      | Hi-Z  | Held                            | Held  | Hi-Z                        | Held                         | Held     |   |   |           |           |
| P53/DDO            | Undefined                                 | Hi-Z <sup>Note 5</sup>                        | Held                            | Held  | Held                        | Held                         | Held     |   |   |           |           |
| AD0 to AD15        | Hi-Z <sup>Note 6</sup>                    | Hi-Z <sup>Note 6</sup>                        | <b>Notes 7, 8</b>               | Hi-Z  | Hi-Z                        | Held                         | Hi-Z     |   |   |           |           |
| A0 to A15          |   |   | Undefined <sup>Notes 7, 9</sup> |   |                             |                              |          |   |   |           |           |
| A16 to A23         |   |   | Undefined <sup>Note 7</sup>     |   |                             |                              |          |   |   |           |           |
| WAIT               |   |   | –                               |   |                             |                              |          |   |   |           |           |
| CLKOUT             |   |   | Operating                       |   |                             |                              |          | L | L | Operating | Operating |
| WR0, WR1           |   |   | H <sup>Note 7</sup>             |   |                             |                              |          | H | H | H         | Hi-Z      |
| RD                 |   |   |                                 |   |                             |                              |          |   |   |           |           |
| ASTB               |   |   |                                 |   |                             |                              |          |   |   |           |           |
| HLDK               |   |   |                                 |   |                             |                              |          |   |   |           |           |
| HLDK               |   |   | Operating <sup>Note 7</sup>     |   |                             |                              |          | – | – | –         | Operating |
| HLDK               |   |   | Operating <sup>Note 7</sup>     |   |                             |                              |          | – | – | –         | Operating |
| HLDK               | Operating <sup>Note 7</sup>               | –   | –                               | –   | Operating                   |                              |          |   |   |           |           |
| CS0 to CS3         | H <sup>Note 7</sup>                       | H   | H                               | H   | Held                        | Hi-Z                         |          |   |   |           |           |
| Other port pins    | Hi-Z                                      | Hi-Z  | Held                            | Held  | Held                        | Held                         | Held     |   |   |           |           |

- Notes**
- Duration until 1 ms elapses after the supply voltage reaches the operating supply voltage range (lower limit) when the power is turned on.
  - Operates while alternate functions are operating.
  - In separate bus mode, the state of the pins in the idle state inserted after the T2 state is shown. In multiplexed bus mode, the state of the pins in the idle state inserted after the T3 state is shown.
  - Pulled down during external reset. During internal reset by the watchdog timer, clock monitor, etc., the state of this pin differs according to the OCDM.OCDM0 bit setting.
  - DDO output is specified in the on-chip debug mode.
  - The bus control pins function alternately as port pins, so they are initialized to the input mode (port mode).
  - Operates even in the HALT mode, during DMA operation.
  - In separate bus mode: Hi-Z  
In multiplexed bus mode: Undefined
  - In separate bus mode

**Remark**

Hi-Z: High impedance  
Held: The state during the immediately preceding external bus cycle is held.  
L: Low-level output  
H: High-level output  
–: Input without sampling (not acknowledged)



## 2.3 Pin I/O Circuit Types, I/O Buffer Power Supplies and Connection of Unused Pins

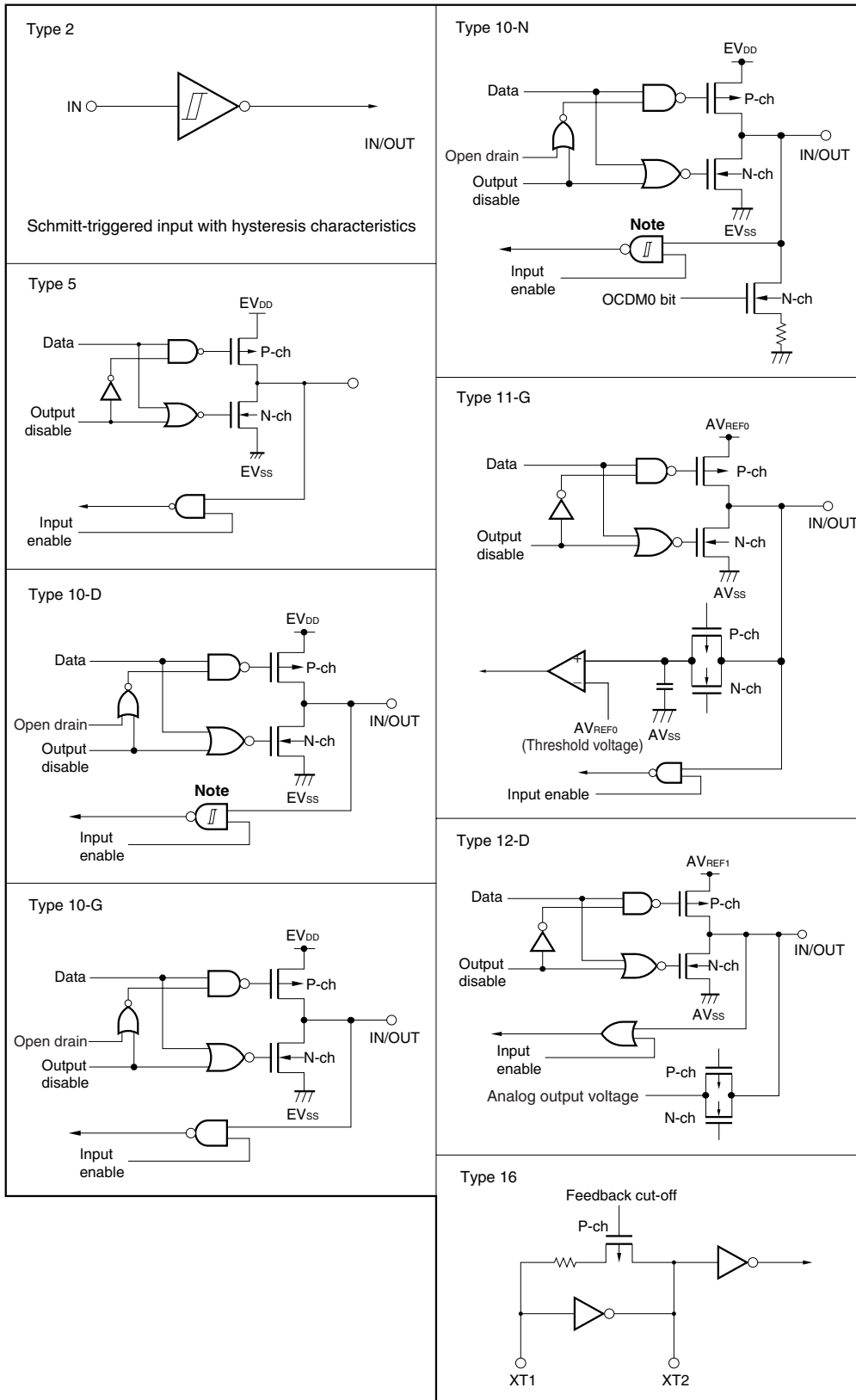
(1/3)

| Pin      | Alternate Function                       | Pin No. | I/O Circuit Type | Recommended Connection  |
|----------|--|---------|------------------|---|
| P00      | TIP61/TOP61                              | 6       | 10-D             | Input: Independently connect to EV <sub>DD</sub> or EV <sub>SS</sub> via a resistor.<br>Output: Leave open.   |
| P01      | TIP60/TOP60                              | 7       |                  |   |
| P02      | NMI                                      | 17      |                  |   |
| P03      | INTP0/ADTRG                              | 18      |                  |   |
| P04      | INTP1                                    | 19      |                  |   |
| P05      | INTP2/ $\overline{\text{DRST}}$          | 20      | 10-N             | Input: Independently connect to EV <sub>SS</sub> via a resistor.<br>Fixing to V <sub>DD</sub> level is prohibited.<br>Output: Leave open.<br>Internally pull-down after reset by $\overline{\text{RESET}}$ pin. |
| P06      | INTP3                                    | 21      | 10-D             | Input: Independently connect to EV <sub>DD</sub> or EV <sub>SS</sub> via a resistor.<br>Output: Leave open.   |
| P10, P11 | ANO0, ANO1                               | 3, 4    | 12-D             | Input: Independently connect to AV <sub>REF1</sub> or AV <sub>SS</sub> via a resistor.<br>Output: Leave open.   |
| P30      | TXDA0/SOB4                               | 25      | 10-G             | Input: Independently connect to EV <sub>DD</sub> or EV <sub>SS</sub> via a resistor.<br>Output: Leave open.   |
| P31      | RXDA0/INTP7/SIB4                         | 26      | 10-D             |   |
| P32      | ASCKA0/SCKB4/TIP00                       | 27      |                  |   |
| P33      | TIP01/TOP01                              | 28      |                  |   |
| P34      | TIP10/TOP10                              | 29      |                  |   |
| P35      | TIP11/TOP11                              | 30      |                  |   |
| P36      | –  | 31      | 10-G             |   |
| P37      | –  | 32      |                  |   |
| P38      | TXDA2/SDA00                              | 35      | 10-D             |   |
| P39      | RXDA2/SCL00                              | 36      |                  |   |
| P40      | SIB0/SDA01                               | 22      |                  |   |
| P41      | SOB0/SCL01                               | 23      |                  |   |
| P42      | SCKB0                                    | 24      |                  |   |
| P50      | TIQ01/KR0/TOQ01/RTP00                    | 37      |                  |   |
| P51      | TIQ02/KR1/TOQ02/RTP01                    | 38      |                  |   |
| P52      | TIQ03/KR2/TOQ03/RTP02/DDI                | 39      |                  |   |
| P53      | SIB2/KR3/TIQ00/TOQ00/RTP03/DDO           | 40      |                  |   |
| P54      | SOB2/KR4/RTP04/DCK                       | 41      |                  |   |
| P55      | $\overline{\text{SCKB2}}$ /KR5/RTP05/DMS | 42      |                  |   |

| Pin          | Alternate Function                   | Pin No.    | I/O Circuit Type | Recommended Connection  |
|--------------|--------------------------------------|------------|------------------|---|
| P60 to P65   | RTP10 to RTP15                       | 43 to 48   | 10-G             | Input: Independently connect to EV <sub>DD</sub> or EV <sub>SS</sub> via a resistor.<br>Output: Leave open.   |
| P66          | SIB5                                 | 49         | 10-D             |   |
| P67          | SOB5                                 | 50         | 10-G             |   |
| P68          | $\overline{SCKB5}$                   | 51         | 10-D             |   |
| P69          | TIP70/TOP70                          | 52         |                  |   |
| P610         | TIP71                                | 53         | 10-G             |   |
| P611         | TOP71                                | 54         |                  |   |
| P612         | TIP80/TOP80                          | 55         | 10-D             |   |
| P613         | TIP81/TOP81                          | 56         |                  |   |
| P614, P615   | –                                    | 57, 58     | 10-G             |   |
| P70 to P715  | ANI0 to ANI15                        | 144 to 129 | 11-G             | Input: Independently connect to AV <sub>REF0</sub> or AV <sub>SS</sub> via a resistor.<br>Output: Leave open. |
| P80          | RXDA3, INTP8                         | 59         | 10-D             | Input: Independently connect to EV <sub>DD</sub> or EV <sub>SS</sub> via a resistor.<br>Output: Leave open.   |
| P81          | TXDA3                                | 60         | 10-G             |   |
| P90          | A0/KR6/TDXA1/SDA02                   | 61         | 10-D             |   |
| P91          | A1/KR7/RXDA1/SCL02                   | 62         |                  |   |
| P92          | A2/TIP41/TOP41                       | 63         |                  |   |
| P93          | A3/TIP40/TOP40                       | 64         |                  |   |
| P94          | A4/TIP31/TOP31                       | 65         |                  |   |
| P95          | A5/TIP30/TOP30                       | 66         |                  |   |
| P96          | A6/TIP21/TOP21                       | 67         |                  |   |
| P97          | A7/SIB1/TIP20/TOP20                  | 68         |                  |   |
| P98          | A8/SOB1                              | 69         | 10-G             |   |
| P99          | A9/ $\overline{SCKB1}$               | 70         | 10-D             |   |
| P910         | A10/SIB3                             | 71         | 10-G             |   |
| P911         | A11/SOB3                             | 72         |                  |   |
| P912         | A12/ $\overline{SCKB3}$              | 73         | 10-D             |   |
| P913         | A13/INTP4                            | 74         |                  |   |
| P914         | A14/INTP5/TIP51/TOP51                | 75         |                  |   |
| P915         | A15/INTP6/TIP50/TOP50                | 76         |                  |   |
| PCD0 to PCD3 | –                                    | 77 to 80   | 5                |   |
| PCM0         | $\overline{WAIT}$                    | 85         |                  |   |
| PCM1         | CLKOUT                               | 86         |                  |   |
| PCM2         | $\overline{HLDAK}$                   | 87         |                  |   |
| PCM3         | $\overline{HLDRQ}$                   | 88         |                  |   |
| PCM4, PCM5   | –                                    | 89, 90     |                  |   |
| PCS0 to PCS3 | $\overline{CS0}$ to $\overline{CS3}$ | 81 to 84   |                  |   |
| PCS4 to PCS7 | –                                    | 91 to 94   |                  |   |

| Pin                | Alternate Function               | Pin No.    | I/O Circuit Type | Recommended Connection  |
|--------------------|----------------------------------|------------|------------------|---|
| PCT0, PCT1         | $\overline{WR0}, \overline{WR1}$ | 95, 96     | 5                | Input: Independently connect to $EV_{DD}$ or $EV_{SS}$ via a resistor.<br>Output: Leave open. |
| PCT2, PCT3         | –                                | 97, 98     |                  |   |
| PCT4               | $\overline{RD}$                  | 99         |                  |   |
| PCT5               | –                                | 100        |                  |   |
| PCT6               | ASTB                             | 101        |                  |   |
| PCT7               | –                                | 102        |                  |   |
| PDH0 to PDH7       | A16 to A23                       | 121 to 128 |                  |   |
| PDL0 to PDL4       | AD0 to AD4                       | 105 to 109 |                  |   |
| PDL5               | AD5/FLMD1                        | 110        |                  |   |
| PDL6 to PDL15      | AD6 to AD15                      | 111 to 120 |                  |   |
| $AV_{REF0}$        | –                                | 1          | –                | Always connect this pin to the power supply (also in the standby mode).                       |
| $AV_{REF1}$        | –                                | 5          | –                |   |
| $AV_{SS}$          | –                                | 2          | –                | Always connect this pin directly to the ground (also in the standby mode).                    |
| $EV_{DD}$          | –                                | 34, 104    | –                | Always connect this pin to the power supply (also in the standby mode).                       |
| $EV_{SS}$          | –                                | 33, 103    | –                | Always connect this pin to the ground (also in the standby mode).                             |
| FLMD0              | –                                | 8          | –                | Connect to $V_{SS}$ in a mode other than the flash memory programming mode.                   |
| REGC               | –                                | 10         | –                | Connect regulator output stabilization capacitance (4.7 $\mu F$ (preliminary value))          |
| $\overline{RESET}$ | –                                | 14         | 2                | –   |
| $V_{DD}$           | –                                | 9          | –                | Always connect this pin to the power supply (also in the standby mode).                       |
| $V_{SS}$           | –                                | 11         | –                | Always connect this pin directly to the ground (also in the standby mode).                    |
| X1                 | –                                | 12         | –                | –   |
| X2                 | –                                | 13         | –                | –   |
| XT1                | –                                | 15         | 16               | Connect to $V_{SS}$ .   |
| XT2                | –                                | 16         | 16               | Leave open.   |

Figure 2-1. Pin I/O Circuits



**Note** Hysteresis characteristics are not available in port mode.

## 2.4 Cautions

When the power is turned on, the following pin may output an undefined level temporarily, even during reset.

- P53/SIB2/KR3/TIQ00/TOQ00/RTP03/DDO pin

## CHAPTER 3 CPU FUNCTION

The CPU of the V850ES/JJ3 is based on RISC architecture and executes almost all instructions with one clock by using a 5-stage pipeline.

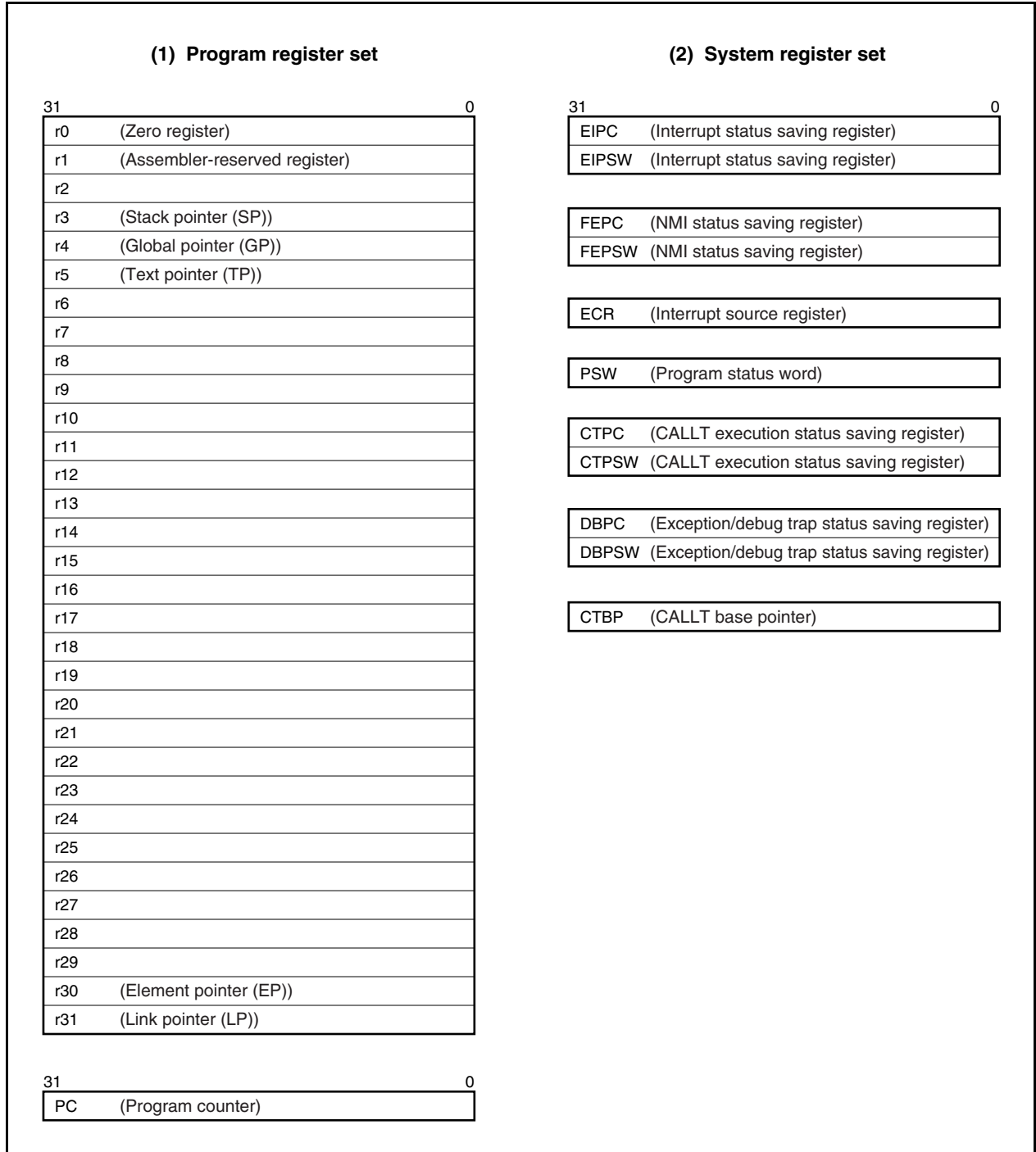
### 3.1 Features

- Minimum instruction execution time: 31.25 ns (at 32 MHz operation)  
30.5  $\mu$ s (with subclock ( $f_{XT}$ ) = 32.768 kHz operation)
- Memory space    Program (physical address) space: 64 MB linear  
                          Data (logical address) space:     4 GB linear
- General-purpose registers: 32 bits  $\times$  32 registers
- Internal 32-bit architecture
- 5-stage pipeline control
- Multiplication/division instruction
- Saturation operation instruction
- 32-bit shift instruction: 1 clock
- Load/store instruction with long/short format
- Four types of bit manipulation instructions
  - SET1
  - CLR1
  - NOT1
  - TST1

### 3.2 CPU Register Set

The registers of the V850ES/JJ3 can be classified into two types: general-purpose program registers and dedicated system registers. All the registers are 32 bits wide.

For details, refer to the **V850ES Architecture User's Manual**.



**3.2.1 Program register set**

The program registers include general-purpose registers and a program counter.

**(1) General-purpose registers (r0 to r31)**

Thirty-two general-purpose registers, r0 to r31, are available. Any of these registers can be used to store a data variable or an address variable.

However, r0 and r30 are implicitly used by instructions and care must be exercised when these registers are used. r0 always holds 0 and is used for an operation that uses 0 or addressing of offset 0. r30 is used by the SLD and SST instructions as a base pointer when these instructions access the memory. r1, r3 to r5, and r31 are implicitly used by the assembler and C compiler. When using these registers, save their contents for protection, and then restore the contents after using the registers. r2 is sometimes used by the real-time OS. If the real-time OS does not use r2, it can be used as a register for variables.

**Table 3-1. Program Registers**

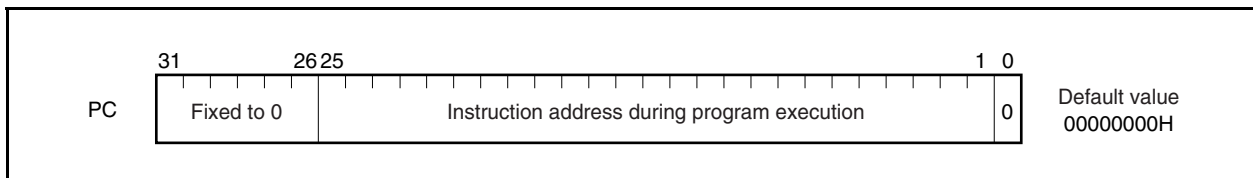
| Name      | Usage  | Operation   |
|-----------|--|---|
| r0        | Zero register  | Always holds 0.   |
| r1        | Assembler-reserved register  | Used as working register to create 32-bit immediate data  |
| r2        | Register for address/data variable (if real-time OS does not use r2) |   |
| r3        | Stack pointer  | Used to create a stack frame when a function is called  |
| r4        | Global pointer   | Used to access a global variable in the data area   |
| r5        | Text pointer   | Used as register that indicates the beginning of a text area (area where program codes are located) |
| r6 to r29 | Register for address/data variable                                   |   |
| r30       | Element pointer  | Used as base pointer to access memory   |
| r31       | Link pointer   | Used when the compiler calls a function   |
| PC        | Program counter  | Holds the instruction address during program execution  |

**Remark** For further details on the r1, r3 to r5, and r31 that are used in the assembler and C compiler, refer to the **CA850 (C Compiler Package) Assembly Language User's Manual**.

**(2) Program counter (PC)**

The program counter holds the instruction address during program execution. The lower 26 bits of this register are valid. Bits 31 to 26 are fixed to 0. A carry from bit 25 to 26 is ignored even if it occurs.

Bit 0 is fixed to 0. This means that execution cannot branch to an odd address.





### 3.2.2 System register set

The system registers control the status of the CPU and hold interrupt information.

These registers can be read or written by using system register load/store instructions (LDSR and STSR), using the system register numbers listed below.

**Table 3-2. System Register Numbers**

| System Register Number | System Register Name   | Operand Specification |                     |
|------------------------|--|-----------------------|---------------------|
|                        |  | LDSR Instruction      | STSR Instruction    |
| 0                      | Interrupt status saving register (EIPC) <sup>Note 1</sup>  | √                     | √                   |
| 1                      | Interrupt status saving register (EIPSW) <sup>Note 1</sup>   | √                     | √                   |
| 2                      | NMI status saving register (FEPC) <sup>Note 1</sup>  | √                     | √                   |
| 3                      | NMI status saving register (FEPSW) <sup>Note 1</sup>   | √                     | √                   |
| 4                      | Interrupt source register (ECR)  | ×                     | √                   |
| 5                      | Program status word (PSW)  | √                     | √                   |
| 6 to 15                | Reserved for future function expansion (operation is not guaranteed if these registers are accessed) | ×                     | ×                   |
| 16                     | CALLT execution status saving register (CTPC)  | √                     | √                   |
| 17                     | CALLT execution status saving register (CTPSW)   | √                     | √                   |
| 18                     | Exception/debug trap status saving register (DBPC)   | √ <sup>Note 2</sup>   | √ <sup>Note 2</sup> |
| 19                     | Exception/debug trap status saving register (DBPSW)  | √ <sup>Note 2</sup>   | √ <sup>Note 2</sup> |
| 20                     | CALLT base pointer (CTBP)  | √                     | √                   |
| 21 to 31               | Reserved for future function expansion (operation is not guaranteed if these registers are accessed) | ×                     | ×                   |

**Notes 1.** Because only one set of these registers is available, the contents of these registers must be saved by program if multiple interrupts are enabled.

**2.** These registers can be accessed only during the interval between the execution of the DBTRAP instruction or illegal opcode and the DBRET instruction.

**Caution** Even if EIPC or FEPC, or bit 0 of CTPC is set to 1 by the LDSR instruction, bit 0 is ignored when execution is returned to the main routine by the RETI instruction after interrupt servicing (this is because bit 0 of the PC is fixed to 0). Set an even value to EIPC, FEPC, and CTPC (bit 0 = 0).

**Remark** √: Can be accessed  
×: Access prohibited

**(1) Interrupt status saving registers (EIPC and EIPSW)**

EIPC and EIPSW are used to save the status when an interrupt occurs.

If a software exception or a maskable interrupt occurs, the contents of the program counter (PC) are saved to EIPC, and the contents of the program status word (PSW) are saved to EIPSW (these contents are saved to the NMI status saving registers (FEPC and FEPSW) if a non-maskable interrupt occurs).

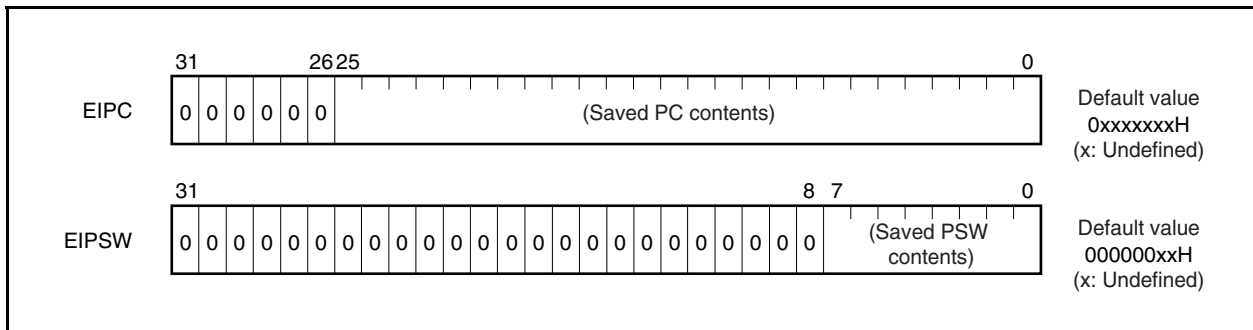
The address of the instruction next to the instruction under execution, except some instructions (see **19.8 Periods in Which Interrupts Are Not Acknowledged by CPU**), is saved to EIPC when a software exception or a maskable interrupt occurs.

The current contents of the PSW are saved to EIPSW.

Because only one set of interrupt status saving registers is available, the contents of these registers must be saved by program when multiple interrupts are enabled.

Bits 31 to 26 of EIPC and bits 31 to 8 of EIPSW are reserved for future function expansion (these bits are always fixed to 0).

The value of EIPC is restored to the PC and the value of EIPSW to the PSW by the RETI instruction.



**(2) NMI status saving registers (FEPC and FEPSW)**

FEPC and FEPSW are used to save the status when a non-maskable interrupt (NMI) occurs.

If an NMI occurs, the contents of the program counter (PC) are saved to FEPC, and those of the program status word (PSW) are saved to FEPSW.

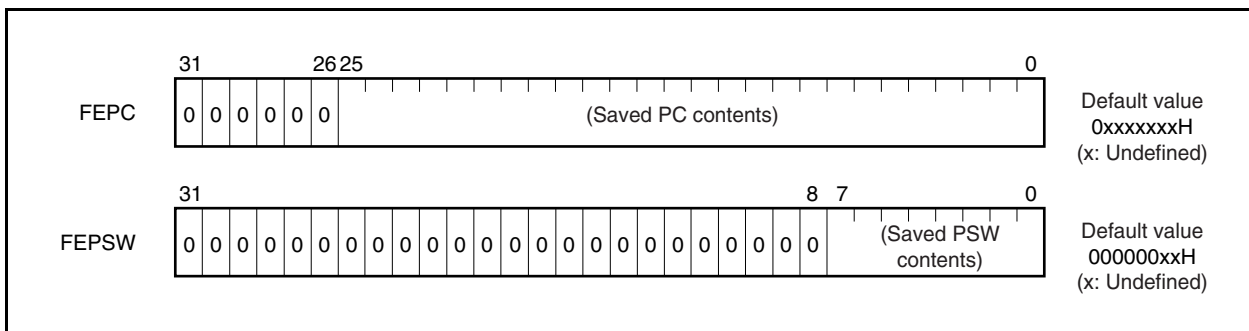
The address of the instruction next to the one of the instruction under execution, except some instructions, is saved to FEPC when an NMI occurs.

The current contents of the PSW are saved to FEPSW.

Because only one set of NMI status saving registers is available, the contents of these registers must be saved by program when multiple interrupts are enabled.

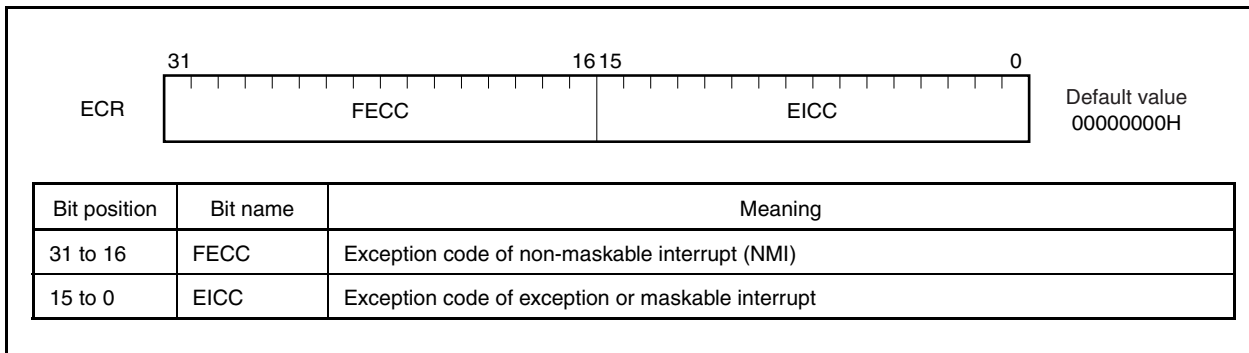
Bits 31 to 26 of FEPC and bits 31 to 8 of FEPSW are reserved for future function expansion (these bits are always fixed to 0).

The value of FEPC is restored to the PC and the value of FEPSW to the PSW by the RETI instruction.



**(3) Interrupt source register (ECR)**

The interrupt source register (ECR) holds the source of an exception or interrupt if an exception or interrupt occurs. This register holds the exception code of each interrupt source. Because this register is a read-only register, data cannot be written to this register using the LDSR instruction.



**(4) Program status word (PSW)**

The program status word (PSW) is a collection of flags that indicate the status of the program (result of instruction execution) and the status of the CPU.

If the contents of a bit of this register are changed by using the LDSR instruction, the new contents are validated immediately after completion of LDSR instruction execution. However if the ID flag is set to 1, interrupt requests will not be acknowledged while the LDSR instruction is being executed.

Bits 31 to 8 of this register are reserved for future function expansion (these bits are fixed to 0).

(1/2)



| Bit position | Flag name           | Meaning  |
|--------------|---------------------|--|
| 31 to 8      | RFU                 | Reserved field. Fixed to 0.  |
| 7            | NP                  | Indicates that a non-maskable interrupt (NMI) is being serviced. This bit is set to 1 when an NMI request is acknowledged, disabling multiple interrupts.<br>0: NMI is not being serviced.<br>1: NMI is being serviced.  |
| 6            | EP                  | Indicates that an exception is being processed. This bit is set to 1 when an exception occurs. Even if this bit is set, interrupt requests are acknowledged.<br>0: Exception is not being processed.<br>1: Exception is being processed.   |
| 5            | ID                  | Indicates whether a maskable interrupt can be acknowledged.<br>0: Interrupt enabled<br>1: Interrupt disabled   |
| 4            | SAT <sup>Note</sup> | Indicates that the result of a saturation operation has overflowed and is saturated. Because this is a cumulative flag, it is set to 1 when the result of a saturation operation instruction is saturated, and is not cleared to 0 even if the subsequent operation result is not saturated. Use the LDSR instruction to clear this bit. This flag is neither set to 1 nor cleared to 0 by execution of an arithmetic operation instruction.<br>0: Not saturated<br>1: Saturated |
| 3            | CY                  | Indicates whether a carry or a borrow occurs as a result of an operation.<br>0: Carry or borrow does not occur.<br>1: Carry or borrow occurs.  |
| 2            | OV <sup>Note</sup>  | Indicates whether an overflow occurs during operation.<br>0: Overflow does not occur.<br>1: Overflow occurs.   |
| 1            | S <sup>Note</sup>   | Indicates whether the result of an operation is negative.<br>0: The result is positive or 0.<br>1: The result is negative.   |
| 0            | Z                   | Indicates whether the result of an operation is 0.<br>0: The result is not 0.<br>1: The result is 0.   |

**Remark** Also read **Note** on the next page.

**Note** The result of the operation that has performed saturation processing is determined by the contents of the OV and S flags. The SAT flag is set to 1 only when the OV flag is set to 1 when a saturation operation is performed.

| Status of Operation Result               | Flag Status                  |    |   | Result of Operation of Saturation Processing |
|--|------------------------------|----|---|--|
|  | SAT                          | OV | S |  |
| Maximum positive value is exceeded       | 1                            | 1  | 0 | 7FFFFFFFH                                    |
| Maximum negative value is exceeded       | 1                            | 1  | 1 | 80000000H                                    |
| Positive (maximum value is not exceeded) | Holds value before operation | 0  | 0 | Operation result itself                      |
| Negative (maximum value is not exceeded) |                              |    | 1 |  |

**(5) CALLT execution status saving registers (CTPC and CTPSW)**

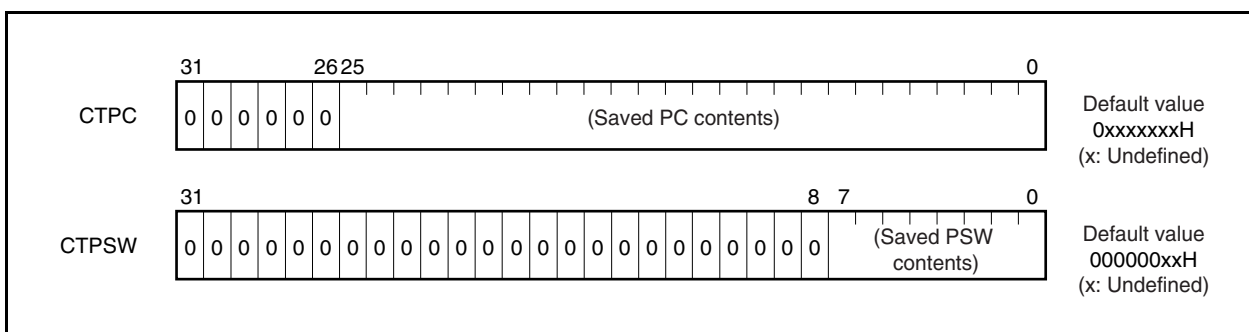
CTPC and CTPSW are CALLT execution status saving registers.

When the CALLT instruction is executed, the contents of the program counter (PC) are saved to CTPC, and those of the program status word (PSW) are saved to CTPSW.

The contents saved to CTPC are the address of the instruction next to CALLT.

The current contents of the PSW are saved to CTPSW.

Bits 31 to 26 of CTPC and bits 31 to 8 of CTPSW are reserved for future function expansion (fixed to 0).



**(6) Exception/debug trap status saving registers (DBPC and DBPSW)**

DBPC and DBPSW are exception/debug trap status registers.

If an exception trap or debug trap occurs, the contents of the program counter (PC) are saved to DBPC, and those of the program status word (PSW) are saved to DBPSW.

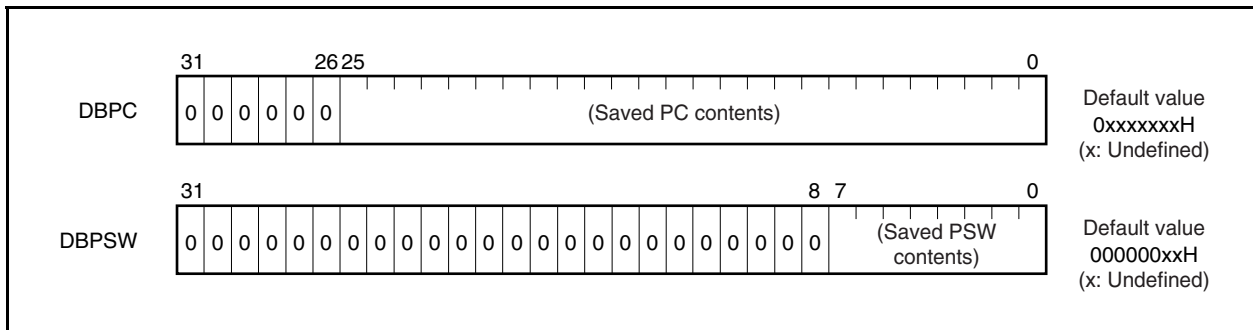
The contents to be saved to DBPC are the address of the instruction next to the one that is being executed when an exception trap or debug trap occurs.

The current contents of the PSW are saved to DBPSW.

These registers can be read or written only during the interval between the execution of the DBTRAP instruction or illegal opcode and the DBRET instruction.

Bits 31 to 26 of DBPC and bits 31 to 8 of DBPSW are reserved for future function expansion (fixed to 0).

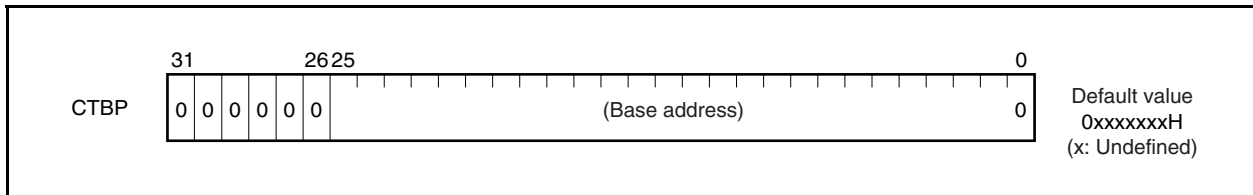
The value of DBPC is restored to the PC and the value of DBPSW to the PSW by the DBRET instruction.



**(7) CALLT base pointer (CTBP)**

The CALLT base pointer (CTBP) is used to specify a table address or generate a target address (bit 0 is fixed to 0).

Bits 31 to 26 of this register are reserved for future function expansion (fixed to 0).



### 3.3 Operation Modes

The V850ES/JJ3 has the following operation modes.

#### (1) Normal operation mode

In this mode, each pin related to the bus interface is set to the port mode after system reset has been released. Execution branches to the reset entry address of the internal ROM, and then instruction processing is started.

#### (2) Flash memory programming mode

In this mode, the internal flash memory can be programmed by using a flash programmer.

#### (3) On-chip debug mode

The V850ES/JJ3 is provided with an on-chip debug function that employs the JTAG (Joint Test Action Group) communication specifications.

For details, see **CHAPTER 28 ON-CHIP DEBUG FUNCTION**.

#### 3.3.1 Specifying operation mode

Specify the operation mode by using the FLMD0 and FLMD1 pins.

In the normal mode, input a low level to the FLMD0 pin when reset is released.

In the flash memory programming mode, a high level is input to the FLMD0 pin from the flash programmer if a flash programmer is connected, but it must be input from an external circuit in the self-programming mode.

| Operation When Reset Is Released |       | Operation Mode After Reset    |
|----------------------------------|-------|-------------------------------|
| FLMD0                            | FLMD1 |                               |
| L                                | ×     | Normal operation mode         |
| H                                | L     | Flash memory programming mode |
| H                                | H     | Setting prohibited            |

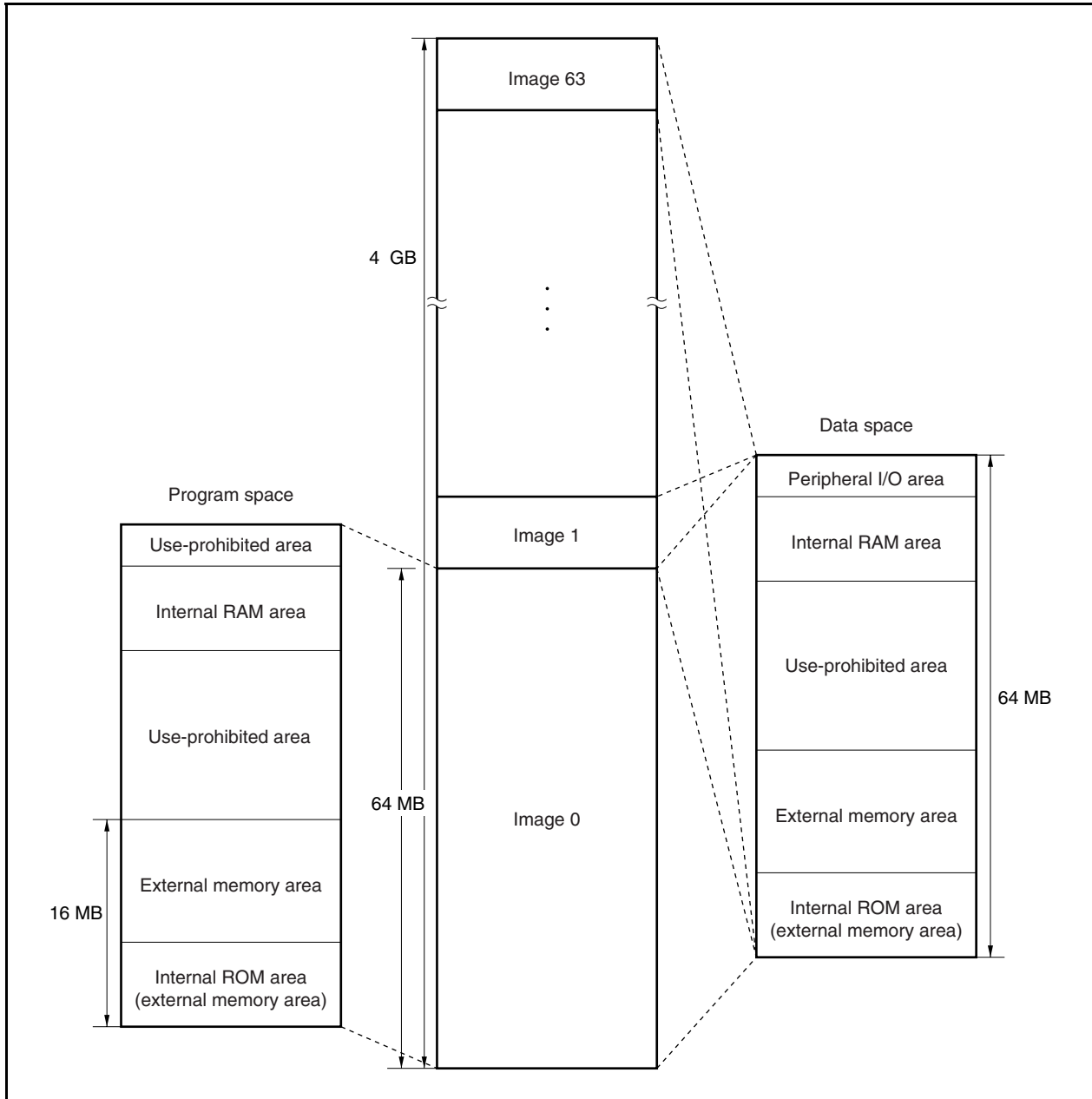
**Remark** L: Low-level input  
H: High-level input  
×: Don't care

### 3.4 Address Space

#### 3.4.1 CPU address space

For instruction addressing, up to a combined total of 16 MB of an external memory area and an internal ROM area, plus an internal RAM area, are supported in a linear address space (program space) of up to 64 MB. For operand addressing (data access), up to 4 GB of a linear address space (data space) is supported. The 4 GB address space, however, is viewed as 64 images of a 64 MB physical address space. This means that the same 64 MB physical address space is accessed regardless of the value of bits 31 to 26.

Figure 3-1. Image on Address Space





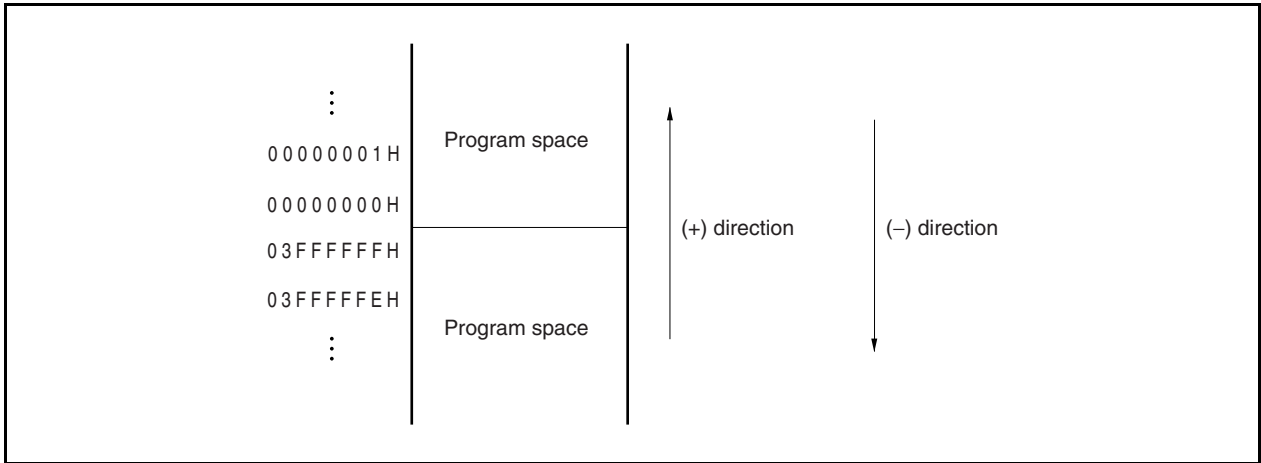
3.4.2 Wraparound of CPU address space

(1) Program space

Of the 32 bits of the PC (program counter), the higher 6 bits are fixed to 0 and only the lower 26 bits are valid. The higher 6 bits ignore a carry or borrow from bit 25 to 26 during branch address calculation.

Therefore, the highest address of the program space, 03FFFFFFH, and the lowest address, 00000000H, are contiguous addresses. That the highest address and the lowest address of the program space are contiguous in this way is called wraparound.

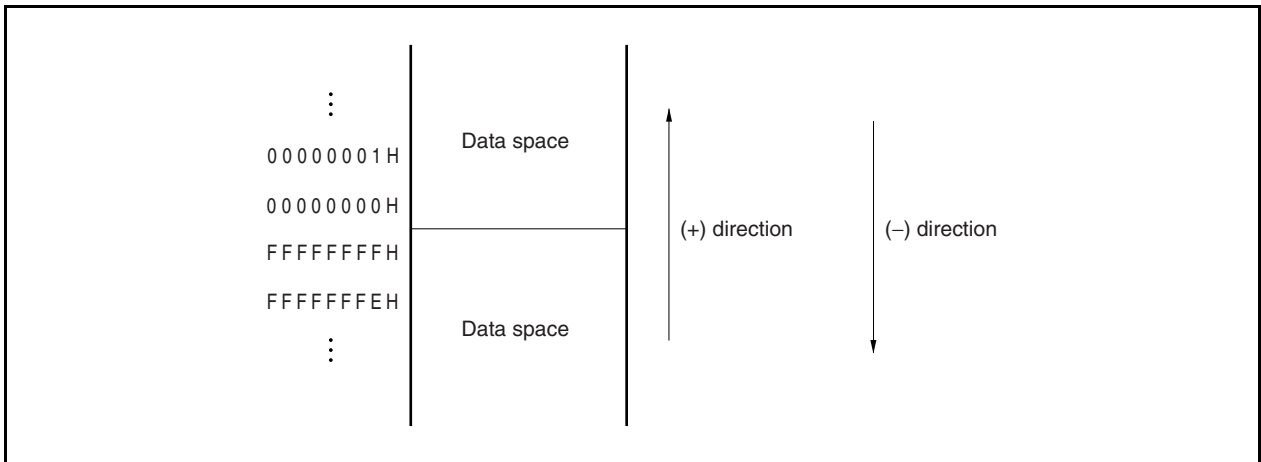
**Caution** Because the 4 KB area of addresses 03FFF000H to 03FFFFFFH is an on-chip peripheral I/O area, instructions cannot be fetched from this area. Therefore, do not execute an operation in which the result of a branch address calculation affects this area.



(2) Data space

The result of an operand address calculation operation that exceeds 32 bits is ignored.

Therefore, the highest address of the data space, FFFFFFFFH, and the lowest address, 00000000H, are contiguous, and wraparound occurs at the boundary of these addresses.



### 3.4.3 Memory map

The areas shown below are reserved in the V850ES/JJ3.

Figure 3-2. Data Memory Map (Physical Addresses)

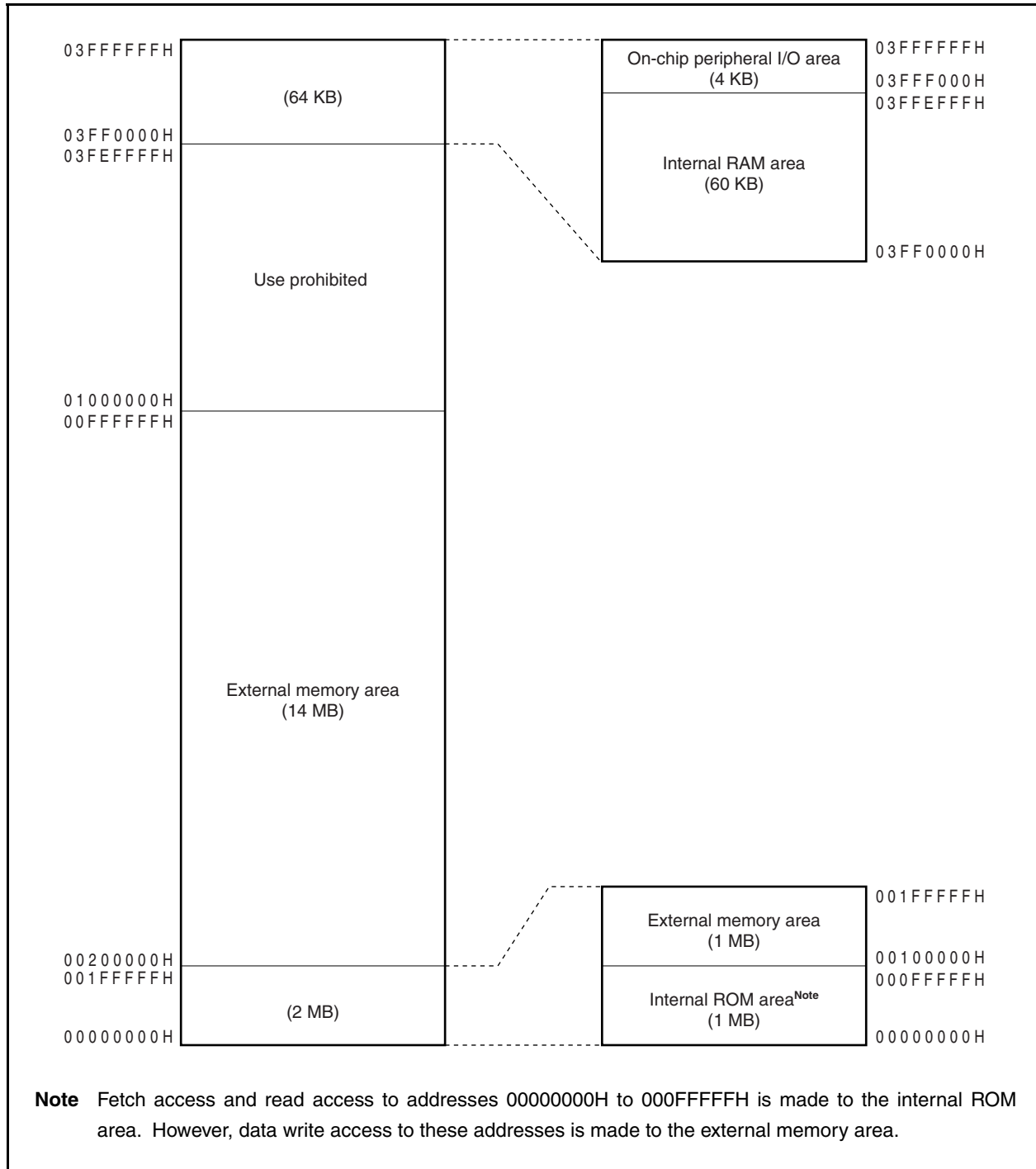
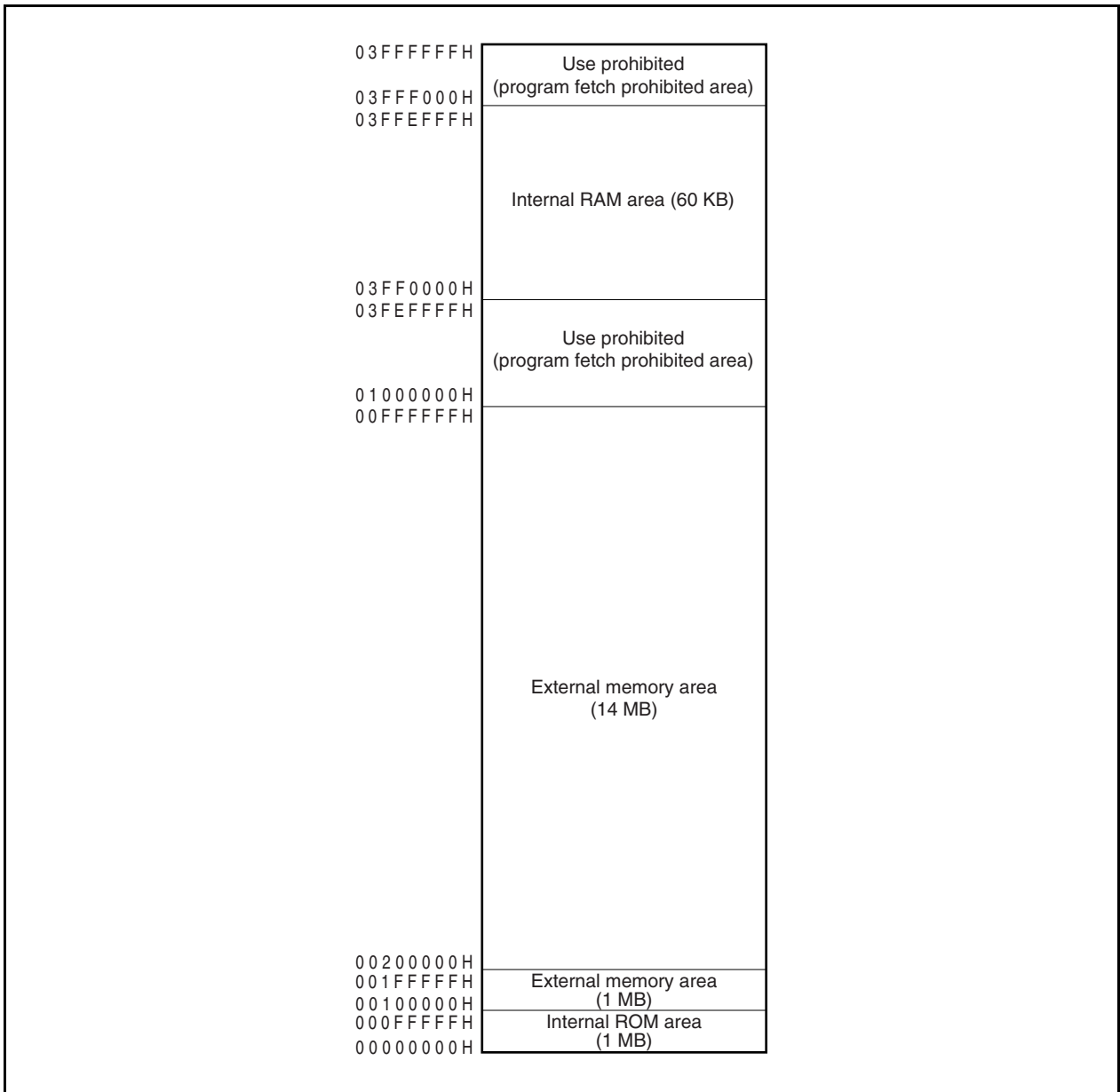


Figure 3-3. Program Memory Map



3.4.4 Areas

(1) Internal ROM area

Up to 1 MB is reserved as an internal ROM area.

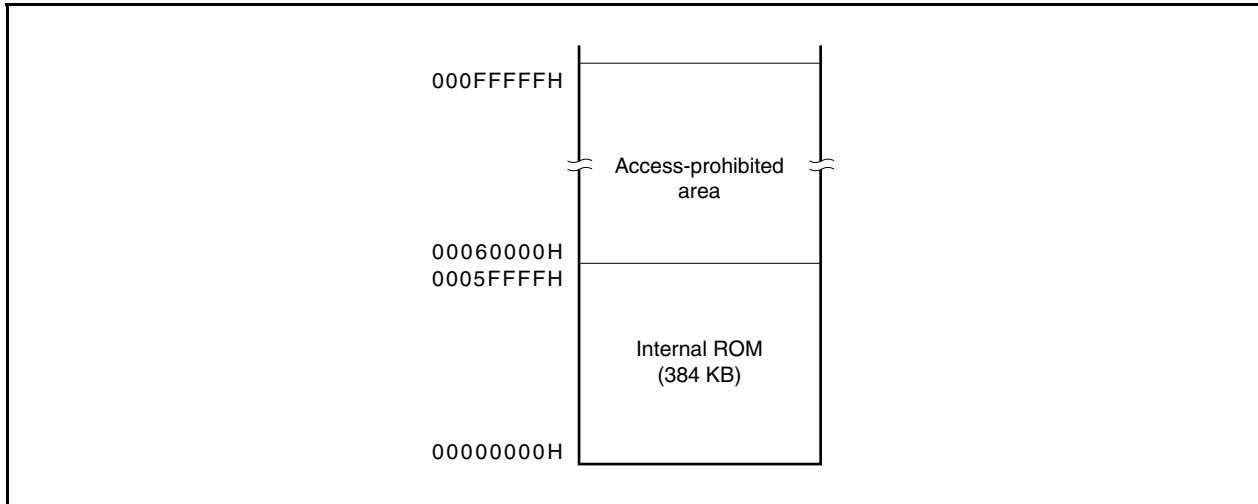
<R>

(a) Internal ROM (384 KB)

384 KB are allocated to addresses 00000000H to 0005FFFFH in the  $\mu$ PD70F3743.

Accessing addresses 00060000H to 000FFFFFFH is prohibited.

Figure 3-4. Internal ROM Area (384 KB)



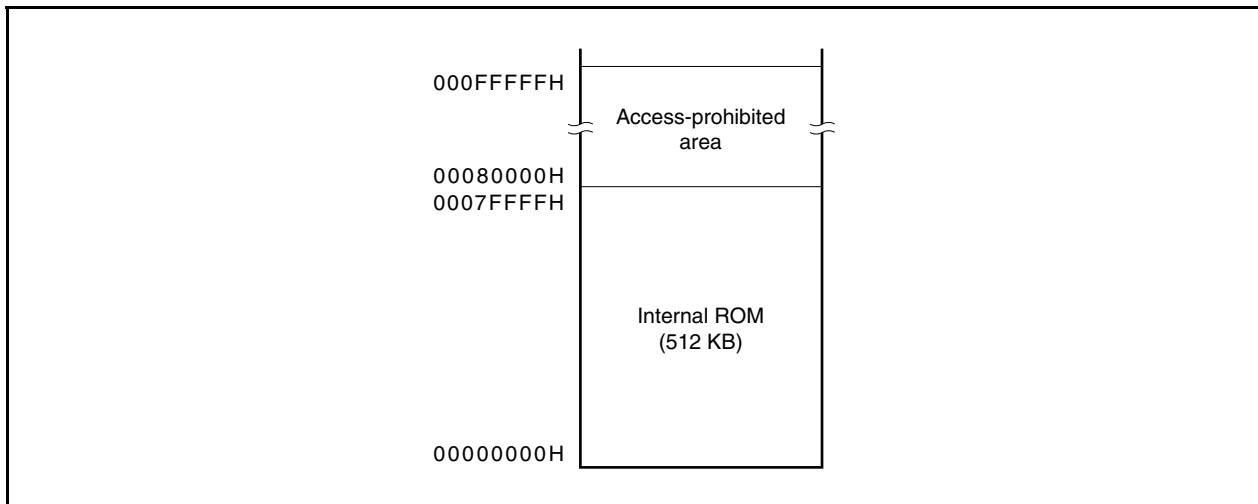
<R>

(b) Internal ROM (512 KB)

512 KB are allocated to addresses 00000000H to 0007FFFFH in the  $\mu$ PD70F3744.

Accessing addresses 00080000H to 000FFFFFFH is prohibited.

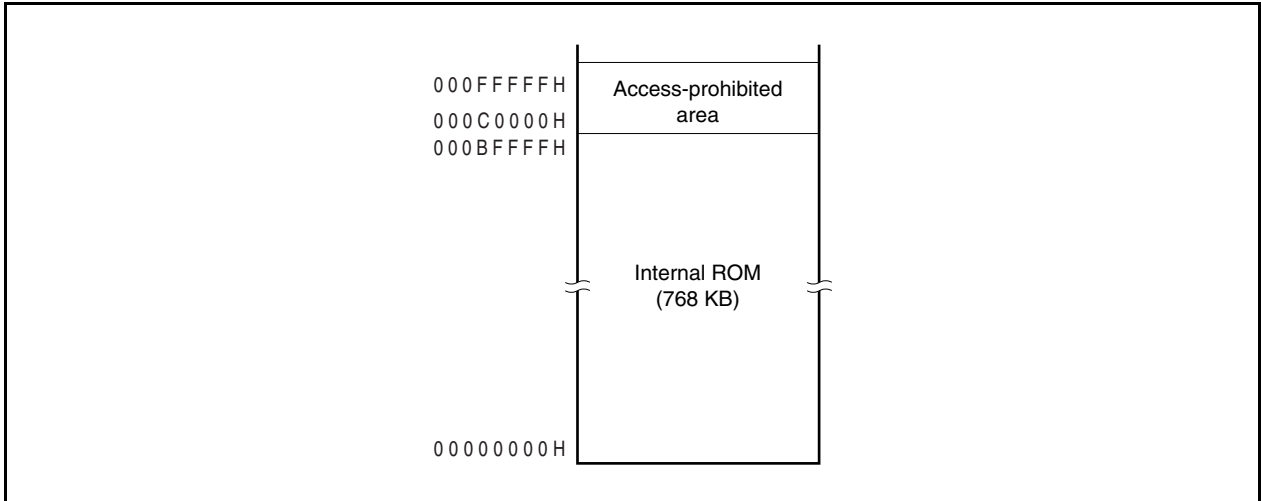
Figure 3-5. Internal ROM Area (512 KB)



**(c) Internal ROM (768 KB)**

768 KB are allocated to addresses 00000000H to 000BFFFFH in the  $\mu$ PD70F3745. Accessing addresses 000C0000H to 000FFFFFFH is prohibited.

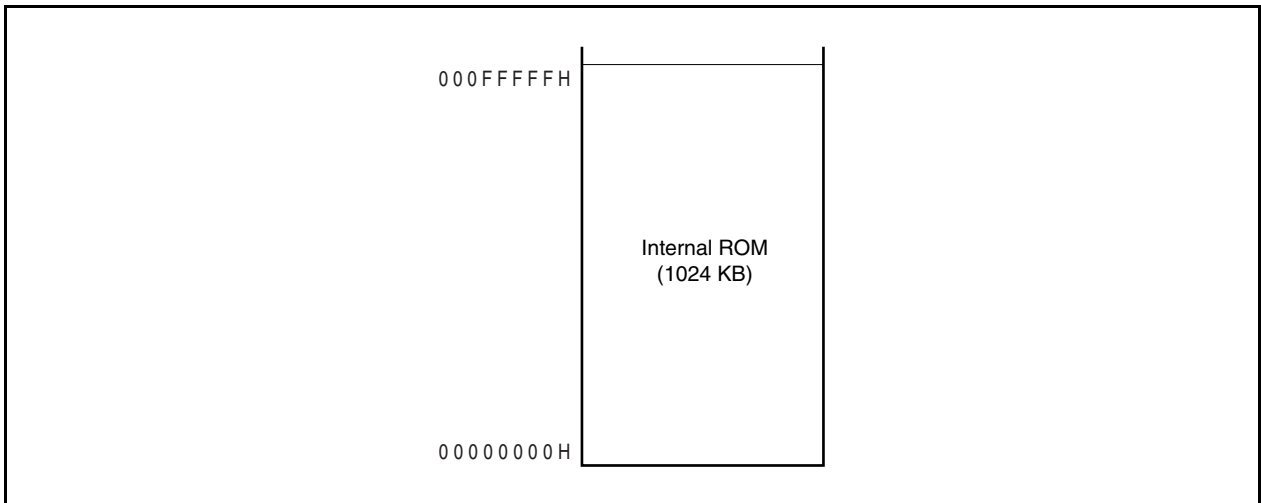
**Figure 3-6. Internal ROM Area (768 KB)**



**(d) Internal ROM (1024 KB)**

1024 KB are allocated to addresses 00000000H to 000FFFFFFH in the  $\mu$ PD70F3746.

**Figure 3-7. Internal ROM Area (1024 KB)**



**(2) Internal RAM area**

Up to 60 KB are reserved as the internal RAM area.

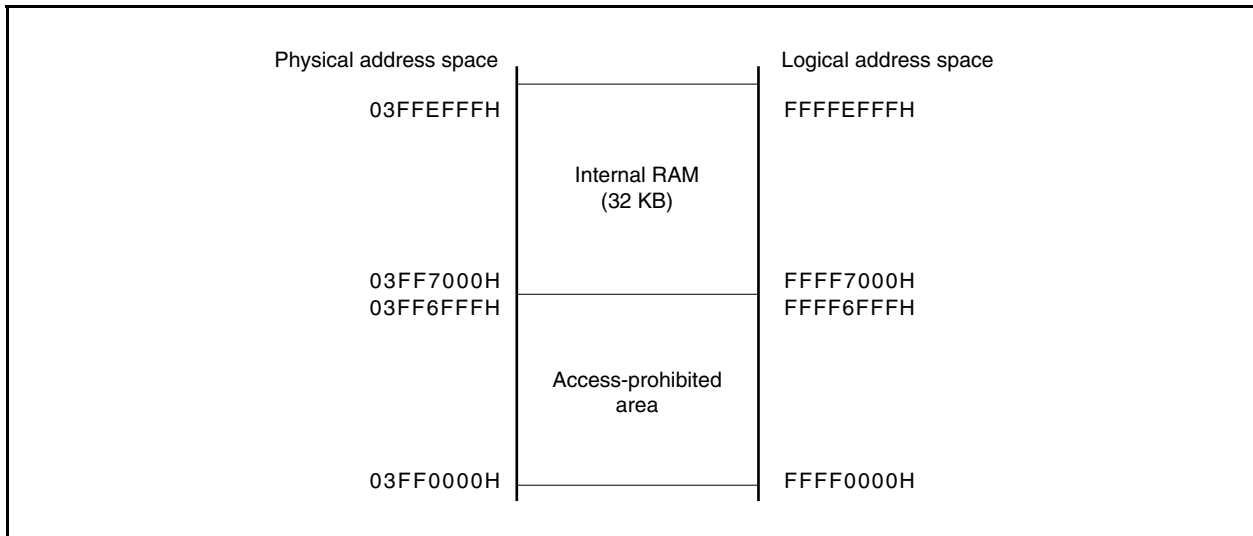
<R>

**(a) Internal RAM (32 KB)**

32 KB are allocated to addresses 03FF7000H to 03FF6FFFH in the  $\mu$ PD70F3743.

Accessing addresses 03FF0000H to 03FF6FFFH is prohibited.

**Figure 3-8. Internal RAM Area (32 KB)**



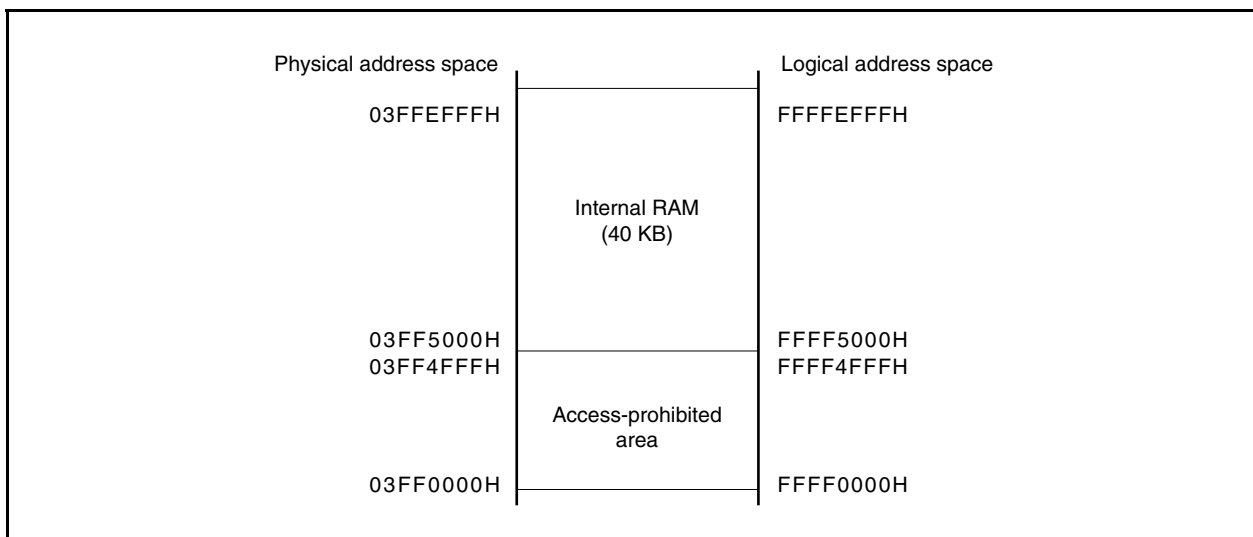
<R>

**(b) Internal RAM (40 KB)**

40 KB are allocated to addresses 03FF5000H to 03FF4FFFH in the  $\mu$ PD70F3744.

Accessing addresses 03FF0000H to 03FF4FFFH is prohibited.

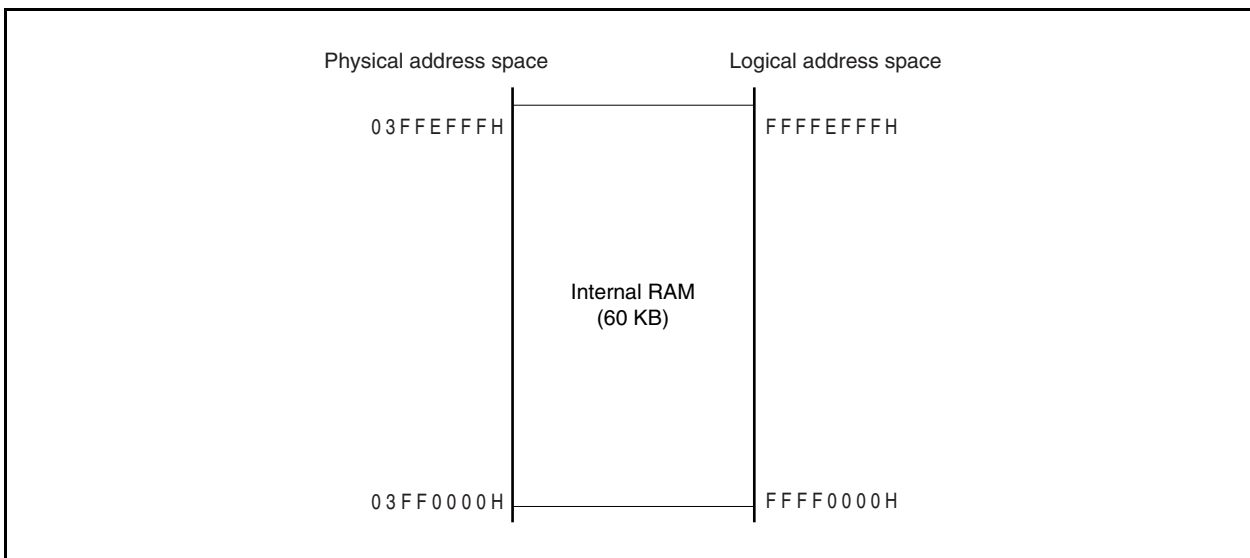
**Figure 3-9. Internal RAM Area (40 KB)**



**(c) Internal RAM (60 KB)**

60 KB are allocated to addresses 03FF0000H to 03FF0000H in the  $\mu$ PD70F3745 and 70F3746.

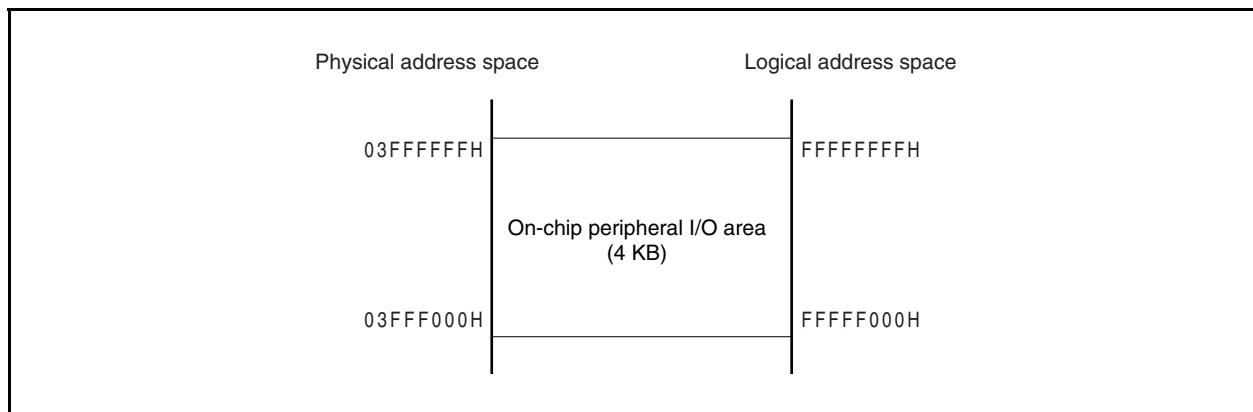
**Figure 3-10. Internal RAM Area (60 KB)**



**(3) On-chip peripheral I/O area**

4 KB of addresses 03FFF000H to 03FFFFFFH are reserved as the on-chip peripheral I/O area.

**Figure 3-11. On-Chip Peripheral I/O Area**



Peripheral I/O registers that have functions to specify the operation mode for and monitor the status of the on-chip peripheral I/O are mapped to the on-chip peripheral I/O area. Program cannot be fetched from this area.

- Cautions**
1. When a register is accessed in word units, a word area is accessed twice in halfword units in the order of lower area and higher area, with the lower 2 bits of the address ignored.
  2. If a register that can be accessed in byte units is accessed in halfword units, the higher 8 bits are undefined when the register is read, and data is written to the lower 8 bits.
  3. Addresses not defined as registers are reserved for future expansion. The operation is undefined and not guaranteed when these addresses are accessed.

**(4) External memory area**

15 MB (00100000H to 00FFFFFFH) are allocated as the external memory area. For details, see **CHAPTER 5 BUS CONTROL FUNCTION**.



### 3.4.5 Recommended use of address space

The architecture of the V850ES/JJ3 requires that a register that serves as a pointer be secured for address generation when operand data in the data space is accessed. The address stored in this pointer  $\pm 32$  KB can be directly accessed by an instruction for operand data. Because the number of general-purpose registers that can be used as a pointer is limited, however, by keeping the performance from dropping during address calculation when a pointer value is changed, as many general-purpose registers as possible can be secured for variables, and the program size can be reduced.

#### (1) Program space

Of the 32 bits of the PC (program counter), the higher 6 bits are fixed to 0, and only the lower 26 bits are valid. Regarding the program space, therefore, a 64 MB space of contiguous addresses starting from 00000000H unconditionally corresponds to the memory map.

To use the internal RAM area as the program space, access the following addresses.

**Caution** If a branch instruction is at the upper limit of the internal RAM area, a prefetch operation (invalid fetch) straddling the on-chip peripheral I/O area does not occur.

| RAM Size | Access Address         |
|----------|------------------------|
| 60 KB    | 03FF0000H to 03FF0000H |
| 40 KB    | 03FF5000H to 03FF5000H |
| 32 KB    | 03FF7000H to 03FF7000H |

#### (2) Data space

With the V850ES/JJ3, it seems that there are sixty-four 64 MB address spaces on the 4 GB CPU address space. Therefore, the least significant bit (bit 25) of a 26-bit address is sign-extended to 32 bits and allocated as an address.

**(a) Application example of wraparound**

If R = r0 (zero register) is specified for the LD/ST disp16 [R] instruction, a range of addresses 00000000H  $\pm$ 32 KB can be addressed by sign-extended disp16. All the resources, including the internal hardware, can be addressed by one pointer.

The zero register (r0) is a register fixed to 0 by hardware, and practically eliminates the need for registers dedicated to pointers.

**Example:**  $\mu$ PD70F3746

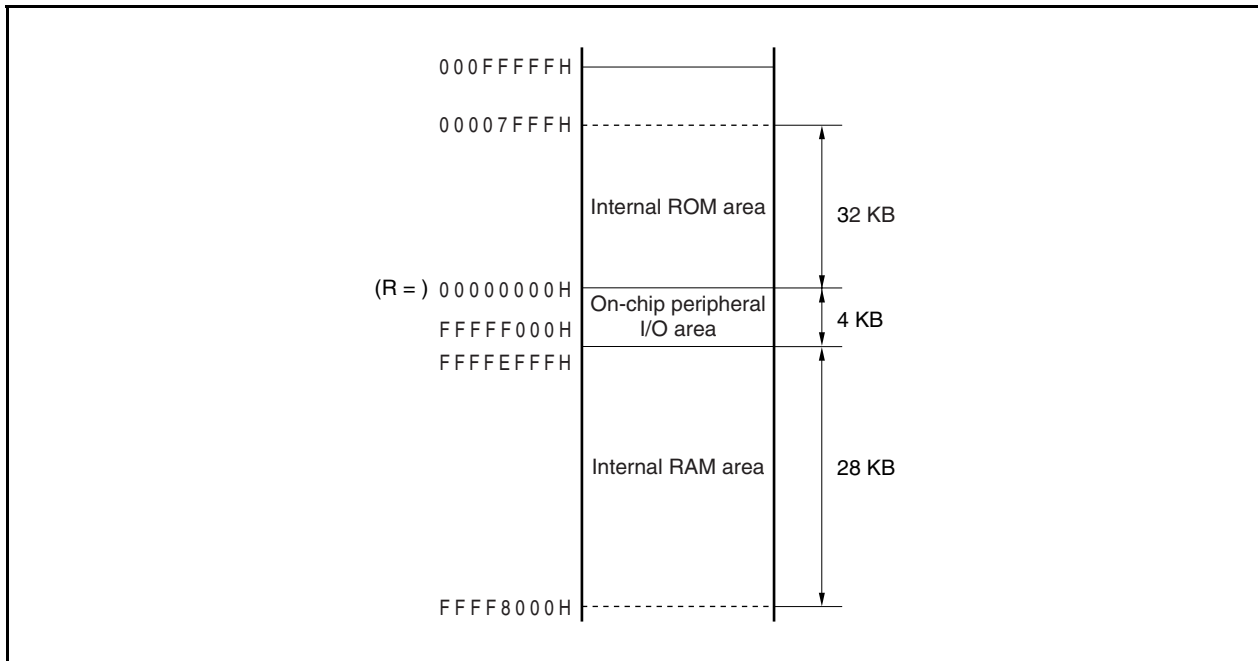
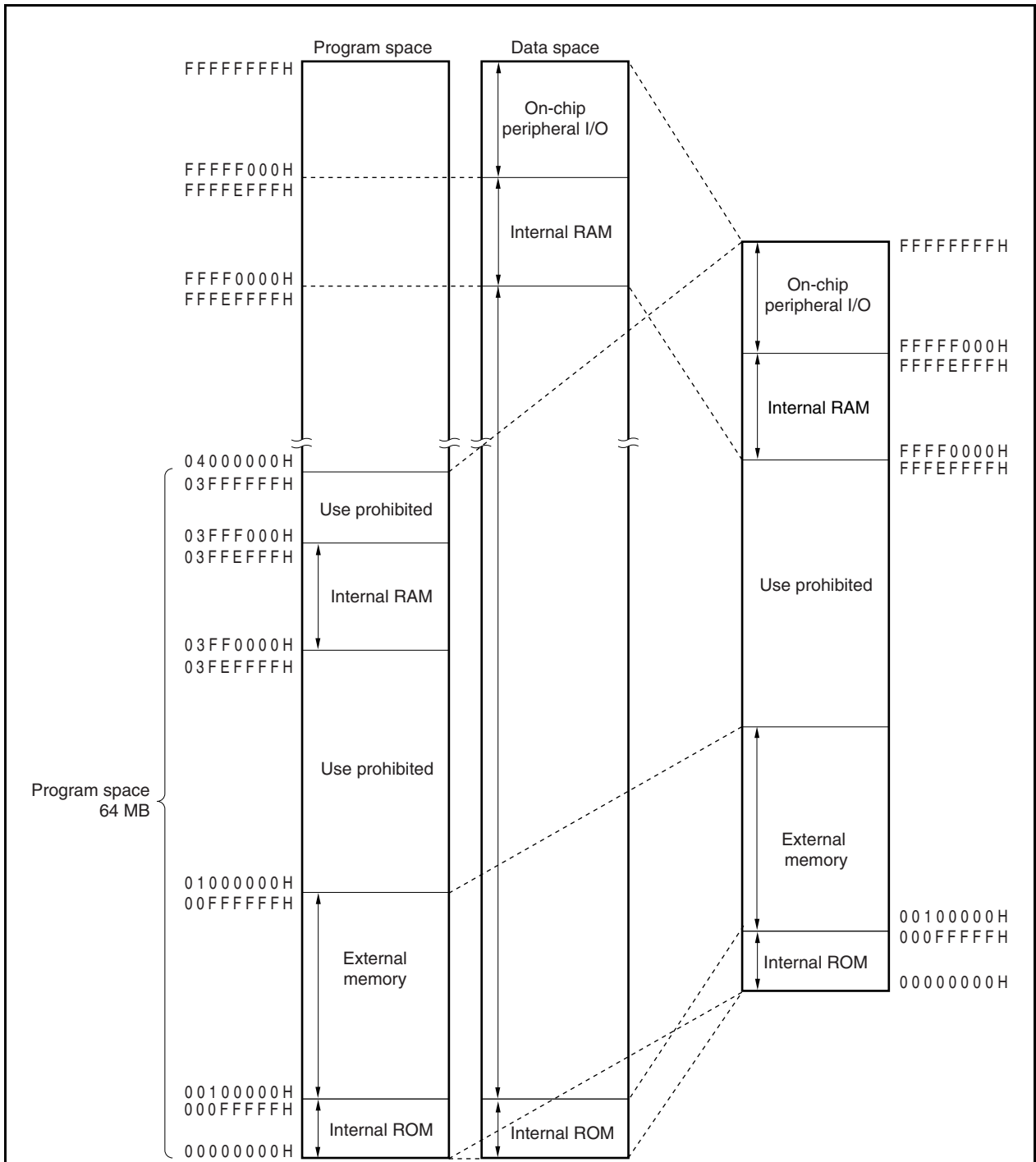


Figure 3-12. Recommended Memory Map



- Remarks 1.** † indicates the recommended area.  
**2.** This figure is the recommended memory map of the  $\mu$ PD70F3746.

3.4.6 Peripheral I/O registers

(1/12)

| Address   | Function Register Name              | Symbol | R/W | Manipulatable Bits |   |           | Default Value         |
|-----------|-------------------------------------|--------|-----|--------------------|---|-----------|-----------------------|
|           |                                     |        |     | 1                  | 8 | 16        |                       |
| FFFFF004H | Port DL register                    | PDL    | R/W |                    |   | √         | 0000H <sup>Note</sup> |
| FFFFF004H | Port DLL register                   | PDLL   |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF005H | Port DLH register                   | PDLH   |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF006H | Port DH register                    | PDH    |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF008H | Port CS register                    | PCS    |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF00AH | Port CT register                    | PCT    |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF00CH | Port CM register                    | PCM    |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF00EH | Port CD register                    | PCD    |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF024H | Port DL mode register               | PMDL   |     |                    |   | √         | FFFFH                 |
| FFFFF024H | Port DL mode register L             | PMDLL  |     | √                  | √ |           | FFH                   |
| FFFFF025H | Port DL mode register H             | PMDLH  |     | √                  | √ |           | FFH                   |
| FFFFF026H | Port DH mode register               | PMDH   |     | √                  | √ |           | FFH                   |
| FFFFF028H | Port CS mode register               | PMCS   |     | √                  | √ |           | FFH                   |
| FFFFF02AH | Port CT mode register               | PMCT   |     | √                  | √ |           | FFH                   |
| FFFFF02CH | Port CM mode register               | PMCM   |     | √                  | √ |           | FFH                   |
| FFFFF02EH | Port CD mode register               | PMCD   |     | √                  | √ |           | FFH                   |
| FFFFF044H | Port DL mode control register       | PMCDL  |     |                    |   | √         | 0000H                 |
| FFFFF044H | Port DL mode control register L     | PMCDLL |     | √                  | √ |           | 00H                   |
| FFFFF045H | Port DL mode control register H     | PMCDLH |     | √                  | √ |           | 00H                   |
| FFFFF046H | Port DH mode control register       | PMCDH  |     | √                  | √ |           | 00H                   |
| FFFFF048H | Port CS mode control register       | PMCCS  |     | √                  | √ |           | 00H                   |
| FFFFF04AH | Port CT mode control register       | PMCCCT |     | √                  | √ |           | 00H                   |
| FFFFF04CH | Port CM mode control register       | PMCCM  |     | √                  | √ |           | 00H                   |
| FFFFF066H | Bus size configuration register     | BSC    |     |                    |   | √         | 5555H                 |
| FFFFF06EH | System wait control register        | VSWC   |     |                    | √ |           | 77H                   |
| FFFFF080H | DMA source address register 0L      | DSA0L  |     |                    |   | √         | Undefined             |
| FFFFF082H | DMA source address register 0H      | DSA0H  |     |                    |   | √         | Undefined             |
| FFFFF084H | DMA destination address register 0L | DDA0L  |     |                    | √ | Undefined |                       |
| FFFFF086H | DMA destination address register 0H | DDA0H  |     |                    | √ | Undefined |                       |
| FFFFF088H | DMA source address register 1L      | DSA1L  |     |                    | √ | Undefined |                       |
| FFFFF08AH | DMA source address register 1H      | DSA1H  |     |                    | √ | Undefined |                       |
| FFFFF08CH | DMA destination address register 1L | DDA1L  |     |                    | √ | Undefined |                       |
| FFFFF08EH | DMA destination address register 1H | DDA1H  |     |                    | √ | Undefined |                       |
| FFFFF090H | DMA source address register 2L      | DSA2L  |     |                    | √ | Undefined |                       |
| FFFFF092H | DMA source address register 2H      | DSA2H  |     |                    | √ | Undefined |                       |
| FFFFF094H | DMA destination address register 2L | DDA2L  |     |                    | √ | Undefined |                       |
| FFFFF096H | DMA destination address register 2H | DDA2H  |     |                    | √ | Undefined |                       |
| FFFFF098H | DMA source address register 3L      | DSA3L  |     |                    | √ | Undefined |                       |
| FFFFF09AH | DMA source address register 3H      | DSA3H  |     |                    | √ | Undefined |                       |
| FFFFF09CH | DMA destination address register 3L | DDA3L  |     |                    | √ | Undefined |                       |
| FFFFF09EH | DMA destination address register 3H | DDA3H  |     |                    | √ | Undefined |                       |
| FFFFF0C0H | DMA transfer count register 0       | DBC0   |     |                    | √ | Undefined |                       |

**Note** The value of the output latch is 00H or 0000H. The status of the pin is read during input.

| Address   | Function Register Name            | Symbol   | R/W | Manipulatable Bits |   |       | Default Value |
|-----------|-----------------------------------|----------|-----|--------------------|---|-------|---------------|
|           |                                   |          |     | 1                  | 8 | 16    |               |
| FFFFF0C2H | DMA transfer count register 1     | DBC1     | R/W |                    |   | √     | Undefined     |
| FFFFF0C4H | DMA transfer count register 2     | DBC2     |     |                    |   | √     | Undefined     |
| FFFFF0C6H | DMA transfer count register 3     | DBC3     |     |                    |   | √     | Undefined     |
| FFFFF0D0H | DMA addressing control register 0 | DADC0    |     |                    |   | √     | 0000H         |
| FFFFF0D2H | DMA addressing control register 1 | DADC1    |     |                    |   | √     | 0000H         |
| FFFFF0D4H | DMA addressing control register 2 | DADC2    |     |                    |   | √     | 0000H         |
| FFFFF0D6H | DMA addressing control register 3 | DADC3    |     |                    |   | √     | 0000H         |
| FFFFF0E0H | DMA channel control register 0    | DCHC0    |     | √                  | √ |       | 00H           |
| FFFFF0E2H | DMA channel control register 1    | DCHC1    |     | √                  | √ |       | 00H           |
| FFFFF0E4H | DMA channel control register 2    | DCHC2    |     | √                  | √ |       | 00H           |
| FFFFF0E6H | DMA channel control register 3    | DCHC3    |     | √                  | √ |       | 00H           |
| FFFFF100H | Interrupt mask register 0         | IMR0     |     |                    |   | √     | FFFFH         |
| FFFFF100H | Interrupt mask register 0L        | IMR0L    |     | √                  | √ |       | FFH           |
| FFFFF101H | Interrupt mask register 0H        | IMR0H    |     | √                  | √ |       | FFH           |
| FFFFF102H | Interrupt mask register 1         | IMR1     |     |                    |   | √     | FFFFH         |
| FFFFF102H | Interrupt mask register 1L        | IMR1L    |     | √                  | √ |       | FFH           |
| FFFFF103H | Interrupt mask register 1H        | IMR1H    |     | √                  | √ |       | FFH           |
| FFFFF104H | Interrupt mask register 2         | IMR2     |     |                    |   | √     | FFFFH         |
| FFFFF104H | Interrupt mask register 2L        | IMR2L    |     | √                  | √ |       | FFH           |
| FFFFF105H | Interrupt mask register 2H        | IMR2H    |     | √                  | √ |       | FFH           |
| FFFFF106H | Interrupt mask register 3         | IMR3     |     |                    | √ | FFFFH |               |
| FFFFF106H | Interrupt mask register 3L        | IMR3L    | √   | √                  |   | FFH   |               |
| FFFFF107H | Interrupt mask register 3H        | IMR3H    | √   | √                  |   | FFH   |               |
| FFFFF108H | Interrupt mask register 4         | IMR4     |     |                    | √ | FFFFH |               |
| FFFFF108H | Interrupt mask register 4L        | IMR4L    | √   | √                  |   | FFH   |               |
| FFFFF109H | Interrupt mask register 4H        | IMR4H    | √   | √                  |   | FFH   |               |
| FFFFF110H | Interrupt control register        | LVIIC    | √   | √                  |   | 47H   |               |
| FFFFF112H | Interrupt control register        | PIC0     | √   | √                  |   | 47H   |               |
| FFFFF114H | Interrupt control register        | PIC1     | √   | √                  |   | 47H   |               |
| FFFFF116H | Interrupt control register        | PIC2     | √   | √                  |   | 47H   |               |
| FFFFF118H | Interrupt control register        | PIC3     | √   | √                  |   | 47H   |               |
| FFFFF11AH | Interrupt control register        | PIC4     | √   | √                  |   | 47H   |               |
| FFFFF11CH | Interrupt control register        | PIC5     | √   | √                  |   | 47H   |               |
| FFFFF11EH | Interrupt control register        | PIC6     | √   | √                  |   | 47H   |               |
| FFFFF120H | Interrupt control register        | PIC7     | √   | √                  |   | 47H   |               |
| FFFFF122H | Interrupt control register        | TQ0OVIC  | √   | √                  |   | 47H   |               |
| FFFFF124H | Interrupt control register        | TQ0CCIC0 | √   | √                  |   | 47H   |               |
| FFFFF126H | Interrupt control register        | TQ0CCIC1 | √   | √                  |   | 47H   |               |
| FFFFF128H | Interrupt control register        | TQ0CCIC2 | √   | √                  |   | 47H   |               |
| FFFFF12AH | Interrupt control register        | TQ0CCIC3 | √   | √                  |   | 47H   |               |
| FFFFF12CH | Interrupt control register        | TP0OVIC  | √   | √                  |   | 47H   |               |
| FFFFF12EH | Interrupt control register        | TP0CCIC0 | √   | √                  |   | 47H   |               |
| FFFFF130H | Interrupt control register        | TP0CCIC1 | √   | √                  |   | 47H   |               |

| Address   | Function Register Name     | Symbol        | R/W | Manipulatable Bits |   |     | Default Value |
|-----------|----------------------------|---------------|-----|--------------------|---|-----|---------------|
|           |                            |               |     | 1                  | 8 | 16  |               |
| FFFFF132H | Interrupt control register | TP1OVIC       | R/W | √                  | √ |     | 47H           |
| FFFFF134H | Interrupt control register | TP1CCIC0      |     | √                  | √ |     | 47H           |
| FFFFF136H | Interrupt control register | TP1CCIC1      |     | √                  | √ |     | 47H           |
| FFFFF138H | Interrupt control register | TP2OVIC       |     | √                  | √ |     | 47H           |
| FFFFF13AH | Interrupt control register | TP2CCIC0      |     | √                  | √ |     | 47H           |
| FFFFF13CH | Interrupt control register | TP2CCIC1      |     | √                  | √ |     | 47H           |
| FFFFF13EH | Interrupt control register | TP3OVIC       |     | √                  | √ |     | 47H           |
| FFFFF140H | Interrupt control register | TP3CCIC0      |     | √                  | √ |     | 47H           |
| FFFFF142H | Interrupt control register | TP3CCIC1      |     | √                  | √ |     | 47H           |
| FFFFF144H | Interrupt control register | TP4OVIC       |     | √                  | √ |     | 47H           |
| FFFFF146H | Interrupt control register | TP4CCIC0      |     | √                  | √ |     | 47H           |
| FFFFF148H | Interrupt control register | TP4CCIC1      |     | √                  | √ |     | 47H           |
| FFFFF14AH | Interrupt control register | TP5OVIC       |     | √                  | √ |     | 47H           |
| FFFFF14CH | Interrupt control register | TP5CCIC0      |     | √                  | √ |     | 47H           |
| FFFFF14EH | Interrupt control register | TP5CCIC1      |     | √                  | √ |     | 47H           |
| FFFFF150H | Interrupt control register | TM0EQIC0      |     | √                  | √ |     | 47H           |
| FFFFF152H | Interrupt control register | CB0RIC/IICIC1 |     | √                  | √ |     | 47H           |
| FFFFF154H | Interrupt control register | CB0TIC        |     | √                  | √ |     | 47H           |
| FFFFF156H | Interrupt control register | CB1RIC        |     | √                  | √ |     | 47H           |
| FFFFF158H | Interrupt control register | CB1TIC        |     | √                  | √ |     | 47H           |
| FFFFF15AH | Interrupt control register | CB2RIC        |     | √                  | √ |     | 47H           |
| FFFFF15CH | Interrupt control register | CB2TIC        |     | √                  | √ |     | 47H           |
| FFFFF15EH | Interrupt control register | CB3RIC        |     | √                  | √ |     | 47H           |
| FFFFF160H | Interrupt control register | CB3TIC        |     | √                  | √ |     | 47H           |
| FFFFF162H | Interrupt control register | UA0RIC/CB4RIC |     | √                  | √ |     | 47H           |
| FFFFF164H | Interrupt control register | UA0TIC/CB4TIC |     | √                  | √ |     | 47H           |
| FFFFF166H | Interrupt control register | UA1RIC/IICIC2 |     | √                  | √ |     | 47H           |
| FFFFF168H | Interrupt control register | UA1TIC        |     | √                  | √ |     | 47H           |
| FFFFF16AH | Interrupt control register | UA2RIC/IICIC0 |     | √                  | √ |     | 47H           |
| FFFFF16CH | Interrupt control register | UA2TIC        |     | √                  | √ |     | 47H           |
| FFFFF16EH | Interrupt control register | ADIC          |     | √                  | √ |     | 47H           |
| FFFFF170H | Interrupt control register | DMAIC0        |     | √                  | √ |     | 47H           |
| FFFFF172H | Interrupt control register | DMAIC1        | √   | √                  |   | 47H |               |
| FFFFF174H | Interrupt control register | DMAIC2        | √   | √                  |   | 47H |               |
| FFFFF176H | Interrupt control register | DMAIC3        | √   | √                  |   | 47H |               |
| FFFFF178H | Interrupt control register | KRIC          | √   | √                  |   | 47H |               |
| FFFFF17AH | Interrupt control register | WTIIC         | √   | √                  |   | 47H |               |
| FFFFF17CH | Interrupt control register | WTIC          | √   | √                  |   | 47H |               |
| FFFFF18EH | Interrupt control register | PIC8          | √   | √                  |   | 47H |               |
| FFFFF190H | Interrupt control register | TP6OVIC       | √   | √                  |   | 47H |               |
| FFFFF192H | Interrupt control register | TP6CCIC0      | √   | √                  |   | 47H |               |
| FFFFF194H | Interrupt control register | TP6CCIC1      | √   | √                  |   | 47H |               |
| FFFFF196H | Interrupt control register | TP7OVIC       | √   | √                  |   | 47H |               |

| Address   | Function Register Name                       | Symbol    | R/W | Manipulatable Bits |   |           | Default Value |           |
|-----------|--|-----------|-----|--------------------|---|-----------|---------------|-----------|
|           |  |           |     | 1                  | 8 | 16        |               |           |
| FFFFF198H | Interrupt control register                   | TP7CCIC0  | R/W | √                  | √ |           | 47H           |           |
| FFFFF19AH | Interrupt control register                   | TP7CCIC1  |     | √                  | √ |           | 47H           |           |
| FFFFF19CH | Interrupt control register                   | TP8OVIC   |     | √                  | √ |           | 47H           |           |
| FFFFF19EH | Interrupt control register                   | TP8CCIC0  |     | √                  | √ |           | 47H           |           |
| FFFFF1A0H | Interrupt control register                   | TP8CCIC1  |     | √                  | √ |           | 47H           |           |
| FFFFF1A2H | Interrupt control register                   | CB5RIC    |     | √                  | √ |           | 47H           |           |
| FFFFF1A4H | Interrupt control register                   | CB5TIC    |     | √                  | √ |           | 47H           |           |
| FFFFF1A6H | Interrupt control register                   | UA3RIC    |     | √                  | √ |           | 47H           |           |
| FFFFF1A8H | Interrupt control register                   | UA3TIC    |     | √                  | √ |           | 47H           |           |
| FFFFF1FAH | In-service priority register                 | ISPR      | R   | √                  | √ |           | 00H           |           |
| FFFFF1FCH | Command register                             | PRCMD     | W   | √                  | √ |           | Undefined     |           |
| FFFFF1FEH | Power save control register                  | PSC       | R/W | √                  | √ |           | 00H           |           |
| FFFFF200H | A/D converter mode register 0                | ADA0M0    |     | √                  | √ |           | 00H           |           |
| FFFFF201H | A/D converter mode register 1                | ADA0M1    |     | √                  | √ |           | 00H           |           |
| FFFFF202H | A/D converter channel specification register | ADA0S     |     | √                  | √ |           | 00H           |           |
| FFFFF203H | A/D converter mode register 2                | ADA0M2    |     | √                  | √ |           | 00H           |           |
| FFFFF204H | Power-fail compare mode register             | ADA0PFM   |     | √                  | √ |           | 00H           |           |
| FFFFF205H | Power-fail compare threshold value register  | ADA0PFT   |     | √                  | √ |           | 00H           |           |
| FFFFF210H | A/D conversion result register 0             | ADA0CR0   |     | R                  |   |           | √             | Undefined |
| FFFFF211H | A/D conversion result register 0H            | ADA0CR0H  |     |                    |   | √         |               | Undefined |
| FFFFF212H | A/D conversion result register 1             | ADA0CR1   |     |                    |   | √         | Undefined     |           |
| FFFFF213H | A/D conversion result register 1H            | ADA0CR1H  |     |                    | √ |           | Undefined     |           |
| FFFFF214H | A/D conversion result register 2             | ADA0CR2   |     |                    |   | √         | Undefined     |           |
| FFFFF215H | A/D conversion result register 2H            | ADA0CR2H  |     |                    | √ |           | Undefined     |           |
| FFFFF216H | A/D conversion result register 3             | ADA0CR3   |     |                    |   | √         | Undefined     |           |
| FFFFF217H | A/D conversion result register 3H            | ADA0CR3H  |     |                    | √ |           | Undefined     |           |
| FFFFF218H | A/D conversion result register 4             | ADA0CR4   |     |                    |   | √         | Undefined     |           |
| FFFFF219H | A/D conversion result register 4H            | ADA0CR4H  |     |                    | √ |           | Undefined     |           |
| FFFFF21AH | A/D conversion result register 5             | ADA0CR5   |     |                    |   | √         | Undefined     |           |
| FFFFF21BH | A/D conversion result register 5H            | ADA0CR5H  |     |                    | √ |           | Undefined     |           |
| FFFFF21CH | A/D conversion result register 6             | ADA0CR6   |     |                    |   | √         | Undefined     |           |
| FFFFF21DH | A/D conversion result register 6H            | ADA0CR6H  |     |                    | √ |           | Undefined     |           |
| FFFFF21EH | A/D conversion result register 7             | ADA0CR7   |     |                    |   | √         | Undefined     |           |
| FFFFF21FH | A/D conversion result register 7H            | ADA0CR7H  |     |                    | √ |           | Undefined     |           |
| FFFFF220H | A/D conversion result register 8             | ADA0CR8   |     |                    |   | √         | Undefined     |           |
| FFFFF221H | A/D conversion result register 8H            | ADA0CR8H  |     |                    | √ |           | Undefined     |           |
| FFFFF222H | A/D conversion result register 9             | ADA0CR9   |     |                    |   | √         | Undefined     |           |
| FFFFF223H | A/D conversion result register 9H            | ADA0CR9H  |     |                    | √ |           | Undefined     |           |
| FFFFF224H | A/D conversion result register 10            | ADA0CR10  |     |                    |   | √         | Undefined     |           |
| FFFFF225H | A/D conversion result register 10H           | ADA0CR10H |     |                    | √ |           | Undefined     |           |
| FFFFF226H | A/D conversion result register 11            | ADA0CR11  |     |                    |   | √         | Undefined     |           |
| FFFFF227H | A/D conversion result register 11H           | ADA0CR11H |     | √                  |   | Undefined |               |           |

| Address   | Function Register Name                  | Symbol    | R/W | Manipulatable Bits |   |           | Default Value         |
|-----------|---|-----------|-----|--------------------|---|-----------|-----------------------|
|           |   |           |     | 1                  | 8 | 16        |                       |
| FFFFF228H | A/D conversion result register 12       | ADA0CR12  | R   |                    |   | √         | Undefined             |
| FFFFF229H | A/D conversion result register 12H      | ADA0CR12H |     |                    | √ |           | Undefined             |
| FFFFF22AH | A/D conversion result register 13       | ADA0CR13  |     |                    |   | √         | Undefined             |
| FFFFF22BH | A/D conversion result register 13H      | ADA0CR13H |     |                    | √ |           | Undefined             |
| FFFFF22CH | A/D conversion result register 14       | ADA0CR14  |     |                    |   | √         | Undefined             |
| FFFFF22DH | A/D conversion result register 14H      | ADA0CR14H |     |                    | √ |           | Undefined             |
| FFFFF22EH | A/D conversion result register 15       | ADA0CR15  |     |                    | √ | Undefined |                       |
| FFFFF22FH | A/D conversion result register 15H      | ADA0CR15H |     | √                  |   | Undefined |                       |
| FFFFF280H | D/A conversion value setting register 0 | DA0CS0    | R/W |                    | √ |           | 00H                   |
| FFFFF281H | D/A conversion value setting register 1 | DA0CS1    |     |                    | √ |           | 00H                   |
| FFFFF282H | D/A converter mode register             | DA0M      |     | √                  | √ |           | 00H                   |
| FFFFF300H | Key return mode register                | KRM       |     | √                  | √ |           | 00H                   |
| FFFFF308H | Selector operation control register 0   | SELCNT0   |     | √                  | √ |           | 00H                   |
| FFFFF310H | CRC input register                      | CRCIN     |     |                    | √ |           | 00H                   |
| FFFFF312H | CRC data register                       | CRCD      |     |                    |   | √         | 0000H                 |
| FFFFF318H | Noise elimination control register      | NFC       |     |                    | √ |           | 00H                   |
| FFFFF320H | Prescaler mode register 1               | PRSM1     |     | √                  | √ |           | 00H                   |
| FFFFF321H | Prescaler compare register 1            | PRSCM1    |     |                    | √ |           | 00H                   |
| FFFFF324H | Prescaler mode register 2               | PRSM2     |     | √                  | √ |           | 00H                   |
| FFFFF325H | Prescaler compare register 2            | PRSCM2    |     |                    | √ |           | 00H                   |
| FFFFF328H | Prescaler mode register 3               | PRSM3     |     | √                  | √ |           | 00H                   |
| FFFFF329H | Prescaler compare register 3            | PRSCM3    |     |                    | √ |           | 00H                   |
| FFFFF340H | IIC division clock select register 0    | OCKS0     |     |                    | √ |           | 00H                   |
| FFFFF344H | IIC division clock select register 1    | OCKS1     |     |                    | √ |           | 00H                   |
| FFFFF400H | Port 0 register                         | P0        |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF402H | Port 1 register                         | P1        |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF406H | Port 3 register                         | P3        |     |                    |   | √         | 0000H <sup>Note</sup> |
| FFFFF406H | Port 3L register                        | P3L       |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF407H | Port 3H register                        | P3H       |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF408H | Port 4 register                         | P4        |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF40AH | Port 5 register                         | P5        |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF40CH | Port 6 register                         | P6        |     |                    |   | √         | 0000H <sup>Note</sup> |
| FFFFF40CH | Port 6L register                        | P6L       |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF40DH | Port 6H register                        | P6H       |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF40EH | Port 7L register                        | P7L       |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF40FH | Port 7H register                        | P7H       |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF410H | Port 8 register                         | P8        |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF412H | Port 9 register                         | P9        |     |                    |   | √         | 0000H <sup>Note</sup> |
| FFFFF412H | Port 9L register                        | P9L       |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF413H | Port 9H register                        | P9H       |     | √                  | √ |           | 00H <sup>Note</sup>   |
| FFFFF420H | Port 0 mode register                    | PM0       | √   | √                  |   | FFH       |                       |

**Note** The value of the output latch is 00H or 0000H. The status of the pin is read during input.



| Address   | Function Register Name             | Symbol | R/W | Manipulatable Bits |   |       | Default Value |
|-----------|------------------------------------|--------|-----|--------------------|---|-------|---------------|
|           |                                    |        |     | 1                  | 8 | 16    |               |
| FFFFF422H | Port 1 mode register               | PM1    | R/W | √                  | √ |       | FFH           |
| FFFFF426H | Port 3 mode register               | PM3    |     |                    |   | √     | FFFFH         |
| FFFFF426H | Port 3 mode register L             | PM3L   |     | √                  | √ |       | FFH           |
| FFFFF427H | Port 3 mode register H             | PM3H   |     | √                  | √ |       | FFH           |
| FFFFF428H | Port 4 mode register               | PM4    |     | √                  | √ |       | FFH           |
| FFFFF42AH | Port 5 mode register               | PM5    |     | √                  | √ |       | FFH           |
| FFFFF42CH | Port 6 mode register               | PM6    |     |                    |   | √     | FFFFH         |
| FFFFF42CH | Port 6 mode register L             | PM6L   |     | √                  | √ |       | FFH           |
| FFFFF42DH | Port 6 mode register H             | PM6H   |     | √                  | √ |       | FFH           |
| FFFFF42EH | Port 7 mode register L             | PM7L   |     | √                  | √ |       | FFH           |
| FFFFF42FH | Port 7 mode register H             | PM7H   |     | √                  | √ |       | FFH           |
| FFFFF430H | Port 8 mode register               | PM8    |     | √                  | √ |       | FFH           |
| FFFFF432H | Port 9 mode register               | PM9    |     |                    |   | √     | FFFFH         |
| FFFFF432H | Port 9 mode register L             | PM9L   |     | √                  | √ |       | FFH           |
| FFFFF433H | Port 9 mode register H             | PM9H   |     | √                  | √ |       | FFH           |
| FFFFF440H | Port 0 mode control register       | PMC0   |     | √                  | √ |       | 00H           |
| FFFFF446H | Port 3 mode control register       | PMC3   |     |                    |   | √     | 0000H         |
| FFFFF446H | Port 3 mode control register L     | PMC3L  |     | √                  | √ |       | 00H           |
| FFFFF447H | Port 3 mode control register H     | PMC3H  |     | √                  | √ |       | 00H           |
| FFFFF448H | Port 4 mode control register       | PMC4   |     | √                  | √ |       | 00H           |
| FFFFF44AH | Port 5 mode control register       | PMC5   |     | √                  | √ |       | 00H           |
| FFFFF44CH | Port 6 mode control register       | PMC6   |     |                    |   | √     | 0000H         |
| FFFFF44CH | Port 6 mode control register L     | PMC6L  |     | √                  | √ |       | 00H           |
| FFFFF44DH | Port 6 mode control register H     | PMC6H  |     | √                  | √ |       | 00H           |
| FFFFF450H | Port 8 mode control register       | PMC8   |     | √                  | √ |       | 00H           |
| FFFFF452H | Port 9 mode control register       | PMC9   |     |                    |   | √     | 0000H         |
| FFFFF452H | Port 9 mode control register L     | PMC9L  |     | √                  | √ |       | 00H           |
| FFFFF453H | Port 9 mode control register H     | PMC9H  |     | √                  | √ |       | 00H           |
| FFFFF460H | Port 0 function control register   | PFC0   |     | √                  | √ |       | 00H           |
| FFFFF466H | Port 3 function control register   | PFC3   |     |                    | √ | 0000H |               |
| FFFFF466H | Port 3 function control register L | PFC3L  | √   | √                  |   | 00H   |               |
| FFFFF467H | Port 3 function control register H | PFC3H  | √   | √                  |   | 00H   |               |
| FFFFF468H | Port 4 function control register   | PFC4   | √   | √                  |   | 00H   |               |
| FFFFF46AH | Port 5 function control register   | PFC5   | √   | √                  |   | 00H   |               |
| FFFFF46DH | Port 6 function control register H | PFC6H  | √   | √                  |   | 00H   |               |
| FFFFF472H | Port 9 function control register   | PFC9   |     |                    | √ | 0000H |               |
| FFFFF472H | Port 9 function control register L | PFC9L  | √   | √                  |   | 00H   |               |
| FFFFF473H | Port 9 function control register H | PFC9H  | √   | √                  |   | 00H   |               |
| FFFFF484H | Data wait control register 0       | DWC0   |     |                    | √ | 7777H |               |
| FFFFF488H | Address wait control register      | AWC    |     |                    | √ | FFFFH |               |
| FFFFF48AH | Bus cycle control register         | BCC    |     |                    | √ | AAAAH |               |

| Address   | Function Register Name            | Symbol  | R/W | Manipulatable Bits |   |    | Default Value |       |
|-----------|-----------------------------------|---------|-----|--------------------|---|----|---------------|-------|
|           |                                   |         |     | 1                  | 8 | 16 |               |       |
| FFFFF540H | TMQ0 control register 0           | TQ0CTL0 | R/W | √                  | √ |    | 00H           |       |
| FFFFF541H | TMQ0 control register 1           | TQ0CTL1 |     | √                  | √ |    | 00H           |       |
| FFFFF542H | TMQ0 I/O control register 0       | TQ0IOC0 |     | √                  | √ |    | 00H           |       |
| FFFFF543H | TMQ0 I/O control register 1       | TQ0IOC1 |     | √                  | √ |    | 00H           |       |
| FFFFF544H | TMQ0 I/O control register 2       | TQ0IOC2 |     | √                  | √ |    | 00H           |       |
| FFFFF545H | TMQ0 option register 0            | TQ0OPT0 |     | √                  | √ |    | 00H           |       |
| FFFFF546H | TMQ0 capture/compare register 0   | TQ0CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF548H | TMQ0 capture/compare register 1   | TQ0CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF54AH | TMQ0 capture/compare register 2   | TQ0CCR2 |     |                    |   | √  | 0000H         |       |
| FFFFF54CH | TMQ0 capture/compare register 3   | TQ0CCR3 |     |                    |   | √  | 0000H         |       |
| FFFFF54EH | TMQ0 counter read buffer register | TQ0CNT  | R   |                    |   | √  | 0000H         |       |
| FFFFF590H | TMP0 control register 0           | TP0CTL0 | R/W | √                  | √ |    | 00H           |       |
| FFFFF591H | TMP0 control register 1           | TP0CTL1 |     | √                  | √ |    | 00H           |       |
| FFFFF592H | TMP0 I/O control register 0       | TP0IOC0 |     | √                  | √ |    | 00H           |       |
| FFFFF593H | TMP0 I/O control register 1       | TP0IOC1 |     | √                  | √ |    | 00H           |       |
| FFFFF594H | TMP0 I/O control register 2       | TP0IOC2 |     | √                  | √ |    | 00H           |       |
| FFFFF595H | TMP0 option register 0            | TP0OPT0 |     | √                  | √ |    | 00H           |       |
| FFFFF596H | TMP0 capture/compare register 0   | TP0CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF598H | TMP0 capture/compare register 1   | TP0CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF59AH | TMP0 counter read buffer register | TP0CNT  |     | R                  |   |    | √             | 0000H |
| FFFFF5A0H | TMP1 control register 0           | TP1CTL0 |     | R/W                | √ | √  |               | 00H   |
| FFFFF5A1H | TMP1 control register 1           | TP1CTL1 | √   |                    | √ |    | 00H           |       |
| FFFFF5A2H | TMP1 I/O control register 0       | TP1IOC0 | √   |                    | √ |    | 00H           |       |
| FFFFF5A3H | TMP1 I/O control register 1       | TP1IOC1 | √   |                    | √ |    | 00H           |       |
| FFFFF5A4H | TMP1 I/O control register 2       | TP1IOC2 | √   |                    | √ |    | 00H           |       |
| FFFFF5A5H | TMP1 option register 0            | TP1OPT0 | √   |                    | √ |    | 00H           |       |
| FFFFF5A6H | TMP1 capture/compare register 0   | TP1CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF5A8H | TMP1 capture/compare register 1   | TP1CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF5AAH | TMP1 counter read buffer register | TP1CNT  | R   |                    |   |    | √             | 0000H |
| FFFFF5B0H | TMP2 control register 0           | TP2CTL0 | R/W |                    | √ | √  |               | 00H   |
| FFFFF5B1H | TMP2 control register 1           | TP2CTL1 |     | √                  | √ |    | 00H           |       |
| FFFFF5B2H | TMP2 I/O control register 0       | TP2IOC0 |     | √                  | √ |    | 00H           |       |
| FFFFF5B3H | TMP2 I/O control register 1       | TP2IOC1 |     | √                  | √ |    | 00H           |       |
| FFFFF5B4H | TMP2 I/O control register 2       | TP2IOC2 |     | √                  | √ |    | 00H           |       |
| FFFFF5B5H | TMP2 option register 0            | TP2OPT0 |     | √                  | √ |    | 00H           |       |
| FFFFF5B6H | TMP2 capture/compare register 0   | TP2CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF5B8H | TMP2 capture/compare register 1   | TP2CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF5BAH | TMP2 counter read buffer register | TP2CNT  |     | R                  |   |    | √             | 0000H |
| FFFFF5C0H | TMP3 control register 0           | TP3CTL0 |     | R/W                | √ | √  |               | 00H   |
| FFFFF5C1H | TMP3 control register 1           | TP3CTL1 | √   |                    | √ |    | 00H           |       |
| FFFFF5C2H | TMP3 I/O control register 0       | TP3IOC0 | √   |                    | √ |    | 00H           |       |
| FFFFF5C3H | TMP3 I/O control register 1       | TP3IOC1 | √   |                    | √ |    | 00H           |       |
| FFFFF5C4H | TMP3 I/O control register 2       | TP3IOC2 | √   |                    | √ |    | 00H           |       |

| Address   | Function Register Name            | Symbol  | R/W | Manipulatable Bits |   |    | Default Value |       |
|-----------|-----------------------------------|---------|-----|--------------------|---|----|---------------|-------|
|           |                                   |         |     | 1                  | 8 | 16 |               |       |
| FFFFF5C5H | TMP3 option register 0            | TP3OPT0 | R/W | √                  | √ |    | 00H           |       |
| FFFFF5C6H | TMP3 capture/compare register 0   | TP3CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF5C8H | TMP3 capture/compare register 1   | TP3CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF5CAH | TMP3 counter read buffer register | TP3CNT  | R   |                    |   | √  | 0000H         |       |
| FFFFF5D0H | TMP4 control register 0           | TP4CTL0 | R/W | √                  | √ |    | 00H           |       |
| FFFFF5D1H | TMP4 control register 1           | TP4CTL1 |     | √                  | √ |    | 00H           |       |
| FFFFF5D2H | TMP4 I/O control register 0       | TP4IOC0 |     | √                  | √ |    | 00H           |       |
| FFFFF5D3H | TMP4 I/O control register 1       | TP4IOC1 |     | √                  | √ |    | 00H           |       |
| FFFFF5D4H | TMP4 I/O control register 2       | TP4IOC2 |     | √                  | √ |    | 00H           |       |
| FFFFF5D5H | TMP4 option register 0            | TP4OPT0 |     | √                  | √ |    | 00H           |       |
| FFFFF5D6H | TMP4 capture/compare register 0   | TP4CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF5D8H | TMP4 capture/compare register 1   | TP4CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF5DAH | TMP4 counter read buffer register | TP4CNT  |     | R                  |   |    | √             | 0000H |
| FFFFF5E0H | TMP5 control register 0           | TP5CTL0 |     | R/W                | √ | √  |               | 00H   |
| FFFFF5E1H | TMP5 control register 1           | TP5CTL1 | √   |                    | √ |    | 00H           |       |
| FFFFF5E2H | TMP5 I/O control register 0       | TP5IOC0 | √   |                    | √ |    | 00H           |       |
| FFFFF5E3H | TMP5 I/O control register 1       | TP5IOC1 | √   |                    | √ |    | 00H           |       |
| FFFFF5E4H | TMP5 I/O control register 2       | TP5IOC2 | √   |                    | √ |    | 00H           |       |
| FFFFF5E5H | TMP5 option register 0            | TP5OPT0 | √   |                    | √ |    | 00H           |       |
| FFFFF5E6H | TMP5 capture/compare register 0   | TP5CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF5E8H | TMP5 capture/compare register 1   | TP5CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF5EAH | TMP5 counter read buffer register | TP5CNT  | R   |                    |   |    | √             | 0000H |
| FFFFF5F0H | TMP6 control register 0           | TP6CTL0 | R/W | √                  | √ |    | 00H           |       |
| FFFFF5F1H | TMP6 control register 1           | TP6CTL1 |     | √                  | √ |    | 00H           |       |
| FFFFF5F2H | TMP6 I/O control register 0       | TP6IOC0 |     | √                  | √ |    | 00H           |       |
| FFFFF5F3H | TMP6 I/O control register 1       | TP6IOC1 |     | √                  | √ |    | 00H           |       |
| FFFFF5F4H | TMP6 I/O control register 2       | TP6IOC2 |     | √                  | √ |    | 00H           |       |
| FFFFF5F5H | TMP6 option register 0            | TP6OPT0 |     | √                  | √ |    | 00H           |       |
| FFFFF5F6H | TMP6 capture/compare register 0   | TP6CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF5F8H | TMP6 capture/compare register 1   | TP6CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF5FAH | TMP6 counter read buffer register | TP6CNT  |     | R                  |   |    | √             | 0000H |
| FFFFF600H | TMP7 control register 0           | TP7CTL0 | R/W | √                  | √ |    | 00H           |       |
| FFFFF601H | TMP7 control register 1           | TP7CTL1 |     | √                  | √ |    | 00H           |       |
| FFFFF602H | TMP7 I/O control register 0       | TP7IOC0 |     | √                  | √ |    | 00H           |       |
| FFFFF603H | TMP7 I/O control register 1       | TP7IOC1 |     | √                  | √ |    | 00H           |       |
| FFFFF604H | TMP7 I/O control register 2       | TP7IOC2 |     | √                  | √ |    | 00H           |       |
| FFFFF605H | TMP7 option register 0            | TP7OPT0 |     | √                  | √ |    | 00H           |       |
| FFFFF606H | TMP7 capture/compare register 0   | TP7CCR0 |     |                    |   | √  | 0000H         |       |
| FFFFF608H | TMP7 capture/compare register 1   | TP7CCR1 |     |                    |   | √  | 0000H         |       |
| FFFFF60AH | TMP7 counter read buffer register | TP7CNT  |     | R                  |   |    | √             | 0000H |
| FFFFF610H | TMP8 control register 0           | TP8CTL0 | R/W | √                  | √ |    | 00H           |       |
| FFFFF611H | TMP8 control register 1           | TP8CTL1 |     | √                  | √ |    | 00H           |       |

| Address   | Function Register Name                         | Symbol  | R/W | Manipulatable Bits |   |     | Default Value |
|-----------|--|---------|-----|--------------------|---|-----|---------------|
|           |  |         |     | 1                  | 8 | 16  |               |
| FFFFF612H | TMP8 I/O control register 0                    | TP8IOC0 | R/W | √                  | √ |     | 00H           |
| FFFFF613H | TMP8 I/O control register 1                    | TP8IOC1 |     | √                  | √ |     | 00H           |
| FFFFF614H | TMP8 I/O control register 2                    | TP8IOC2 |     | √                  | √ |     | 00H           |
| FFFFF615H | TMP8 option register 0                         | TP8OPT0 |     | √                  | √ |     | 00H           |
| FFFFF616H | TMP8 capture/compare register 0                | TP8CCR0 |     |                    |   | √   | 0000H         |
| FFFFF618H | TMP8 capture/compare register 1                | TP8CCR1 |     |                    |   | √   | 0000H         |
| FFFFF61AH | TMP8 counter read buffer register              | TP8CNT  | R   |                    |   | √   | 0000H         |
| FFFFF680H | Watch timer operation mode register            | WTM     | R/W | √                  | √ |     | 00H           |
| FFFFF690H | TMM0 control register 0                        | TM0CTL0 |     | √                  | √ |     | 00H           |
| FFFFF694H | TMM0 compare register 0                        | TM0CMP0 |     |                    |   | √   | 0000H         |
| FFFFF6C0H | Oscillation stabilization time select register | OSTS    |     |                    | √ |     | 06H           |
| FFFFF6C1H | PLL lockup time specification register         | PLLS    |     |                    | √ |     | 03H           |
| FFFFF6D0H | Watchdog timer mode register 2                 | WDTM2   |     |                    | √ |     | 67H           |
| FFFFF6D1H | Watchdog timer enable register                 | WDTE    |     |                    | √ |     | 9AH           |
| FFFFF6E0H | Real-time output buffer register 0L            | RTBL0   |     | √                  | √ |     | 00H           |
| FFFFF6E2H | Real-time output buffer register 0H            | RTBH0   |     | √                  | √ |     | 00H           |
| FFFFF6E4H | Real-time output port mode register 0          | RTPM0   |     | √                  | √ |     | 00H           |
| FFFFF6E5H | Real-time output port control register 0       | RTPC0   |     | √                  | √ |     | 00H           |
| FFFFF6F0H | Real-time output buffer register 1L            | RTBL1   |     | √                  | √ |     | 00H           |
| FFFFF6F2H | Real-time output buffer register 1H            | RTBH1   |     | √                  | √ |     | 00H           |
| FFFFF6F4H | Real-time output port mode register 1          | RTPM1   |     | √                  | √ |     | 00H           |
| FFFFF6F5H | Real-time output port control register 1       | RTPC1   |     | √                  | √ |     | 00H           |
| FFFFF706H | Port 3 function control expansion register L   | PFCE3L  |     | √                  | √ |     | 00H           |
| FFFFF70AH | Port 5 function control expansion register     | PFCE5   |     | √                  | √ |     | 00H           |
| FFFFF712H | Port 9 function control expansion register     | PFCE9   |     |                    |   | √   | 0000H         |
| FFFFF712H | Port 9 function control expansion register L   | PFCE9L  |     | √                  | √ |     | 00H           |
| FFFFF713H | Port 9 function control expansion register H   | PFCE9H  |     | √                  | √ |     | 00H           |
| FFFFF802H | System status register                         | SYS     |     | √                  | √ |     | 00H           |
| FFFFF80CH | Internal oscillation mode register             | RCM     |     | √                  | √ |     | 00H           |
| FFFFF810H | DMA trigger factor register 0                  | DTFR0   |     | √                  | √ |     | 00H           |
| FFFFF812H | DMA trigger factor register 1                  | DTFR1   |     | √                  | √ |     | 00H           |
| FFFFF814H | DMA trigger factor register 2                  | DTFR2   |     | √                  | √ |     | 00H           |
| FFFFF816H | DMA trigger factor register 3                  | DTFR3   |     | √                  | √ |     | 00H           |
| FFFFF820H | Power save mode register                       | PSMR    |     | √                  | √ |     | 00H           |
| FFFFF822H | Clock control register                         | CKC     | √   | √                  |   | 0AH |               |
| FFFFF824H | Lock register                                  | LOCKR   | R   | √                  | √ |     | 00H           |
| FFFFF828H | Processor clock control register               | PCC     | R/W | √                  | √ |     | 03H           |
| FFFFF82CH | PLL control register                           | PLLCTL  |     | √                  | √ |     | 01H           |
| FFFFF82EH | CPU operation clock status register            | CCLS    | R   | √                  | √ |     | 00H           |
| FFFFF870H | Clock monitor mode register                    | CLM     | R/W | √                  | √ |     | 00H           |
| FFFFF888H | Reset source flag register                     | RESF    |     | √                  | √ |     | 00H           |
| FFFFF890H | Low-voltage detection register                 | LVIM    |     | √                  | √ |     | 00H           |

| Address   | Function Register Name                                    | Symbol                | R/W | Manipulatable Bits |   |    | Default Value |
|-----------|---|-----------------------|-----|--------------------|---|----|---------------|
|           |   |                       |     | 1                  | 8 | 16 |               |
| FFFFF891H | Low-voltage detection level select register               | LVIS                  | R/W |                    | √ |    | 00H           |
| FFFFF892H | Internal RAM data status register                         | RAMS                  |     | √                  | √ |    | 01H           |
| FFFFF8B0H | Prescaler mode register 0                                 | PRSM0                 |     | √                  | √ |    | 00H           |
| FFFFF8B1H | Prescaler compare register 0                              | PRSCM0                |     |                    | √ |    | 00H           |
| FFFFF9FCH | On-chip debug mode register                               | OCDM                  |     | √                  | √ |    | 01H           |
| FFFFF9FEH | Peripheral emulation register 1                           | PEMU1 <sup>Note</sup> |     | √                  | √ |    | 00H           |
| FFFFFA00H | UARTA0 control register 0                                 | UA0CTL0               |     | √                  | √ |    | 10H           |
| FFFFFA01H | UARTA0 control register 1                                 | UA0CTL1               |     |                    | √ |    | 00H           |
| FFFFFA02H | UARTA0 control register 2                                 | UA0CTL2               |     |                    | √ |    | FFH           |
| FFFFFA03H | UARTA0 option control register 0                          | UA0OPT0               |     | √                  | √ |    | 14H           |
| FFFFFA04H | UARTA0 status register                                    | UA0STR                |     | √                  | √ |    | 00H           |
| FFFFFA06H | UARTA0 receive data register                              | UA0RX                 | R   |                    | √ |    | FFH           |
| FFFFFA07H | UARTA0 transmit data register                             | UA0TX                 | R/W |                    | √ |    | FFH           |
| FFFFFA10H | UARTA1 control register 0                                 | UA1CTL0               |     | √                  | √ |    | 10H           |
| FFFFFA11H | UARTA1 control register 1                                 | UA1CTL1               |     |                    | √ |    | 00H           |
| FFFFFA12H | UARTA1 control register 2                                 | UA1CTL2               |     |                    | √ |    | FFH           |
| FFFFFA13H | UARTA1 option control register 0                          | UA1OPT0               |     | √                  | √ |    | 14H           |
| FFFFFA14H | UARTA1 status register                                    | UA1STR                |     | √                  | √ |    | 00H           |
| FFFFFA16H | UARTA1 receive data register                              | UA1RX                 |     | R                  |   | √  |               |
| FFFFFA17H | UARTA1 transmit data register                             | UA1TX                 | R/W |                    | √ |    | FFH           |
| FFFFFA20H | UARTA2 control register 0                                 | UA2CTL0               |     | √                  | √ |    | 10H           |
| FFFFFA21H | UARTA2 control register 1                                 | UA2CTL1               |     |                    | √ |    | 00H           |
| FFFFFA22H | UARTA2 control register 2                                 | UA2CTL2               |     |                    | √ |    | FFH           |
| FFFFFA23H | UARTA2 option control register 0                          | UA2OPT0               |     | √                  | √ |    | 14H           |
| FFFFFA24H | UARTA2 status register                                    | UA2STR                |     | √                  | √ |    | 00H           |
| FFFFFA26H | UARTA2 receive data register                              | UA2RX                 |     | R                  |   | √  |               |
| FFFFFA27H | UARTA2 transmit data register                             | UA2TX                 | R/W |                    | √ |    | FFH           |
| FFFFFA30H | UARTA3 control register 0                                 | UA3CTL0               |     | √                  | √ |    | 10H           |
| FFFFFA31H | UARTA3 control register 1                                 | UA3CTL1               |     |                    | √ |    | 00H           |
| FFFFFA32H | UARTA3 control register 2                                 | UA3CTL2               |     |                    | √ |    | FFH           |
| FFFFFA33H | UARTA3 option control register 0                          | UA3OPT0               |     | √                  | √ |    | 14H           |
| FFFFFA34H | UARTA3 status register                                    | UA3STR                |     | √                  | √ |    | 00H           |
| FFFFFA36H | UARTA3 receive data register                              | UA3RX                 | R   |                    | √ |    | FFH           |
| FFFFFA37H | UARTA3 transmit data register                             | UA3TX                 | R/W |                    | √ |    | FFH           |
| FFFFFC00H | External interrupt falling edge specification register 0  | INTF0                 |     | √                  | √ |    | 00H           |
| FFFFFC06H | External interrupt falling edge specification register 3  | INTF3                 |     | √                  | √ |    | 00H           |
| FFFFFC10H | External interrupt falling edge specification register 8  | INTF8                 |     | √                  | √ |    | 00H           |
| FFFFFC13H | External interrupt falling edge specification register 9H | INTF9H                |     | √                  | √ |    | 00H           |
| FFFFFC20H | External interrupt rising edge specification register 0   | INTR0                 |     | √                  | √ |    | 00H           |
| FFFFFC26H | External interrupt rising edge specification register 3   | INTR3                 |     | √                  | √ |    | 00H           |
| FFFFFC30H | External interrupt rising edge specification register 8   | INTR8                 |     | √                  | √ |    | 00H           |
| FFFFFC33H | External interrupt rising edge specification register 9H  | INTR9H                |     | √                  | √ |    | 00H           |

**Note** Only during emulation

| Address   | Function Register Name         | Symbol  | R/W | Manipulatable Bits |   |    | Default Value |
|-----------|--------------------------------|---------|-----|--------------------|---|----|---------------|
|           |                                |         |     | 1                  | 8 | 16 |               |
| FFFFFC60H | Port 0 function register       | PF0     | R/W | √                  | √ |    | 00H           |
| FFFFFC66H | Port 3 function register       | PF3     |     |                    |   | √  | 0000H         |
| FFFFFC66H | Port 3 function register L     | PF3L    |     | √                  | √ |    | 00H           |
| FFFFFC67H | Port 3 function register H     | PF3H    |     | √                  | √ |    | 00H           |
| FFFFFC68H | Port 4 function register       | PF4     |     | √                  | √ |    | 00H           |
| FFFFFC6AH | Port 5 function register       | PF5     |     | √                  | √ |    | 00H           |
| FFFFFC6CH | Port 6 function register       | PF6     |     |                    |   | √  | 0000H         |
| FFFFFC6CH | Port 6 function register L     | PF6L    |     | √                  | √ |    | 00H           |
| FFFFFC6DH | Port 6 function register H     | PF6H    |     | √                  | √ |    | 00H           |
| FFFFFC70H | Port 8 function register       | PF8     |     | √                  | √ |    | 00H           |
| FFFFFC72H | Port 9 function register       | PF9     |     |                    |   | √  | 0000H         |
| FFFFFC72H | Port 9 function register L     | PF9L    |     | √                  | √ |    | 00H           |
| FFFFFC73H | Port 9 function register H     | PF9H    |     | √                  | √ |    | 00H           |
| FFFFFD00H | CSIB0 control register 0       | CB0CTL0 |     | √                  | √ |    | 01H           |
| FFFFFD01H | CSIB0 control register 1       | CB0CTL1 |     | √                  | √ |    | 00H           |
| FFFFFD02H | CSIB0 control register 2       | CB0CTL2 |     |                    | √ |    | 00H           |
| FFFFFD03H | CSIB0 status register          | CB0STR  |     | √                  | √ |    | 00H           |
| FFFFFD04H | CSIB0 receive data register    | CB0RX   | R   |                    |   | √  | 0000H         |
| FFFFFD04H | CSIB0 receive data register L  | CB0RXL  |     |                    | √ |    | 00H           |
| FFFFFD06H | CSIB0 transmit data register   | CB0TX   | R/W |                    |   | √  | 0000H         |
| FFFFFD06H | CSIB0 transmit data register L | CB0TXL  |     |                    |   | √  | 00H           |
| FFFFFD10H | CSIB1 control register 0       | CB1CTL0 |     | √                  | √ |    | 01H           |
| FFFFFD11H | CSIB1 control register 1       | CB1CTL1 |     | √                  | √ |    | 00H           |
| FFFFFD12H | CSIB1 control register 2       | CB1CTL2 |     |                    | √ |    | 00H           |
| FFFFFD13H | CSIB1 status register          | CB1STR  |     | √                  | √ |    | 00H           |
| FFFFFD14H | CSIB1 receive data register    | CB1RX   | R   |                    |   | √  | 0000H         |
| FFFFFD14H | CSIB1 receive data register L  | CB1RXL  |     |                    | √ |    | 00H           |
| FFFFFD16H | CSIB1 transmit data register   | CB1TX   | R/W |                    |   | √  | 0000H         |
| FFFFFD16H | CSIB1 transmit data register L | CB1TXL  |     |                    |   | √  | 00H           |
| FFFFFD20H | CSIB2 control register 0       | CB2CTL0 |     | √                  | √ |    | 01H           |
| FFFFFD21H | CSIB2 control register 1       | CB2CTL1 |     | √                  | √ |    | 00H           |
| FFFFFD22H | CSIB2 control register 2       | CB2CTL2 |     |                    | √ |    | 00H           |
| FFFFFD23H | CSIB2 status register          | CB2STR  |     | √                  | √ |    | 00H           |
| FFFFFD24H | CSIB2 receive data register    | CB2RX   | R   |                    |   | √  | 0000H         |
| FFFFFD24H | CSIB2 receive data register L  | CB2RXL  |     |                    | √ |    | 00H           |
| FFFFFD26H | CSIB2 transmit data register   | CB2TX   | R/W |                    |   | √  | 0000H         |
| FFFFFD26H | CSIB2 transmit data register L | CB2TXL  |     |                    |   | √  | 00H           |
| FFFFFD30H | CSIB3 control register 0       | CB3CTL0 |     | √                  | √ |    | 01H           |
| FFFFFD31H | CSIB3 control register 1       | CB3CTL1 |     | √                  | √ |    | 00H           |
| FFFFFD32H | CSIB3 control register 2       | CB3CTL2 |     |                    | √ |    | 00H           |
| FFFFFD33H | CSIB3 status register          | CB3STR  |     | √                  | √ |    | 00H           |
| FFFFFD34H | CSIB3 receive data register    | CB3RX   | R   |                    |   | √  | 0000H         |
| FFFFFD34H | CSIB3 receive data register L  | CB3RXL  |     |                    | √ |    | 00H           |

| Address   | Function Register Name                       | Symbol  | R/W | Manipulatable Bits |   |    | Default Value |       |
|-----------|--|---------|-----|--------------------|---|----|---------------|-------|
|           |  |         |     | 1                  | 8 | 16 |               |       |
| FFFFFD36H | CSIB3 transmit data register                 | CB3TX   | R/W |                    |   | √  | 0000H         |       |
| FFFFFD36H | CSIB3 transmit data register L               | CB3TXL  |     |                    | √ |    | 00H           |       |
| FFFFFD40H | CSIB4 control register 0                     | CB4CTL0 | R/W | √                  | √ |    | 01H           |       |
| FFFFFD41H | CSIB4 control register 1                     | CB4CTL1 |     | √                  | √ |    | 00H           |       |
| FFFFFD42H | CSIB4 control register 2                     | CB4CTL2 |     |                    | √ |    | 00H           |       |
| FFFFFD43H | CSIB4 status register                        | CB4STR  |     | √                  | √ |    | 00H           |       |
| FFFFFD44H | CSIB4 receive data register                  | CB4RX   |     | R                  |   |    | √             | 0000H |
| FFFFFD44H | CSIB4 receive data register L                | CB4RXL  |     |                    |   | √  |               | 00H   |
| FFFFFD46H | CSIB4 transmit data register                 | CB4TX   | R/W |                    |   | √  | 0000H         |       |
| FFFFFD46H | CSIB4 transmit data register L               | CB4TXL  |     |                    | √ |    | 00H           |       |
| FFFFFD50H | CSIB5 control register 0                     | CB5CTL0 | R/W | √                  | √ |    | 01H           |       |
| FFFFFD51H | CSIB5 control register 1                     | CB5CTL1 |     | √                  | √ |    | 00H           |       |
| FFFFFD52H | CSIB5 control register 2                     | CB5CTL2 |     |                    | √ |    | 00H           |       |
| FFFFFD53H | CSIB5 status register                        | CB5STR  |     | √                  | √ |    | 00H           |       |
| FFFFFD54H | CSIB5 receive data register                  | CB5RX   |     | R                  |   |    | √             | 0000H |
| FFFFFD54H | CSIB5 receive data register L                | CB5RXL  |     |                    |   | √  |               | 00H   |
| FFFFFD56H | CSIB5 transmit data register                 | CB5TX   | R/W |                    |   | √  | 0000H         |       |
| FFFFFD56H | CSIB5 transmit data register L               | CB5TXL  |     |                    | √ |    | 00H           |       |
| FFFFFD80H | IIC shift register 0                         | IIC0    | R/W |                    | √ |    | 00H           |       |
| FFFFFD82H | IIC control register 0                       | IICC0   |     | √                  | √ |    | 00H           |       |
| FFFFFD83H | Slave address register 0                     | SVA0    |     |                    | √ |    | 00H           |       |
| FFFFFD84H | IIC clock select register 0                  | IICCL0  |     | √                  | √ |    | 00H           |       |
| FFFFFD85H | IIC function expansion register 0            | IICX0   |     | √                  | √ |    | 00H           |       |
| FFFFFD86H | IIC status register 0                        | IICS0   |     | R                  | √ | √  |               | 00H   |
| FFFFFD8AH | IIC flag register 0                          | IICF0   | R/W | √                  | √ |    | 00H           |       |
| FFFFFD90H | IIC shift register 1                         | IIC1    |     |                    | √ |    | 00H           |       |
| FFFFFD92H | IIC control register 1                       | IICC1   |     | √                  | √ |    | 00H           |       |
| FFFFFD93H | Slave address register 1                     | SVA1    |     |                    | √ |    | 00H           |       |
| FFFFFD94H | IIC clock select register 1                  | IICCL1  |     | √                  | √ |    | 00H           |       |
| FFFFFD95H | IIC function expansion register 1            | IICX1   |     | √                  | √ |    | 00H           |       |
| FFFFFD96H | IIC status register 1                        | IICS1   | R   | √                  | √ |    | 00H           |       |
| FFFFFD9AH | IIC flag register 1                          | IICF1   | R/W | √                  | √ |    | 00H           |       |
| FFFFFDA0H | IIC shift register 2                         | IIC2    |     |                    | √ |    | 00H           |       |
| FFFFFDA2H | IIC control register 2                       | IICC2   |     | √                  | √ |    | 00H           |       |
| FFFFFDA3H | Slave address register 2                     | SVA2    |     |                    | √ |    | 00H           |       |
| FFFFFDA4H | IIC clock select register 2                  | IICCL2  |     | √                  | √ |    | 00H           |       |
| FFFFFDA5H | IIC function expansion register 2            | IICX2   |     | √                  | √ |    | 00H           |       |
| FFFFFDA6H | IIC status register 2                        | IICS2   | R   | √                  | √ |    | 00H           |       |
| FFFFDAAH  | IIC flag register 2                          | IICF2   | R/W | √                  | √ |    | 00H           |       |
| FFFFFBEH  | External bus interface mode control register | EXIMC   |     | √                  | √ |    | 00H           |       |

### 3.4.7 Special registers

Special registers are registers that are protected from being written with illegal data due to a program hang-up. The V850ES/JJ3 has the following eight special registers.

- Power save control register (PSC)
- Clock control register (CKC)
- Processor clock control register (PCC)
- Clock monitor mode register (CLM)
- Reset source flag register (RESF)
- Low-voltage detection register (LVIM)
- Internal RAM data status register (RAMS)
- On-chip debug mode register (OCDM)

In addition, the PRCDM register is provided to protect against a write access to the special registers so that the application system does not inadvertently stop due to a program hang-up. A write access to the special registers is made in a specific sequence, and an illegal store operation is reported to the SYS register.



**(1) Setting data to special registers**

Set data to the special registers in the following sequence.

- <1> Disable DMA operation.
- <2> Prepare data to be set to the special register in a general-purpose register.
- <3> Write the data prepared in <2> to the PRCMD register.
- <4> Write the setting data to the special register (by using the following instructions).
  - Store instruction (ST/SST instruction)
  - Bit manipulation instruction (SET1/CLR1/NOT1 instruction)
- (<5> to <9> Insert NOP instructions (5 instructions).)<sup>Note</sup>
- <10> Enable DMA operation if necessary.

[Example] With PSC register (setting standby mode)

```

    ST.B r11, PSMR[r0] ; Set PSMR register (setting IDLE1, IDLE2, and STOP modes).
<1>CLR1 0, DCHCn[r0] ; Disable DMA operation. n = 0 to 3
<2>MOV0x02, r10
<3>ST.B r10, PRCMD[r0] ; Write PRCMD register.
<4>ST.B r10, PSC[r0] ; Set PSC register.
<5>NOPNote ; Dummy instruction
<6>NOPNote ; Dummy instruction
<7>NOPNote ; Dummy instruction
<8>NOPNote ; Dummy instruction
<9>NOPNote ; Dummy instruction
<10>SET1 0, DCHCn[r0] ; Enable DMA operation. n = 0 to 3
(next instruction)

```

There is no special sequence to read a special register.

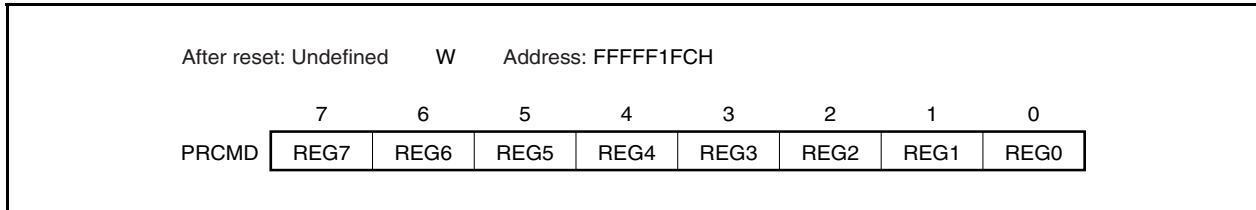
**Note** Five NOP instructions or more must be inserted immediately after setting the IDLE1 mode, IDLE2 mode, or STOP mode (by setting the PSC.STP bit to 1).

- Cautions 1.** When a store instruction is executed to store data in the command register, interrupts are not acknowledged. This is because it is assumed that steps <3> and <4> above are performed by successive store instructions. If another instruction is placed between <3> and <4>, and if an interrupt is acknowledged by that instruction, the above sequence may not be established, causing malfunction.
- 2.** Although dummy data is written to the PRCMD register, use the same general-purpose register used to set the special register (<4> in Example) to write data to the PRCMD register (<3> in Example). The same applies when a general-purpose register is used for addressing.

**(2) Command register (PRCMD)**

The PRCMD register is an 8-bit register that protects the registers that may seriously affect the application system from being written, so that the system does not inadvertently stop due to a program hang-up. The first write access to a special register is valid after data has been written in advance to the PRCMD register. In this way, the value of the special register can be rewritten only in a specific sequence, so as to protect the register from an illegal write access.

The PRCMD register is write-only, in 8-bit units (undefined data is read when this register is read).



**(3) System status register (SYS)**

Status flags that indicate the operation status of the overall system are allocated to this register.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

|                  |       |                                |   |   |   |   |   |   |       |
|------------------|-------|--------------------------------|---|---|---|---|---|---|-------|
| After reset: 00H | R/W   | Address: FFFFF802H             |   |   |   |   |   |   |       |
|                  |       | 7                              | 6 | 5 | 4 | 3 | 2 | 1 | <0>   |
| SYS              |       | 0                              | 0 | 0 | 0 | 0 | 0 | 0 | PRERR |
|                  | PRERR | Detects protection error       |   |   |   |   |   |   |       |
|                  | 0     | Protection error did not occur |   |   |   |   |   |   |       |
|                  | 1     | Protection error occurred      |   |   |   |   |   |   |       |

The PRERR flag operates under the following conditions.

**(a) Set condition (PRERR flag = 1)**

- (i) When data is written to a special register without writing anything to the PRCMD register (when <4> is executed without executing <3> in **3.4.7 (1) Setting data to special registers**)
- (ii) When data is written to an on-chip peripheral I/O register other than a special register (including execution of a bit manipulation instruction) after writing data to the PRCMD register (if <4> in **3.4.7 (1) Setting data to special registers** is not the setting of a special register)

**Remark** Even if an on-chip peripheral I/O register is read (except by a bit manipulation instruction) between an operation to write the PRCMD register and an operation to write a special register, the PRERR flag is not set, and the set data can be written to the special register.

**(b) Clear condition (PRERR flag = 0)**

- (i) When 0 is written to the PRERR flag
- (ii) When the system is reset

**Cautions 1.** If 0 is written to the PRERR bit of the SYS register, which is not a special register, immediately after a write access to the PRCMD register, the PRERR bit is cleared to 0 (the write access takes precedence).

**2.** If data is written to the PRCMD register, which is not a special register, immediately after a write access to the PRCMD register, the PRERR bit is set to 1.

### 3.4.8 Cautions

#### (1) Registers to be set first

Be sure to set the following registers first when using the V850ES/JJ3.

- System wait control register (VSWC)
- On-chip debug mode register (OCDM)
- Watchdog timer mode register 2 (WDTM2)

After setting the VSWC, OCDM, and WDTM2 registers, set the other registers as necessary.

When using the external bus, set each pin to the alternate-function bus control pin mode by using the port-related registers after setting the above registers.

#### (a) System wait control register (VSWC)

The VSWC register controls wait of bus access to the on-chip peripheral I/O registers.

Three clocks are required to access an on-chip peripheral I/O register (without a wait cycle). The V850ES/JJ3 requires wait cycles according to the operating frequency. Set the following value to the VSWC register in accordance with the frequency used.

The VSWC register can be read or written in 8-bit units (address: FFFFF06EH, default value: 77H).

| Operating Frequency ( $f_{CLK}$ )                 | Set Value of VSWC | Number of Waits |
|---|-------------------|-----------------|
| $32 \text{ kHz} \leq f_{CLK} < 16.6 \text{ MHz}$  | 00H               | 0 (no waits)    |
| $16.6 \text{ MHz} \leq f_{CLK} < 25 \text{ MHz}$  | 01H               | 1               |
| $25 \text{ MHz} \leq f_{CLK} \leq 32 \text{ MHz}$ | 11H               | 2               |

#### (b) On-chip debug mode register (OCDM)

For details, see **CHAPTER 28 ON-CHIP DEBUG FUNCTION**.

#### (c) Watchdog timer mode register 2 (WDTM2)

The WDTM2 register sets the overflow time and the operation clock of watchdog timer 2.

Watchdog timer 2 automatically starts in the reset mode after reset is released. Write the WDTM2 register to activate this operation.

For details, refer to **CHAPTER 11 FUNCTIONS OF WATCHDOG TIMER 2**.

**(2) Accessing specific on-chip peripheral I/O registers**

This product has two types of internal system buses.

One is a CPU bus and the other is a peripheral bus that interfaces with low-speed peripheral hardware.

The clock of the CPU bus and the clock of the peripheral bus are asynchronous. If an access to the CPU and an access to the peripheral hardware conflict, therefore, unexpected illegal data may be transferred. If there is a possibility of a conflict, the number of cycles for accessing the CPU changes when the peripheral hardware is accessed, so that correct data is transferred. As a result, the CPU does not start processing of the next instruction but enters the wait state. If this wait state occurs, the number of clocks required to execute an instruction increases by the number of wait clocks shown below.

This must be taken into consideration if real-time processing is required.

When specific on-chip peripheral I/O registers are accessed, more wait states may be required in addition to the wait states set by the VSWC register.

The access conditions and how to calculate the number of wait states to be inserted (number of CPU clocks) at this time are shown below.

| Peripheral Function                                | Register Name         | Access                          | k   |
|--|-----------------------|---------------------------------|---|
| 16-bit timer/event counter P (TMP)<br>(n = 0 to 8) | TPnCNT                | Read                            | 1 or 2  |
|  | TPnCCR0, TPnCCR1      | Write                           | <ul style="list-style-type: none"> <li>• 1st access: No wait</li> <li>• Continuous write: 3 or 4</li> </ul> |
|  |                       | Read                            | 1 or 2  |
| 16-bit timer/event counter Q (TMQ)                 | TQ0CNT                | Read                            | 1 or 2  |
|  | TQ0CCR0 to TQ0CCR3    | Write                           | <ul style="list-style-type: none"> <li>• 1st access: No wait</li> <li>• Continuous write: 3 or 4</li> </ul> |
|  |                       | Read                            | 1 or 2  |
| Watchdog timer 2 (WDT2)                            | WDTM2                 | Write<br>(when WDT2 operating)  | 3   |
| Real-time output function (RTO)<br>(n = 0, 1)      | RTBLn, RTBHn          | Write<br>(RTPCn.RTPOEn bit = 0) | 1   |
| A/D converter                                      | ADA0M0                | Read                            | 1 or 2  |
|  | ADA0CR0 to ADA0CR15   | Read                            | 1 or 2  |
|  | ADA0CR0H to ADA0CR15H | Read                            | 1 or 2  |
| I <sup>2</sup> C00 to I <sup>2</sup> C02           | IICS0 to IICS2        | Read                            | 1   |
| CRC  | CRCD                  | Write                           | 1   |

Number of clocks necessary for access = 3 + i + j + (2 + j) × k

**Caution** Accessing the above registers is prohibited in the following statuses. If a wait cycle is generated, it can only be cleared by a reset.

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock

**Remark** i: Values (0 or 1) of higher 4 bits of VSWC register  
j: Values (0 or 1) of lower 4 bits of VSWC register

**(3) Restriction on conflict between sld instruction and interrupt request****(a) Description**

If a conflict occurs between the decode operation of an instruction in <2> immediately before the sld instruction following an instruction in <1> and an interrupt request before the instruction in <1> is complete, the execution result of the instruction in <1> may not be stored in a register.

Instruction <1>

- ld instruction: ld.b, ld.h, ld.w, ld.bu, ld.hu
- sld instruction: sld.b, sld.h, sld.w, sld.bu, sld.hu
- Multiplication instruction: mul, mulh, mulhi, mulu

Instruction <2>

|                   |                   |                    |                   |
|-------------------|-------------------|--------------------|-------------------|
| mov reg1, reg2    | not reg1, reg2    | satsubr reg1, reg2 | satsub reg1, reg2 |
| satadd reg1, reg2 | satadd imm5, reg2 | or reg1, reg2      | xor reg1, reg2    |
| and reg1, reg2    | tst reg1, reg2    | subr reg1, reg2    | sub reg1, reg2    |
| add reg1, reg2    | add imm5, reg2    | cmp reg1, reg2     | cmp imm5, reg2    |
| mulh reg1, reg2   | shr imm5, reg2    | sar imm5, reg2     | shl imm5, reg2    |

<Example>

<i> ld.w [r11], r10  
 •  
 •  
 •

If the decode operation of the mov instruction <ii> immediately before the sld instruction <iii> and an interrupt request conflict before execution of the ld instruction <i> is complete, the execution result of instruction <i> may not be stored in a register.

<ii> mov r10, r28

<iii> sld.w 0x28, r10

**(b) Countermeasure**

<1> When compiler (CA850) is used

Use CA850 Ver. 2.61 or later because generation of the corresponding instruction sequence can be automatically suppressed.

<2> Countermeasure by assembler

When executing the sld instruction immediately after instruction <ii>, avoid the above operation using either of the following methods.

- Insert a nop instruction immediately before the sld instruction.
- Do not use the same register as the sld instruction destination register in the above instruction <ii> executed immediately before the sld instruction.

## CHAPTER 4 PORT FUNCTIONS

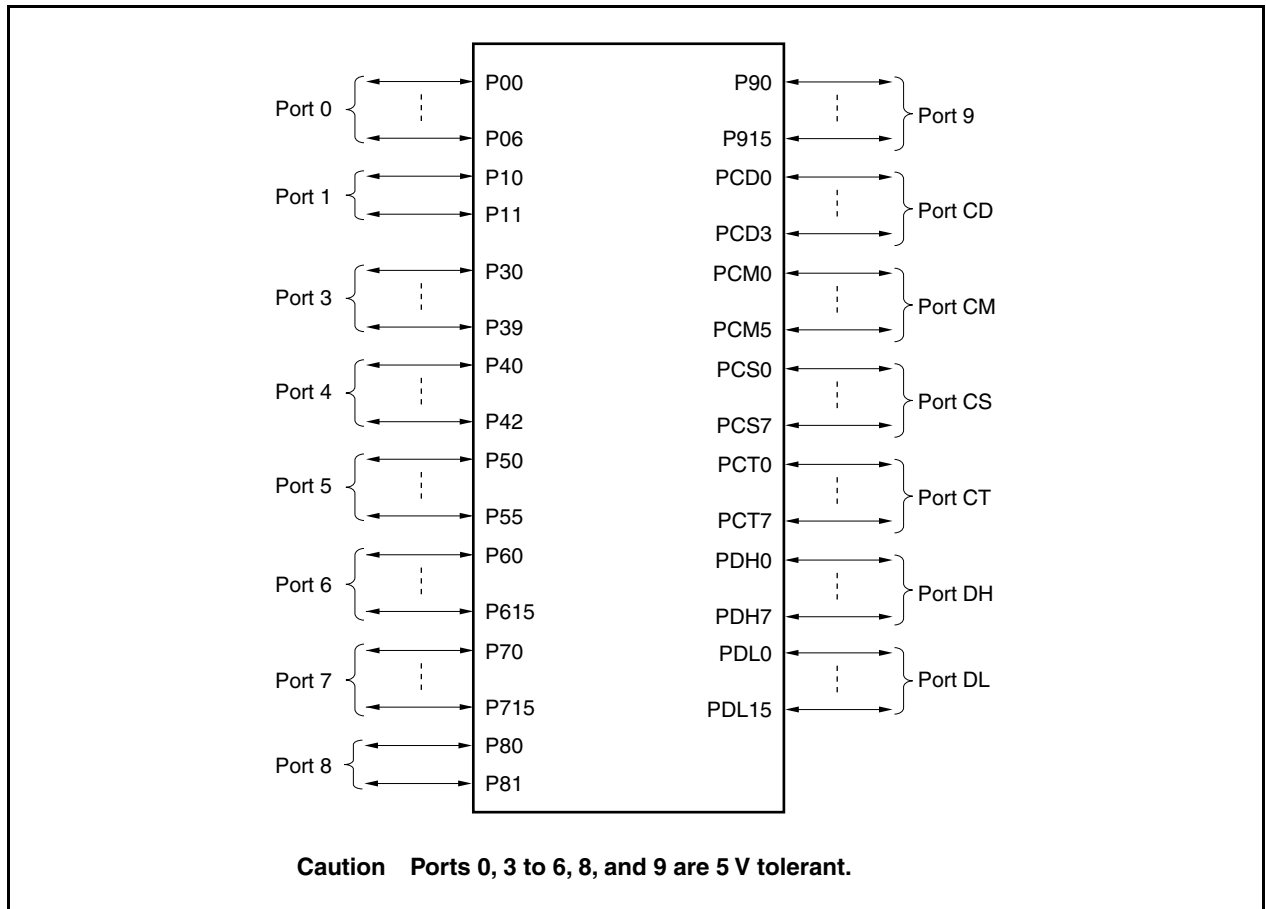
### 4.1 Features

- I/O ports: 128
  - 5 V tolerant/N-ch open-drain output switchable: 60 (ports 0, 3 to 6, 8, 9)
- Input/output specifiable in 1-bit units

### 4.2 Basic Port Configuration

The V850ES/JJ3 features a total of 128 I/O ports consisting of ports 0, 1, 3 to 9, CD, CM, CS, CT, DH, and DL. The port configuration is shown below.

**Figure 4-1. Port Configuration Diagram**



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

| Power Supply       | Corresponding Pins                                   |
|--------------------|--|
| AV <sub>REF0</sub> | Port 7   |
| AV <sub>REF1</sub> | Port 1   |
| EV <sub>DD</sub>   | RESET, ports 0, 3 to 6, 8, 9, CD, CM, CS, CT, DH, DL |

### 4.3 Port Configuration

**Table 4-2. Port Configuration**

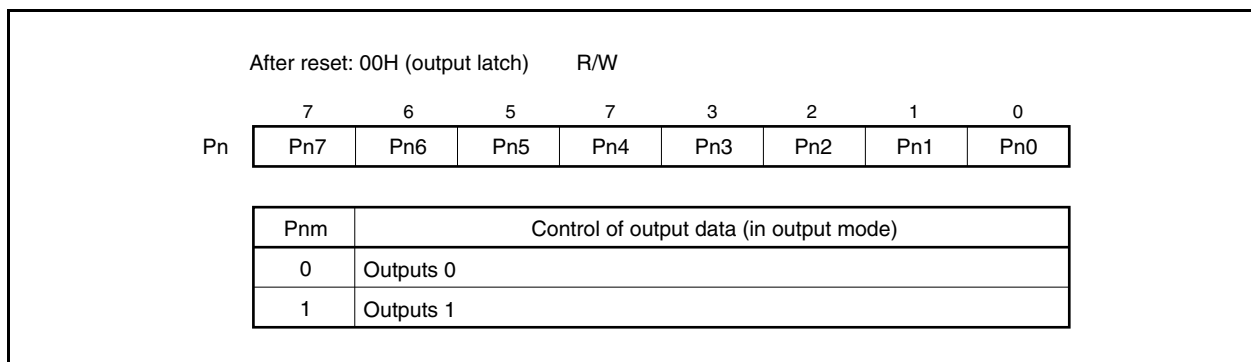
| Item             | Configuration   |
|------------------|---|
| Control register | Port n mode register (PMn: n = 0, 1, 3 to 9, CD, CM, CS, CT, DH, DL)<br>Port n mode control register (PMCn: n = 0, 3 to 6, 8, 9, CM, CS, CT, DH, DL)<br>Port n function control register (PFCn: n = 0, 3 to 6, 9)<br>Port n function control expansion register (PFCEn: n = 3, 5, 9)<br>Port n function register (PFn: n = 0, 3 to 6, 8, 9) |
| Ports            | I/O: 128  |

#### (1) Port n register (Pn)

Data is input from or output to an external device by writing or reading the Pn register.

The Pn register consists of a port latch that holds output data, and a circuit that reads the status of pins.

Each bit of the Pn register corresponds to one pin of port n, and can be read or written in 1-bit units.



Data is written to or read from the Pn register as follows, regardless of the setting of the PMCn register.

**Table 4-3. Writing/Reading Pn Register**

| Setting of PMn Register   | Writing to Pn Register   | Reading from Pn Register               |
|---------------------------|--|--|
| Output mode<br>(PMnm = 0) | Data is written to the output latch <sup>Note</sup> .<br>In the port mode (PMCn = 0), the contents of the output latch are output from the pins. | The value of the output latch is read. |
| Input mode<br>(PMnm = 1)  | Data is written to the output latch.<br>The pin status is not affected <sup>Note</sup> .   | The pin status is read.                |

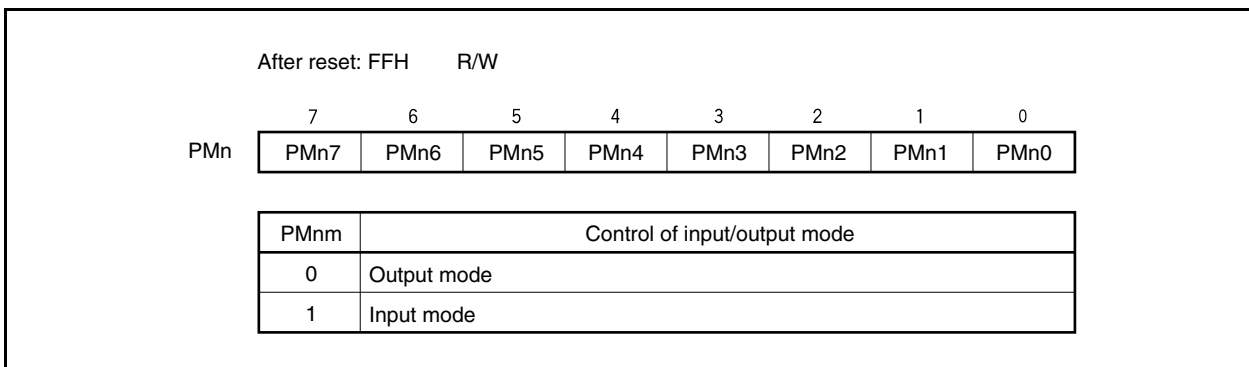
**Note** The value written to the output latch is retained until a new value is written to the output latch.



**(2) Port n mode register (PMn)**

The PMn register specifies the input or output mode of the corresponding port pin.

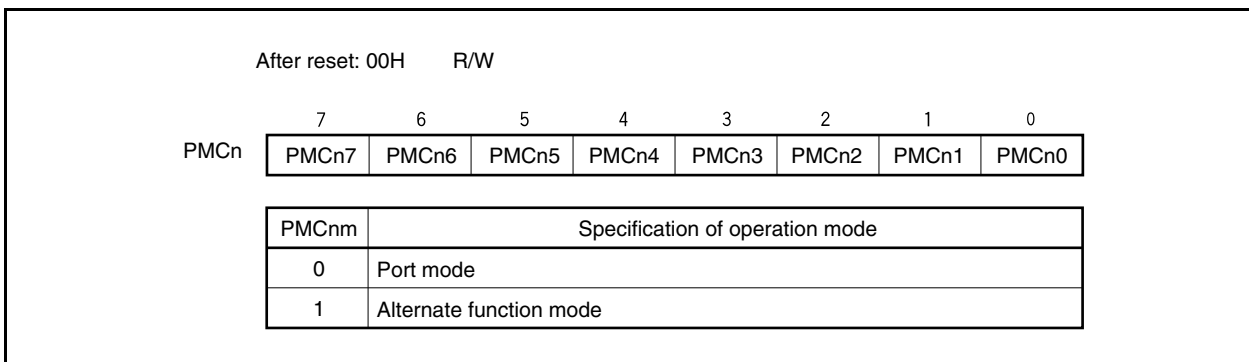
Each bit of this register corresponds to one pin of port n, and the input or output mode can be specified in 1-bit units.



**(3) Port n mode control register (PMCn)**

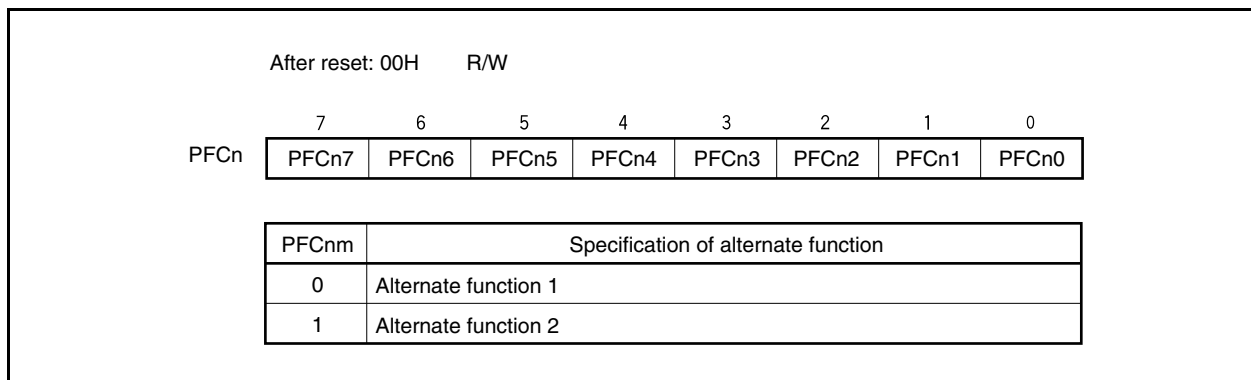
The PMCn register specifies the port mode or alternate function.

Each bit of this register corresponds to one pin of port n, and the mode of the port can be specified in 1-bit units.



**(4) Port n function control register (PFCn)**

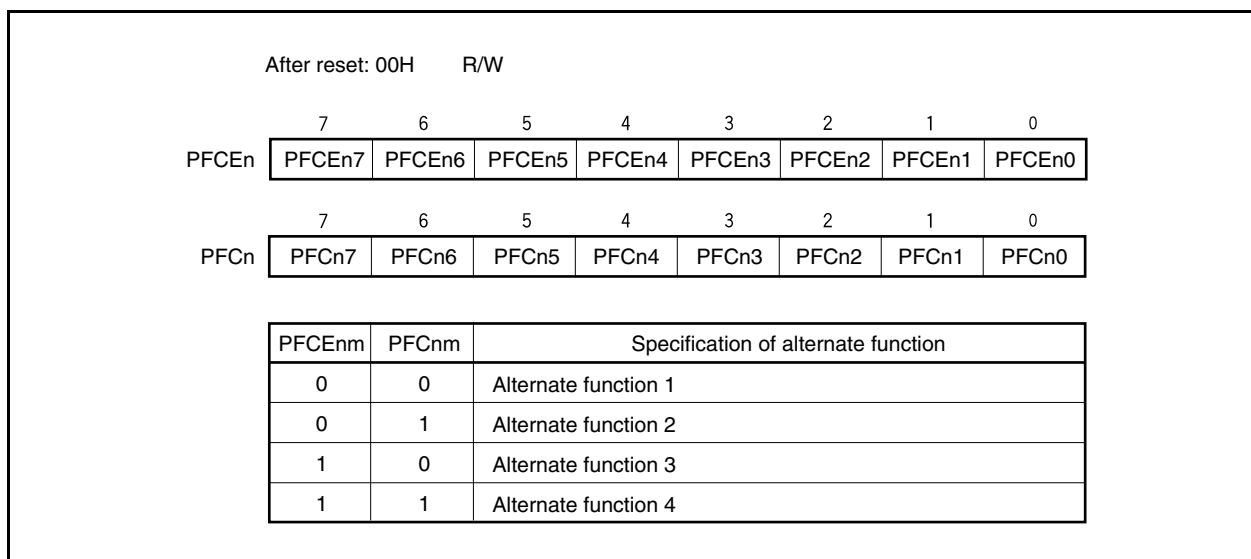
The PFCn register specifies the alternate function of a port pin to be used if the pin has two alternate functions. Each bit of this register corresponds to one pin of port n, and the alternate function of a port pin can be specified in 1-bit units.



**(5) Port n function control expansion register (PFCEn)**

The PFCEn register specifies the alternate function of a port pin to be used if the pin has three or more alternate functions.

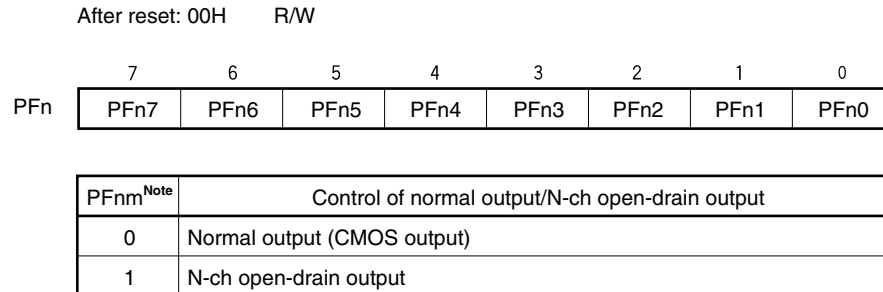
Each bit of this register corresponds to one pin of port n, and the alternate function of a port pin can be specified in 1-bit units.



**(6) Port n function register (PFn)**

The PFn register specifies normal output or N-ch open-drain output.

Each bit of this register corresponds to one pin of port n, and the output mode of the port pin can be specified in 1-bit units.

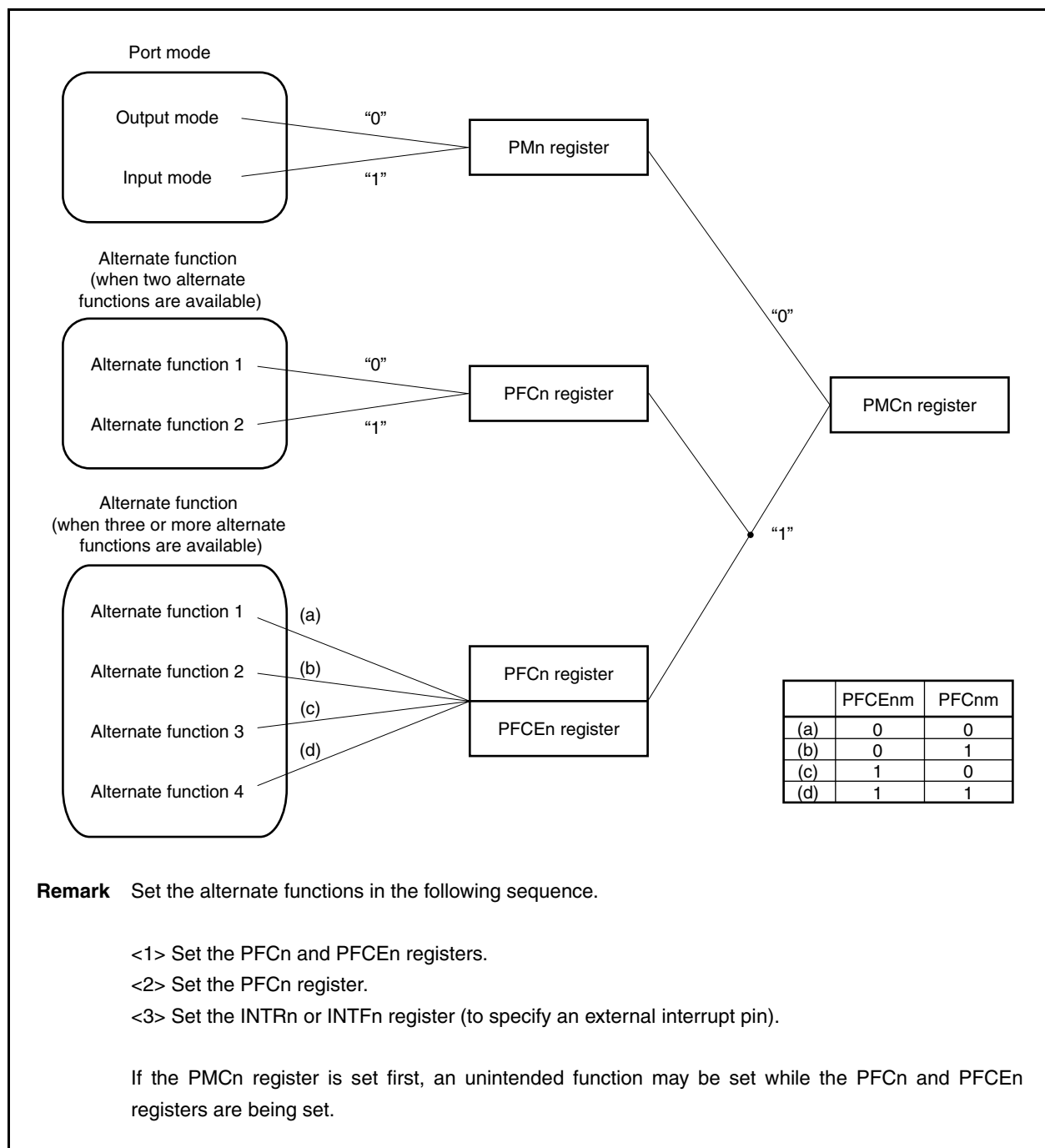


**Note** The PFnm bit of the PFn register is valid only when the PMnm bit of the PMn register is 0 (when the output mode is specified) in port mode (PMCnm bit = 0). When the PMnm bit is 1 (when the input mode is specified), the set value of the PFn register is invalid.

**(7) Port setting**

Set a port as illustrated below.

**Figure 4-2. Setting of Each Register and Pin Function**



4.3.1 Port 0

Port 0 is a 7-bit port for which I/O settings can be controlled in 1-bit units.

Port 0 includes the following alternate-function pins.

Table 4-4. Port 0 Alternate-Function Pins

| Pin Name | Pin No. | Alternate-Function Pin Name                     | I/O   | Remark                               | Block Type |
|----------|---------|---|-------|--------------------------------------|------------|
| P00      | 6       | TIP61/TOP61                                     | I/O   | Selectable as N-ch open-drain output | G-1        |
| P01      | 7       | TIP60/TOP60                                     | I/O   |                                      | G-1        |
| P02      | 17      | NMI   | Input |                                      | L-1        |
| P03      | 18      | INTP0/ADTRG                                     | Input |                                      | N-1        |
| P04      | 19      | INTP1   | Input |                                      | L-1        |
| P05      | 20      | INTP2/ $\overline{\text{DRST}}$ <sup>Note</sup> | Input |                                      | AA-1       |
| P06      | 21      | INTP3   | Input |                                      | L-1        |

**Note** The  $\overline{\text{DRST}}$  pin is used for on-chip debugging.

If on-chip debugging is not used, fix the P05/INTP2/ $\overline{\text{DRST}}$  pin to low level between when the reset signal of the  $\overline{\text{RESET}}$  pin is released and when the OCDM.OCDM0 bit is cleared (0).

For details, see 4.6.3 Cautions on on-chip debug pins.

**Caution** The P00 to P06 pins have hysteresis characteristics in the input mode of the alternate function, but do not have hysteresis characteristics in the port mode.

(1) Port 0 register (P0)

|                                 |     |   |                    |     |     |     |     |     |
|---------------------------------|-----|---|--------------------|-----|-----|-----|-----|-----|
| After reset: 00H (output latch) |     | R/W   | Address: FFFFF400H |     |     |     |     |     |
|                                 | 7   | 6   | 5                  | 4   | 3   | 2   | 1   | 0   |
| P0                              | 0   | P06   | P05                | P04 | P03 | P02 | P01 | P00 |
|                                 | P0n | Output data control (in output mode) (n = 0 to 6) |                    |     |     |     |     |     |
|                                 | 0   | Outputs 0   |                    |     |     |     |     |     |
|                                 | 1   | Outputs 1   |                    |     |     |     |     |     |

(2) Port 0 mode register (PM0)

After reset: FFH R/W Address: FFFFF420H

|     |   |      |      |      |      |      |      |      |
|-----|---|------|------|------|------|------|------|------|
|     | 7 | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PM0 | 1 | PM06 | PM05 | PM04 | PM03 | PM02 | PM01 | PM00 |

|      |                               |
|------|-------------------------------|
| PM0n | I/O mode control (n = 0 to 6) |
| 0    | Output mode                   |
| 1    | Input mode                    |

(3) Port 0 mode control register (PMC0)

After reset: 00H R/W Address: FFFFF440H

|       | 7                                       | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
|-------|---|-------|-------|-------|-------|-------|-------|-------|
| PMC0  | 0                                       | PMC06 | PMC05 | PMC04 | PMC03 | PMC02 | PMC01 | PMC00 |
| PMC06 | Specification of P06 pin operation mode |       |       |       |       |       |       |       |
| 0     | I/O port                                |       |       |       |       |       |       |       |
| 1     | INTP3 input                             |       |       |       |       |       |       |       |
| PMC05 | Specification of P05 pin operation mode |       |       |       |       |       |       |       |
| 0     | I/O port                                |       |       |       |       |       |       |       |
| 1     | INTP2 input                             |       |       |       |       |       |       |       |
| PMC04 | Specification of P04 pin operation mode |       |       |       |       |       |       |       |
| 0     | I/O port                                |       |       |       |       |       |       |       |
| 1     | INTP1 input                             |       |       |       |       |       |       |       |
| PMC03 | Specification of P03 pin operation mode |       |       |       |       |       |       |       |
| 0     | I/O port                                |       |       |       |       |       |       |       |
| 1     | INTP0 input/ADTRG input                 |       |       |       |       |       |       |       |
| PMC02 | Specification of P02 pin operation mode |       |       |       |       |       |       |       |
| 0     | I/O port                                |       |       |       |       |       |       |       |
| 1     | NMI input                               |       |       |       |       |       |       |       |
| PMC01 | Specification of P01 pin operation mode |       |       |       |       |       |       |       |
| 0     | I/O port                                |       |       |       |       |       |       |       |
| 1     | TIP60 input/TOP60 output                |       |       |       |       |       |       |       |
| PMC00 | Specification of P00 pin operation mode |       |       |       |       |       |       |       |
| 0     | I/O port                                |       |       |       |       |       |       |       |
| 1     | TIP61 input/TOP61 output                |       |       |       |       |       |       |       |

**Caution** The P05/INTP2/ $\overline{\text{DRST}}$  pin becomes the  $\overline{\text{DRST}}$  pin regardless of the value of the PMC05 bit when the OCDM.OCDM0 bit = 1.

**(4) Port 0 function control register (PFC0)**

After reset: 00H R/W Address: FFFFF460H

|      |   |   |   |   |       |   |       |       |
|------|---|---|---|---|-------|---|-------|-------|
|      | 7 | 6 | 5 | 4 | 3     | 2 | 1     | 0     |
| PFC0 | 0 | 0 | 0 | 0 | PFC03 | 0 | PFC01 | PFC00 |

|       |   |
|-------|---|
| PFC03 | Specification of P03 pin alternate function |
| 0     | INTP0 input                                 |
| 1     | ADTRG input                                 |

|       |   |
|-------|---|
| PFC01 | Specification of P01 pin alternate function |
| 0     | TIP60 input                                 |
| 1     | TOP60 output                                |

|       |   |
|-------|---|
| PFC00 | Specification of P00 pin alternate function |
| 0     | TIP61 input                                 |
| 1     | TOP61 output                                |

**(5) Port 0 function register (PF0)**

After reset: 00H R/W Address: FFFFC60H

|     |   |      |      |      |      |      |      |      |
|-----|---|------|------|------|------|------|------|------|
|     | 7 | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PF0 | 0 | PF06 | PF05 | PF04 | PF03 | PF02 | PF01 | PF00 |

|      |   |
|------|---|
| PF0n | Control of normal output or N-ch open-drain output (n = 0 to 6) |
| 0    | Normal output (CMOS output)                                     |
| 1    | N-ch open drain output  |

**Caution** When an output pin is pulled up at  $EV_{DD}$  or higher, be sure to set the PF0n bit to 1.



4.3.2 Port 1

Port 1 is a 2-bit port for which I/O settings can be controlled in 1-bit units.

Port 1 includes the following alternate-function pins.

Table 4-5. Port 1 Alternate-Function Pins

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O    | Remark | Block Type |
|----------|---------|-----------------------------|--------|--------|------------|
| P10      | 3       | ANO0                        | Output | –      | A-2        |
| P11      | 4       | ANO1                        | Output | –      | A-2        |

(1) Port 1 register (P1)

After reset: 00H (output latch) R/W Address: FFFFF402H

|    |   |   |   |   |   |   |     |     |
|----|---|---|---|---|---|---|-----|-----|
|    | 7 | 6 | 5 | 4 | 3 | 2 | 1   | 0   |
| P1 | 0 | 0 | 0 | 0 | 0 | 0 | P11 | P10 |

| P1n | Output data control (in output mode) (n = 0, 1) |
|-----|---|
| 0   | Outputs 0                                       |
| 1   | Outputs 1                                       |

**Caution** Do not read or write the P1 register during D/A conversion (see 14.4.3 Cautions).

(2) Port 1 mode register (PM1)

After reset: FFH R/W Address: FFFFF422H

|     |   |   |   |   |   |   |      |      |
|-----|---|---|---|---|---|---|------|------|
|     | 7 | 6 | 5 | 4 | 3 | 2 | 1    | 0    |
| PM1 | 1 | 1 | 1 | 1 | 1 | 1 | PM11 | PM10 |

| PM1n | I/O mode control (n = 0, 1) |
|------|-----------------------------|
| 0    | Output mode                 |
| 1    | Input mode                  |

**Cautions**

- When using P1n as alternate functions (ANOn pin output), set the PM1n bit to 1.
- When using one of the P10 and P11 pins as an I/O port and the other as a D/A output pin, do so in an application where the port I/O level does not change during D/A output.

### 4.3.3 Port 3

Port 3 is a 10-bit port for which I/O settings can be controlled in 1-bit units.

Port 3 includes the following alternate-function pins.

**Table 4-6. Port 3 Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O    | Remark                               | Block Type |
|----------|---------|-----------------------------|--------|--------------------------------------|------------|
| P30      | 25      | TXDA0/SOB4                  | Output | Selectable as N-ch open-drain output | G-3        |
| P31      | 26      | RXDA0/INTP7/SIB4            | Input  |                                      | N-3        |
| P32      | 27      | ASCKA0/SCKB4/TIP00/TOP00    | I/O    |                                      | U-1        |
| P33      | 28      | TIP01/TOP01                 | I/O    |                                      | G-1        |
| P34      | 29      | TIP10/TOP10                 | I/O    |                                      | G-1        |
| P35      | 30      | TIP11/TOP11                 | I/O    |                                      | G-1        |
| P36      | 31      | –                           | –      |                                      | C-1        |
| P37      | 32      | –                           | –      |                                      | C-1        |
| P38      | 35      | TXDA2/SDA00                 | I/O    |                                      | G-12       |
| P39      | 36      | RXDA2/SCL00                 | I/O    |                                      | G-6        |

**Caution** The P31 to P35, P38, and P39 pins have hysteresis characteristics in the input mode of the alternate-function pin, but do not have the hysteresis characteristics in the port mode.

(1) Port 3 register (P3)

After reset: 0000H (output latch)    R/W    Address: P3 FFFFF406H,  
P3L FFFFF406H, P3H FFFFF407H

|          |     |     |     |     |     |     |     |     |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|
|          | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   |
| P3 (P3H) | 0   | 0   | 0   | 0   | 0   | 0   | P39 | P38 |
|          | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
| (P3L)    | P37 | P36 | P35 | P34 | P33 | P32 | P31 | P30 |

|     |   |
|-----|---|
| P3n | Output data control (in output mode) (n = 0 to 9) |
| 0   | Outputs 0   |
| 1   | Outputs 1   |

**Remarks**

1. The P3 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the P3 register as the P3H register and the lower 8 bits as the P3L register, P3 can be read or written in 8-bit or 1-bit units.
2. To read/write bits 8 to 15 of the P3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the P3H register.

(2) Port 3 mode register (PM3)

After reset: FFFFH    R/W    Address: PM3 FFFFF426H,  
PM3L FFFFF426H, PM3H FFFFF427H

|            |      |      |      |      |      |      |      |      |
|------------|------|------|------|------|------|------|------|------|
|            | 15   | 14   | 13   | 12   | 11   | 10   | 9    | 8    |
| PM3 (PM3H) | 1    | 1    | 1    | 1    | 1    | 1    | PM39 | PM38 |
|            | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| (PM3L)     | PM37 | PM36 | PM35 | PM34 | PM33 | PM32 | PM31 | PM30 |

|      |                               |
|------|-------------------------------|
| PM3n | I/O mode control (n = 0 to 9) |
| 0    | Output mode                   |
| 1    | Input mode                    |

**Remarks**

1. The PM3 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PM3 register as the PM3H register and the lower 8 bits as the PM3L register, PM3 can be read or written in 8-bit or 1-bit units.
2. To read/write bits 8 to 15 of the PM3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PM3H register.

(3) Port 3 mode control register (PMC3)

After reset: 0000H R/W Address: PMC3 FFFF446H,  
 PMC3L FFFF446H, PMC3H FFFF447H

|              |    |    |       |       |       |       |       |       |
|--------------|----|----|-------|-------|-------|-------|-------|-------|
|              | 15 | 14 | 13    | 12    | 11    | 10    | 9     | 8     |
| PMC3 (PMC3H) | 0  | 0  | 0     | 0     | 0     | 0     | PMC39 | PMC38 |
|              | 7  | 6  | 5     | 4     | 3     | 2     | 1     | 0     |
| (PMC3L)      | 0  | 0  | PMC35 | PMC34 | PMC33 | PMC32 | PMC31 | PMC30 |

|       |   |
|-------|---|
| PMC39 | Specification of P39 pin operation mode |
| 0     | I/O port                                |
| 1     | RXDA2 input/SCL00 I/O                   |

|       |   |
|-------|---|
| PMC38 | Specification of P38 pin operation mode |
| 0     | I/O port                                |
| 1     | TXDA2 output/SDA00 I/O                  |

|       |   |
|-------|---|
| PMC35 | Specification of P35 pin operation mode |
| 0     | I/O port                                |
| 1     | TIP11 input/TOP11 output                |

|       |   |
|-------|---|
| PMC34 | Specification of P34 pin operation mode |
| 0     | I/O port                                |
| 1     | TIP10 input/TOP10 output                |

|       |   |
|-------|---|
| PMC33 | Specification of P33 pin operation mode |
| 0     | I/O port                                |
| 1     | TIP01 input/TOP01 output                |

|       |   |
|-------|---|
| PMC32 | Specification of P32 pin operation mode         |
| 0     | I/O port  |
| 1     | ASCKA0 input/SCKB4 I/O/TIP00 input/TOP00 output |

|       |   |
|-------|---|
| PMC31 | Specification of P31 pin operation mode |
| 0     | I/O port                                |
| 1     | RXDA0 input/SIB4 input/INTP7 input      |

|       |   |
|-------|---|
| PMC30 | Specification of P30 pin operation mode |
| 0     | I/O port                                |
| 1     | TXDA0 output/SOB4 output                |

**Caution** Be sure to clear bits 15 to 10, 7, and 6 to "0".

- Remarks**
- The PMC3 register can be read or written in 16-bit units.  
 However, when using the higher 8 bits of the PMC3 register as the PMC3H register and the lower 8 bits as the PMC3L register, PMC3 can be read or written in 8-bit or 1-bit units.
  - To read/write bits 8 to 15 of the PMC3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMC3H register.

**(4) Port 3 function control register (PFC3)**

After reset: 0000H    R/W    Address: PFC3 FFFFF466H,  
PFC3L FFFFF466H, PFC3L FFFFF467H

|              |    |    |       |       |       |       |       |       |
|--------------|----|----|-------|-------|-------|-------|-------|-------|
|              | 15 | 14 | 13    | 12    | 11    | 10    | 9     | 8     |
| PFC3 (PFC3H) | 0  | 0  | 0     | 0     | 0     | 0     | PFC39 | PFC38 |
|              | 7  | 6  | 5     | 4     | 3     | 2     | 1     | 0     |
| (PFC3L)      | 0  | 0  | PFC35 | PFC34 | PFC33 | PFC32 | PFC31 | PFC30 |

**Remarks**

- For details of alternate function specification, see **4.3.3 (6) Port 3 alternate function specifications**.
- The PFC3 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PFC3 register as the PFC3H register and the lower 8 bits as the PFC3L register, PFC3 can be read or written in 8-bit and 1-bit units.
- To read/write bits 8 to 15 of the PFC3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PFC3H register.

**(5) Port 3 function control expansion register L (PFCE3L)**

After reset: 00H    R/W    Address: FFFFF706H

|        |   |   |   |   |   |        |   |   |
|--------|---|---|---|---|---|--------|---|---|
|        | 7 | 6 | 5 | 4 | 3 | 2      | 1 | 0 |
| PFCE3L | 0 | 0 | 0 | 0 | 0 | PFCE32 | 0 | 0 |

**Caution** Be sure to clear bits 7 to 3, 1, and 0 to “0”.

**Remark** For details of alternate function specification, see **4.3.3 (6) Port 3 alternate function specifications**.

(6) Port 3 alternate function specifications

| PFC39 | Specification of P39 pin alternate function |
|-------|---|
| 0     | RXDA2 input                                 |
| 1     | SCL00 input                                 |

| PFC38 | Specification of P38 pin alternate function |
|-------|---|
| 0     | TXDA2 output                                |
| 1     | SDA00 I/O                                   |

| PFC35 | Specification of P35 pin alternate function |
|-------|---|
| 0     | TIP11 input                                 |
| 1     | TOP11 output                                |

| PFC34 | Specification of P34 pin alternate function |
|-------|---|
| 0     | TIP10 input                                 |
| 1     | TOP10 output                                |

| PFC33 | Specification of P33 pin alternate function |
|-------|---|
| 0     | TIP01 input                                 |
| 1     | TOP01 output                                |

| PFCE32 | PFC32 | Specification of P32 pin alternate function |
|--------|-------|---|
| 0      | 0     | ASCKA0 input                                |
| 0      | 1     | SCKB4 I/O                                   |
| 1      | 0     | TIP00 input                                 |
| 1      | 1     | TOP00 output                                |

| PFC31 | Specification of P31 pin alternate function |
|-------|---|
| 0     | RXDA0 input/INTP7 <sup>Note</sup> input     |
| 1     | SIB4 input                                  |

| PFC30 | Specification of P30 pin alternate function |
|-------|---|
| 0     | TXDA0 output                                |
| 1     | SOB4 output                                 |

**Note** The INTP7 pin and RXDA0 pin are alternate-function pins. When using the pin as the RXDA0 pin, disable edge detection for the INTP7 alternate-function pin. (Clear the INTF3.INTF31 bit and the INTR3.INTR31 bit to 0.) When using the pin as the INTP7 pin, stop UARTA0 reception. (Clear the UA0CTL0.UA0RXE bit to 0.)

(7) Port 3 function register (PF3)

After reset: 0000H    R/W    Address: PF3 FFFFFFFC66H,  
PF3L FFFFFFFC66H, PF3H FFFFFFFC67H

|            |      |      |      |      |      |      |      |      |
|------------|------|------|------|------|------|------|------|------|
|            | 15   | 14   | 13   | 12   | 11   | 10   | 9    | 8    |
| PF3 (PF3H) | 0    | 0    | 0    | 0    | 0    | 0    | PF39 | PF38 |
|            | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| (PF3L)     | PF37 | PF36 | PF35 | PF34 | PF33 | PF32 | PF31 | PF30 |

|      |   |
|------|---|
| PF3n | Control of normal output or N-ch open-drain output (n = 0 to 9) |
| 0    | Normal output (CMOS output)                                     |
| 1    | N-ch open-drain output  |

**Caution** When an output pin is pulled up at  $EV_{DD}$  or higher, be sure to set the PF3n bit to 1.

- Remarks**
1. The PF3 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PF3 register as the PF3H register and the lower 8 bits as the PF3L register, PF3 can be read or written in 8-bit or 1-bit units.
  2. To read/write bits 8 to 15 of the PF3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PF3H register.

4.3.4 Port 4

Port 4 is a 3-bit port that controls I/O in 1-bit units.

Port 4 includes the following alternate-function pins.

Table 4-7. Port 4 Alternate-Function Pins

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O | Remark                               | Block Type |
|----------|---------|-----------------------------|-----|--------------------------------------|------------|
| P40      | 22      | SIB0/SDA01                  | I/O | Selectable as N-ch open-drain output | G-6        |
| P41      | 23      | SOB0/SCL01                  | I/O |                                      | G-12       |
| P42      | 24      | SCKB0                       | I/O |                                      | E-3        |

**Caution** The P40 to P42 pins have hysteresis characteristics in the input mode of the alternate-function pin, but do not have the hysteresis characteristics in the port mode.

(1) Port 4 register (P4)

After reset: 00H (output latch) R/W Address: FFFFF408H

|    |   |   |   |   |   |     |     |     |
|----|---|---|---|---|---|-----|-----|-----|
|    | 7 | 6 | 5 | 4 | 3 | 2   | 1   | 0   |
| P4 | 0 | 0 | 0 | 0 | 0 | P42 | P41 | P40 |

|     |   |
|-----|---|
| P4n | Output data control (in output mode) (n = 0 to 2) |
| 0   | Outputs 0   |
| 1   | Outputs 1   |

(2) Port 4 mode register (PM4)

After reset: FFH R/W Address: FFFFF428H

|     |   |   |   |   |   |      |      |      |
|-----|---|---|---|---|---|------|------|------|
|     | 7 | 6 | 5 | 4 | 3 | 2    | 1    | 0    |
| PM4 | 1 | 1 | 1 | 1 | 1 | PM42 | PM41 | PM40 |

|      |                               |
|------|-------------------------------|
| PM4n | I/O mode control (n = 0 to 2) |
| 0    | Output mode                   |
| 1    | Input mode                    |



**(3) Port 4 mode control register (PMC4)**

After reset: 00H R/W Address: FFFFF448H

|      |   |   |   |   |   |       |       |       |
|------|---|---|---|---|---|-------|-------|-------|
|      | 7 | 6 | 5 | 4 | 3 | 2     | 1     | 0     |
| PMC4 | 0 | 0 | 0 | 0 | 0 | PMC42 | PMC41 | PMC40 |

|       |   |
|-------|---|
| PMC42 | Specification of P42 pin operation mode |
| 0     | I/O port                                |
| 1     | SCKB0 I/O                               |

|       |   |
|-------|---|
| PMC41 | Specification of P41 pin operation mode |
| 0     | I/O port                                |
| 1     | SOB0 output/SCL01 I/O                   |

|       |   |
|-------|---|
| PMC40 | Specification of P40 pin operation mode |
| 0     | I/O port                                |
| 1     | SIB0 input/SDA01 I/O                    |

**(4) Port 4 function control register (PFC4)**

After reset: 00H R/W Address: FFFFF468H

|      |   |   |   |   |   |   |       |       |
|------|---|---|---|---|---|---|-------|-------|
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1     | 0     |
| PFC4 | 0 | 0 | 0 | 0 | 0 | 0 | PFC41 | PFC40 |

|       |   |
|-------|---|
| PFC41 | Specification of P41 pin alternate function |
| 0     | SOB0 output                                 |
| 1     | SCL01 I/O                                   |

|       |   |
|-------|---|
| PFC40 | Specification of P40 pin alternate function |
| 0     | SIB0 input                                  |
| 1     | SDA01 I/O                                   |

**(5) Port 4 function register (PF4)**

After reset: 00H R/W Address: FFFFC68H

|     |   |   |   |   |   |      |      |      |
|-----|---|---|---|---|---|------|------|------|
|     | 7 | 6 | 5 | 4 | 3 | 2    | 1    | 0    |
| PF4 | 0 | 0 | 0 | 0 | 0 | PF42 | PF41 | PF40 |

|      |   |
|------|---|
| PF4n | Control of normal output or N-ch open-drain output (n = 0 to 2) |
| 0    | Normal output (CMOS output)                                     |
| 1    | N-ch open-drain output  |

**Caution** When an output pin is pulled up at EV<sub>DD</sub> or higher, be sure to set the PF4n bit to 1.

4.3.5 Port 5

Port 5 is a 6-bit port that controls I/O in 1-bit units.

Port 5 includes the following alternate-function pins.

Table 4-8. Port 5 Alternate-Function Pins

| Pin Name | Pin No. | Alternate-Function Pin Name                    | I/O | Remark                               | Block Type |
|----------|---------|--|-----|--------------------------------------|------------|
| P50      | 37      | TIQ01/KR0/TOQ01/RTP00                          | I/O | Selectable as N-ch open-drain output | U-5        |
| P51      | 38      | TIQ02/KR1/TOQ02/RTP01                          | I/O |                                      | U-5        |
| P52      | 39      | TIQ03/KR2/TOQ03/RTP02/DDI <sup>Note</sup>      | I/O |                                      | U-6        |
| P53      | 40      | SIB2/KR3/TIQ00/TOQ00/RTP03/DDO <sup>Note</sup> | I/O |                                      | U-7        |
| P54      | 41      | SOB2/KR4/RTP04/DCK <sup>Note</sup>             | I/O |                                      | U-8        |
| P55      | 42      | SCKB2/KR5/RTP05/DMS <sup>Note</sup>            | I/O |                                      | U-9        |

**Note** The DDI, DDO, DCK, and DMS pins are used for on-chip debugging.

If on-chip debugging is not used, fix the P05/INTP2/ $\overline{DRST}$  pin to low level between when the reset signal of the RESET pin is released and when the OCDM.OCDM0 bit is cleared (0).

For details, see 4.6.3 Cautions on on-chip debug pins.

- Cautions**
1. When the power is turned on, the P53 pin may output undefined level temporarily, even during reset.
  2. The P50 to P55 pins have hysteresis characteristics in the input mode of the alternate function, but do not have hysteresis characteristics in the port mode.

(1) Port 5 register (P5)

|                                 |   |     |                   |     |     |     |     |     |
|---------------------------------|---|-----|-------------------|-----|-----|-----|-----|-----|
| After reset: 00H (output latch) |   | R/W | Address: FFFF40AH |     |     |     |     |     |
|                                 | 7   | 6   | 5                 | 4   | 3   | 2   | 1   | 0   |
| P5                              | 0   | 0   | P55               | P54 | P53 | P52 | P51 | P50 |
| P5n                             | Output data control (in output mode) (n = 0 to 5) |     |                   |     |     |     |     |     |
| 0                               | Outputs 0   |     |                   |     |     |     |     |     |
| 1                               | Outputs 1   |     |                   |     |     |     |     |     |

(2) Port 5 mode register (PM5)

|                  |                               |     |                   |      |      |      |      |      |
|------------------|-------------------------------|-----|-------------------|------|------|------|------|------|
| After reset: FFH |                               | R/W | Address: FFFF42AH |      |      |      |      |      |
|                  | 7                             | 6   | 5                 | 4    | 3    | 2    | 1    | 0    |
| PM5              | 1                             | 1   | PM55              | PM54 | PM53 | PM52 | PM51 | PM50 |
| PM5n             | I/O mode control (n = 0 to 5) |     |                   |      |      |      |      |      |
| 0                | Output mode                   |     |                   |      |      |      |      |      |
| 1                | Input mode                    |     |                   |      |      |      |      |      |

**(3) Port 5 mode control register (PMC5)**

After reset: 00H R/W Address: FFFF44AH

|      |   |   |       |       |       |       |       |       |
|------|---|---|-------|-------|-------|-------|-------|-------|
|      | 7 | 6 | 5     | 4     | 3     | 2     | 1     | 0     |
| PMC5 | 0 | 0 | PMC55 | PMC54 | PMC53 | PMC52 | PMC51 | PMC50 |

|       |   |
|-------|---|
| PMC55 | Specification of P55 pin operation mode |
| 0     | I/O port                                |
| 1     | SCKB2 I/O/KR5 input/RTP05 output        |

|       |   |
|-------|---|
| PMC54 | Specification of P54 pin operation mode |
| 0     | I/O port                                |
| 1     | SOB2 output/KR4 input/RTP04 output      |

|       |  |
|-------|--|
| PMC53 | Specification of P53 pin operation mode                    |
| 0     | I/O port   |
| 1     | SIB2 input/KR3 input/TIQ00 input/TOQ00 output/RTP03 output |

|       |   |
|-------|---|
| PMC52 | Specification of P52 pin operation mode         |
| 0     | I/O port  |
| 1     | TIQ03 input/KR2 input/TOQ03 output/RTP02 output |

|       |   |
|-------|---|
| PMC51 | Specification of P51 pin operation mode         |
| 0     | I/O port  |
| 1     | TIQ02 input/KR1 input/TOQ02 output/RTP01 output |

|       |   |
|-------|---|
| PMC50 | Specification of P50 pin operation mode         |
| 0     | I/O port  |
| 1     | TIQ01 input/KR0 input/TOQ01 output/RTP00 output |

**(4) Port 5 function control register (PFC5)**

After reset: 00H R/W Address: FFFF46AH

|      |   |   |       |       |       |       |       |       |
|------|---|---|-------|-------|-------|-------|-------|-------|
|      | 7 | 6 | 5     | 4     | 3     | 2     | 1     | 0     |
| PFC5 | 0 | 0 | PFC55 | PFC54 | PFC53 | PFC52 | PFC51 | PFC50 |

**Remark** For details of alternate function specification, see **4.3.5 (6) Port 5 alternate function specifications.**

(5) Port 5 function control expansion register (PFCE5)

After reset: 00H R/W Address: FFFFF70AH

|       |   |   |        |        |        |        |        |        |
|-------|---|---|--------|--------|--------|--------|--------|--------|
|       | 7 | 6 | 5      | 4      | 3      | 2      | 1      | 0      |
| PFCE5 | 0 | 0 | PFCE55 | PFCE54 | PFCE53 | PFCE52 | PFCE51 | PFCE50 |

**Remark** For details of alternate function specification, see 4.3.5 (6) Port 5 alternate function specifications.

(6) Port 5 alternate function specifications

| PFCE55 | PFC55 | Specification of P55 pin alternate function |
|--------|-------|---|
| 0      | 0     | $\overline{\text{SCKB2}}$ I/O               |
| 0      | 1     | KR5 input                                   |
| 1      | 0     | Setting prohibited                          |
| 1      | 1     | RTP05 output                                |

| PFCE54 | PFC54 | Specification of P54 pin alternate function |
|--------|-------|---|
| 0      | 0     | SOB2 output                                 |
| 0      | 1     | KR4 input                                   |
| 1      | 0     | Setting prohibited                          |
| 1      | 1     | RTP04 output                                |

| PFCE53 | PFC53 | Specification of P53 pin alternate function |
|--------|-------|---|
| 0      | 0     | SIB2 input                                  |
| 0      | 1     | TIQ00 input/KR3 <sup>Note</sup> input       |
| 1      | 0     | TOQ00 output                                |
| 1      | 1     | RTP03 output                                |

| PFCE52 | PFC52 | Specification of P52 pin alternate function |
|--------|-------|---|
| 0      | 0     | Setting prohibited                          |
| 0      | 1     | TIQ03 input/KR2 <sup>Note</sup> input       |
| 1      | 0     | TOQ03 output                                |
| 1      | 1     | RTP02 output                                |

| PFCE51 | PFC51 | Specification of P51 pin alternate function |
|--------|-------|---|
| 0      | 0     | Setting prohibited                          |
| 0      | 1     | TIQ02 input/KR1 <sup>Note</sup> input       |
| 1      | 0     | TOQ02 output                                |
| 1      | 1     | RTP01 output                                |

| PFCE50 | PFC50 | Specification of P50 pin alternate function |
|--------|-------|---|
| 0      | 0     | Setting prohibited                          |
| 0      | 1     | TIQ01 input/KR0 <sup>Note</sup> input       |
| 1      | 0     | TOQ01 output                                |
| 1      | 1     | RTP00 output                                |

**Note** The KRn pin and TIQ0m pin are alternate-function pins. When using the pin as the TIQ0m pin, disable KRn pin key return detection, which is the alternate function. (Clear the KRM.KRMn bit to 0.) Also, when using the pin as the KRn pin, disable TIQ0m pin edge detection, which is the alternate function (n = 0 to 3, m = 0 to 3).

| Pin Name  | Use as TIQ0m Pin | Use as KRn Pin  |
|-----------|------------------|---|
| KR0/TIQ01 | KRM.KRM0 bit = 0 | TQ0IOC1.TQ0TIG2, TQ0IOC1.TQ0TIG3 bits = 0   |
| KR1/TIQ02 | KRM.KRM1 bit = 0 | TQ0IOC1.TQ0TIG4, TQ0IOC1.TQ0TIG5 bits = 0   |
| KR2/TIQ03 | KRM.KRM2 bit = 0 | TQ0IOC1.TQ0TIG6, TQ0IOC1.TQ0TIG7 bits = 0   |
| KR3/TIQ00 | KRM.KRM3 bit = 0 | TQ0IOC1.TQ0TIG0, TQ0IOC1.TQ0TIG1 bits = 0<br>TQ0IOC2.TQ0EES0, TQ0IOC2.TQ0EES1 bits = 0<br>TQ0IOC2.TQ0ETS0, TQ0IOC2.TQ0ETS1 bits = 0 |

**(7) Port 5 function register (PF5)**

After reset: 00H    R/W    Address: FFFFC6AH

|     |   |   |      |      |      |      |      |      |
|-----|---|---|------|------|------|------|------|------|
|     | 7 | 6 | 5    | 4    | 3    | 2    | 1    | 0    |
| PF5 | 0 | 0 | PF55 | PF54 | PF53 | PF52 | PF51 | PF50 |

| PF5n | Control of normal output or N-ch open-drain output (n = 0 to 5) |
|------|---|
| 0    | Normal output (CMOS output)                                     |
| 1    | N-ch open-drain output  |

**Caution** When an output pin is pulled up at EV<sub>DD</sub> or higher, be sure to set the PF5n bit to 1.

### 4.3.6 Port 6

Port 6 is a 16-bit port for which I/O settings can be controlled in 1-bit units.

Port 6 includes the following alternate-function pins.

**Table 4-9. Port 6 Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O    | Remark                               | Block Type |
|----------|---------|-----------------------------|--------|--------------------------------------|------------|
| P60      | 43      | RTP10                       | Output | Selectable as N-ch open-drain output | E-2        |
| P61      | 44      | RTP11                       | Output |                                      | E-2        |
| P62      | 45      | RTP12                       | Output |                                      | E-2        |
| P63      | 46      | RTP13                       | Output |                                      | E-2        |
| P64      | 47      | RTP14                       | Output |                                      | E-2        |
| P65      | 48      | RTP15                       | Output |                                      | E-2        |
| P66      | 49      | SIB5                        | Input  |                                      | E-1        |
| P67      | 50      | SOB5                        | Output |                                      | E-2        |
| P68      | 51      | SCKB5                       | I/O    |                                      | E-3        |
| P69      | 52      | TIP70/TOP70                 | I/O    |                                      | G-1        |
| P610     | 53      | TIP71                       | Input  |                                      | E-1        |
| P611     | 54      | TOP71                       | Output |                                      | E-2        |
| P612     | 55      | TIP80/TOP80                 | I/O    |                                      | G-1        |
| P613     | 56      | TIP81/TOP81                 | I/O    |                                      | G-1        |
| P614     | 57      | –                           | –      |                                      | C-1        |
| P615     | 58      | –                           | –      | C-1                                  |            |

**Caution** The P66, P68 to P610, P612, and P613 pins have hysteresis characteristics in the input mode of the alternate-function pin, but do not have the hysteresis characteristics in the port mode.

**(1) Port 6 register (P6)**

After reset: 0000H (output latch)    R/W    Address: P6 FFFFF40CH  
P6L FFFFF40CH, P6LH FFFFF40DH

|          |      |      |      |      |      |      |     |     |
|----------|------|------|------|------|------|------|-----|-----|
|          | 15   | 14   | 13   | 12   | 11   | 10   | 9   | 8   |
| P6 (P6H) | P615 | P614 | P613 | P612 | P611 | P610 | P69 | P68 |

|       |     |     |     |     |     |     |     |     |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|
|       | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
| (P6L) | P67 | P66 | P65 | P64 | P63 | P62 | P61 | P60 |

|     |  |
|-----|--|
| P6n | Output data control (in output mode) (n = 0 to 15) |
| 0   | Outputs 0  |
| 1   | Outputs 1  |

**Remarks**

1. The P6 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the P6 register as the P6H register and the lower 8 bits as the P6L register, P6 can be read or written in 8-bit or 1-bit units.
2. To read/write bits 8 to 15 of the P6 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the P6H register.

**(2) Port 6 mode register (PM6)**

After reset: FFFFH    R/W    Address: PM6 FFFFF42CH  
PM6L FFFFF42CH, PM6H FFFFF42DH

|            |       |       |       |       |       |       |      |      |
|------------|-------|-------|-------|-------|-------|-------|------|------|
|            | 15    | 14    | 13    | 12    | 11    | 10    | 9    | 8    |
| PM6 (PM6H) | PM615 | PM614 | PM613 | PM612 | PM611 | PM610 | PM69 | PM68 |

|        |      |      |      |      |      |      |      |      |
|--------|------|------|------|------|------|------|------|------|
|        | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| (PM6L) | PM67 | PM66 | PM65 | PM64 | PM63 | PM62 | PM61 | PM60 |

|      |                                |
|------|--------------------------------|
| PM6n | I/O mode control (n = 0 to 15) |
| 0    | Output mode                    |
| 1    | Input mode                     |

**Remarks**

1. The PM6 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PM6 register as the PM6H register and the lower 8 bits as the PM6L register, PM6 can be read or written in 8-bit or 1-bit units.
2. To read/write bits 8 to 15 of the PM6 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PM6H register.

(3) Port 6 mode control register (PMC6)

After reset: 0000H R/W Address: PMC6 FFFFF44CH  
 PMC6L FFFFF44CH, PMC6H FFFFF44DH

|              |    |    |        |        |        |        |       |       |
|--------------|----|----|--------|--------|--------|--------|-------|-------|
|              | 15 | 14 | 13     | 12     | 11     | 10     | 9     | 8     |
| PMC6 (PMC6H) | 0  | 0  | PMC613 | PMC612 | PMC611 | PMC610 | PMC69 | PMC68 |

|         |       |       |       |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|
|         | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
| (PMC6L) | PMC67 | PMC66 | PMC65 | PMC64 | PMC63 | PMC62 | PMC61 | PMC60 |

|        |  |
|--------|--|
| PMC613 | Specification of P613 pin operation mode |
| 0      | I/O port                                 |
| 1      | TIP81 input/TOP81 output                 |

|        |  |
|--------|--|
| PMC612 | Specification of P612 pin operation mode |
| 0      | I/O port                                 |
| 1      | TIP80 input/TOP80 output                 |

|        |  |
|--------|--|
| PMC611 | Specification of P611 pin operation mode |
| 0      | I/O port                                 |
| 1      | TOP71 output                             |

|        |  |
|--------|--|
| PMC610 | Specification of P610 pin operation mode |
| 0      | I/O port                                 |
| 1      | TIP71 input                              |

|       |   |
|-------|---|
| PMC69 | Specification of P69 pin operation mode |
| 0     | I/O port                                |
| 1     | TIP70 input/TOP70 output                |

|       |   |
|-------|---|
| PMC68 | Specification of P68 pin operation mode |
| 0     | I/O port                                |
| 1     | SCKB5 I/O                               |

|       |   |
|-------|---|
| PMC67 | Specification of P67 pin operation mode |
| 0     | I/O port                                |
| 1     | SOB5 output                             |

|       |   |
|-------|---|
| PMC66 | Specification of P66 pin operation mode |
| 0     | I/O port                                |
| 1     | SIB5 input                              |

|       |  |
|-------|--|
| PMC6m | Specification of P6m pin operation mode (m = 0 to 5) |
| 0     | I/O port   |
| 1     | RTP1m output   |

- Remarks**
- The PMC6 register can be read or written in 16-bit units.  
 However, when using the higher 8 bits of the PMC6 register as the PMC6H register and the lower 8 bits as the PMC6L register, PMC6 can be read or written in 8-bit or 1-bit units.
  - To read/write bits 8 to 15 of the PMC6 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMC6H register.



**(4) Port 6 function control register H (PFC6H)**

After reset: 00H    R/W    Address: FFFFF46DH

|       | 15 | 14 | 13     | 12     | 11 | 10 | 9     | 8 |
|-------|----|----|--------|--------|----|----|-------|---|
| PFC6H | 0  | 0  | PFC613 | PFC612 | 0  | 0  | PFC69 | 0 |

| PFC613 | Specification of P613 pin alternate function |
|--------|--|
| 0      | TIP81 input                                  |
| 1      | TOP81 output                                 |

| PFC612 | Specification of P612 pin alternate function |
|--------|--|
| 0      | TIP80 input                                  |
| 1      | TOP80 output                                 |

| PFC69 | Specification of P69 pin alternate function |
|-------|---|
| 0     | TIP70 input                                 |
| 1     | TOP70 output                                |

**(5) Port 6 function register (PF6)**

After reset: 0000H    R/W    Address: PF6 FFFFC6CH  
PF6L FFFFC6CH, PF6H FFFFC6DH

|            | 15    | 14    | 13    | 12    | 11    | 10    | 9    | 8    |
|------------|-------|-------|-------|-------|-------|-------|------|------|
| PF6 (PF6H) | PF615 | PF614 | PF613 | PF612 | PF611 | PF610 | PF69 | PF68 |

|        | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|--------|------|------|------|------|------|------|------|------|
| (PF6L) | PF67 | PF66 | PF65 | PF64 | PF63 | PF62 | PF61 | PF60 |

| PF6n | Normal output/N-ch open-drain output control (n = 0 to 15) |
|------|--|
| 0    | Normal output (CMOS output)                                |
| 1    | N-ch open-drain output                                     |

**Caution** When an output pin is pulled up at  $EV_{DD}$  or higher, be sure to set the PF6n bit to 1.

**Remarks**

- The PF6 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PF6 register as the PF6H register and the lower 8 bits as the PF6L register, PF6 can be read or written in 8-bit and 1-bit units.
- To read/write bits 8 to 15 of the PF6 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PF6H register.

**4.3.7 Port 7**

Port 7 is a 16-bit port for which I/O settings can be controlled in 1-bit units.

Port 7 includes the following alternate-function pins.

**Table 4-10. Port 7 Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O   | Remark | Block Type |
|----------|---------|-----------------------------|-------|--------|------------|
| P70      | 144     | ANI0                        | Input | -      | A-1        |
| P71      | 143     | ANI1                        | Input |        | A-1        |
| P72      | 142     | ANI2                        | Input |        | A-1        |
| P73      | 141     | ANI3                        | Input |        | A-1        |
| P74      | 140     | ANI4                        | Input |        | A-1        |
| P77      | 139     | ANI5                        | Input |        | A-1        |
| P76      | 138     | ANI6                        | Input |        | A-1        |
| P77      | 137     | ANI7                        | Input |        | A-1        |
| P78      | 136     | ANI8                        | Input |        | A-1        |
| P79      | 135     | ANI9                        | Input |        | A-1        |
| P710     | 134     | ANI10                       | Input |        | A-1        |
| P711     | 133     | ANI11                       | Input |        | A-1        |
| P712     | 132     | ANI12                       | Input |        | A-1        |
| P713     | 131     | ANI13                       | Input |        | A-1        |
| P714     | 130     | ANI14                       | Input |        | A-1        |
| P715     | 129     | ANI15                       | Input |        | A-1        |

(1) Port 7 register H, port 7 register L (P7H, P7L)

After reset: 00H (output latch) R/W Address: P7L FFFFF40EH, P7H FFFFF40FH

|     |      |      |      |      |      |      |     |     |
|-----|------|------|------|------|------|------|-----|-----|
|     | 7    | 6    | 5    | 4    | 3    | 2    | 1   | 0   |
| P7H | P715 | P714 | P713 | P712 | P711 | P710 | P79 | P78 |

|     |     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|     | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
| P7L | P77 | P76 | P75 | P74 | P73 | P72 | P71 | P70 |

|     |  |
|-----|--|
| P7n | Output data control (in output mode) (n = 0 to 15) |
| 0   | Outputs 0  |
| 1   | Outputs 1  |

**Caution** Do not read or write the P7H and P7L registers during A/D conversion (see 13.6 (4) Alternate I/O).

**Remark** These registers cannot be accessed in 16-bit units as the P7 register. They can be read or written in 8-bit or 1-bit units as the P7H and P7L registers.

(2) Port 7 mode register H, port 7 mode register L (PM7H, PM7L)

After reset: FFH R/W Address: PM7L FFFFF42EH, PM7H FFFFF42FH

|      |       |       |       |       |       |       |      |      |
|------|-------|-------|-------|-------|-------|-------|------|------|
|      | 7     | 6     | 5     | 4     | 3     | 2     | 1    | 0    |
| PM7H | PM715 | PM714 | PM713 | PM712 | PM711 | PM710 | PM79 | PM78 |

|      |      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|------|
|      | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PM7L | PM77 | PM76 | PM75 | PM74 | PM73 | PM72 | PM71 | PM70 |

|      |                                |
|------|--------------------------------|
| PM7n | I/O mode control (n = 0 to 15) |
| 0    | Output mode                    |
| 1    | Input mode                     |

**Caution** When using the P7n pin as its alternate function (ANIn pin), set the PM7n bit to 1.

**Remark** These registers cannot be accessed in 16-bit units as the PM7 register. They can be read or written in 8-bit or 1-bit units as the PM7H and PM7L registers.

4.3.8 Port 8

Port 8 is a 2-bit port for which I/O settings can be controlled in 1-bit units.

Port 8 includes the following alternate-function pins.

Table 4-11. Port 8 Alternate-Function Pins

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O    | Remark                               | Block Type |
|----------|---------|-----------------------------|--------|--------------------------------------|------------|
| P80      | 59      | RXDA3/INTP8                 | Input  | Selectable as N-ch open-drain output | L-2        |
| P81      | 60      | TXDA3                       | Output |                                      | E-2        |

**Caution** The P80 pin has hysteresis characteristics in the input mode of the alternate-function pin, but does not have the hysteresis characteristics in the port mode.

(1) Port 8 register (P8)

After reset: 00H (output latch) R/W Address: FFFFF410H

|    |   |   |   |   |   |   |     |     |
|----|---|---|---|---|---|---|-----|-----|
|    | 7 | 6 | 5 | 4 | 3 | 2 | 1   | 0   |
| P8 | 0 | 0 | 0 | 0 | 0 | 0 | P81 | P80 |

|     |                                |
|-----|--------------------------------|
| P8n | Output data control (n = 0, 1) |
| 0   | Outputs 0                      |
| 1   | Outputs 1                      |

(2) Port 8 mode register (PM8)

After reset: FFH R/W Address: FFFFF430H

|     |   |   |   |   |   |   |      |      |
|-----|---|---|---|---|---|---|------|------|
|     | 7 | 6 | 5 | 4 | 3 | 2 | 1    | 0    |
| PM8 | 1 | 1 | 1 | 1 | 1 | 1 | PM81 | PM80 |

|      |                             |
|------|-----------------------------|
| PM8n | I/O mode control (n = 0, 1) |
| 0    | Output mode                 |
| 1    | Input mode                  |

**(3) Port 8 mode control register (PMC8)**

After reset: 00H    R/W    Address: FFFFF450H

|      |   |   |   |   |   |   |       |       |
|------|---|---|---|---|---|---|-------|-------|
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1     | 0     |
| PMC8 | 0 | 0 | 0 | 0 | 0 | 0 | PMC81 | PMC80 |

|       |   |
|-------|---|
| PMC81 | Specification of P81 pin operation mode |
| 0     | I/O port                                |
| 1     | TXDA3 output                            |

|       |   |
|-------|---|
| PMC80 | Specification of P80 pin operation mode |
| 0     | I/O port                                |
| 1     | RXDA3 input/INTP8 <sup>Note</sup> input |

**Note** The INTP8 and RXDA3 pins are alternate-function pins. When using the RXDA3 pin, disable detection of the edge of the INTP8 pin (INTF8.INTF80 bit = 0 and INTR8.INTR80 bit = 0). When using the INTP8 pin, stop the reception operation of UARTA3 (UA3CTL0.UA3RXE bit = 0).

**(4) Port 8 function register (PF8)**

After reset: 00H    R/W    Address: FFFFFC70H

|     |   |   |   |   |   |   |      |      |
|-----|---|---|---|---|---|---|------|------|
|     | 7 | 6 | 5 | 4 | 3 | 2 | 1    | 0    |
| PF8 | 0 | 0 | 0 | 0 | 0 | 0 | PF81 | PF80 |

|      |   |
|------|---|
| PF8n | Control of normal output or N-ch open-drain output (n = 0, 1) |
| 0    | Normal output (CMOS output)                                   |
| 1    | N-ch open-drain output  |

**Caution** When an output pin is pulled up at EV<sub>DD</sub> or higher, be sure to set the PF8n bit to 1.

### 4.3.9 Port 9

Port 9 is a 16-bit port for which I/O settings can be controlled in 1-bit units.

Port 9 includes the following alternate-function pins.

**Table 4-12. Port 9 Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name    | I/O    | Remark                               | Block Type |
|----------|---------|--------------------------------|--------|--------------------------------------|------------|
| P90      | 61      | A0/KR6/TXDA1/SDA02             | I/O    | Selectable as N-ch open-drain output | U-10       |
| P91      | 62      | A1/KR7/RXDA1/SCL02             | I/O    |                                      | U-11       |
| P92      | 63      | A2/TIP41/TOP41                 | I/O    |                                      | U-12       |
| P93      | 64      | A3/TIP40/TOP40                 | I/O    |                                      | U-12       |
| P94      | 65      | A4/TIP31/TOP31                 | I/O    |                                      | U-12       |
| P95      | 66      | A5/TIP30/TOP30                 | I/O    |                                      | U-12       |
| P96      | 67      | A6/TIP21/TOP21                 | I/O    |                                      | U-13       |
| P97      | 68      | A7/SIB1/TIP20/TOP20            | I/O    |                                      | U-14       |
| P98      | 69      | A8/SOB1                        | Output |                                      | G-3        |
| P99      | 70      | A9/ $\overline{\text{SCKB1}}$  | I/O    |                                      | G-5        |
| P910     | 71      | A10/SIB3                       | I/O    |                                      | G-2        |
| P911     | 72      | A11/SOB3                       | Output |                                      | G-3        |
| P912     | 73      | A12/ $\overline{\text{SCKB3}}$ | I/O    |                                      | G-5        |
| P913     | 74      | A13/INTP4                      | I/O    |                                      | N-2        |
| P914     | 75      | A14/INTP5/TIP51/TOP51          | I/O    |                                      | U-15       |
| P915     | 76      | A15/INTP6/TIP50/TOP50          | I/O    | U-15                                 |            |

**Caution** The P90 to P97, P99, P910, and P912 to P915 pins have hysteresis characteristics in the input mode of the alternate-function pin, but do not have the hysteresis characteristics in the port mode.

(1) Port 9 register (P9)

After reset: 0000H (output latch) R/W Address: P9 FFFFF412H,  
P9L FFFFF412H, P9H FFFFF413H

|          |      |      |      |      |      |      |     |     |
|----------|------|------|------|------|------|------|-----|-----|
|          | 15   | 14   | 13   | 12   | 11   | 10   | 9   | 8   |
| P9 (P9H) | P915 | P914 | P913 | P912 | P911 | P910 | P99 | P98 |

|       |     |     |     |     |     |     |     |     |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|
|       | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
| (P9L) | P97 | P96 | P95 | P94 | P93 | P92 | P91 | P90 |

|     |  |
|-----|--|
| P9n | Output data control (in output mode) (n = 0 to 15) |
| 0   | Outputs 0  |
| 1   | Outputs 1  |

**Remarks**

- The P9 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the P9 register as the P9H register and the lower 8 bits as the P9L register, P9 can be read or written in 8-bit or 1-bit units.
- To read/write bits 8 to 15 of the P9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the P9H register.

(2) Port 9 mode register (PM9)

After reset: FFFFH R/W Address: PM9 FFFFF432H,  
PM9L FFFFF432H, PM9H FFFFF433H

|            |       |       |       |       |       |       |      |      |
|------------|-------|-------|-------|-------|-------|-------|------|------|
|            | 15    | 14    | 13    | 12    | 11    | 10    | 9    | 8    |
| PM9 (PM9H) | PM915 | PM914 | PM913 | PM912 | PM911 | PM910 | PM99 | PM98 |

|        |      |      |      |      |      |      |      |      |
|--------|------|------|------|------|------|------|------|------|
|        | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| (PM9L) | PM97 | PM96 | PM95 | PM94 | PM93 | PM92 | PM91 | PM90 |

|      |                                |
|------|--------------------------------|
| PM9n | I/O mode control (n = 0 to 15) |
| 0    | Output mode                    |
| 1    | Input mode                     |

**Remarks**

- The PM9 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PM9 register as the PM9H register and the lower 8 bits as the PM9L register, PM9 can be read or written in 8-bit and 1-bit units.
- To read/write bits 8 to 15 of the PM9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PM9H register.

(3) Port 9 mode control register (PMC9)

(1/2)

After reset: 0000H R/W Address: PMC9 FFFF452H,  
PMC9L FFFF452H, PMC9H FFFF453H

|              |        |        |        |        |        |        |       |       |
|--------------|--------|--------|--------|--------|--------|--------|-------|-------|
|              | 15     | 14     | 13     | 12     | 11     | 10     | 9     | 8     |
| PMC9 (PMC9H) | PMC915 | PMC914 | PMC913 | PMC912 | PMC911 | PMC910 | PMC99 | PMC98 |

|         |       |       |       |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|
|         | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
| (PMC9L) | PMC97 | PMC96 | PMC95 | PMC94 | PMC93 | PMC92 | PMC91 | PMC90 |

|        |   |
|--------|---|
| PMC915 | Specification of P915 pin operation mode        |
| 0      | I/O port  |
| 1      | A15 output/INTP6 input/TIP50 input/TOP50 output |

|        |   |
|--------|---|
| PMC914 | Specification of P914 pin operation mode        |
| 0      | I/O port  |
| 1      | A14 output/INTP5 input/TIP51 input/TOP51 output |

|        |  |
|--------|--|
| PMC913 | Specification of P913 pin operation mode |
| 0      | I/O port                                 |
| 1      | A13 output/INTP4 input                   |

|        |  |
|--------|--|
| PMC912 | Specification of P912 pin operation mode |
| 0      | I/O port                                 |
| 1      | A12 output/SCKB3 I/O                     |

|        |  |
|--------|--|
| PMC911 | Specification of P911 pin operation mode |
| 0      | I/O port                                 |
| 1      | A11 output/SOB3 output                   |

|        |  |
|--------|--|
| PMC910 | Specification of P910 pin operation mode |
| 0      | I/O port                                 |
| 1      | A10 output/SIB3 input                    |

|       |   |
|-------|---|
| PMC99 | Specification of P99 pin operation mode |
| 0     | I/O port                                |
| 1     | A9 output/SCKB1 I/O                     |

|       |   |
|-------|---|
| PMC98 | Specification of P98 pin operation mode |
| 0     | I/O port                                |
| 1     | A8 output/SOB1 output                   |

- Remarks**
- The PMC9 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PMC9 register as the PMC9H register and the lower 8 bits as the PMC9L register, PMC9 can be read or written in 8-bit or 1-bit units.
  - To read/write bits 8 to 15 of the PMC9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMC9H register.



|       |   |
|-------|---|
| PMC97 | Specification of P97 pin operation mode       |
| 0     | I/O port                                      |
| 1     | A7 output/SIB1 input/TIP20 input/TOP20 output |
| PMC96 | Specification of P96 pin operation mode       |
| 0     | I/O port                                      |
| 1     | A6 output/TIP21 input/TOP21 output            |
| PMC95 | Specification of P95 pin operation mode       |
| 0     | I/O port                                      |
| 1     | A5 output/TIP30 input/TOP30 output            |
| PMC94 | Specification of P94 pin operation mode       |
| 0     | I/O port                                      |
| 1     | A4 output/TIP31 input/TOP31 output            |
| PMC93 | Specification of P93 pin operation mode       |
| 0     | I/O port                                      |
| 1     | A3 output/TIP40 input/TOP40 output            |
| PMC92 | Specification of P92 pin operation mode       |
| 0     | I/O port                                      |
| 1     | A2 output/TIP41 input/TOP41 output            |
| PMC91 | Specification of P91 pin operation mode       |
| 0     | I/O port                                      |
| 1     | A1 output/KR7 input/RXDA1 input/SCL02 I/O     |
| PMC90 | Specification of P90 pin operation mode       |
| 0     | I/O port                                      |
| 1     | A0 output/KR6 input/TXDA1 output/SDA02 I/O    |

**Caution** When using the A0 to A15 pins as the alternate functions of the P90 to P915 pins, be sure to set all 16 bits of the PMC9 register to FFFFH at once.

(4) Port 9 function control register (PFC9)

**Caution** When performing separate address bus output (A0 to A15), set the PMC9 register to FFFFH for all 16 bits at once after clearing the PFC9 or PFCE9 register to 0000H.

After reset: 0000H    R/W    Address: PFC9 FFFF472H,  
PFC9L FFFF472H, PFC9H FFFF473H

|              |        |        |        |        |        |        |       |       |
|--------------|--------|--------|--------|--------|--------|--------|-------|-------|
|              | 15     | 14     | 13     | 12     | 11     | 10     | 9     | 8     |
| PFC9 (PFC9H) | PFC915 | PFC914 | PFC913 | PFC912 | PFC911 | PFC910 | PFC99 | PFC98 |
|              | 7      | 6      | 5      | 4      | 3      | 2      | 1     | 0     |
| (PFC9L)      | PFC97  | PFC96  | PFC95  | PFC94  | PFC93  | PFC92  | PFC91 | PFC90 |

- Remarks**
1. For details of alternate function specification, see 4.3.9 (6) Port 9 alternate function specifications.
  2. The PFC9 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PFC9 register as the PFC9H register and the lower 8 bits as the PFC9L register, PFC9 can be read or written in 8-bit or 1-bit units.
  3. To read/write bits 8 to 15 of the PFC9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PFC9H register.

(5) Port 9 function control expansion register (PFCE9)

**Caution** When performing separate address bus output (A0 to A15), set the PMC9 register to FFFFH for all 16 bits at once after clearing the PFC9 or PFCE9 register to 0000H.

After reset: 0000H    R/W    Address: PFCE9 FFFF712H,  
PFCE9L FFFF712H, PFCE9H FFFF713H

|                |         |         |        |        |        |        |        |        |
|----------------|---------|---------|--------|--------|--------|--------|--------|--------|
|                | 15      | 14      | 13     | 12     | 11     | 10     | 9      | 8      |
| PFCE9 (PFCE9H) | PFCE915 | PFCE914 | 0      | 0      | 0      | 0      | 0      | 0      |
|                | 7       | 6       | 5      | 4      | 3      | 2      | 1      | 0      |
| (PFCE9L)       | PFCE97  | PFCE96  | PFCE95 | PFCE94 | PFCE93 | PFCE92 | PFCE91 | PFCE90 |

- Remarks**
1. For details of alternate function specification, see 4.3.9 (6) Port 9 alternate function specifications.
  2. The PFCE9 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PFCE9 register as the PFCE9H register and the lower 8 bits as the PFCE9L register, PFCE9 can be read or written in 8-bit or 1-bit units.
  3. To read/write bits 8 to 15 of the PFCE9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PFCE9H register.

## (6) Port 9 alternate function specifications

| PFCE915 | PFC915 | Specification of P915 pin alternate function |
|---------|--------|--|
| 0       | 0      | A15 output                                   |
| 0       | 1      | INTP6 input                                  |
| 1       | 0      | TIP50 input                                  |
| 1       | 1      | TOP50 output                                 |

| PFCE914 | PFC914 | Specification of P914 pin alternate function |
|---------|--------|--|
| 0       | 0      | A14 output                                   |
| 0       | 1      | INTP5 input                                  |
| 1       | 0      | TIP51 input                                  |
| 1       | 1      | TOP51 output                                 |

| PFC913 | Specification of P913 pin alternate function |
|--------|--|
| 0      | A13 output                                   |
| 1      | INTP4 input                                  |

| PFC912 | Specification of P912 pin alternate function |
|--------|--|
| 0      | A12 output                                   |
| 1      | SCKB3 I/O                                    |

| PFC911 | Specification of P911 pin alternate function |
|--------|--|
| 0      | A11 output                                   |
| 1      | SOB3 output                                  |

| PFC910 | Specification of P910 pin alternate function |
|--------|--|
| 0      | A10 output                                   |
| 1      | SIB3 input                                   |

| PFC99 | Specification of P99 pin alternate function |
|-------|---|
| 0     | A9 output                                   |
| 1     | SCKB1 I/O                                   |

| PFC98 | Specification of P98 pin alternate function |
|-------|---|
| 0     | A8 output                                   |
| 1     | SOB1 output                                 |

| PFCE97 | PFC97 | Specification of P97 pin alternate function |
|--------|-------|---|
| 0      | 0     | A7 output                                   |
| 0      | 1     | SIB1 input                                  |
| 1      | 0     | TIP20 input                                 |
| 1      | 1     | TOP20 output                                |

| PFCE96 | PFC96 | Specification of P96 pin alternate function |
|--------|-------|---|
| 0      | 0     | A6 output                                   |
| 0      | 1     | Setting prohibited                          |
| 1      | 0     | TIP21 input                                 |
| 1      | 1     | TOP21 output                                |

| PFCE95 | PFC95 | Specification of P95 pin alternate function |
|--------|-------|---|
| 0      | 0     | A5 output                                   |
| 0      | 1     | TIP30 input                                 |
| 1      | 0     | TOP30 output                                |
| 1      | 1     | Setting prohibited                          |

| PFCE94 | PFC94 | Specification of P94 pin alternate function |
|--------|-------|---|
| 0      | 0     | A4 output                                   |
| 0      | 1     | TIP31 input                                 |
| 1      | 0     | TOP31 output                                |
| 1      | 1     | Setting prohibited                          |

| PFCE93 | PFC93 | Specification of P93 pin alternate function |
|--------|-------|---|
| 0      | 0     | A3 output                                   |
| 0      | 1     | TIP40 input                                 |
| 1      | 0     | TOP40 output                                |
| 1      | 1     | Setting prohibited                          |

| PFCE92 | PFC92 | Specification of P92 pin alternate function |
|--------|-------|---|
| 0      | 0     | A2 output                                   |
| 0      | 1     | TIP41 input                                 |
| 1      | 0     | TOP41 output                                |
| 1      | 1     | Setting prohibited                          |

| PFCE91 | PFC91 | Specification of P91 pin alternate function |
|--------|-------|---|
| 0      | 0     | A1 output                                   |
| 0      | 1     | KR7 input                                   |
| 1      | 0     | RXDA1 input/KR7 input <sup>Note</sup>       |
| 1      | 1     | SCL02 I/O                                   |

| PFCE90 | PFC90 | Specification of P90 pin alternate function |
|--------|-------|---|
| 0      | 0     | A0 output                                   |
| 0      | 1     | KR6 input                                   |
| 1      | 0     | TXDA1 output                                |
| 1      | 1     | SDA02 I/O                                   |

**Note** The RXDA1 and KR7 pins must not be used at the same time. When using the RXDA1 pin, do not use the KR7 pin. When using the KR7 pin, do not use the RXDA1 pin (it is recommended to set the PFC91 bit to 1 and clear the PFCE91 bit to 0).

(7) Port 9 function register (PF9)

After reset: 0000H R/W Address: PF3 FFFFC72H,  
PF9L FFFFC72H, PF9H FFFFC73H

|            |       |  |       |       |       |       |      |      |
|------------|-------|--|-------|-------|-------|-------|------|------|
|            | 15    | 14   | 13    | 12    | 11    | 10    | 9    | 8    |
| PF9 (PF9H) | PF915 | PF914  | PF913 | PF912 | PF911 | PF910 | PF99 | PF98 |
|            | 7     | 6  | 5     | 4     | 3     | 2     | 1    | 0    |
| (PF9L)     | PF97  | PF96   | PF95  | PF94  | PF93  | PF92  | PF91 | PF90 |
|            | PF9n  | Control of normal output or N-ch open-drain output (n = 0 to 15) |       |       |       |       |      |      |
|            | 0     | Normal output (CMOS output)                                      |       |       |       |       |      |      |
|            | 1     | N-ch open-drain output   |       |       |       |       |      |      |

**Caution** When an output pin is pulled up at  $EV_{DD}$  or higher, be sure to set the PF9n bit to 1.

- Remarks**
1. The PF9 register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PF9 register as the PF9H register and the lower 8 bits as the PF9L register, PF9 can be read or written in 8-bit or 1-bit units.
  2. To read/write bits 8 to 15 of the PF9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PF9H register.

**4.3.10 Port CD**

Port CD is a 4-bit port for which I/O settings can be controlled in 1-bit units.

Port CD includes the following alternate-function pins.

**Table 4-13. Port CD Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O | Remark | Block Type |
|----------|---------|-----------------------------|-----|--------|------------|
| PCD0     | 77      | –                           | –   | –      | B-1        |
| PCD1     | 78      | –                           | –   |        | B-1        |
| PCD2     | 79      | –                           | –   |        | B-1        |
| PCD3     | 80      | –                           | –   |        | B-1        |

**(1) Port CD register (PCD)**

|                                 |   |     |                    |   |      |      |      |      |
|---------------------------------|---|-----|--------------------|---|------|------|------|------|
| After reset: 00H (output latch) |   | R/W | Address: FFFFF00EH |   |      |      |      |      |
| PCD                             | 7   | 6   | 5                  | 4 | 3    | 2    | 1    | 0    |
|                                 | 0   | 0   | 0                  | 0 | PCD3 | PCD2 | PCD1 | PCD0 |
| PCDn                            | Output data control (in output mode) (n = 0 to 3) |     |                    |   |      |      |      |      |
| 0                               | Outputs 0   |     |                    |   |      |      |      |      |
| 1                               | Outputs 1   |     |                    |   |      |      |      |      |

**(2) Port CD mode register (PMCD)**

|                  |                               |     |                    |   |       |       |       |       |
|------------------|-------------------------------|-----|--------------------|---|-------|-------|-------|-------|
| After reset: FFH |                               | R/W | Address: FFFFF02EH |   |       |       |       |       |
| PMCD             | 7                             | 6   | 5                  | 4 | 3     | 2     | 1     | 0     |
|                  | 1                             | 1   | 1                  | 1 | PMCD3 | PMCD2 | PMCD1 | PMCD0 |
| PMCDn            | I/O mode control (n = 0 to 3) |     |                    |   |       |       |       |       |
| 0                | Output mode                   |     |                    |   |       |       |       |       |
| 1                | Input mode                    |     |                    |   |       |       |       |       |

**4.3.11 Port CM**

Port CM is a 6-bit port for which I/O settings can be controlled in 1-bit units.

Port CM includes the following alternate-function pins.

**Table 4-14. Port CM Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O    | Remark | Block Type |
|----------|---------|-----------------------------|--------|--------|------------|
| PCM0     | 85      | WAIT                        | Input  | -      | D-1        |
| PCM1     | 86      | CLKOUT                      | Output |        | D-2        |
| PCM2     | 87      | HLD $\overline{\text{AK}}$  | Output |        | D-2        |
| PCM3     | 88      | H $\overline{\text{LDRQ}}$  | Input  |        | D-1        |
| PCM4     | 89      | -                           | -      |        | B-1        |
| PCM5     | 90      | -                           | -      |        | B-1        |

**(1) Port CM register (PCM)**

After reset: 00H (output latch) R/W Address: FFFFF00CH

|     |   |   |      |      |      |      |      |      |
|-----|---|---|------|------|------|------|------|------|
|     | 7 | 6 | 5    | 4    | 3    | 2    | 1    | 0    |
| PCM | 0 | 0 | PCM5 | PCM4 | PCM3 | PCM2 | PCM1 | PCM0 |

|      |   |
|------|---|
| PCMn | Output data control (in output mode) (n = 0 to 5) |
| 0    | Outputs 0   |
| 1    | Outputs 1   |

**(2) Port CM mode register (PMCM)**

After reset: FFH R/W Address: FFFFF02CH

|      |   |   |       |       |       |       |       |       |
|------|---|---|-------|-------|-------|-------|-------|-------|
|      | 7 | 6 | 5     | 4     | 3     | 2     | 1     | 0     |
| PMCM | 1 | 1 | PMCM5 | PMCM4 | PMCM3 | PMCM2 | PMCM1 | PMCM0 |

|       |                               |
|-------|-------------------------------|
| PMCMn | I/O mode control (n = 0 to 5) |
| 0     | Output mode                   |
| 1     | Input mode                    |

(3) Port CM mode control register (PMCCM)

After reset: 00H R/W Address: FFFFF04CH

|       |   |   |   |   |        |        |        |        |
|-------|---|---|---|---|--------|--------|--------|--------|
|       | 7 | 6 | 5 | 4 | 3      | 2      | 1      | 0      |
| PMCCM | 0 | 0 | 0 | 0 | PMCCM3 | PMCCM2 | PMCCM1 | PMCCM0 |

|        |  |  |
|--------|--|--|
| PMCCM3 | Specification of PCM3 pin operation mode |  |
| 0      | I/O port                                 |  |
| 1      | $\overline{\text{HLDRQ}}$ input          |  |

|        |  |  |
|--------|--|--|
| PMCCM2 | Specification of PCM2 pin operation mode |  |
| 0      | I/O port                                 |  |
| 1      | $\overline{\text{HLDAK}}$ output         |  |

|        |  |  |
|--------|--|--|
| PMCCM1 | Specification of PCM1 pin operation mode |  |
| 0      | I/O port                                 |  |
| 1      | CLKOUT output                            |  |

|        |  |  |
|--------|--|--|
| PMCCM0 | Specification of PCM0 pin operation mode |  |
| 0      | I/O port                                 |  |
| 1      | $\overline{\text{WAIT}}$ input           |  |



**4.3.12 Port CS**

Port CS is an 8-bit port for which I/O settings can be controlled in 1-bit units.

Port CS includes the following alternate-function pins.

**Table 4-15. Port CS Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O    | Remark | Block Type |
|----------|---------|-----------------------------|--------|--------|------------|
| PCS0     | 81      | $\overline{CS0}$            | Output | -      | D-2        |
| PCS1     | 82      | $\overline{CS1}$            | Output |        | D-2        |
| PCS2     | 83      | $\overline{CS2}$            | Output |        | D-2        |
| PCS3     | 84      | $\overline{CS3}$            | Output |        | D-2        |
| PCS4     | 91      | -                           | -      |        | B-1        |
| PCS5     | 92      | -                           | -      |        | B-1        |
| PCS6     | 93      | -                           | -      |        | B-1        |
| PCS7     | 94      | -                           | -      |        | B-1        |

**(1) Port CS register (PCS)**

After reset: 00H (output latch)    R/W    Address: FFFFF008H

|     |      |      |      |      |      |      |      |      |
|-----|------|------|------|------|------|------|------|------|
|     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PCS | PCS7 | PCS6 | PCS5 | PCS4 | PCS3 | PCS2 | PCS1 | PCS0 |

|                  |   |
|------------------|---|
| PCS <sub>n</sub> | Output data control (in output mode) (n = 0 to 7) |
| 0                | Outputs 0   |
| 1                | Outputs 1   |

**(2) Port CS mode register (PMCS)**

After reset: FFH    R/W    Address: FFFFF028H

|      |       |       |       |       |       |       |       |       |
|------|-------|-------|-------|-------|-------|-------|-------|-------|
|      | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
| PMCS | PMCS7 | PMCS6 | PMCS5 | PMCS4 | PMCS3 | PMCS2 | PMCS1 | PMCS0 |

|                   |                               |
|-------------------|-------------------------------|
| PMCS <sub>n</sub> | I/O mode control (n = 0 to 7) |
| 0                 | Output mode                   |
| 1                 | Input mode                    |

(3) Port CS mode control register (PMCCS)

After reset: 00H R/W Address: FFFF048H

|       |   |   |   |   |        |        |        |        |
|-------|---|---|---|---|--------|--------|--------|--------|
|       | 7 | 6 | 5 | 4 | 3      | 2      | 1      | 0      |
| PMCCS | 0 | 0 | 0 | 0 | PMCCS3 | PMCCS2 | PMCCS1 | PMCCS0 |

|        |  |
|--------|--|
| PMCCS3 | Specification of PCS3 pin operation mode |
| 0      | I/O port                                 |
| 1      | $\overline{CS3}$ output                  |

|        |  |
|--------|--|
| PMCCS2 | Specification of PCS2 pin operation mode |
| 0      | I/O port                                 |
| 1      | $\overline{CS2}$ output                  |

|        |  |
|--------|--|
| PMCCS1 | Specification of PCS1 pin operation mode |
| 0      | I/O port                                 |
| 1      | $\overline{CS1}$ output                  |

|        |  |
|--------|--|
| PMCCS0 | Specification of PCS0 pin operation mode |
| 0      | I/O port                                 |
| 1      | $\overline{CS0}$ output                  |

**4.3.13 Port CT**

Port CT is an 8-bit port for which I/O settings can be controlled in 1-bit units.

Port CT includes the following alternate-function pins.

**Table 4-16. Port CT Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O    | Remark | Block Type |
|----------|---------|-----------------------------|--------|--------|------------|
| PCT0     | 95      | $\overline{WR0}$            | Output | -      | D-2        |
| PCT1     | 96      | $\overline{WR1}$            | Output |        | D-2        |
| PCT2     | 97      | -                           | -      |        | B-1        |
| PCT3     | 98      | -                           | -      |        | B-1        |
| PCT4     | 99      | $\overline{RD}$             | Output |        | D-2        |
| PCT5     | 100     | -                           | -      |        | B-1        |
| PCT6     | 101     | ASTB                        | Output |        | D-2        |
| PCT7     | 102     | -                           | -      |        | B-1        |

**(1) Port CT register (PCT)**

After reset: 00H (output latch) R/W Address: FFFFF00AH

|     |      |      |      |      |      |      |      |      |
|-----|------|------|------|------|------|------|------|------|
|     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PCT | PCT7 | PCT6 | PCT5 | PCT4 | PCT3 | PCT2 | PCT1 | PCT0 |

|      |   |
|------|---|
| PCTn | Output data control (in output mode) (n = 0 to 7) |
| 0    | Outputs 0   |
| 1    | Outputs 1   |

**(2) Port CT mode register (PMCT)**

After reset: FFH R/W Address: FFFFF02AH

|      |       |       |       |       |       |       |       |       |
|------|-------|-------|-------|-------|-------|-------|-------|-------|
|      | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
| PMCT | PMCT7 | PMCT6 | PMCT5 | PMCT4 | PMCT3 | PMCT2 | PMCT1 | PMCT0 |

|       |                               |
|-------|-------------------------------|
| PMCTn | I/O mode control (n = 0 to 7) |
| 0     | Output mode                   |
| 1     | Input mode                    |

(3) Port CT mode control register (PMCCT)

After reset: 00H R/W Address: FFFFF04AH

|       |   |        |   |        |   |   |        |        |
|-------|---|--------|---|--------|---|---|--------|--------|
|       | 7 | 6      | 5 | 4      | 3 | 2 | 1      | 0      |
| PMCCT | 0 | PMCCT6 | 0 | PMCCT4 | 0 | 0 | PMCCT1 | PMCCT0 |

|        |  |
|--------|--|
| PMCCT6 | Specification of PCT6 pin operation mode |
| 0      | I/O port                                 |
| 1      | ASTB output                              |

|        |  |
|--------|--|
| PMCCT4 | Specification of PCT4 pin operation mode |
| 0      | I/O port                                 |
| 1      | $\overline{RD}$ output                   |

|        |  |
|--------|--|
| PMCCT1 | Specification of PCT1 pin operation mode |
| 0      | I/O port                                 |
| 1      | $\overline{WR1}$ output                  |

|        |  |
|--------|--|
| PMCCT0 | Specification of PCT0 pin operation mode |
| 0      | I/O port                                 |
| 1      | $\overline{WR0}$ output                  |

4.3.14 Port DH

Port DH is an 8-bit port for which I/O settings can be controlled in 1-bit units.

Port DH includes the following alternate-function pins.

Table 4-17. Port DH Alternate-Function Pins

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O    | Remark | Block Type |
|----------|---------|-----------------------------|--------|--------|------------|
| PDH0     | 121     | A16                         | Output | -      | D-2        |
| PDH1     | 122     | A17                         | Output |        | D-2        |
| PDH2     | 123     | A18                         | Output |        | D-2        |
| PDH3     | 124     | A19                         | Output |        | D-2        |
| PDH4     | 125     | A20                         | Output |        | D-2        |
| PDH5     | 126     | A21                         | Output |        | D-2        |
| PDH6     | 127     | A22                         | Output |        | D-2        |
| PDH7     | 128     | A23                         | Output |        | D-2        |

(1) Port DH register (PDH)

After reset: 00H (output latch) R/W Address: FFFFF006H

|     |      |      |      |      |      |      |      |      |
|-----|------|------|------|------|------|------|------|------|
|     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| PDH | PDH7 | PDH6 | PDH5 | PDH4 | PDH3 | PDH2 | PDH1 | PDH0 |

|      |   |
|------|---|
| PDHn | Output data control (in output mode) (n = 0 to 7) |
| 0    | Outputs 0   |
| 1    | Outputs 1   |

(2) Port DH mode register (PMDH)

After reset: FFH R/W Address: FFFFF026H

|      |       |       |       |       |       |       |       |       |
|------|-------|-------|-------|-------|-------|-------|-------|-------|
|      | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
| PMDH | PMDH7 | PMDH6 | PMDH5 | PMDH4 | PMDH3 | PMDH2 | PMDH1 | PMDH0 |

|       |                               |
|-------|-------------------------------|
| PMDHn | I/O mode control (n = 0 to 7) |
| 0     | Output mode                   |
| 1     | Input mode                    |

(3) Port DH mode control register (PMCDH)

After reset: 00H R/W Address: FFFFF046H

|       |        |        |        |        |        |        |        |        |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|
|       | 7      | 6      | 5      | 4      | 3      | 2      | 1      | 0      |
| PMCDH | PMCDH7 | PMCDH6 | PMCDH5 | PMCDH4 | PMCDH3 | PMCDH2 | PMCDH1 | PMCDH0 |

|        |   |
|--------|---|
| PMCDHn | Specification of PDHn pin operation mode (n = 0 to 7) |
| 0      | I/O port  |
| 1      | Am output (address bus output) (m = 16 to 23)         |

### 4.3.15 Port DL

Port DL is a 16-bit port for which I/O settings can be controlled in 1-bit units.

Port DL includes the following alternate-function pins.

**Table 4-18. Port DL Alternate-Function Pins**

| Pin Name | Pin No. | Alternate-Function Pin Name | I/O | Remark | Block Type |
|----------|---------|-----------------------------|-----|--------|------------|
| PDL0     | 105     | AD0                         | I/O | –      | D-3        |
| PDL1     | 106     | AD1                         | I/O |        | D-3        |
| PDL2     | 107     | AD2                         | I/O |        | D-3        |
| PDL3     | 108     | AD3                         | I/O |        | D-3        |
| PDL4     | 109     | AD4                         | I/O |        | D-3        |
| PDL5     | 110     | AD5/FLMD1 <sup>Note</sup>   | I/O |        | D-3        |
| PDL6     | 111     | AD6                         | I/O |        | D-3        |
| PDL7     | 112     | AD7                         | I/O |        | D-3        |
| PDL8     | 113     | AD8                         | I/O |        | D-3        |
| PDL9     | 114     | AD9                         | I/O |        | D-3        |
| PDL10    | 115     | AD10                        | I/O |        | D-3        |
| PDL11    | 116     | AD11                        | I/O |        | D-3        |
| PDL12    | 117     | AD12                        | I/O |        | D-3        |
| PDL13    | 118     | AD13                        | I/O |        | D-3        |
| PDL14    | 119     | AD14                        | I/O |        | D-3        |
| PDL15    | 120     | AD15                        | I/O |        | D-3        |

**Note** Since this pin is set in the flash memory programming mode, it does not need to be manipulated with the port control register. For details, see **CHAPTER 27 FLASH MEMORY**.

(1) Port DL register (PDL)

After reset: 0000H (output latch) R/W Address: PDL FFFF004H,  
PDL FFFF004H, PDLH FFFF005H

|            |       |       |       |       |       |       |      |      |
|------------|-------|-------|-------|-------|-------|-------|------|------|
|            | 15    | 14    | 13    | 12    | 11    | 10    | 9    | 8    |
| PDL (PDLH) | PDL15 | PDL14 | PDL13 | PDL12 | PDL11 | PDL10 | PDL9 | PDL8 |

|        |      |      |      |      |      |      |      |      |
|--------|------|------|------|------|------|------|------|------|
|        | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| (PDLL) | PDL7 | PDL6 | PDL5 | PDL4 | PDL3 | PDL2 | PDL1 | PDL0 |

|      |  |
|------|--|
| PDLn | Output data control (in output mode) (n = 0 to 15) |
| 0    | Outputs 0  |
| 1    | Outputs 1  |

**Remarks**

1. The PDL register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PDL register as the PDLH register and the lower 8 bits as the PDLL register, PDL can be read or written in 8-bit or 1-bit units.
2. To read/write bits 8 to 15 of the PDL register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PDLH register.

(2) Port DL mode register (PMDL)

After reset: FFFFH R/W Address: PMDL FFFF024H,  
PMDL FFFF024H, PMDLH FFFF025H

|              |        |        |        |        |        |        |       |       |
|--------------|--------|--------|--------|--------|--------|--------|-------|-------|
|              | 15     | 14     | 13     | 12     | 11     | 10     | 9     | 8     |
| PMDL (PMDLH) | PMDL15 | PMDL14 | PMDL13 | PMDL12 | PMDL11 | PMDL10 | PMDL9 | PMDL8 |

|         |       |       |       |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|
|         | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
| (PMDLL) | PMDL7 | PMDL6 | PMDL5 | PMDL4 | PMDL3 | PMDL2 | PMDL1 | PMDL0 |

|       |                                |
|-------|--------------------------------|
| PMDLn | I/O mode control (n = 0 to 15) |
| 0     | Output mode                    |
| 1     | Input mode                     |

**Remarks**

1. The PMDL register can be read or written in 16-bit units.  
However, when using the higher 8 bits of the PMDL register as the PMDLH register and the lower 8 bits as the PMDLL register, PMDL can be read or written in 8-bit or 1-bit units.
2. To read/write bits 8 to 15 of the PMDL register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMDLH register.



**(3) Port DL mode control register (PMCDL)**

After reset: 0000H    R/W    Address: PMCDL FFFFF044H,  
 PMCDLL FFFFF044H, PMCDLH FFFFF045H

|                |         |         |         |         |         |         |        |        |
|----------------|---------|---------|---------|---------|---------|---------|--------|--------|
|                | 15      | 14      | 13      | 12      | 11      | 10      | 9      | 8      |
| PMCDL (PMCDLH) | PMCDL15 | PMCDL14 | PMCDL13 | PMCDL12 | PMCDL11 | PMCDL10 | PMCDL9 | PMCDL8 |

|          |        |        |        |        |        |        |        |        |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|
|          | 7      | 6      | 5      | 4      | 3      | 2      | 1      | 0      |
| (PMCDLL) | PMCDL7 | PMCDL6 | PMCDL5 | PMCDL4 | PMCDL3 | PMCDL2 | PMCDL1 | PMCDL0 |

| PMCDLn | Specification of PDLn pin operation mode (n = 0 to 15) |
|--------|--|
| 0      | I/O port   |
| 1      | ADn I/O (address/data bus I/O)                         |

**Caution** When the SMSEL bit of the EXIMC register = 1 (separate mode) and the BS30 to BS00 bits of the BSC register = 0 (8-bit bus width), do not specify the AD8 to AD15 pins.

**Remarks**

1. The PMCDL register can be read or written in 16-bit units.  
 However, when using the higher 8 bits of the PMCDL register as the PMCDLH register and the lower 8 bits as the PMCDLL register, PMCDL can be read or written in 8-bit or 1-bit units.
2. To read/write bits 8 to 15 of the PMCDL register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMCDLH register.

4.4 Block Diagrams

Figure 4-3. Block Diagram of Type A-1

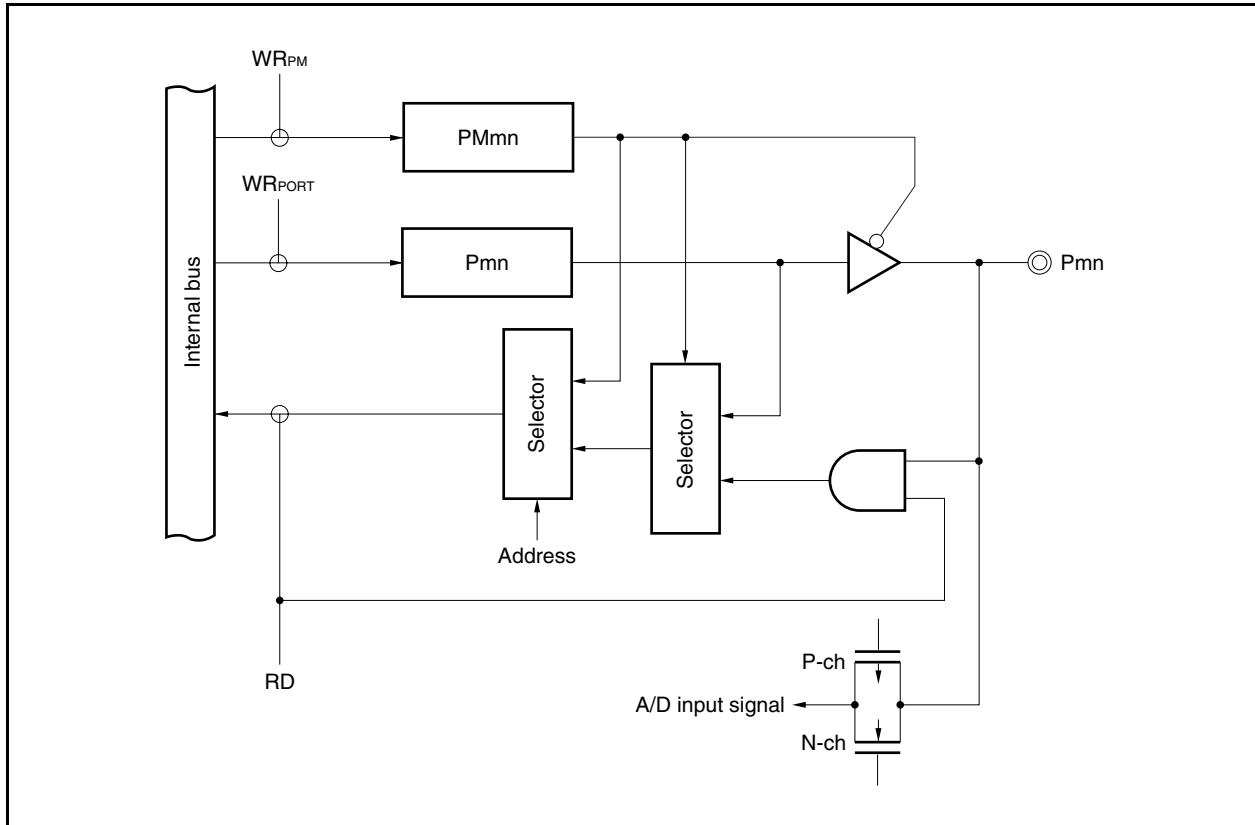


Figure 4-4. Block Diagram of Type A-2

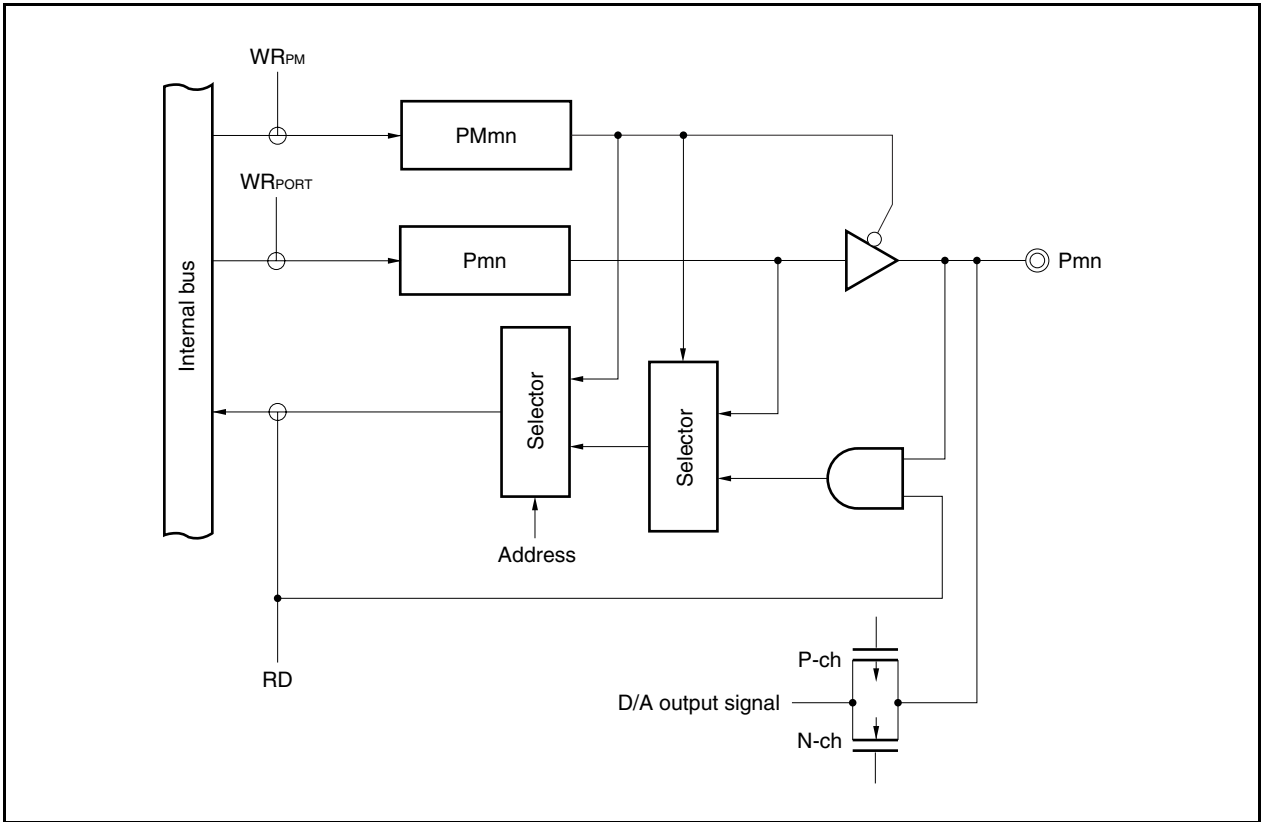


Figure 4-5. Block Diagram of Type B-1

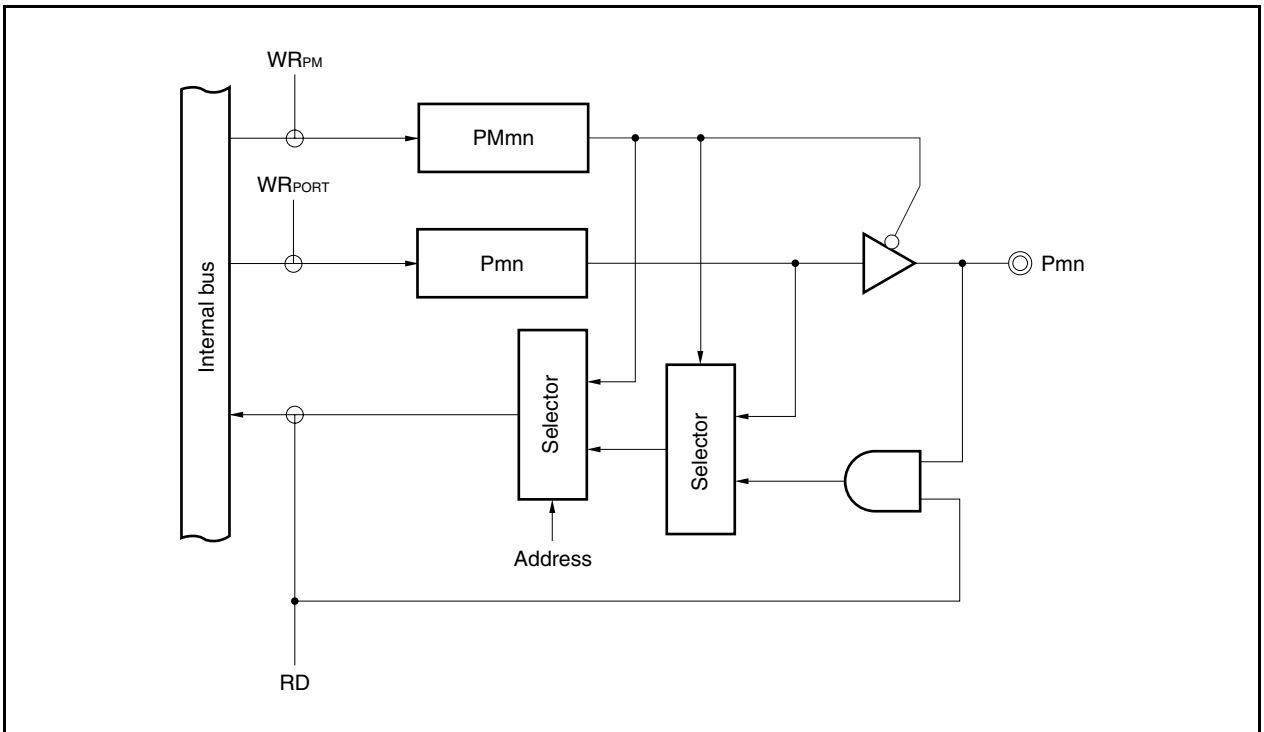


Figure 4-6. Block Diagram of Type C-1

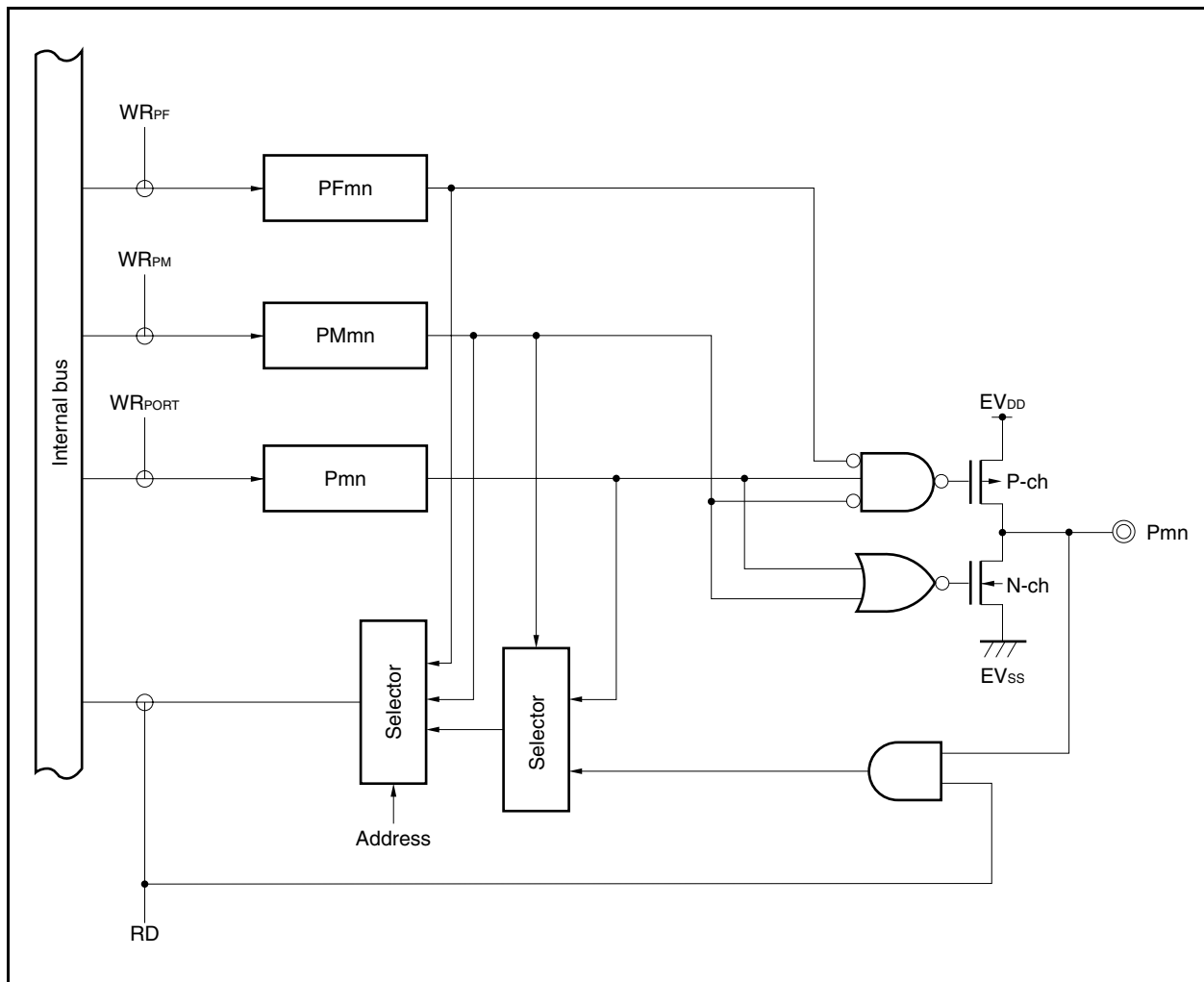


Figure 4-7. Block Diagram of Type D-1

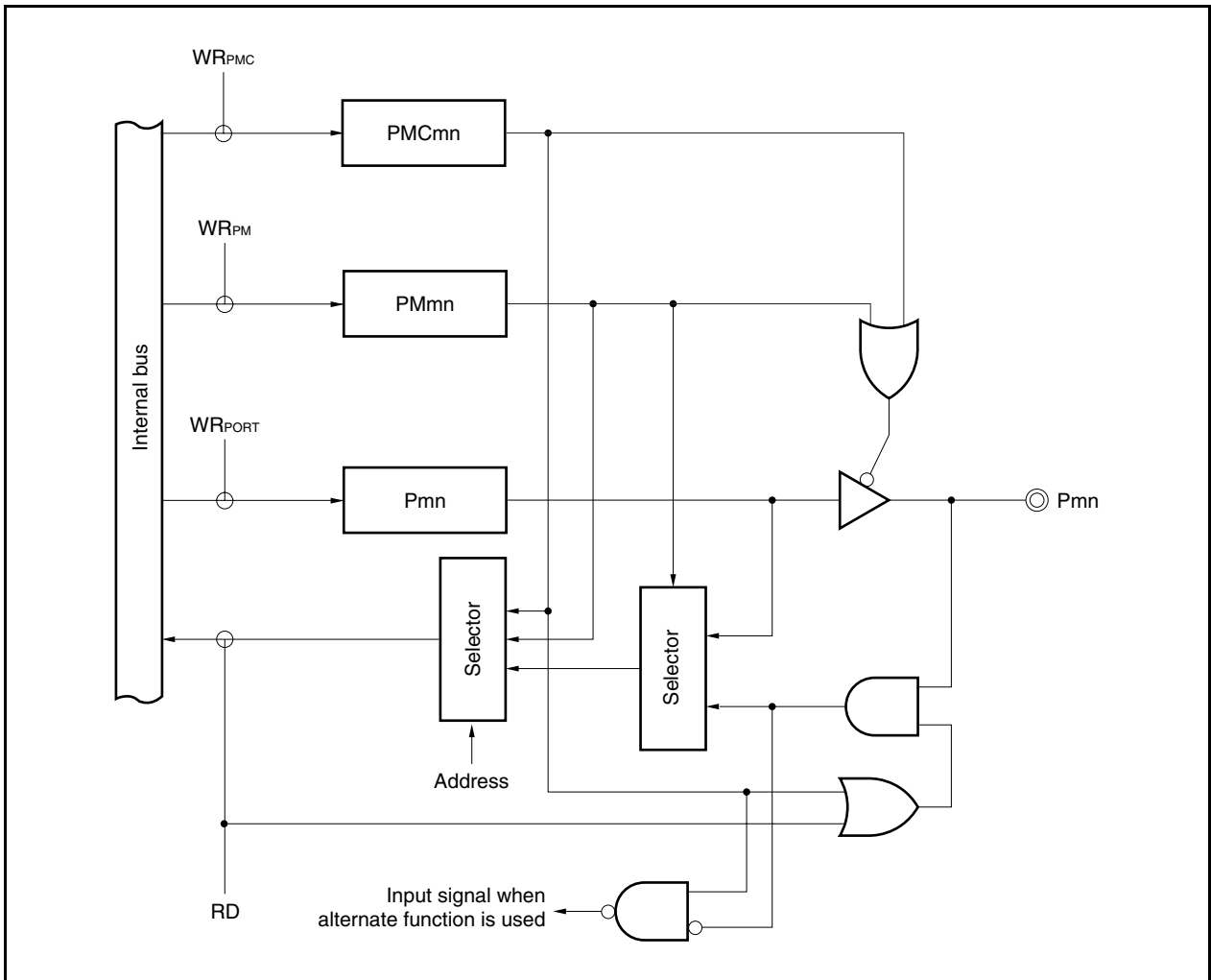


Figure 4-8. Block Diagram of Type D-2

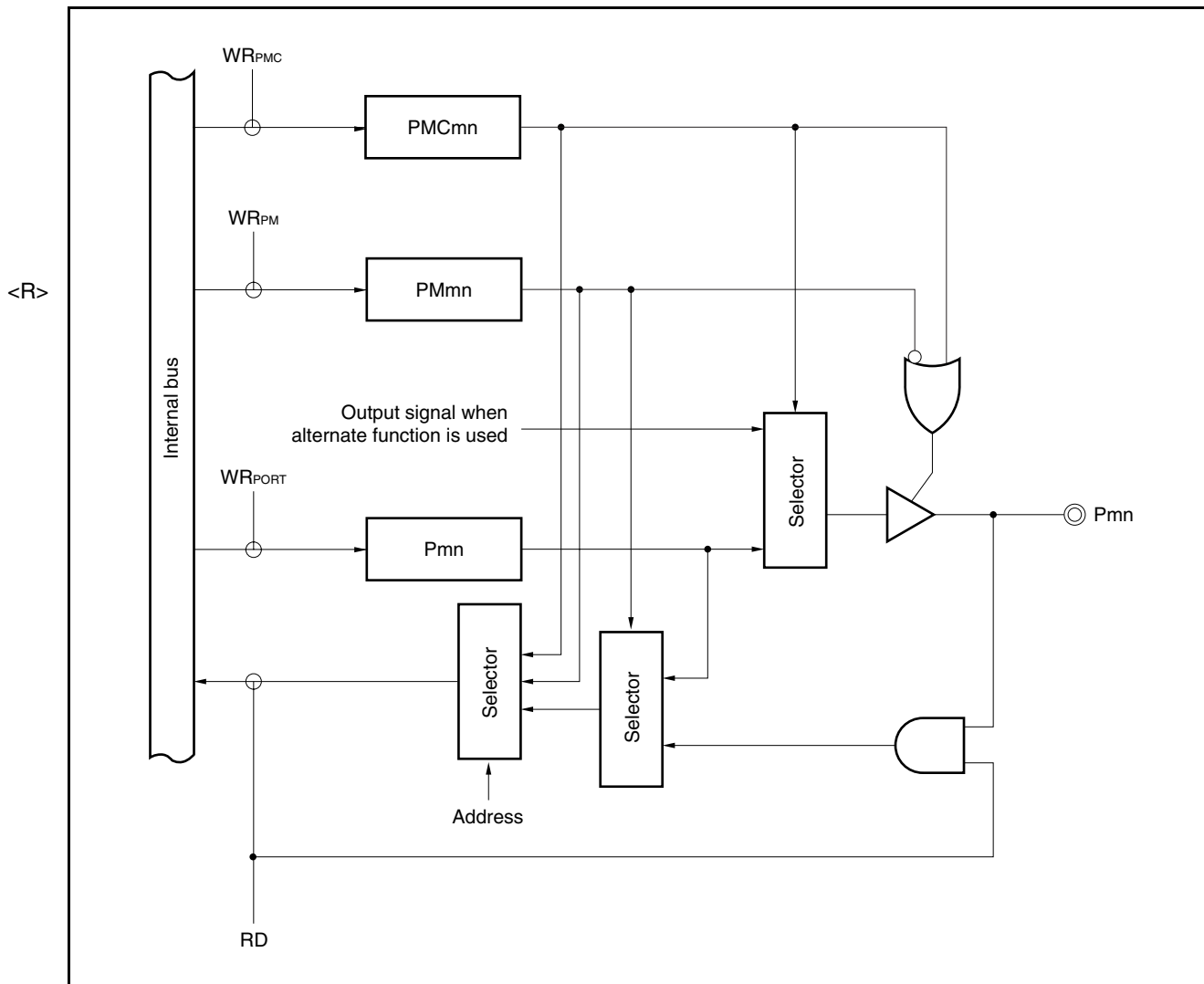


Figure 4-9. Block Diagram of Type D-3

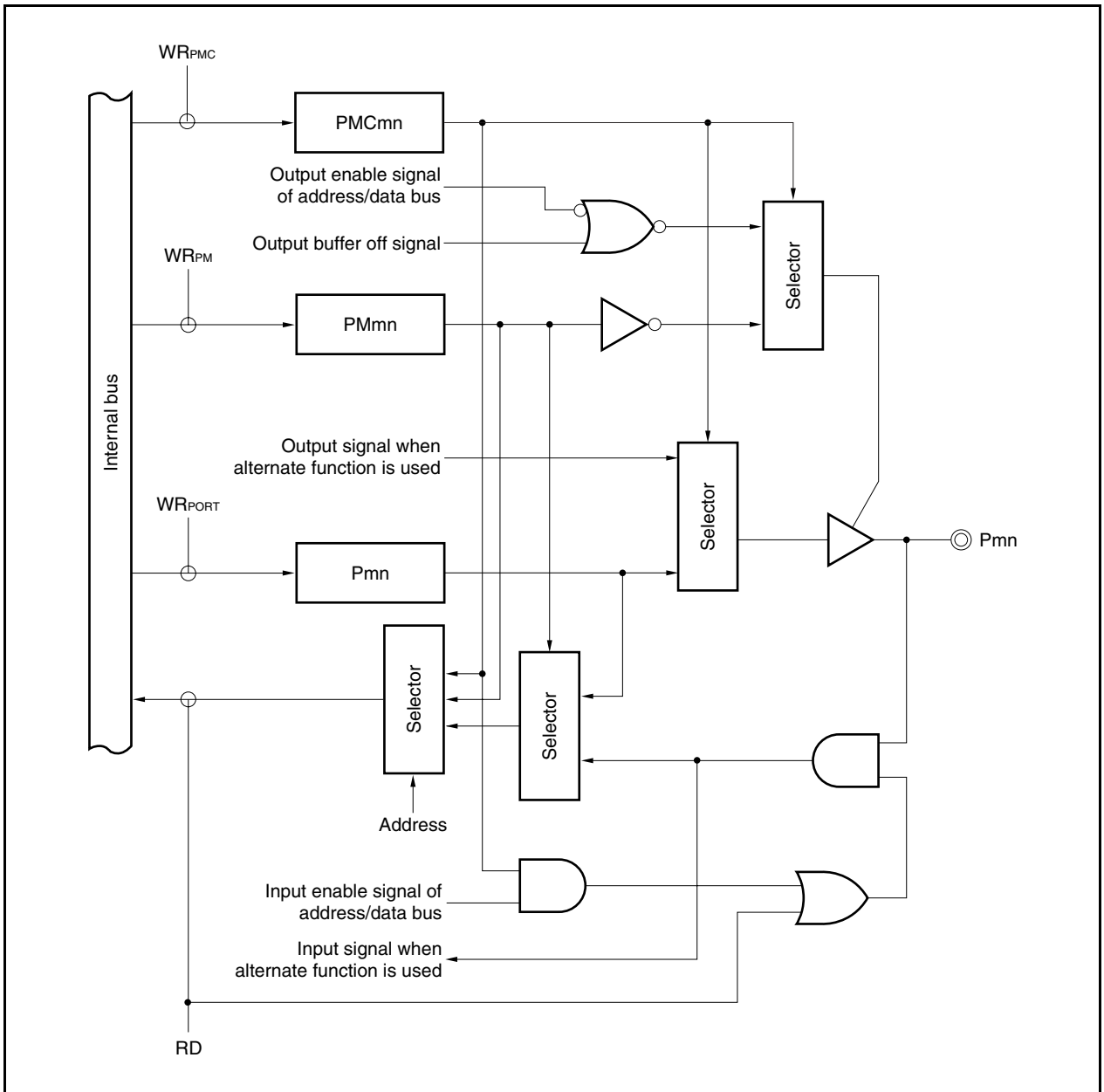


Figure 4-10. Block Diagram of Type E-1

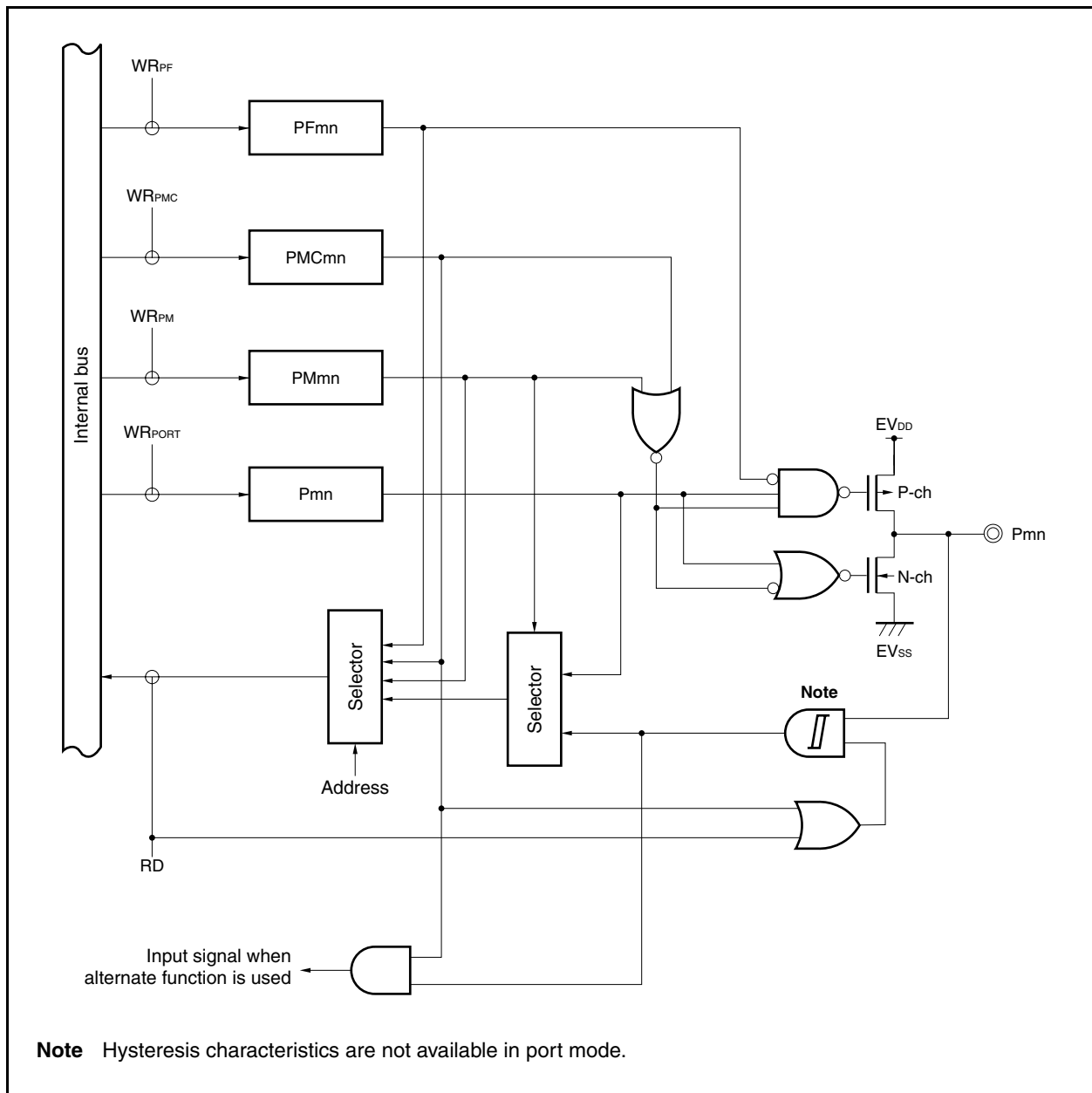
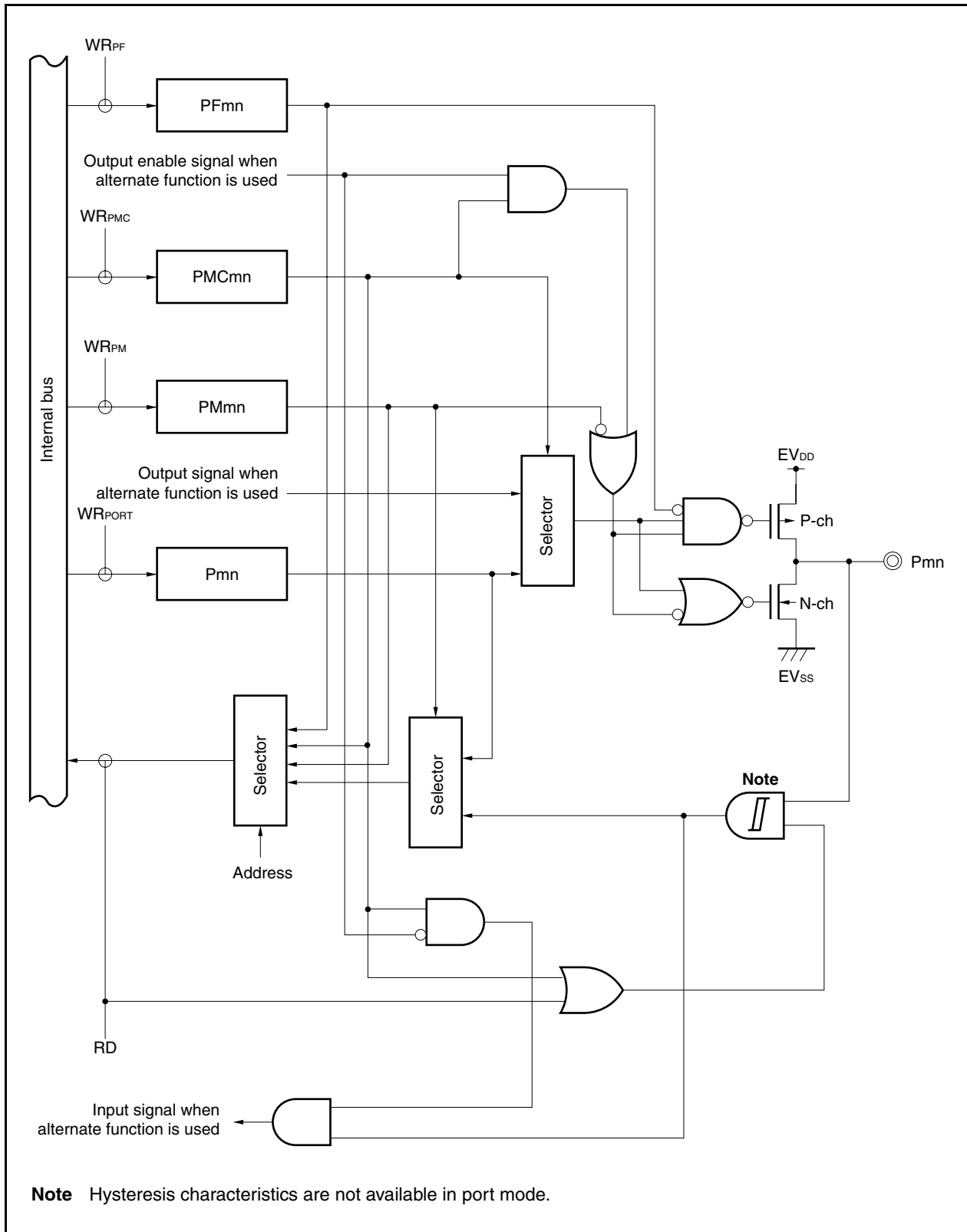






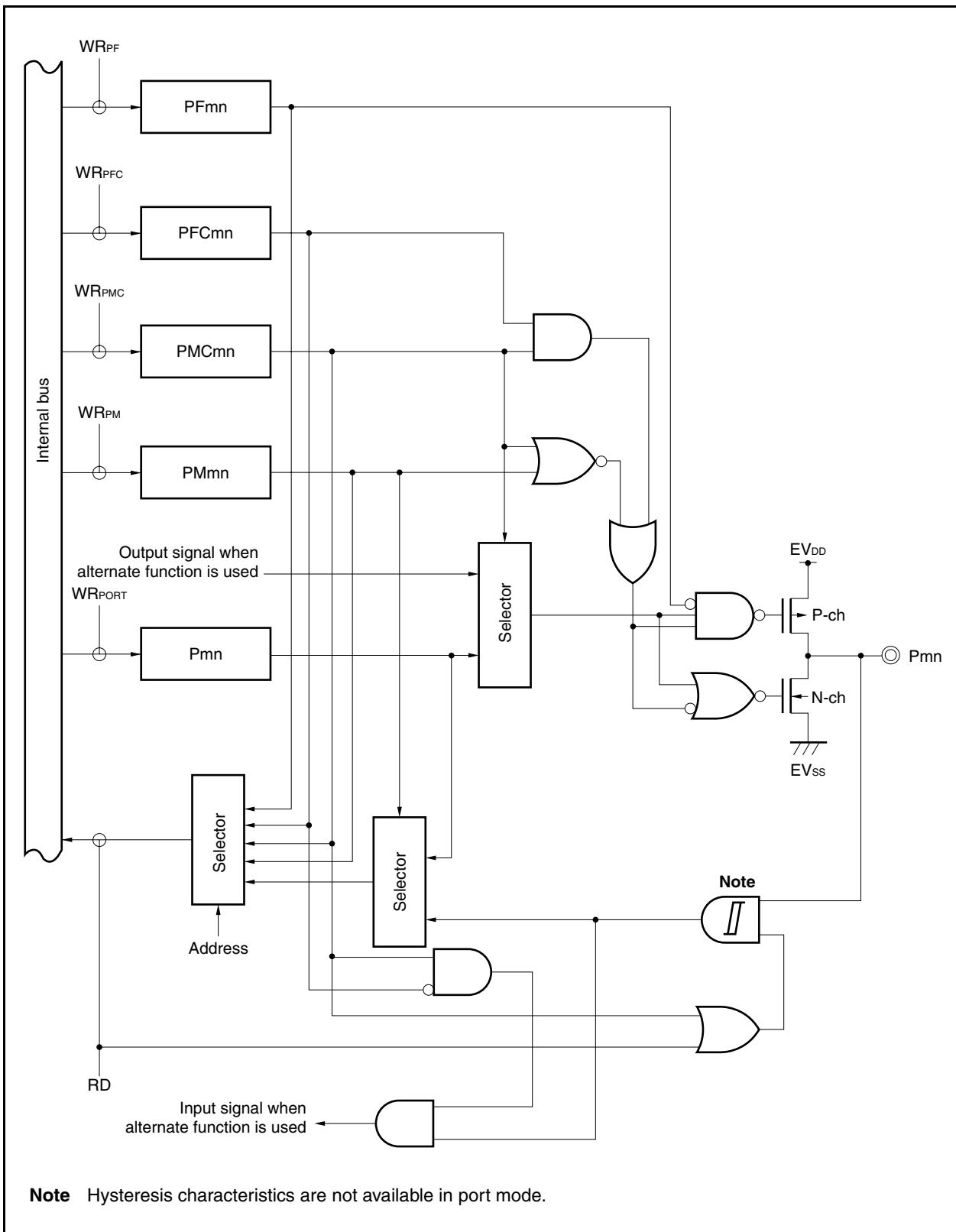
Figure 4-12. Block Diagram of Type E-3



**Note** Hysteresis characteristics are not available in port mode.

<R>

Figure 4-13. Block Diagram of Type G-1



<R>

Figure 4-14. Block Diagram of Type G-2

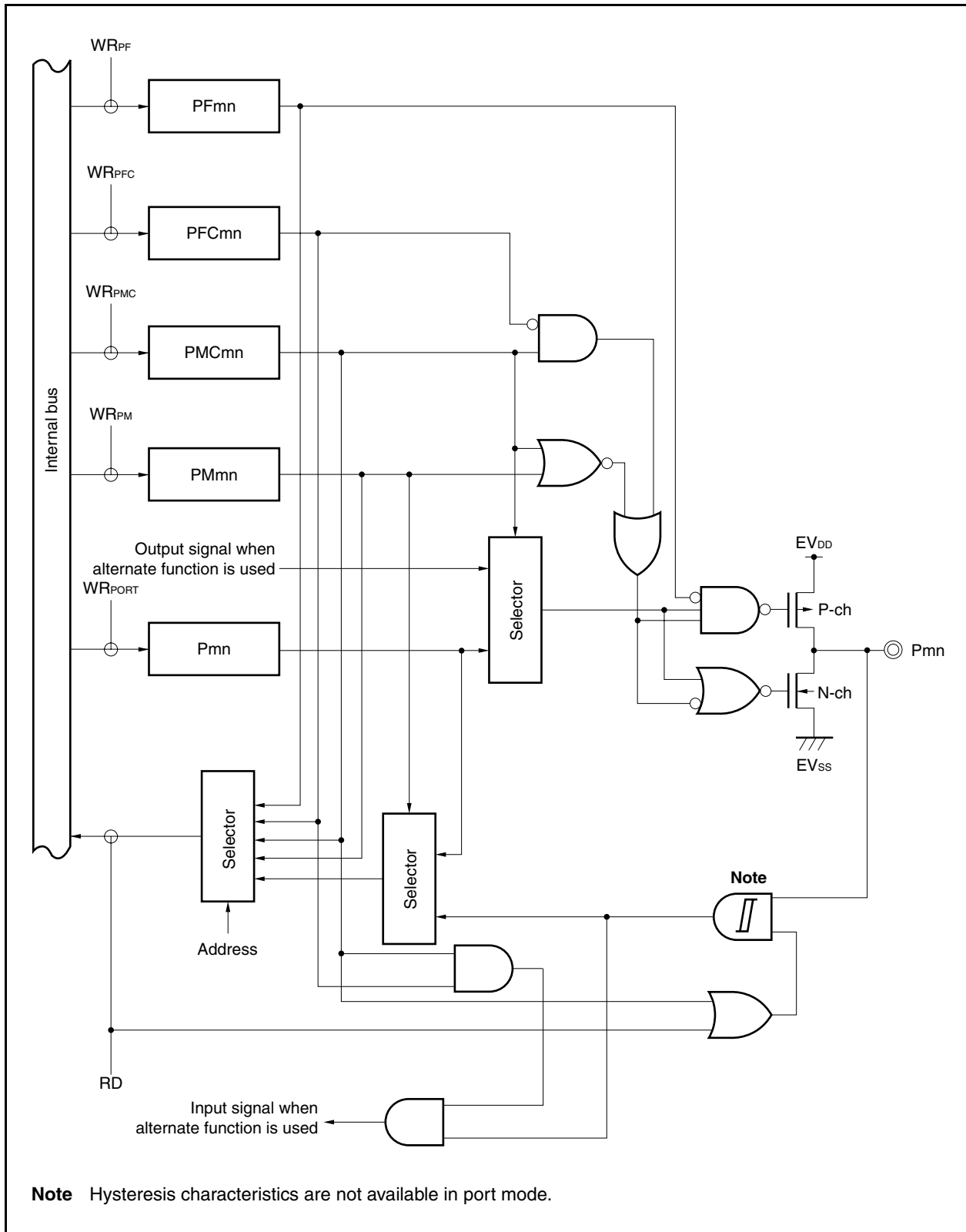
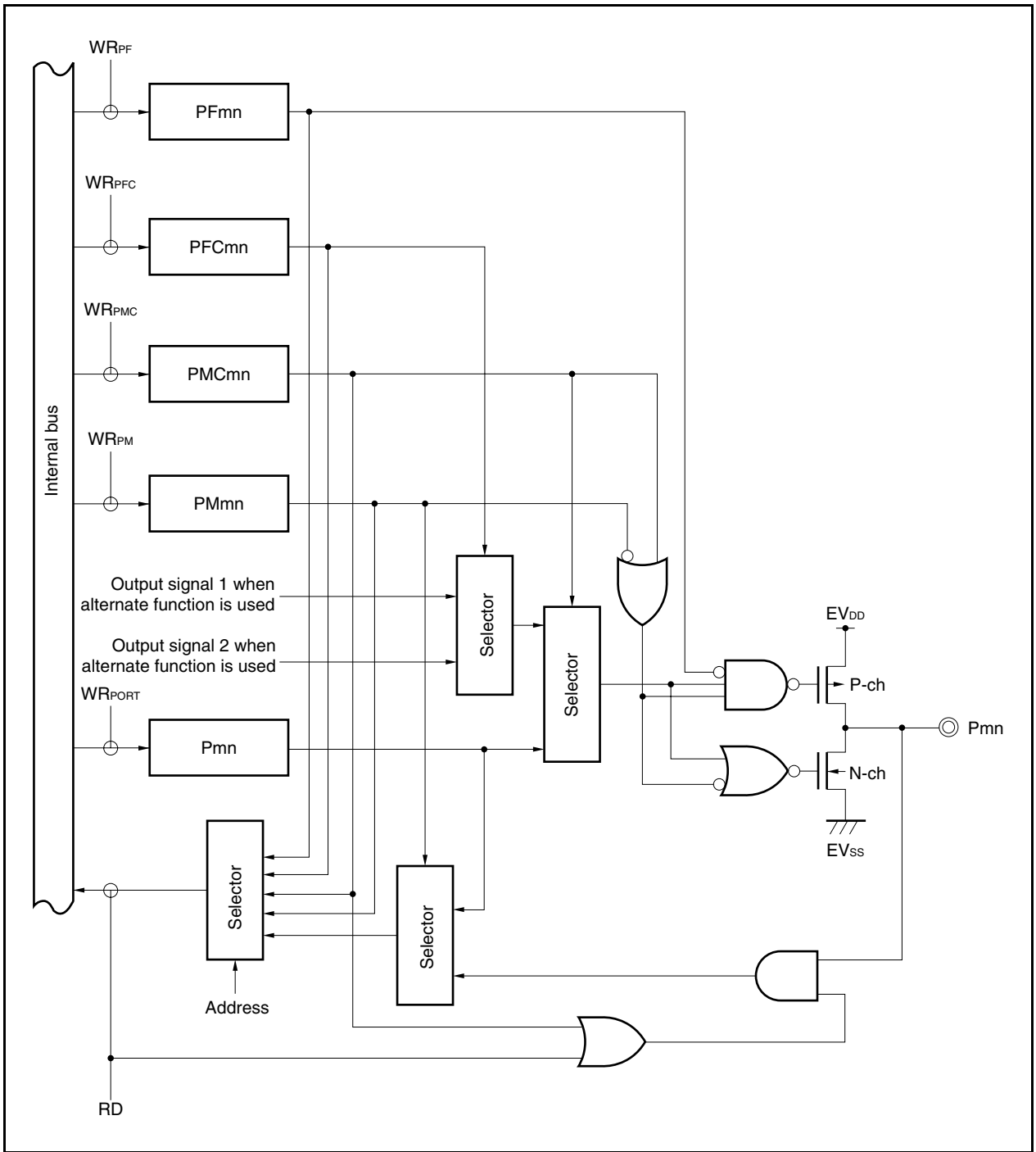
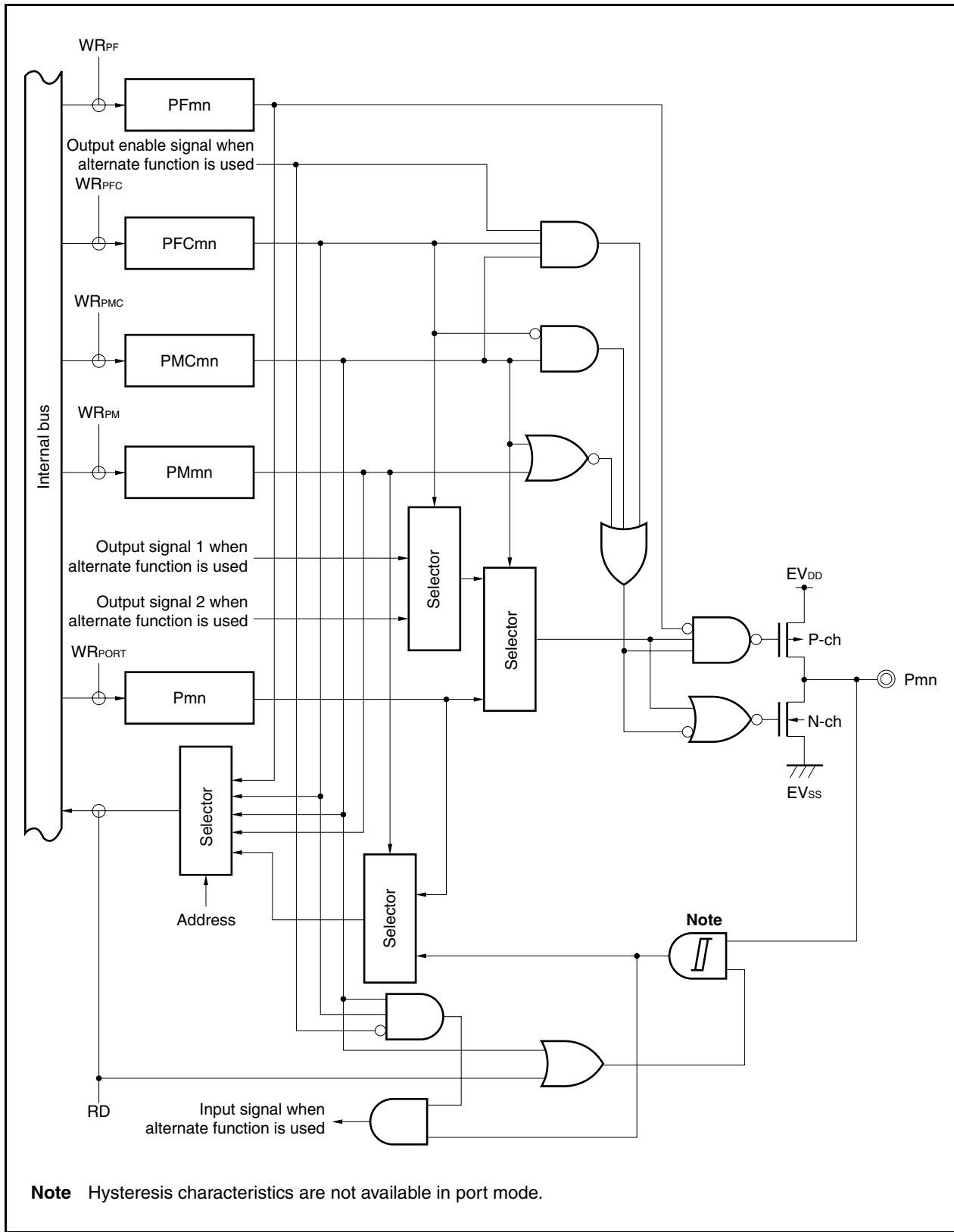


Figure 4-15. Block Diagram of Type G-3



<R>

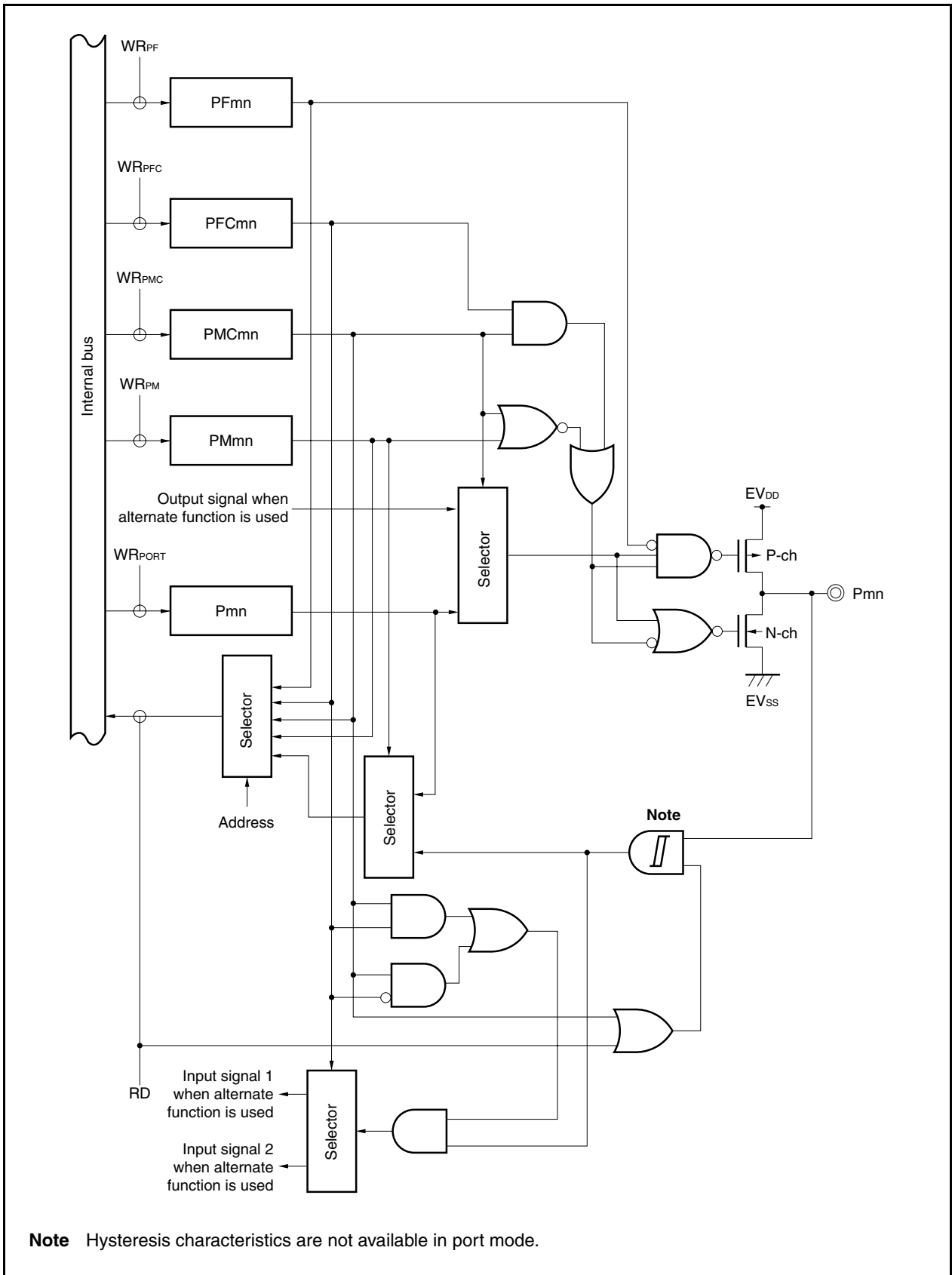
Figure 4-16. Block Diagram of Type G-5



**Note** Hysteresis characteristics are not available in port mode.

<R>

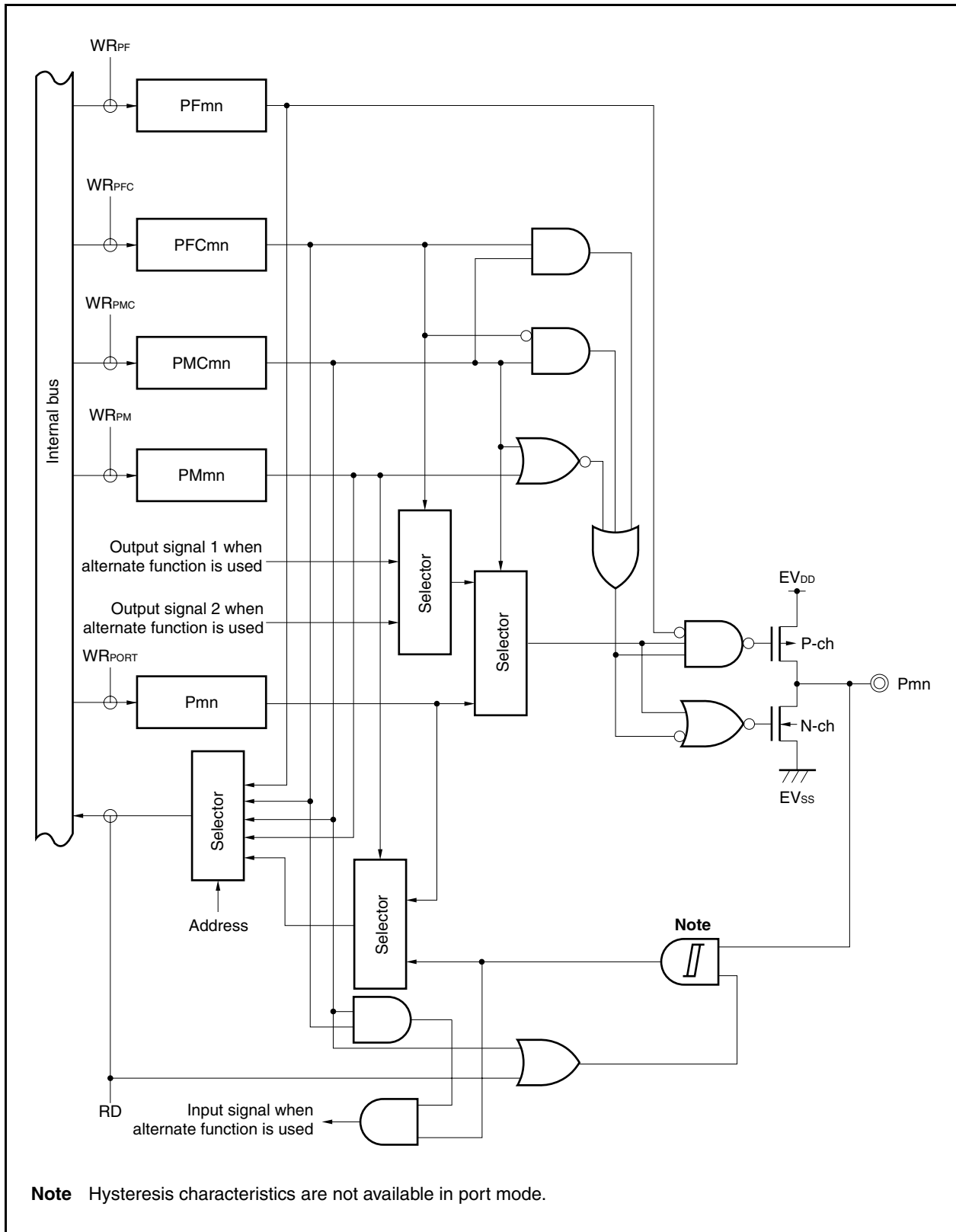
Figure 4-17. Block Diagram of Type G-6



**Note** Hysteresis characteristics are not available in port mode.

<R>

Figure 4-18. Block Diagram of Type G-12



**Note** Hysteresis characteristics are not available in port mode.

<R>



Figure 4-19. Block Diagram of Type L-1

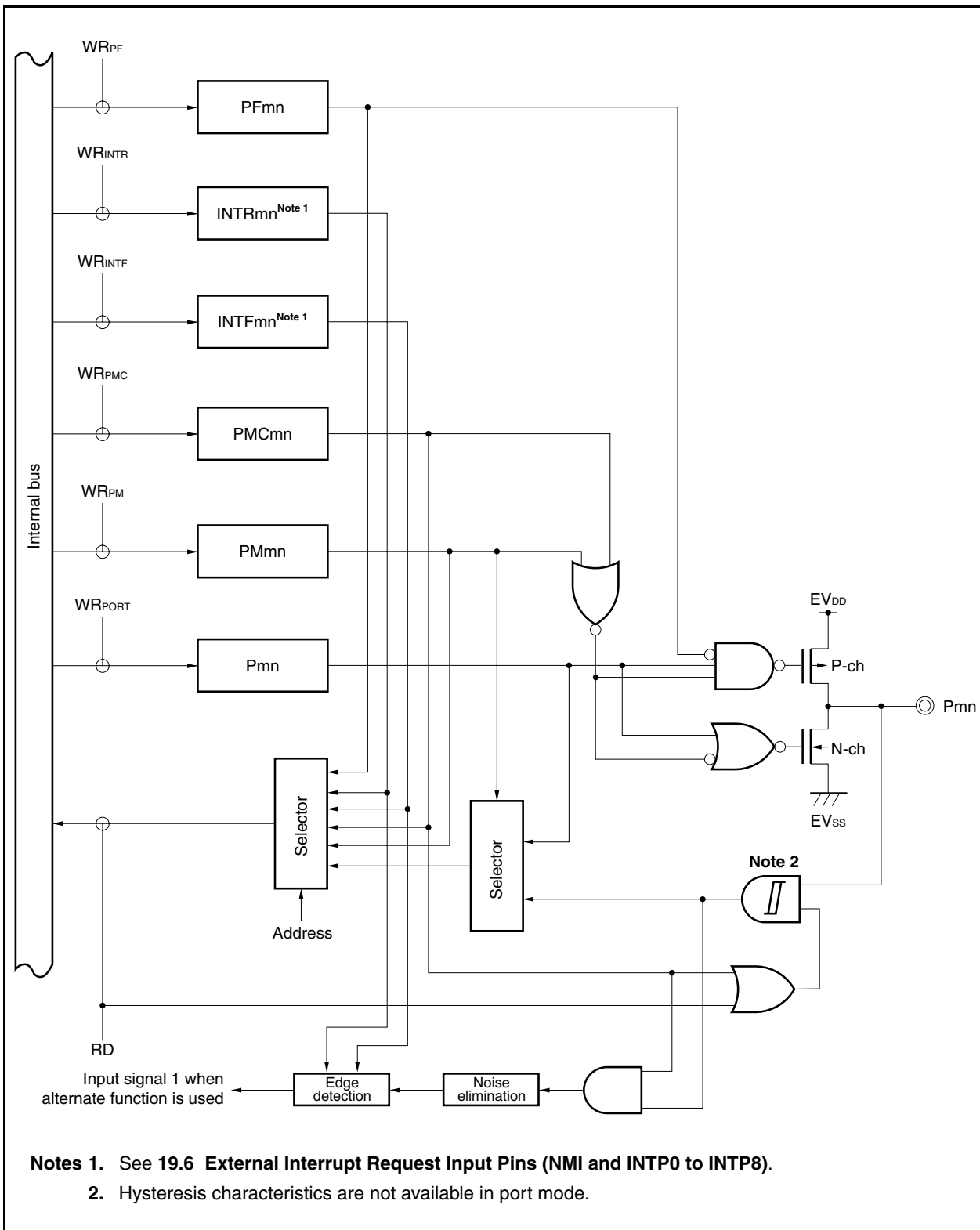
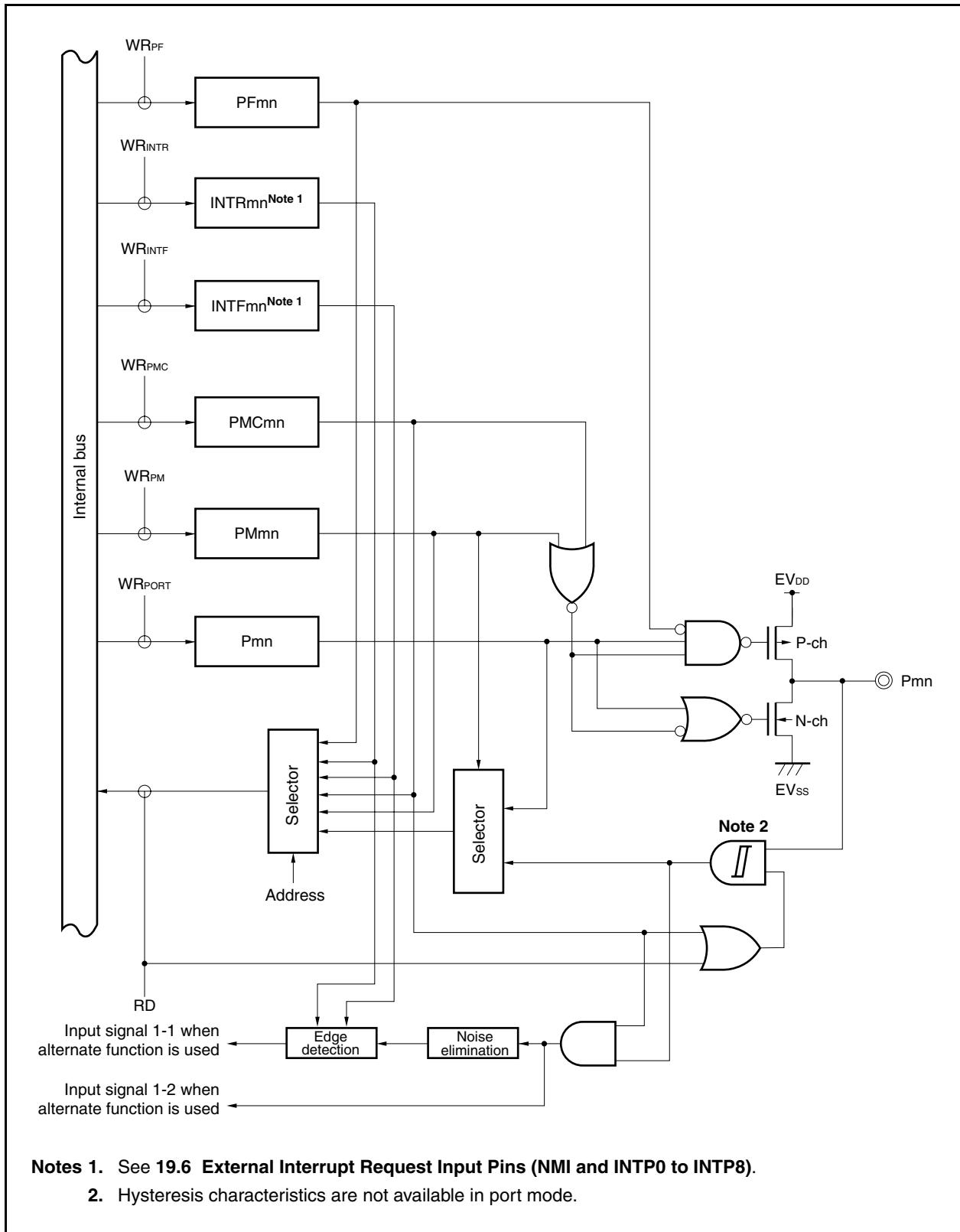
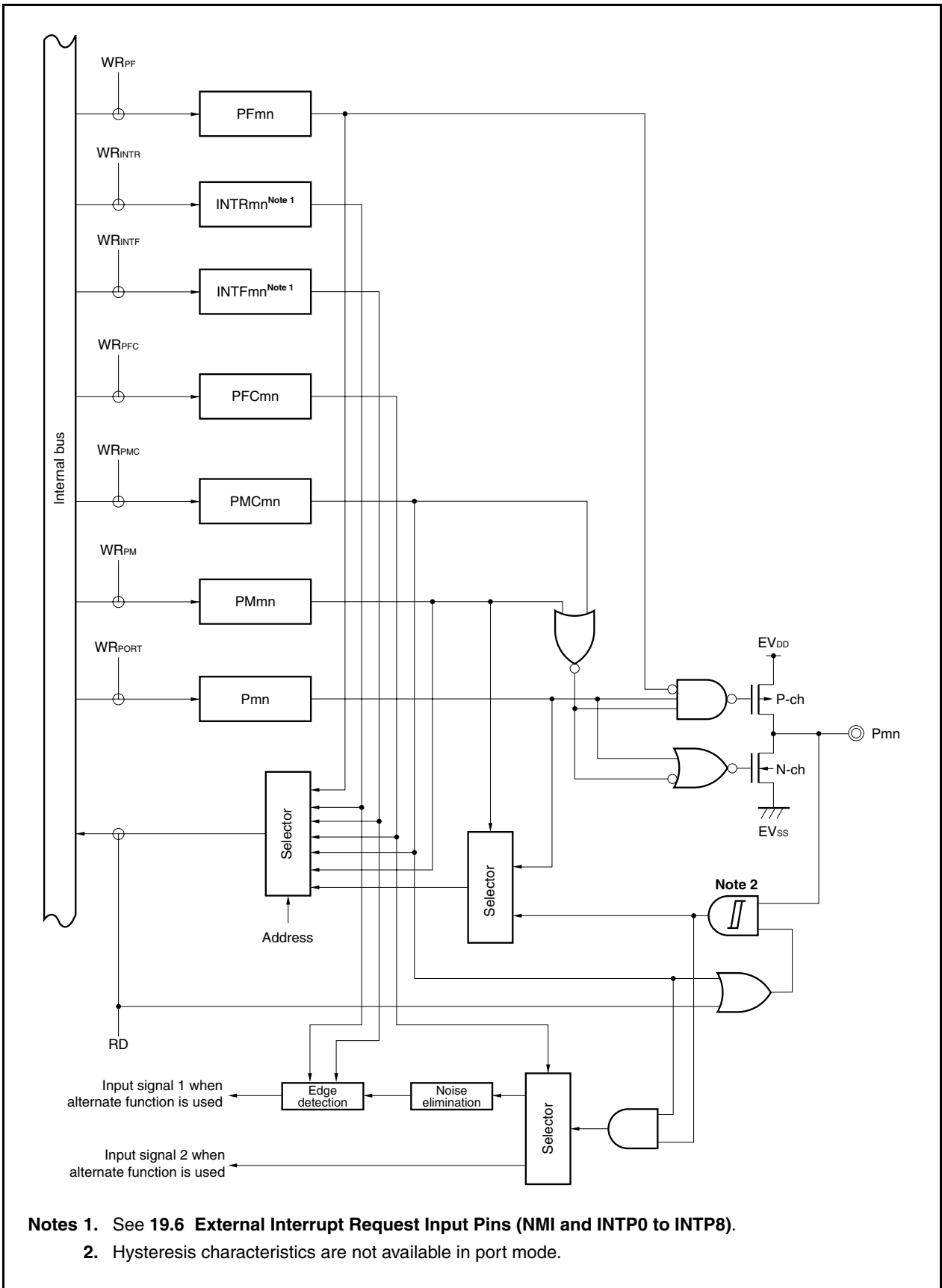


Figure 4-20. Block Diagram of Type L-2



<R>

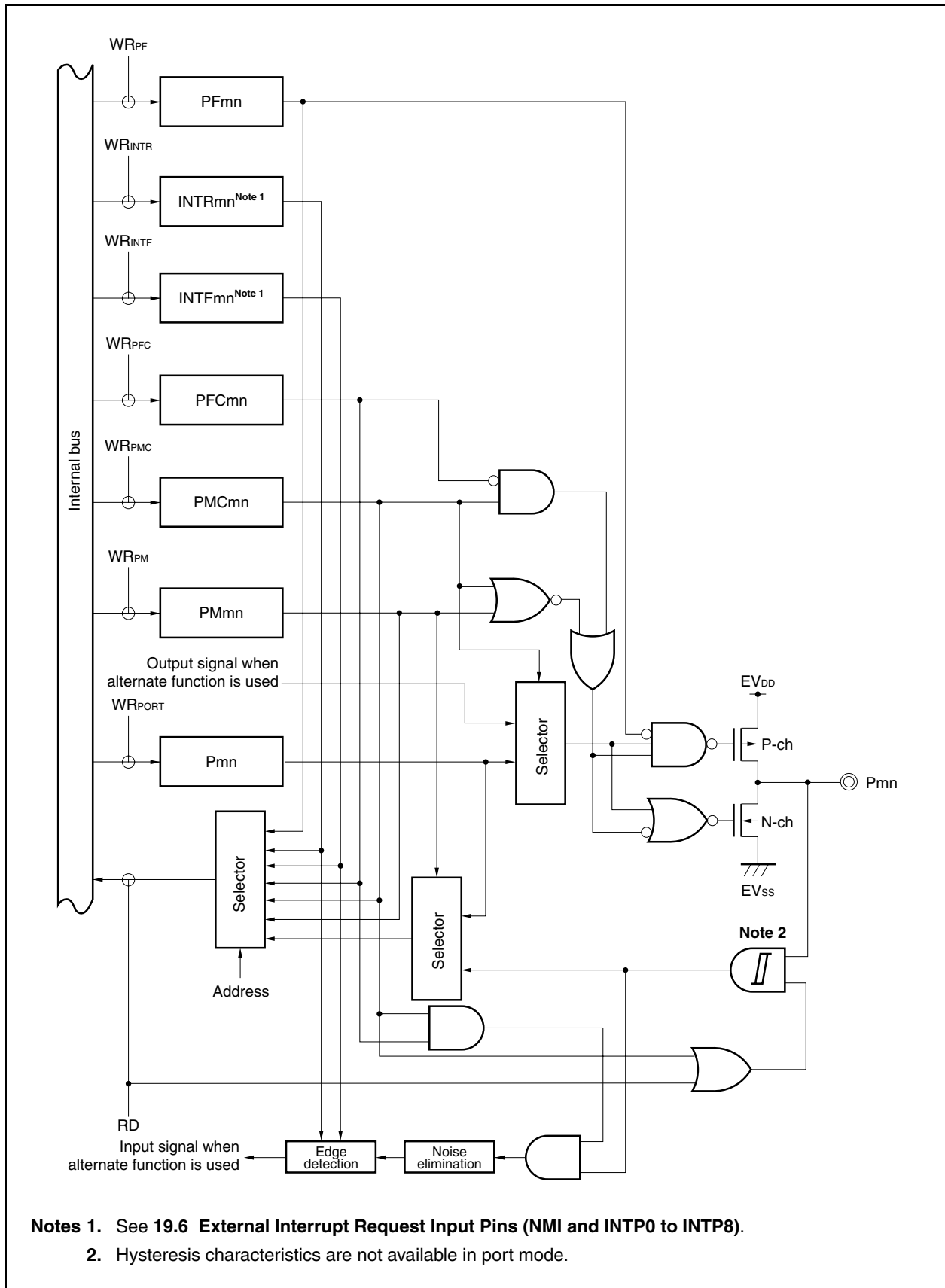
Figure 4-21. Block Diagram of Type N-1



**Notes 1.** See 19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP8).

**2.** Hysteresis characteristics are not available in port mode.

Figure 4-22. Block Diagram of Type N-2

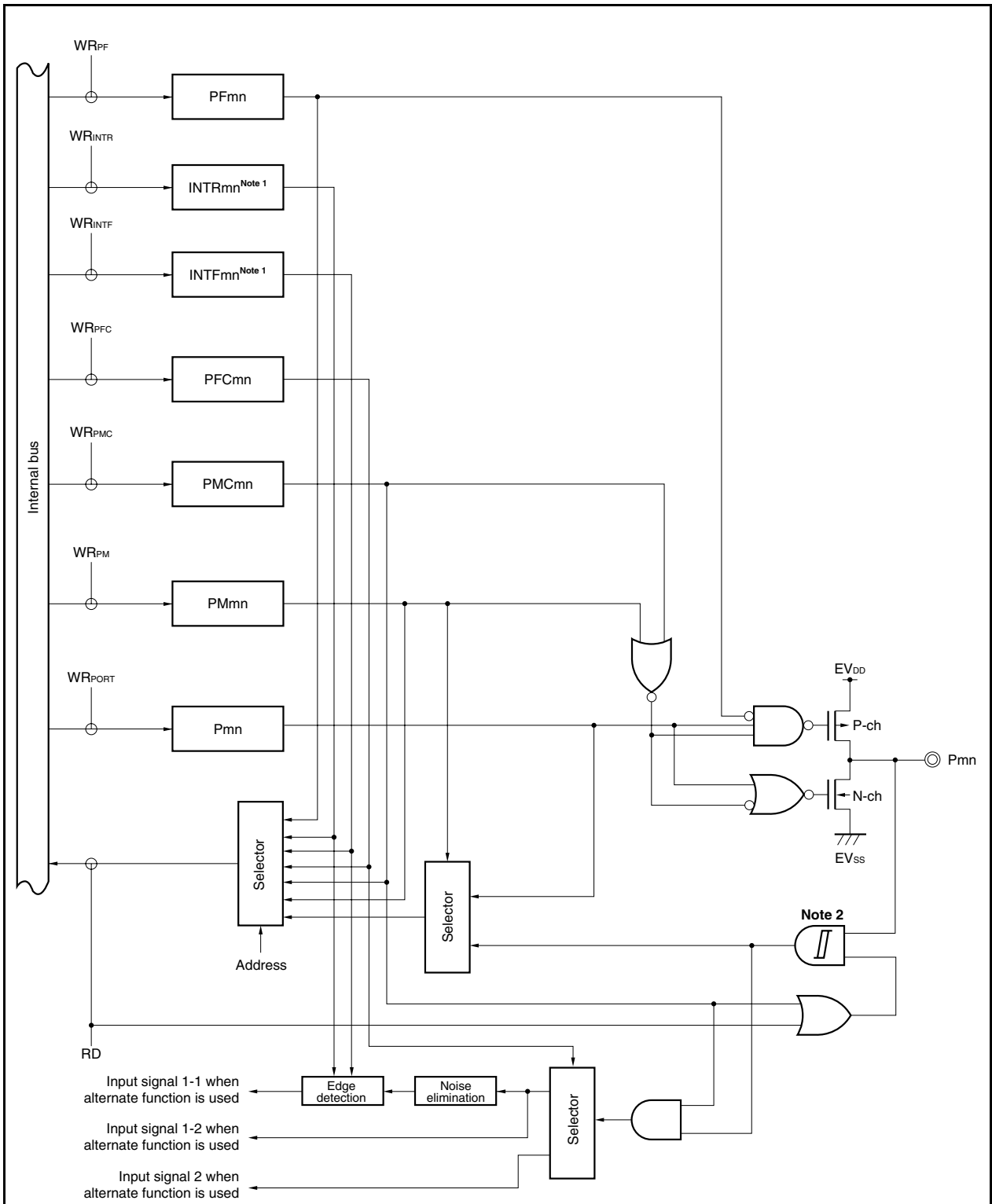


**Notes 1.** See 19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP8).

**2.** Hysteresis characteristics are not available in port mode.

<R>

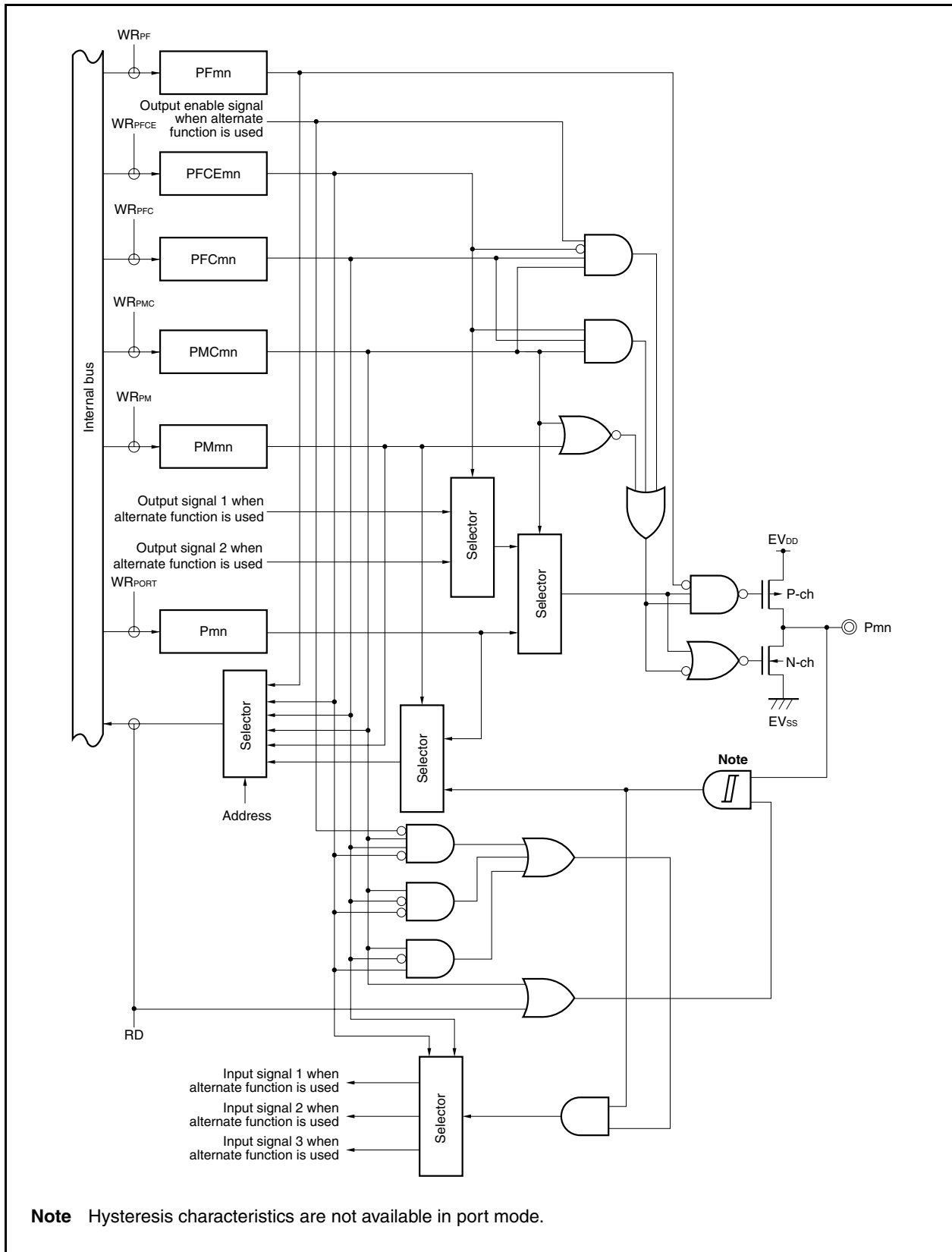
Figure 4-23. Block Diagram of Type N-3



**Notes 1.** See 19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP8).

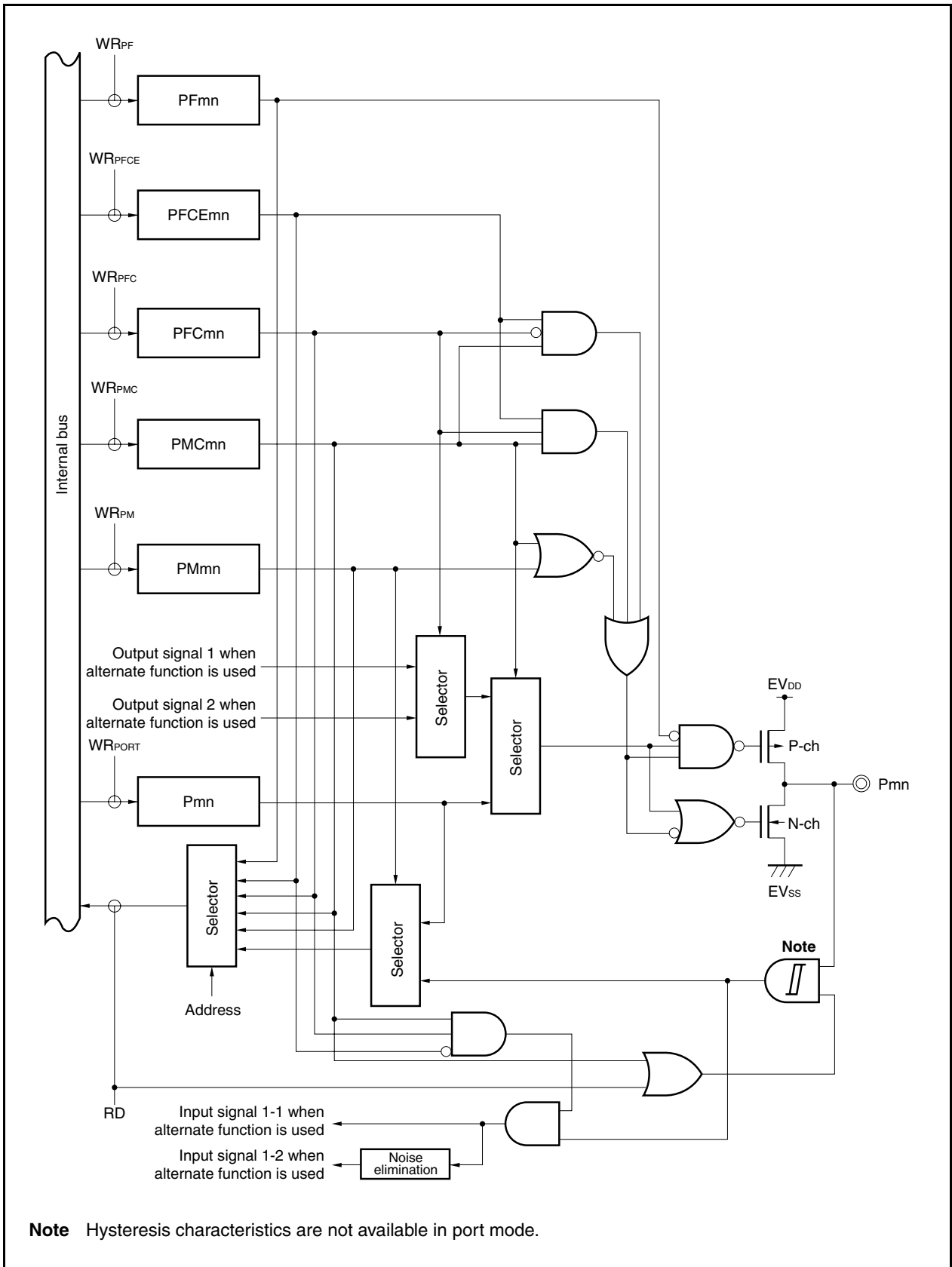
**2.** Hysteresis characteristics are not available in port mode.

Figure 4-24. Block Diagram of Type U-1



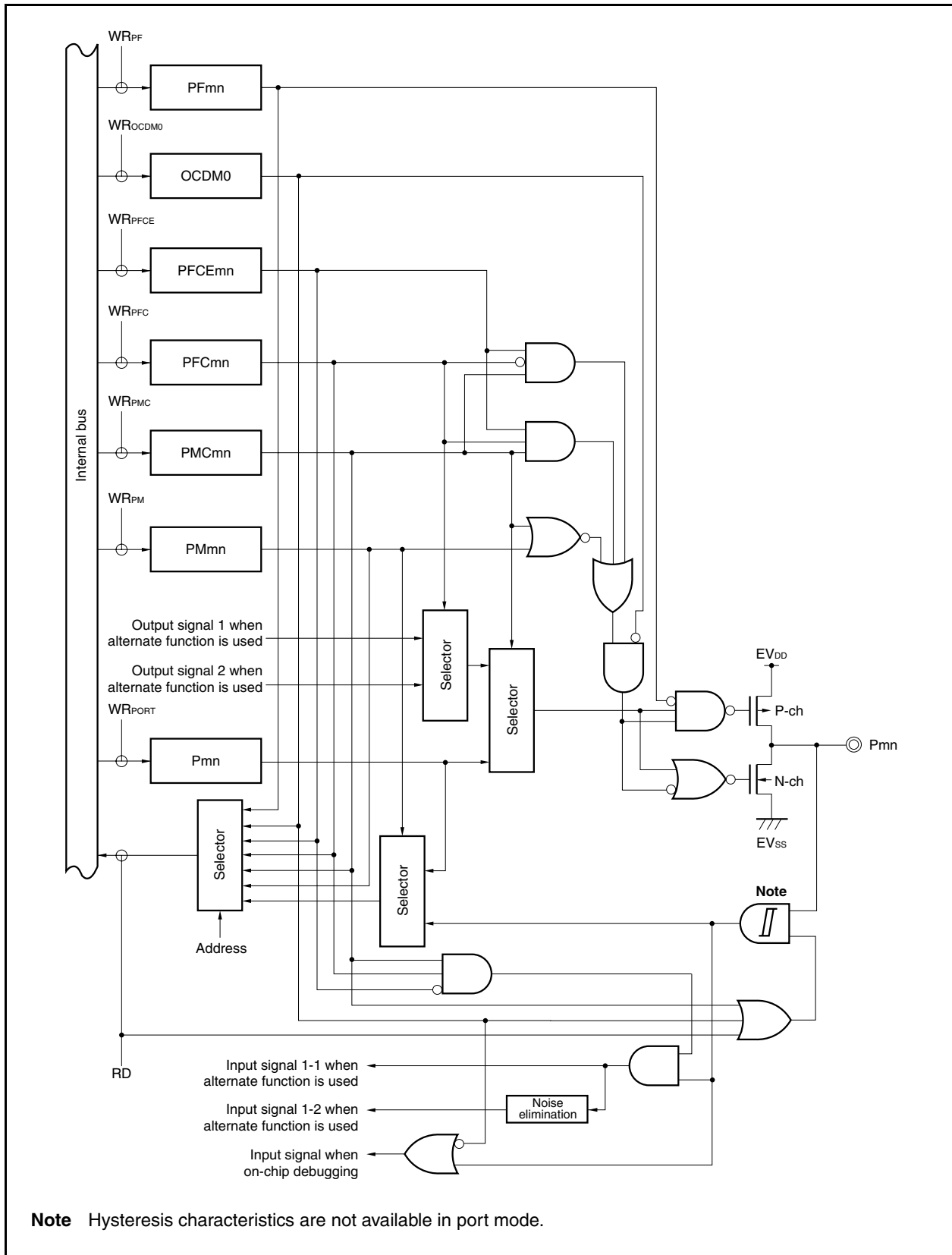
<R>

Figure 4-25. Block Diagram of Type U-5



<R>

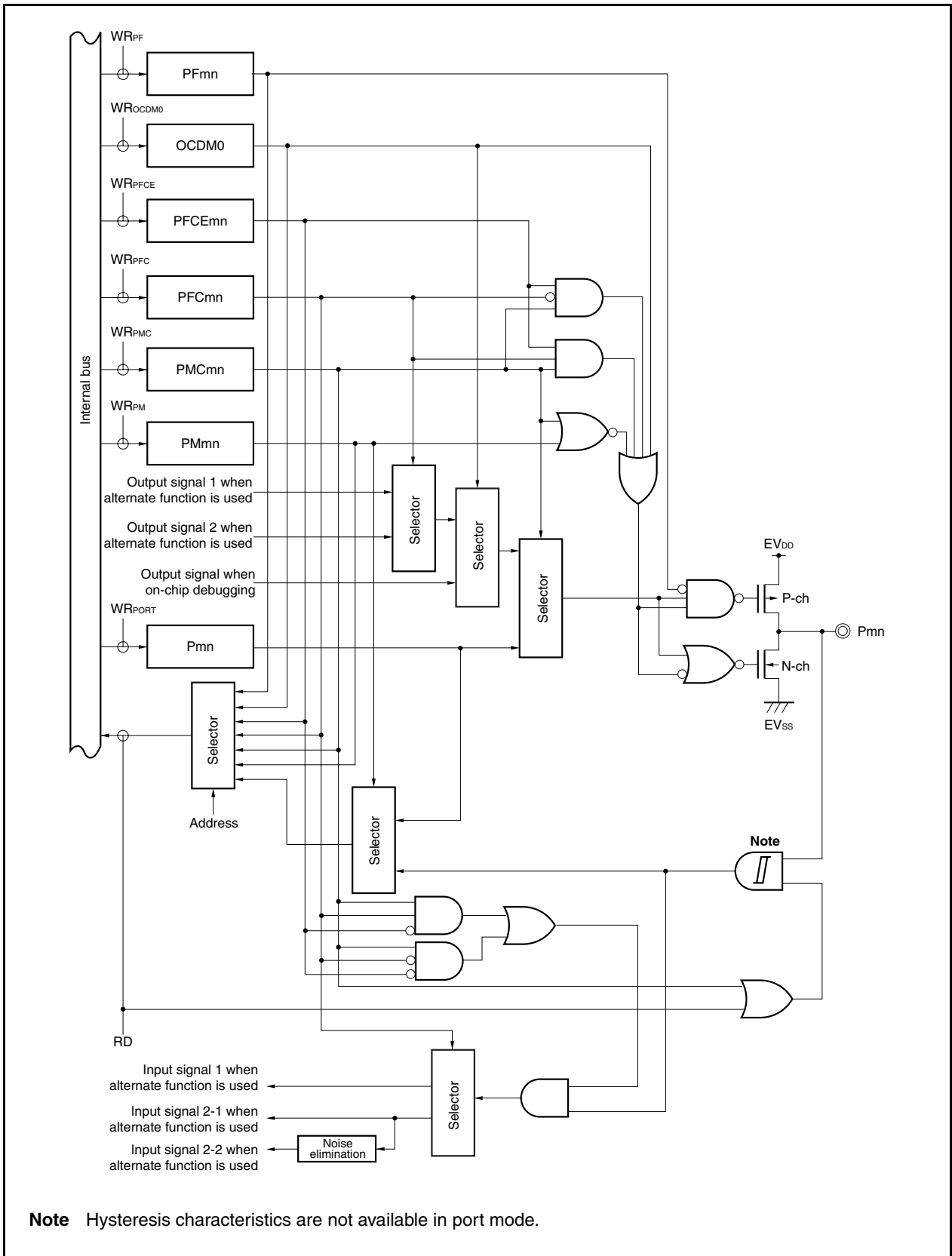
Figure 4-26. Block Diagram of Type U-6



<R>

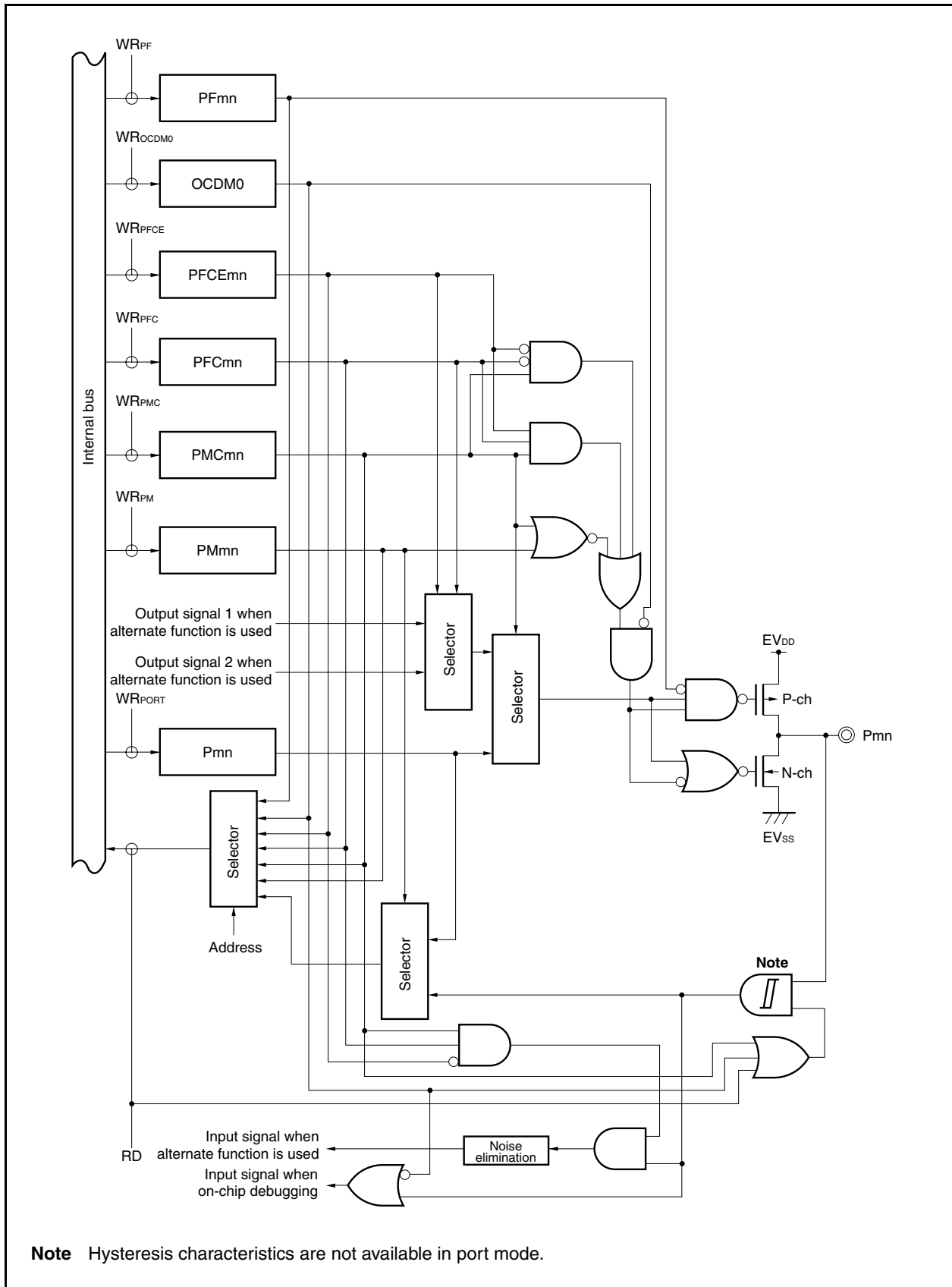


Figure 4-27. Block Diagram of Type U-7



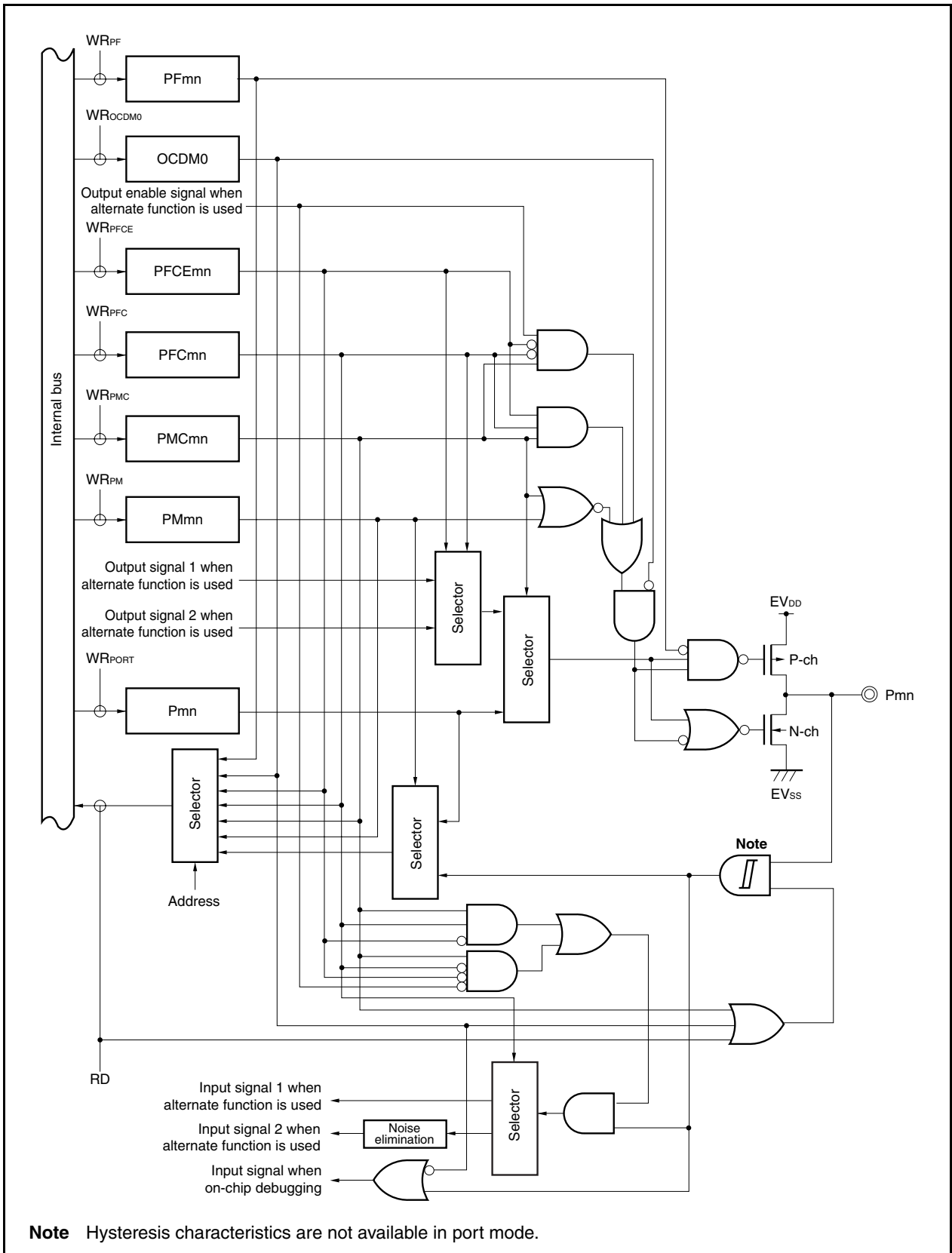
<R>

Figure 4-28. Block Diagram of Type U-8



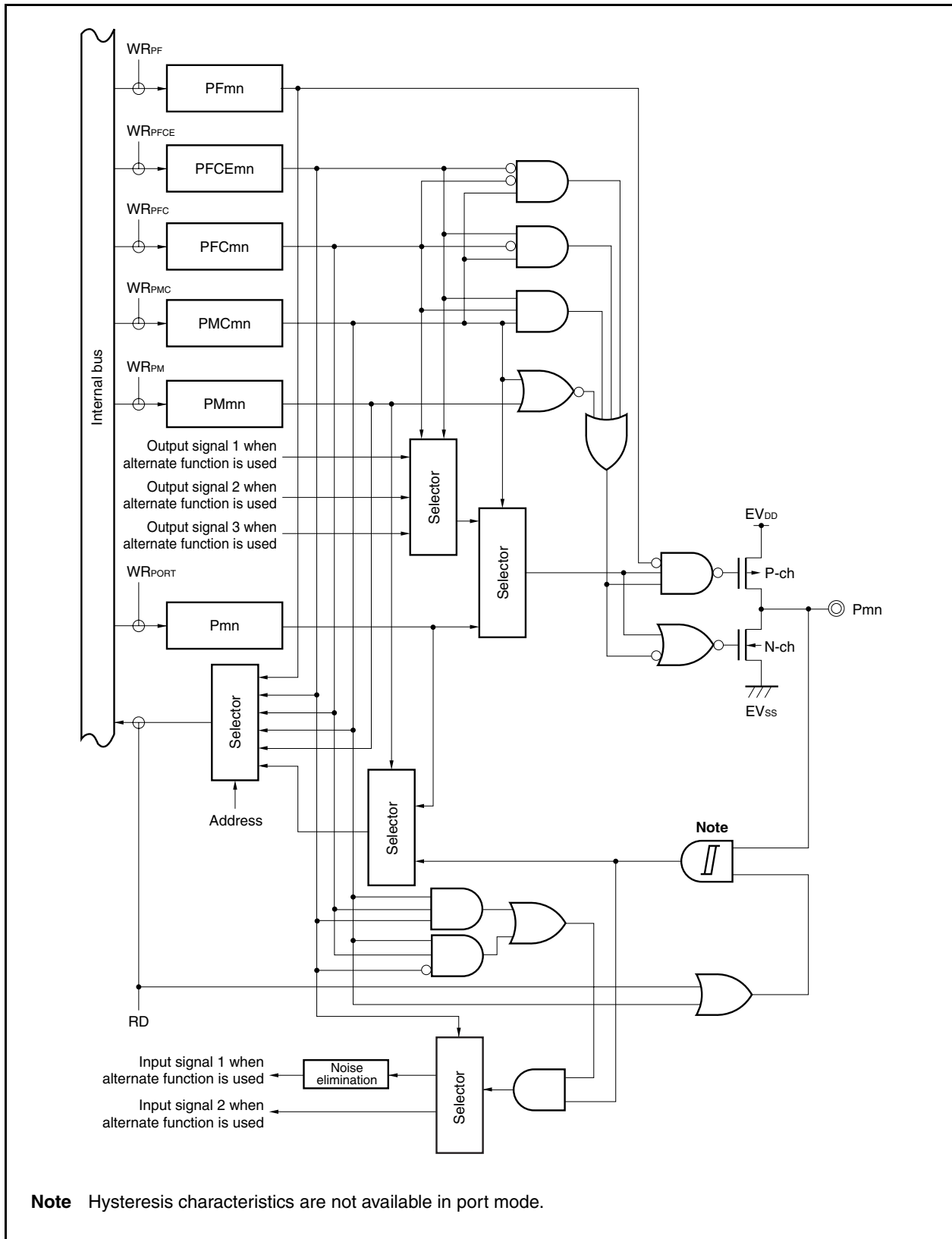
<R>

Figure 4-29. Block Diagram of Type U-9



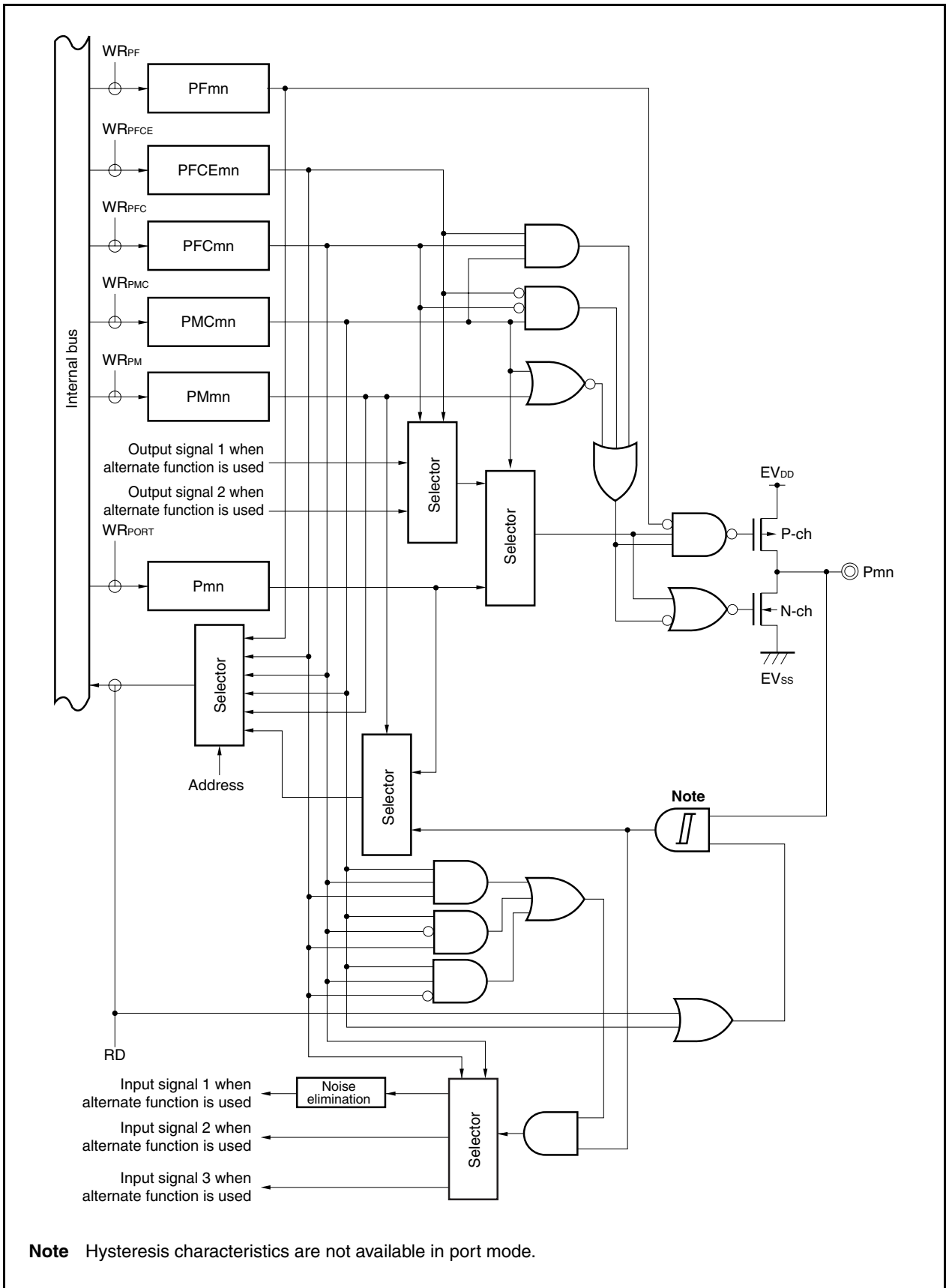
<R>

Figure 4-30. Block Diagram of Type U-10



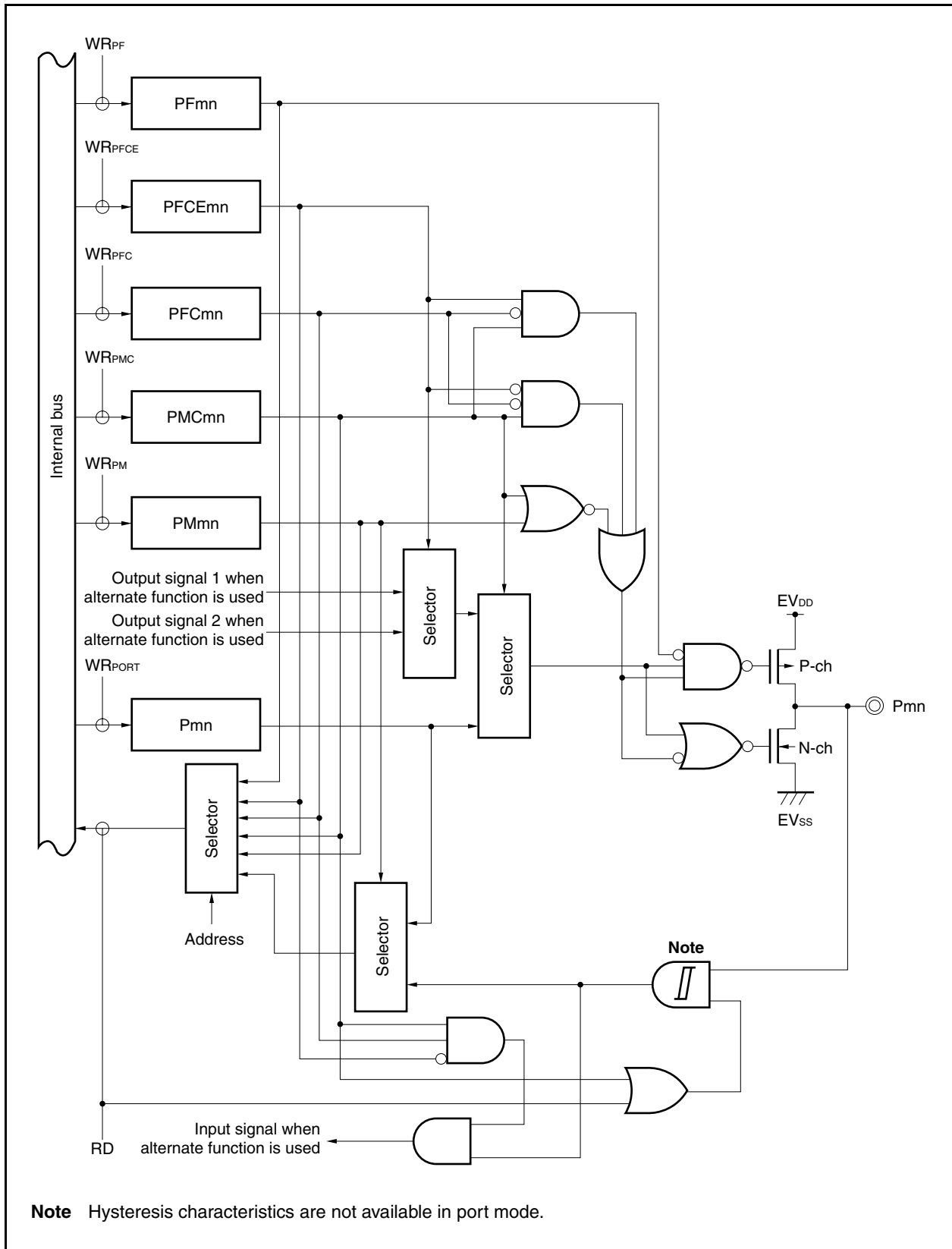
<R>

Figure 4-31. Block Diagram of Type U-11



<R>

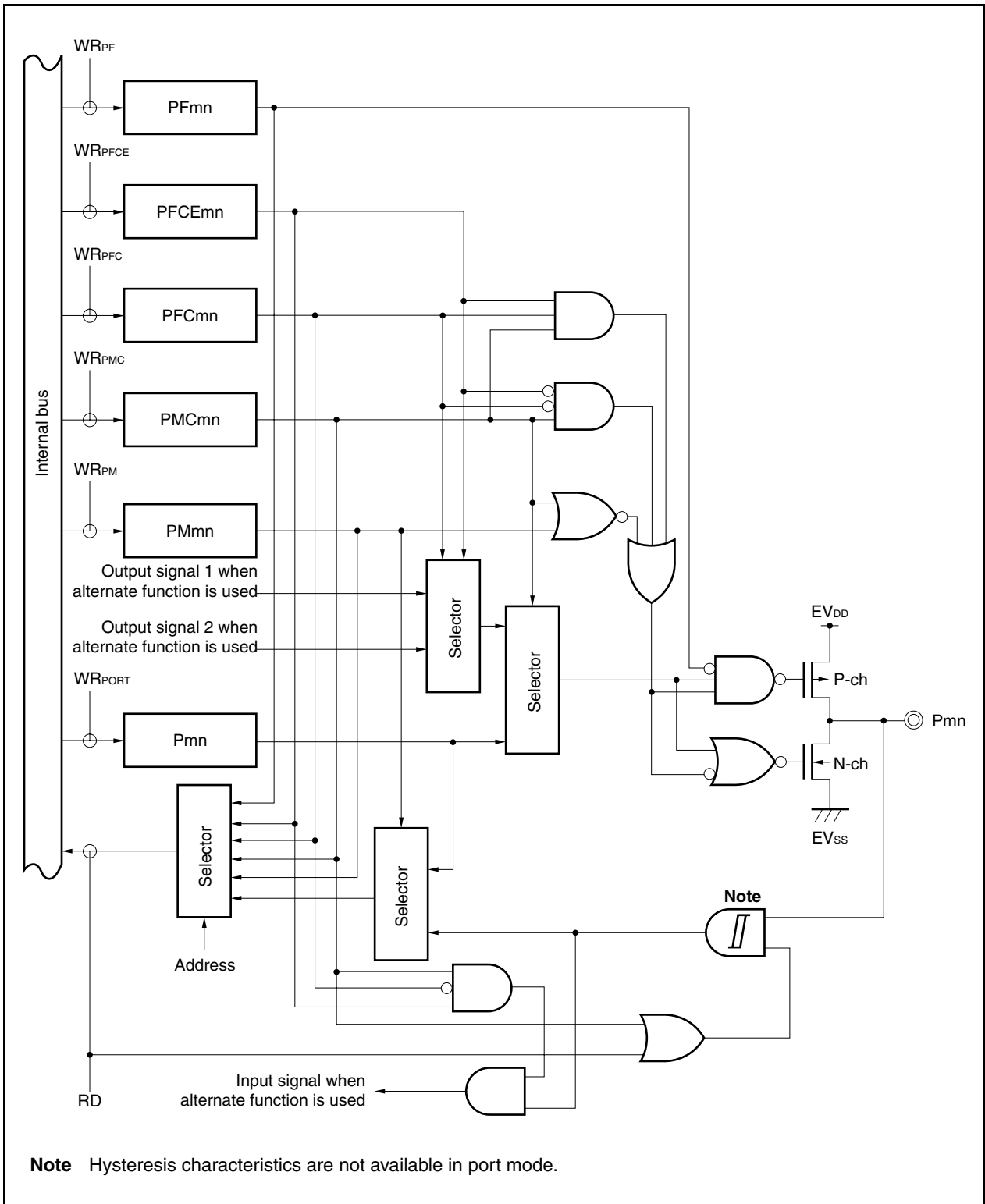
Figure 4-32. Block Diagram of Type U-12



**Note** Hysteresis characteristics are not available in port mode.

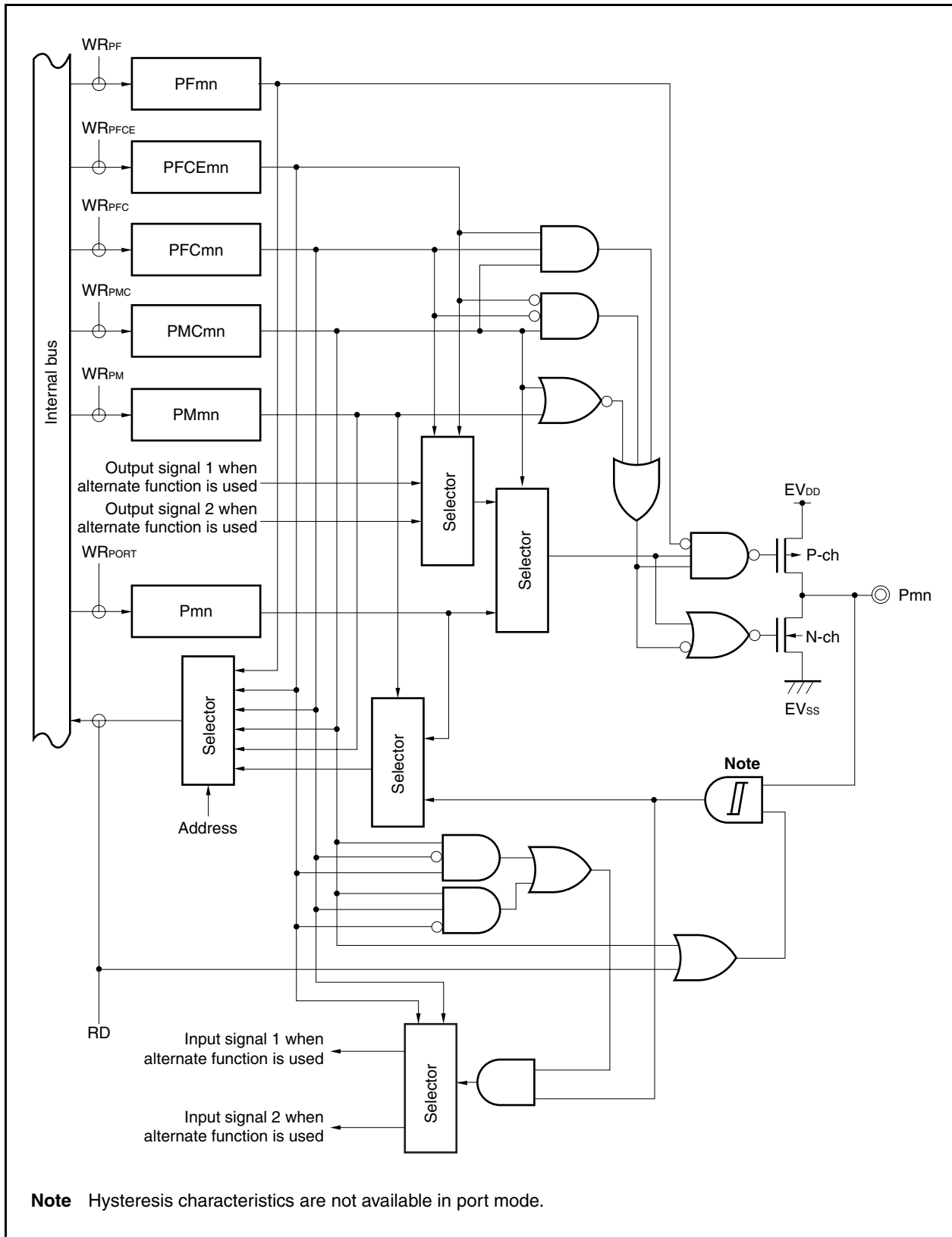
<R>

Figure 4-33. Block Diagram of Type U-13



<R>

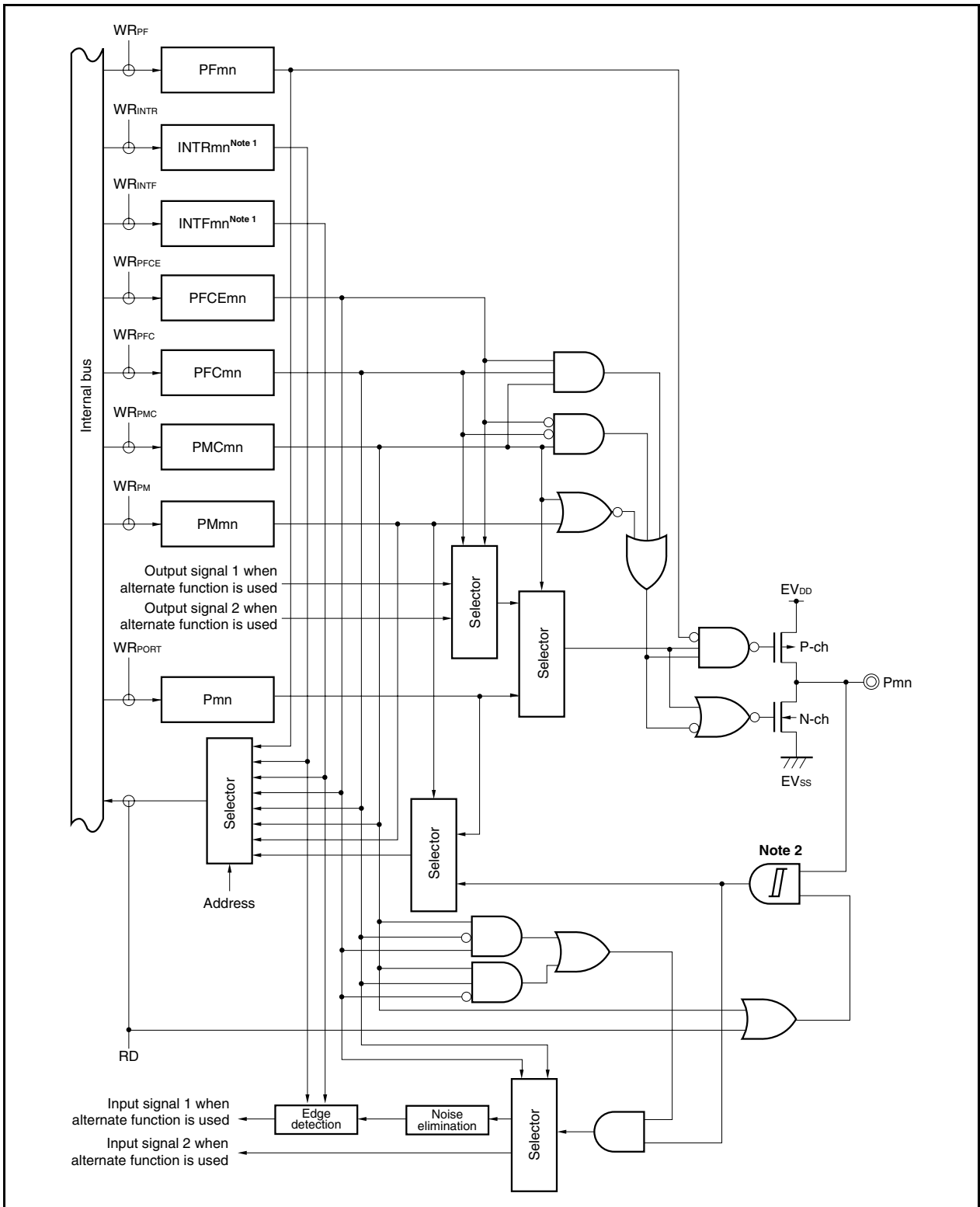
Figure 4-34. Block Diagram of Type U-14



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Figure 4-35. Block Diagram of Type U-15

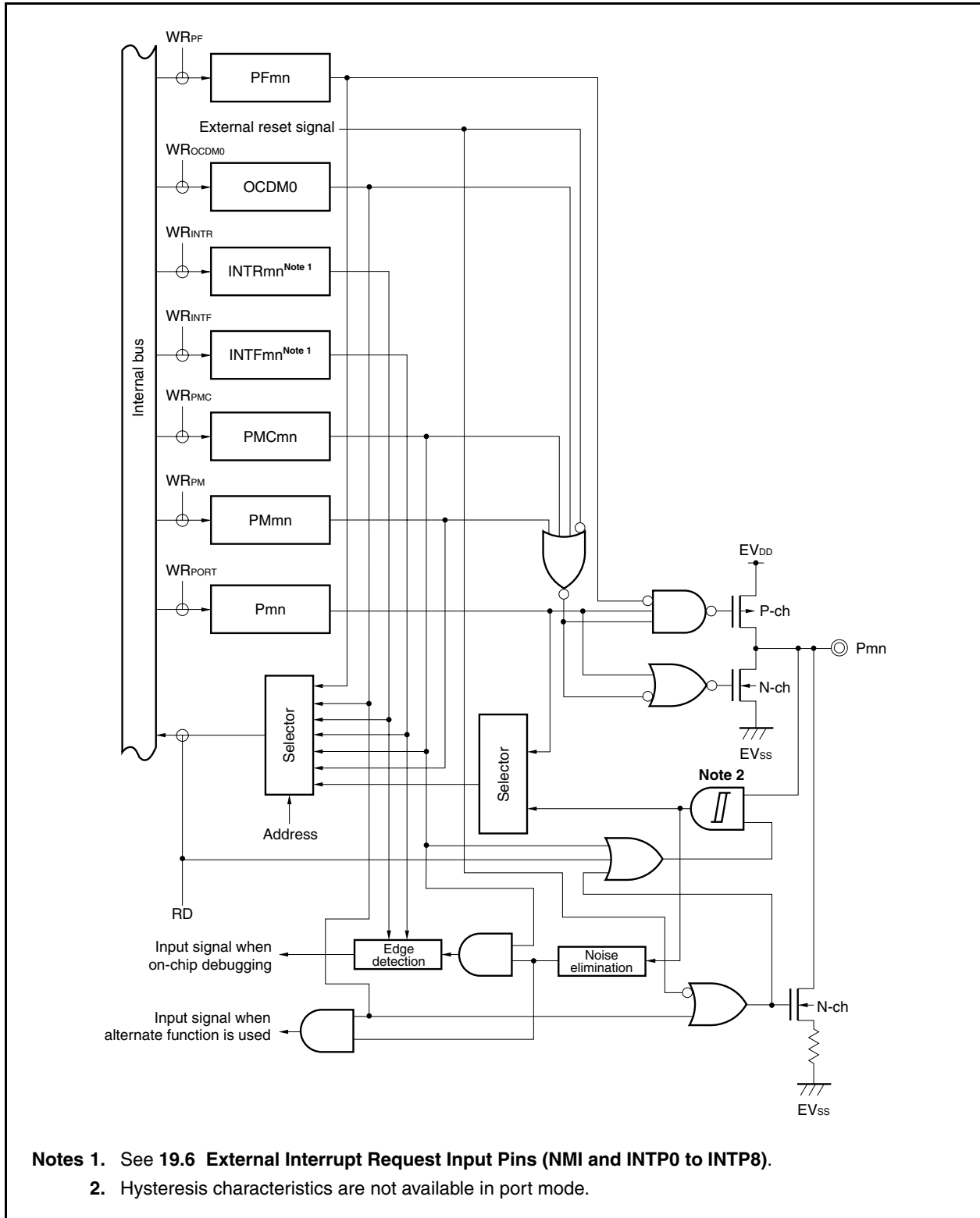


**Notes 1.** See 19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP8).

**2.** Hysteresis characteristics are not available in port mode.

<R>

Figure 4-36. Block Diagram of Type AA-1



- Notes 1.** See 19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP8).  
**2.** Hysteresis characteristics are not available in port mode.

#### 4.5 Port Register Settings When Alternate Function Is Used

Table 4-19 shows the port register settings when each port is used for an alternate function. When using a port pin as an alternate-function pin, refer to the description of each pin.

**Table 4-19. Using Port Pins as Alternate-Function Pins (1/8)**

| Pin Name | Alternate Function        |        | Pnx Bit of Pn Register     | PMnx Bit of PMn Register    | PMCnx Bit of PMCn Register   | PFCEnx Bit of PFCEn Register | PFCnx Bit of PFCn Register |    |
|----------|---------------------------|--------|----------------------------|-----------------------------|------------------------------|------------------------------|----------------------------|----|
|          | Name                      | I/O    |                            |                             |                              |                              |                            |    |
| P00      | TIP61                     | Input  | P00 = Setting not required | PM00 = Setting not required | PMC00 = 1                    | –                            | PFC00 = 0                  |    |
|          | TOP61                     | Output | P00 = Setting not required | PM00 = Setting not required | PMC00 = 1                    | –                            | PFC00 = 1                  |    |
| P01      | TIP60                     | Input  | P01 = Setting not required | PM01 = Setting not required | PMC01 = 1                    | –                            | PFC01 = 0                  |    |
|          | TOP60                     | Output | P01 = Setting not required | PM01 = Setting not required | PMC01 = 1                    | –                            | PFC01 = 1                  |    |
| P02      | NMI                       | Input  | P02 = Setting not required | PM02 = Setting not required | PMC02 = 1                    | –                            | –                          |    |
| P03      | INTP0                     | Input  | P03 = Setting not required | PM03 = Setting not required | PMC03 = 1                    | –                            | PFC03 = 0                  |    |
|          | ADTRG                     | Input  | P03 = Setting not required | PM03 = Setting not required | PMC03 = 1                    | –                            | PFC03 = 1                  |    |
| P04      | INTP1                     | Input  | P04 = Setting not required | PM04 = Setting not required | PMC04 = 1                    | –                            | –                          |    |
| P05      | INTP2                     | Input  | P05 = Setting not required | PM05 = Setting not required | PMC05 = 1                    | –                            | –                          |    |
|          | $\overline{\text{DRST}}$  | Input  | P05 = Setting not required | PM05 = Setting not required | PMC05 = Setting not required | –                            | –                          | OC |
| P06      | INTP3                     | Input  | P06 = Setting not required | PM06 = Setting not required | PMC06 = 1                    | –                            | –                          |    |
| P10      | ANO0                      | Output | P10 = Setting not required | PM10 = 1                    | –                            | –                            | –                          |    |
| P11      | ANO1                      | Output | P11 = Setting not required | PM11 = 1                    | –                            | –                            | –                          |    |
| P30      | TXDA0                     | Output | P30 = Setting not required | PM30 = Setting not required | PMC30 = 1                    | –                            | PFC30 = 0                  |    |
|          | SOB4                      | Output | P30 = Setting not required | PM30 = Setting not required | PMC30 = 1                    | –                            | PFC30 = 1                  |    |
| P31      | RXDA0                     | Input  | P31 = Setting not required | PM31 = Setting not required | PMC31 = 1                    | –                            | <b>Note</b> , PFC31 = 0    |    |
|          | INTP7                     | Input  | P31 = Setting not required | PM31 = Setting not required | PMC31 = 1                    | –                            | <b>Note</b> , PFC31 = 0    |    |
|          | SIB4                      | Input  | P31 = Setting not required | PM31 = Setting not required | PMC31 = 1                    | –                            | PFC31 = 1                  |    |
| P32      | ASCKA0                    | Input  | P32 = Setting not required | PM32 = Setting not required | PMC32 = 1                    | PFCE32 = 0                   | PFC32 = 0                  |    |
|          | $\overline{\text{SCKB4}}$ | I/O    | P32 = Setting not required | PM32 = Setting not required | PMC32 = 1                    | PFCE32 = 0                   | PFC32 = 1                  |    |
|          | TIP00                     | Input  | P32 = Setting not required | PM32 = Setting not required | PMC32 = 1                    | PFCE32 = 1                   | PFC32 = 0                  |    |
|          | TOP00                     | Output | P32 = Setting not required | PM32 = Setting not required | PMC32 = 1                    | PFCE32 = 1                   | PFC32 = 1                  |    |

**Note** The INTP7 pin and RXDA0 pin are alternate-function pins. When using the pin as the RXDA0 pin, disable edge detection for the RXDA0 pin. (Clear the INTF3.INTF31 bit and the INRT3.INRT31 bit to 0.) When using the pin as the INTP7 pin, stop UARTA0 reception. (Clear the INTF3.INTF31 bit to 0.)

**Caution** Between the P10 and P11 pins, when one pin is used as the I/O port, and the other pin is used as the D/A output pin, ensure that the port I/O level does not change during D/A output.

Table 4-19. Using Port Pins as Alternate-Function Pins (2/8)

| Pin Name | Alternate Function |        | Pnx Bit of Pn Register     | PMnx Bit of PMn Register    | PMCnx Bit of PMCn Register   | PFCEnx Bit of PFCEn Register  | PFCnx Bit of PFCn Register   |    |
|----------|--------------------|--------|----------------------------|-----------------------------|------------------------------|-------------------------------|------------------------------|----|
|          | Name               | I/O    |                            |                             |                              |                               |                              |    |
| P33      | TIP01              | Input  | P33 = Setting not required | PM33 = Setting not required | PMC33 = 1                    | –                             | PFC33 = 0                    |    |
|          | TOP01              | Output | P33 = Setting not required | PM33 = Setting not required | PMC33 = 1                    | –                             | PFC33 = 1                    |    |
| P34      | TIP10              | Input  | P34 = Setting not required | PM34 = Setting not required | PMC34 = 1                    | –                             | PFC34 = 0                    |    |
|          | TOP10              | Input  | P34 = Setting not required | PM34 = Setting not required | PMC34 = 1                    | –                             | PFC34 = 1                    |    |
| P35      | TIP11              | Input  | P35 = Setting not required | PM35 = Setting not required | PMC35 = 1                    | –                             | PFC35 = 0                    |    |
|          | TOP11              | Output | P35 = Setting not required | PM35 = Setting not required | PMC35 = 1                    | –                             | PFC35 = 1                    |    |
| P38      | TXDA2              | Output | P38 = Setting not required | PM38 = Setting not required | PMC38 = 1                    | –                             | PFC38 = 0                    |    |
|          | SDA00              | I/O    | P38 = Setting not required | PM38 = Setting not required | PMC38 = 1                    | –                             | PFC38 = 1                    | PI |
| P39      | RXDA2              | Input  | P39 = Setting not required | PM39 = Setting not required | PMC39 = 1                    | –                             | PFC39 = 0                    |    |
|          | SCL00              | I/O    | P39 = Setting not required | PM39 = Setting not required | PMC39 = 1                    | –                             | PFC39 = 1                    | PI |
| P40      | SIB0               | Input  | P40 = Setting not required | PM40 = Setting not required | PMC40 = 1                    | –                             | PFC40 = 0                    |    |
|          | SDA01              | I/O    | P40 = Setting not required | PM40 = Setting not required | PMC40 = 1                    | –                             | PFC40 = 1                    | PI |
| P41      | SOB0               | Output | P41 = Setting not required | PM41 = Setting not required | PMC41 = 1                    | –                             | PFC41 = 0                    |    |
|          | SCL01              | I/O    | P41 = Setting not required | PM41 = Setting not required | PMC41 = 1                    | –                             | PFC41 = 1                    | PI |
| P42      | SCKB0              | I/O    | P42 = Setting not required | PM42 = Setting not required | PMC42 = 1                    | –                             | –                            |    |
| P50      | TIQ01              | Input  | P50 = Setting not required | PM50 = Setting not required | PMC50 = 1                    | PFCE50 = 0                    | PFC50 = 1                    | KI |
|          | KR0                | Input  | P50 = Setting not required | PM50 = Setting not required | PMC50 = 1                    | PFCE50 = 0                    | PFC50 = 1                    | TO |
|          | TOQ01              | Output | P50 = Setting not required | PM50 = Setting not required | PMC50 = 1                    | PFCE50 = 1                    | PFC50 = 0                    |    |
|          | RTP00              | Output | P50 = Setting not required | PM50 = Setting not required | PMC50 = 1                    | PFCE50 = 1                    | PFC50 = 1                    |    |
| P51      | TIQ02              | Input  | P51 = Setting not required | PM51 = Setting not required | PMC51 = 1                    | PFCE51 = 0                    | PFC51 = 1                    | KI |
|          | KR1                | Input  | P51 = Setting not required | PM51 = Setting not required | PMC51 = 1                    | PFCE51 = 0                    | PFC51 = 1                    | TO |
|          | TOQ02              | Output | P51 = Setting not required | PM51 = Setting not required | PMC51 = 1                    | PFCE51 = 1                    | PFC51 = 0                    |    |
|          | RTP01              | Output | P51 = Setting not required | PM51 = Setting not required | PMC51 = 1                    | PFCE51 = 1                    | PFC51 = 1                    |    |
| P52      | TIQ03              | Input  | P52 = Setting not required | PM52 = Setting not required | PMC52 = 1                    | PFCE52 = 0                    | PFC52 = 1                    | KI |
|          | KR2                | Input  | P52 = Setting not required | PM52 = Setting not required | PMC52 = 1                    | PFCE52 = 0                    | PFC52 = 1                    | TO |
|          | TOQ03              | Output | P52 = Setting not required | PM52 = Setting not required | PMC52 = 1                    | PFCE52 = 1                    | PFC52 = 0                    |    |
|          | RTP02              | Output | P52 = Setting not required | PM52 = Setting not required | PMC52 = 1                    | PFCE52 = 1                    | PFC52 = 1                    |    |
|          | DDI                | Input  | P52 = Setting not required | PM52 = Setting not required | PMC52 = Setting not required | PFCE52 = Setting not required | PFC52 = Setting not required | O  |

**Table 4-19. Using Port Pins as Alternate-Function Pins (3/8)**

| Pin Name | Alternate Function        |        | Pnx Bit of Pn Register      | PMnx Bit of PMn Register     | PMCnx Bit of PMCn Register   | PFCEnx Bit of PFCEn Register  | PFCnx Bit of PFCn Register   |                |
|----------|---------------------------|--------|-----------------------------|------------------------------|------------------------------|-------------------------------|------------------------------|----------------|
|          | Name                      | I/O    |                             |                              |                              |                               |                              |                |
| P53      | SIB2                      | Input  | P53 = Setting not required  | PM53 = Setting not required  | PMC53 = 1                    | PFCE53 = 0                    | PFC53 = 0                    |                |
|          | TIQ00                     | Input  | P53 = Setting not required  | PM53 = Setting not required  | PMC53 = 1                    | PFCE53 = 0                    | PFC53 = 1                    | KP             |
|          | KR3                       | Input  | P53 = Setting not required  | PM53 = Setting not required  | PMC53 = 1                    | PFCE53 = 0                    | PFC53 = 1                    | TG<br>TG<br>TG |
|          | TOQ00                     | Input  | P53 = Setting not required  | PM53 = Setting not required  | PMC53 = 1                    | PFCE53 = 1                    | PFC53 = 0                    |                |
|          | RTP03                     | Output | P53 = Setting not required  | PM53 = Setting not required  | PMC53 = 1                    | PFCE53 = 1                    | PFC53 = 1                    |                |
|          | DDO                       | Output | P53 = Setting not required  | PM53 = Setting not required  | PMC53 = Setting not required | PFCE53 = Setting not required | PFC53 = Setting not required | OC             |
| P54      | SOB2                      | Output | P54 = Setting not required  | PM54 = Setting not required  | PMC54 = 1                    | PFCE54 = 0                    | PFC54 = 0                    |                |
|          | KR4                       | Input  | P54 = Setting not required  | PM54 = Setting not required  | PMC54 = 1                    | PFCE54 = 0                    | PFC54 = 1                    |                |
|          | RTP04                     | Output | P54 = Setting not required  | PM54 = Setting not required  | PMC54 = 1                    | PFCE54 = 1                    | PFC54 = 1                    |                |
|          | DCK                       | Input  | P54 = Setting not required  | PM54 = Setting not required  | PMC54 = Setting not required | PFCE54 = Setting not required | PFC54 = Setting not required | OC             |
| P55      | $\overline{\text{SCKB2}}$ | I/O    | P55 = Setting not required  | PM55 = Setting not required  | PMC55 = 1                    | PFCE55 = 0                    | PFC55 = 0                    |                |
|          | KR5                       | Input  | P55 = Setting not required  | PM55 = Setting not required  | PMC55 = 1                    | PFCE55 = 0                    | PFC55 = 1                    |                |
|          | RTP05                     | Output | P55 = Setting not required  | PM55 = Setting not required  | PMC55 = 1                    | PFCE55 = 1                    | PFC55 = 1                    |                |
|          | DMS                       | Input  | P55 = Setting not required  | PM55 = Setting not required  | PMC55 = Setting not required | PFCE55 = Setting not required | PFC55 = Setting not required | OC             |
| P60      | RTP10                     | Output | P60 = Setting not required  | PM60 = Setting not required  | PMC60 = 1                    | –                             | –                            |                |
| P61      | RTP11                     | Output | P61 = Setting not required  | PM61 = Setting not required  | PMC61 = 1                    | –                             | –                            |                |
| P62      | RTP12                     | Output | P62 = Setting not required  | PM62 = Setting not required  | PMC62 = 1                    | –                             | –                            |                |
| P63      | RTP13                     | Output | P63 = Setting not required  | PM63 = Setting not required  | PMC63 = 1                    | –                             | –                            |                |
| P64      | RTP14                     | Output | P64 = Setting not required  | PM64 = Setting not required  | PMC64 = 1                    | –                             | –                            |                |
| P65      | RTP15                     | Output | P65 = Setting not required  | PM65 = Setting not required  | PMC65 = 1                    | –                             | –                            |                |
| P66      | SIB5                      | Input  | P66 = Setting not required  | PM66 = Setting not required  | PMC66 = 1                    | –                             | –                            |                |
| P67      | SOB5                      | Output | P67 = Setting not required  | PM67 = Setting not required  | PMC67 = 1                    | –                             | –                            |                |
| P68      | $\overline{\text{SCKB5}}$ | I/O    | P68 = Setting not required  | PM68 = Setting not required  | PMC68 = 1                    | –                             | –                            |                |
| P69      | TIP70                     | Input  | P69 = Setting not required  | PM69 = Setting not required  | PMC69 = 1                    | –                             | PFC69 = 0                    |                |
|          | TOP70                     | Output | P69 = Setting not required  | PM69 = Setting not required  | PMC69 = 1                    | –                             | PFC69 = 1                    |                |
| P610     | TIP71                     | Input  | P610 = Setting not required | PM610 = Setting not required | PMC610 = 1                   | –                             | –                            |                |
| P611     | TOP71                     | Output | P611 = Setting not required | PM611 = Setting not required | PMC611 = 1                   | –                             | –                            |                |

Table 4-19. Using Port Pins as Alternate-Function Pins (4/8)

| Pin Name | Alternate Function |        | Pnx Bit of Pn Register      | PMnx Bit of PMn Register     | PMCnx Bit of PMCn Register | PFCEnx Bit of PFCEn Register | PFCnx Bit of PFCn Register |   |
|----------|--------------------|--------|-----------------------------|------------------------------|----------------------------|------------------------------|----------------------------|---|
|          | Name               | I/O    |                             |                              |                            |                              |                            |   |
| P612     | TIP80              | Input  | P612 = Setting not required | PM612 = Setting not required | PMC612 = 1                 | –                            | PFC612 = 0                 |   |
|          | TOP80              | Output | P612 = Setting not required | PM612 = Setting not required | PMC612 = 1                 | –                            | PFC612 = 1                 |   |
| P613     | TIP81              | Input  | P613 = Setting not required | PM613 = Setting not required | PMC613 = 1                 | –                            | PFC613 = 0                 |   |
|          | TOP81              | Output | P613 = Setting not required | PM613 = Setting not required | PMC613 = 1                 | –                            | PFC613 = 1                 |   |
| P70      | ANI0               | Input  | P70 = Setting not required  | PM70 = 1                     | –                          | –                            | –                          |   |
| P71      | ANI1               | Input  | P71 = Setting not required  | PM71 = 1                     | –                          | –                            | –                          |   |
| P72      | ANI2               | Input  | P72 = Setting not required  | PM72 = 1                     | –                          | –                            | –                          |   |
| P73      | ANI3               | Input  | P73 = Setting not required  | PM73 = 1                     | –                          | –                            | –                          |   |
| P74      | ANI4               | Input  | P74 = Setting not required  | PM74 = 1                     | –                          | –                            | –                          |   |
| P75      | ANI5               | Input  | P75 = Setting not required  | PM75 = 1                     | –                          | –                            | –                          |   |
| P76      | ANI6               | Input  | P76 = Setting not required  | PM76 = 1                     | –                          | –                            | –                          |   |
| P77      | ANI7               | Input  | P77 = Setting not required  | PM77 = 1                     | –                          | –                            | –                          |   |
| P78      | ANI8               | Input  | P78 = Setting not required  | PM78 = 1                     | –                          | –                            | –                          |   |
| P79      | ANI9               | Input  | P79 = Setting not required  | PM79 = 1                     | –                          | –                            | –                          |   |
| P710     | ANI10              | Input  | P710 = Setting not required | PM710 = 1                    | –                          | –                            | –                          |   |
| P711     | ANI11              | Input  | P711 = Setting not required | PM711 = 1                    | –                          | –                            | –                          |   |
| P712     | ANI12              | Input  | P712 = Setting not required | PM712 = 1                    | –                          | –                            | –                          |   |
| P713     | ANI13              | Input  | P713 = Setting not required | PM713 = 1                    | –                          | –                            | –                          |   |
| P714     | ANI14              | Input  | P714 = Setting not required | PM714 = 1                    | –                          | –                            | –                          |   |
| P715     | ANI15              | Input  | P715 = Setting not required | PM715 = 1                    | –                          | –                            | –                          |   |
| P80      | RXDA3              | Input  | P80 = Setting not required  | PM80 = Setting not required  | PMC80 = 1                  | –                            | –                          | N |
|          | INTP8              | Input  | P80 = Setting not required  | PM80 = Setting not required  | PMC80 = 1                  | –                            | –                          | N |
| P81      | TXDA3              | Output | P81 = Setting not required  | PM81 = Setting not required  | PMC81 = 1                  | –                            | –                          |   |

**Note** The INTP8 pin and RXDA3 pin are alternate-function pins. When using the pin as the RXDA3 pin, disable edge detection for the pin (Clear the INTF8.INTF80 bit and the INTR8.INTR80 bit to 0.) When using the pin as the INTP8 pin, stop UARTA3 reception. (Clear the INTP8.INTP80 bit to 0.)

**Table 4-19. Using Port Pins as Alternate-Function Pins (5/8)**

| Pin Name | Alternate Function          |        | Pnx Bit of Pn Register     | PMnx Bit of PMn Register    | PMCnx Bit of PMCn Register | PFCEnx Bit of PFCEn Register | PFCnx Bit of PFCn Register |     |
|----------|-----------------------------|--------|----------------------------|-----------------------------|----------------------------|------------------------------|----------------------------|-----|
|          | Name                        | I/O    |                            |                             |                            |                              |                            |     |
| P90      | A0                          | Output | P90 = Setting not required | PM90 = Setting not required | PMC90 = 1                  | PFCE90 = 0                   | PFC90 = 0                  | Not |
|          | KR6                         | Input  | P90 = Setting not required | PM90 = Setting not required | PMC90 = 1                  | PFCE90 = 0                   | PFC90 = 1                  |     |
|          | TXDA1                       | Output | P90 = Setting not required | PM90 = Setting not required | PMC90 = 1                  | PFCE90 = 1                   | PFC90 = 0                  |     |
|          | SDA02                       | I/O    | P90 = Setting not required | PM90 = Setting not required | PMC90 = 1                  | PFCE90 = 1                   | PFC90 = 1                  | PF9 |
| P91      | A1                          | Output | P91 = Setting not required | PM91 = Setting not required | PMC91 = 1                  | PFCE91 = 0                   | PFC91 = 0                  | Not |
|          | KR7                         | Input  | P91 = Setting not required | PM91 = Setting not required | PMC91 = 1                  | PFCE91 = 0                   | PFC91 = 1                  |     |
|          | RXDA1/KR7 <sup>Note 2</sup> | Input  | P91 = Setting not required | PM91 = Setting not required | PMC91 = 1                  | PFCE91 = 1                   | PFC91 = 0                  |     |
|          | SCL02                       | I/O    | P91 = Setting not required | PM91 = Setting not required | PMC91 = 1                  | PFCE91 = 1                   | PFC91 = 1                  | PF9 |
| P92      | A2                          | Output | P92 = Setting not required | PM92 = Setting not required | PMC92 = 1                  | PFCE92 = 0                   | PFC92 = 0                  | Not |
|          | TIP41                       | Input  | P92 = Setting not required | PM92 = Setting not required | PMC92 = 1                  | PFCE92 = 0                   | PFC92 = 1                  |     |
|          | TOP41                       | Output | P92 = Setting not required | PM92 = Setting not required | PMC92 = 1                  | PFCE92 = 1                   | PFC92 = 0                  |     |
| P93      | A3                          | Output | P93 = Setting not required | PM93 = Setting not required | PMC93 = 1                  | PFCE93 = 0                   | PFC93 = 0                  | Not |
|          | TIP40                       | Input  | P93 = Setting not required | PM93 = Setting not required | PMC93 = 1                  | PFCE93 = 0                   | PFC93 = 1                  |     |
|          | TOP40                       | Output | P93 = Setting not required | PM93 = Setting not required | PMC93 = 1                  | PFCE93 = 1                   | PFC93 = 0                  |     |
| P94      | A4                          | Output | P94 = Setting not required | PM94 = Setting not required | PMC94 = 1                  | PFCE94 = 0                   | PFC94 = 0                  | Not |
|          | TIP31                       | Input  | P94 = Setting not required | PM94 = Setting not required | PMC94 = 1                  | PFCE94 = 0                   | PFC94 = 1                  |     |
|          | TOP31                       | Output | P94 = Setting not required | PM94 = Setting not required | PMC94 = 1                  | PFCE94 = 1                   | PFC94 = 0                  |     |
| P95      | A5                          | Output | P95 = Setting not required | PM95 = Setting not required | PMC95 = 1                  | PFCE95 = 0                   | PFC95 = 0                  | Not |
|          | TIP30                       | Input  | P95 = Setting not required | PM95 = Setting not required | PMC95 = 1                  | PFCE95 = 0                   | PFC95 = 1                  |     |
|          | TOP30                       | Output | P95 = Setting not required | PM95 = Setting not required | PMC95 = 1                  | PFCE95 = 1                   | PFC95 = 0                  |     |
| P96      | A6                          | Output | P96 = Setting not required | PM96 = Setting not required | PMC96 = 1                  | PFCE96 = 0                   | PFC96 = 0                  | Not |
|          | TIP21                       | Input  | P96 = Setting not required | PM96 = Setting not required | PMC96 = 1                  | PFCE96 = 1                   | PFC96 = 0                  |     |
|          | TOP21                       | Output | P96 = Setting not required | PM96 = Setting not required | PMC96 = 1                  | PFCE96 = 1                   | PFC96 = 1                  |     |

**Notes 1.** When setting pins A0 to A15 as the alternate function, set the PMC9 register to FFFFH for all 16 bits at once.

**2.** The RXDA1 and KR7 pins must not be used at the same time. When using the RXDA1 pin, do not use the KR7 pin. When using the KR7 pin, do not use the RXDA1 pin (it is recommended to set the PFC91 bit to 1 and clear the PFCE91 bit to 0).

Table 4-19. Using Port Pins as Alternate-Function Pins (6/8)

| Pin Name | Alternate Function |        | Pnx Bit of Pn Register      | PMnx Bit of PMn Register     | PMCnx Bit of PMCn Register | PFCEnx Bit of PFCEn Register | PFCnx Bit of PFCn Register |   |
|----------|--------------------|--------|-----------------------------|------------------------------|----------------------------|------------------------------|----------------------------|---|
|          | Name               | I/O    |                             |                              |                            |                              |                            |   |
| P97      | A7                 | Output | P97 = Setting not required  | PM97 = Setting not required  | PMC97 = 1                  | PFCE97 = 0                   | PFC97 = 0                  | N |
|          | SIB1               | Input  | P97 = Setting not required  | PM97 = Setting not required  | PMC97 = 1                  | PFCE97 = 0                   | PFC97 = 1                  |   |
|          | TIP20              | Input  | P97 = Setting not required  | PM97 = Setting not required  | PMC97 = 1                  | PFCE97 = 1                   | PFC97 = 0                  |   |
|          | TOP20              | Output | P97 = Setting not required  | PM97 = Setting not required  | PMC97 = 1                  | PFCE97 = 1                   | PFC97 = 1                  |   |
| P98      | A8                 | Output | P98 = Setting not required  | PM98 = Setting not required  | PMC98 = 1                  | –                            | PFC98 = 0                  | N |
|          | SOB1               | Output | P98 = Setting not required  | PM98 = Setting not required  | PMC98 = 1                  | –                            | PFC98 = 1                  |   |
| P99      | A9                 | Output | P99 = Setting not required  | PM99 = Setting not required  | PMC99 = 1                  | –                            | PFC99 = 0                  | N |
|          | SCKB1              | I/O    | P99 = Setting not required  | PM99 = Setting not required  | PMC99 = 1                  | –                            | PFC99 = 1                  |   |
| P910     | A10                | Output | P910 = Setting not required | PM910 = Setting not required | PMC910 = 1                 | –                            | PFC910 = 0                 | N |
|          | SIB3               | Input  | P910 = Setting not required | PM910 = Setting not required | PMC910 = 1                 | –                            | PFC910 = 1                 |   |
| P911     | A11                | Output | P911 = Setting not required | PM911 = Setting not required | PMC911 = 1                 | –                            | PFC911 = 0                 | N |
|          | SOB3               | Output | P911 = Setting not required | PM911 = Setting not required | PMC911 = 1                 | –                            | PFC911 = 1                 |   |
| P912     | A12                | Output | P912 = Setting not required | PM912 = Setting not required | PMC912 = 1                 | –                            | PFC912 = 0                 | N |
|          | SCKB3              | I/O    | P912 = Setting not required | PM912 = Setting not required | PMC912 = 1                 | –                            | PFC912 = 1                 |   |
| P913     | A13                | Output | P913 = Setting not required | PM913 = Setting not required | PMC913 = 1                 | –                            | PFC913 = 0                 | N |
|          | INTP4              | Input  | P913 = Setting not required | PM913 = Setting not required | PMC913 = 1                 | –                            | PFC913 = 1                 |   |
| P914     | A14                | Output | P914 = Setting not required | PM914 = Setting not required | PMC914 = 1                 | PFCE914 = 0                  | PFC914 = 0                 | N |
|          | INTP5              | Input  | P914 = Setting not required | PM914 = Setting not required | PMC914 = 1                 | PFCE914 = 0                  | PFC914 = 1                 |   |
|          | TIP51              | Input  | P914 = Setting not required | PM914 = Setting not required | PMC914 = 1                 | PFCE914 = 1                  | PFC914 = 0                 |   |
|          | TOP51              | Output | P914 = Setting not required | PM914 = Setting not required | PMC914 = 1                 | PFCE914 = 1                  | PFC914 = 1                 |   |
| P915     | A15                | Output | P915 = Setting not required | PM915 = Setting not required | PMC915 = 1                 | PFCE915 = 0                  | PFC915 = 0                 | N |
|          | INTP6              | Input  | P915 = Setting not required | PM915 = Setting not required | PMC915 = 1                 | PFCE915 = 0                  | PFC915 = 1                 |   |
|          | TIP50              | Input  | P915 = Setting not required | PM915 = Setting not required | PMC915 = 1                 | PFCE915 = 1                  | PFC915 = 0                 |   |
|          | TOP50              | Output | P915 = Setting not required | PM915 = Setting not required | PMC915 = 1                 | PFCE915 = 1                  | PFC915 = 1                 |   |
| PCS0     | CS0                | Output | PCS0 = Setting not required | PMCS0 = Setting not required | PMCCS0 = 1                 | –                            | –                          |   |
| PCS1     | CS1                | Output | PCS1 = Setting not required | PMCS1 = Setting not required | PMCCS1 = 1                 | –                            | –                          |   |
| PCS2     | CS2                | Output | PCS2 = Setting not required | PMCS2 = Setting not required | PMCCS2 = 1                 | –                            | –                          |   |
| PCS3     | CS3                | Output | PCS3 = Setting not required | PMCS3 = Setting not required | PMCCS3 = 1                 | –                            | –                          |   |

**Note** When setting pins A0 to A15 as the alternate function, set the PMC9 register to FFFFH for all 16 bits at once.



**Table 4-19. Using Port Pins as Alternate-Function Pins (7/8)**

| Pin Name | Alternate Function         |        | Pnx Bit of Pn Register      | PMnx Bit of PMn Register     | PMCnx Bit of PMCn Register      | PFCEnx Bit of PFCEn Register | PFCnx Bit of PFCn Register |
|----------|----------------------------|--------|-----------------------------|------------------------------|---------------------------------|------------------------------|----------------------------|
|          | Name                       | I/O    |                             |                              |                                 |                              |                            |
| PCM0     | WAIT                       | Input  | PCM0 = Setting not required | PMCM0 = Setting not required | PMCCM0 = 1                      | –                            | –                          |
| PCM1     | CLKOUT                     | Output | PCM1 = Setting not required | PMCM1 = Setting not required | PMCCM1 = 1                      | –                            | –                          |
| PCM2     | HLD $\overline{\text{AK}}$ | Output | PCM2 = Setting not required | PMCM2 = Setting not required | PMCCM2 = 1                      | –                            | –                          |
| PCM3     | H $\overline{\text{LDRQ}}$ | Input  | PCM3 = Setting not required | PMCM3 = Setting not required | PMCCM3 = 1                      | –                            | –                          |
| PCT0     | WR0                        | Output | PCT0 = Setting not required | PMCT0 = Setting not required | PMCC $\overline{\text{T0}}$ = 1 | –                            | –                          |
| PCT1     | WR1                        | Output | PCT1 = Setting not required | PMCT1 = Setting not required | PMCC $\overline{\text{T1}}$ = 1 | –                            | –                          |
| PCT4     | R $\overline{\text{D}}$    | Output | PCT4 = Setting not required | PMCT4 = Setting not required | PMCC $\overline{\text{T4}}$ = 1 | –                            | –                          |
| PCT6     | ASTB                       | Output | PCT6 = Setting not required | PMCT6 = Setting not required | PMCC $\overline{\text{T6}}$ = 1 | –                            | –                          |
| PDH0     | A16                        | Output | PDH0 = Setting not required | PMDH0 = Setting not required | PMCDH0 = 1                      | –                            | –                          |
| PDH1     | A17                        | Output | PDH1 = Setting not required | PMDH1 = Setting not required | PMCDH1 = 1                      | –                            | –                          |
| PDH2     | A18                        | Output | PDH2 = Setting not required | PMDH2 = Setting not required | PMCDH2 = 1                      | –                            | –                          |
| PDH3     | A19                        | Output | PDH3 = Setting not required | PMDH3 = Setting not required | PMCDH3 = 1                      | –                            | –                          |
| PDH4     | A20                        | Output | PDH4 = Setting not required | PMDH4 = Setting not required | PMCDH4 = 1                      | –                            | –                          |
| PDH5     | A21                        | Output | PDH5 = Setting not required | PMDH5 = Setting not required | PMCDH5 = 1                      | –                            | –                          |
| PDH6     | A22                        | Output | PDH6 = Setting not required | PMDH6 = Setting not required | PMCDH6 = 1                      | –                            | –                          |
| PDH7     | A23                        | Output | PDH7 = Setting not required | PMDH7 = Setting not required | PMCDH7 = 1                      | –                            | –                          |
| PDL0     | AD0                        | I/O    | PDL0 = Setting not required | PMDL0 = Setting not required | PMCDL0 = 1                      | –                            | –                          |
| PDL1     | AD1                        | I/O    | PDL1 = Setting not required | PMDL1 = Setting not required | PMCDL1 = 1                      | –                            | –                          |
| PDL2     | AD2                        | I/O    | PDL2 = Setting not required | PMDL2 = Setting not required | PMCDL2 = 1                      | –                            | –                          |
| PDL3     | AD3                        | I/O    | PDL3 = Setting not required | PMDL3 = Setting not required | PMCDL3 = 1                      | –                            | –                          |
| PDL4     | AD4                        | I/O    | PDL4 = Setting not required | PMDL4 = Setting not required | PMCDL4 = 1                      | –                            | –                          |
| PDL5     | AD5                        | I/O    | PDL5 = Setting not required | PMDL5 = Setting not required | PMCDL5 = 1                      | –                            | –                          |
|          | FLMD1 <sup>Note</sup>      | Input  | PDL5 = Setting not required | PMDL5 = Setting not required | PMCDL5 = Setting not required   | –                            | –                          |
| PDL6     | AD6                        | I/O    | PDL6 = Setting not required | PMDL6 = Setting not required | PMCDL6 = 1                      | –                            | –                          |
| PDL7     | AD7                        | I/O    | PDL7 = Setting not required | PMDL7 = Setting not required | PMCDL7 = 1                      | –                            | –                          |

**Note** Since this pin is set in the flash memory programming mode, it does not need to be manipulated with the port control register. P  
**FLASH MEMORY.**

**Table 4-19. Using Port Pins as Alternate-Function Pins (8/8)**

| Pin Name | Alternate Function |     | Pnx Bit of Pn Register       | PMnx Bit of PMn Register      | PMCnx Bit of PMCn Register | PFCEnx Bit of PFCEn Register | PFCnx Bit of PFCn Register |
|----------|--------------------|-----|------------------------------|-------------------------------|----------------------------|------------------------------|----------------------------|
|          | Name               | I/O |                              |                               |                            |                              |                            |
| PDL8     | AD8                | I/O | PDL8 = Setting not required  | PMDL8 = Setting not required  | PMCDL8 = 1                 | –                            | –                          |
| PDL9     | AD9                | I/O | PDL9 = Setting not required  | PMDL9 = Setting not required  | PMCDL9 = 1                 | –                            | –                          |
| PDL10    | AD10               | I/O | PDL10 = Setting not required | PMDL10 = Setting not required | PMCDL10 = 1                | –                            | –                          |
| PDL11    | AD11               | I/O | PDL11 = Setting not required | PMDL11 = Setting not required | PMCDL11 = 1                | –                            | –                          |
| PDL12    | AD12               | I/O | PDL12 = Setting not required | PMDL12 = Setting not required | PMCDL12 = 1                | –                            | –                          |
| PDL13    | AD13               | I/O | PDL13 = Setting not required | PMDL13 = Setting not required | PMCDL13 = 1                | –                            | –                          |
| PDL14    | AD14               | I/O | PDL14 = Setting not required | PMDL14 = Setting not required | PMCDL14 = 1                | –                            | –                          |
| PDL15    | AD15               | I/O | PDL15 = Setting not required | PMDL15 = Setting not required | PMCDL15 = 1                | –                            | –                          |

## 4.6 Cautions

### 4.6.1 Cautions on setting port pins

(1) In the V850ES/JJ3, the general-purpose port function and several peripheral function I/O pin share a pin. To switch between the general-purpose port (port mode) and the peripheral function I/O pin (alternate-function mode), set by the PMCn register. In regards to this register setting sequence, note with caution the following.

(a) Cautions on switching from port mode to alternate-function mode

To switch from the port mode to alternate-function mode in the following order.

- <1> Set the PFn register<sup>Note</sup>: N-ch open-drain setting
- <2> Set the PFCn and PFCEn registers: Alternate-function selection
- <3> Set the corresponding bit of the PMCn register to 1: Switch to alternate-function mode

If the PMCn register is set first, note with caution that, at that moment or depending on the change of the pin states in accordance with the setting of the PFn, PFCn, and PFCEn registers, unexpected operations may occur.

A concrete example is shown as Example below.

**Note** No-ch open-drain output pin only

**Caution** Regardless of the port mode/alternate-function mode, the Pn register is read and written as follows.

- Pn register read: Read the port output latch value (when PMn.PMnm bit = 0), or read the pin states (PMn.PMnm bit = 1).
- Pn register write: Write to the port output latch

[Example] SCL01 pin setting example

The SCL01 pin is used alternately with the P41/SOB0 pin. Select the valid pin functions with the PMC4, PFC4, and PF4 registers.

| PMC41 Bit | PFC41 Bit  | PF41 Bit | Valid Pin Functions                               |
|-----------|------------|----------|---|
| 0         | don't care | 1        | P41 (in output port mode, N-ch open-drain output) |
| 1         | 0          | 1        | SOB0 output (N-ch open-drain output)              |
|           | 1          | 1        | SCL01 I/O (N-ch open-drain output)                |

The order of setting in which malfunction may occur on switching from the P41 pin to the SCL01 pin are shown below.

| Setting Order | Setting Contents  | Pin States        | Pin Level   |
|---------------|---|-------------------|---|
| <1>           | Initial value<br>(PMC41 bit = 0,<br>PFC41 bit = 0,<br>PF41 bit = 0) | Port mode (input) | Hi-Z  |
| <2>           | PMC41 bit ← 1   | SOB0 output       | Low level (high level depending on the CSIB0 setting) |
| <3>           | PFC41 bit ← 1   | SCL01 I/O         | High level (CMOS output)                              |
| <4>           | PF41 bit ← 1  | SCL01 I/O         | Hi-Z (N-ch open-drain output)                         |

In <2>, I<sup>2</sup>C communication may be affected since the alternate-function SOB0 output is output to the pin. In the CMOS output period of <2> or <3>, unnecessary current may be generated.

(b) Cautions on alternate-function mode (input)

The input signal to the alternate-function block is low level when the PMCn.PMCnm bit is 0 due to the AND output of the PMCn register set value and the pin level. Thus, depending on the port setting and alternate-function operation enable timing, unexpected operations may occur. Therefore, switch between the port mode and alternate-function mode in the following sequence.

- To switch from port mode to alternate-function mode (input)  
Set the pins to the alternate-function mode using the PMCn register and then enable the alternate-function operation.
- To switch from alternate-function mode (input) to port mode  
Stop the alternate-function operation and then switch the pins to the port mode.

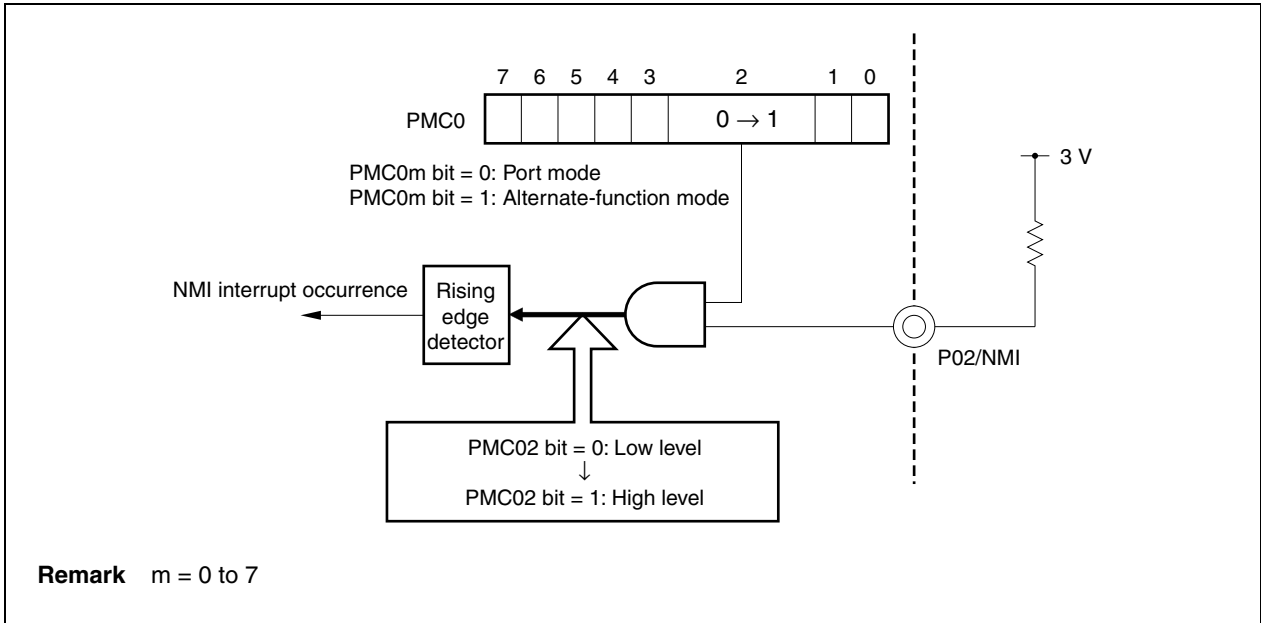
The concrete examples are shown as Example 1 and Example 2.

[Example 1] Switch from general-purpose port (P02) to external interrupt pin (NMI)

When the P02/NMI pin is pulled up as shown in Figure 4-37 and the rising edge is specified in the NMI pin edge detection setting, even though high level is input continuously to the NMI pin during switching from the P02 pin to the an NMI pin (PMC02 bit = 0 → 1), this is detected as a rising edge as if the low level changed to high level, and an NMI interrupt occurs.

To avoid it, set the NMI pin's valid edge after switching from the P02 pin to the NMI pin.

Figure 4-37. Example of Switching from P02 to NMI (Incorrect)

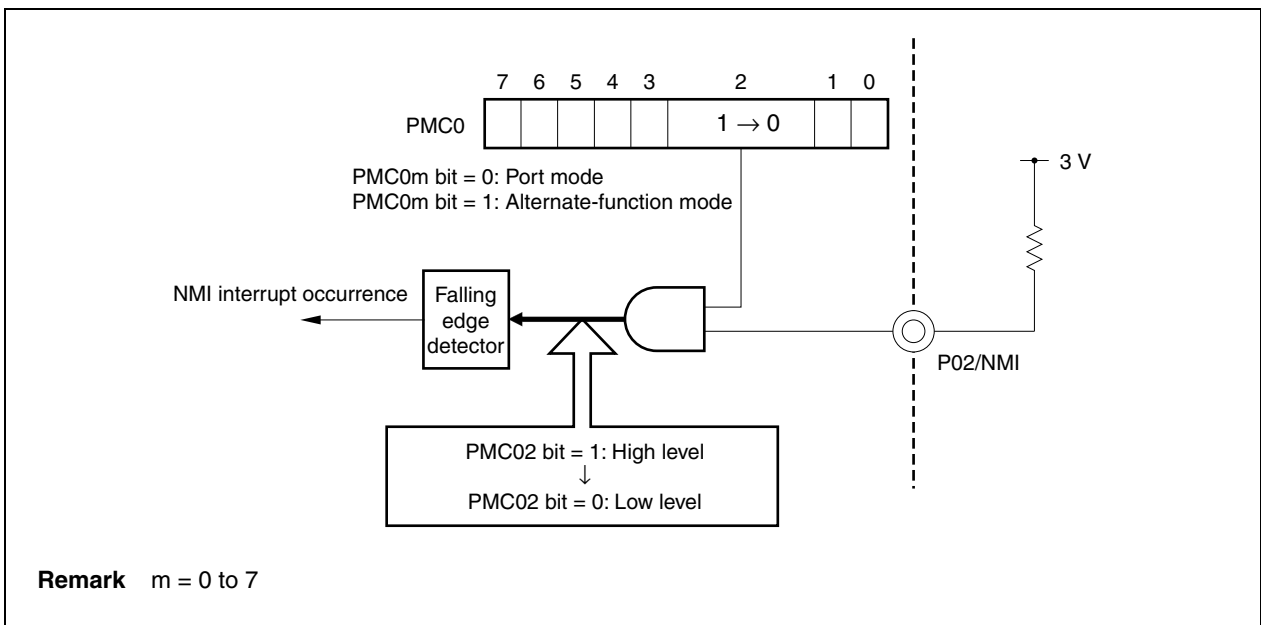


[Example 2] Switch from external pin (NMI) to general-purpose port (P02)

When the P02/NMI pin is pulled up as shown in Figure 4-38 and the falling edge is specified in the NMI pin edge detection setting, even though high level is input continuously to the NMI pin at switching from the NMI pin to the P02 pin (PMCO2 bit = 1 → 0), this is detected as falling edge as if high level changed to low level, and NMI interrupt occurs.

To avoid this, set the NMI pin edge detection as "No edge detected" before switching to the P02 pin.

Figure 4-38. Example of Switching from NMI to P02 (Incorrect)



(2) In port mode, the PF<sub>n</sub>.PF<sub>nm</sub> bit is valid only in the output mode (PM<sub>n</sub>.PM<sub>nm</sub> bit = 0). In the input mode (PM<sub>nm</sub> bit = 1), the value of the PF<sub>nm</sub> bit is not reflected in the buffer.

**4.6.2 Cautions on bit manipulation instruction for port n register (Pn)**

When a 1-bit manipulation instruction is executed on a port that provides both input and output functions, the value of the output latch of an input port that is not subject to manipulation may be written in addition to the targeted bit.

Therefore, it is recommended to rewrite the output latch when switching a port from input mode to output mode.

<Example> When P90 pin is an output port, P91 to P97 pins are input ports (all pin statuses are high level), and the value of the port latch is 00H, if the output of P90 pin is changed from low level to high level via a bit manipulation instruction, the value of the port latch is FFH.

Explanation: The targets of writing to and reading from the Pn register of a port whose PMnm bit is 1 are the output latch and pin status, respectively.

A bit manipulation instruction is executed in the following order in the V850ES/JJ3.

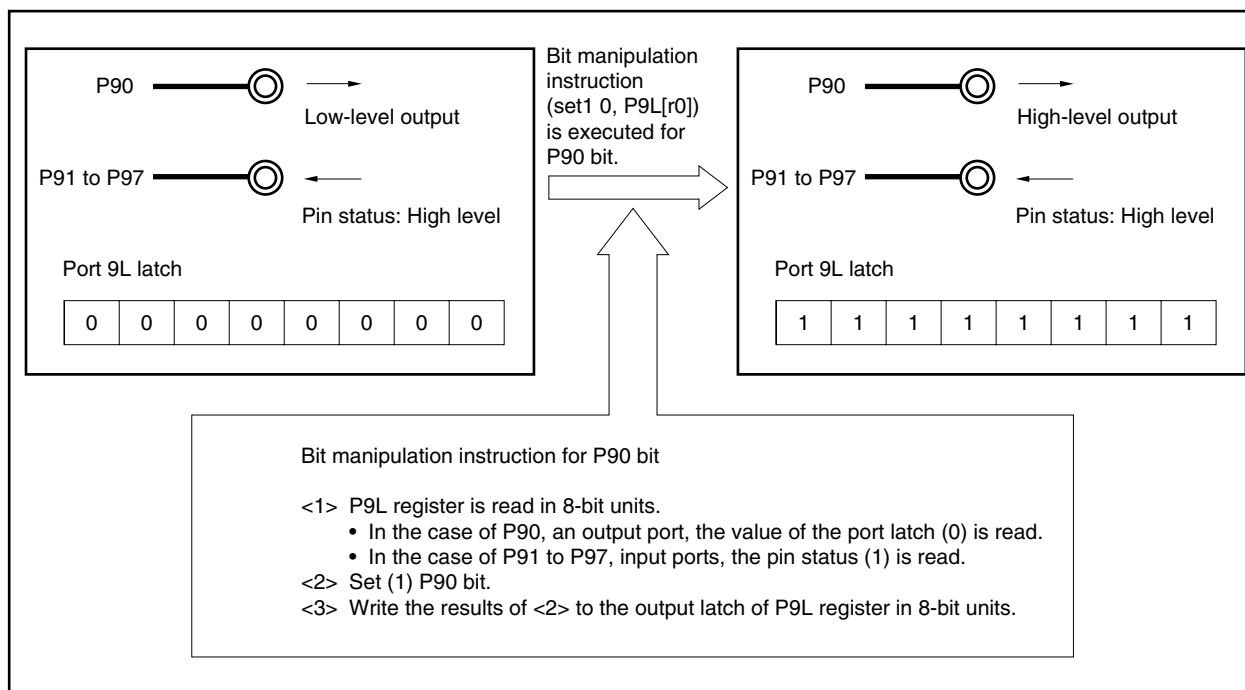
- <1> The Pn register is read in 8-bit units.
- <2> The targeted one bit is manipulated.
- <3> The Pn register is written in 8-bit units.

In step <1>, the value of the output latch (0) of P90 pin, which is an output port, is read, while the pin statuses of P91 to P97 pins, which are input ports, are read. If the pin statuses of P91 to P97 pins are high level at this time, the read value is FEH.

The value is changed to FFH by the manipulation in <2>.

FFH is written to the output latch by the manipulation in <3>.

**Figure 4-39. Bit Manipulation Instruction (P90 Pin)**



#### 4.6.3 Cautions on on-chip debug pins

The  $\overline{\text{DRST}}$ , DCK, DMS, DDI, and DDO pins are on-chip debug pins.

After reset by the  $\overline{\text{RESET}}$  pin, the P05/INTP2/ $\overline{\text{DRST}}$  pin is initialized to function as an on-chip debug pin ( $\overline{\text{DRST}}$ ). If a high level is input to the  $\overline{\text{DRST}}$  pin at this time, the on-chip debug mode is set, and the DCK, DMS, DDI, and DDO pins can be used.

The following action must be taken if on-chip debugging is not used.

- Clear the OCDM0 bit of the OCDM register (special register) (0)

At this time, fix the P05/INTP2/ $\overline{\text{DRST}}$  pin to low level from when reset by the  $\overline{\text{RESET}}$  pin is released until the above action is taken.

If a high level is input to the  $\overline{\text{DRST}}$  pin before the above action is taken, it may cause a malfunction (CPU deadlock). Handle the P05 pin with the utmost care.

**Caution** After reset by the WDT2RES signal, clock monitor (CLM), or low-voltage detector (LVI), the P05/INTP2/ $\overline{\text{DRST}}$  pin is not initialized to function as an on-chip debug pin ( $\overline{\text{DRST}}$ ). The OCDM register holds the current value.

#### 4.6.4 Cautions on P05/INTP2/ $\overline{\text{DRST}}$ pin

The P05/INTP2/ $\overline{\text{DRST}}$  pin has an internal pull-down resistor (30 k $\Omega$  TYP.). After a reset by the  $\overline{\text{RESET}}$  pin, a pull-down resistor is connected. The pull-down resistor is disconnected when the OCDM0 bit is cleared (0).

#### 4.6.5 Cautions on P53 pin when power is turned on

When the power is turned on, the following pin may output an undefined level temporarily, even during reset.

- P53/SIB2/KR3/TIQ00/TOQ00/RTP03/DDO pin

#### 4.6.6 Hysteresis characteristics

In port mode, the following port pins do not have hysteresis characteristics.

P00 to P06

P31 to P35, P38, P39

P40 to P42

P50 to P55

P66, P68 to P610, P612, P613

P80

P90 to P97, P99, P910, P912 to P915

## CHAPTER 5 BUS CONTROL FUNCTION

The V850ES/JJ3 is provided with an external bus interface function by which external memories such as ROM and RAM, and I/O can be connected.

### 5.1 Features

- Output is selectable from a multiplexed bus with a minimum of 3 bus cycles and a separate bus with a minimum of 2 bus cycles.
- 8-bit/16-bit data bus selectable
- Wait function
  - Programmable wait function of up to 7 states
  - External wait function using  $\overline{\text{WAIT}}$  pin
- Idle state function
- Bus hold function
- Up to 16 MB of physical memory connectable (of which 1 MB is internal ROM space)



## 5.2 Bus Control Pins

The pins used to connect an external device are listed in the table below.

**Table 5-1. Bus Control Pins (Multiplexed Bus)**

| Bus Control Pin                                    | Alternate-Function Pin | I/O    | Function              |
|--|------------------------|--------|-----------------------|
| AD0 to AD15  | PDL0 to PDL15          | I/O    | Address/data bus      |
| A16 to A23   | PDH0 to PDH7           | Output | Address bus           |
| $\overline{\text{WAIT}}$                           | PCM0                   | Input  | External wait control |
| CLKOUT   | PCM1                   | Output | Internal system clock |
| $\overline{\text{WR0}}, \overline{\text{WR1}}$     | PCT0, PCT1             | Output | Write strobe signal   |
| $\overline{\text{RD}}$                             | PCT4                   | Output | Read strobe signal    |
| ASTB   | PCT6                   | Output | Address strobe signal |
| $\overline{\text{HLDRQ}}$                          | PCM3                   | Input  | Bus hold control      |
| $\overline{\text{HLDAK}}$                          | PCM2                   | Output |                       |
| $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$ | PCS0 to PCS3           | Output | Chip select           |

**Table 5-2. External Control Pins (Separate Bus)**

| Bus Control Pin                                    | Alternate-Function Pin | I/O    | Function              |
|--|------------------------|--------|-----------------------|
| AD0 to AD15  | PDL0 to PDL15          | I/O    | Data bus              |
| A0 to A15  | P90 to P915            | Output | Address bus           |
| A16 to A23   | PDH0 to PDH7           | Output | Address bus           |
| $\overline{\text{WAIT}}$                           | PCM0                   | Input  | External wait control |
| CLKOUT   | PCM1                   | Output | Internal system clock |
| $\overline{\text{WR0}}, \overline{\text{WR1}}$     | PCT0, PCT1             | Output | Write strobe signal   |
| $\overline{\text{RD}}$                             | PCT4                   | Output | Read strobe signal    |
| $\overline{\text{HLDRQ}}$                          | PCM3                   | Input  | Bus hold control      |
| $\overline{\text{HLDAK}}$                          | PCM2                   | Output |                       |
| $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$ | PCS0 to PCS3           | Output | Chip select           |

### 5.2.1 Pin status when internal ROM, internal RAM, or on-chip peripheral I/O is accessed

When the internal ROM, internal RAM, or on-chip peripheral I/O are accessed, the status of each pin is as follows.

**Table 5-3. Pin Statuses When Internal ROM, Internal RAM, or On-Chip Peripheral I/O Is Accessed**

| Separate Bus Mode       |           | Multiplexed Bus Mode           |           |
|-------------------------|-----------|--------------------------------|-----------|
| Address bus (A23 to A0) | Undefined | Address bus (A23 to A16)       | Undefined |
| Data bus (AD15 to AD0)  | Hi-Z      | Address/data bus (AD15 to AD0) | Undefined |
| Control signal          | Inactive  | Control signal                 | Inactive  |

**Caution** When a write access is performed to the internal ROM area, address, data, and control signals are activated in the same way as access to the external memory area.

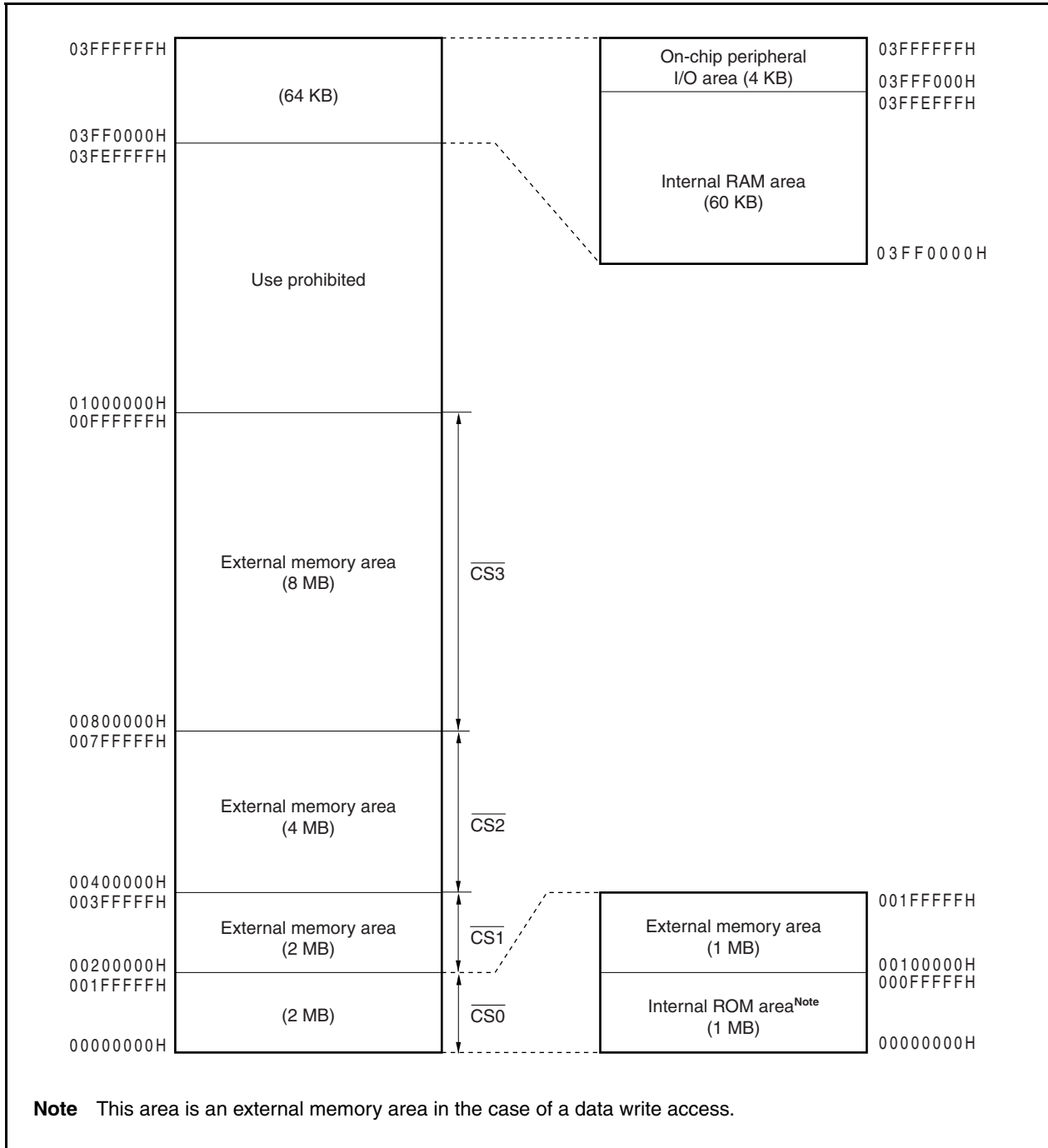
### 5.2.2 Pin status in each operation mode

For the pin status of the V850ES/JJ3 in each operation mode, see **2.2 Pin States**.

### 5.3 Memory Block Function

The 16 MB external memory space is divided into memory blocks of (lower) 2 MB, 2 MB, 4 MB, and 8 MB. The programmable wait function and bus cycle operation mode for each of these blocks can be independently controlled in one-block units.

Figure 5-1. Data Memory Map: Physical Address



## 5.4 External Bus Interface Mode Control Function

The V850ES/JJ3 includes the following two external bus interface modes.

- Multiplexed bus mode
- Separate bus mode

These two modes can be selected by using the EXIMC register.

### (1) External bus interface mode control register (EXIMC)

The EXIMC register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

|  |                      |                     |   |   |   |   |   |       |       |                |   |                      |   |                   |
|--|----------------------|---------------------|---|---|---|---|---|-------|-------|----------------|---|----------------------|---|-------------------|
| After reset: 00H   | R/W                  | Address: FFFFFFFBEH |   |   |   |   |   |       |       |                |   |                      |   |                   |
| EXIMC  | 7                    | 6                   | 5 | 4 | 3 | 2 | 1 | 0     |       |                |   |                      |   |                   |
|  | 0                    | 0                   | 0 | 0 | 0 | 0 | 0 | SMSEL |       |                |   |                      |   |                   |
| <table border="1" style="border-collapse: collapse; width: 100%; text-align: left;"> <tr> <td style="width: 10%; padding: 2px;">SMSEL</td> <td style="padding: 2px;">Mode selection</td> </tr> <tr> <td style="padding: 2px;">0</td> <td style="padding: 2px;">Multiplexed bus mode</td> </tr> <tr> <td style="padding: 2px;">1</td> <td style="padding: 2px;">Separate bus mode</td> </tr> </table> |                      |                     |   |   |   |   |   |       | SMSEL | Mode selection | 0 | Multiplexed bus mode | 1 | Separate bus mode |
| SMSEL  | Mode selection       |                     |   |   |   |   |   |       |       |                |   |                      |   |                   |
| 0  | Multiplexed bus mode |                     |   |   |   |   |   |       |       |                |   |                      |   |                   |
| 1  | Separate bus mode    |                     |   |   |   |   |   |       |       |                |   |                      |   |                   |

**Caution** Set the EXIMC register from the internal ROM or internal RAM area before making an external access.

After setting the EXIMC register, be sure to insert a NOP instruction.

## 5.5 Bus Access

### 5.5.1 Number of clocks for access

The following table shows the number of basic clocks required for accessing each resource.

| Area (Bus Width) / Bus Cycle Type | Internal ROM (32 Bits) | Internal RAM (32 Bits) | External Memory (16 Bits) |
|-----------------------------------|------------------------|------------------------|---------------------------|
| Instruction fetch (normal access) | 1                      | 1 <sup>Note 1</sup>    | 3 + n <sup>Note 2</sup>   |
| Instruction fetch (branch)        | 2                      | 2 <sup>Note 1</sup>    | 3 + n <sup>Note 2</sup>   |
| Operand data access               | 3                      | 1                      | 3 + n <sup>Note 2</sup>   |

**Notes 1.** Increases by 1 if a conflict with a data access occurs.

**2.** 2 + n clocks (n: Number of wait states) when the separate bus mode is selected.

**Remark** Unit: Clocks/access

### 5.5.2 Bus size setting function

Each external memory area selected by  $\overline{CSn}$  can be set by using the BSC register. However, the bus size can be set to 8 bits and 16 bits only.

The external memory area of the V850ES/JJ3 is selected by  $\overline{CS0}$  to  $\overline{CS3}$ .

#### (1) Bus size configuration register (BSC)

The BSC register can be read or written in 16-bit units.

Reset sets this register to 5555H.

**Caution** Write to the BSC register after reset, and then do not change the set values. Also, do not access an external memory area until the initial settings of the BSC register are complete.

After reset: 5555H    R/W    Address: FFFFF066H

|     |    |                  |    |                  |    |                  |   |                  |
|-----|----|------------------|----|------------------|----|------------------|---|------------------|
|     | 15 | 14               | 13 | 12               | 11 | 10               | 9 | 8                |
| BSC | 0  | 1                | 0  | 1                | 0  | 1                | 0 | 1                |
|     | 7  | 6                | 5  | 4                | 3  | 2                | 1 | 0                |
|     | 0  | BS30             | 0  | BS20             | 0  | BS10             | 0 | BS00             |
|     |    | $\overline{CS3}$ |    | $\overline{CS2}$ |    | $\overline{CS1}$ |   | $\overline{CS0}$ |

|      |  |
|------|--|
| BSn0 | Data bus width of CSn space (n = 0 to 3) |
| 0    | 8 bits                                   |
| 1    | 16 bits                                  |

**Caution** Be sure to set bits 14, 12, 10, and 8 to “1”, and clear bits 15, 13, 11, 9, 7, 5, 3, and 1 to “0”.

### 5.5.3 Access by bus size

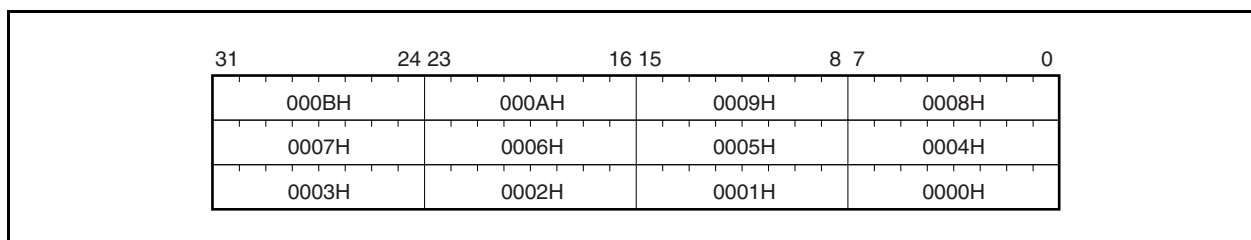
The V850ES/JJ3 accesses the on-chip peripheral I/O and external memory in 8-bit, 16-bit, or 32-bit units. The bus size is as follows.

- The bus size of the on-chip peripheral I/O is fixed to 16 bits.
- The bus size of the external memory is selectable from 8 bits or 16 bits (by using the BSC register).

The operation when each of the above is accessed is described below. All data is accessed starting from the lower side.

The V850ES/JJ3 supports only the little-endian format.

**Figure 5-2. Little-Endian Address in Word**



#### (1) Data space

The V850ES/JJ3 has an address misalign function.

With this function, data can be placed at all addresses, regardless of the format of the data (word data or halfword data). However, if the word data or halfword data is not aligned at the boundary, a bus cycle is generated at least twice, causing the bus efficiency to drop.

##### (a) Halfword-length data access

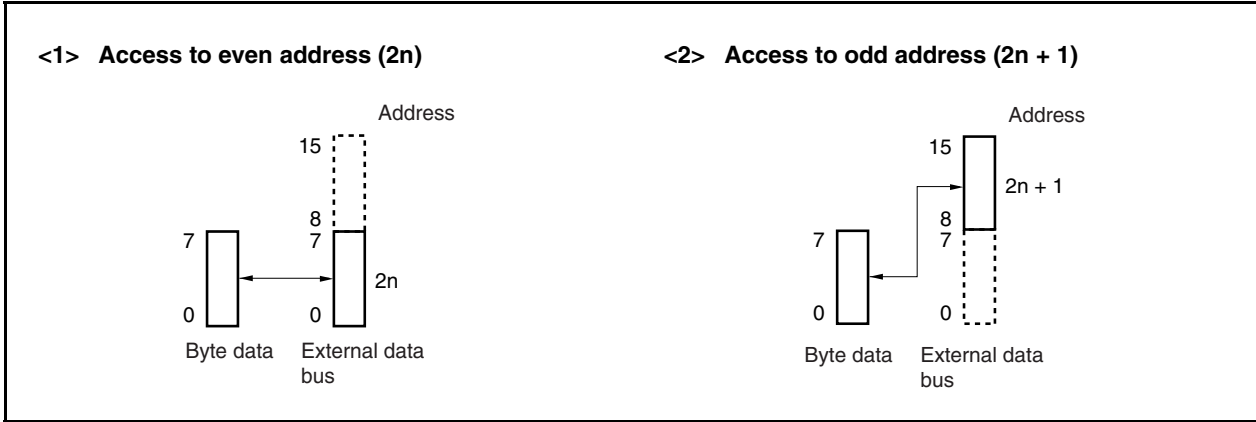
A byte-length bus cycle is generated twice if the least significant bit of the address is 1.

##### (b) Word-length data access

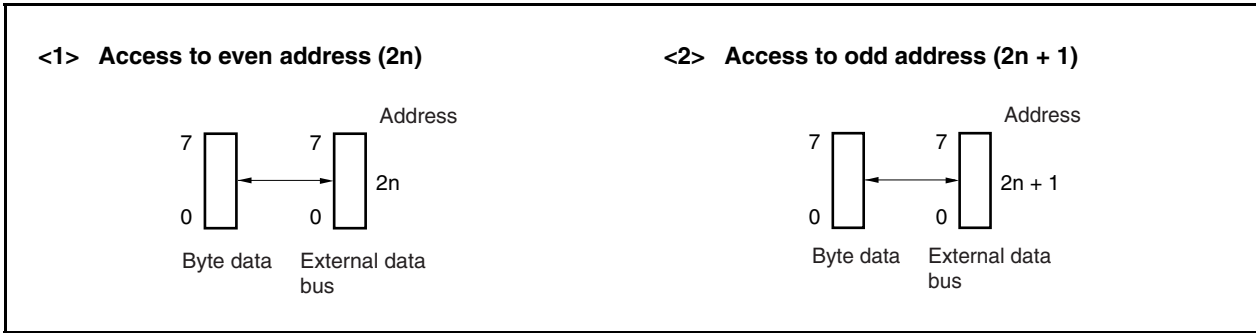
- (i) A byte-length bus cycle, halfword-length bus cycle, and byte-length bus cycle are generated in that order if the least significant bit of the address is 1.
- (ii) A halfword-length bus cycle is generated twice if the lower 2 bits of the address are 10.

(2) Byte access (8 bits)

(a) 16-bit data bus width

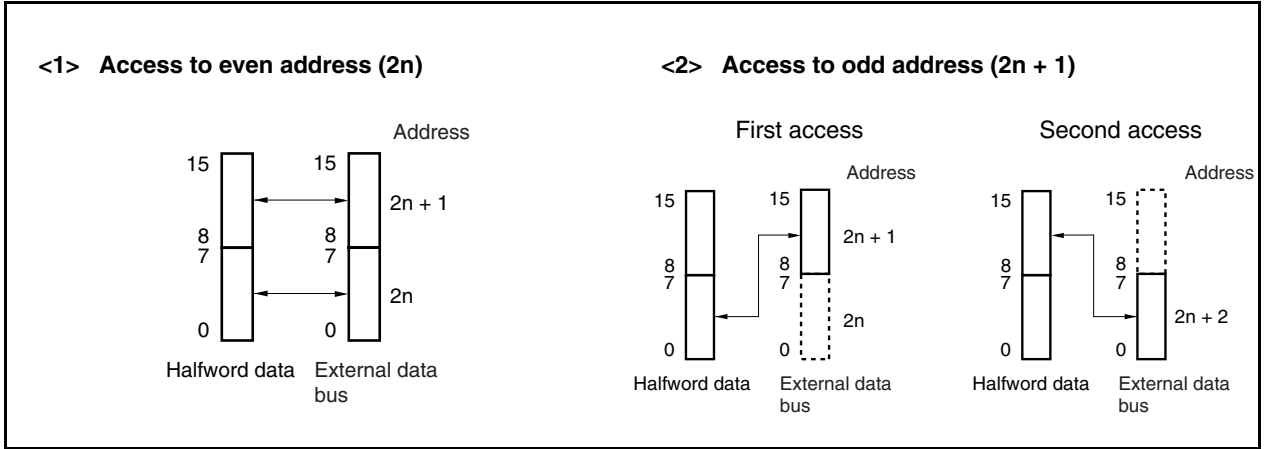


(b) 8-bit data bus width

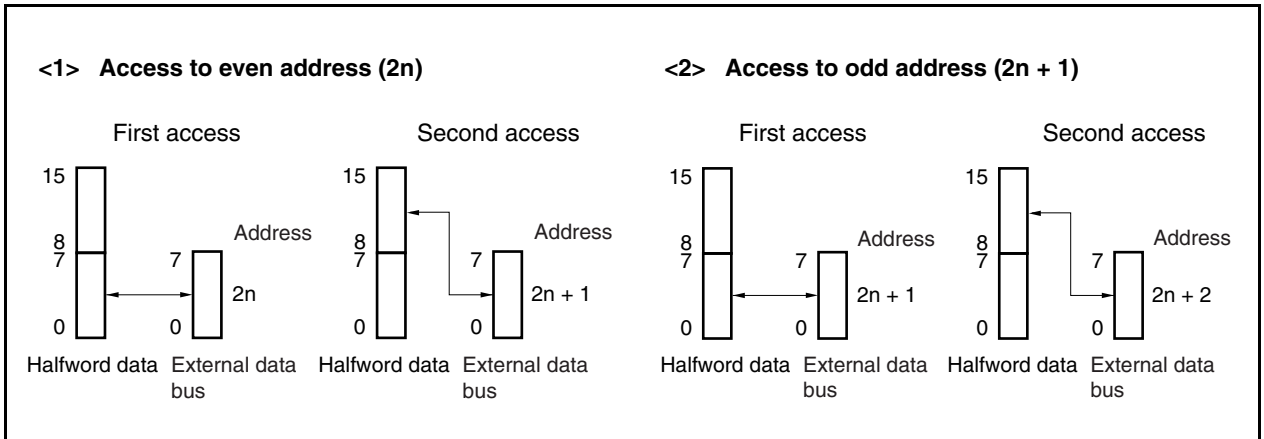


(3) Halfword access (16 bits)

(a) With 16-bit data bus width



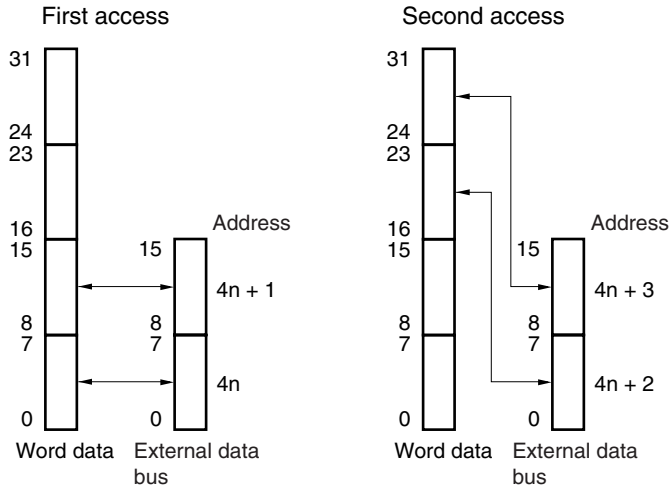
(b) 8-bit data bus width



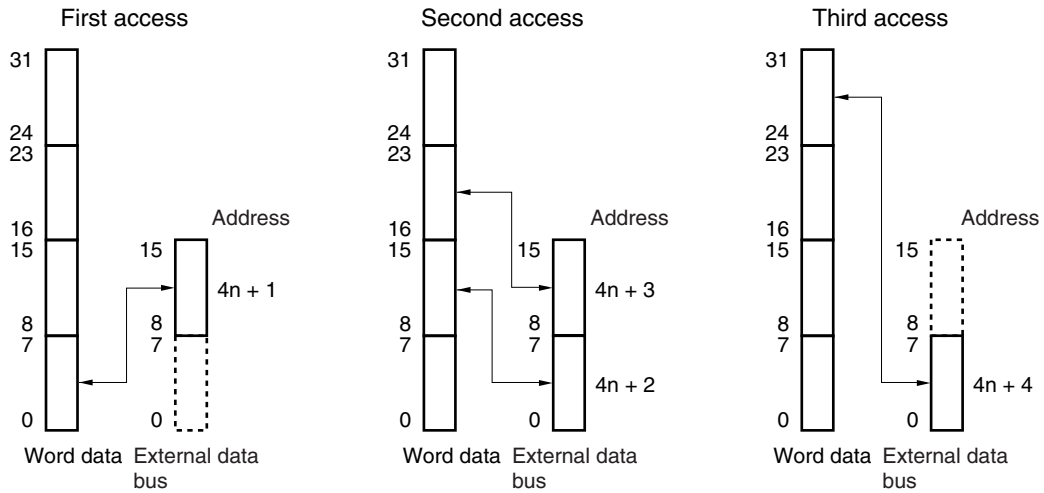
(4) Word access (32 bits)

(a) 16-bit data bus width (1/2)

<1> Access to address (4n)



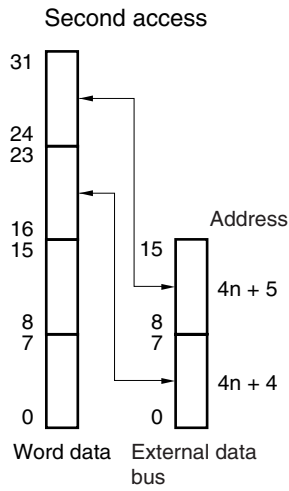
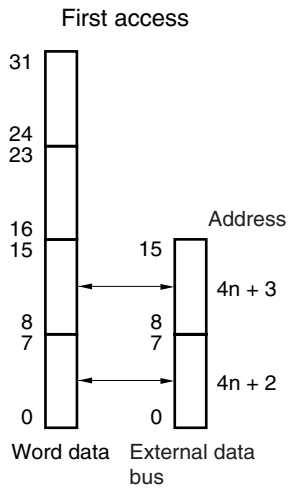
<2> Access to address (4n + 1)



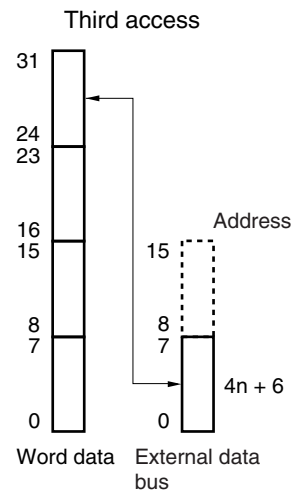
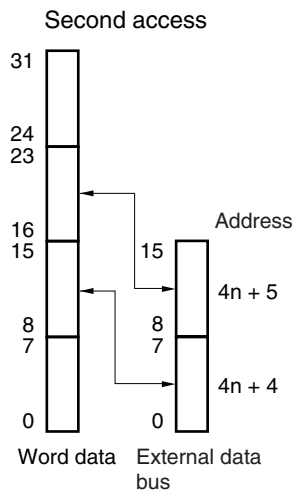
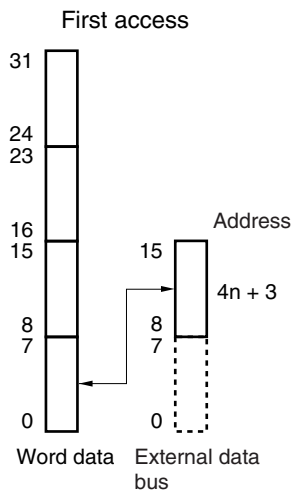


(a) 16-bit data bus width (2/2)

<3> Access to address (4n + 2)

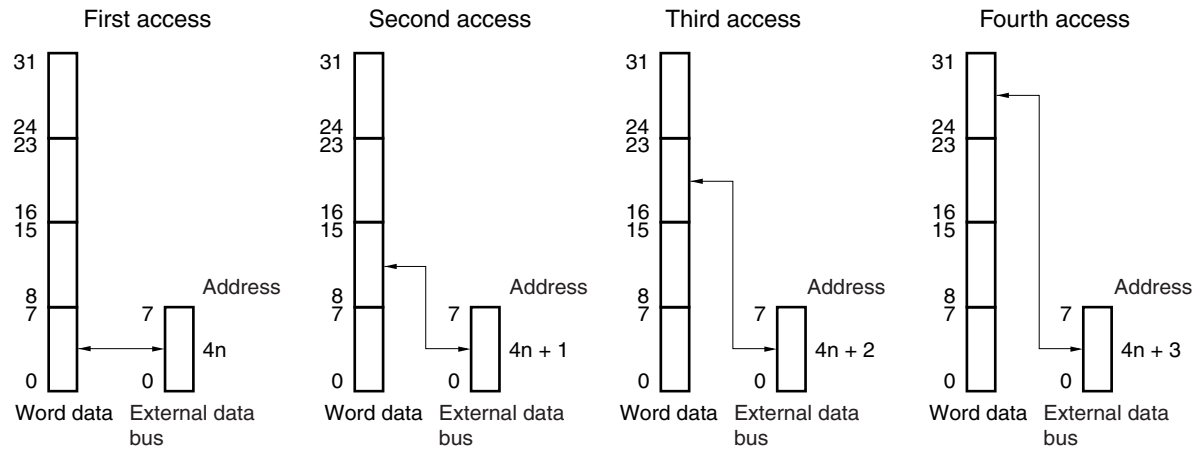


<4> Access to address (4n + 3)

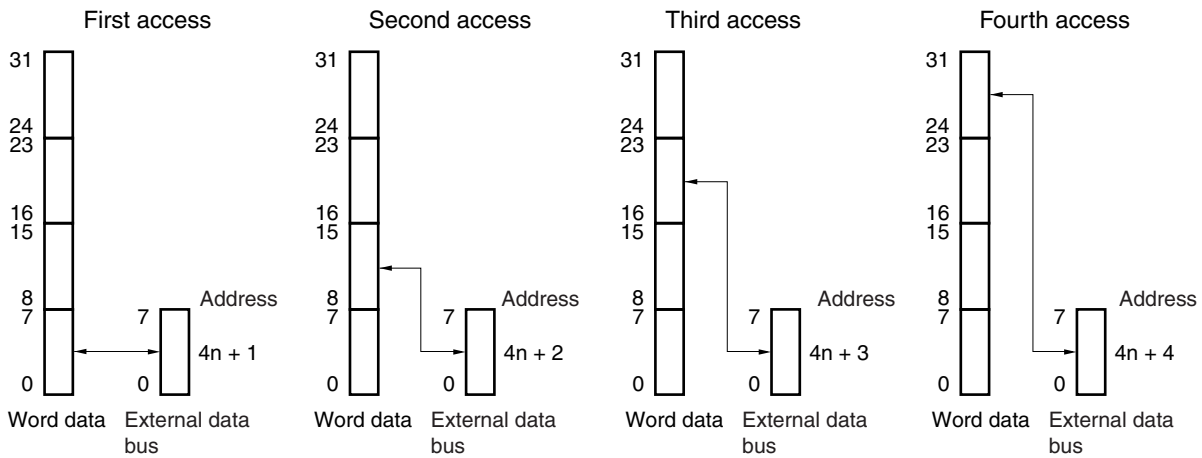


(b) 8-bit data bus width (1/2)

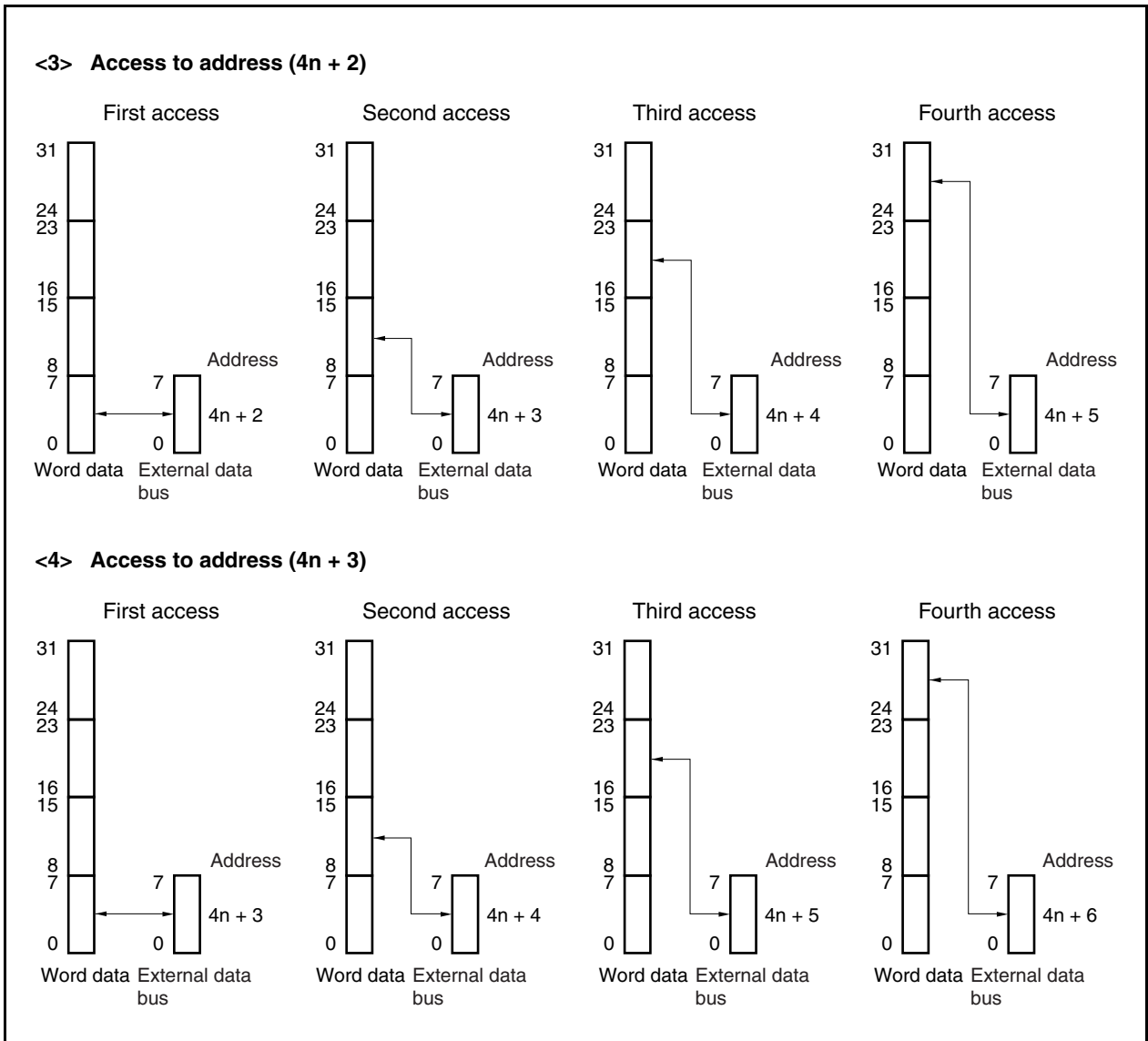
<1> Access to address (4n)



<2> Access to address (4n + 1)



(b) 8-bit data bus width (2/2)



5.6 Wait Function

5.6.1 Programmable wait function

(1) Data wait control register 0 (DWC0)

To realize interfacing with a low-speed memory or I/O, up to seven data wait states can be inserted in the bus cycle that is executed for each CS space.

The number of wait states can be programmed by using the DWC0 register . Immediately after system reset, 7 data wait states are inserted for all the blocks.

The DWC0 register can be read or written in 16-bit units.

Reset sets this register to 7777H.

- Cautions**
1. The internal ROM and internal RAM areas are not subject to programmable wait, and are always accessed without a wait state. The on-chip peripheral I/O area is also not subject to programmable wait, and only wait control from each peripheral function is performed.
  2. Write to the DWC0 register after reset, and then do not change the set values. Also, do not access an external memory area until the initial settings of the DWC0 register are complete.
  3. When the V850ES/JJ3 is used in separate bus mode and operated at  $f_{xx} > 20$  MHz, be sure to insert one or more waits.

After reset: 7777H    R/W    Address: FFFFF484H

|      |     |      |      |      |    |      |      |      |
|------|-----|------|------|------|----|------|------|------|
|      | 15  | 14   | 13   | 12   | 11 | 10   | 9    | 8    |
| DWC0 | 0   | DW32 | DW31 | DW30 | 0  | DW22 | DW21 | DW20 |
|      | CS3 |      |      | CS2  |    |      |      |      |
|      | 7   | 6    | 5    | 4    | 3  | 2    | 1    | 0    |
|      | 0   | DW12 | DW11 | DW10 | 0  | DW02 | DW01 | DW00 |
|      | CS1 |      |      | CS0  |    |      |      |      |

| DWn2 | DWn1 | DWn0 | Number of wait states inserted in CSn space (n = 0 to 3) |                      |                    |
|------|------|------|--|----------------------|--------------------|
|      |      |      | Multiplexed bus  | Separate bus         |                    |
|      |      |      |  | $f_{xx} \leq 20$ MHz | $f_{xx} > 20$ MHz  |
| 0    | 0    | 0    | None   | None                 | Setting prohibited |
| 0    | 0    | 1    | 1  |                      |                    |
| 0    | 1    | 0    | 2  |                      |                    |
| 0    | 1    | 1    | 3  |                      |                    |
| 1    | 0    | 0    | 4  |                      |                    |
| 1    | 0    | 1    | 5  |                      |                    |
| 1    | 1    | 0    | 6  |                      |                    |
| 1    | 1    | 1    | 7  |                      |                    |

**Caution** Be sure to clear bits 15, 11, 7, and 3 to "0".

### 5.6.2 External wait function

To synchronize an extremely slow external memory, I/O, or asynchronous system, any number of wait states can be inserted in the bus cycle by using the external wait pin ( $\overline{\text{WAIT}}$ ).

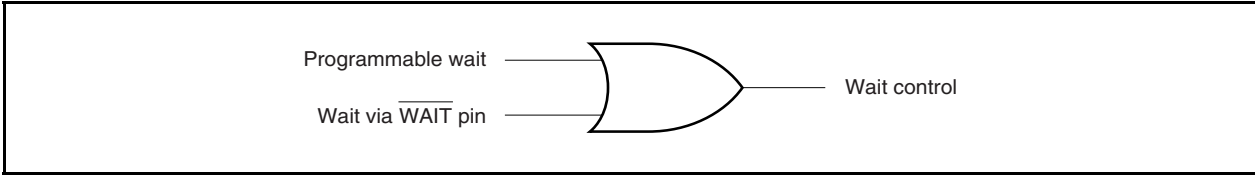
When the PCM0 pin is set to alternate function, the external wait function is enabled.

Access to each area of the internal ROM, internal RAM, and on-chip peripheral I/O is not subject to control by the external wait function, in the same manner as the programmable wait function.

The  $\overline{\text{WAIT}}$  signal can be input asynchronously to CLKOUT, and is sampled at the falling edge of the clock in the T2 and TW states of the bus cycle in the multiplexed bus mode. In the separate bus mode, it is sampled at the rising edge of the clock immediately after the T1 and TW states of the bus cycle. If the setup/hold time of the sampling timing is not satisfied, a wait state is inserted in the next state, or not inserted at all.

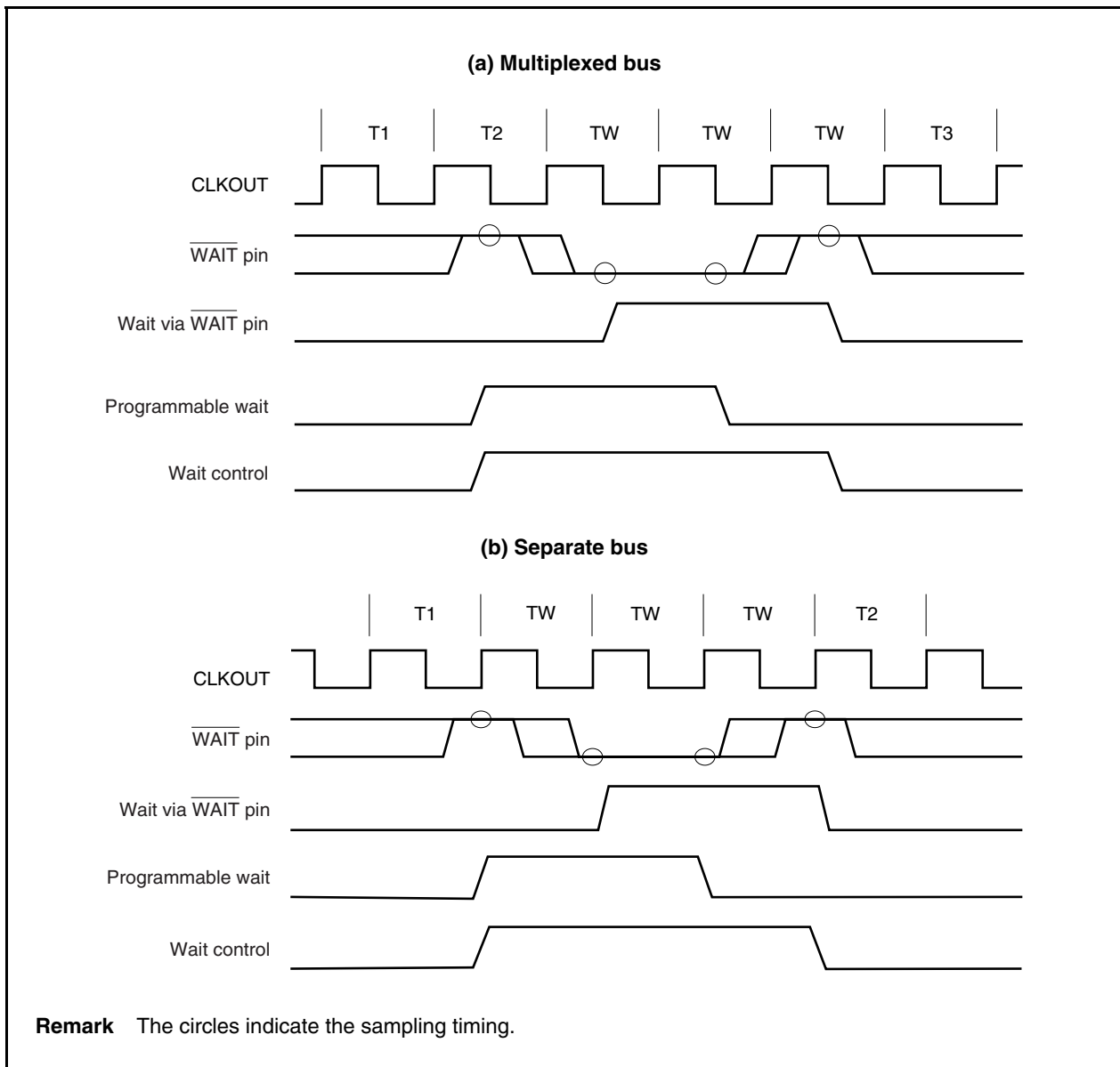
5.6.3 Relationship between programmable wait and external wait

Wait cycles are inserted as the result of an OR operation between the wait cycles specified by the set value of the programmable wait and the wait cycles controlled by the  $\overline{\text{WAIT}}$  pin.



For example, if the timing of the programmable wait and the  $\overline{\text{WAIT}}$  pin signal is as illustrated below, three wait states will be inserted in the bus cycle.

Figure 5-3. Inserting Wait Example



**5.6.4 Programmable address wait function**

Address-setup or address-hold waits to be inserted in each bus cycle can be set by using the AWC register. Address wait insertion is set for each chip select area ( $\overline{CS0}$  to  $\overline{CS3}$ ).

If an address setup wait is inserted, it seems that the high-clock period of the T1 state is extended by 1 clock. If an address hold wait is inserted, it seems that the low-clock period of the T1 state is extended by 1 clock.

**(1) Address wait control register (AWC)**

The AWC register can be read or written in 16-bit units.

Reset sets this register to FFFFH.

- Cautions**
- 1. Address setup wait and address hold wait cycles are not inserted when the internal ROM area, internal RAM area, and on-chip peripheral I/O areas are accessed.**
  - 2. Write to the AWC register after reset, and then do not change the set values. Also, do not access an external memory area until the initial settings of the AWC register are complete.**
  - 3. When the V850ES/JJ3 is operated at  $f_{xx} > 20$  MHz, be sure to insert the address hold wait and the address setup wait.**

After reset: FFFFH    R/W    Address: FFFFF488H

|     |                  |    |                  |    |                  |    |                  |   |
|-----|------------------|----|------------------|----|------------------|----|------------------|---|
|     | 15               | 14 | 13               | 12 | 11               | 10 | 9                | 8 |
| AWC | 1                | 1  | 1                | 1  | 1                | 1  | 1                | 1 |
|     | 7                | 6  | 5                | 4  | 3                | 2  | 1                | 0 |
|     | AHW3             |    | ASW3             |    | AHW2             |    | ASW2             |   |
|     | AHW1             |    | ASW1             |    | AHW0             |    | ASW0             |   |
|     | $\overline{CS3}$ |    | $\overline{CS2}$ |    | $\overline{CS1}$ |    | $\overline{CS0}$ |   |

| AHWn | Specifies insertion of address hold wait (n = 0 to 3) |                    |
|------|---|--------------------|
|      | $f_{xx} \leq 20$ MHz                                  | $f_{xx} > 20$ MHz  |
| 0    | Not inserted  | Setting prohibited |
| 1    | Inserted  | Inserted           |

| ASWn | Specifies insertion of address setup wait (n = 0 to 3) |                    |
|------|--|--------------------|
|      | $f_{xx} \leq 20$ MHz                                   | $f_{xx} > 20$ MHz  |
| 0    | Not inserted   | Setting prohibited |
| 1    | Inserted   | Inserted           |

**Caution** Be sure to set bits 15 to 8 to “1”.

## 5.7 Idle State Insertion Function

To facilitate interfacing with low-speed memories, one idle state (TI) can be inserted after the T3 state in the bus cycle that is executed for each space selected by the chip select function in the multiplex address/data bus mode. In the separate bus mode, one idle state (TI) can be inserted after the T2 state. By inserting an idle state, the data output float delay time of the memory can be secured during read access (an idle state cannot be inserted during write access).

Whether the idle state is to be inserted can be programmed by using the BCC register.

An idle state is inserted for all the areas immediately after system reset.

### (1) Bus cycle control register (BCC)

The BCC register can be read or written in 16-bit units.

Reset sets this register to AAAAH.

**Cautions 1. The internal ROM, internal RAM, and on-chip peripheral I/O areas are not subject to idle state insertion.**

**2. Write to the BCC register after reset, and then do not change the set values. Also, do not access an external memory area until the initial settings of the BCC register are complete.**

After reset: AAAAH    R/W    Address: FFFFF48AH

|     |                          |    |                          |    |                          |    |                          |   |
|-----|--------------------------|----|--------------------------|----|--------------------------|----|--------------------------|---|
|     | 15                       | 14 | 13                       | 12 | 11                       | 10 | 9                        | 8 |
| BCC | 1                        | 0  | 1                        | 0  | 1                        | 0  | 1                        | 0 |
|     | 7                        | 6  | 5                        | 4  | 3                        | 2  | 1                        | 0 |
|     | BC31                     | 0  | BC21                     | 0  | BC11                     | 0  | BC01                     | 0 |
|     | <input type="checkbox"/> |    | <input type="checkbox"/> |    | <input type="checkbox"/> |    | <input type="checkbox"/> |   |
|     | CS3                      |    | CS2                      |    | CS1                      |    | CS0                      |   |

|      |  |
|------|--|
| BCn1 | Specifies insertion of idle state (n = 0 to 3) |
| 0    | Not inserted                                   |
| 1    | Inserted                                       |

**Caution** Be sure to set bits 15, 13, 11, and 9 to “1”, and clear bits 14, 12, 10, 8, 6, 4, 2, and 0 to “0”.



## 5.8 Bus Hold Function

### 5.8.1 Functional outline

The  $\overline{\text{HLDRQ}}$  and  $\overline{\text{HLDAK}}$  functions are valid if the PCM2 and PCM3 pins are set to alternate function.

When the  $\overline{\text{HLDRQ}}$  pin is asserted (low level), indicating that another bus master has requested bus mastership, the external address/data bus goes into a high-impedance state and is released (bus hold status). If the request for the bus mastership is cleared and the  $\overline{\text{HLDRQ}}$  pin is deasserted (high level), driving these pins is started again.

During the bus hold period, execution of the program in the internal ROM and internal RAM is continued until an on-chip peripheral I/O register or the external memory is accessed.

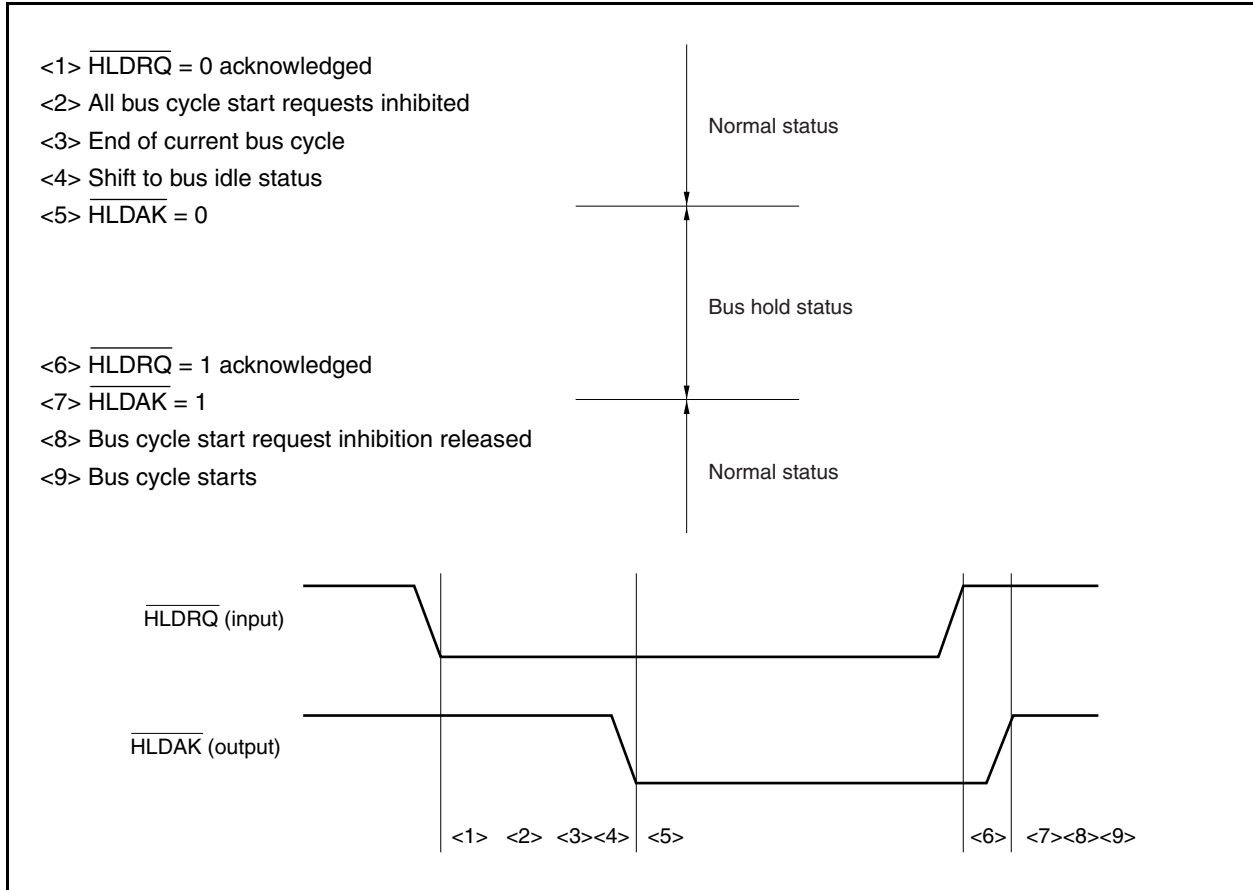
The bus hold status is indicated by assertion of the  $\overline{\text{HLDAK}}$  pin (low level). The bus hold function enables the configuration of multi-processor type systems in which two or more bus masters exist.

Note that the bus hold request is not acknowledged during a multiple-access cycle initiated by the bus sizing function or a bit manipulation instruction.

| Status   | Data Bus Width                  | Access Type                    | Timing at Which Bus Hold Request Is Not Acknowledged |
|--|---------------------------------|--------------------------------|--|
| CPU bus lock   | 16 bits                         | Word access to even address    | Between first and second access                      |
|  |                                 | Word access to odd address     | Between first and second access                      |
|  |                                 |                                | Between second and third access                      |
|  | 8 bits                          | Halfword access to odd address | Between first and second access                      |
|  |                                 | Word access                    | Between first and second access                      |
|  |                                 |                                | Between second and third access                      |
|  |                                 |                                | Between third and fourth access                      |
| Halfword access  | Between first and second access |                                |  |
| Read-modify-write access of bit manipulation instruction | –                               | –                              | Between read access and write access                 |

**5.8.2 Bus hold procedure**

The bus hold status transition procedure is shown below.



**5.8.3 Operation in power save mode**

Because the internal system clock is stopped in the STOP, IDLE1, and IDLE2 modes, the bus hold status is not entered even if the  $\overline{\text{HLDARQ}}$  pin is asserted.

In the HALT mode, the  $\overline{\text{HLDARQ}}$  pin is asserted as soon as the  $\overline{\text{HLDARQ}}$  pin has been asserted, and the bus hold status is entered. When the  $\overline{\text{HLDARQ}}$  pin is later deasserted, the  $\overline{\text{HLDARQ}}$  pin is also deasserted, and the bus hold status is cleared.

## 5.9 Bus Priority

Bus hold, DMA transfer, operand data accesses, instruction fetch (branch), and instruction fetch (successive) are executed in the external bus cycle.

Bus hold has the highest priority, followed by DMA transfer, operand data access, instruction fetch (branch), and instruction fetch (successive).

An instruction fetch may be inserted between the read access and write access in a read-modify-write access.

If an instruction is executed for two or more accesses, an instruction fetch and bus hold are not inserted between accesses due to bus size limitations.

**Table 5-4. Bus Priority**

| Priority              | External Bus Cycle             | Bus Master      |
|-----------------------|--------------------------------|-----------------|
| High<br>↑<br>↓<br>Low | Bus hold                       | External device |
|                       | DMA transfer                   | DMAC            |
|                       | Operand data access            | CPU             |
|                       | Instruction fetch (branch)     | CPU             |
|                       | Instruction fetch (successive) | CPU             |

5.10 Bus Timing

Figure 5-4. Multiplexed Bus Read Timing (Bus Size: 16 Bits, 16-Bit Access)

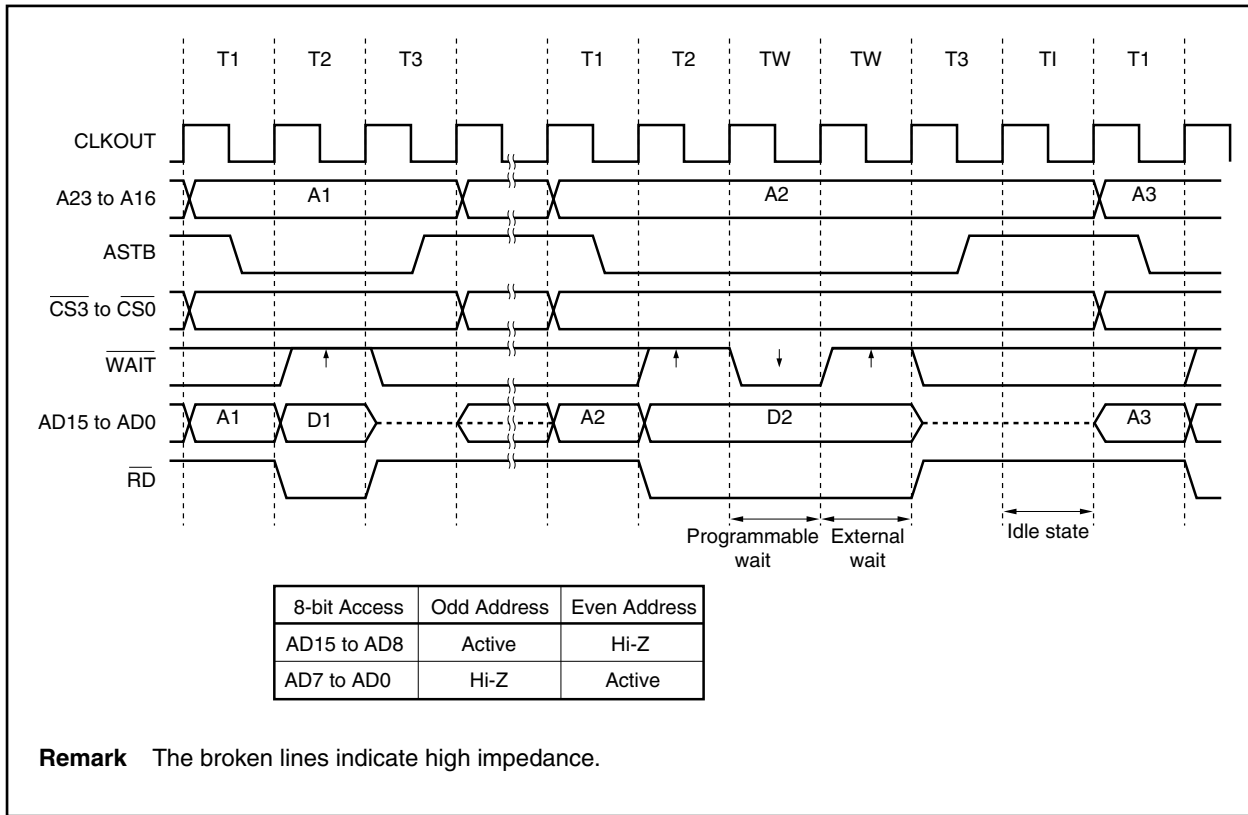


Figure 5-5. Multiplexed Bus Read Timing (Bus Size: 8 Bits)

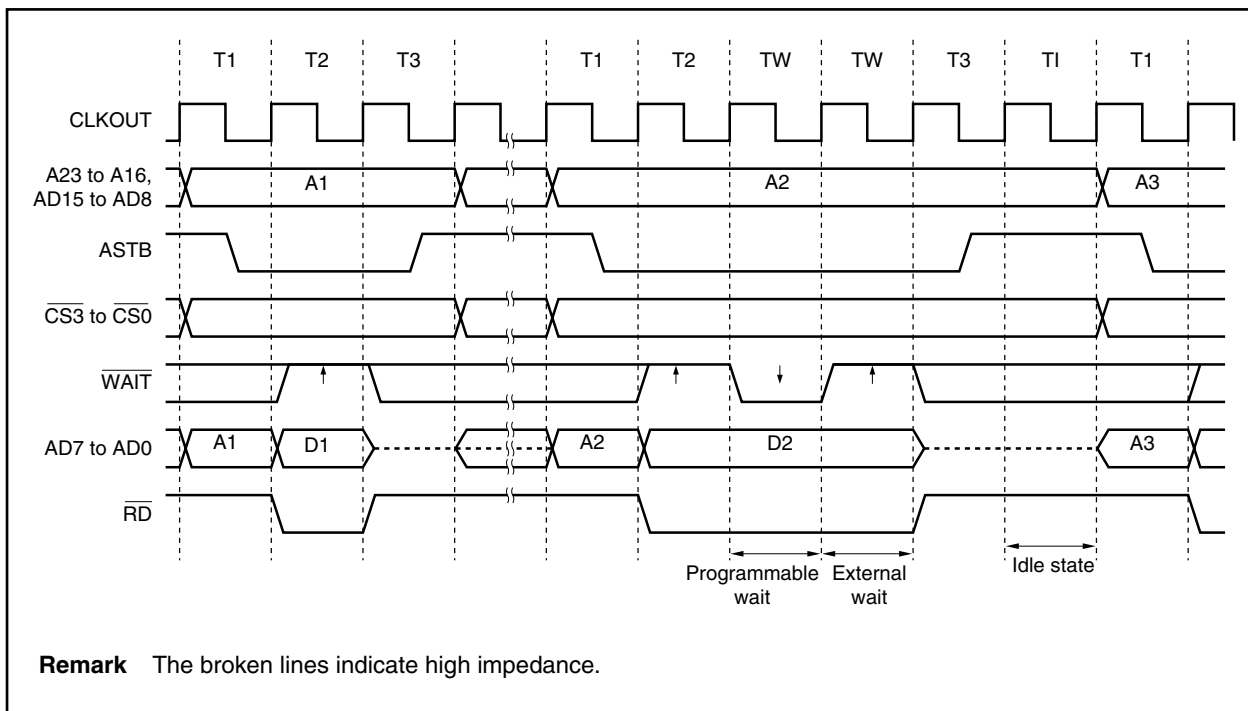


Figure 5-6. Multiplexed Bus Write Timing (Bus Size: 16 Bits, 16-Bit Access)

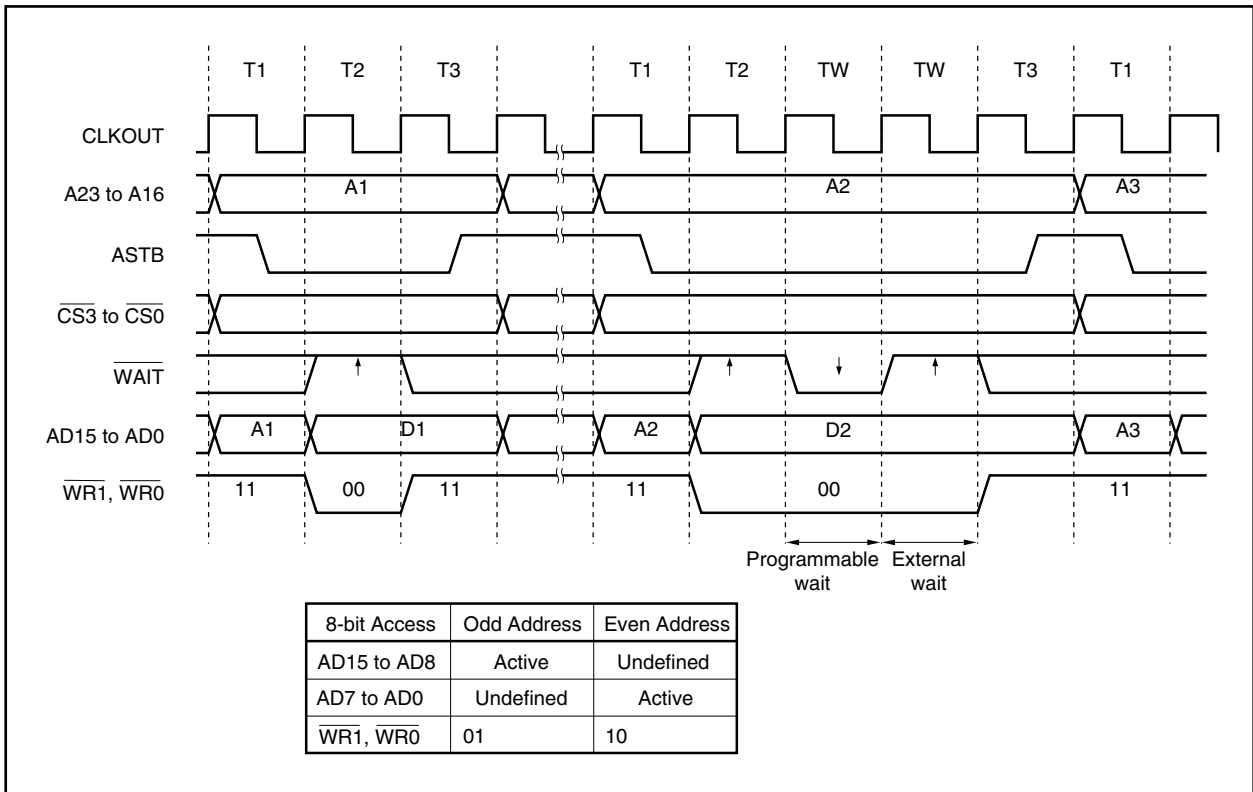


Figure 5-7. Multiplexed Bus Write Timing (Bus Size: 8 Bits)

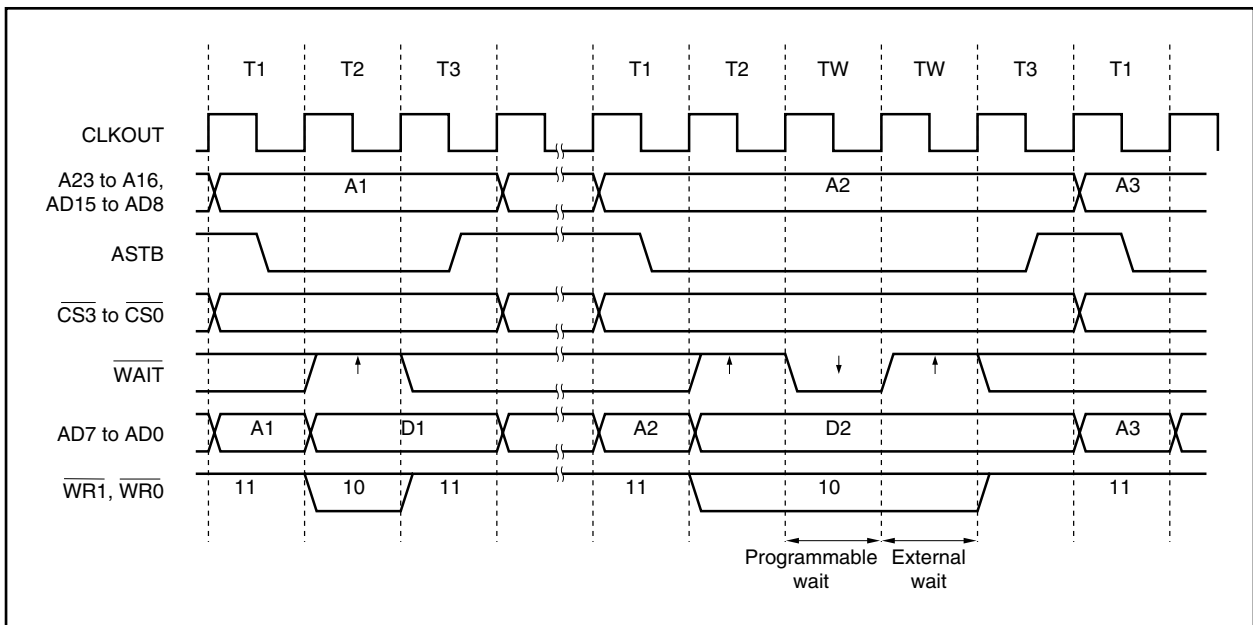


Figure 5-8. Multiplexed Bus Hold Timing (Bus Size: 16 Bits, 16-Bit Access)

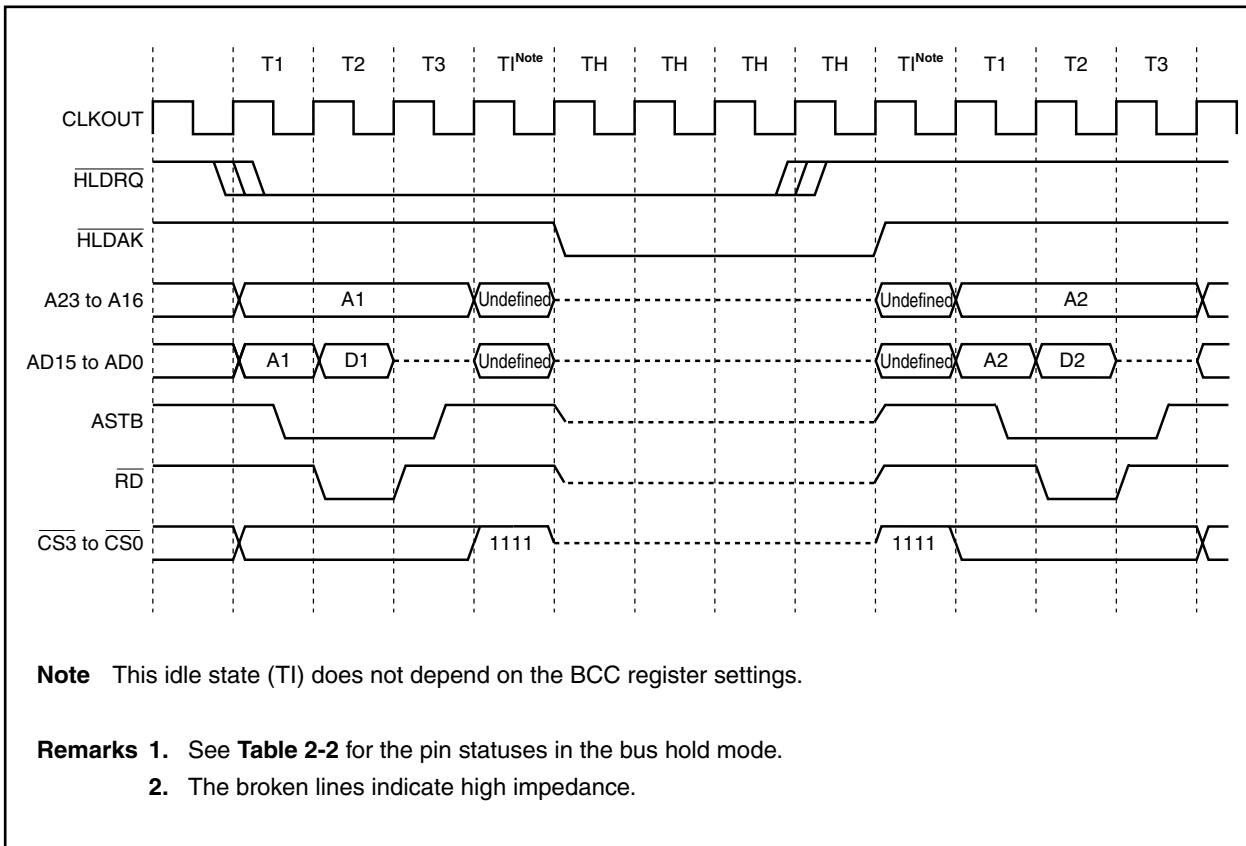


Figure 5-9. Separate Bus Read Timing (Bus Size: 16 Bits, 16-Bit Access)

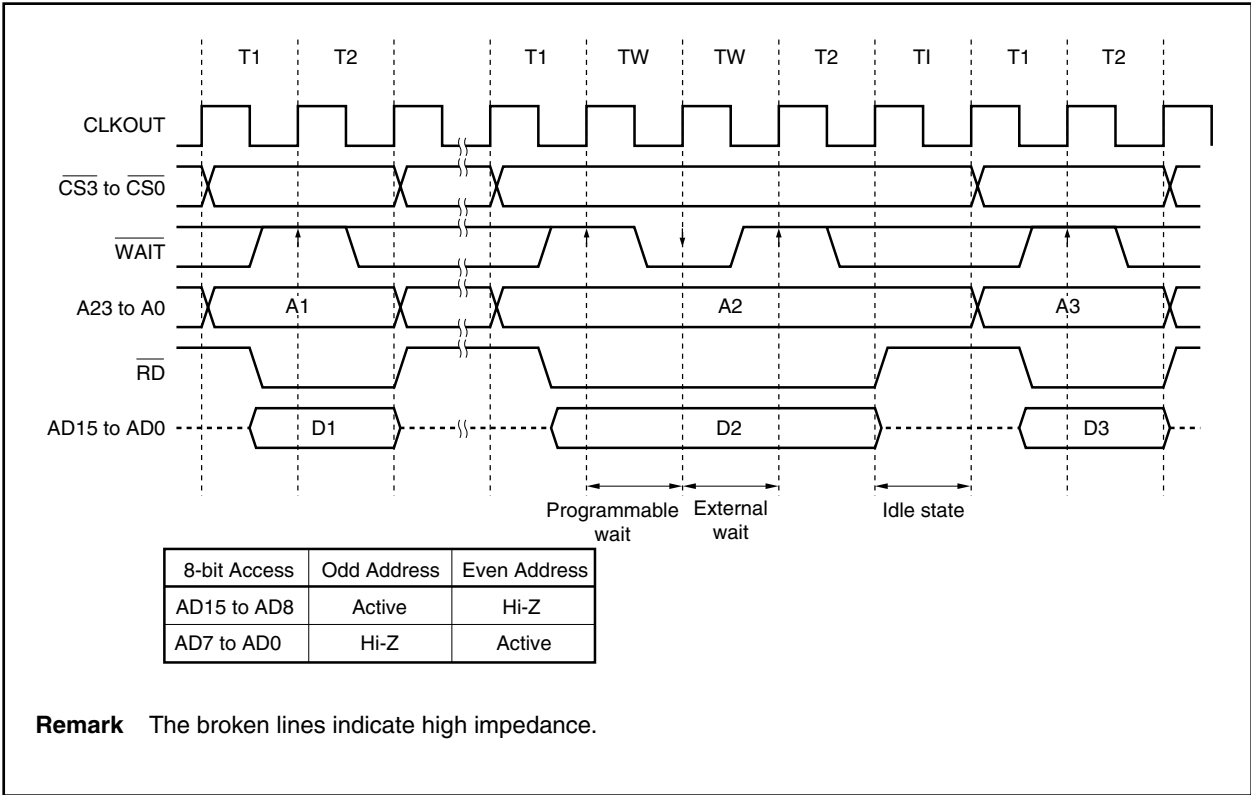


Figure 5-10. Separate Bus Read Timing (Bus Size: 8 Bits)

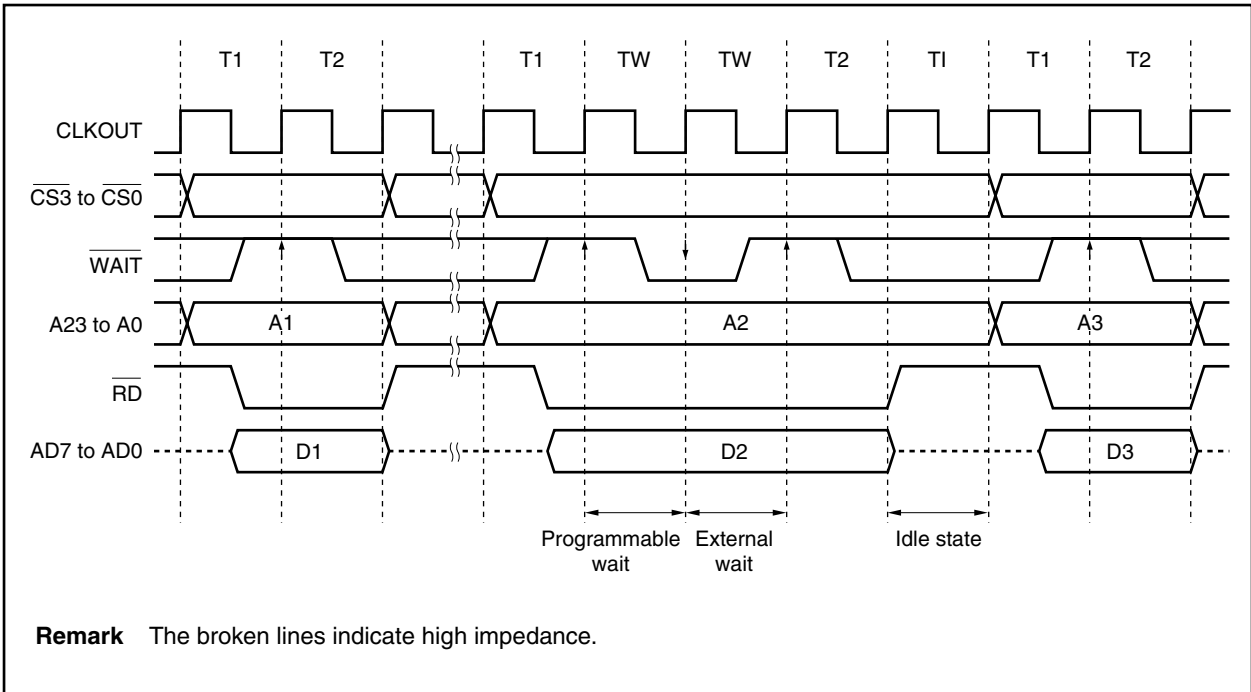
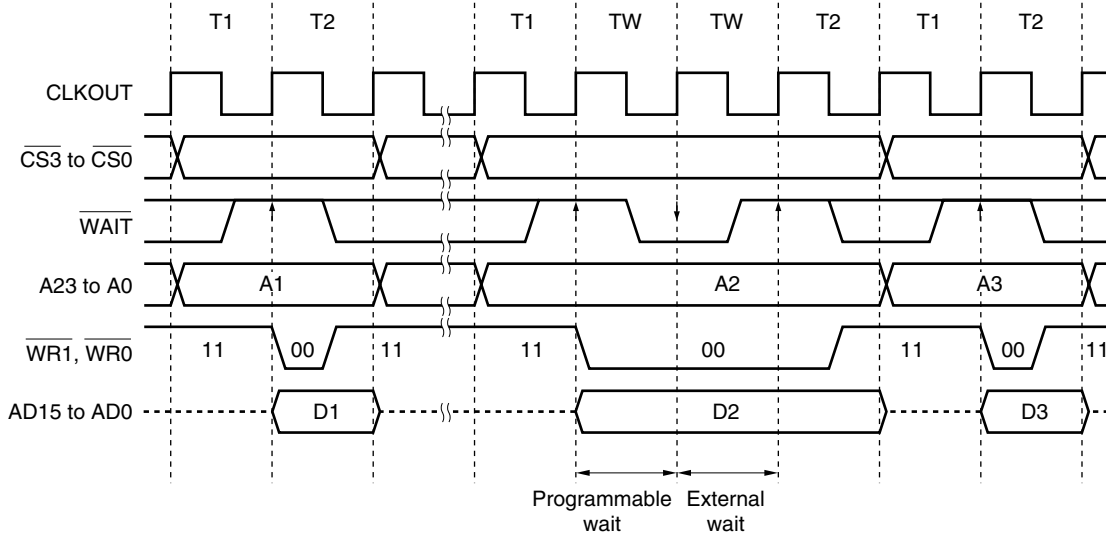


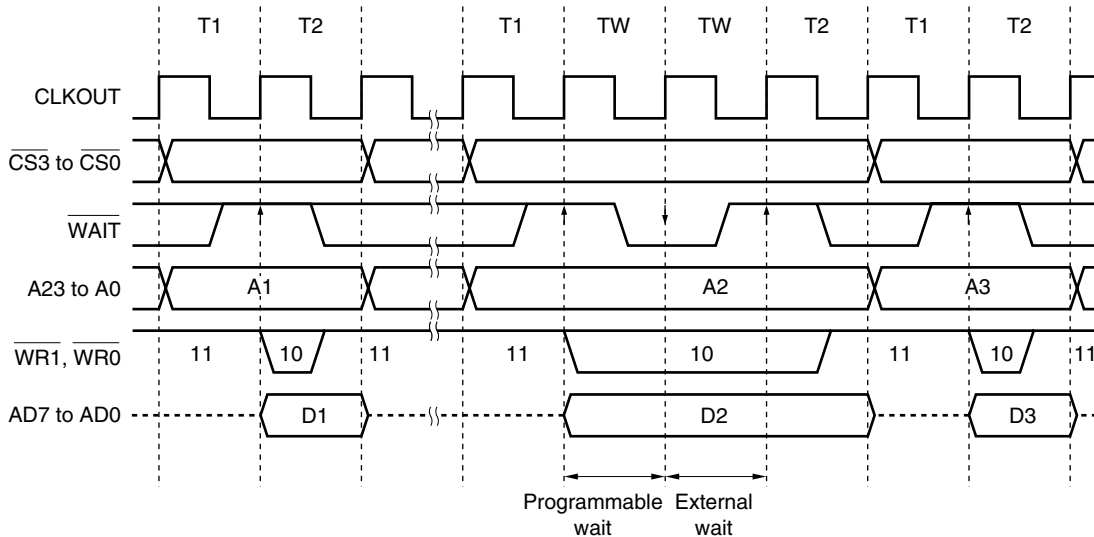
Figure 5-11. Separate Bus Write Timing (Bus Size: 16 Bits, 16-Bit Access)



| 8-bit Access | Odd Address | Even Address |
|--------------|-------------|--------------|
| AD15 to AD8  | Active      | Undefined    |
| AD7 to AD0   | Undefined   | Active       |
| WR1, WR0     | 01          | 10           |

**Remark** The broken lines indicate high impedance.

Figure 5-12. Separate Bus Write Timing (Bus Size: 8 Bits)



**Remark** The broken lines indicate high impedance.



Figure 5-13. Separate Bus Hold Timing (Bus Size: 8 Bits, Write)

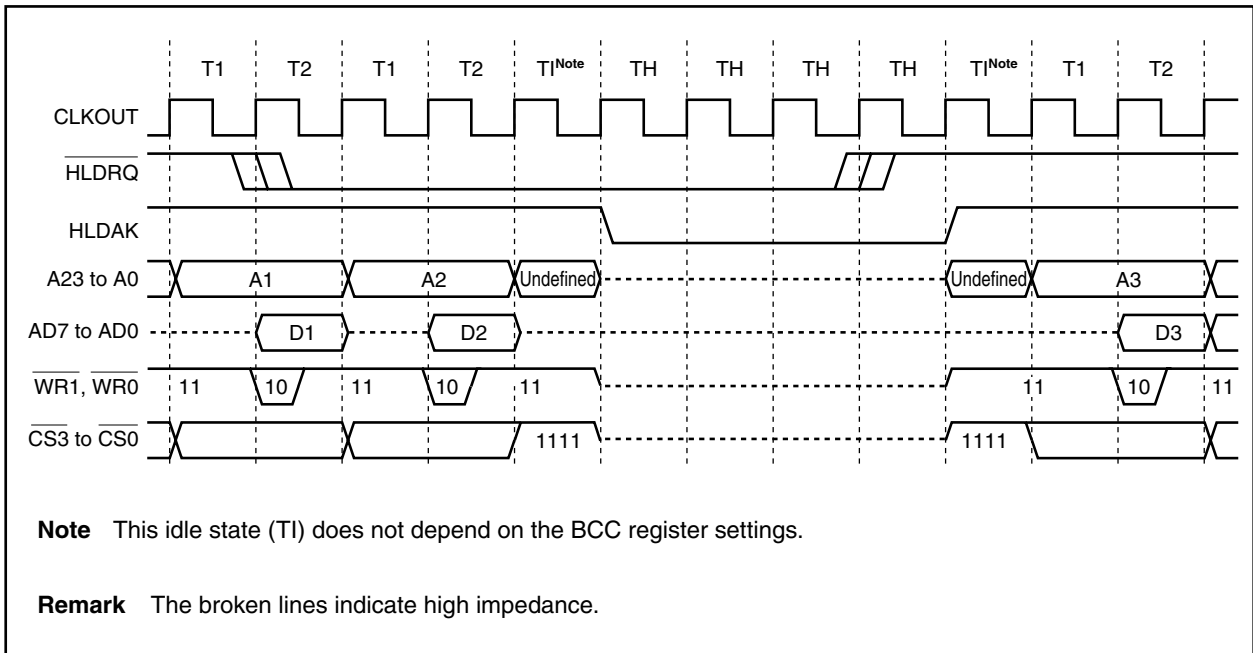
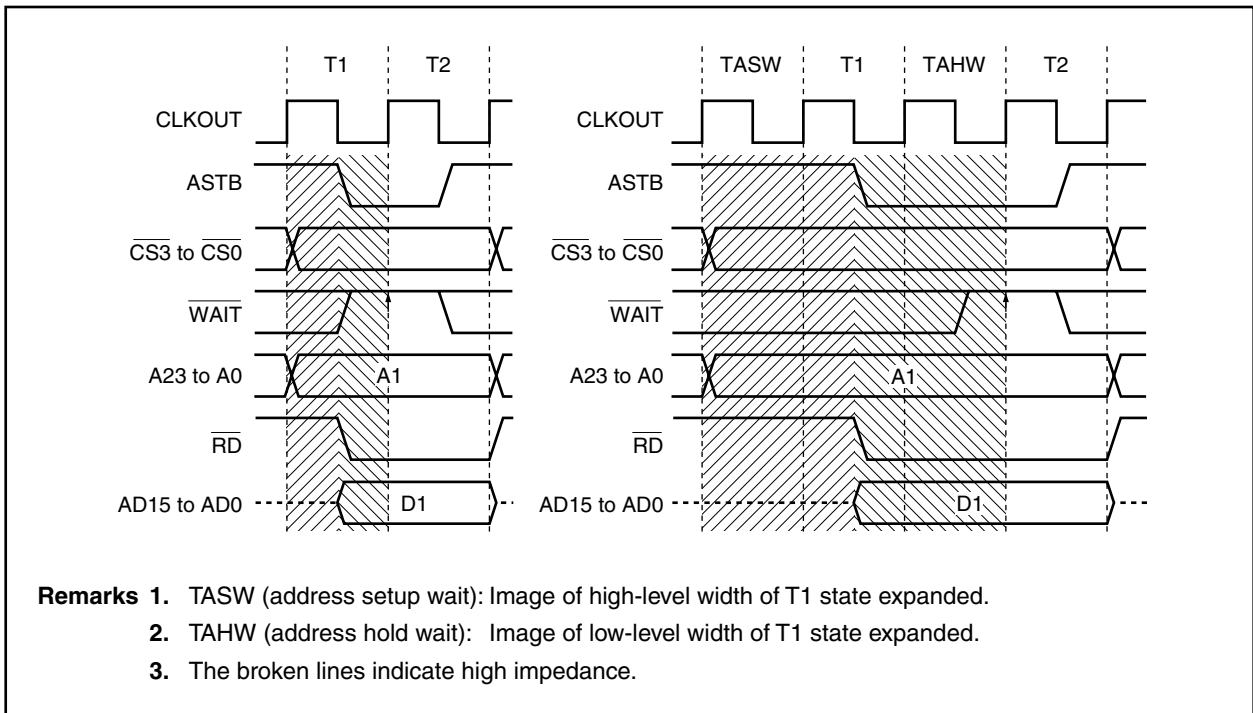


Figure 5-14. Address Wait Timing (Separate Bus Read, Bus Size: 16 Bits, 16-Bit Access)



## CHAPTER 6 CLOCK GENERATION FUNCTION

### 6.1 Overview

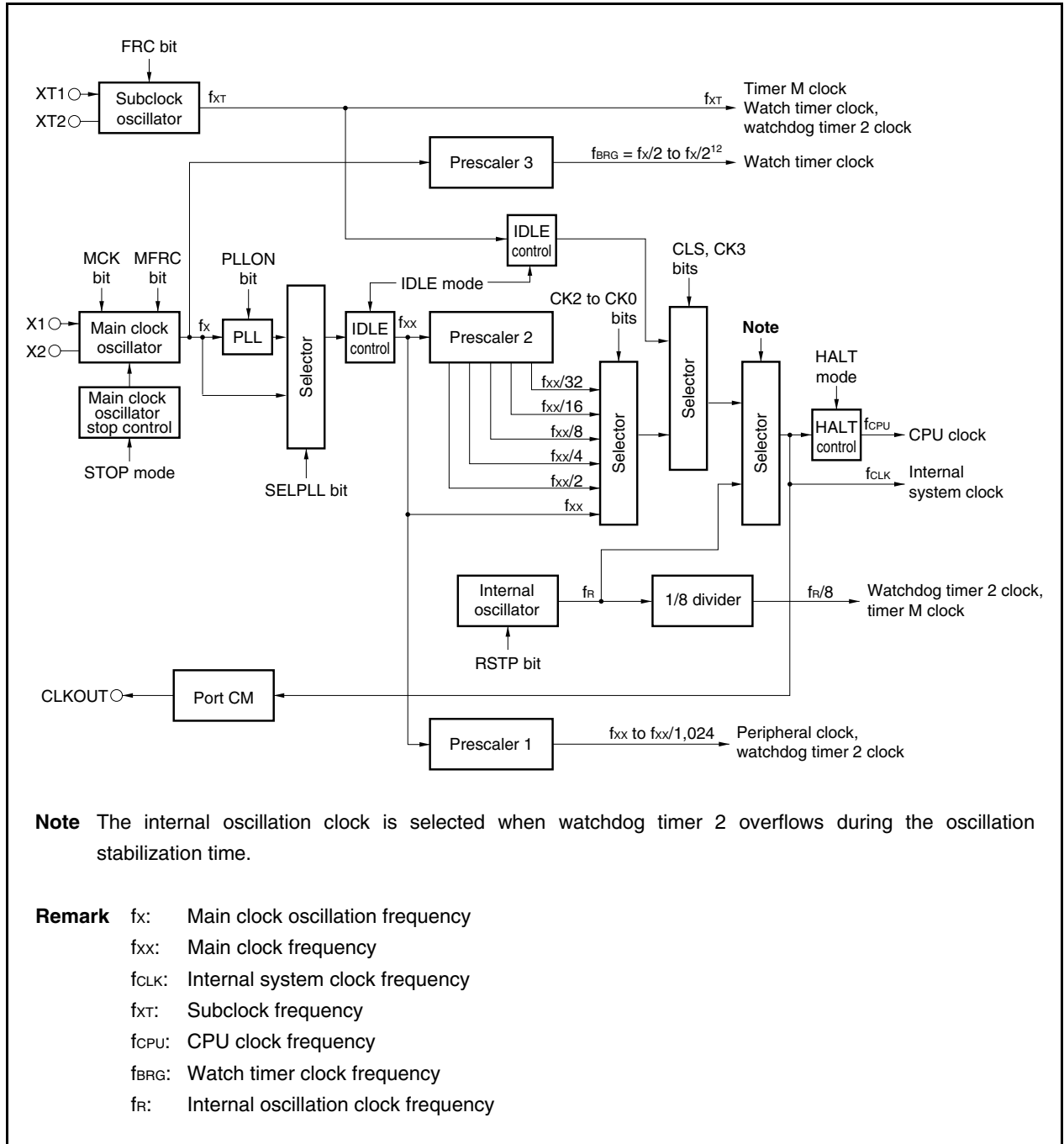
The following clock generation functions are available.

- Main clock oscillator
  - In clock-through mode  
 $f_x = 2.5$  to  $10$  MHz ( $f_{xx} = 2.5$  to  $10$  MHz)
  - In PLL mode  
 $f_x = 2.5$  to  $5$  MHz ( $\times 4$ :  $f_{xx} = 10$  to  $20$  MHz)  
 $f_x = 2.5$  to  $4$  MHz ( $\times 8$ :  $f_{xx} = 20$  to  $32$  MHz)
- Subclock oscillator
  - $f_{xT} = 32.768$  kHz
- Multiply ( $\times 4/\times 8$ ) function by PLL (Phase Locked Loop)
  - Clock-through mode/PLL mode selectable
- Internal oscillator
  - $f_R = 220$  kHz (TYP.)
- Internal system clock generation
  - 7 steps ( $f_{xx}$ ,  $f_{xx}/2$ ,  $f_{xx}/4$ ,  $f_{xx}/8$ ,  $f_{xx}/16$ ,  $f_{xx}/32$ ,  $f_{xT}$ )
- Peripheral clock generation
- Clock output function

**Remark**  $f_x$ : Main clock oscillation frequency  
 $f_{xx}$ : Main clock frequency  
 $f_{xT}$ : Subclock frequency  
 $f_R$ : Internal oscillation clock frequency

6.2 Configuration

Figure 6-1. Clock Generator



**(1) Main clock oscillator**

The main resonator oscillates the following frequencies ( $f_x$ ).

- In clock-through mode  
 $f_x = 2.5$  to  $10$  MHz
- In PLL mode  
 $f_x = 2.5$  to  $5$  MHz ( $\times 4$ )  
 $f_x = 2.5$  to  $4$  MHz ( $\times 8$ )

**(2) Subclock oscillator**

The sub-resonator oscillates a frequency of  $32.768$  kHz ( $f_{XT}$ ).

**(3) Main clock oscillator stop control**

This circuit generates a control signal that stops oscillation of the main clock oscillator.

Oscillation of the main clock oscillator is stopped in the STOP mode or when the PCC.MCK bit = 1 (valid only when the PCC.CLS bit = 1).

**(4) Internal oscillator**

Oscillates a frequency ( $f_R$ ) of  $220$  kHz (TYP.).

**(5) Prescaler 1**

This prescaler generates the clock ( $f_{xx}$  to  $f_{xx}/1,024$ ) to be supplied to the following on-chip peripheral functions: TMP0 to TMP8, TMQ0, TMM0, CSIB0 to CSIB5, UARTA0 to UARTA3, I<sup>2</sup>C00 to I<sup>2</sup>C02, ADC, and WDT2

**(6) Prescaler 2**

This circuit divides the main clock ( $f_{xx}$ ).

The clock generated by prescaler 2 ( $f_{xx}$  to  $f_{xx}/32$ ) is supplied to the selector that generates the CPU clock ( $f_{CPU}$ ) and internal system clock ( $f_{CLK}$ ).

$f_{CLK}$  is the clock supplied to the INTC, ROM, and RAM blocks, and can be output from the CLKOUT pin.

**(7) Prescaler 3**

This circuit divides the clock generated by the main clock oscillator ( $f_x$ ) to a specific frequency ( $32.768$  kHz) and supplies that clock to the watch timer block.

For details, see **CHAPTER 10 WATCH TIMER FUNCTIONS**.

**(8) PLL**

This circuit multiplies the clock generated by the main clock oscillator ( $f_x$ ) by 4 or 8.

It operates in two modes: clock-through mode in which  $f_x$  is output as is, and PLL mode in which a multiplied clock is output. These modes can be selected by using the PLLCTL.SELPLL bit.

Whether the clock is multiplied by 4 or 8 is selected by the CKC.CKDIV0 bit, and PLL is started or stopped by the PLLCTL.PLLON bit.

## 6.3 Registers

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

The PCC register is a special register. Data can be written to this register only in combination of specific sequences (see **3.4.7 Special registers**).

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 03H.

After reset: 03H R/W Address: FFFFF828H

|   | 7   | <6> | 5    | <4>                                   | <3> | 2   | 1   | 0   |
|---|---|-----|------|---------------------------------------|-----|-----|-----|-----|
| PCC   | FRC   | MCK | MFRC | CLS <sup>Note</sup>                   | CK3 | CK2 | CK1 | CK0 |
| FRC   | Use of subclock on-chip feedback resistor   |     |      |                                       |     |     |     |     |
| 0   | Used  |     |      |                                       |     |     |     |     |
| 1   | Not used                                    |     |      |                                       |     |     |     |     |
| MCK   | Main clock oscillator control               |     |      |                                       |     |     |     |     |
| 0   | Oscillation enabled                         |     |      |                                       |     |     |     |     |
| 1   | Oscillation stopped                         |     |      |                                       |     |     |     |     |
| <ul style="list-style-type: none"> <li>• Even if the MCK bit is set (1) while the system is operating with the main clock as the CPU clock, the operation of the main clock does not stop. It stops after the CPU clock has been changed to the subclock.</li> <li>• Before setting the MCK bit from 0 to 1, stop the on-chip peripheral functions operating with the main clock.</li> <li>• When the main clock is stopped and the device is operating with the subclock, clear (0) the MCK bit and secure the oscillation stabilization time by software before switching the CPU clock to the main clock or operating the on-chip peripheral functions.</li> </ul> |   |     |      |                                       |     |     |     |     |
| MFRC  | Use of main clock on-chip feedback resistor |     |      |                                       |     |     |     |     |
| 0   | Used  |     |      |                                       |     |     |     |     |
| 1   | Not used                                    |     |      |                                       |     |     |     |     |
| CLS <sup>Note</sup>   | Status of CPU clock ( $f_{CPU}$ )           |     |      |                                       |     |     |     |     |
| 0   | Main clock operation                        |     |      |                                       |     |     |     |     |
| 1   | Subclock operation                          |     |      |                                       |     |     |     |     |
| CK3   | CK2   | CK1 | CK0  | Clock selection ( $f_{CLK}/f_{CPU}$ ) |     |     |     |     |
| 0   | 0   | 0   | 0    | $f_{xx}$                              |     |     |     |     |
| 0   | 0   | 0   | 1    | $f_{xx}/2$                            |     |     |     |     |
| 0   | 0   | 1   | 0    | $f_{xx}/4$                            |     |     |     |     |
| 0   | 0   | 1   | 1    | $f_{xx}/8$                            |     |     |     |     |
| 0   | 1   | 0   | 0    | $f_{xx}/16$                           |     |     |     |     |
| 0   | 1   | 0   | 1    | $f_{xx}/32$                           |     |     |     |     |
| 0   | 1   | 1   | ×    | Setting prohibited                    |     |     |     |     |
| 1   | ×   | ×   | ×    | $f_{XT}$                              |     |     |     |     |

**Note** The CLS bit is a read-only bit.

- Cautions**
1. Do not change the CPU clock (by using the CK3 to CK0 bits) while CLKOUT is being output.
  2. Use a bit manipulation instruction to manipulate the CK3 bit. When using an 8-bit manipulation instruction, do not change the set values of the CK2 to CK0 bits.

**Remark** ×: don't care

**(a) Example of setting main clock operation → subclock operation**

- <1> CK3 bit ← 1: Use of a bit manipulation instruction is recommended. Do not change the CK2 to CK0 bits.
- <2> Subclock operation: Read the CLS bit to check if subclock operation has started. It takes the following time after the CK3 bit is set until subclock operation is started.  
Max.:  $1/f_{XT}$  (1/subclock frequency)
- <3> MCK bit ← 1: Set the MCK bit to 1 only when stopping the main clock.

**Cautions 1. When stopping the main clock, stop the PLL. Also stop the operations of the on-chip peripheral functions operating with the main clock.**

- 2. If the following conditions are not satisfied, change the CK2 to CK0 bits so that the conditions are satisfied, then change to the subclock operation mode.**

**Internal system clock ( $f_{CLK}$ ) > Subclock ( $f_{XT}$ : 32.768 kHz) × 4**

**Remark** Internal system clock ( $f_{CLK}$ ): Clock generated from the main clock ( $f_{XX}$ ) by setting bits CK2 to CK0

[Description example]

```

_DMA_DISABLE:
    clr1      0, DCHCn[r0]      -- DMA operation disabled. n = 0 to 3
<1> _SET_SUB_RUN :
    st.b      r0, PRCMD[r0]
    set1      3, PCC[r0]      -- CK3 bit ← 1
<2> _CHECK_CLS :
    tst1      4, PCC[r0]      -- Wait until subclock operation starts.
    bz        _CHECK_CLS
<3> _STOP_MAIN_CLOCK :
    st.b      r0, PRCMD[r0]
    set1      6, PCC[r0]      -- MCK bit ← 1, main clock is stopped.
_DMA_ENABLE:
    set1      0, DCHCn[r0]      -- DMA operation enabled. n = 0 to 3

```

**Remark** The description above is simply an example. Note that in <2> above, the CLS bit is read in a closed loop.

**(b) Example of setting subclock operation → main clock operation**

- <1> MCK bit ← 0: Main clock starts oscillating
- <2> Insert waits by the program and wait until the oscillation stabilization time of the main clock elapses.
- <3> CK3 bit ← 0: Use of a bit manipulation instruction is recommended. Do not change the CK2 to CK0 bits.
- <4> Main clock operation: It takes the following time after the CK3 bit is set until main clock operation is started.  
 Max.:  $1/f_{XT}$  (1/subclock frequency)  
 Therefore, insert one NOP instruction immediately after setting the CK3 bit to 0 or read the CLS bit to check if main clock operation has started.

**Caution** Enable operation of the on-chip peripheral functions operating with the main clock only after the oscillation of the main clock stabilizes. If their operations are enabled before the lapse of the oscillation stabilization time, a malfunction may occur.

[Description example]

```

_DMA_DISABLE:
  clr1      0, DCHCn[r0]          -- DMA operation disabled. n = 0 to 3
<1> _START_MAIN_OSC :
  st.b      r0, PRCMD[r0]        -- Release of protection of special registers
  clr1      6, PCC[r0]           -- Main clock starts oscillating.
<2> movea    0x55, r0, r11        -- Wait for oscillation stabilization time.
  _WAIT_OST :
  nop
  nop
  nop
  addi      -1, r11, r11
  cmp       r0, r11
  bne                      _WAIT_OST
<3> st.b     r0, PRCMD[r0]
  clr1      3, PCC[r0]           -- CK3 ← 0
<4> _CHECK_CLS :
  tst1      4, PCC[r0]           -- Wait until main clock operation starts.
  bnz      _CHECK_CLS
_DMA_ENABLE:
  set1      0, DCHCn[r0]        -- DMA operation enabled. n = 0 to 3

```

**Remark** The description above is simply an example. Note that in <4> above, the CLS bit is read in a closed loop.



**(2) Internal oscillation mode register (RCM)**

The RCM register is an 8-bit register that sets the operation mode of the internal oscillator.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF80CH

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

|       |   |
|-------|---|
| RSTOP | Oscillation/stop of internal oscillator |
| 0     | Internal oscillator oscillation         |
| 1     | Internal oscillator stopped             |

- Cautions**
1. The internal oscillator cannot be stopped while the CPU is operating on the internal oscillation clock (CCLS.CCLS<sub>F</sub> bit = 1). Do not set the RSTOP bit to 1.
  2. The internal oscillator oscillates if the CCLS.CCLS<sub>F</sub> bit is set to 1 (when WDT overflow occurs during oscillation stabilization) even when the RSTOP bit is set to 1. At this time, the RSTOP bit remains being set to 1.

**(3) CPU operation clock status register (CCLS)**

The CCLS register indicates the status of the CPU operation clock.

This register is read-only, in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H<sup>Note</sup>    R    Address: FFFFF82EH

|      |   |   |   |   |   |   |   |                   |
|------|---|---|---|---|---|---|---|-------------------|
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0                 |
| CCLS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | CCLS <sub>F</sub> |

|                   |   |
|-------------------|---|
| CCLS <sub>F</sub> | CPU operation clock status  |
| 0                 | Operating on main clock (f <sub>x</sub> ) or subclock (f <sub>xT</sub> ). |
| 1                 | Operating on internal oscillation clock (f <sub>R</sub> ).                |

**Note** If WDT overflow occurs during oscillation stabilization after a reset is released, the CCLS<sub>F</sub> bit is set to 1 and the reset value is 01H.

## 6.4 Operation

### 6.4.1 Operation of each clock

The following table shows the operation status of each clock.

**Table 6-1. Operation Status of Each Clock**

| Register Setting and<br>Operation Status<br><br>Target Clock | PCC Register             |  |              |                         |              |                             |                  |                             |                  |
|--|--------------------------|--|--------------|-------------------------|--------------|-----------------------------|------------------|-----------------------------|------------------|
|  | CLK Bit = 0, MCK Bit = 0 |  |              |                         |              | CLS Bit = 1,<br>MCK Bit = 0 |                  | CLS Bit = 1,<br>MCK Bit = 1 |                  |
|  | During<br>Reset          | During<br>Oscillation<br>Stabilization<br>Time Count | HALT<br>Mode | IDLE1,<br>IDLE2<br>Mode | STOP<br>Mode | Subclock<br>Mode            | Sub-IDLE<br>Mode | Subclock<br>Mode            | Sub-IDLE<br>Mode |
| Main clock oscillator (fx)                                   | ×                        | ○  | ○            | ○                       | ×            | ○                           | ○                | ×                           | ×                |
| Subclock oscillator (fxT)                                    | ○                        | ○  | ○            | ○                       | ○            | ○                           | ○                | ○                           | ○                |
| CPU clock (f <sub>CPU</sub> )                                | ×                        | ×  | ×            | ×                       | ×            | ○                           | ×                | ○                           | ×                |
| Internal system clock (f <sub>CLK</sub> )                    | ×                        | ×  | ○            | ×                       | ×            | ○                           | ×                | ○                           | ×                |
| Main clock (in PLL mode, f <sub>xx</sub> )                   | ×                        | ○ <sup>Note</sup>                                    | ○            | ×                       | ×            | ○                           | ○                | ×                           | ×                |
| Peripheral clock (f <sub>xx</sub> to f <sub>xx</sub> /1,024) | ×                        | ×  | ○            | ×                       | ×            | ○                           | ×                | ×                           | ×                |
| WT clock (main)  | ×                        | ×  | ○            | ○                       | ×            | ○                           | ○                | ×                           | ×                |
| WT clock (sub)   | ○                        | ○  | ○            | ○                       | ○            | ○                           | ○                | ○                           | ○                |
| WDT2 clock (internal oscillation)                            | ×                        | ○  | ○            | ○                       | ○            | ○                           | ○                | ○                           | ○                |
| WDT2 clock (main)  | ×                        | ×  | ○            | ×                       | ×            | ○                           | ×                | ×                           | ×                |
| WDT2 clock (sub)   | ○                        | ○  | ○            | ○                       | ○            | ○                           | ○                | ○                           | ○                |

**Note** Lockup time

**Remark** ○: Operable  
×: Stopped

### 6.4.2 Clock output function

The clock output function is used to output the internal system clock (f<sub>CLK</sub>) from the CLKOUT pin.

The internal system clock (f<sub>CLK</sub>) is selected by using the PCC.CK3 to PCC.CK0 bits.

The CLKOUT pin functions alternately as the PCM1 pin and functions as a clock output pin if so specified by the control register of port CM.

The status of the CLKOUT pin is the same as the internal system clock in Table 6-1 and the pin can output the clock when it is in the operable status. It outputs a low level in the stopped status. However, the CLKOUT pin is in the port mode (PCM1 pin: input mode) after reset and until it is set in the output mode. Therefore, the status of the pin is Hi-Z.

## 6.5 PLL Function

### 6.5.1 Overview

In the V850ES/JJ3, an operating clock that is 4 or 8 times higher than the oscillation frequency output by the PLL function or the clock-through mode can be selected as the operating clock of the CPU and on-chip peripheral functions.

When PLL function is used (×4): Input clock = 2.5 to 5 MHz (output: 10 to 20 MHz)

When PLL function is used (×8): Input clock = 2.5 to 4 MHz (output: 20 to 32 MHz)

Clock-through mode: Input clock = 2.5 to 10 MHz (output: 2.5 to 10 MHz)

### 6.5.2 Registers

#### (1) PLL control register (PLLCTL)

The PLLCTL register is an 8-bit register that controls the PLL function.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 01H.

|                  |  |     |                    |   |   |   |        |       |
|------------------|--|-----|--------------------|---|---|---|--------|-------|
| After reset: 01H |  | R/W | Address: FFFFF82CH |   |   |   |        |       |
|                  | 7  | 6   | 5                  | 4 | 3 | 2 | <1>    | <0>   |
| PLLCTL           | 0  | 0   | 0                  | 0 | 0 | 0 | SELPLL | PLLON |
| PLLON            | PLL operation stop register  |     |                    |   |   |   |        |       |
| 0                | PLL stopped  |     |                    |   |   |   |        |       |
| 1                | PLL operating<br>(After PLL operation starts, a lockup time is required for frequency stabilization) |     |                    |   |   |   |        |       |
| SELPLL           | CPU operation clock selection register   |     |                    |   |   |   |        |       |
| 0                | Clock-through mode   |     |                    |   |   |   |        |       |
| 1                | PLL mode   |     |                    |   |   |   |        |       |

**Cautions**

1. When the PLLON bit is cleared to 0, the SELPLL bit is automatically cleared to 0 (clock-through mode).
2. The SELPLL bit can be set to 1 only when the PLL clock frequency is stabilized. If not (unlocked), "0" is written to the SELPLL bit if data is written to it.

**(2) Clock control register (CKC)**

The CKC register is a special register. Data can be written to this register only in a combination of specific sequence (see **3.4.7 Special registers**).

The CKC register controls the internal system clock in the PLL mode.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 0AH.

After reset: 0AH    R/W    Address: FFFFF822H

|     |   |   |   |   |   |   |   |        |
|-----|---|---|---|---|---|---|---|--------|
|     | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0      |
| CKC | 0 | 0 | 0 | 0 | 1 | 0 | 1 | CKDIV0 |

|        |   |
|--------|---|
| CKDIV0 | Internal system clock ( $f_{xx}$ ) in PLL mode      |
| 0      | $f_{xx} = 4 \times f_x$ ( $f_x = 2.5$ to $5.0$ MHz) |
| 1      | $f_{xx} = 8 \times f_x$ ( $f_x = 2.5$ to $4.0$ MHz) |

- Cautions**
1. The PLL mode cannot be used at  $f_x = 5.0$  to  $10.0$  MHz.
  2. Before changing the multiplication factor between 4 and 8 by using the CKC register, set the clock-through mode and stop the PLL.
  3. Be sure to set bits 3 and 1 to “1” and clear bits 7 to 4 and 2 to “0”.

**Remark** Both the CPU clock and peripheral clock are divided by the CKC register, but only the CPU clock is divided by the PCC register.

**(3) Lock register (LOCKR)**

Phase lock occurs at a given frequency following power application or immediately after the STOP mode is released, and the time required for stabilization is the lockup time (frequency stabilization time). This state until stabilization is called the lockup status, and the stabilized state is called the locked status.

The LOCKR register includes a LOCK bit that reflects the PLL frequency stabilization status.

This register is read-only, in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R    Address: FFFFF824H

|       |   |   |   |   |   |   |   |      |
|-------|---|---|---|---|---|---|---|------|
|       | 7 | 6 | 5 | 4 | 3 | 2 | 1 | <0>  |
| LOCKR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | LOCK |

|      |                       |
|------|-----------------------|
| LOCK | PLL lock status check |
| 0    | Locked status         |
| 1    | Unlocked status       |

**Caution** The LOCK register does not reflect the lock status of the PLL in real time. The set/clear conditions are as follows.

**[Set conditions]**

- Upon system reset<sup>Note</sup>
- In IDLE2 or STOP mode
- Upon setting of PLL stop (clearing of PLLCTL.PLLON bit to 0)
- Upon stopping main clock and using CPU with subclock (setting of PCC.CK3 bit to 1 and setting of PCC.MCK bit to 1)

**Note** This register is set to 01H by reset and cleared to 00H after the reset has been released and the oscillation stabilization time has elapsed.

**[Clear conditions]**

- Upon overflow of oscillation stabilization time following reset release (OSTS register default time (see **21.2 (3) Oscillation stabilization time select register (OSTS)**))
- Upon oscillation stabilization timer overflow (time set by OSTS register) following STOP mode release, when the STOP mode was set in the PLL operating status
- Upon PLL lockup time timer overflow (time set by PLLS register) when the PLLCTL.PLLON bit is changed from 0 to 1
- After the setup time inserted upon release of the IDLE2 mode is released (time set by the OSTS register) when the IDLE2 mode is set during PLL operation.

**(4) PLL lockup time specification register (PLLS)**

The PLLS register is an 8-bit register used to select the PLL lockup time when the PLLCTL.PLLON bit is changed from 0 to 1.

This register can be read or written in 8-bit units.

Reset sets this register to 03H.

After reset: 03H    R/W    Address: FFFFF6C1H

|      |   |   |   |   |   |   |       |       |
|------|---|---|---|---|---|---|-------|-------|
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1     | 0     |
| PLLS | 0 | 0 | 0 | 0 | 0 | 0 | PLLS1 | PLLS0 |

| PLLS1 | PLLS0 | Selection of PLL lockup time |
|-------|-------|------------------------------|
| 0     | 0     | $2^{10}/f_x$                 |
| 0     | 1     | $2^{11}/f_x$                 |
| 1     | 0     | $2^{12}/f_x$                 |
| 1     | 1     | $2^{13}/f_x$ (default value) |

- Cautions**
1. Set so that the lockup time is 800  $\mu$ s or longer.
  2. Do not change the PLLS register setting during the lockup period.

**6.5.3 Usage****(1) When PLL is used**

- After the reset signal has been released, the PLL operates (PLLCTL.PLLON bit = 1), but because the default mode is the clock-through mode (PLLCTL.SELPLL bit = 0), select the PLL mode (SELPLL bit = 1).
- To enable PLL operation, first set the PLLON bit to 1, and then set the SELPLL bit to 1 after the LOCKR.LOCK bit = 0. To stop the PLL, first select the clock-through mode (SELPLL bit = 0), wait for 8 clocks or more, and then stop the PLL (PLLON bit = 0).
- The PLL stops during transition to the IDLE2 or STOP mode regardless of the setting and is restored from the IDLE2 or STOP mode to the status before transition. The time required for restoration is as follows.

(a) When transiting to the IDLE2 or STOP mode from the clock through mode

- STOP mode: Set the OSTS register so that the oscillation stabilization time is 1 ms (min.) or longer.
- IDLE2 mode: Set the OSTS register so that the setup time is 350  $\mu$ s (min.) or longer.

(b) When transiting to the IDLE 2 or STOP mode while remaining in the PLL operation mode

- STOP mode: Set the OSTS register so that the oscillation stabilization time is 1 ms (min.) or longer.
- IDLE2 mode: Set the OSTS register so that the setup time is 800  $\mu$ s (min.) or longer.

When transiting to the IDLE1 mode, the PLL does not stop. Stop the PLL if necessary.

**(2) When PLL is not used**

- The clock-through mode (SELPLL bit = 0) is selected after the reset signal has been released, but the PLL is operating (PLLON bit = 1) and must therefore be stopped (PLLON bit = 0).

## CHAPTER 7 16-BIT TIMER/EVENT COUNTER P (TMP)

Timer P (TMP) is a 16-bit timer/event counter.

The V850ES/JJ3 has nine timer/event counter channels, TMP0 to TMP8.

### 7.1 Overview

An outline of TMP<sub>n</sub> is shown below.

- Clock selection: 8 ways
- Capture/trigger input pins: 2
- External event count input pins: 1
- External trigger input pins: 1
- Timer/counters: 1
- Capture/compare registers: 2
- Capture/compare match interrupt request signals: 2
- Timer output pins: 2

**Remark** n = 0 to 8

### 7.2 Functions

TMP<sub>n</sub> has the following functions.

- Interval timer
- External event counter
- External trigger pulse output
- One-shot pulse output
- PWM output
- Free-running timer
- Pulse width measurement

**Remark** n = 0 to 8

### 7.3 Configuration

TMPn includes the following hardware.

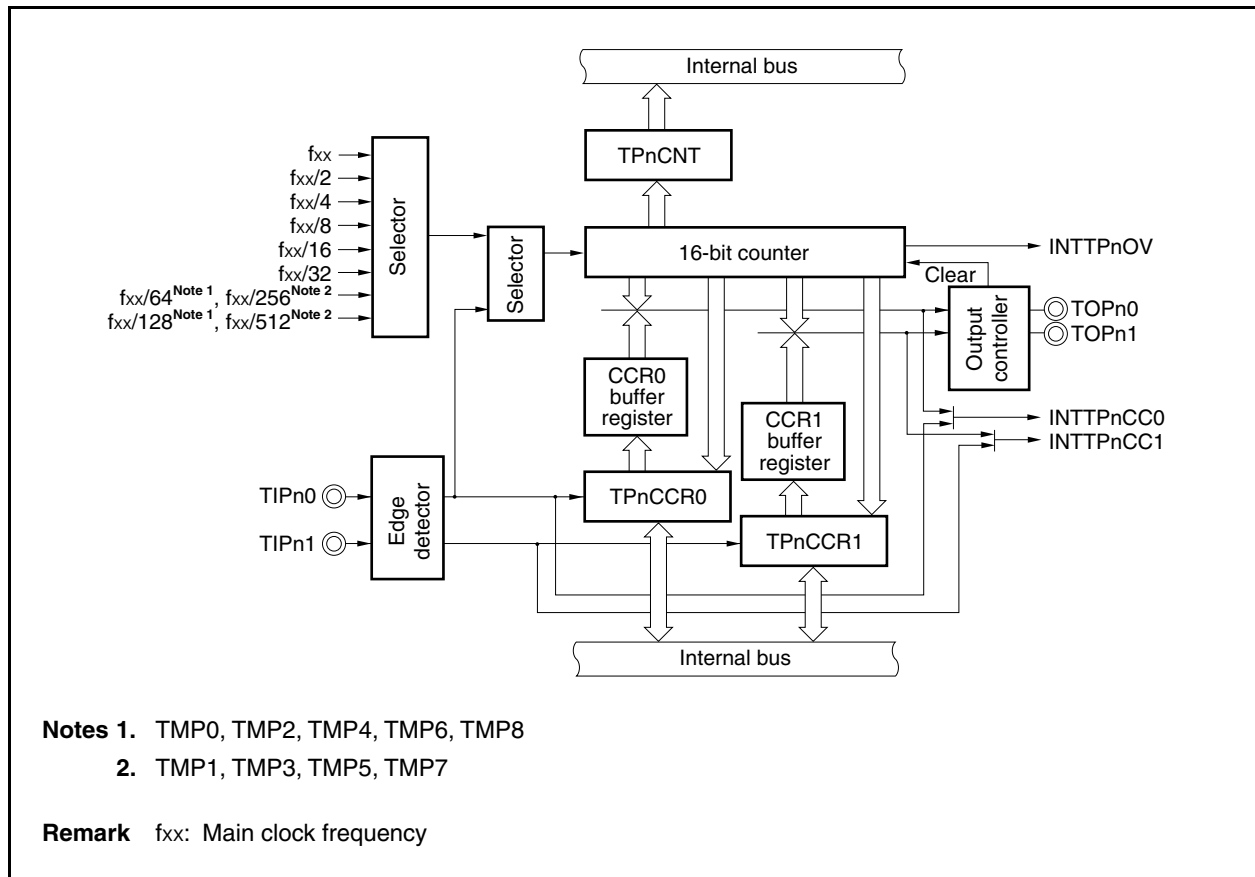
**Table 7-1. Configuration of TMPn**

| Item                                | Configuration  |
|-------------------------------------|--|
| Timer register                      | 16-bit counter   |
| Registers                           | TMPn capture/compare registers 0, 1 (TPnCCR0, TPnCCR1)<br>TMPn counter read buffer register (TPnCNT)<br>CCR0, CCR1 buffer registers          |
| Timer inputs                        | 2 (TIPn0 <sup>Note 1</sup> , TIPn1 pins)   |
| Timer outputs                       | 2 (TOPn0, TOPn1 pins)  |
| Control registers <sup>Note 2</sup> | TMPn control registers 0, 1 (TPnCTL0, TPnCTL1)<br>TMPn I/O control registers 0 to 2 (TPnIOC0 to TPnIOC2)<br>TMPn option register 0 (TPnOPT0) |

- Notes**
- The TIPn0 pin functions alternately as a capture trigger input signal, external event count input signal, and external trigger input signal.
  - When using the functions of the TIPn0, TIPn1, TOPn0, and TOPn1 pins, see **Table 4-19 Using Port Pins as Alternate-Function Pins**.

**Remark** n = 0 to 8

**Figure 7-1. Block Diagram of TMPn**





**(1) 16-bit counter**

This 16-bit counter can count internal clocks or external events.

The count value of this counter can be read by using the TPnCNT register.

When the TPnCTL0.TPnCE bit = 0, the value of the 16-bit counter is FFFFH. If the TPnCNT register is read at this time, 0000H is read.

Reset sets the TPnCE bit to 0. Therefore, the 16-bit counter is set to FFFFH.

**(2) CCR0 buffer register**

This is a 16-bit compare register that compares the count value of the 16-bit counter.

When the TPnCCR0 register is used as a compare register, the value written to the TPnCCR0 register is transferred to the CCR0 buffer register. When the count value of the 16-bit counter matches the value of the CCR0 buffer register, a compare match interrupt request signal (INTTPnCC0) is generated.

The CCR0 buffer register cannot be read or written directly.

The CCR0 buffer register is cleared to 0000H after reset, as the TPnCCR0 register is cleared to 0000H.

**(3) CCR1 buffer register**

This is a 16-bit compare register that compares the count value of the 16-bit counter.

When the TPnCCR1 register is used as a compare register, the value written to the TPnCCR1 register is transferred to the CCR1 buffer register. When the count value of the 16-bit counter matches the value of the CCR1 buffer register, a compare match interrupt request signal (INTTPnCC1) is generated.

The CCR1 buffer register cannot be read or written directly.

The CCR1 buffer register is cleared to 0000H after reset, as the TPnCCR1 register is cleared to 0000H.

**(4) Edge detector**

This circuit detects the valid edges input to the TIPn0 and TIPn1 pins. No edge, rising edge, falling edge, or both the rising and falling edges can be selected as the valid edge by using the TPnIOC1 and TPnIOC2 registers.

**(5) Output controller**

This circuit controls the output of the TOPn0 and TOPn1 pins. The output controller is controlled by the TPnIOC0 register.

**(6) Selector**

This selector selects the count clock for the 16-bit counter. Eight types of internal clocks or an external event can be selected as the count clock.

## 7.4 Registers

The registers that control TMPn are as follows.

- TMPn control register 0 (TPnCTL0)
- TMPn control register 1 (TPnCTL1)
- TMPn I/O control register 0 (TPnIOC0)
- TMPn I/O control register 1 (TPnIOC1)
- TMPn I/O control register 2 (TPnIOC2)
- TMPn option register 0 (TPnOPT0)
- TMPn capture/compare register 0 (TPnCCR0)
- TMPn capture/compare register 1 (TPnCCR1)
- TMPn counter read buffer register (TPnCNT)

**Remarks 1.** When using the functions of the TIPn0, TIPn1, TOPn0, and TOPn1 pins, see **Table 4-19 Using Port Pins as Alternate-Function Pins.**

**2.** n = 0 to 8

**(1) TMPn control register 0 (TPnCTL0)**

The TPnCTL0 register is an 8-bit register that controls the operation of TMPn.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

The same value can always be written to the TPnCTL0 register by software.

After reset: 00H    R/W    Address:    TP0CTL0 FFFFF590H, TP1CTL0 FFFFF5A0H,  
 TP2CTL0 FFFFF5B0H, TP3CTL0 FFFFF5C0H,  
 TP4CTL0 FFFFF5D0H, TP5CTL0 FFFFF5E0H,  
 TP6CTL0 FFFFF5F0H, TP7CTL0 FFFFF600H,  
 TP8CTL0 FFFFF610H

|                         |       |   |   |   |   |         |         |         |
|-------------------------|-------|---|---|---|---|---------|---------|---------|
|                         | <7>   | 6 | 5 | 4 | 3 | 2       | 1       | 0       |
| TPnCTL0<br>(n = 0 to 8) | TPnCE | 0 | 0 | 0 | 0 | TPnCKS2 | TPnCKS1 | TPnCKS0 |

|       |   |
|-------|---|
| TPnCE | TMPn operation control  |
| 0     | TMPn operation disabled (TMPn reset asynchronously <sup>Note</sup> ). |
| 1     | TMPn operation enabled. TMPn operation started.                       |

|         |         |         |                                |                      |
|---------|---------|---------|--------------------------------|----------------------|
| TPnCKS2 | TPnCKS1 | TPnCKS0 | Internal count clock selection |                      |
|         |         |         | n = 0, 2, 4, 6, 8              | n = 1, 3, 5, 7       |
| 0       | 0       | 0       | f <sub>xx</sub>                |                      |
| 0       | 0       | 1       | f <sub>xx</sub> /2             |                      |
| 0       | 1       | 0       | f <sub>xx</sub> /4             |                      |
| 0       | 1       | 1       | f <sub>xx</sub> /8             |                      |
| 1       | 0       | 0       | f <sub>xx</sub> /16            |                      |
| 1       | 0       | 1       | f <sub>xx</sub> /32            |                      |
| 1       | 1       | 0       | f <sub>xx</sub> /64            | f <sub>xx</sub> /256 |
| 1       | 1       | 1       | f <sub>xx</sub> /128           | f <sub>xx</sub> /512 |

**Note** TPn0PT0.TPnOVF bit, 16-bit counter, timer output (TOPn0, TOPn1 pins)

- Cautions**
1. Set the TPnCKS2 to TPnCKS0 bits when the TPnCE bit = 0. When the value of the TPnCE bit is changed from 0 to 1, the TPnCKS2 to TPnCKS0 bits can be set simultaneously.
  2. Be sure to clear bits 3 to 6 to “0”.

**Remark** f<sub>xx</sub>: Main clock frequency

**(2) TMPn control register 1 (TPnCTL1)**

The TPnCTL1 register is an 8-bit register that controls the operation of TMPn.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H R/W Address: TP0CTL1 FFFF591H, TP1CTL1 FFFF5A1H,  
 TP2CTL1 FFFF5B1H, TP3CTL1 FFFF5C1H,  
 TP4CTL1 FFFF5D1H, TP5CTL1 FFFF5E1H,  
 TP6CTL1 FFFF5F1H, TP7CTL1 FFFF601H,  
 TP8CTL1 FFFF611H

|                         |   |        |        |   |   |        |        |        |
|-------------------------|---|--------|--------|---|---|--------|--------|--------|
|                         | 7 | <6>    | <5>    | 4 | 3 | 2      | 1      | 0      |
| TPnCTL1<br>(n = 0 to 8) | 0 | TPnEST | TPnEEE | 0 | 0 | TPnMD2 | TPnMD1 | TPnMD0 |

|        |  |
|--------|--|
| TPnEST | Software trigger control   |
| 0      | –  |
| 1      | Generate a valid signal for external trigger input. <ul style="list-style-type: none"> <li>• In one-shot pulse output mode: A one-shot pulse is output with writing 1 to the TPnEST bit as the trigger.</li> <li>• In external trigger pulse output mode: A PWM waveform is output with writing 1 to the TPnEST bit as the trigger.</li> </ul> |

|   |  |
|---|--|
| TPnEEE  | Count clock selection  |
| 0   | Disable operation with external event count input.<br>(Perform counting with the count clock selected by the TPnCTL0.TPnCK0 to TPnCK2 bits.) |
| 1   | Enable operation with external event count input.<br>(Perform counting at the valid edge of the external event count input signal.)          |
| The TPnEEE bit selects whether counting is performed with the internal count clock or the valid edge of the external event count input. |  |

|        |        |        |                                    |
|--------|--------|--------|------------------------------------|
| TPnMD2 | TPnMD1 | TPnMD0 | Timer mode selection               |
| 0      | 0      | 0      | Interval timer mode                |
| 0      | 0      | 1      | External event count mode          |
| 0      | 1      | 0      | External trigger pulse output mode |
| 0      | 1      | 1      | One-shot pulse output mode         |
| 1      | 0      | 0      | PWM output mode                    |
| 1      | 0      | 1      | Free-running timer mode            |
| 1      | 1      | 0      | Pulse width measurement mode       |
| 1      | 1      | 1      | Setting prohibited                 |

- Cautions**
1. The TPnEST bit is valid only in the external trigger pulse output mode or one-shot pulse output mode. In any other mode, writing 1 to this bit is ignored.
  2. External event count input is selected in the external event count mode regardless of the value of the TPnEEE bit.
  3. Set the TPnEEE and TPnMD2 to TPnMD0 bits when the TPnCTL0.TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) The operation is not guaranteed when rewriting is performed with the TPnCE bit = 1. If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again.
  4. Be sure to clear bits 3, 4, and 7 to “0”.

**(3) TMPn I/O control register 0 (TPnIOC0)**

The TPnIOC0 register is an 8-bit register that controls the timer output (TOPn0, TOPn1 pins). This register can be read or written in 8-bit or 1-bit units. Reset sets this register to 00H.

After reset: 00H R/W Address: TP0IOC0 FFFFF592H, TP1IOC0 FFFFF5A2H, TP2IOC0 FFFFF5B2H, TP3IOC0 FFFFF5C2H, TP4IOC0 FFFFF5D2H, TP5IOC0 FFFFF5E2H, TP6IOC0 FFFFF5F2H, TP7IOC0 FFFFF602H, TP8IOC0 FFFFF612H

|                         |   |   |   |   |        |        |        |        |
|-------------------------|---|---|---|---|--------|--------|--------|--------|
|                         | 7 | 6 | 5 | 4 | 3      | <2>    | 1      | <0>    |
| TPnIOC0<br>(n = 0 to 8) | 0 | 0 | 0 | 0 | TPnOL1 | TPnOE1 | TPnOL0 | TPnOE0 |

|        |  |
|--------|--|
| TPnOL1 | TOPn1 pin output level setting <sup>Note</sup> |
| 0      | TOPn1 pin output starts at high level          |
| 1      | TOPn1 pin output starts at low level           |

|        |  |
|--------|--|
| TPnOE1 | TOPn1 pin output setting   |
| 0      | Timer output disabled<br>• When TPnOL1 bit = 0: Low level is output from the TOPn1 pin<br>• When TPnOL1 bit = 1: High level is output from the TOPn1 pin |
| 1      | Timer output enabled (a square wave is output from the TOPn1 pin).   |

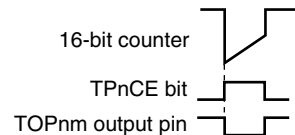
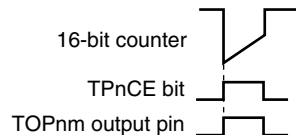
|        |  |
|--------|--|
| TPnOL0 | TOPn0 pin output level setting <sup>Note</sup> |
| 0      | TOPn0 pin output starts at high level          |
| 1      | TOPn0 pin output starts at low level           |

|        |  |
|--------|--|
| TPnOE0 | TOPn0 pin output setting   |
| 0      | Timer output disabled<br>• When TPnOL0 bit = 0: Low level is output from the TOPn0 pin<br>• When TPnOL0 bit = 1: High level is output from the TOPn0 pin |
| 1      | Timer output enabled (a square wave is output from the TOPn0 pin).   |

**Note** The output level of the timer output pin (TOPnm) specified by the TPnOLm bit is shown below (m = 0, 1).

• When TPnOLm bit = 0

• When TPnOLm bit = 1



- Cautions**
1. Rewrite the TPnOL1, TPnOE1, TPnOL0, and TPnOE0 bits when the TPnCTL0.TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again.
  2. Even if the TPnOLm bit is manipulated when the TPnCE and TPnOEm bits are 0, the TOPnm pin output level varies (m = 0, 1).

**(4) TMPn I/O control register 1 (TPnIOC1)**

The TPnIOC1 register is an 8-bit register that controls the valid edge of the capture trigger input signals (TIPn0, TIPn1 pins).

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address:    TP0IOC1 FFFFF593H, TP1IOC1 FFFFF5A3H,  
 TP2IOC1 FFFFF5B3H, TP3IOC1 FFFFF5C3H,  
 TP4IOC1 FFFFF5D3H, TP5IOC1 FFFFF5E3H,  
 TP6IOC1 FFFFF5F3H, TP7IOC1 FFFFF603H,  
 TP8IOC1 FFFFF613H

|                         |   |   |   |   |        |        |        |        |
|-------------------------|---|---|---|---|--------|--------|--------|--------|
|                         | 7 | 6 | 5 | 4 | 3      | 2      | 1      | 0      |
| TPnIOC1<br>(n = 0 to 8) | 0 | 0 | 0 | 0 | TPnIS3 | TPnIS2 | TPnIS1 | TPnIS0 |

| TPnIS3 | TPnIS2 | Capture trigger input signal (TIPn1 pin) valid edge setting |
|--------|--------|---|
| 0      | 0      | No edge detection (capture operation invalid)               |
| 0      | 1      | Detection of rising edge                                    |
| 1      | 0      | Detection of falling edge                                   |
| 1      | 1      | Detection of both edges                                     |

| TPnIS1 | TPnIS0 | Capture trigger input signal (TIPn0 pin) valid edge setting |
|--------|--------|---|
| 0      | 0      | No edge detection (capture operation invalid)               |
| 0      | 1      | Detection of rising edge                                    |
| 1      | 0      | Detection of falling edge                                   |
| 1      | 1      | Detection of both edges                                     |

- Cautions**
1. Rewrite the TPnIS3 to TPnIS0 bits when the TPnCTL0.TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again.
  2. The TPnIS3 to TPnIS0 bits are valid only in the free-running timer mode and the pulse width measurement mode. In all other modes, a capture operation is not possible.



**(6) TMPn option register 0 (TPnOPT0)**

The TPnOPT0 register is an 8-bit register used to set the capture/compare operation and detect an overflow. This register can be read or written in 8-bit or 1-bit units. Reset sets this register to 00H.

After reset: 00H R/W Address: TP0OPT0 FFFFF595H, TP1OPT0 FFFFF5A5H,  
TP2OPT0 FFFFF5B5H, TP3OPT0 FFFFF5C5H,  
TP4OPT0 FFFFF5D5H, TP5OPT0 FFFFF5E5H,  
TP6OPT0 FFFFF5F5H, TP7OPT0 FFFFF605H,  
TP8OPT0 FFFFF615H

|                         |   |   |         |         |   |   |   |        |
|-------------------------|---|---|---------|---------|---|---|---|--------|
|                         | 7 | 6 | 5       | 4       | 3 | 2 | 1 | <0>    |
| TPnOPT0<br>(n = 0 to 8) | 0 | 0 | TPnCCS1 | TPnCCS0 | 0 | 0 | 0 | TPnOVF |

|   |  |
|---|--|
| TPnCCS1   | TPnCCR1 register capture/compare selection |
| 0   | Compare register selected                  |
| 1   | Capture register selected                  |
| The TPnCCS1 bit setting is valid only in the free-running timer mode. |  |

|   |  |
|---|--|
| TPnCCS0   | TPnCCR0 register capture/compare selection |
| 0   | Compare register selected                  |
| 1   | Capture register selected                  |
| The TPnCCS0 bit setting is valid only in the free-running timer mode. |  |

|   |   |
|---|---|
| TPnOVF  | TMPn overflow detection flag                  |
| Set (1)   | Overflow occurred                             |
| Reset (0)   | TPnOVF bit 0 written or TPnCTL0.TPnCE bit = 0 |
| <ul style="list-style-type: none"> <li>• The TPnOVF bit is set when the 16-bit counter count value overflows from FFFFH to 0000H in the free-running timer mode or the pulse width measurement mode.</li> <li>• An interrupt request signal (INTTPnOV) is generated at the same time that the TPnOVF bit is set to 1. The INTTPnOV signal is not generated in modes other than the free-running timer mode and the pulse width measurement mode.</li> <li>• The TPnOVF bit is not cleared even when the TPnOVF bit or the TPnOPT0 register are read when the TPnOVF bit = 1.</li> <li>• The TPnOVF bit can be both read and written, but the TPnOVF bit cannot be set to 1 by software. Writing 1 has no influence on the operation of TMPn.</li> </ul> |   |

- Cautions**
1. Rewrite the TPnCCS1 and TPnCCS0 bits when the TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again.
  2. Be sure to clear bits 1 to 3, 6, and 7 to “0”.



**(7) TMPn capture/compare register 0 (TPnCCR0)**

The TPnCCR0 register can be used as a capture register or a compare register depending on the mode.

This register can be used as a capture register or a compare register only in the free-running timer mode, depending on the setting of the TPnOPT0.TPnCCS0 bit. In the pulse width measurement mode, the TPnCCR0 register can be used only as a capture register. In any other mode, this register can be used only as a compare register.

The TPnCCR0 register can be read or written during operation.

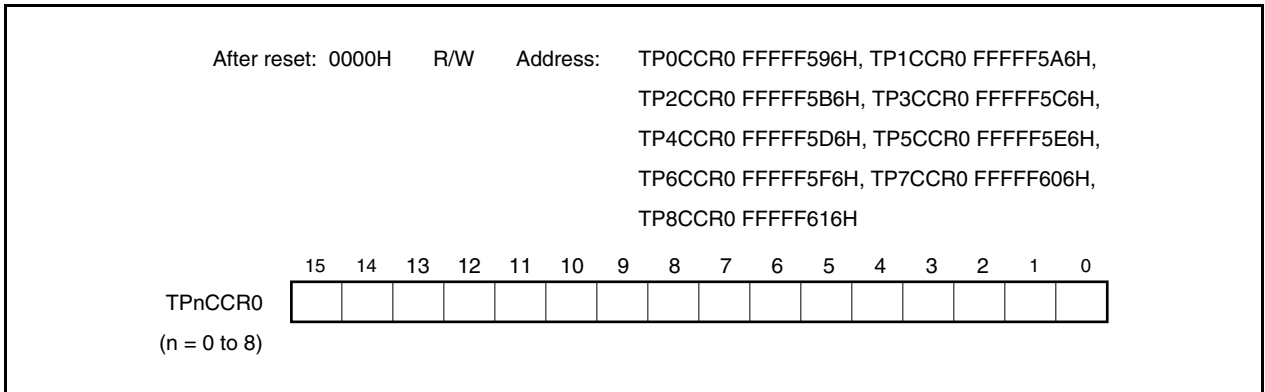
This register can be read or written in 16-bit units.

Reset sets this register to 0000H.

**Caution** Accessing the TPnCCR0 register is prohibited in the following statuses. For details, see 3.4.8

**(2) Accessing specific on-chip peripheral I/O registers.**

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock



**(a) Function as compare register**

The TPnCCR0 register can be rewritten even when the TPnCTL0.TPnCE bit = 1.

The set value of the TPnCCR0 register is transferred to the CCR0 buffer register. When the value of the 16-bit counter matches the value of the CCR0 buffer register, a compare match interrupt request signal (INTTPnCC0) is generated. If TOPn0 pin output is enabled at this time, the output of the TOPn0 pin is inverted.

When the TPnCCR0 register is used as a cycle register in the interval timer mode, external event count mode, external trigger pulse output mode, one-shot pulse output mode, or PWM output mode, the value of the 16-bit counter is cleared (0000H) if its count value matches the value of the CCR0 buffer register.

**(b) Function as capture register**

When the TPnCCR0 register is used as a capture register in the free-running timer mode, the count value of the 16-bit counter is stored in the TPnCCR0 register if the valid edge of the capture trigger input pin (TIPn0 pin) is detected. In the pulse-width measurement mode, the count value of the 16-bit counter is stored in the TPnCCR0 register and the 16-bit counter is cleared (0000H) if the valid edge of the capture trigger input pin (TIPn0) is detected.

Even if the capture operation and reading the TPnCCR0 register conflict, the correct value of the TPnCCR0 register can be read.

The following table shows the functions of the capture/compare register in each mode, and how to write data to the compare register.

**Table 7-2. Function of Capture/Compare Register in Each Mode and How to Write Compare Register**

| Operation Mode                | Capture/Compare Register | How to Write Compare Register |
|-------------------------------|--------------------------|-------------------------------|
| Interval timer                | Compare register         | Anytime write                 |
| External event counter        | Compare register         | Anytime write                 |
| External trigger pulse output | Compare register         | Batch write                   |
| One-shot pulse output         | Compare register         | Anytime write                 |
| PWM output                    | Compare register         | Batch write                   |
| Free-running timer            | Capture/compare register | Anytime write                 |
| Pulse width measurement       | Capture register         | –                             |

**(8) TMPn capture/compare register 1 (TPnCCR1)**

The TPnCCR1 register can be used as a capture register or a compare register depending on the mode.

This register can be used as a capture register or a compare register only in the free-running timer mode, depending on the setting of the TPnOPT0.TPnCCS1 bit. In the pulse width measurement mode, the TPnCCR1 register can be used only as a capture register. In any other mode, this register can be used only as a compare register.

The TPnCCR1 register can be read or written during operation.

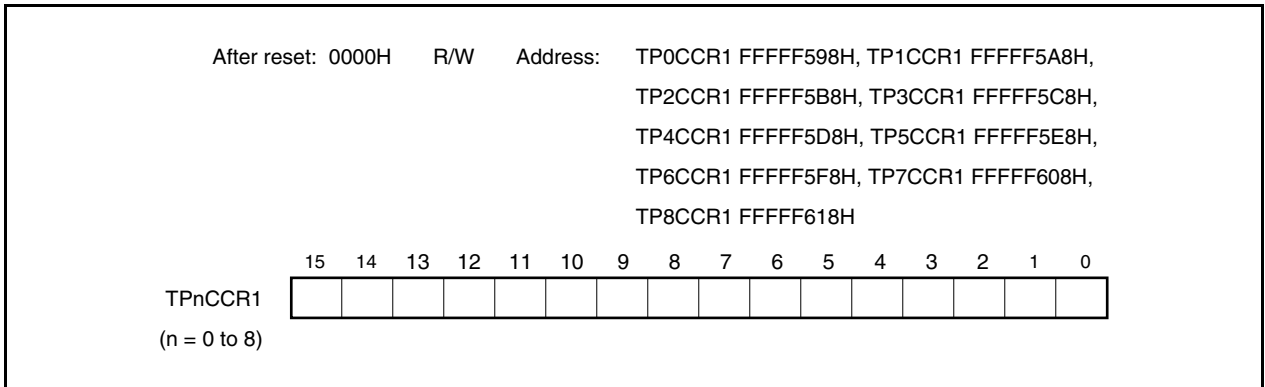
This register can be read or written in 16-bit units.

Reset sets this register to 0000H.

**Caution** Accessing the TPnCCR1 register is prohibited in the following statuses. For details, see 3.4.8

**(2) Accessing specific on-chip peripheral I/O registers.**

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock



**(a) Function as compare register**

The TPnCCR1 register can be rewritten even when the TPnCTL0.TPnCE bit = 1.

The set value of the TPnCCR1 register is transferred to the CCR1 buffer register. When the value of the 16-bit counter matches the value of the CCR1 buffer register, a compare match interrupt request signal (INTTPnCC1) is generated. If TOPn1 pin output is enabled at this time, the output of the TOPn1 pin is inverted.

**(b) Function as capture register**

When the TPnCCR1 register is used as a capture register in the free-running timer mode, the count value of the 16-bit counter is stored in the TPnCCR1 register if the valid edge of the capture trigger input pin (TIPn1 pin) is detected. In the pulse-width measurement mode, the count value of the 16-bit counter is stored in the TPnCCR1 register and the 16-bit counter is cleared (0000H) if the valid edge of the capture trigger input pin (TIPn1) is detected.

Even if the capture operation and reading the TPnCCR1 register conflict, the correct value of the TPnCCR1 register can be read.

The following table shows the functions of the capture/compare register in each mode, and how to write data to the compare register.

**Table 7-3. Function of Capture/Compare Register in Each Mode and How to Write Compare Register**

| Operation Mode                | Capture/Compare Register | How to Write Compare Register |
|-------------------------------|--------------------------|-------------------------------|
| Interval timer                | Compare register         | Anytime write                 |
| External event counter        | Compare register         | Anytime write                 |
| External trigger pulse output | Compare register         | Batch write                   |
| One-shot pulse output         | Compare register         | Anytime write                 |
| PWM output                    | Compare register         | Batch write                   |
| Free-running timer            | Capture/compare register | Anytime write                 |
| Pulse width measurement       | Capture register         | –                             |

**(9) TMPn counter read buffer register (TPnCNT)**

The TPnCNT register is a read buffer register that can read the count value of the 16-bit counter.

If this register is read when the TPnCTL0.TPnCE bit = 1, the count value of the 16-bit timer can be read.

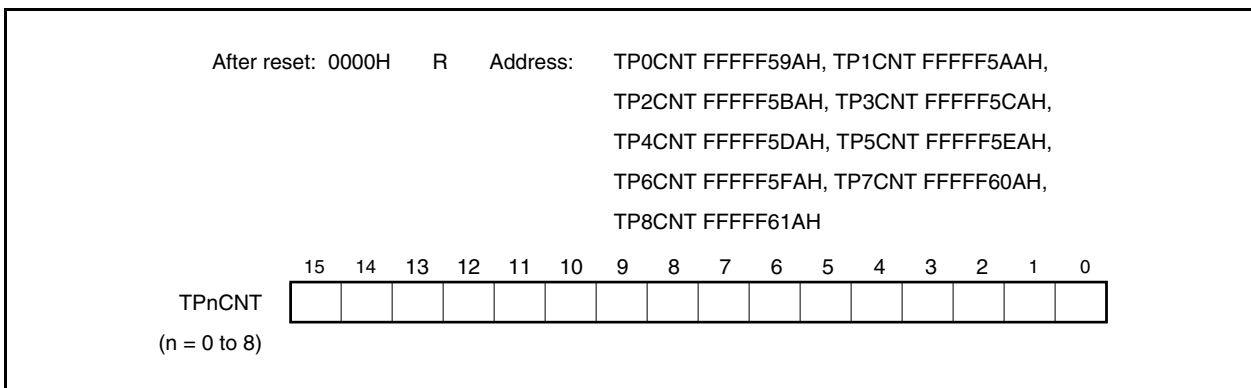
This register is read-only, in 16-bit units.

The value of the TPnCNT register is cleared to 0000H when the TPnCE bit = 0. If the TPnCNT register is read at this time, the value of the 16-bit counter (FFFFH) is not read, but 0000H is read.

The value of the TPnCNT register is cleared to 0000H after reset, as the TPnCE bit is cleared to 0.

**Caution** Accessing the TPnCNT register is prohibited in the following statuses. For details, see 3.4.8 (2) Accessing specific on-chip peripheral I/O registers.

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock



## 7.5 Operation

TMPn can perform the following operations.

| Operation  | TPnCTL1.TPnEST Bit<br>(Software Trigger Bit) | TIPn0 Pin<br>(External Trigger Input) | Capture/Compare<br>Register Setting | Compare Register<br>Write |
|--|--|---------------------------------------|-------------------------------------|---------------------------|
| Interval timer mode                                  | Invalid                                      | Invalid                               | Compare only                        | Anytime write             |
| External event count mode <sup>Note 1</sup>          | Invalid                                      | Invalid                               | Compare only                        | Anytime write             |
| External trigger pulse output mode <sup>Note 2</sup> | Valid  | Valid                                 | Compare only                        | Batch write               |
| One-shot pulse output mode <sup>Note 2</sup>         | Valid  | Valid                                 | Compare only                        | Anytime write             |
| PWM output mode                                      | Invalid                                      | Invalid                               | Compare only                        | Batch write               |
| Free-running timer mode                              | Invalid                                      | Invalid                               | Switching enabled                   | Anytime write             |
| Pulse width measurement mode <sup>Note 2</sup>       | Invalid                                      | Invalid                               | Capture only                        | Not applicable            |

- Notes 1.** To use the external event count mode, specify that the valid edge of the TIPn0 pin capture trigger input is not detected (by clearing the TPnIOC1.TPnIS1 and TPnIOC1.TPnIS0 bits to "00").
- 2.** When using the external trigger pulse output mode, one-shot pulse output mode, and pulse width measurement mode, select the internal clock as the count clock (by clearing the TPnCTL1.TPnEEE bit to 0).

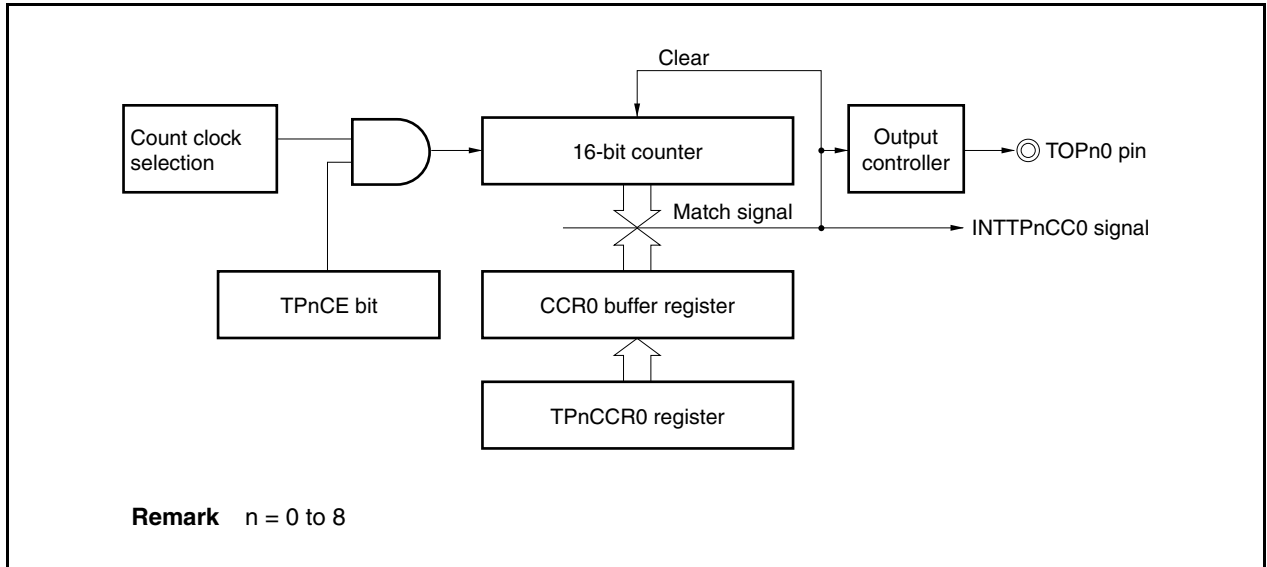
**Remark** n = 0 to 8

**7.5.1 Interval timer mode (TPnMD2 to TPnMD0 bits = 000)**

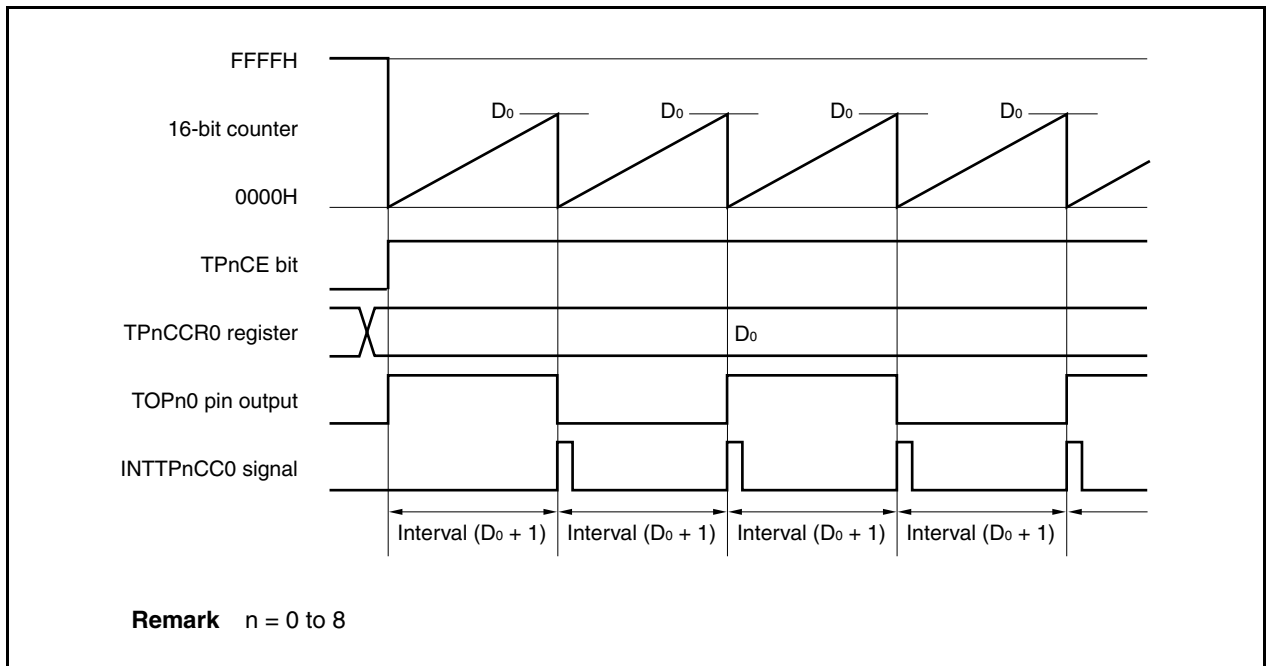
In the interval timer mode, an interrupt request signal (INTTPnCC0) is generated at the specified interval if the TPnCTL0.TPnCE bit is set to 1. A square wave whose half cycle is equal to the interval can be output from the TOPn0 pin.

Usually, the TPnCCR1 register is not used in the interval timer mode.

**Figure 7-2. Configuration of Interval Timer**



**Figure 7-3. Basic Timing of Operation in Interval Timer Mode**



When the TPnCE bit is set to 1, the value of the 16-bit counter is cleared from FFFFH to 0000H in synchronization with the count clock, and the counter starts counting. At this time, the output of the TOPn0 pin is inverted. Additionally, the set value of the TPnCCR0 register is transferred to the CCR0 buffer register.

When the count value of the 16-bit counter matches the value of the CCR0 buffer register, the 16-bit counter is cleared to 0000H, the output of the TOPn0 pin is inverted, and a compare match interrupt request signal (INTTPnCC0) is generated.

The interval can be calculated by the following expression.

$$\text{Interval} = (\text{Set value of TPnCCR0 register} + 1) \times \text{Count clock cycle}$$

**Remark** n = 0 to 8

**Figure 7-4. Register Setting for Interval Timer Mode Operation (1/2)**

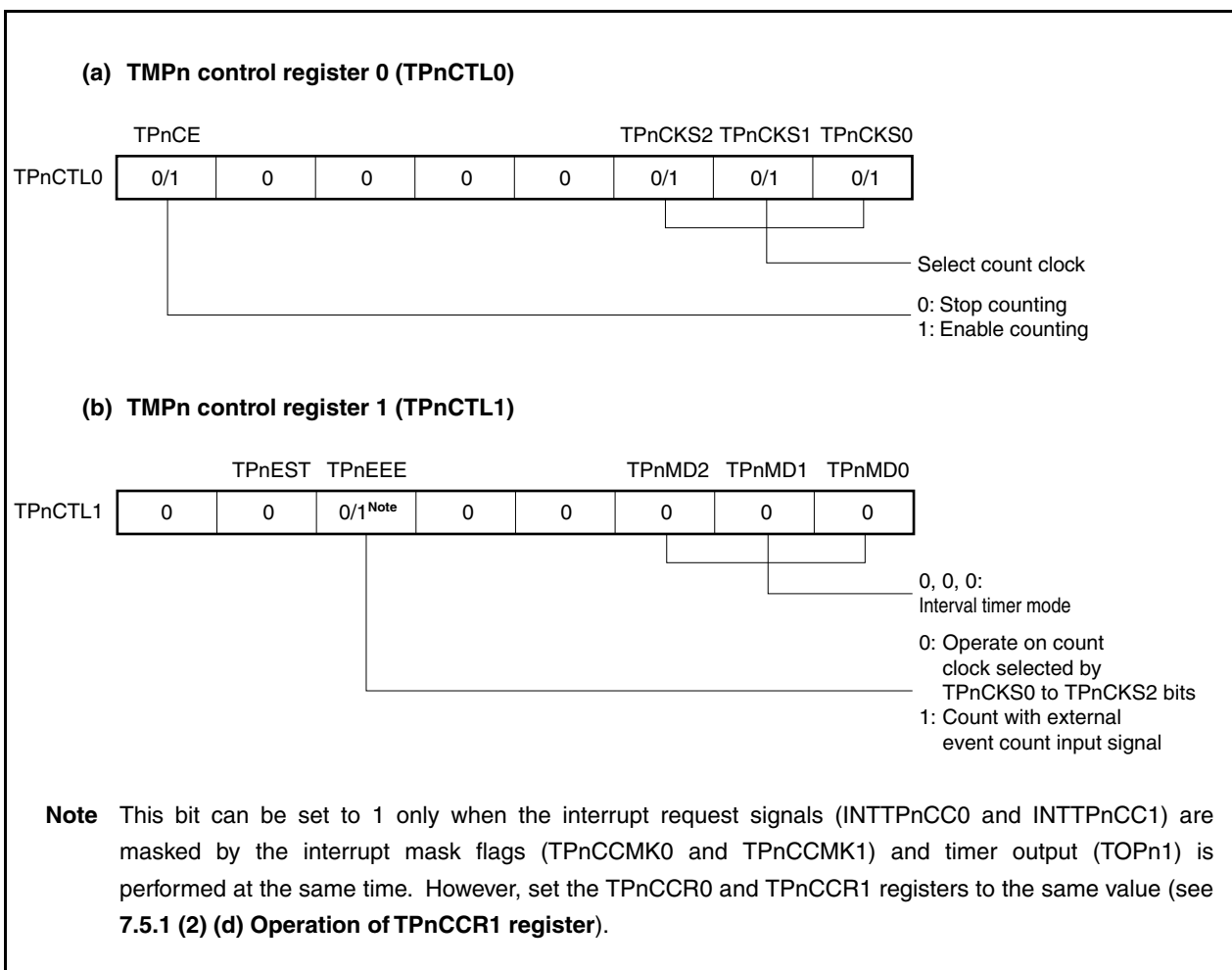
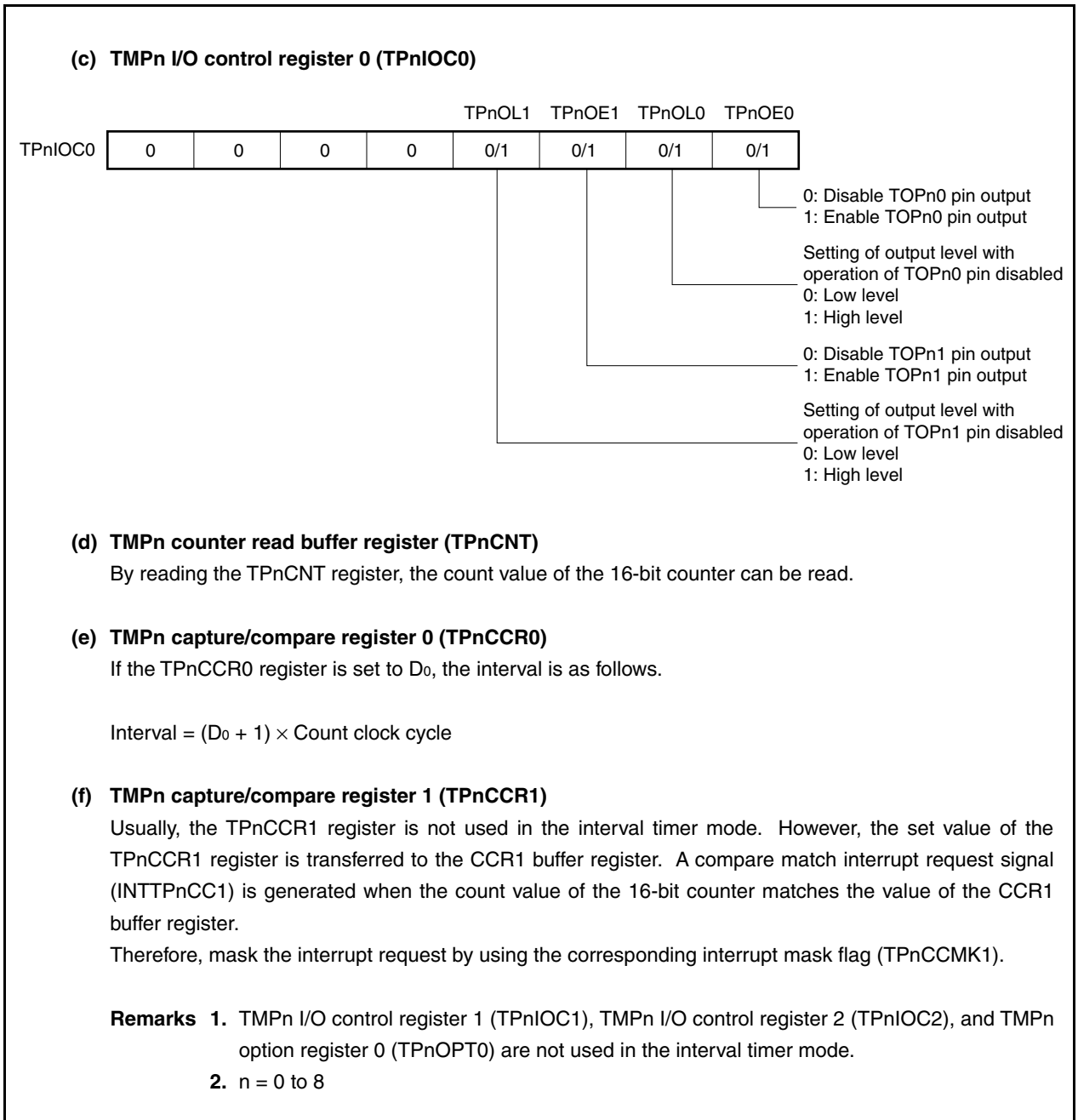


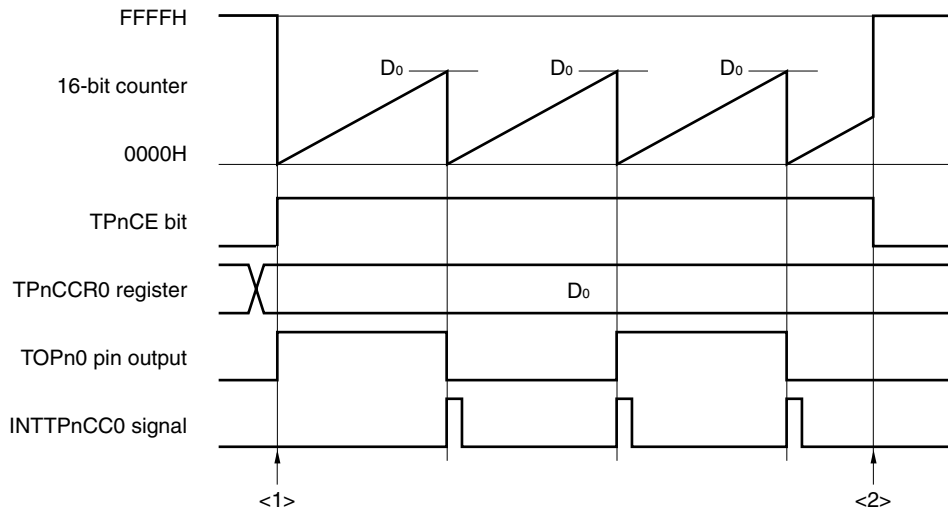


Figure 7-4. Register Setting for Interval Timer Mode Operation (2/2)

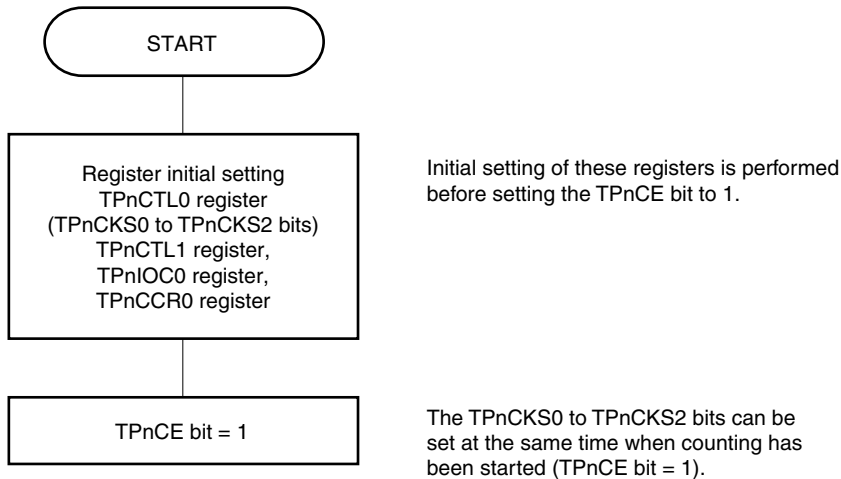


(1) Interval timer mode operation flow

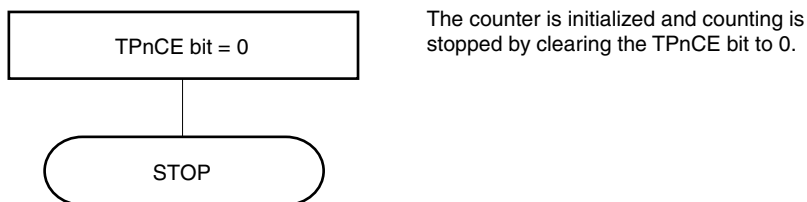
Figure 7-5. Software Processing Flow in Interval Timer Mode



<1> Count operation start flow



<2> Count operation stop flow



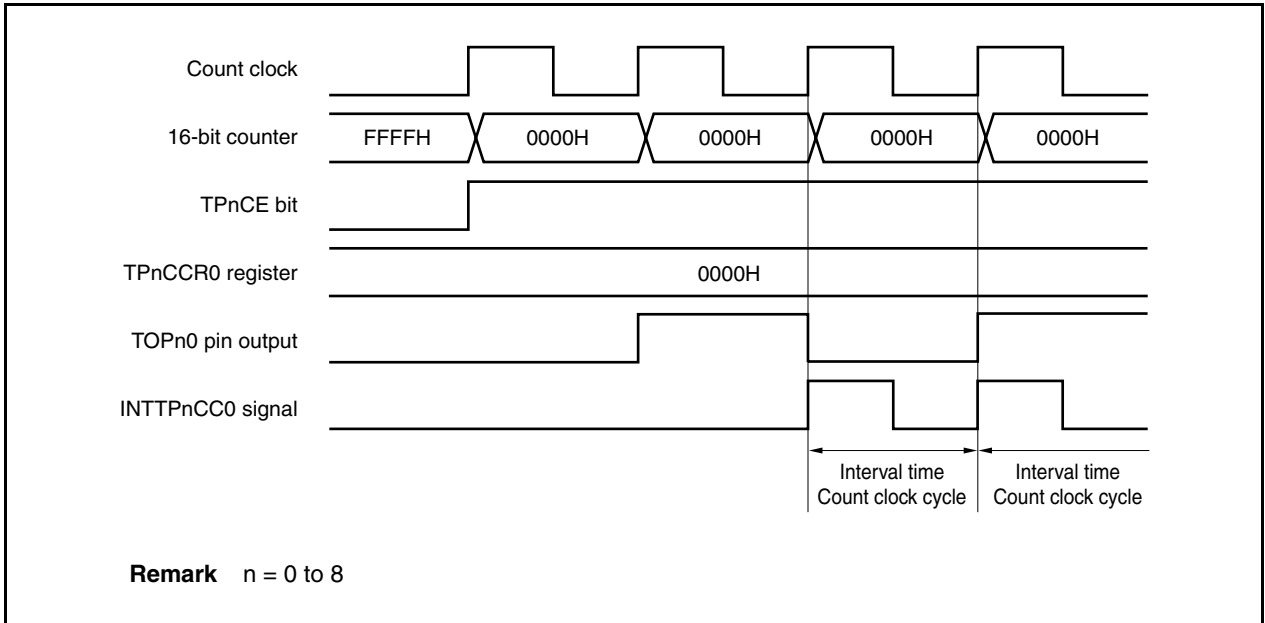
**Remark** n = 0 to 8

(2) Interval timer mode operation timing

(a) Operation if TPnCCR0 register is set to 0000H

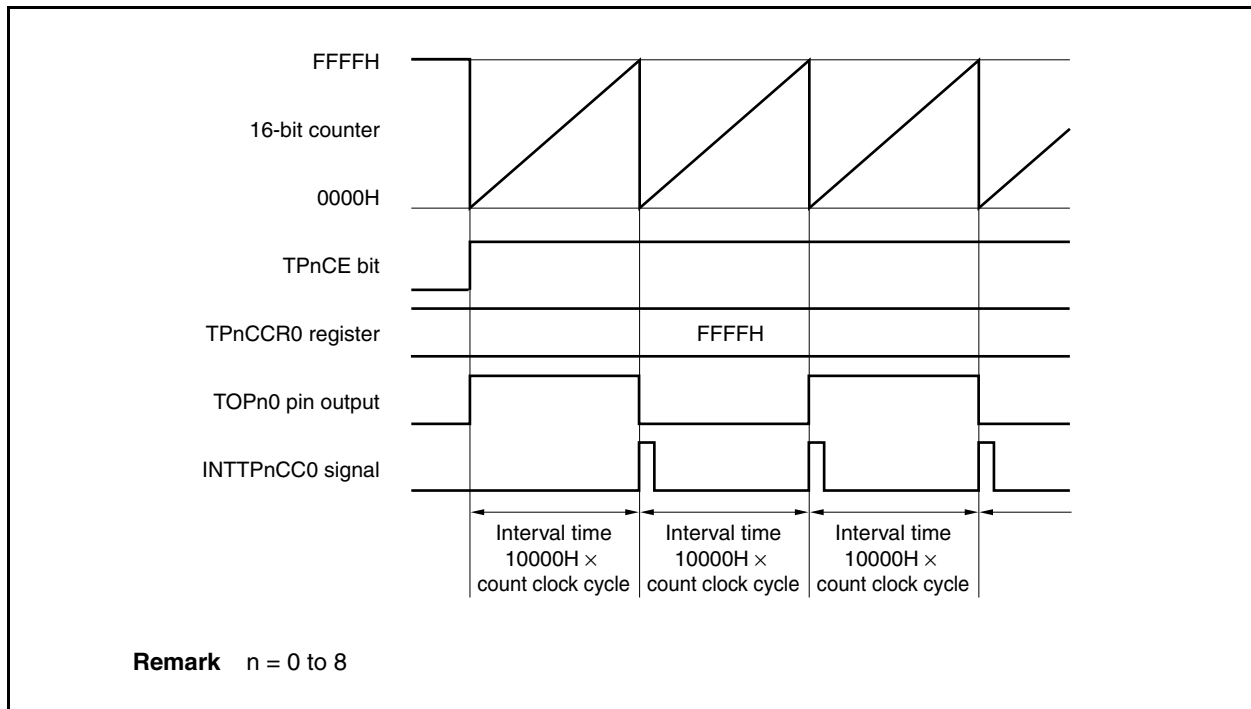
If the TPnCCR0 register is set to 0000H, the INTTPnCC0 signal is generated at each count clock subsequent to the first count clock, and the output of the TOPn0 pin is inverted.

The value of the 16-bit counter is always 0000H.



**(b) Operation if TPnCCR0 register is set to FFFFH**

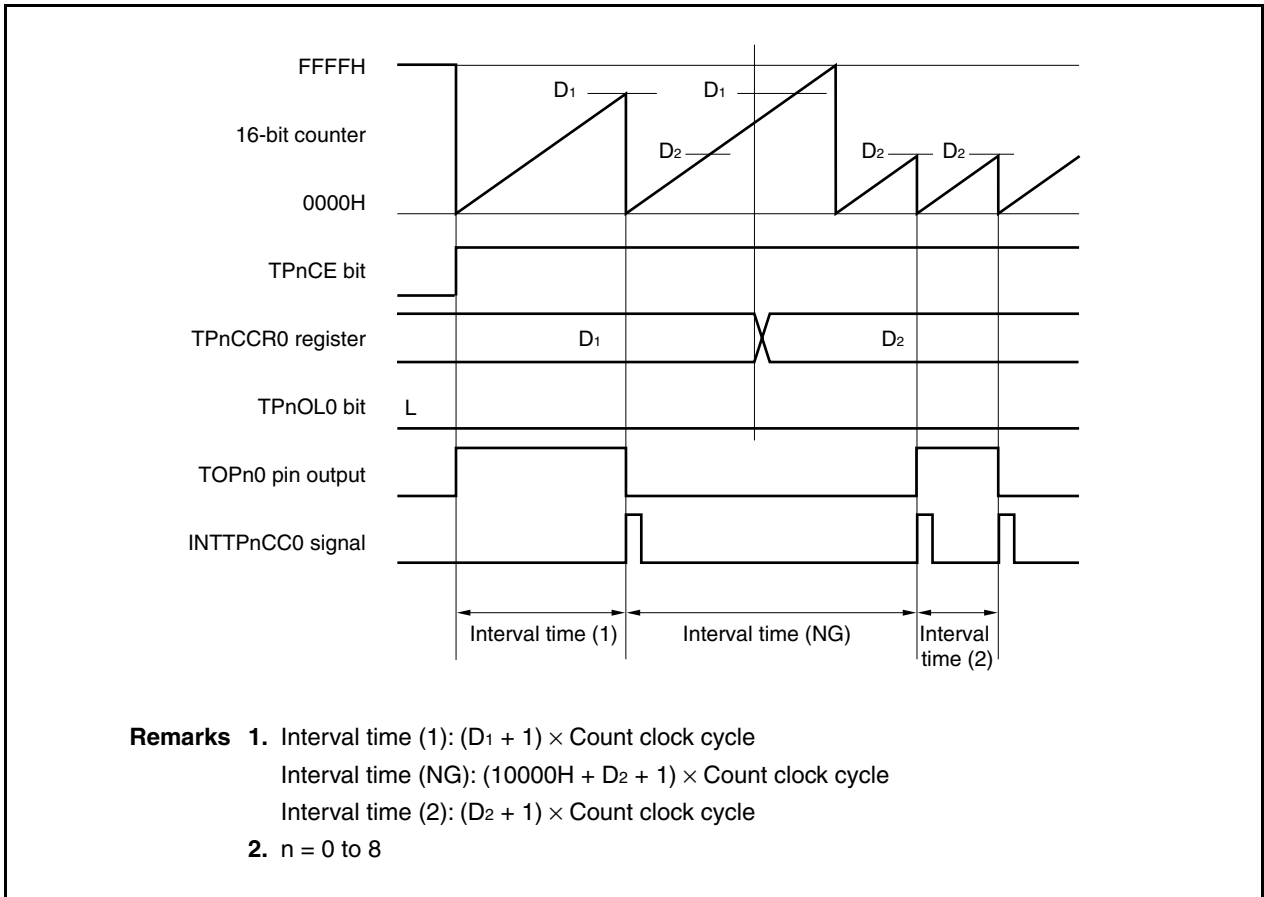
If the TPnCCR0 register is set to FFFFH, the 16-bit counter counts up to FFFFH. The counter is cleared to 0000H in synchronization with the next count-up timing. The INTTPnCC0 signal is generated and the output of the TOPn0 pin is inverted. At this time, an overflow interrupt request signal (INTTPnOV) is not generated, nor is the overflow flag (TPnOPT0.TPnOVF bit) set to 1.



**(c) Notes on rewriting TPnCCR0 register**

To change the value of the TPnCCR0 register to a smaller value, stop counting once and then change the set value.

If the value of the TPnCCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.



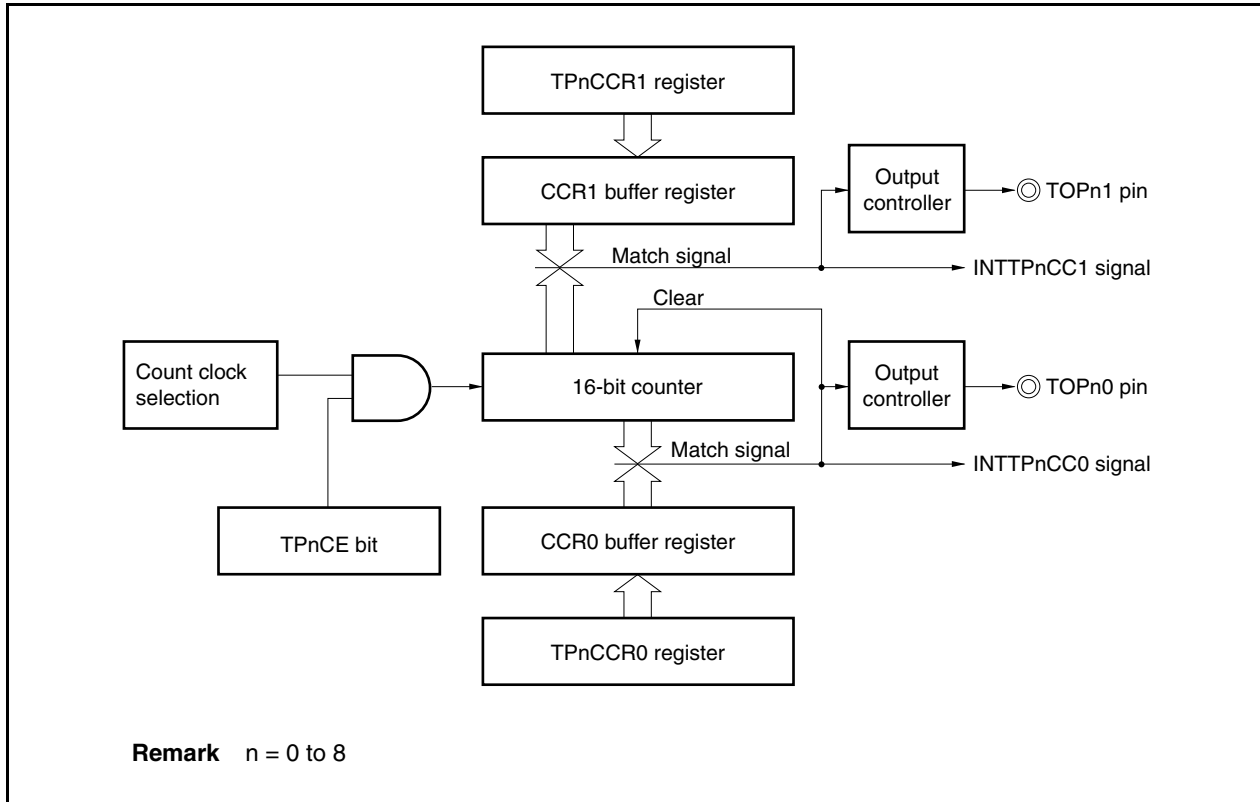
If the value of the TPnCCR0 register is changed from  $D_1$  to  $D_2$  while the count value is greater than  $D_2$  but less than  $D_1$ , the count value is transferred to the CCR0 buffer register as soon as the TPnCCR0 register has been rewritten. Consequently, the value of the 16-bit counter that is compared is  $D_2$ .

Because the count value has already exceeded  $D_2$ , however, the 16-bit counter counts up to FFFFH, overflows, and then counts up again from 0000H. When the count value matches  $D_2$ , the INTTPnCC0 signal is generated and the output of the TOPn0 pin is inverted.

Therefore, the INTTPnCC0 signal may not be generated at the interval time " $(D_1 + 1) \times \text{Count clock cycle}$ " or " $(D_2 + 1) \times \text{Count clock cycle}$ " originally expected, but may be generated at an interval of " $(10000H + D_2 + 1) \times \text{Count clock period}$ ".

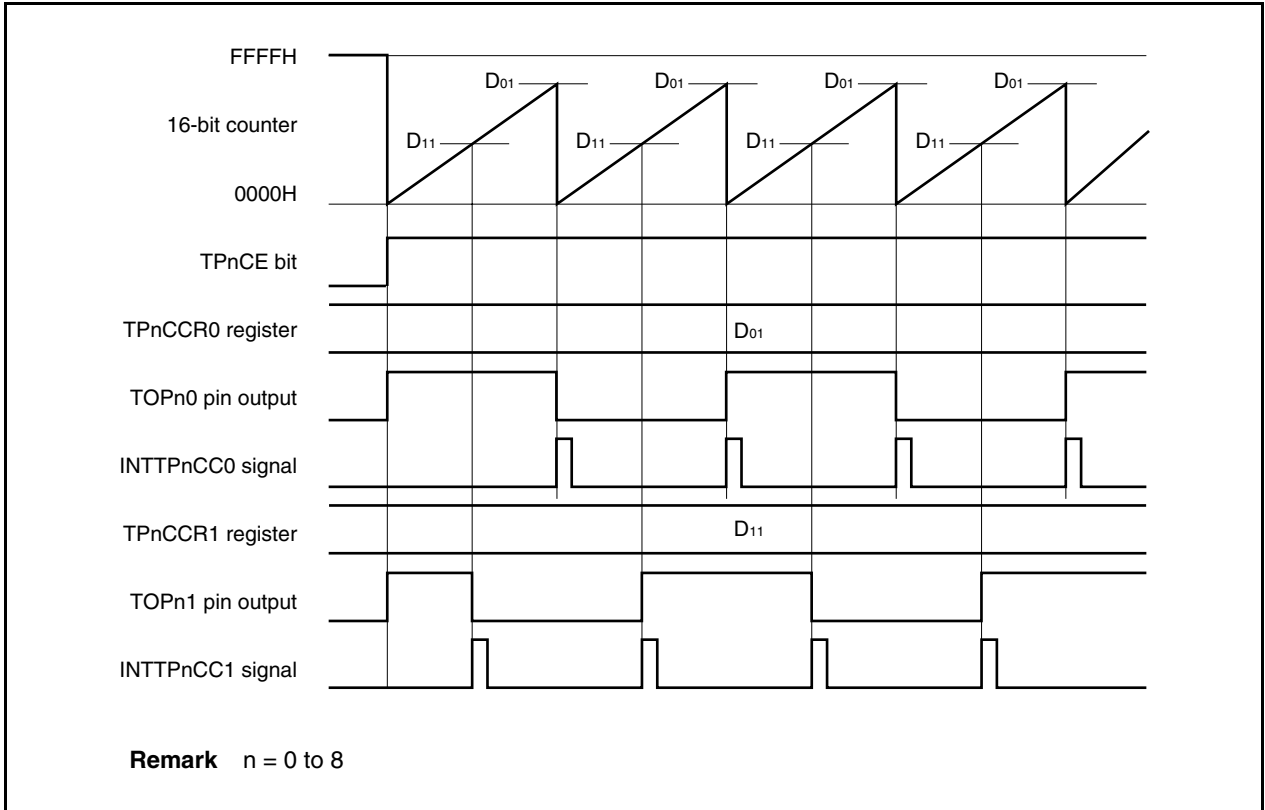
(d) Operation of TPnCCR1 register

Figure 7-6. Configuration of TPnCCR1 Register



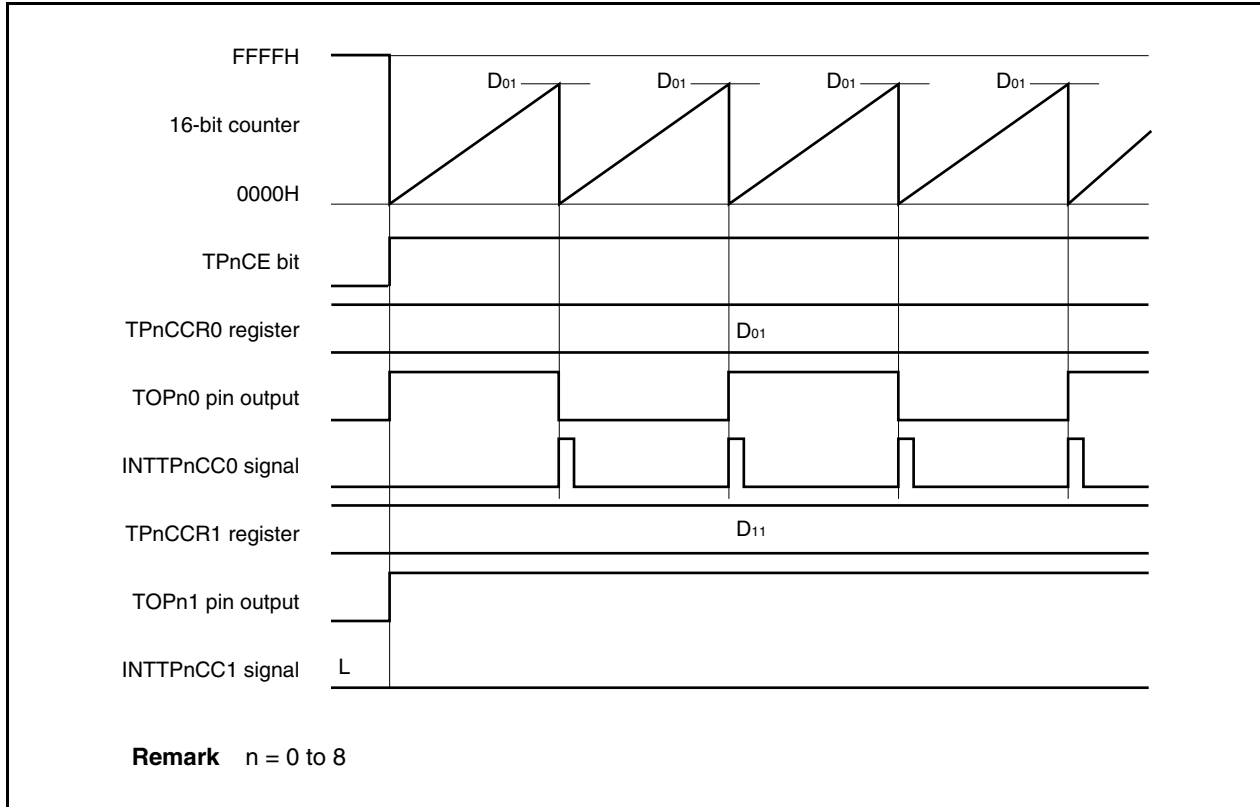
If the set value of the TPnCCR1 register is less than the set value of the TPnCCR0 register, the INTTPnCC1 signal is generated once per cycle. At the same time, the output of the TOPn1 pin is inverted. The TOPn1 pin outputs a square wave with the same cycle as that output by the TOPn0 pin.

Figure 7-7. Timing Chart When  $D_{01} \geq D_{11}$



If the set value of the TPnCCR1 register is greater than the set value of the TPnCCR0 register, the count value of the 16-bit counter does not match the value of the TPnCCR1 register. Consequently, the INTTPnCC1 signal is not generated, nor is the output of the TOPn1 pin changed.

Figure 7-8. Timing Chart When  $D_{01} < D_{11}$



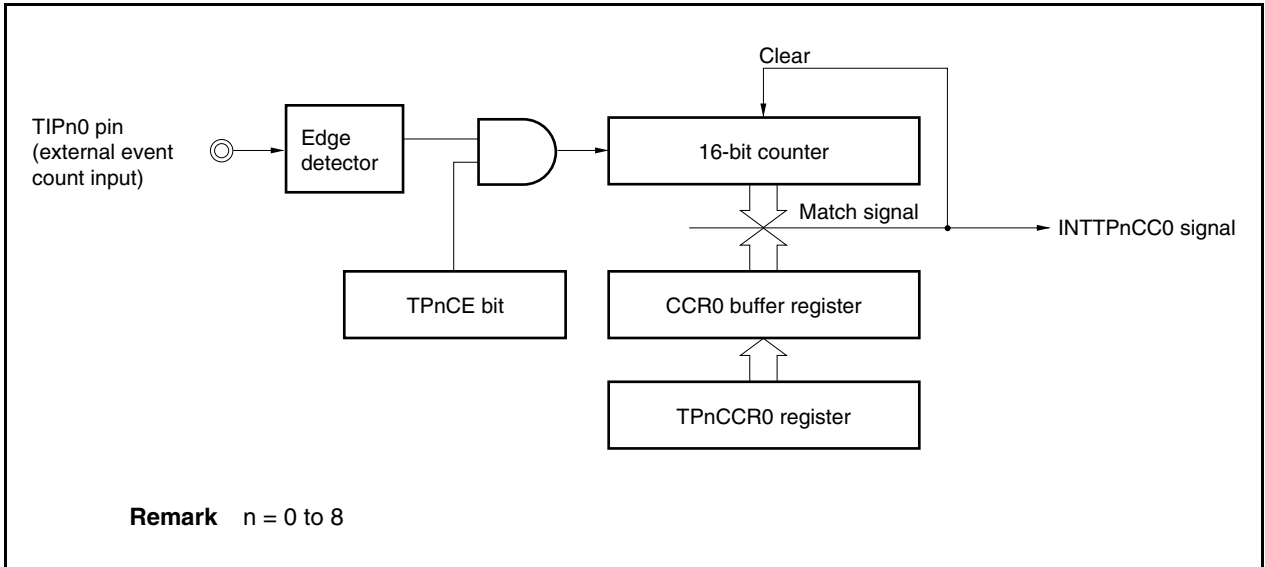


**7.5.2 External event count mode (TPnMD2 to TPnMD0 bits = 001)**

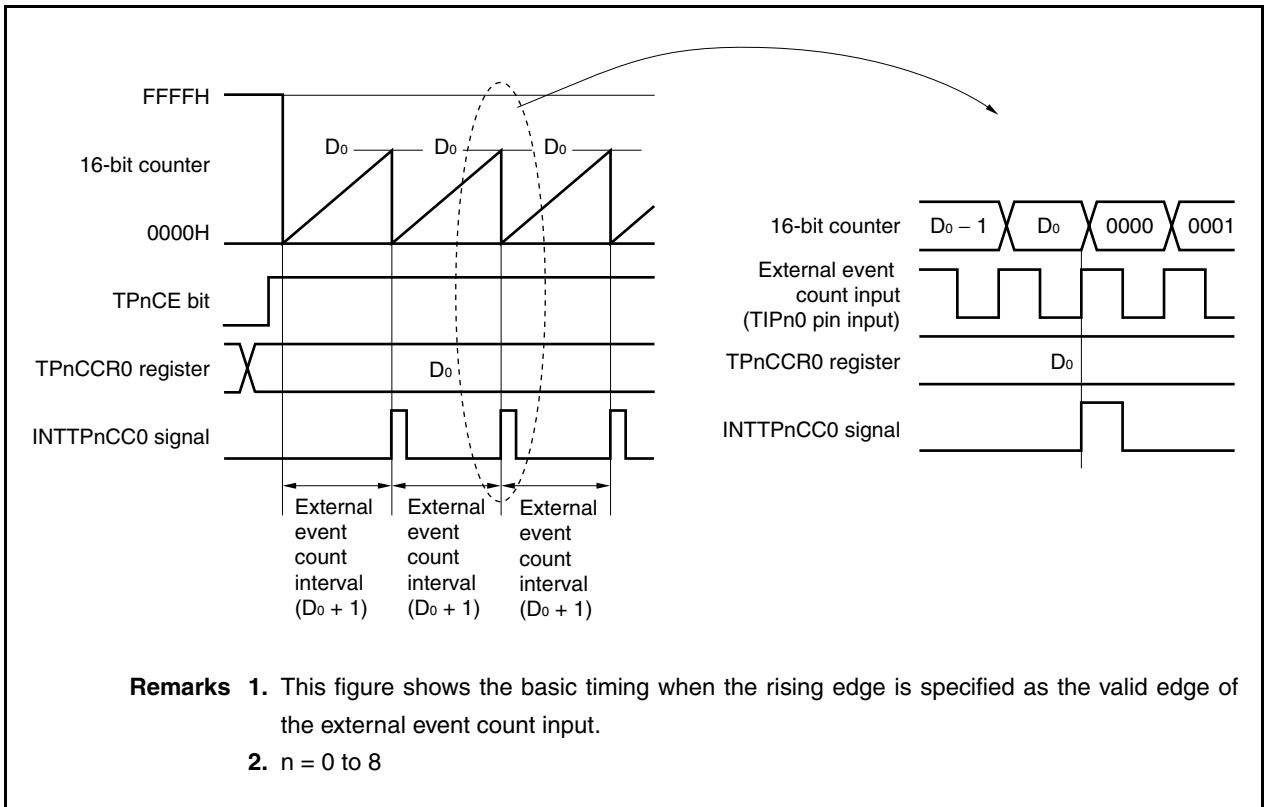
In the external event count mode, the valid edge of the external event count input is counted when the TPnCTL0.TPnCE bit is set to 1, and an interrupt request signal (INTTPnCC0) is generated each time the specified number of edges have been counted. The TOPn0 pin cannot be used.

Usually, the TPnCCR1 register is not used in the external event count mode.

**Figure 7-9. Configuration in External Event Count Mode**



**Figure 7-10. Basic Timing in External Event Count Mode**



When the TPnCE bit is set to 1, the value of the 16-bit counter is cleared from FFFFH to 0000H. The counter counts each time the valid edge of external event count input is detected. Additionally, the set value of the TPnCCR0 register is transferred to the CCR0 buffer register.

When the count value of the 16-bit counter matches the value of the CCR0 buffer register, the 16-bit counter is cleared to 0000H, and a compare match interrupt request signal (INTTPnCC0) is generated.

The INTTPnCC0 signal is generated each time the valid edge of the external event count input has been detected (set value of TPnCCR0 register + 1) times.

**Figure 7-11. Register Setting for Operation in External Event Count Mode (1/2)**

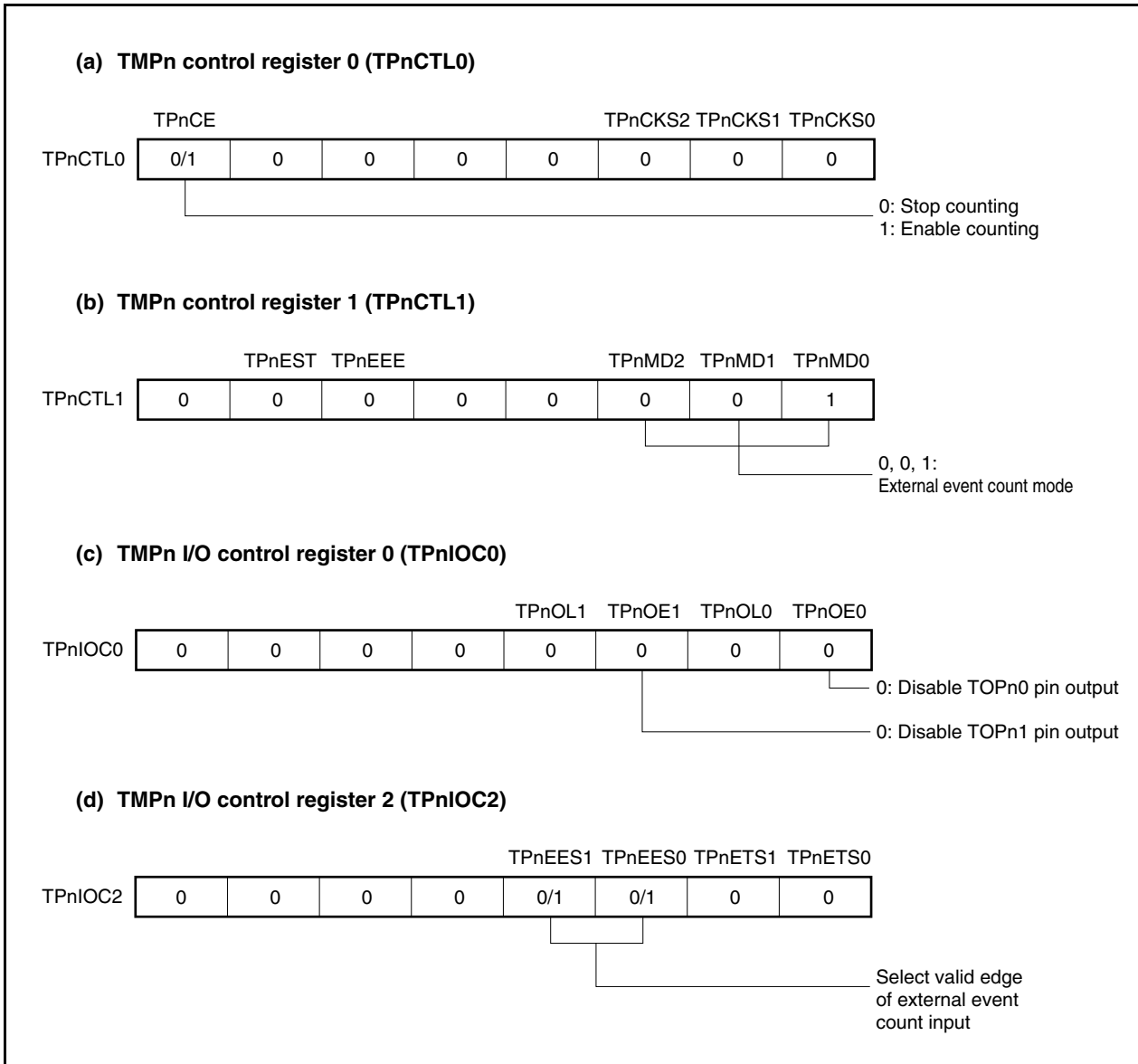


Figure 7-11. Register Setting for Operation in External Event Count Mode (2/2)

**(e) TMPn counter read buffer register (TPnCNT)**

The count value of the 16-bit counter can be read by reading the TPnCNT register.

**(f) TMPn capture/compare register 0 (TPnCCR0)**

If  $D_0$  is set to the TPnCCR0 register, the counter is cleared and a compare match interrupt request signal (INTTPnCC0) is generated when the number of external event counts reaches  $(D_0 + 1)$ .

**(g) TMPn capture/compare register 1 (TPnCCR1)**

Usually, the TPnCCR1 register is not used in the external event count mode. However, the set value of the TPnCCR1 register is transferred to the CCR1 buffer register. When the count value of the 16-bit counter matches the value of the CCR1 buffer register, a compare match interrupt request signal (INTTPnCC1) is generated.

Therefore, mask the interrupt signal by using the interrupt mask flag (TPnCCMK1).

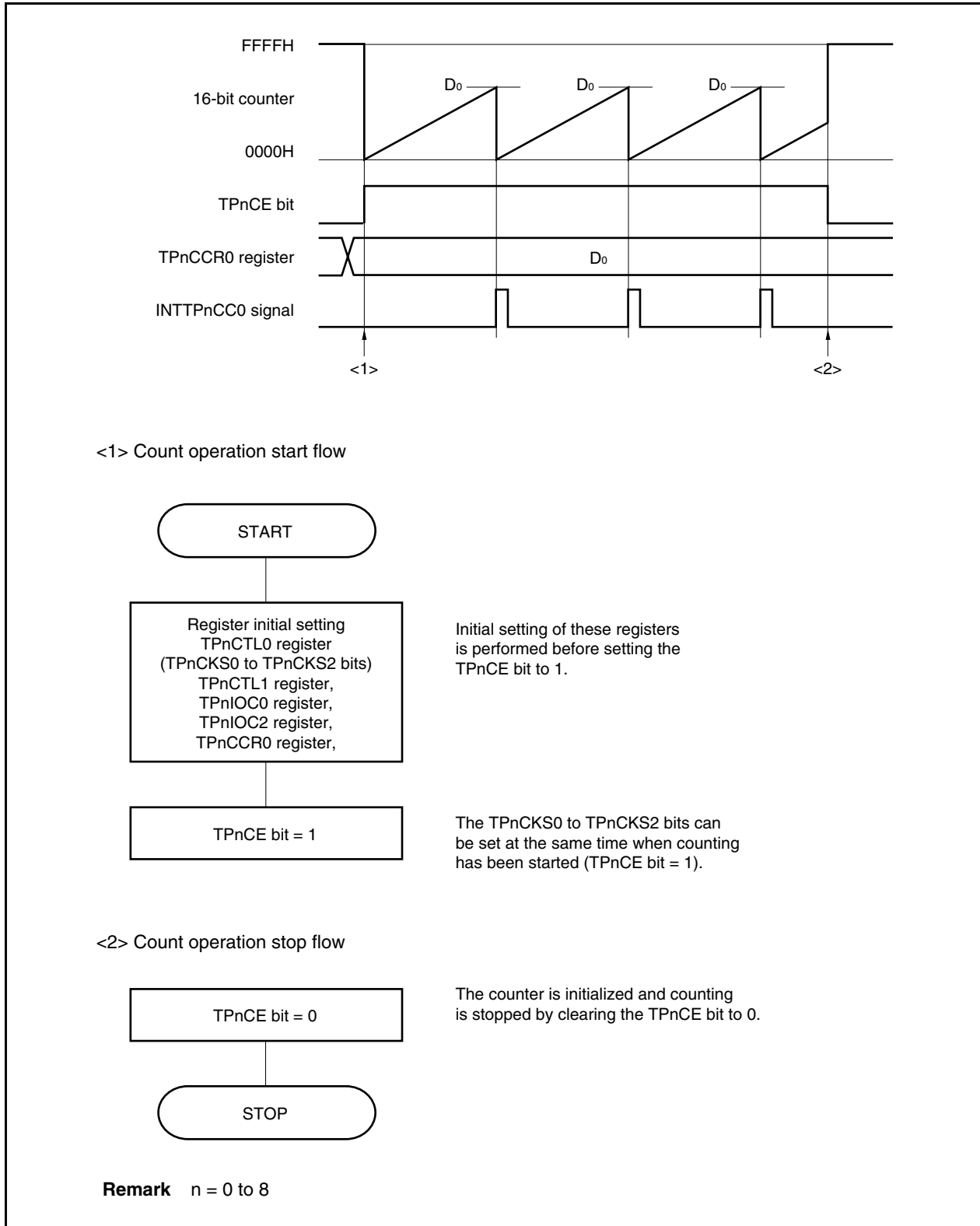
**Caution** When an external clock is used as the count clock, the external clock can be input only from the TIPn0 pin. At this time, set the TPnIOC1.TPnIS1 and TPnIOC1.TPnIS0 bits to 00 (capture trigger input (TIPn0 pin): no edge detection).

**Remarks** 1. TMPn I/O control register 1 (TPnIOC1) and TMPn option register 0 (TPnOPT0) are not used in the external event count mode.

2.  $n = 0$  to 8

(1) External event count mode operation flow

Figure 7-12. Flow of Software Processing in External Event Count Mode



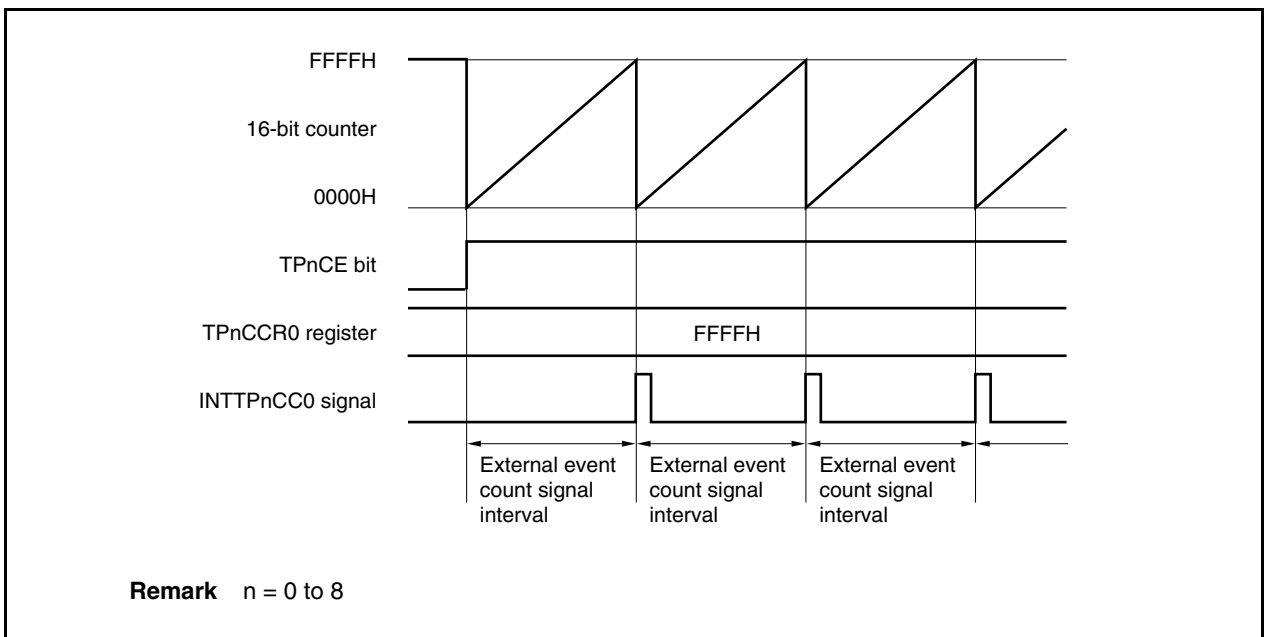
## (2) Operation timing in external event count mode

**Cautions 1.** In the external event count mode, do not set the TPnCCR0 register to 0000H.

**2.** In the external event count mode, use of the timer output is disabled. If performing timer output using external event count input, set the interval timer mode, and select the operation enabled by the external event count input for the count clock (TPnCTL1.TPnMD2 to TPnCTL1.TPnMD0 bits = 000, TPnCTL1.TPnEEE bit = 1).

## (a) Operation if TPnCCR0 register is set to FFFFH

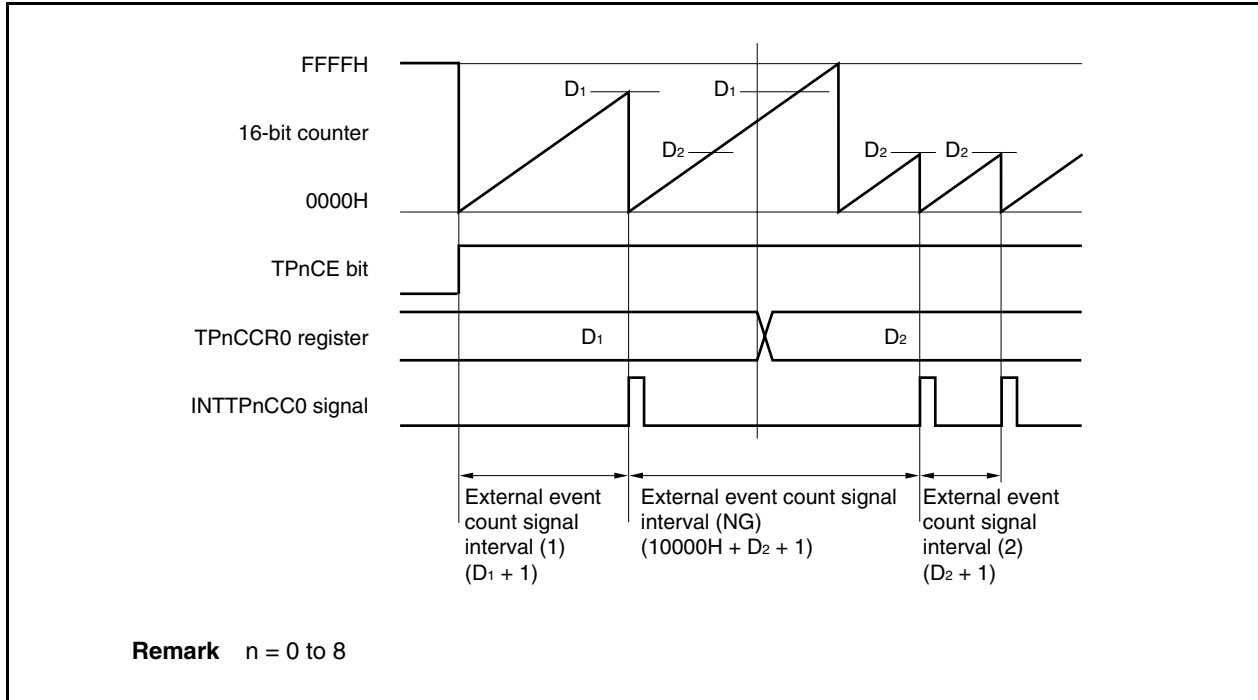
If the TPnCCR0 register is set to FFFFH, the 16-bit counter counts to FFFFH each time the valid edge of the external event count signal has been detected. The 16-bit counter is cleared to 0000H in synchronization with the next count-up timing, and the INTTPnCC0 signal is generated. At this time, the TPnOPT0.TPnOVF bit is not set.



**(b) Notes on rewriting the TPnCCR0 register**

To change the value of the TPnCCR0 register to a smaller value, stop counting once and then change the set value.

If the value of the TPnCCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.



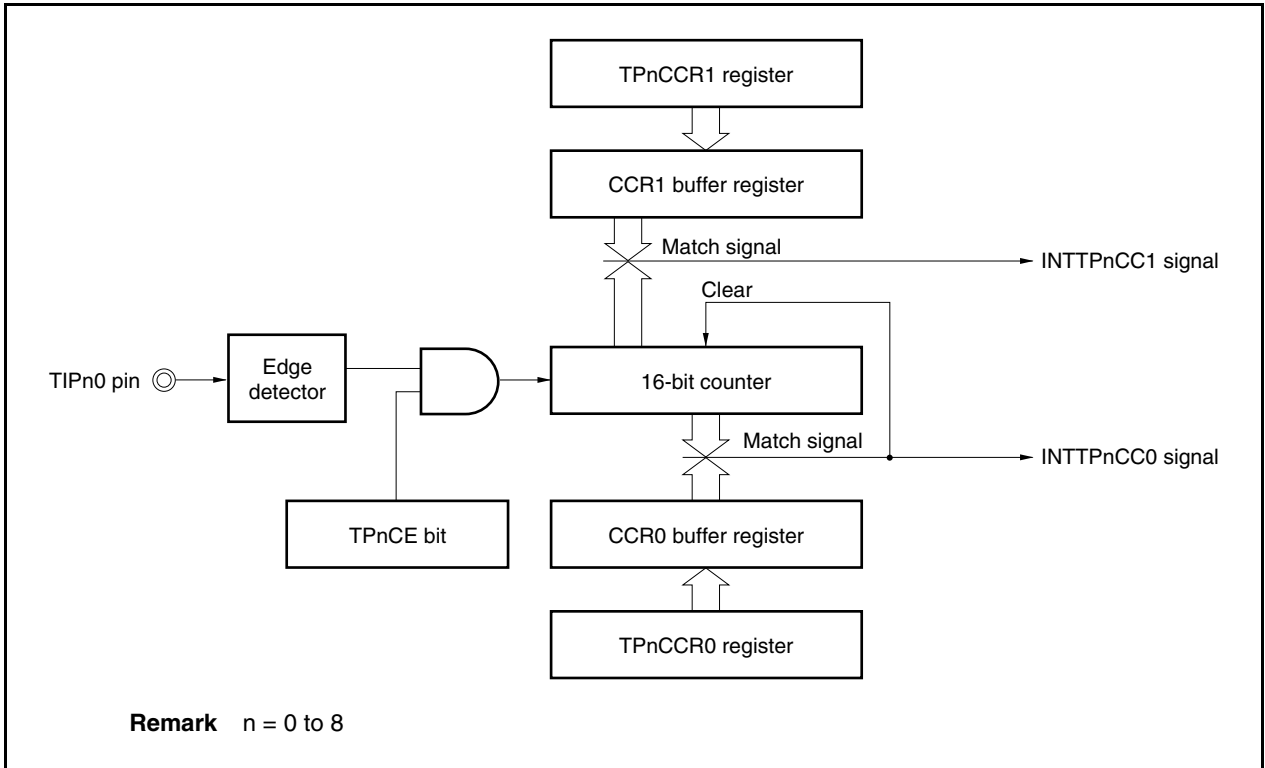
If the value of the TPnCCR0 register is changed from  $D_1$  to  $D_2$  while the count value is greater than  $D_2$  but less than  $D_1$ , the count value is transferred to the CCR0 buffer register as soon as the TPnCCR0 register has been rewritten. Consequently, the value that is compared with the 16-bit counter is  $D_2$ .

Because the count value has already exceeded  $D_2$ , however, the 16-bit counter counts up to FFFFH, overflows, and then counts up again from 0000H. When the count value matches  $D_2$ , the INTTPnCC0 signal is generated.

Therefore, the INTTPnCC0 signal may not be generated at the valid edge count of " $(D_1 + 1)$  times" or " $(D_2 + 1)$  times" originally expected, but may be generated at the valid edge count of " $(10000H + D_2 + 1)$  times".

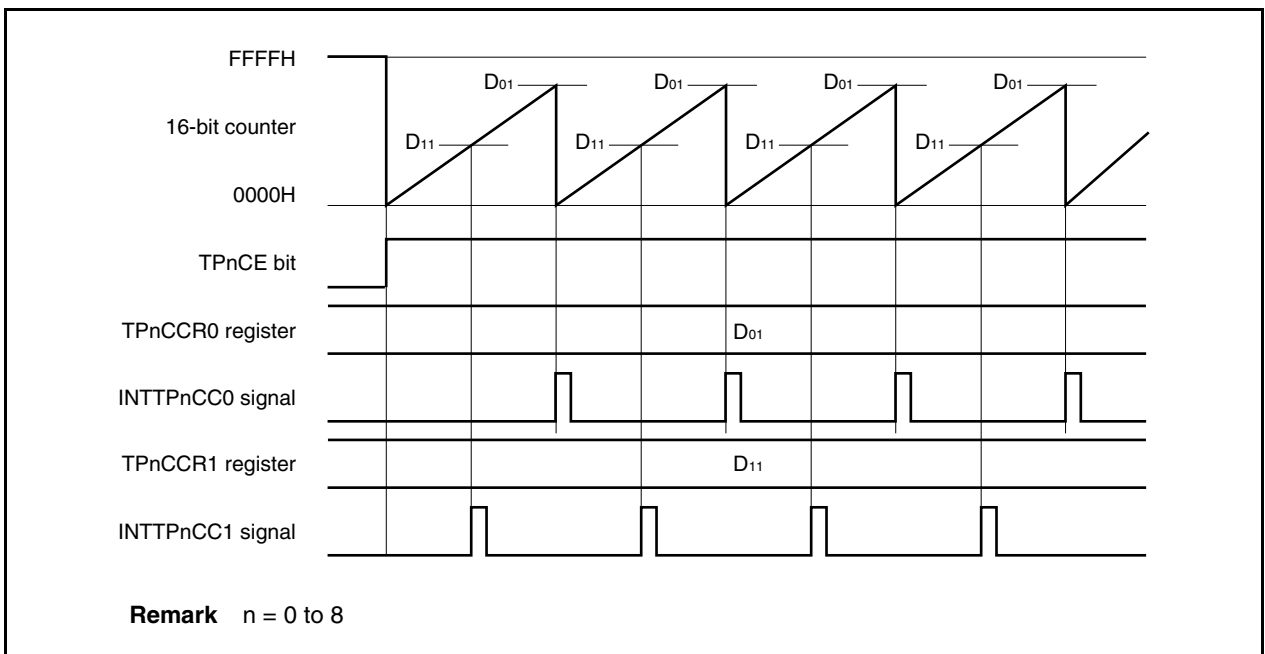
(c) Operation of TPnCCR1 register

Figure 7-13. Configuration of TPnCCR1 Register



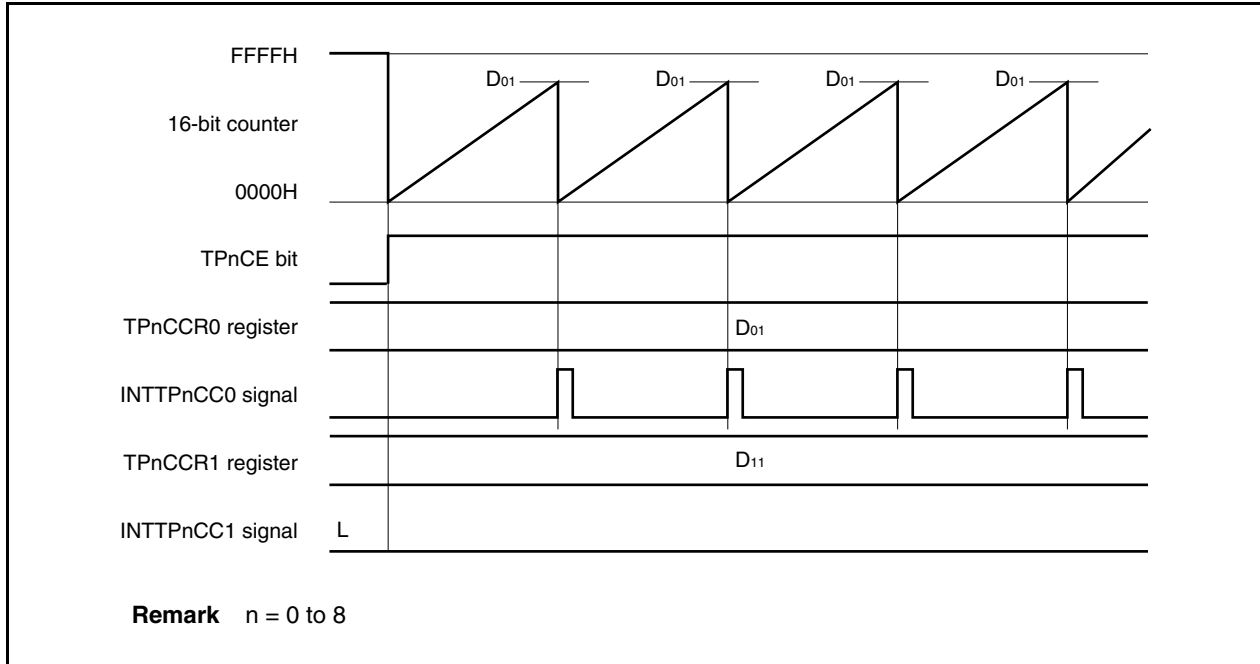
If the set value of the TPnCCR1 register is smaller than the set value of the TPnCCR0 register, the INTTPnCC1 signal is generated once per cycle.

Figure 7-14. Timing Chart When  $D_{01} \geq D_{11}$



If the set value of the TPnCCR1 register is greater than the set value of the TPnCCR0 register, the INTTPnCC1 signal is not generated because the count value of the 16-bit counter and the value of the TPnCCR1 register do not match.

Figure 7-15. Timing Chart When  $D_{01} < D_{11}$





**7.5.3 External trigger pulse output mode (TPnMD2 to TPnMD0 bits = 010)**

In the external trigger pulse output mode, 16-bit timer/event counter P waits for a trigger when the TPnCTL0.TPnCE bit is set to 1. When the valid edge of an external trigger input signal is detected, 16-bit timer/event counter P starts counting, and outputs a PWM waveform from the TOPn1 pin.

Pulses can also be output by generating a software trigger instead of using the external trigger. When using a software trigger, a square wave that has one cycle of the PWM waveform as half its cycle can also be output from the TOPn0 pin.

**Figure 7-16. Configuration in External Trigger Pulse Output Mode**

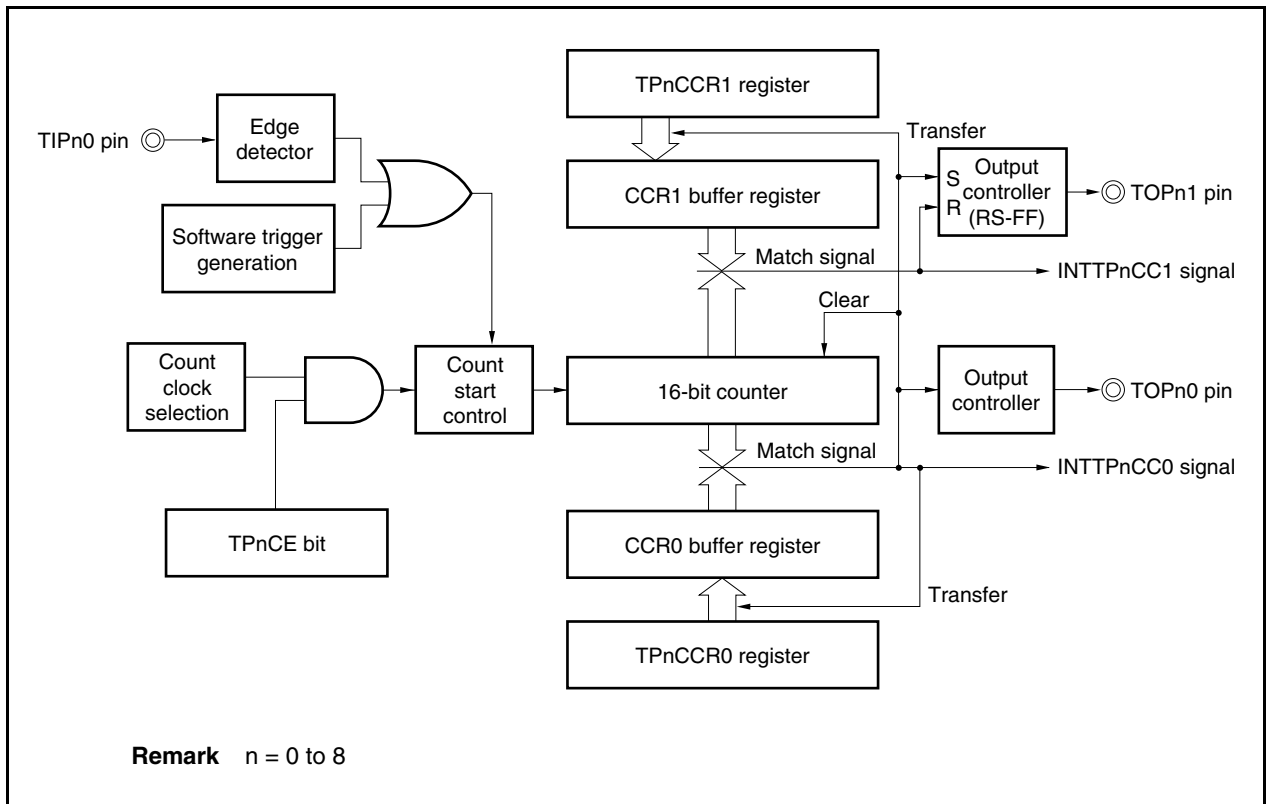
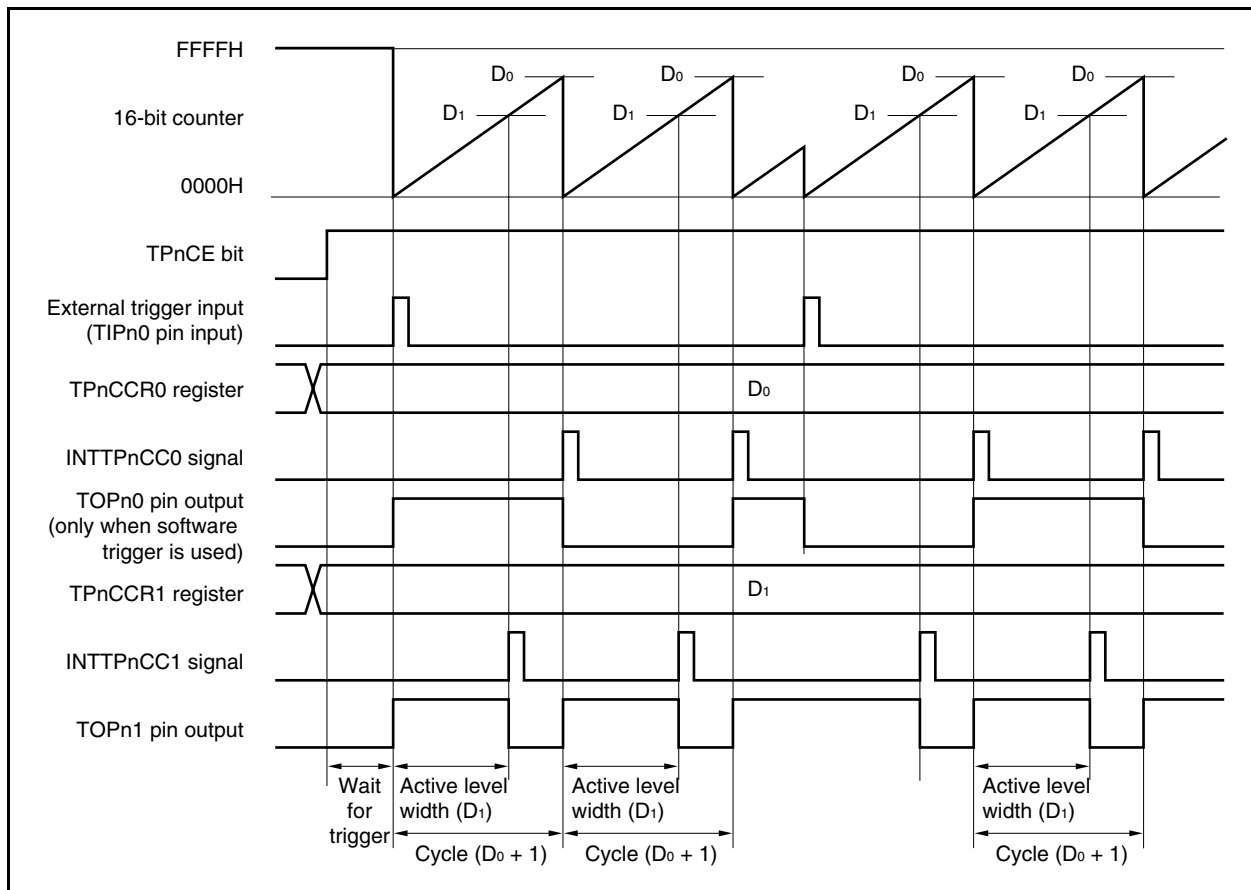


Figure 7-17. Basic Timing in External Trigger Pulse Output Mode



16-bit timer/event counter P waits for a trigger when the TPnCE bit is set to 1. When the trigger is generated, the 16-bit counter is cleared from FFFFH to 0000H, starts counting at the same time, and outputs a PWM waveform from the TOPn1 pin. If the trigger is generated again while the counter is operating, the counter is cleared to 0000H and restarted. (The output of the TOPn0 pin is inverted. The TOPn1 pin outputs a high-level regardless of the status (high/low) when a trigger occurs.)

The active level width, cycle, and duty factor of the PWM waveform can be calculated as follows.

$$\text{Active level width} = (\text{Set value of TPnCCR1 register}) \times \text{Count clock cycle}$$

$$\text{Cycle} = (\text{Set value of TPnCCR0 register} + 1) \times \text{Count clock cycle}$$

$$\text{Duty factor} = (\text{Set value of TPnCCR1 register}) / (\text{Set value of TPnCCR0 register} + 1)$$

The compare match request signal INTTPnCC0 is generated when the 16-bit counter counts next time after its count value matches the value of the CCR0 buffer register, and the 16-bit counter is cleared to 0000H. The compare match interrupt request signal INTTPnCC1 is generated when the count value of the 16-bit counter matches the value of the CCR1 buffer register.

The value set to the TPnCCRm register is transferred to the CCRm buffer register when the count value of the 16-bit counter matches the value of the CCRm buffer register and the 16-bit counter is cleared to 0000H.

The valid edge of an external trigger input signal, or setting the software trigger (TPnCTL1.TPnEST bit) to 1 is used as the trigger.

**Remark** n = 0 to 8, m = 0, 1

Figure 7-18. Register Setting for Operation in External Trigger Pulse Output Mode (1/2)

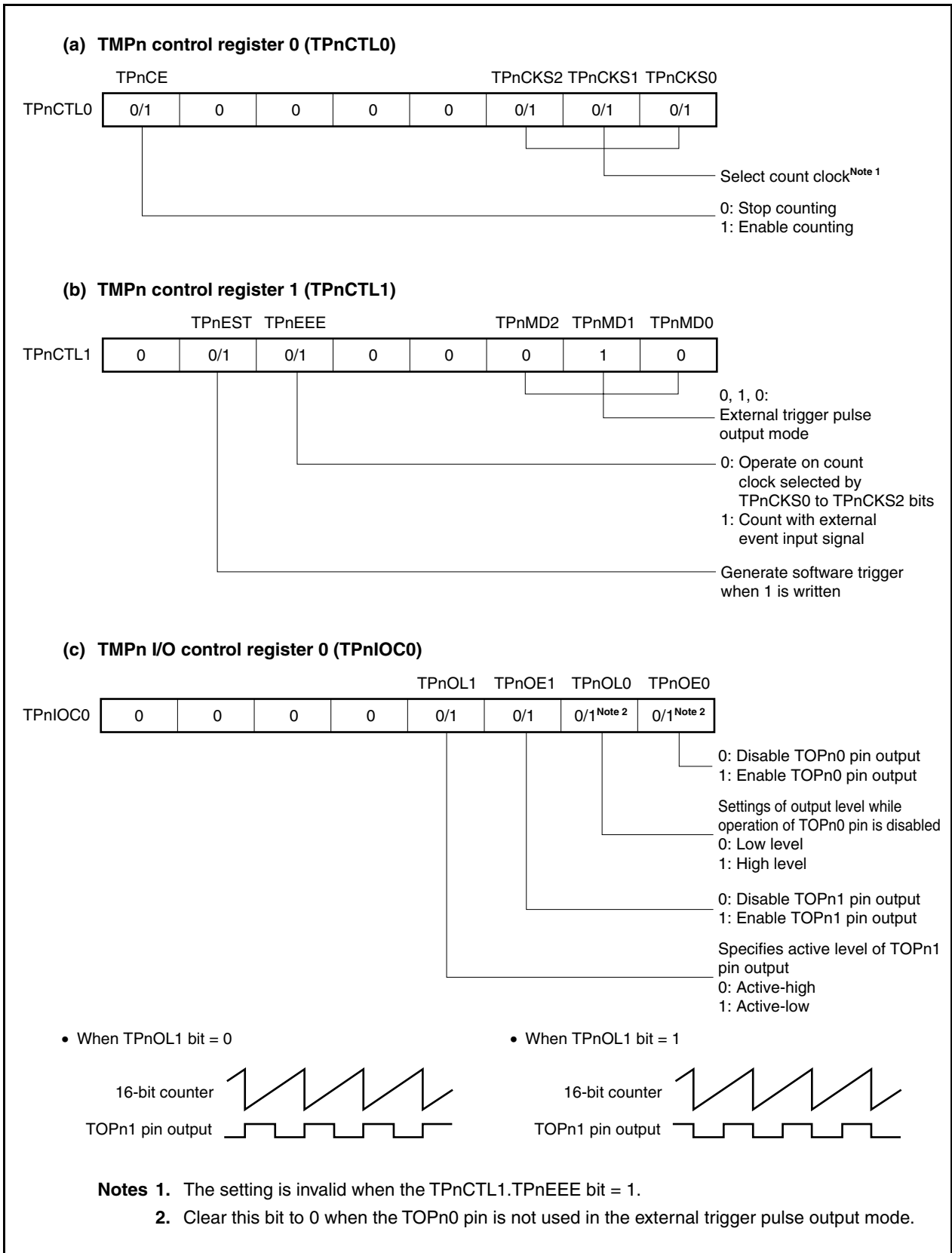
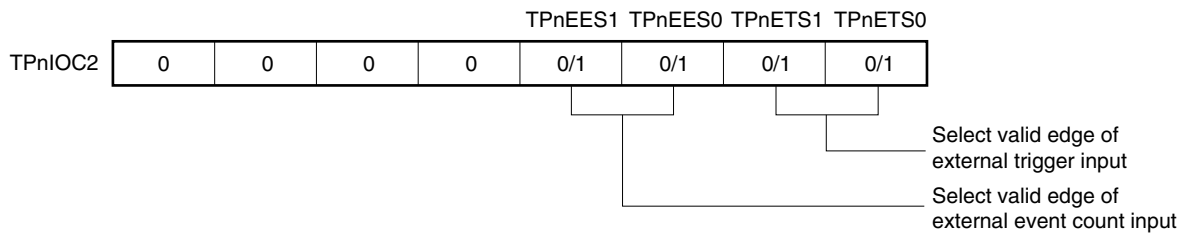


Figure 7-18. Register Setting for Operation in External Trigger Pulse Output Mode (2/2)

**(d) TMPn I/O control register 2 (TPnIOC2)****(e) TMPn counter read buffer register (TPnCNT)**

The value of the 16-bit counter can be read by reading the TPnCNT register.

**(f) TMPn capture/compare registers 0 and 1 (TPnCCR0 and TPnCCR1)**

If  $D_0$  is set to the TPnCCR0 register and  $D_1$  to the TPnCCR1 register, the cycle and active level of the PWM waveform are as follows.

$$\text{Cycle} = (D_0 + 1) \times \text{Count clock cycle}$$

$$\text{Active level width} = D_1 \times \text{Count clock cycle}$$

**Remarks** 1. TMPn I/O control register 1 (TPnIOC1) and TMPn option register 0 (TPnOPT0) are not used in the external trigger pulse output mode.

2.  $n = 0$  to 8

(1) Operation flow in external trigger pulse output mode

Figure 7-19. Software Processing Flow in External Trigger Pulse Output Mode (1/2)

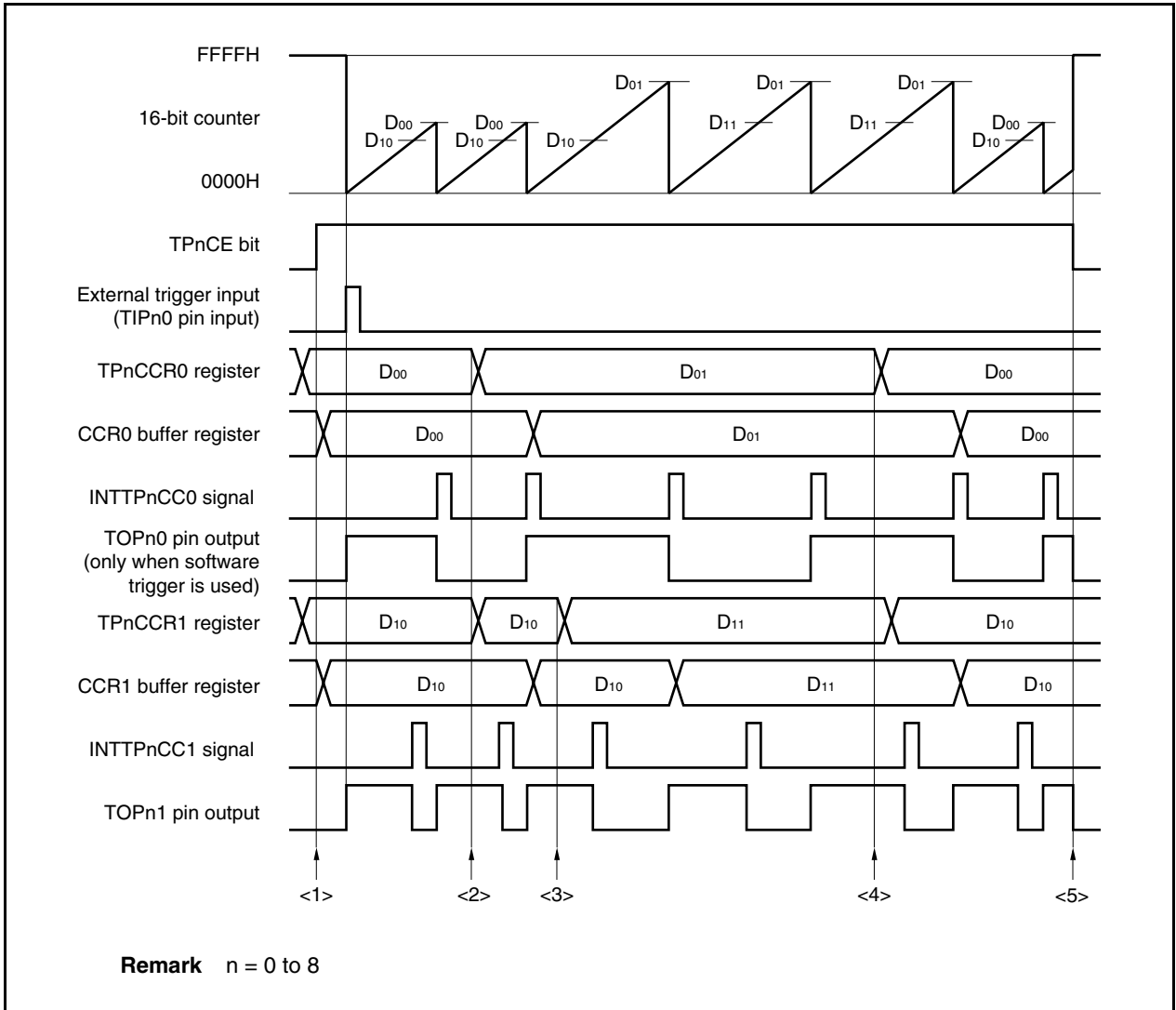
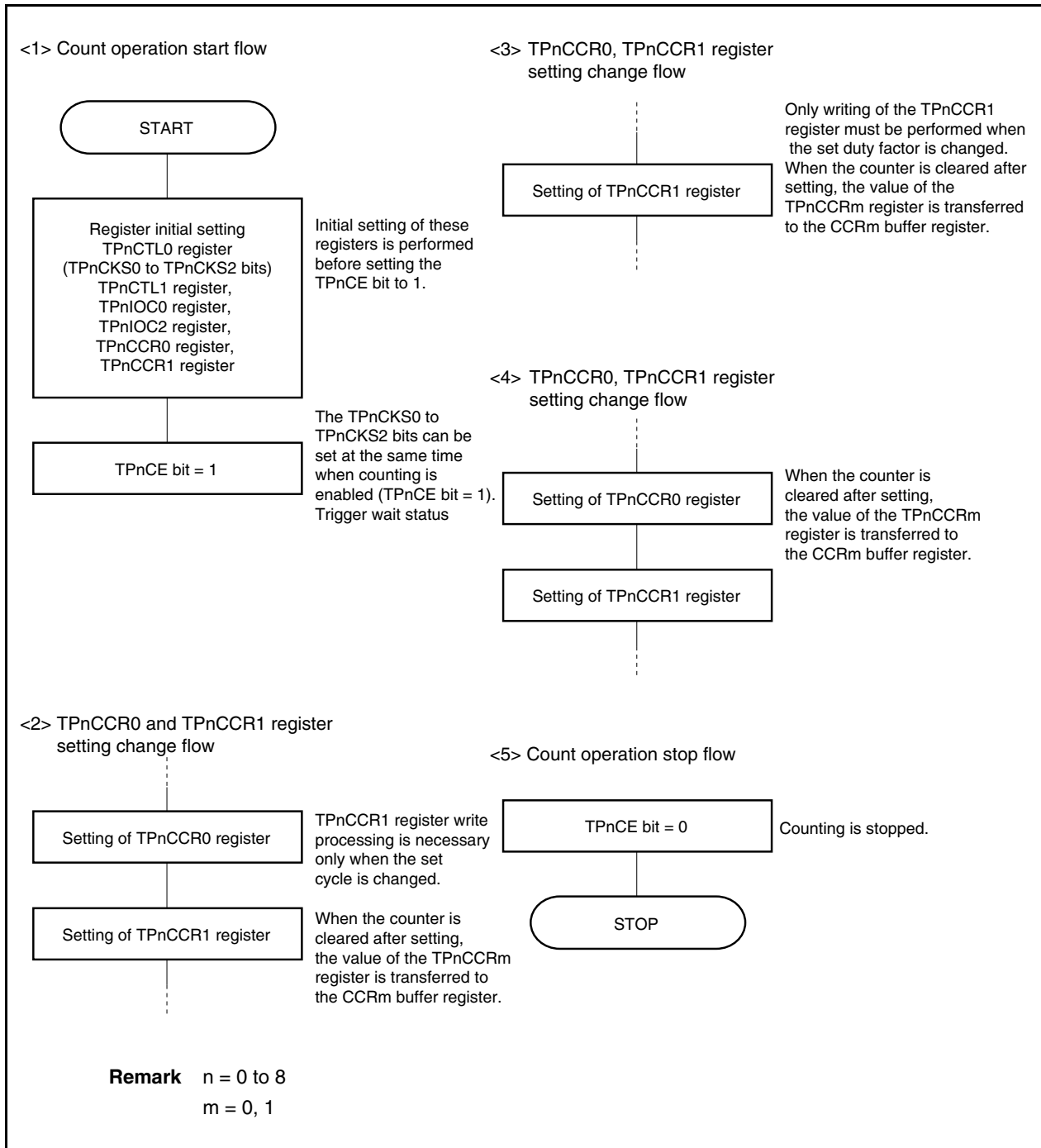


Figure 7-19. Software Processing Flow in External Trigger Pulse Output Mode (2/2)

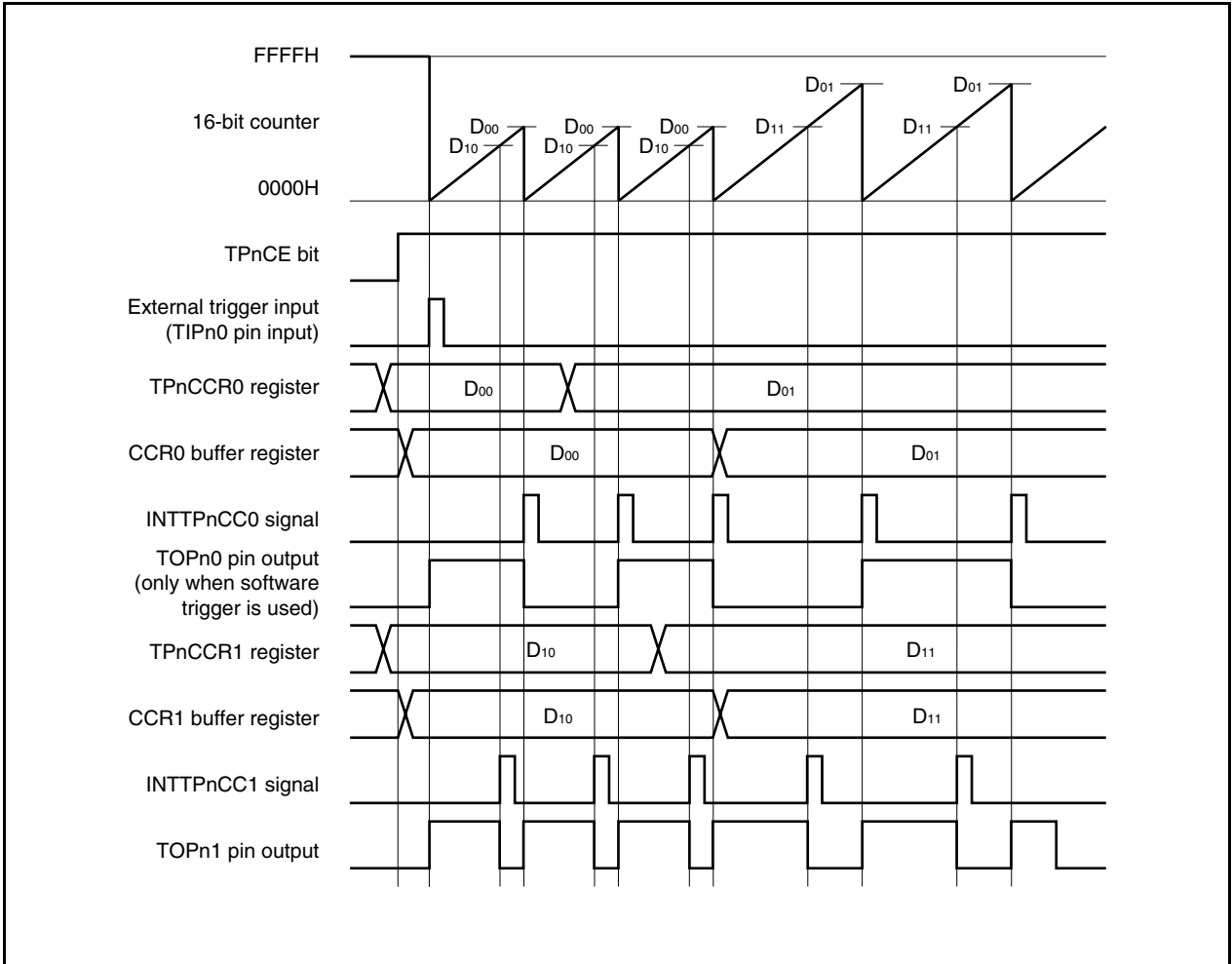


(2) External trigger pulse output mode operation timing

(a) Note on changing pulse width during operation

To change the PWM waveform while the counter is operating, write the TPnCCR1 register last.

Rewrite the TPnCCRm register after writing the TPnCCR1 register after the INTTPnCC0 signal is detected.



In order to transfer data from the TPnCCRm register to the CCRm buffer register, the TPnCCR1 register must be written.

To change both the cycle and active level width of the PWM waveform at this time, first set the cycle to the TPnCCR0 register and then set the active level width to the TPnCCR1 register.

To change only the cycle of the PWM waveform, first set the cycle to the TPnCCR0 register, and then write the same value to the TPnCCR1 register.

To change only the active level width (duty factor) of the PWM waveform, only the TPnCCR1 register has to be set.

After data is written to the TPnCCR1 register, the value written to the TPnCCRm register is transferred to the CCRm buffer register in synchronization with clearing of the 16-bit counter, and is used as the value compared with the 16-bit counter.

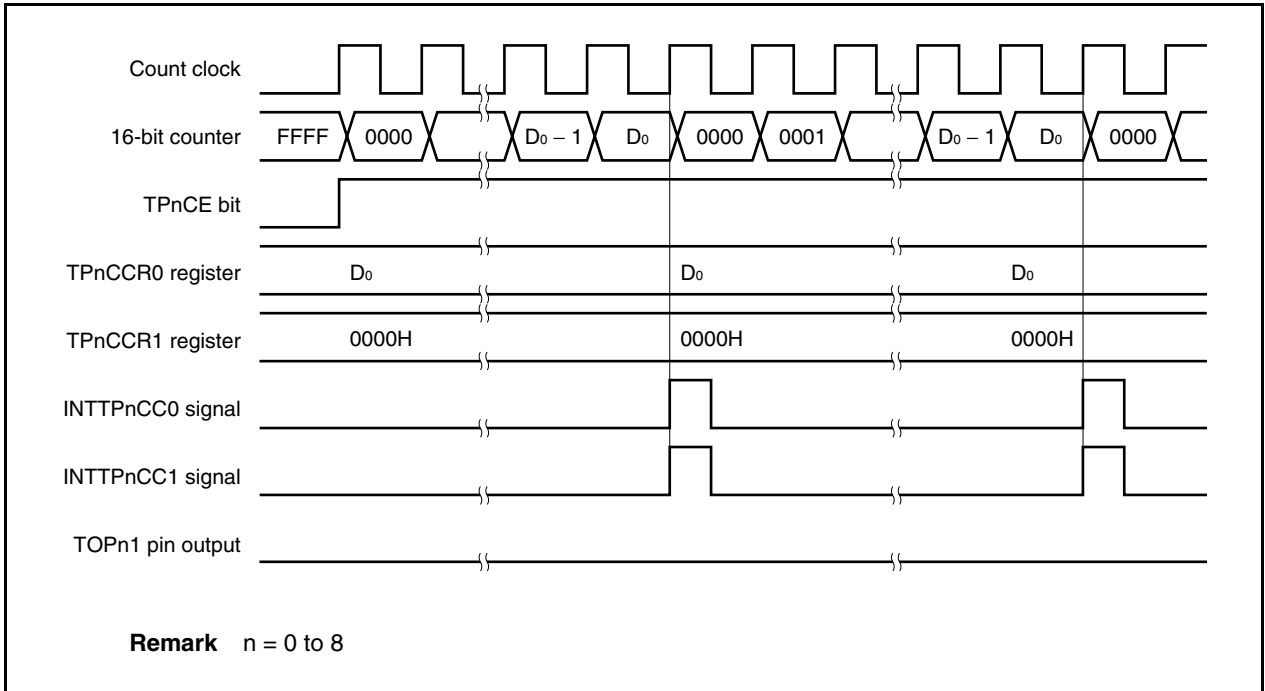
To write the TPnCCR0 or TPnCCR1 register again after writing the TPnCCR1 register once, do so after the INTTPnCC0 signal is generated. Otherwise, the value of the CCRm buffer register may become undefined because the timing of transferring data from the TPnCCRm register to the CCRm buffer register conflicts with writing the TPnCCRm register.

**Remark** n = 0 to 8  
m = 0, 1

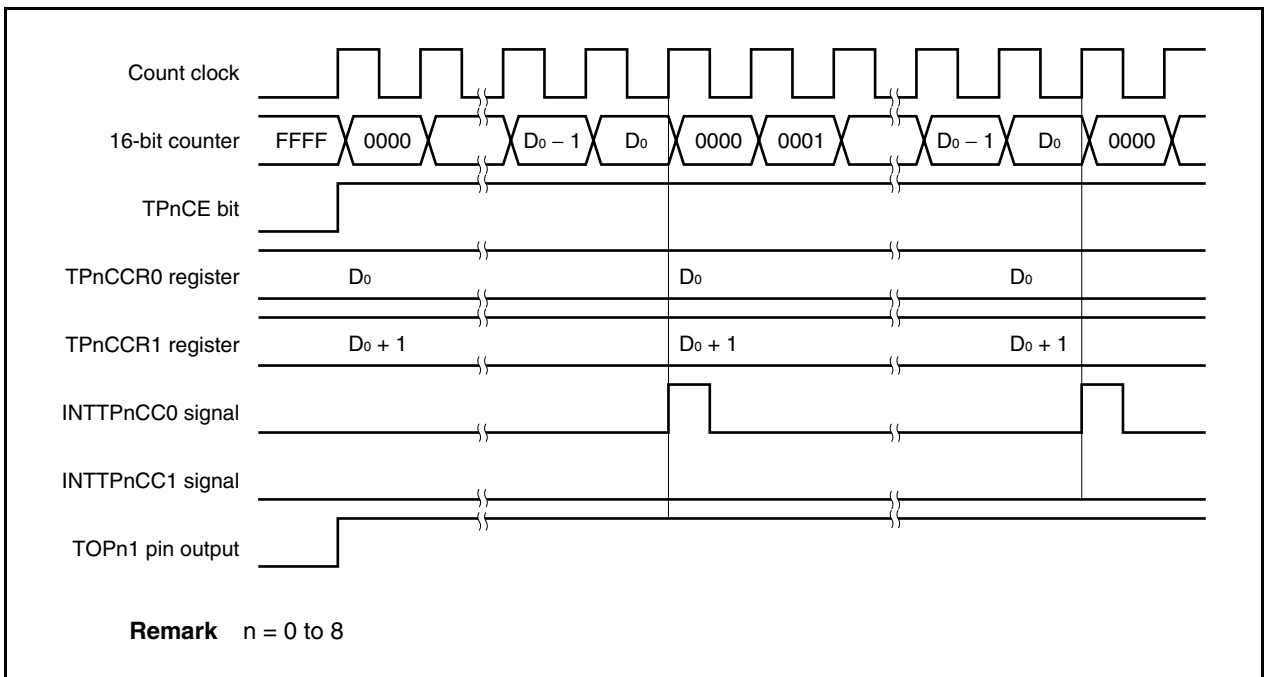


**(b) 0%/100% output of PWM waveform**

To output a 0% waveform, set the TPnCCR1 register to 0000H. If the set value of the TPnCCR0 register is FFFFH, the INTTPnCC1 signal is generated periodically.

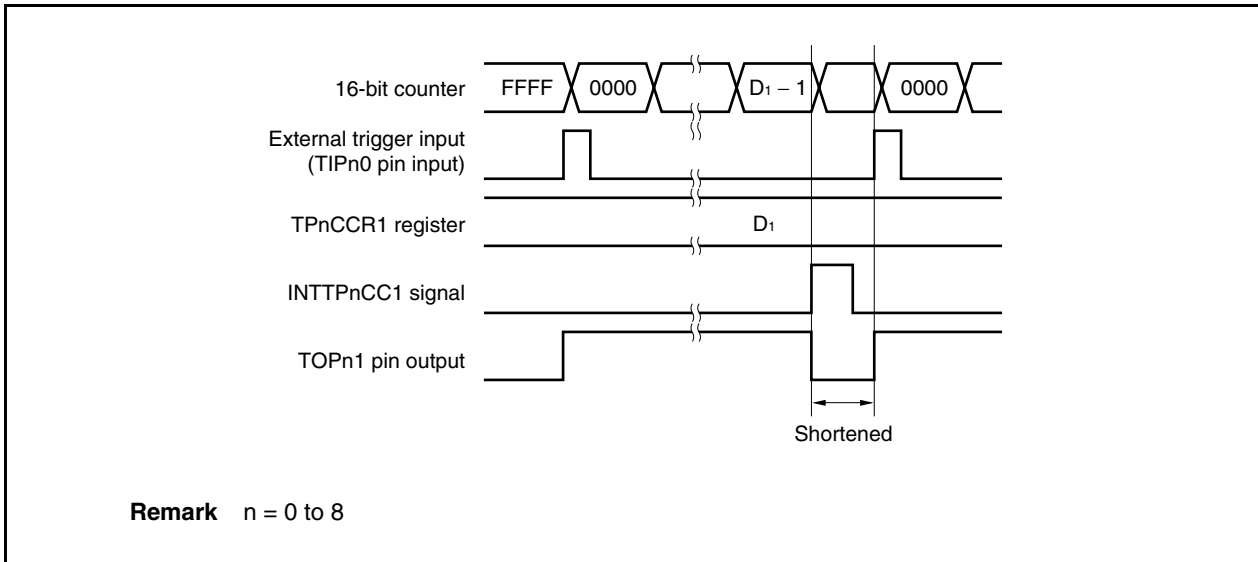


To output a 100% waveform, set a value of (set value of TPnCCR0 register + 1) to the TPnCCR1 register. If the set value of the TPnCCR0 register is FFFFH, 100% output cannot be produced.

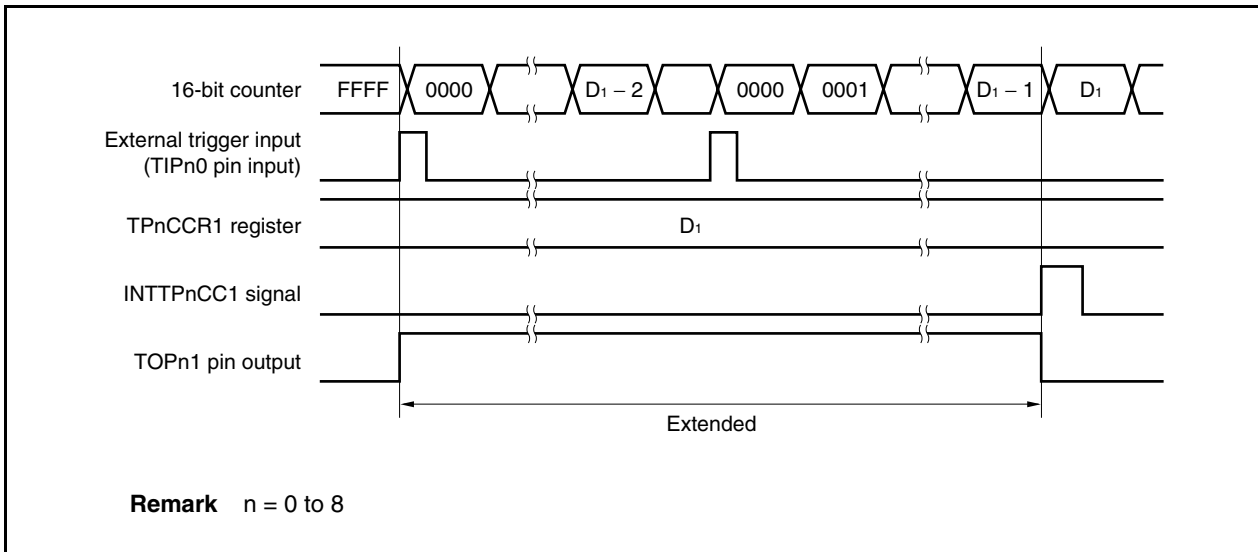


**(c) Conflict between trigger detection and match with TPnCCR1 register**

If the trigger is detected immediately after the INTTPnCC1 signal is generated, the 16-bit counter is immediately cleared to 0000H, the output signal of the TOPn1 pin is asserted, and the counter continues counting. Consequently, the inactive period of the PWM waveform is shortened.

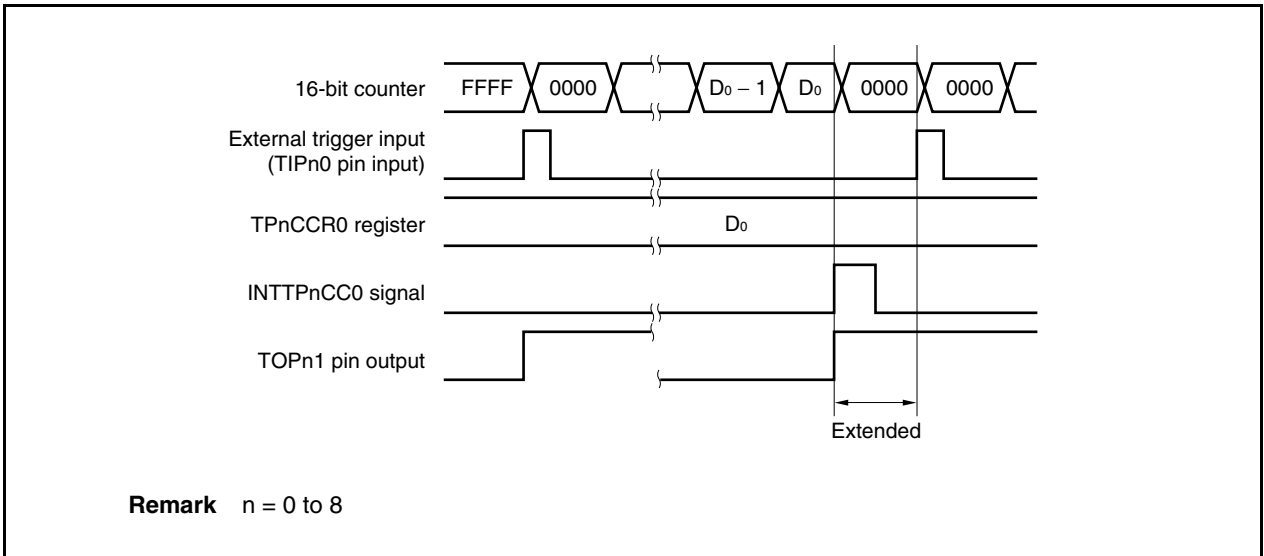


If the trigger is detected immediately before the INTTPnCC1 signal is generated, the INTTPnCC1 signal is not generated, and the 16-bit counter is cleared to 0000H and continues counting. The output signal of the TOPn1 pin remains active. Consequently, the active period of the PWM waveform is extended.

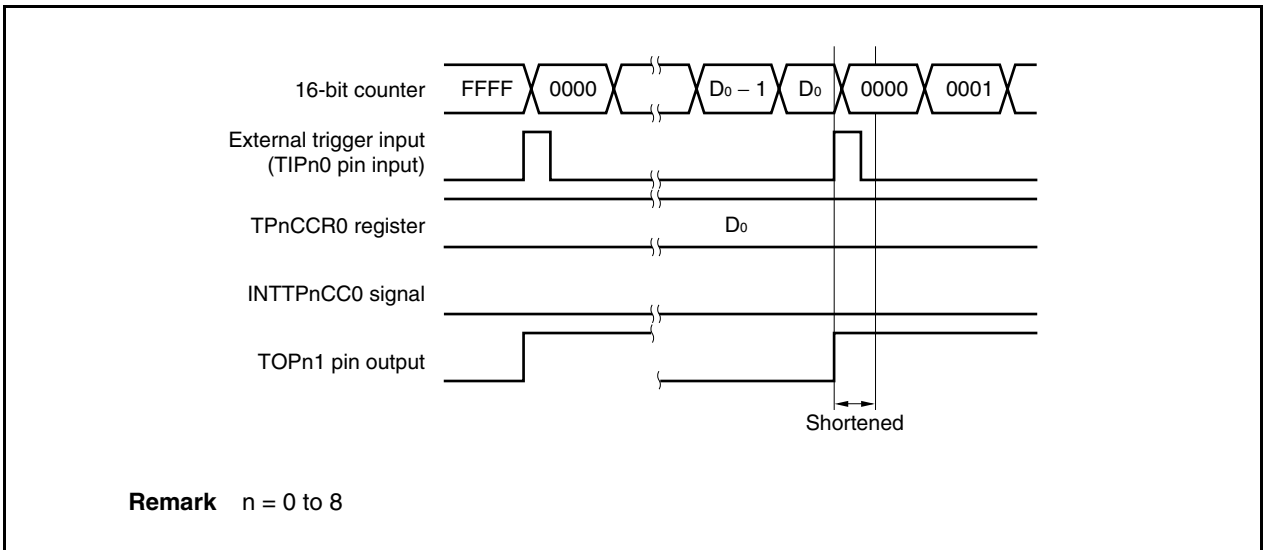


**(d) Conflict between trigger detection and match with TPnCCR0 register**

If the trigger is detected immediately after the INTTPnCC0 signal is generated, the 16-bit counter is cleared to 0000H and continues counting up. Therefore, the active period of the TOPn1 pin is extended by time from generation of the INTTPnCC0 signal to trigger detection.

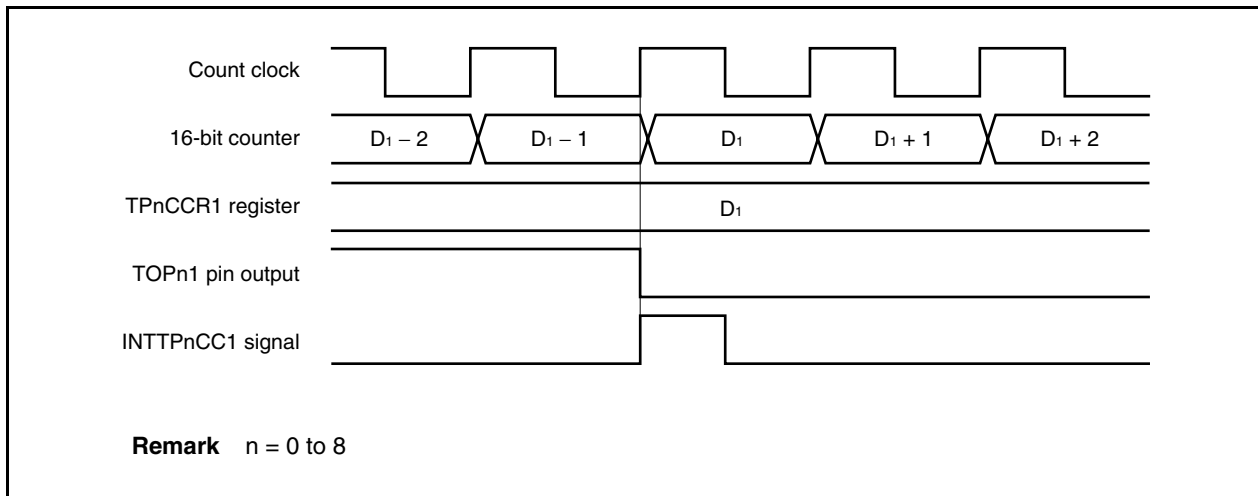


If the trigger is detected immediately before the INTTPnCC0 signal is generated, the INTTPnCC0 signal is not generated. The 16-bit counter is cleared to 0000H, the TOPn1 pin is asserted, and the counter continues counting. Consequently, the inactive period of the PWM waveform is shortened.



**(e) Generation timing of compare match interrupt request signal (INTTPnCC1)**

The timing of generation of the INTTPnCC1 signal in the external trigger pulse output mode differs from the timing of other INTTPnCC1 signals; the INTTPnCC1 signal is generated when the count value of the 16-bit counter matches the value of the TPnCCR1 register.



Usually, the INTTPnCC1 signal is generated in synchronization with the next count up, after the count value of the 16-bit counter matches the value of the TPnCCR1 register.

In the external trigger pulse output mode, however, it is generated one clock earlier. This is because the timing is changed to match the timing of changing the output signal of the TOPn1 pin.

**7.5.4 One-shot pulse output mode (TPnMD2 to TPnMD0 bits = 011)**

In the one-shot pulse output mode, 16-bit timer/event counter P waits for a trigger when the TPnCTL0.TPnCE bit is set to 1. When the valid edge of an external trigger input is detected, 16-bit timer/event counter P starts counting, and outputs a one-shot pulse from the TOPn1 pin.

Instead of the external trigger, a software trigger can also be generated to output the pulse. When the software trigger is used, the TOPn0 pin outputs the active level while the 16-bit counter is counting, and the inactive level when the counter is stopped (waiting for a trigger).

**Figure 7-20. Configuration in One-Shot Pulse Output Mode**

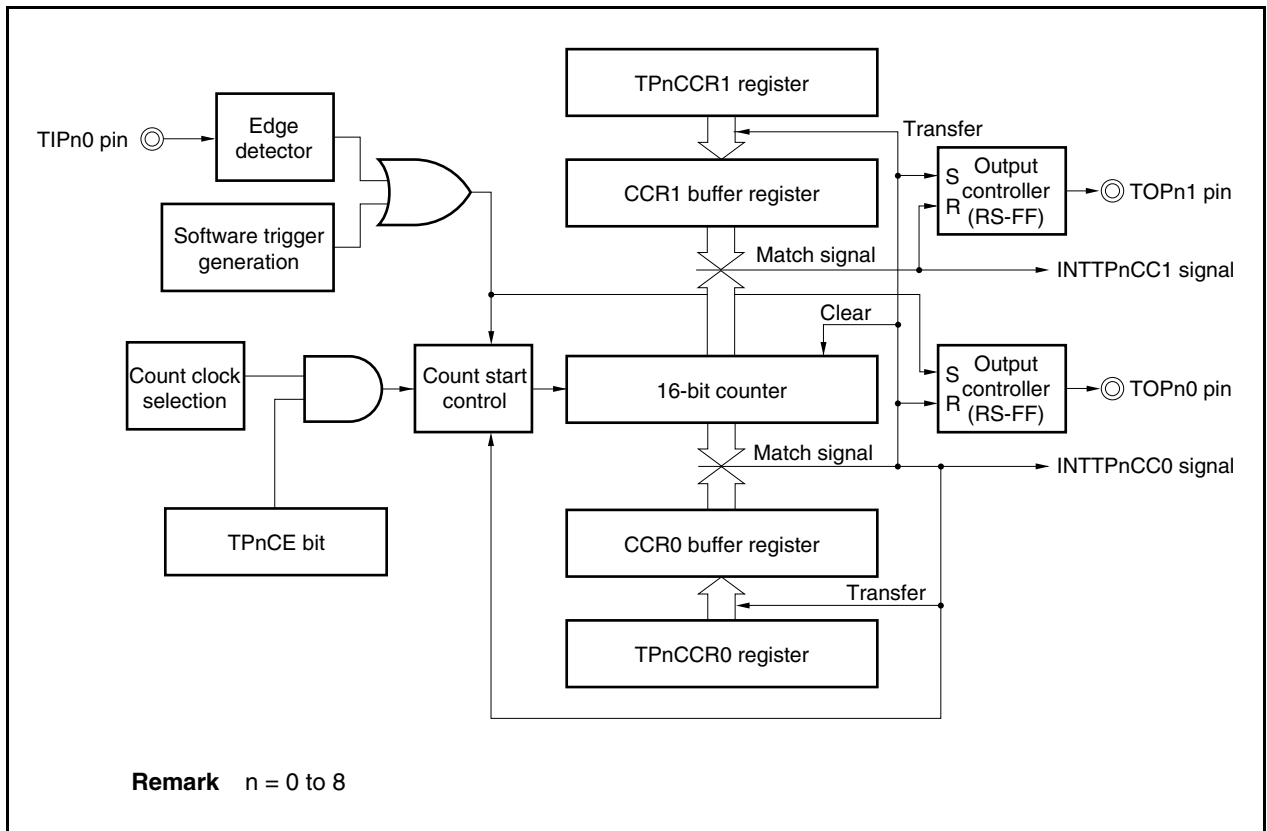
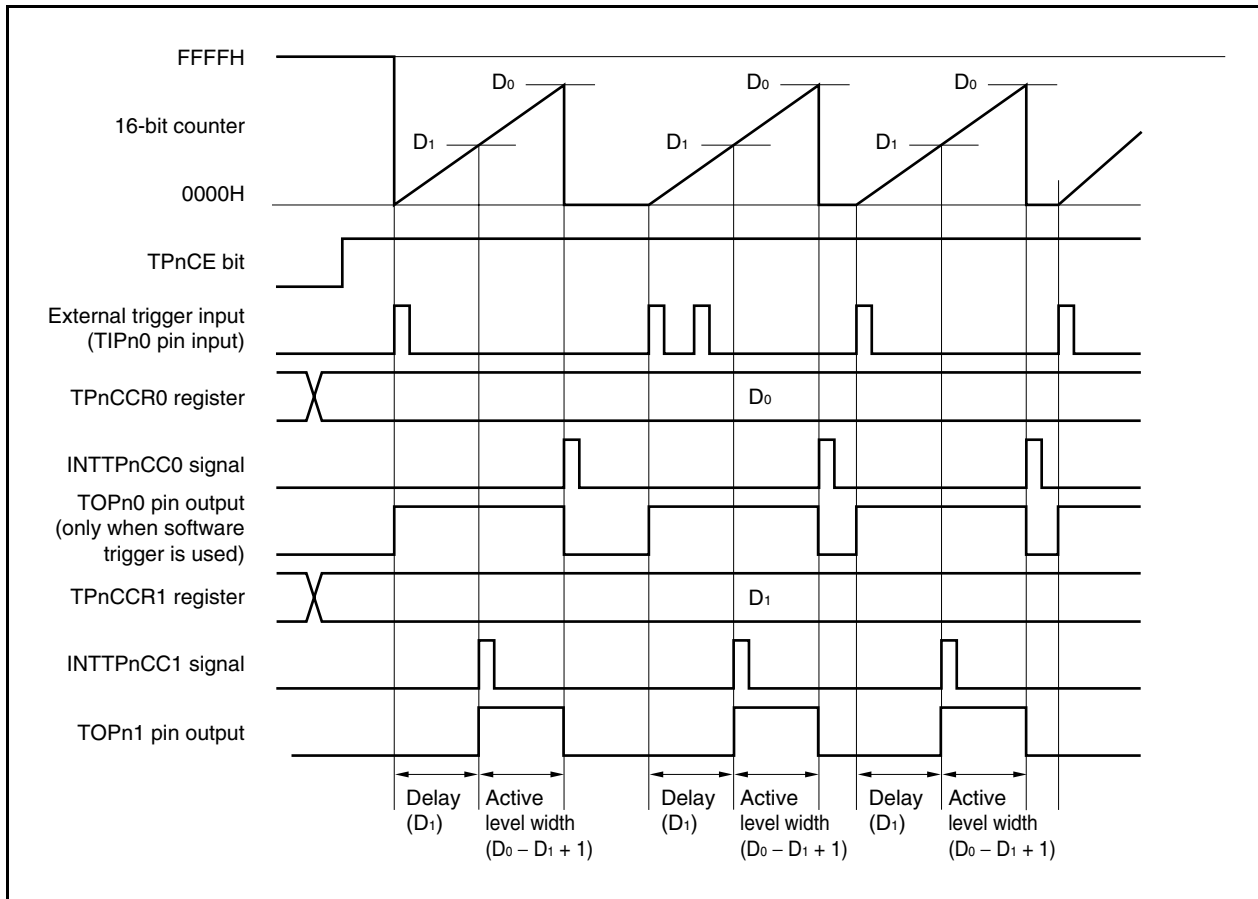


Figure 7-21. Basic Timing in One-Shot Pulse Output Mode



When the TPnCE bit is set to 1, 16-bit timer/event counter P waits for a trigger. When the trigger is generated, the 16-bit counter is cleared from FFFFH to 0000H, starts counting, and outputs a one-shot pulse from the TOPn1 pin. After the one-shot pulse is output, the 16-bit counter is set to FFFFH, stops counting, and waits for a trigger. If a trigger is generated again while the one-shot pulse is being output, it is ignored.

The output delay period and active level width of the one-shot pulse can be calculated as follows.

$$\text{Output delay period} = (\text{Set value of TPnCCR1 register}) \times \text{Count clock cycle}$$

$$\text{Active level width} = (\text{Set value of TPnCCR0 register} - \text{Set value of TPnCCR1 register} + 1) \times \text{Count clock cycle}$$

The compare match interrupt request signal INTTPnCC0 is generated when the 16-bit counter counts after its count value matches the value of the CCR0 buffer register. The compare match interrupt request signal INTTPnCC1 is generated when the count value of the 16-bit counter matches the value of the CCR1 buffer register.

The valid edge of an external trigger input or setting the software trigger (TPnCTL1.TPnEST bit) to 1 is used as the trigger.

**Remark** n = 0 to 8  
m = 0, 1

Figure 7-22. Register Setting for Operation in One-Shot Pulse Output Mode (1/2)

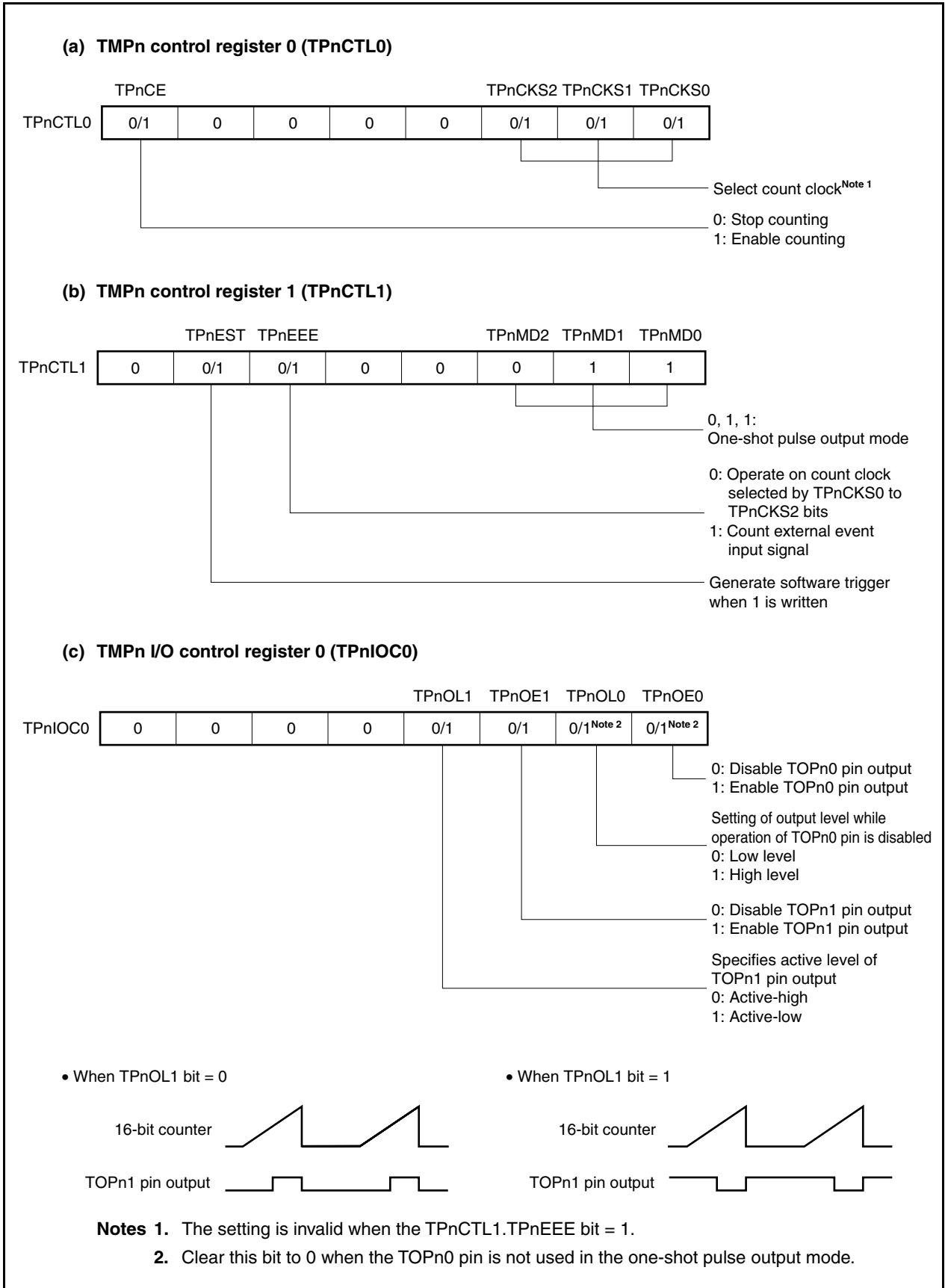
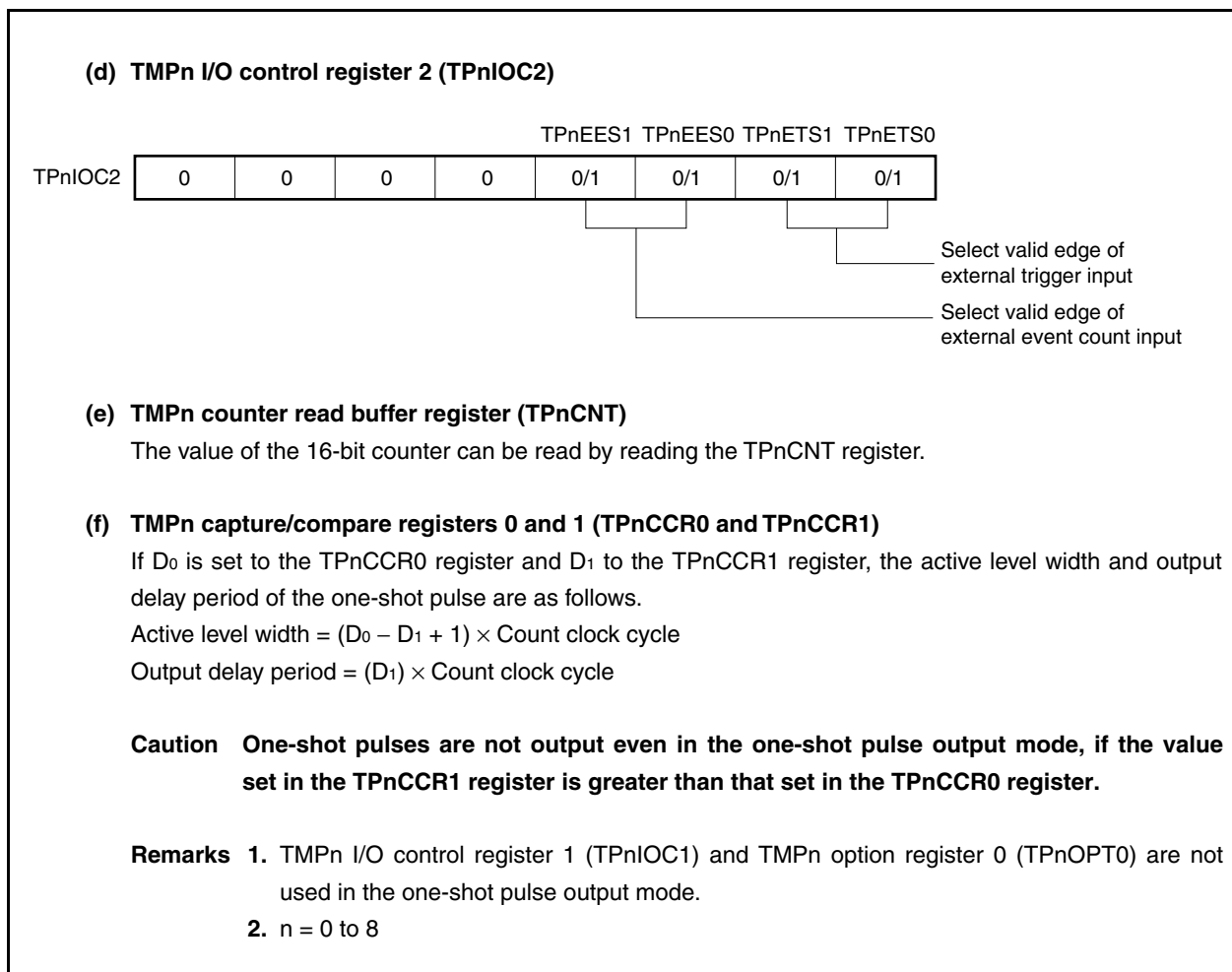


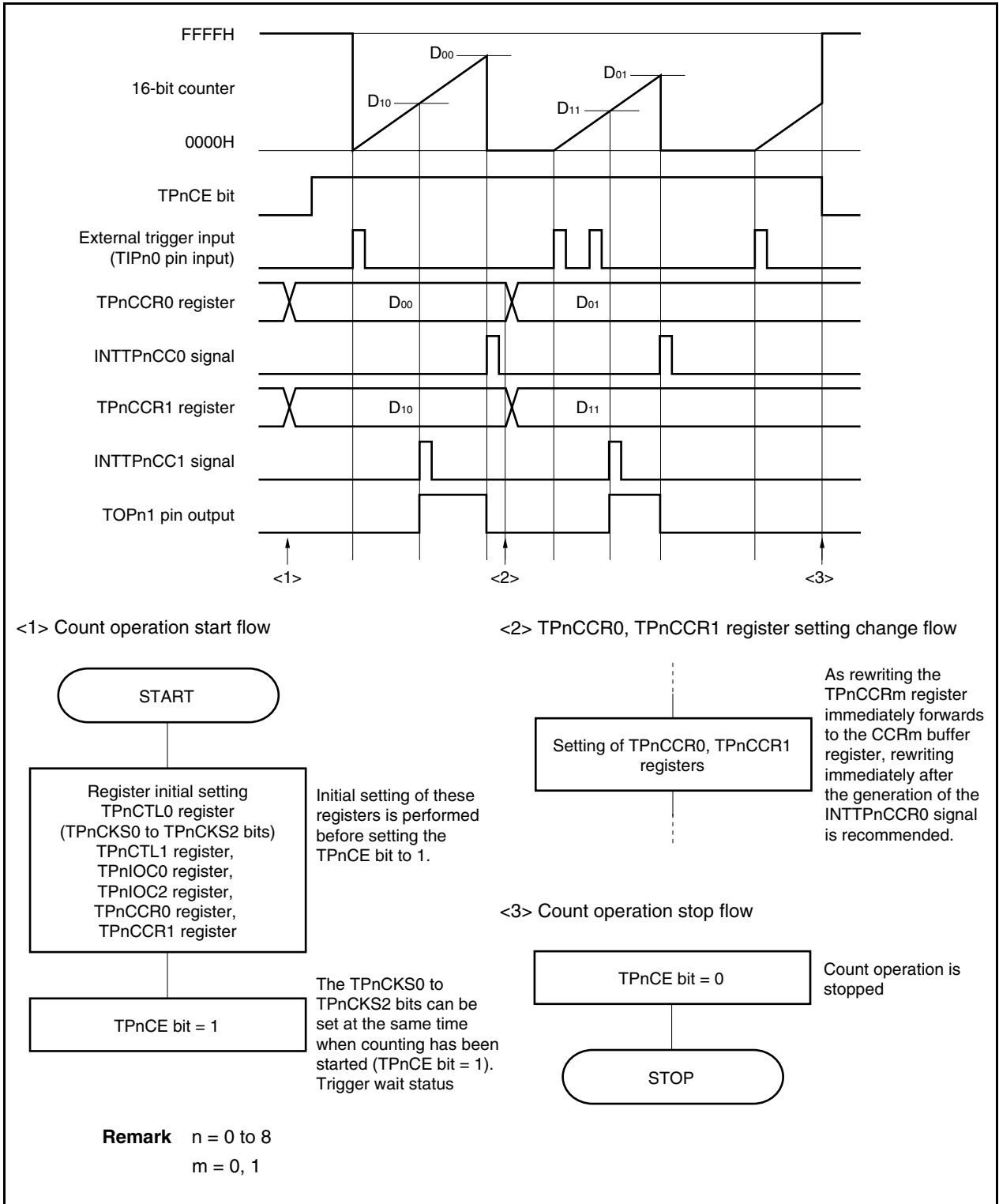
Figure 7-22. Register Setting for Operation in One-Shot Pulse Output Mode (2/2)





(1) Operation flow in one-shot pulse output mode

Figure 7-23. Software Processing Flow in One-Shot Pulse Output Mode

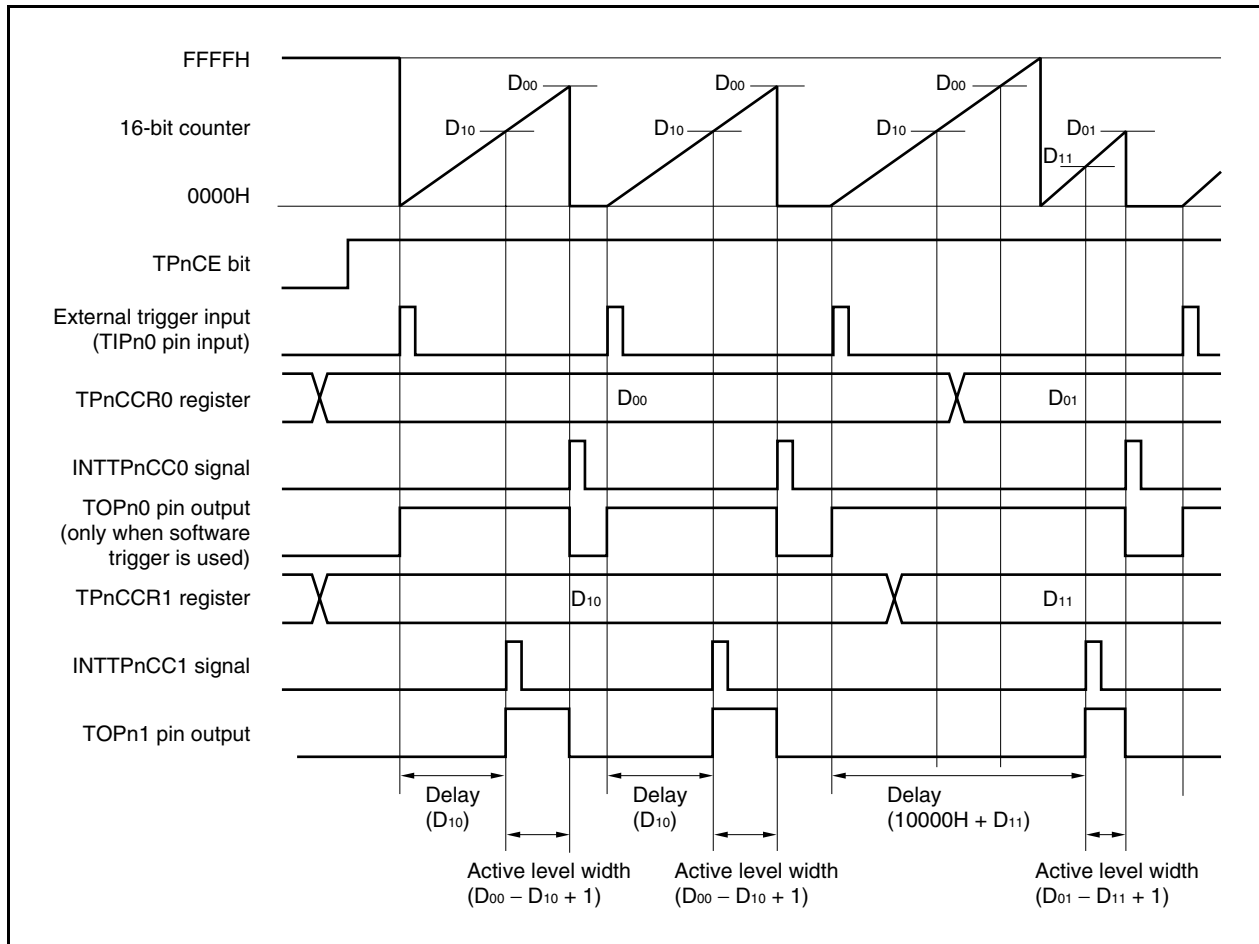


## (2) Operation timing in one-shot pulse output mode

## (a) Note on rewriting TPnCCRm register

To change the set value of the TPnCCRm register to a smaller value, stop counting once, and then change the set value.

If the value of the TPnCCRm register is rewritten to a smaller value during counting, the 16-bit counter may overflow.



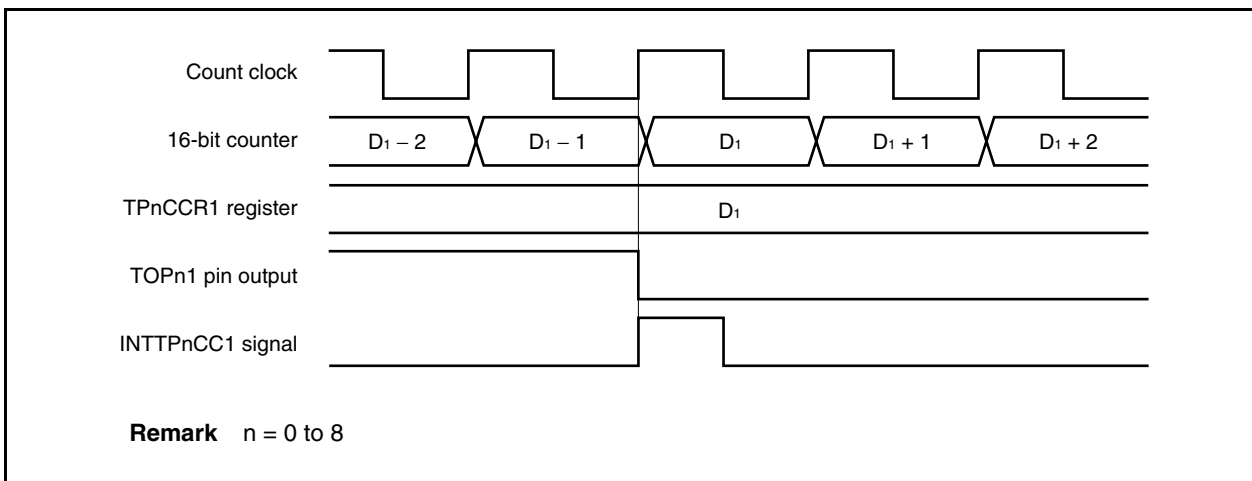
When the TPnCCR0 register is rewritten from D<sub>00</sub> to D<sub>01</sub> and the TPnCCR1 register from D<sub>10</sub> to D<sub>11</sub> where D<sub>00</sub> > D<sub>01</sub> and D<sub>10</sub> > D<sub>11</sub>, if the TPnCCR1 register is rewritten when the count value of the 16-bit counter is greater than D<sub>11</sub> and less than D<sub>10</sub> and if the TPnCCR0 register is rewritten when the count value is greater than D<sub>01</sub> and less than D<sub>00</sub>, each set value is reflected as soon as the register has been rewritten and compared with the count value. The counter counts up to FFFFH and then counts up again from 0000H. When the count value matches D<sub>11</sub>, the counter generates the INTTPnCC1 signal and asserts the TOPn1 pin. When the count value matches D<sub>01</sub>, the counter generates the INTTPnCC0 signal, deasserts the TOPn1 pin, and stops counting.

Therefore, the counter may output a pulse with a delay period or active period different from that of the one-shot pulse that is originally expected.

**Remark** n = 0 to 8  
m = 0, 1

**(b) Generation timing of compare match interrupt request signal (INTTPnCC1)**

The generation timing of the INTTPnCC1 signal in the one-shot pulse output mode is different from other INTTPnCC1 signals; the INTTPnCC1 signal is generated when the count value of the 16-bit counter matches the value of the TPnCCR1 register.



Usually, the INTTPnCC1 signal is generated when the 16-bit counter counts up next time after its count value matches the value of the TPnCCR1 register.

In the one-shot pulse output mode, however, it is generated one clock earlier. This is because the timing is changed to match the change timing of the TOPn1 pin.

**Remark**  $n = 0$  to 8

### 7.5.5 PWM output mode (TPnMD2 to TPnMD0 bits = 100)

In the PWM output mode, a PWM waveform is output from the TOPn1 pin when the TPnCTL0.TPnCE bit is set to 1. In addition, a pulse with one cycle of the PWM waveform as half its cycle is output from the TOPn0 pin.

Figure 7-24. Configuration in PWM Output Mode

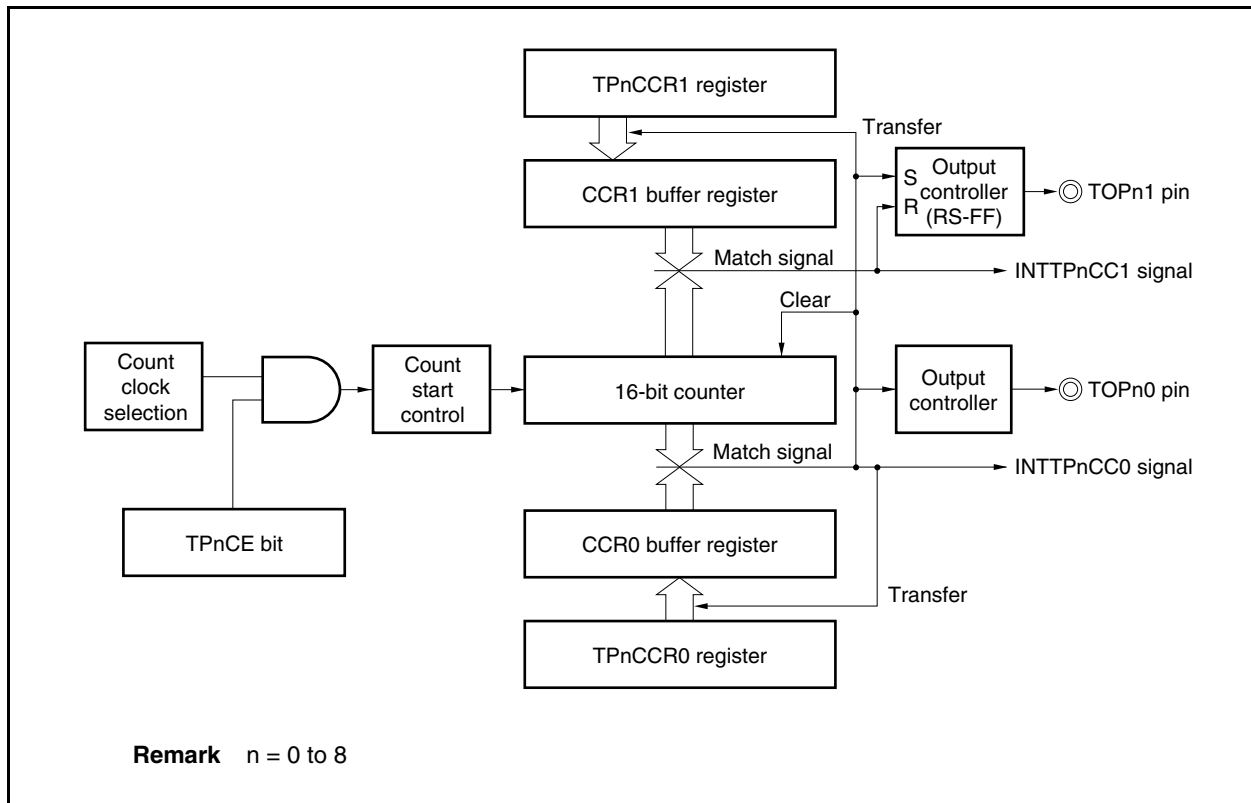
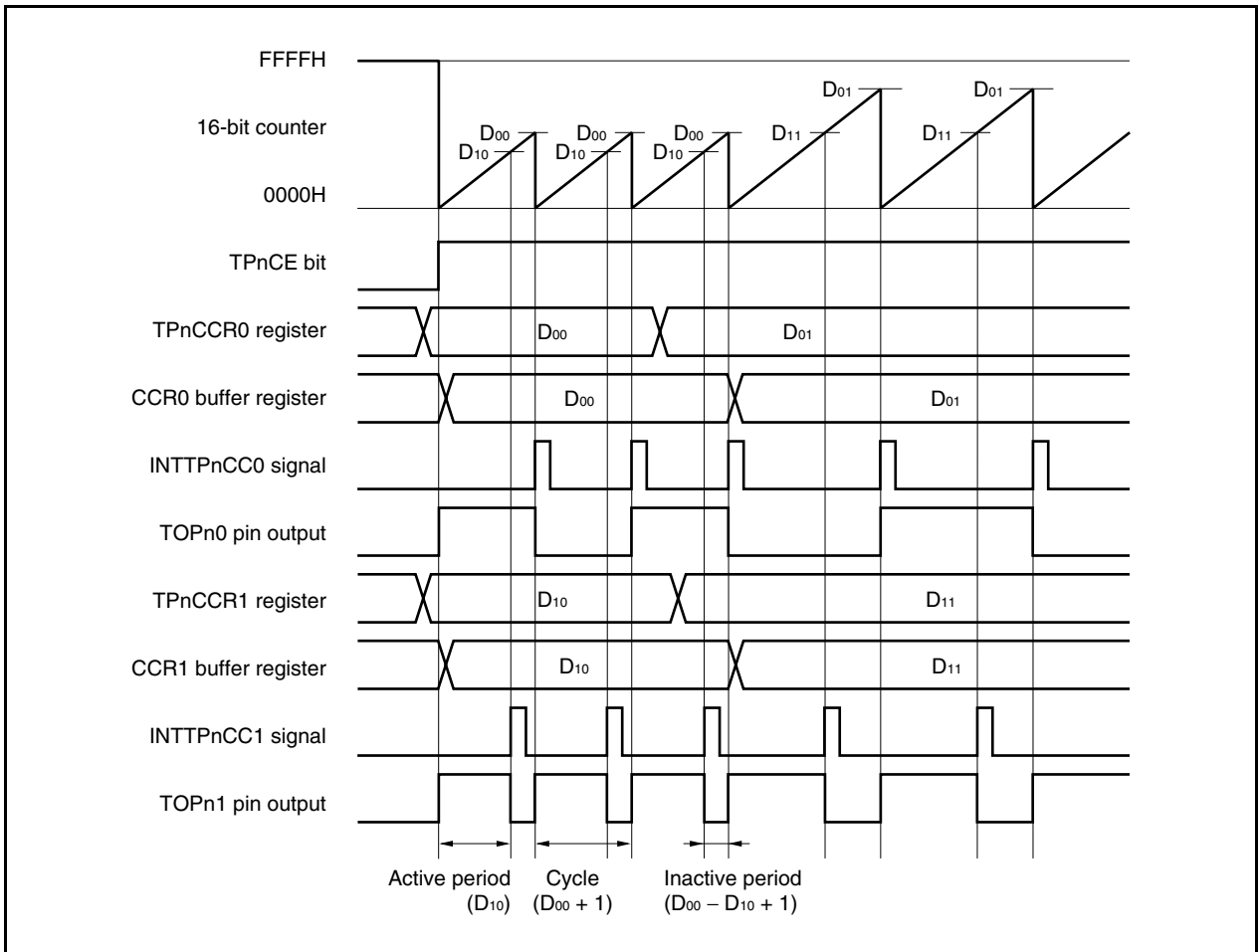


Figure 7-25. Basic Timing in PWM Output Mode



When the TPnCE bit is set to 1, the 16-bit counter is cleared from FFFFH to 0000H, starts counting, and outputs a PWM waveform from the TOPn1 pin.

The active level width, cycle, and duty factor of the PWM waveform can be calculated as follows.

$$\text{Active level width} = (\text{Set value of TPnCCR1 register}) \times \text{Count clock cycle}$$

$$\text{Cycle} = (\text{Set value of TPnCCR0 register} + 1) \times \text{Count clock cycle}$$

$$\text{Duty factor} = (\text{Set value of TPnCCR1 register}) / (\text{Set value of TPnCCR0 register} + 1)$$

The PWM waveform can be changed by rewriting the TPnCCRm register while the counter is operating. The newly written value is reflected when the count value of the 16-bit counter matches the value of the CCR0 buffer register and the 16-bit counter is cleared to 0000H.

The compare match interrupt request signal INTTPnCC0 is generated when the 16-bit counter counts next time after its count value matches the value of the CCR0 buffer register, and the 16-bit counter is cleared to 0000H. The compare match interrupt request signal INTTPnCC1 is generated when the count value of the 16-bit counter matches the value of the CCR1 buffer register.

The value set to the TPnCCRm register is transferred to the CCRm buffer register when the count value of the 16-bit counter matches the value of the CCRm buffer register and the 16-bit counter is cleared to 0000H.

**Remark** n = 0 to 8, m = 0, 1

Figure 7-26. Register Setting for Operation in PWM Output Mode (1/2)

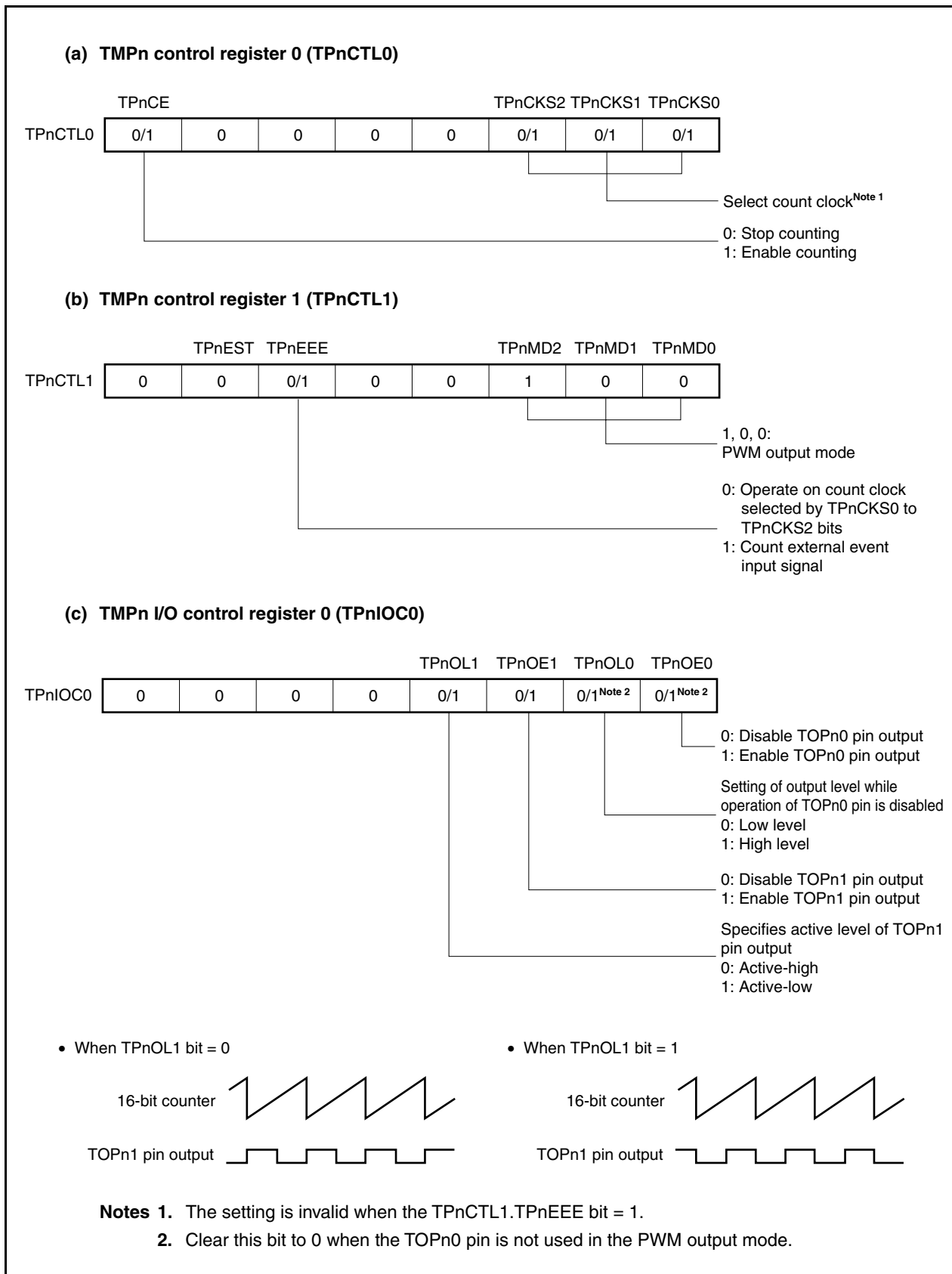
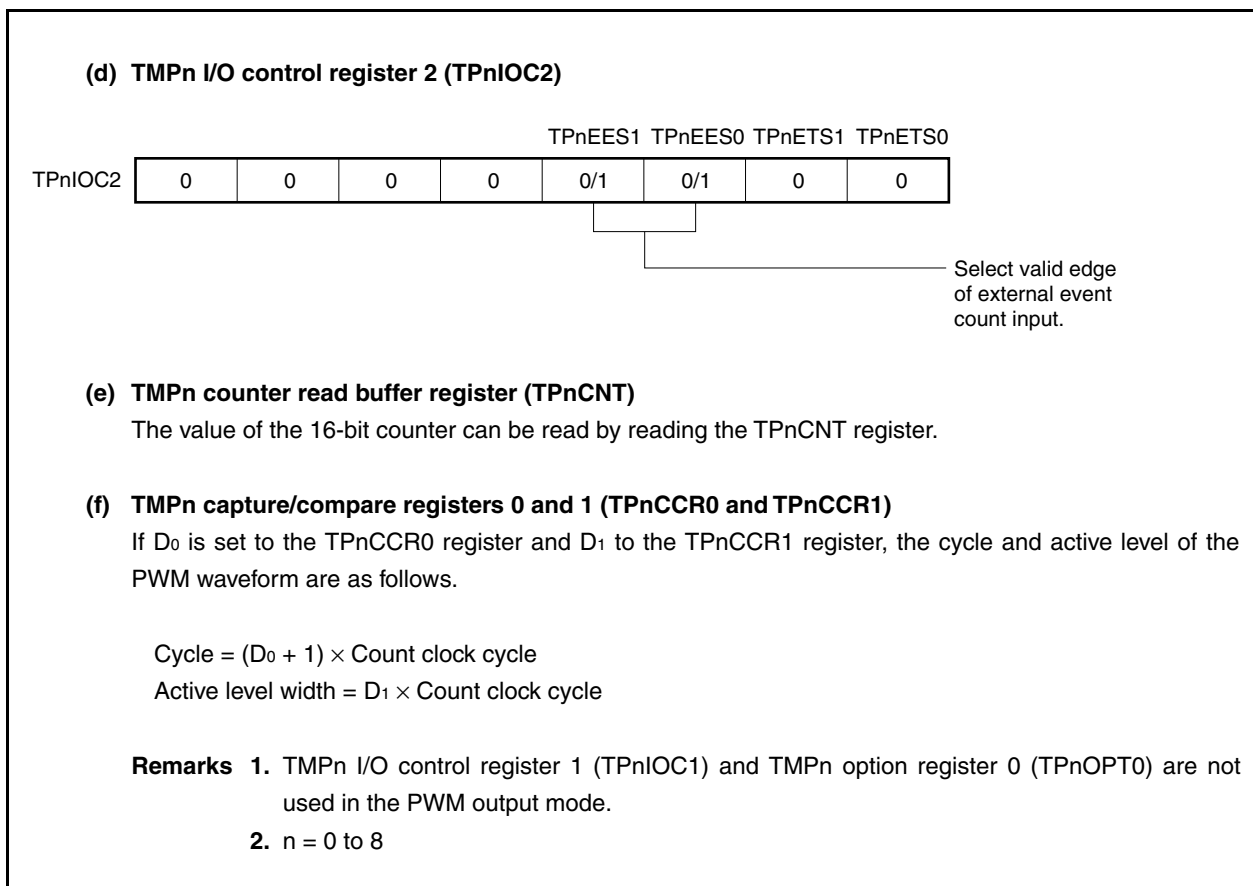


Figure 7-26. Register Setting for Operation in PWM Output Mode (2/2)



(1) Operation flow in PWM output mode

Figure 7-27. Software Processing Flow in PWM Output Mode (1/2)

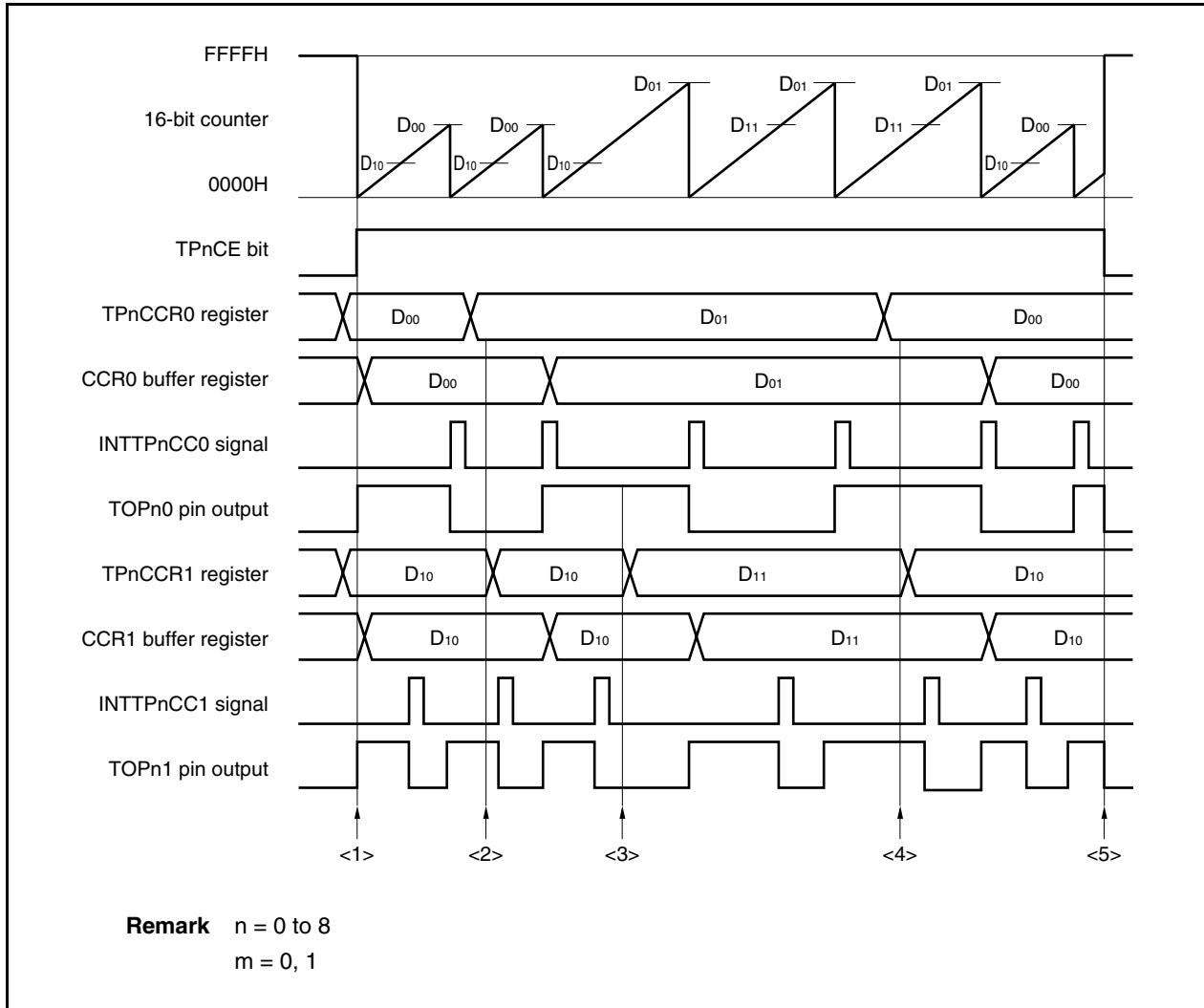
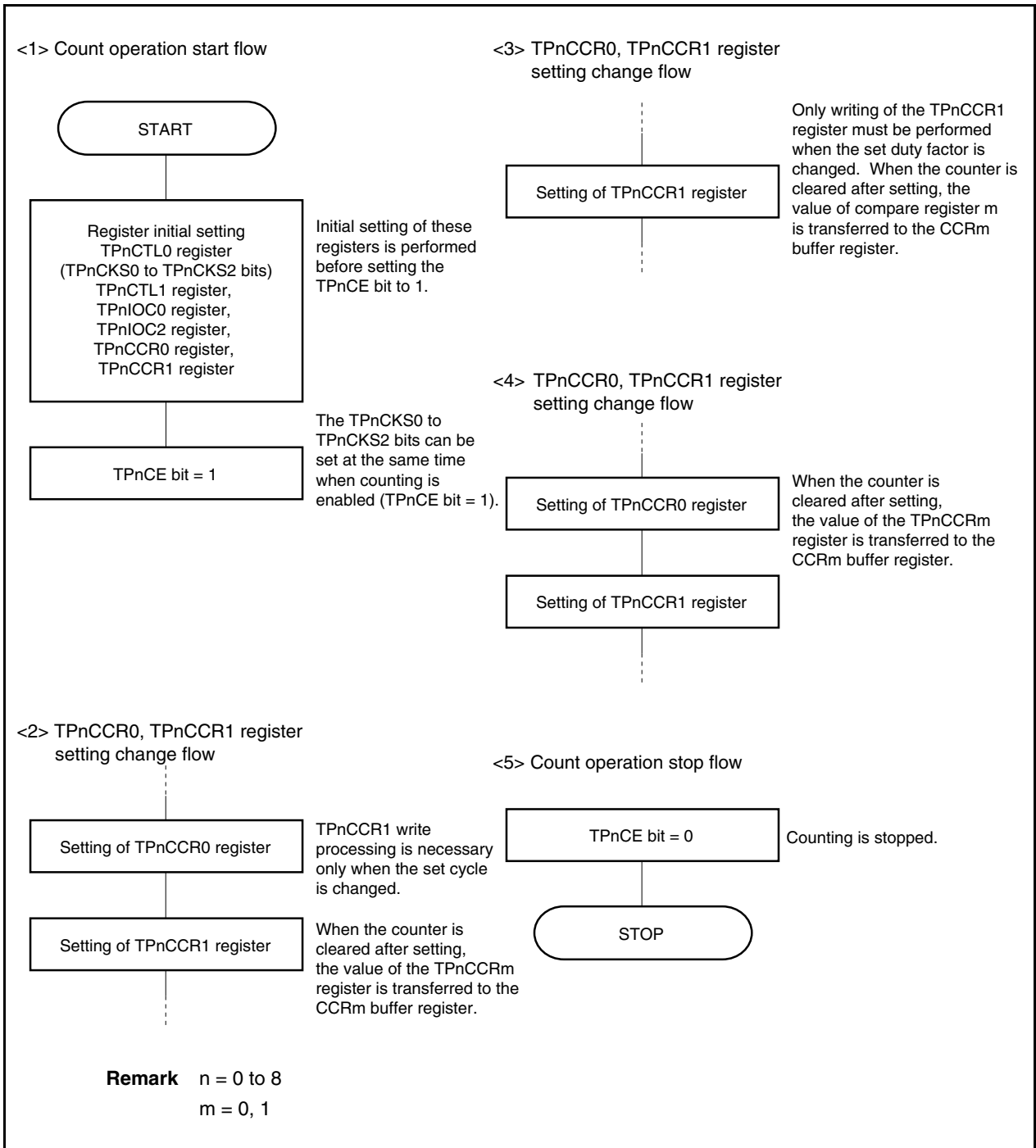




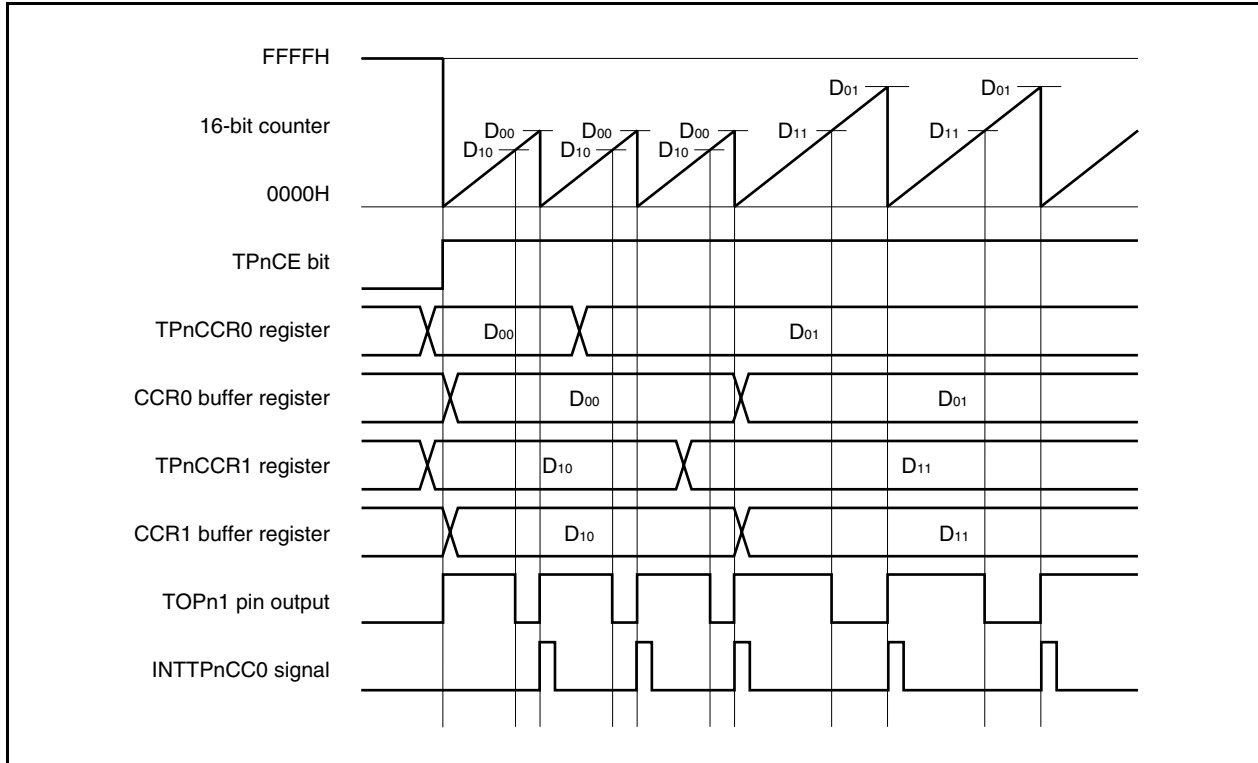
Figure 7-27. Software Processing Flow in PWM Output Mode (2/2)



**(2) PWM output mode operation timing****(a) Changing pulse width during operation**

To change the PWM waveform while the counter is operating, write the TPnCCR1 register last.

Rewrite the TPnCCRm register after writing the TPnCCR1 register after the INTTPnCC1 signal is detected.



To transfer data from the TPnCCRm register to the CCRm buffer register, the TPnCCR1 register must be written.

To change both the cycle and active level of the PWM waveform at this time, first set the cycle to the TPnCCR0 register and then set the active level to the TPnCCR1 register.

To change only the cycle of the PWM waveform, first set the cycle to the TPnCCR0 register, and then write the same value to the TPnCCR1 register.

To change only the active level width (duty factor) of the PWM waveform, only the TPnCCR1 register has to be set.

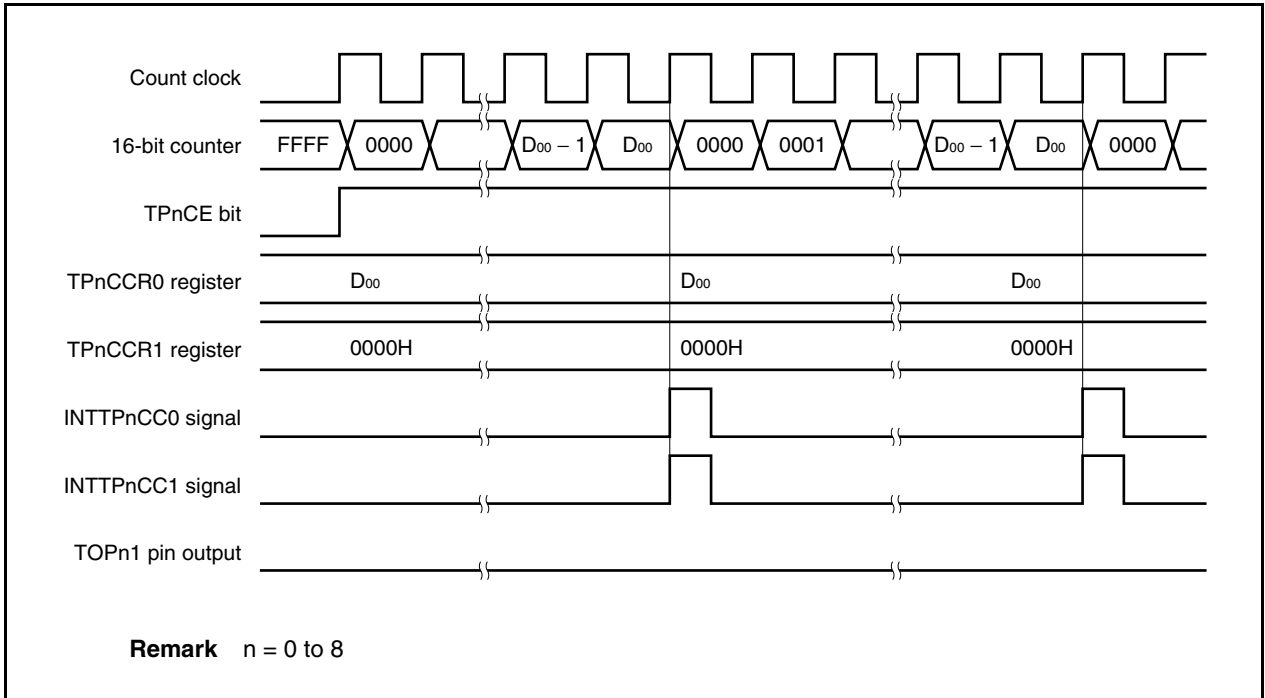
After data is written to the TPnCCR1 register, the value written to the TPnCCRm register is transferred to the CCRm buffer register in synchronization with clearing of the 16-bit counter, and is used as the value compared with the 16-bit counter.

To write the TPnCCR0 or TPnCCR1 register again after writing the TPnCCR1 register once, do so after the INTTPnCC0 signal is generated. Otherwise, the value of the CCRm buffer register may become undefined because the timing of transferring data from the TPnCCRm register to the CCRm buffer register conflicts with writing the TPnCCRm register.

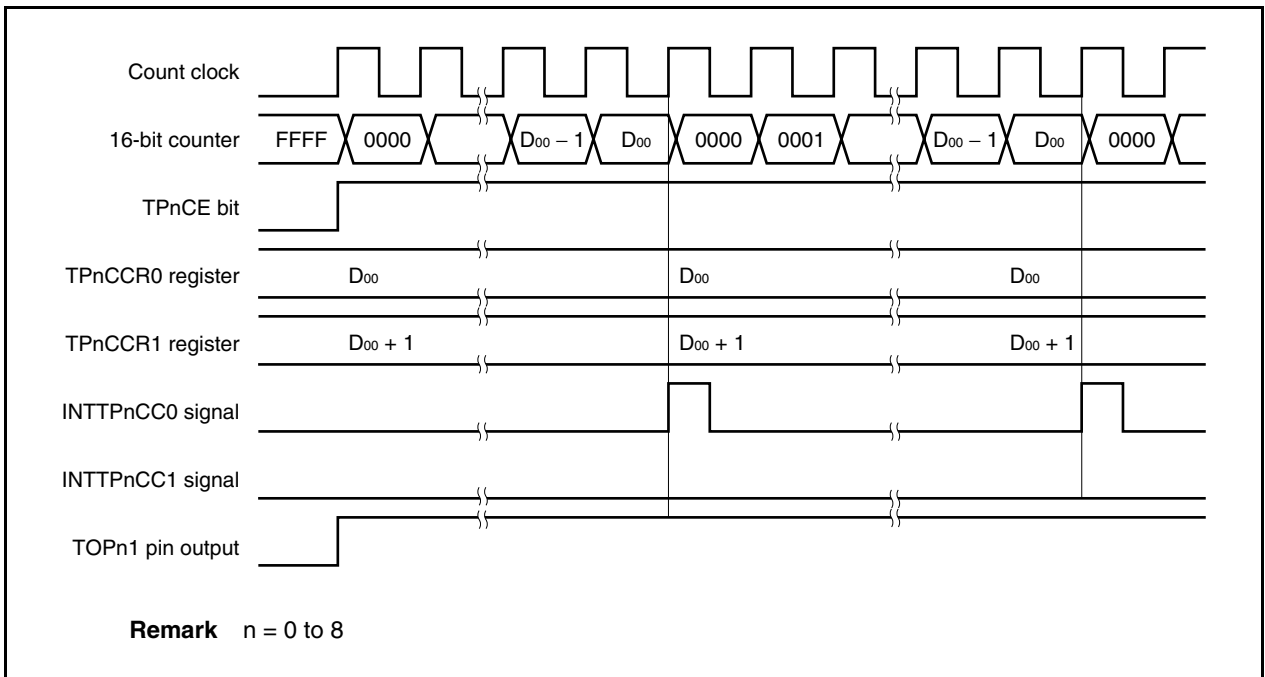
**Remark** n = 0 to 8, m = 0, 1

**(b) 0%/100% output of PWM waveform**

To output a 0% waveform, set the TPnCCR1 register to 0000H. If the set value of the TPnCCR0 register is FFFFH, the INTTPnCC1 signal is generated periodically.

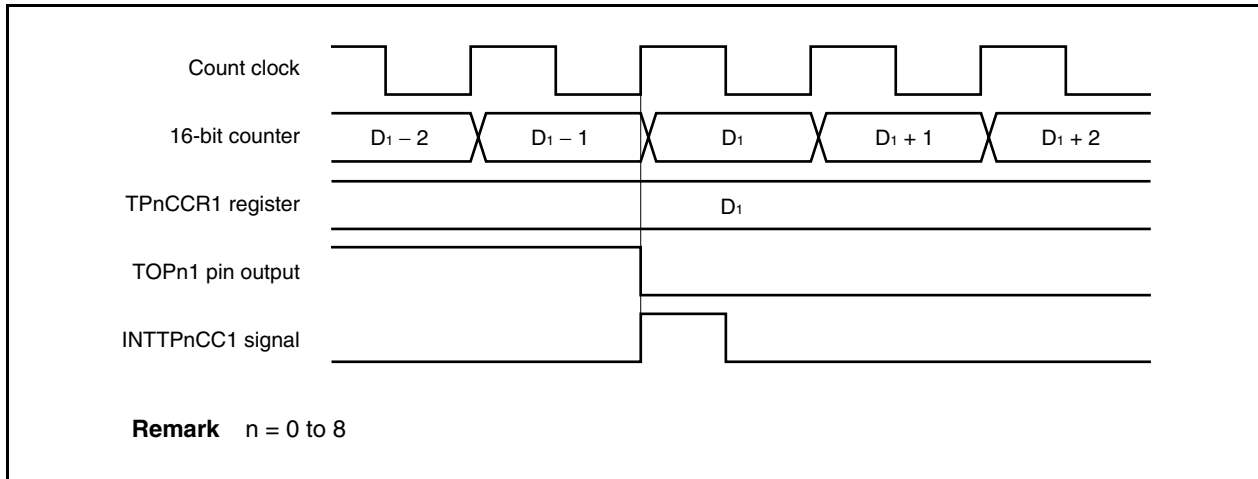


To output a 100% waveform, set a value of (set value of TPnCCR0 register + 1) to the TPnCCR1 register. If the set value of the TPnCCR0 register is FFFFH, 100% output cannot be produced.



**(c) Generation timing of compare match interrupt request signal (INTTPnCC1)**

The timing of generation of the INTTPnCC1 signal in the PWM output mode differs from the timing of other INTTPnCC1 signals; the INTTPnCC1 signal is generated when the count value of the 16-bit counter matches the value of the TPnCCR1 register.



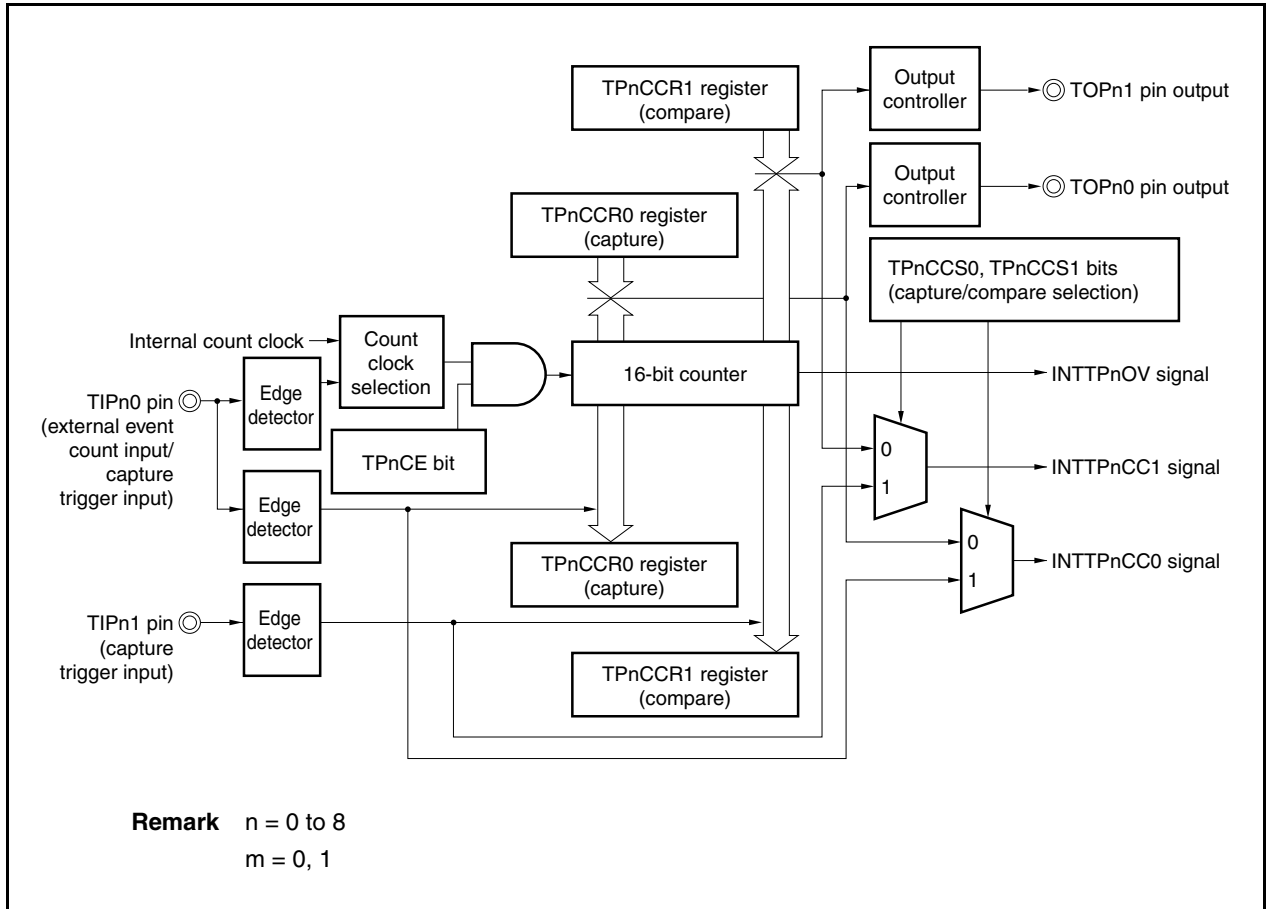
Usually, the INTTPnCC1 signal is generated in synchronization with the next counting up after the count value of the 16-bit counter matches the value of the TPnCCR1 register.

In the PWM output mode, however, it is generated one clock earlier. This is because the timing is changed to match the change timing of the output signal of the TOPn1 pin.

**7.5.6 Free-running timer mode (TPnMD2 to TPnMD0 bits = 101)**

In the free-running timer mode, 16-bit timer/event counter P starts counting when the TPnCTL0.TPnCE bit is set to 1. At this time, the TPnCCRm register can be used as a compare register or a capture register, depending on the setting of the TPnOPT0.TPnCCS0 and TPnOPT0.TPnCCS1 bits.

**Figure 7-28. Configuration in Free-Running Timer Mode**

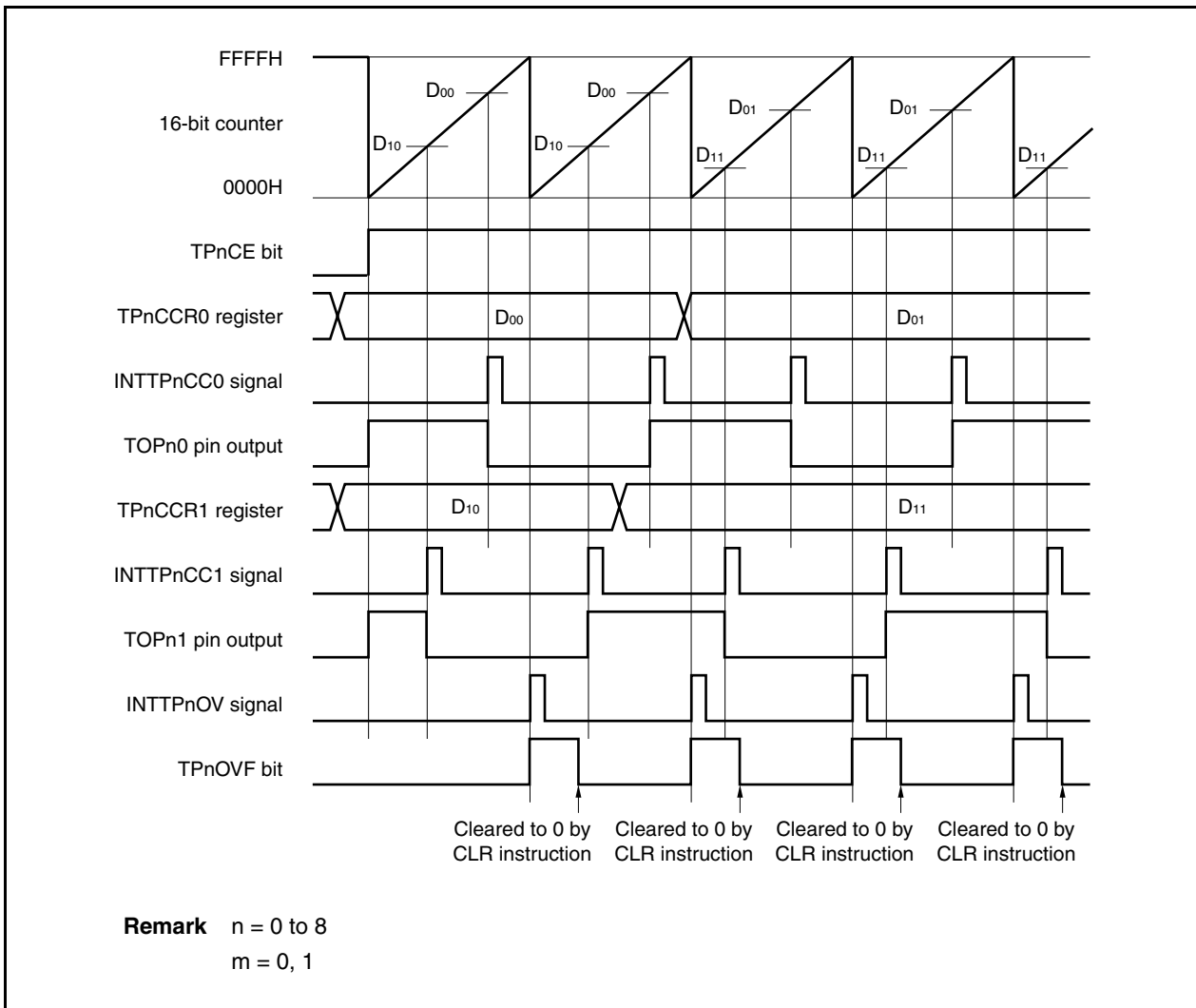


When the TPnCE bit is set to 1, 16-bit timer/event counter P starts counting, and the output signals of the TOPn0 and TOPn1 pins are inverted. When the count value of the 16-bit counter later matches the set value of the TPnCCRm register, a compare match interrupt request signal (INTTPnCCm) is generated, and the output signal of the TOPnm pin is inverted.

The 16-bit counter continues counting in synchronization with the count clock. When it counts up to FFFFH, it generates an overflow interrupt request signal (INTTPnOV) at the next clock, is cleared to 0000H, and continues counting. At this time, the overflow flag (TPnOPT0.TPnOVF bit) is also set to 1. Clear the overflow flag to 0 by executing the CLR instruction by software.

The TPnCCRm register can be rewritten while the counter is operating. If it is rewritten, the new value is reflected at that time, and compared with the count value.

**Figure 7-29. Basic Timing in Free-Running Timer Mode (Compare Function)**



When the TPnCE bit is set to 1, the 16-bit counter starts counting. When the valid edge input to the TIPnm pin is detected, the count value of the 16-bit counter is stored in the TPnCCRm register, and a capture interrupt request signal (INTTPnCCm) is generated.

The 16-bit counter continues counting in synchronization with the count clock. When it counts up to FFFFH, it generates an overflow interrupt request signal (INTTPnOV) at the next clock, is cleared to 0000H, and continues counting. At this time, the overflow flag (TPnOPT0.TPnOVF bit) is also set to 1. Clear the overflow flag to 0 by executing the CLR instruction by software.

**Figure 7-30. Basic Timing in Free-Running Timer Mode (Capture Function)**

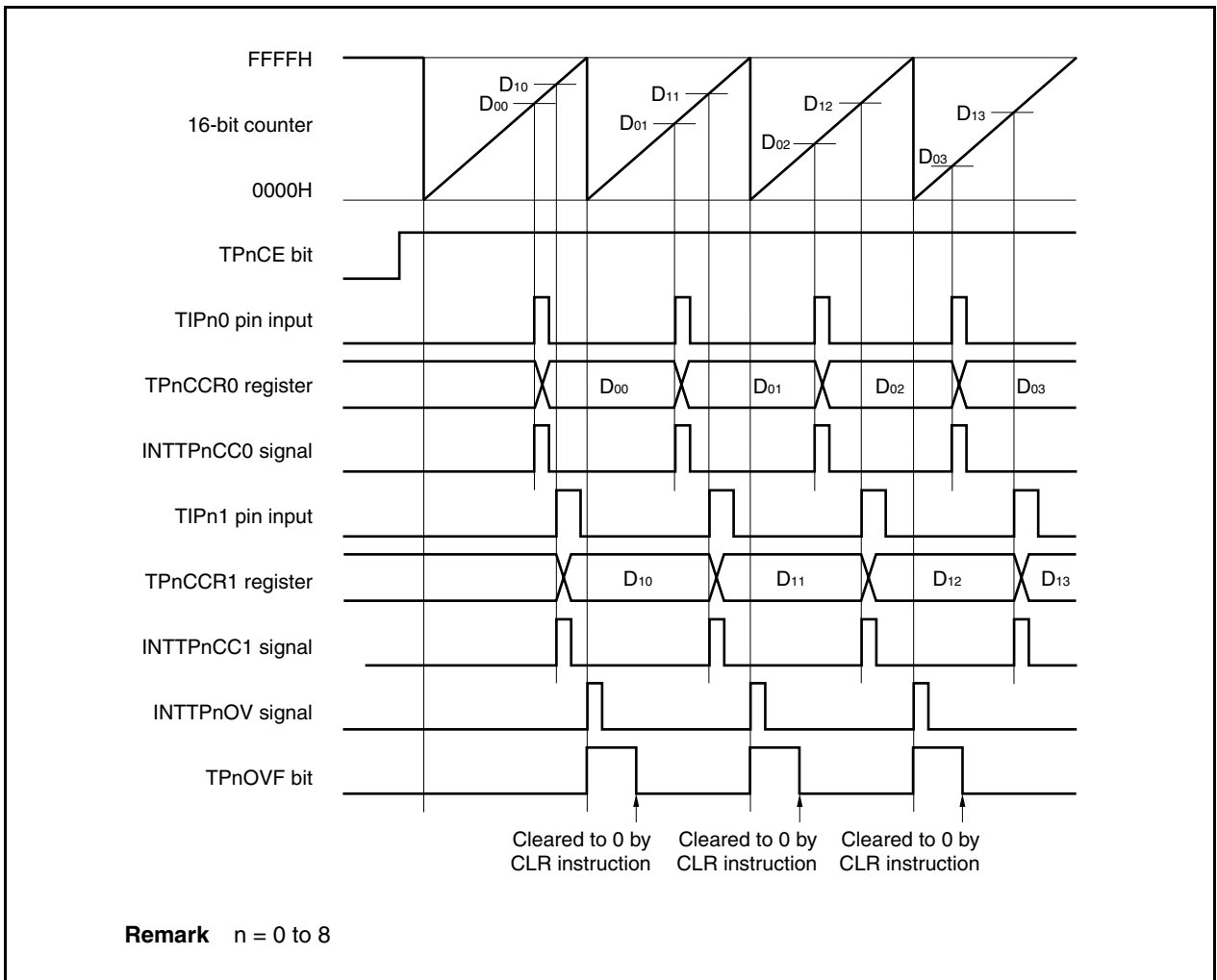


Figure 7-31. Register Setting in Free-Running Timer Mode (1/2)

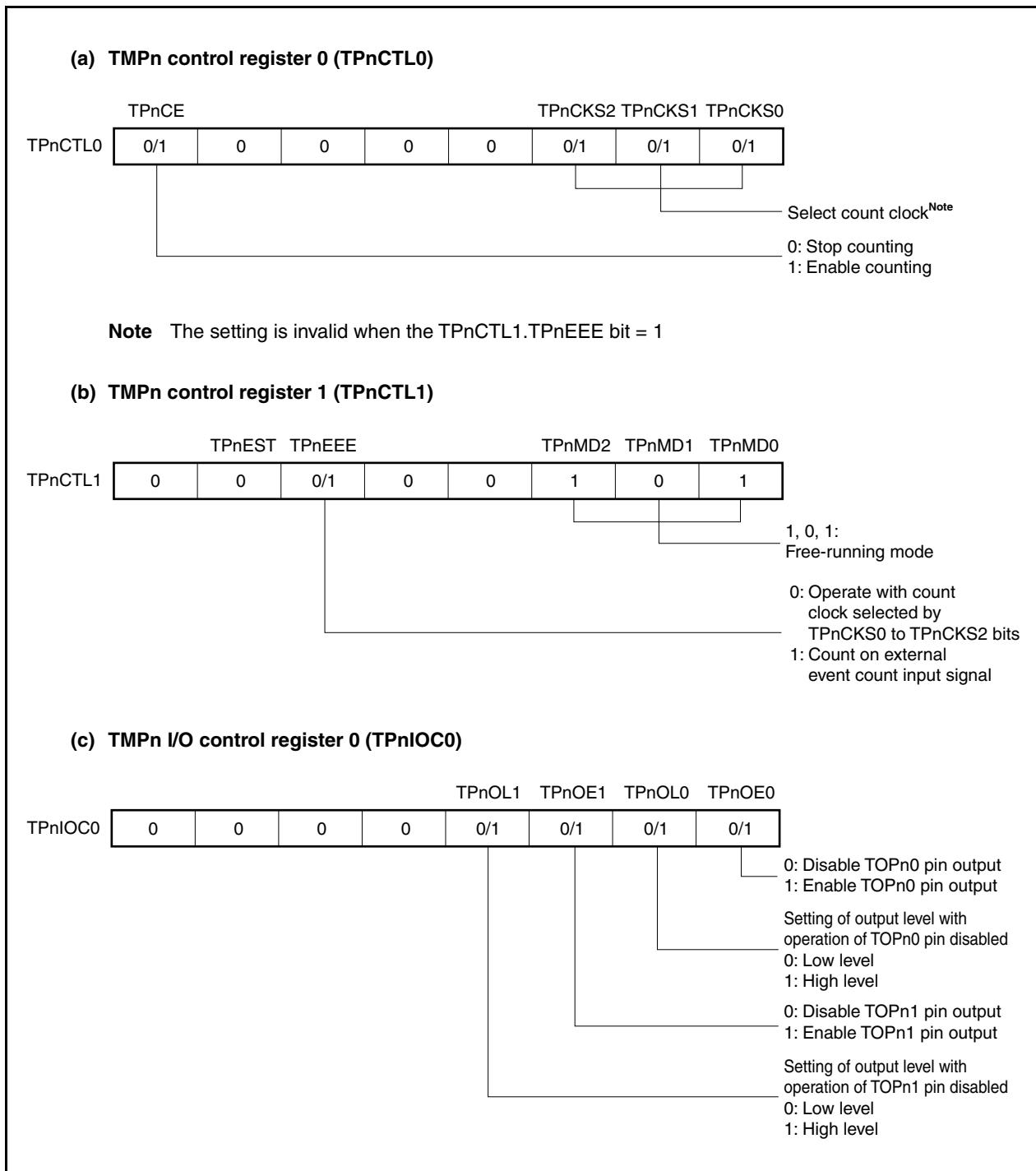
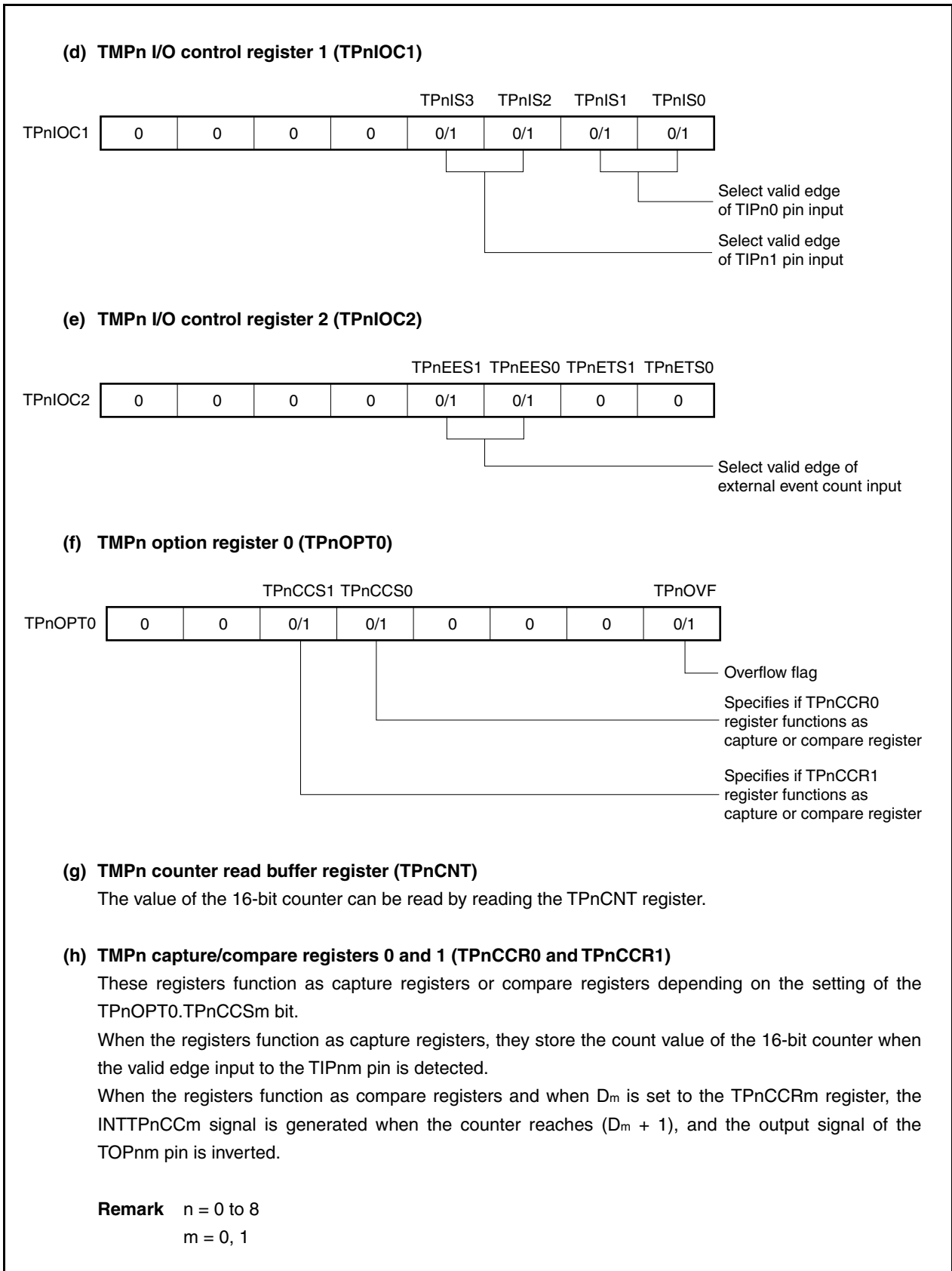




Figure 7-31. Register Setting in Free-Running Timer Mode (2/2)



(1) Operation flow in free-running timer mode

(a) When using capture/compare register as compare register

Figure 7-32. Software Processing Flow in Free-Running Timer Mode (Compare Function) (1/2)

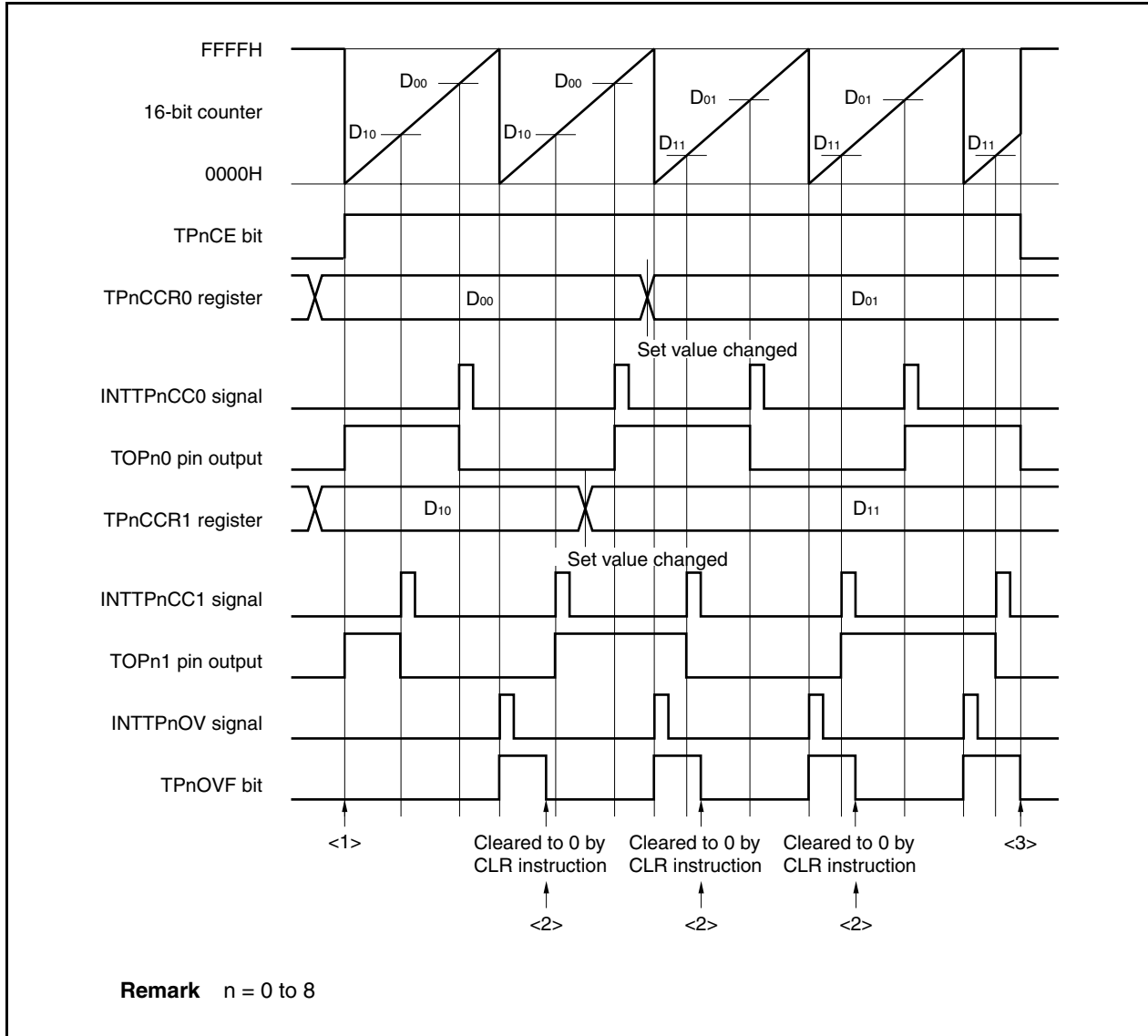
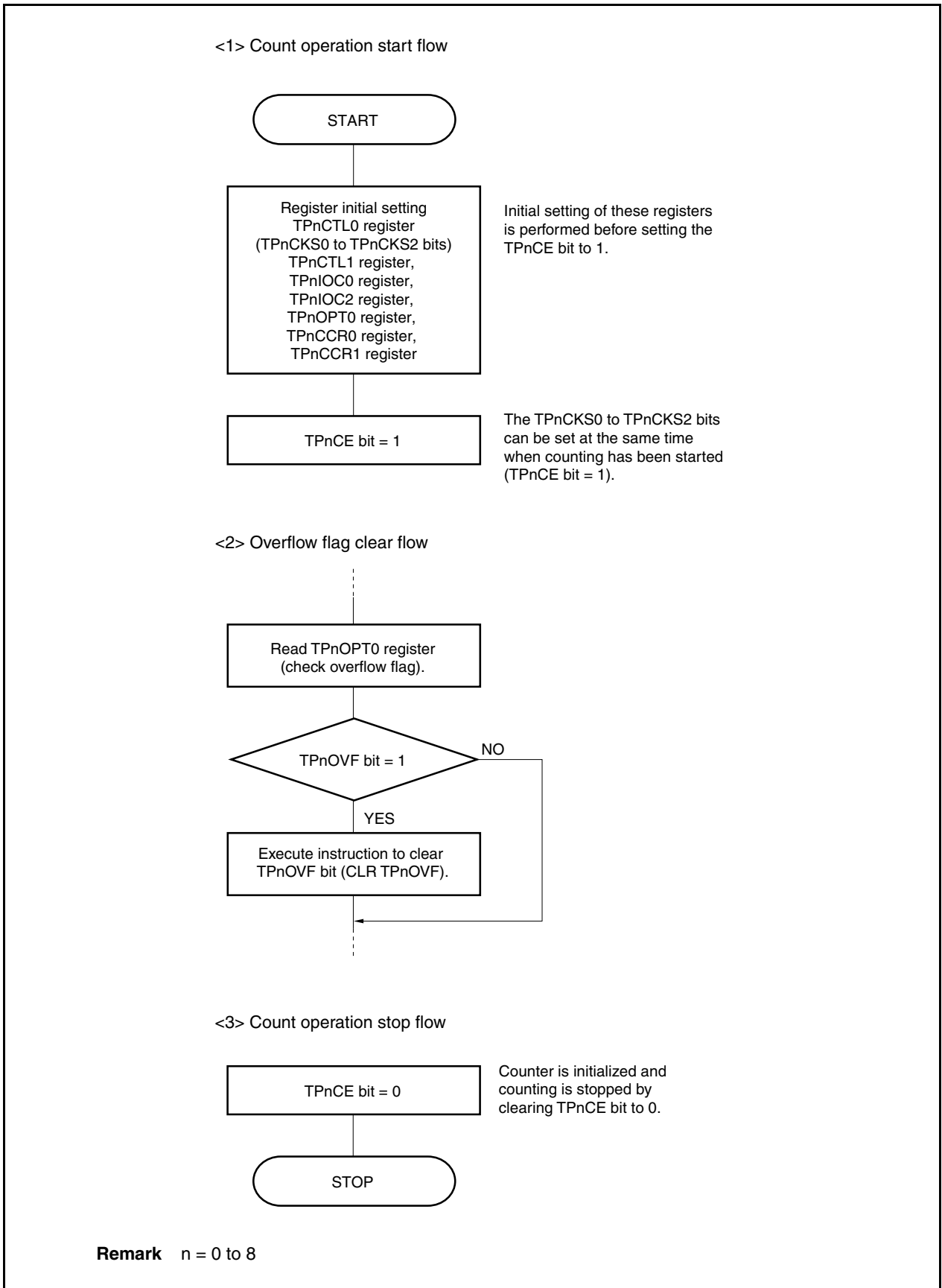


Figure 7-32. Software Processing Flow in Free-Running Timer Mode (Compare Function) (2/2)



(b) When using capture/compare register as capture register

Figure 7-33. Software Processing Flow in Free-Running Timer Mode (Capture Function) (1/2)

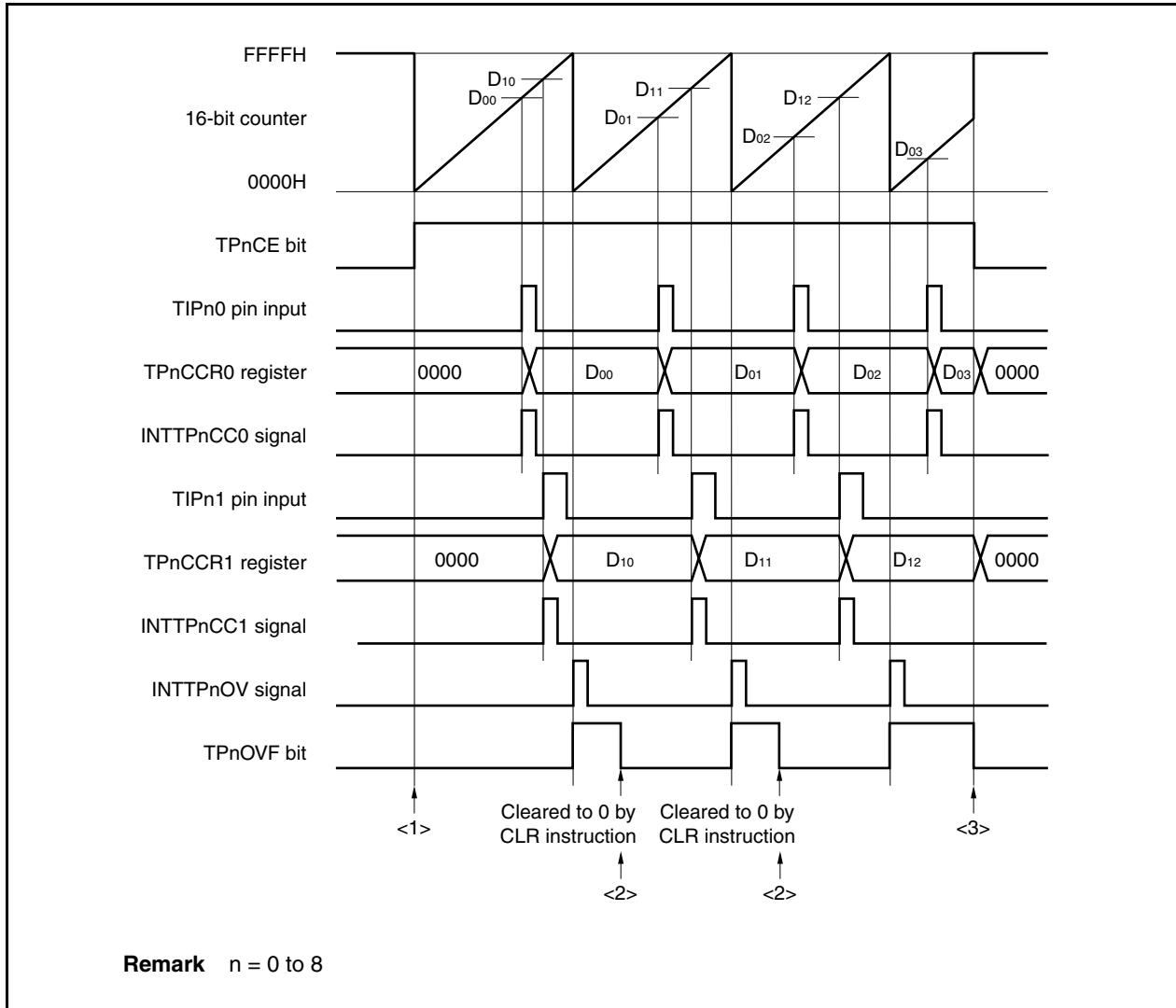
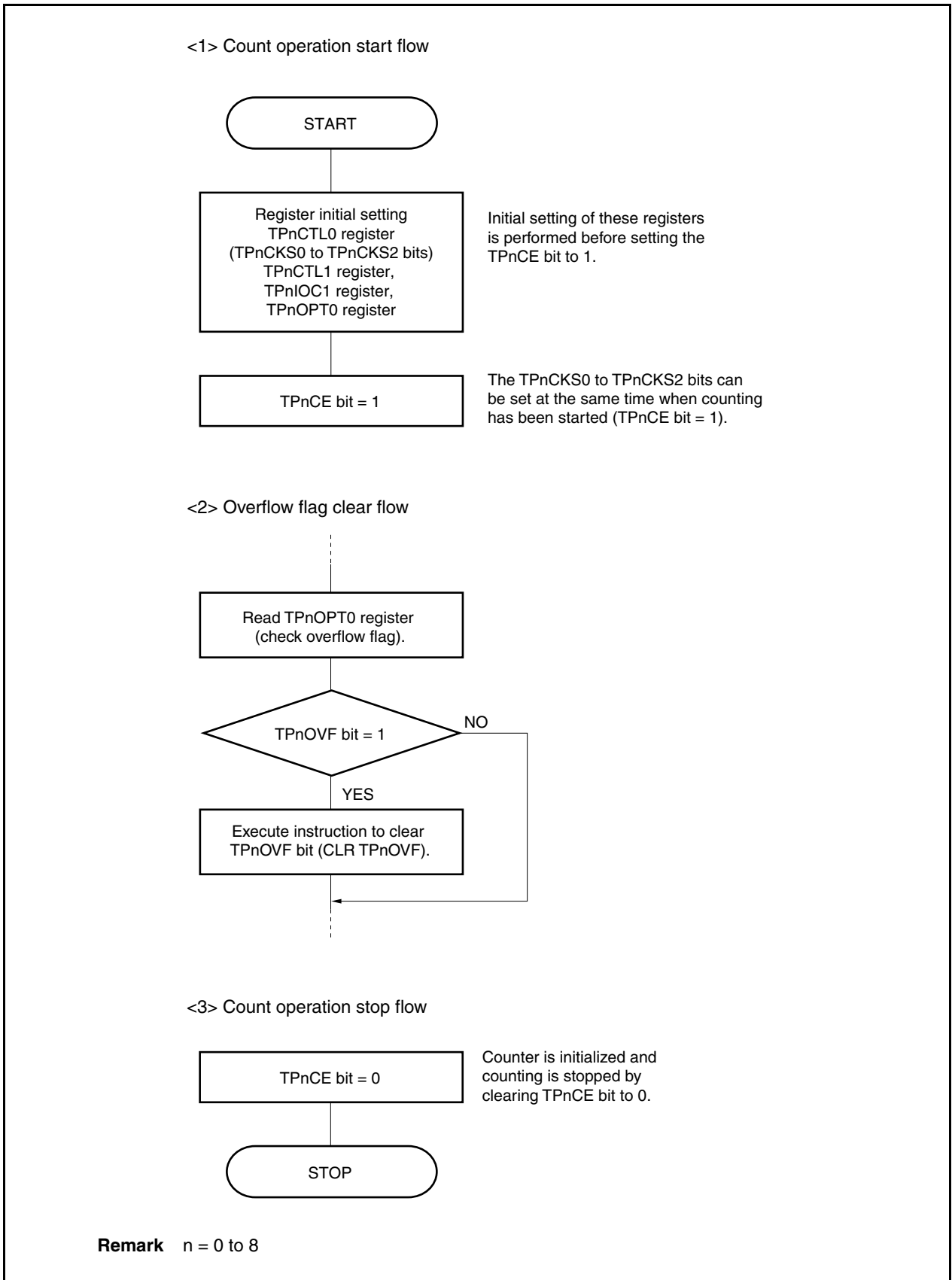


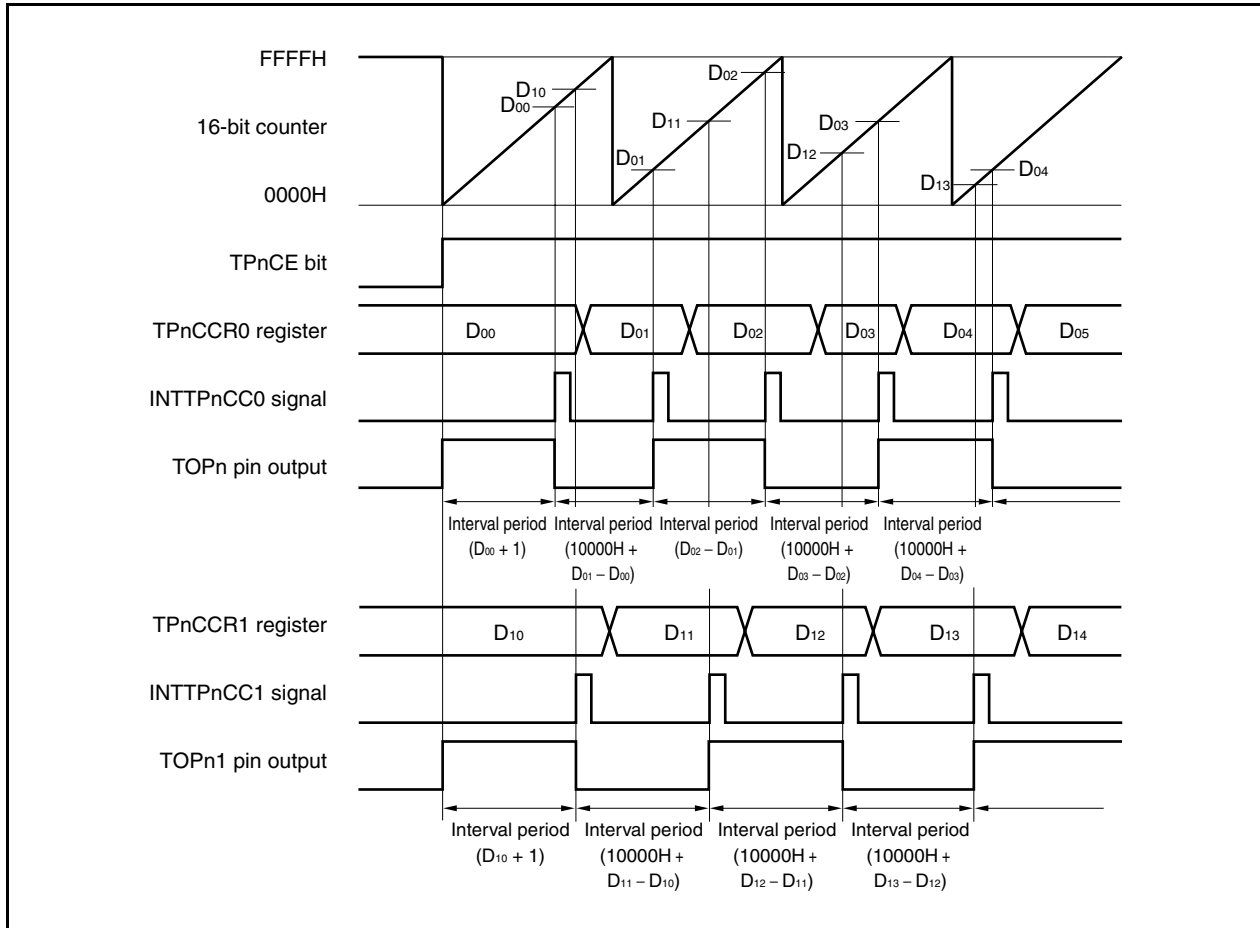
Figure 7-33. Software Processing Flow in Free-Running Timer Mode (Capture Function) (2/2)



(2) Operation timing in free-running timer mode

(a) Interval operation with compare register

When 16-bit timer/event counter P is used as an interval timer with the TPnCCRm register used as a compare register, software processing is necessary for setting a comparison value to generate the next interrupt request signal each time the INTTPnCCm signal has been detected.



When performing an interval operation in the free-running timer mode, two intervals can be set with one channel.

To perform the interval operation, the value of the corresponding TPnCCRm register must be re-set in the interrupt servicing that is executed when the INTTPnCCm signal is detected.

The set value for re-setting the TPnCCRm register can be calculated by the following expression, where "D<sub>m</sub>" is the interval period.

Compare register default value:  $D_m - 1$

Value set to compare register second and subsequent time: Previous set value +  $D_m$

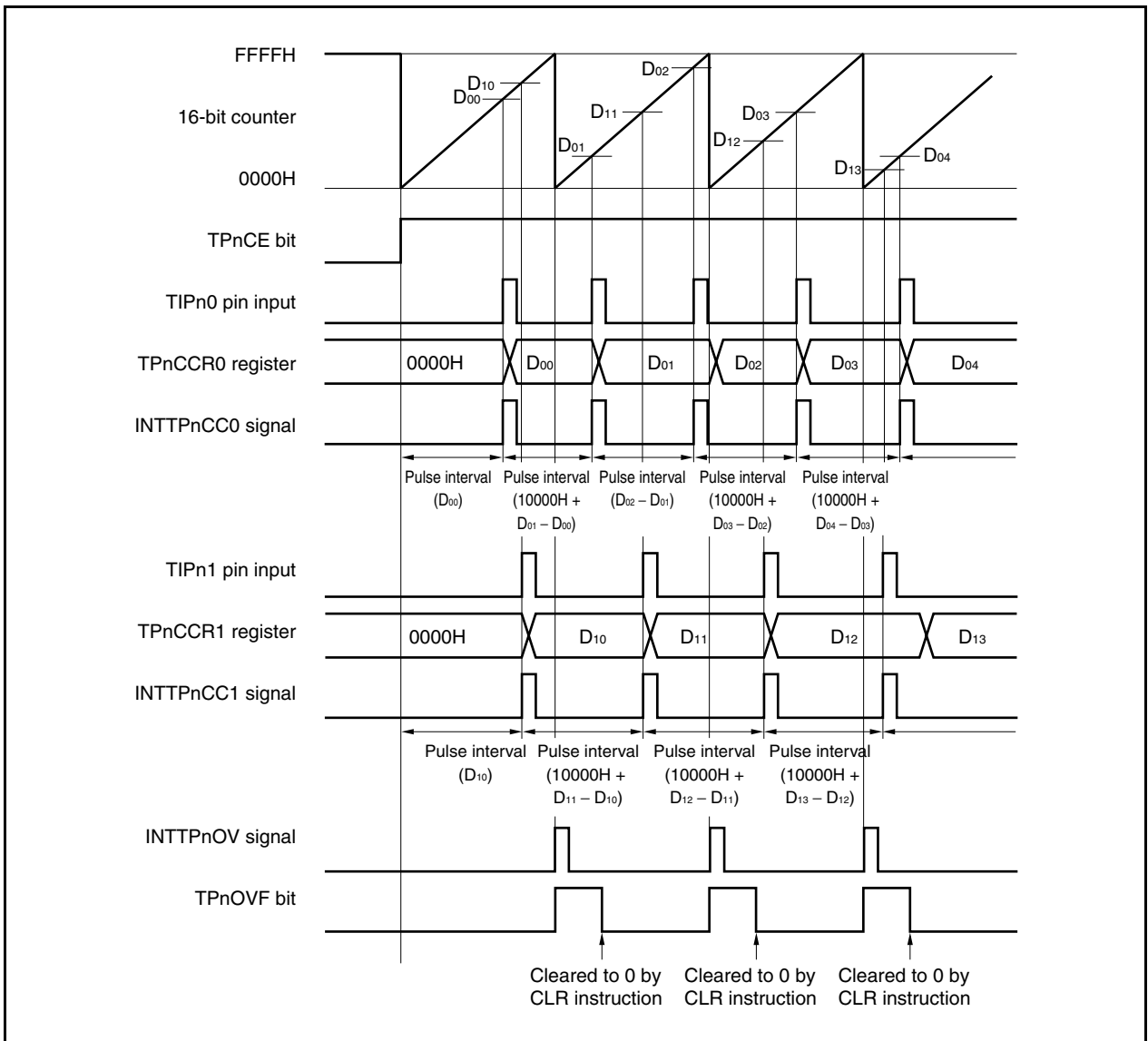
(If the calculation result is greater than FFFFH, subtract 10000H from the result and set this value to the register.)

**Remark** n = 0 to 8

m = 0, 1

**(b) Pulse width measurement with capture register**

When pulse width measurement is performed with the TPnCCRm register used as a capture register, software processing is necessary for reading the capture register each time the INTTPnCCm signal has been detected and for calculating an interval.



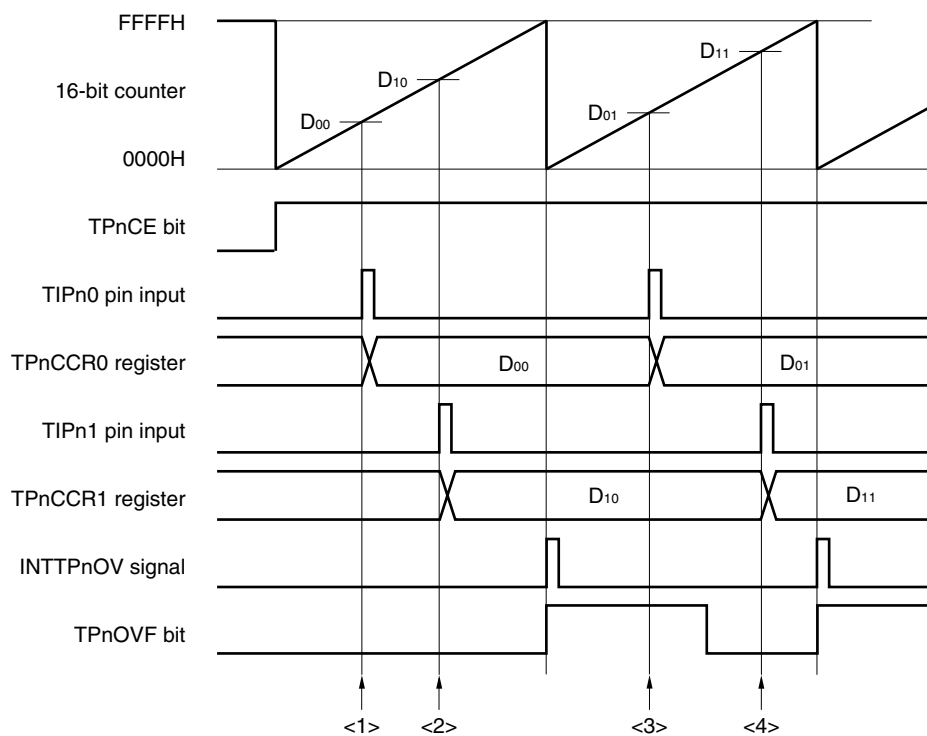
When executing pulse width measurement in the free-running timer mode, two pulse widths can be measured with one channel.

To measure a pulse width, the pulse width can be calculated by reading the value of the TPnCCRm register in synchronization with the INTTPnCCm signal, and calculating the difference between the read value and the previously read value.

**Remark** n = 0 to 8  
m = 0, 1

**(c) Processing of overflow when two capture registers are used**

Care must be exercised in processing the overflow flag when two capture registers are used. First, an example of incorrect processing is shown below.

**Example of incorrect processing when two capture registers are used**

The following problem may occur when two pulse widths are measured in the free-running timer mode.

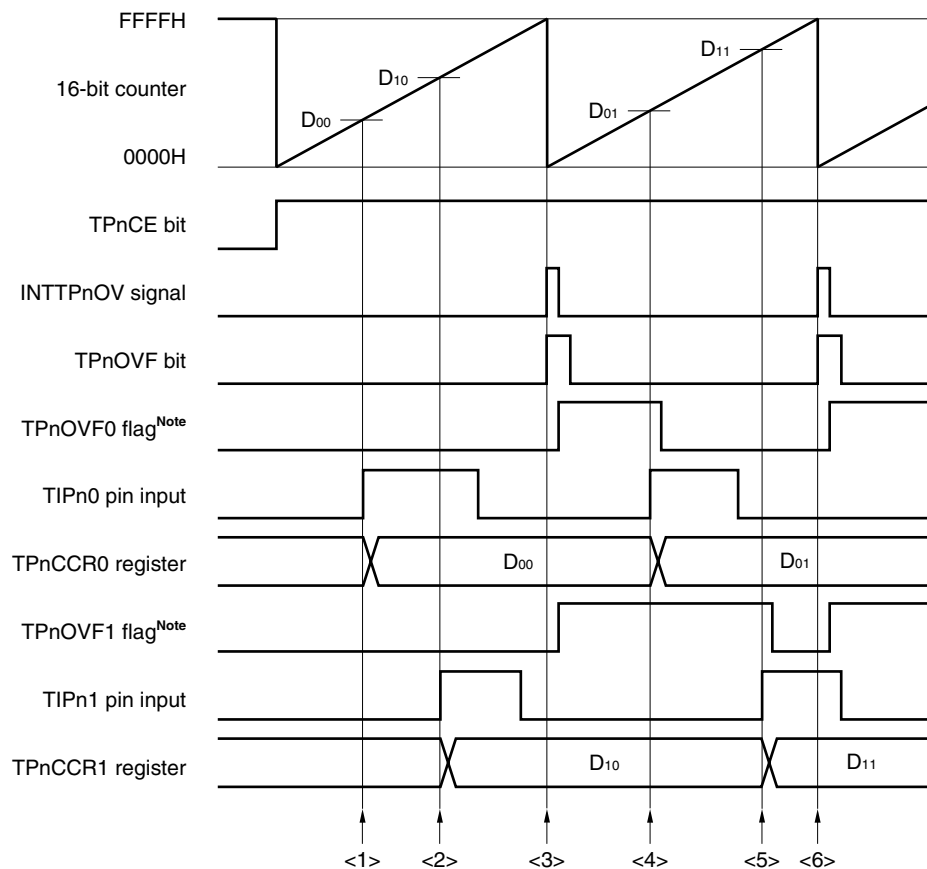
- <1> Read the TPnCCR0 register (setting of the default value of the TIPn0 pin input).
- <2> Read the TPnCCR1 register (setting of the default value of the TIPn1 pin input).
- <3> Read the TPnCCR0 register.  
Read the overflow flag. If the overflow flag is 1, clear it to 0.  
Because the overflow flag is 1, the pulse width can be calculated by  $(10000H + D_{01} - D_{00})$ .
- <4> Read the TPnCCR1 register.  
Read the overflow flag. Because the flag is cleared in <3>, 0 is read.  
Because the overflow flag is 0, the pulse width can be calculated by  $(D_{11} - D_{10})$  (incorrect).

When two capture registers are used, and if the overflow flag is cleared to 0 by one capture register, the other capture register may not obtain the correct pulse width.

Use software when using two capture registers. An example of how to use software is shown below.



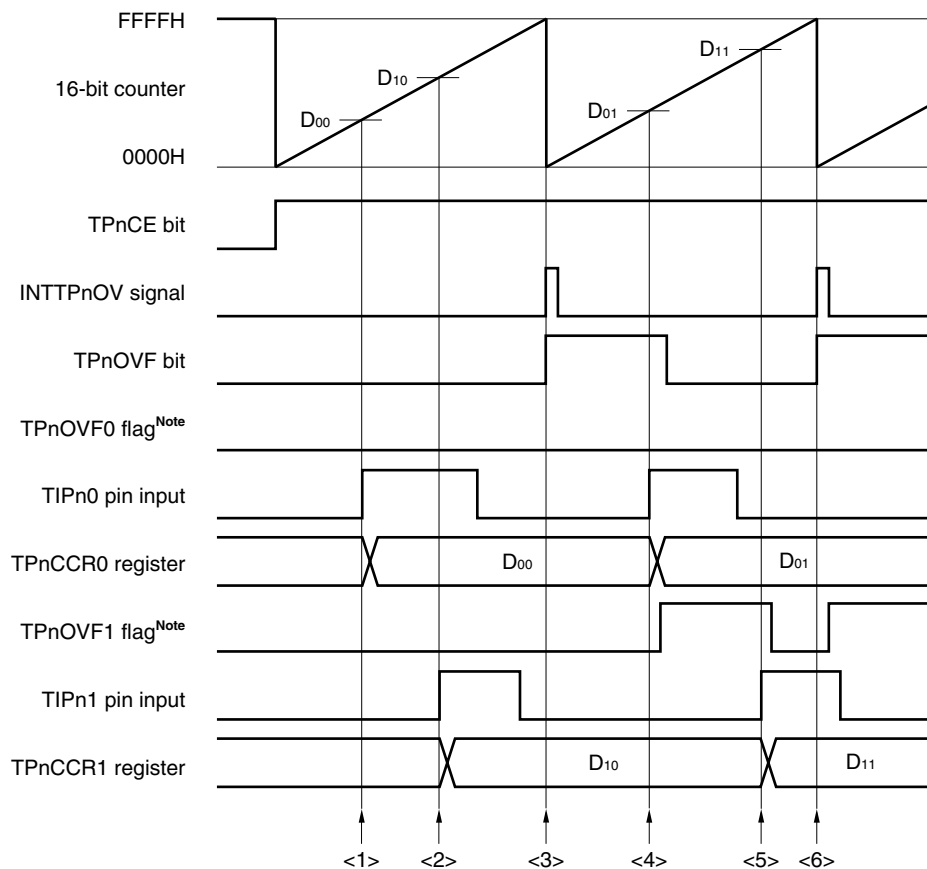
### Example when two capture registers are used (using overflow interrupt)



**Note** The TPnOVF0 and TPnOVF1 flags are set on the internal RAM by software.

- <1> Read the TPnCCR0 register (setting of the default value of the TIPn0 pin input).
- <2> Read the TPnCCR1 register (setting of the default value of the TIPn1 pin input).
- <3> An overflow occurs. Set the TPnOVF0 and TPnOVF1 flags to 1 in the overflow interrupt servicing, and clear the overflow flag to 0.
- <4> Read the TPnCCR0 register.  
Read the TPnOVF0 flag. If the TPnOVF0 flag is 1, clear it to 0.  
Because the TPnOVF0 flag is 1, the pulse width can be calculated by  $(10000H + D_{01} - D_{00})$ .
- <5> Read the TPnCCR1 register.  
Read the TPnOVF1 flag. If the TPnOVF1 flag is 1, clear it to 0 (the TPnOVF0 flag is cleared in <4>, and the TPnOVF1 flag remains 1).  
Because the TPnOVF1 flag is 1, the pulse width can be calculated by  $(10000H + D_{11} - D_{10})$  (correct).
- <6> Same as <3>

### Example when two capture registers are used (without using overflow interrupt)



**Note** The TPnOVF0 and TPnOVF1 flags are set on the internal RAM by software.

<1> Read the TPnCCR0 register (setting of the default value of the TIPn0 pin input).

<2> Read the TPnCCR1 register (setting of the default value of the TIPn1 pin input).

<3> An overflow occurs. Nothing is done by software.

<4> Read the TPnCCR0 register.

Read the overflow flag. If the overflow flag is 1, set only the TPnOVF1 flag to 1, and clear the overflow flag to 0.

Because the overflow flag is 1, the pulse width can be calculated by  $(10000H + D_{01} - D_{00})$ .

<5> Read the TPnCCR1 register.

Read the overflow flag. Because the overflow flag is cleared in <4>, 0 is read.

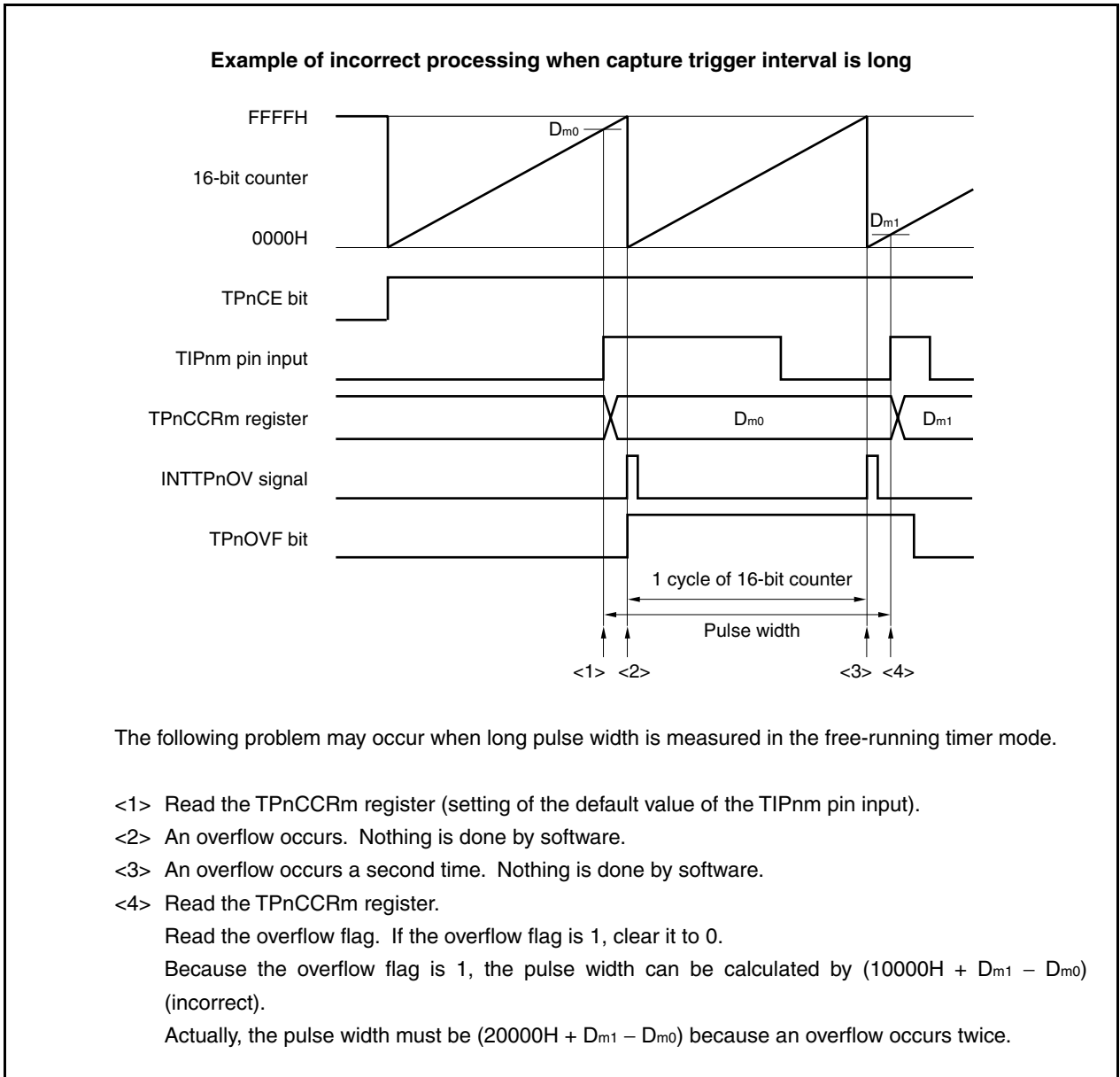
Read the TPnOVF1 flag. If the TPnOVF1 flag is 1, clear it to 0.

Because the TPnOVF1 flag is 1, the pulse width can be calculated by  $(10000H + D_{11} - D_{10})$  (correct).

<6> Same as <3>

**(d) Processing of overflow if capture trigger interval is long**

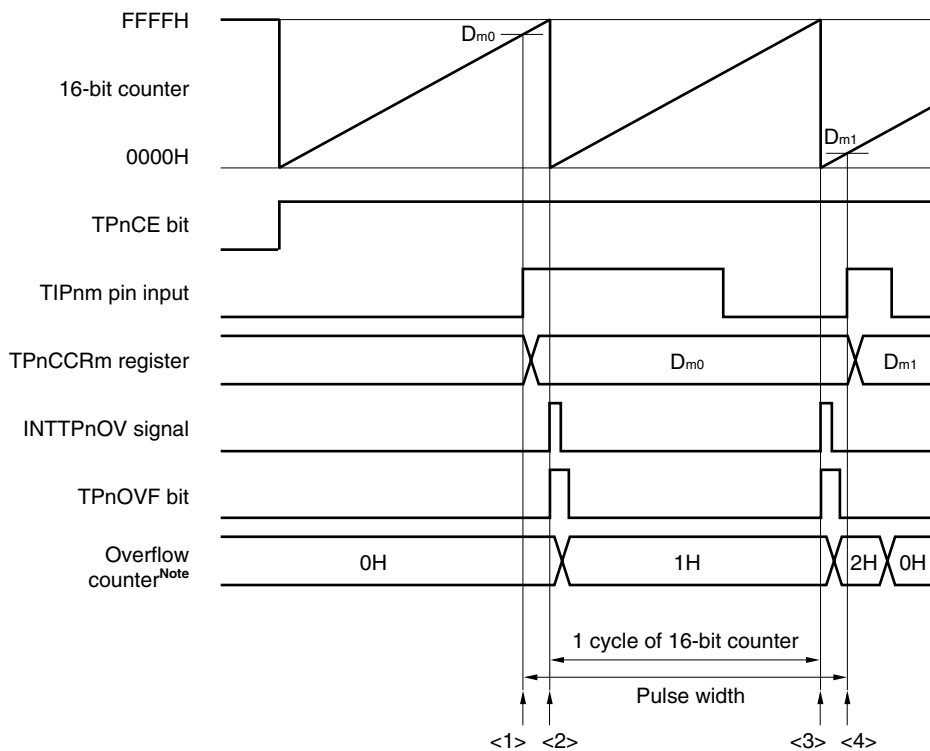
If the pulse width is greater than one cycle of the 16-bit counter, care must be exercised because an overflow may occur more than once from the first capture trigger to the next. First, an example of incorrect processing is shown below.



If an overflow occurs twice or more when the capture trigger interval is long, the correct pulse width may not be obtained.

If the capture trigger interval is long, slow the count clock to lengthen one cycle of the 16-bit counter, or use software. An example of how to use software is shown next.

## Example when capture trigger interval is long

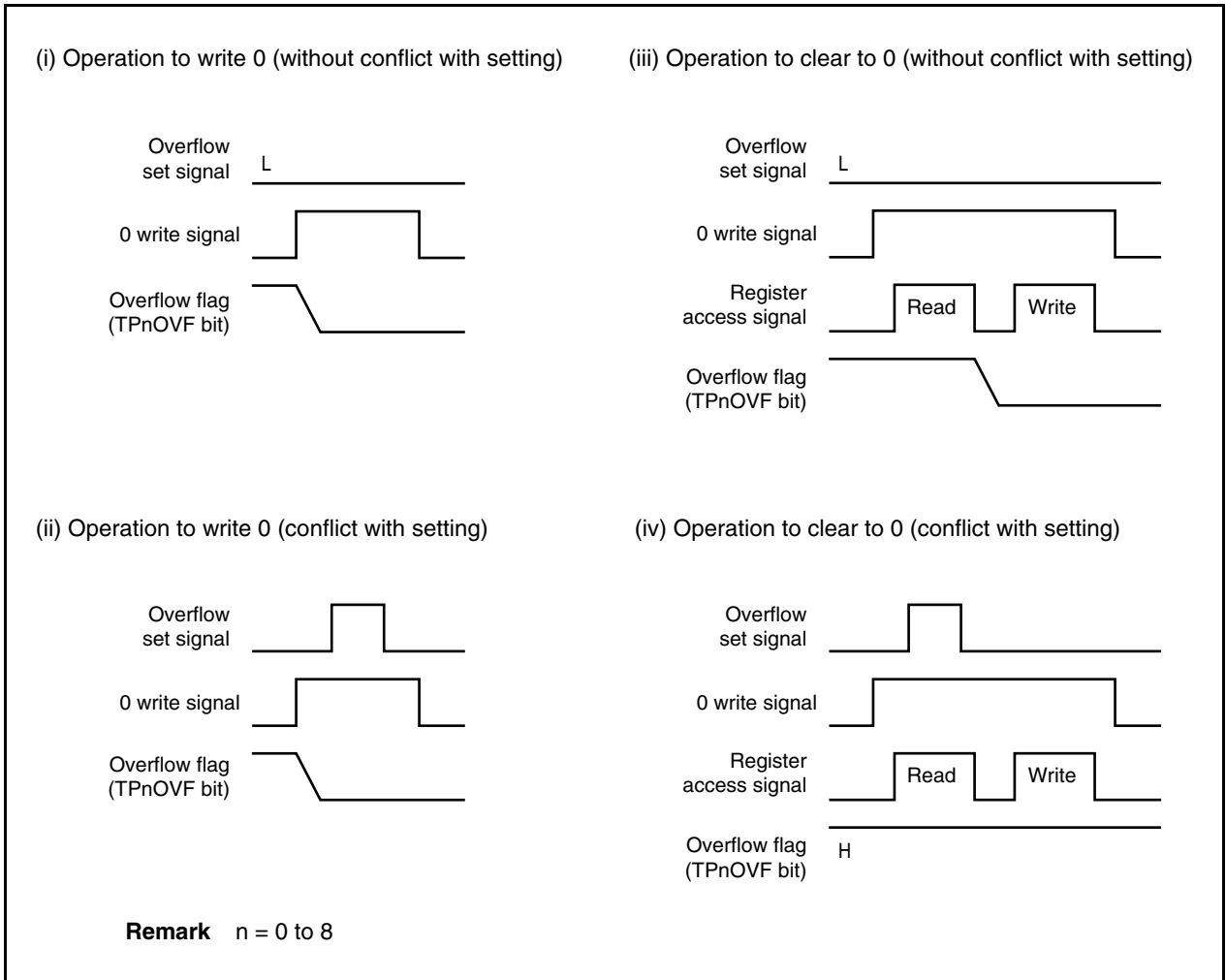


**Note** The overflow counter is set arbitrarily by software on the internal RAM.

- <1> Read the TPnCCRm register (setting of the default value of the TIPnm pin input).
- <2> An overflow occurs. Increment the overflow counter and clear the overflow flag to 0 in the overflow interrupt servicing.
- <3> An overflow occurs a second time. Increment (+1) the overflow counter and clear the overflow flag to 0 in the overflow interrupt servicing.
- <4> Read the TPnCCRm register.  
Read the overflow counter.  
→ When the overflow counter is "N", the pulse width can be calculated by  $(N \times 10000H + D_{m1} - D_{m0})$ .  
In this example, the pulse width is  $(20000H + D_{m1} - D_{m0})$  because an overflow occurs twice.  
Clear the overflow counter (0H).

**(e) Clearing overflow flag**

The overflow flag can be cleared to 0 by clearing the TPnOVF bit to 0 with the CLR instruction and by writing 8-bit data (bit 0 is 0) to the TPnOPT0 register. To accurately detect an overflow, read the TPnOVF bit when it is 1, and then clear the overflow flag by using a bit manipulation instruction.



To clear the overflow flag to 0, read the overflow flag to check if it is set to 1, and clear it with the CLR instruction. If 0 is written to the overflow flag without checking if the flag is 1, the set information of overflow may be erased by writing 0 ((ii) in the above chart). Therefore, software may judge that no overflow has occurred even when an overflow actually has occurred.

If execution of the CLR instruction conflicts with occurrence of an overflow when the overflow flag is cleared to 0 with the CLR instruction, the overflow flag remains set even after execution of the clear instruction.

### 7.5.7 Pulse width measurement mode (TPnMD2 to TPnMD0 bits = 110)

In the pulse width measurement mode, 16-bit timer/event counter P starts counting when the TPnCTL0.TPnCE bit is set to 1. Each time the valid edge input to the TIPnm pin has been detected, the count value of the 16-bit counter is stored in the TPnCCRm register, and the 16-bit counter is cleared to 0000H.

The interval of the valid edge can be measured by reading the TPnCCRm register after a capture interrupt request signal (INTTPnCCm) occurs.

Select either the TIPn0 or TIPn1 pin as the capture trigger input pin. Specify "No edge detected" by using the TPnIOC1 register for the unused pins.

When an external clock is used as the count clock, measure the pulse width of the TIPn1 pin because the external clock is fixed to the TIPn0 pin. At this time, clear the TPnIOC1.TPnIS1 and TPnIOC1.TPnIS0 bits to 00 (capture trigger input (TIPn0 pin): No edge detected).

**Figure 7-34. Configuration in Pulse Width Measurement Mode**

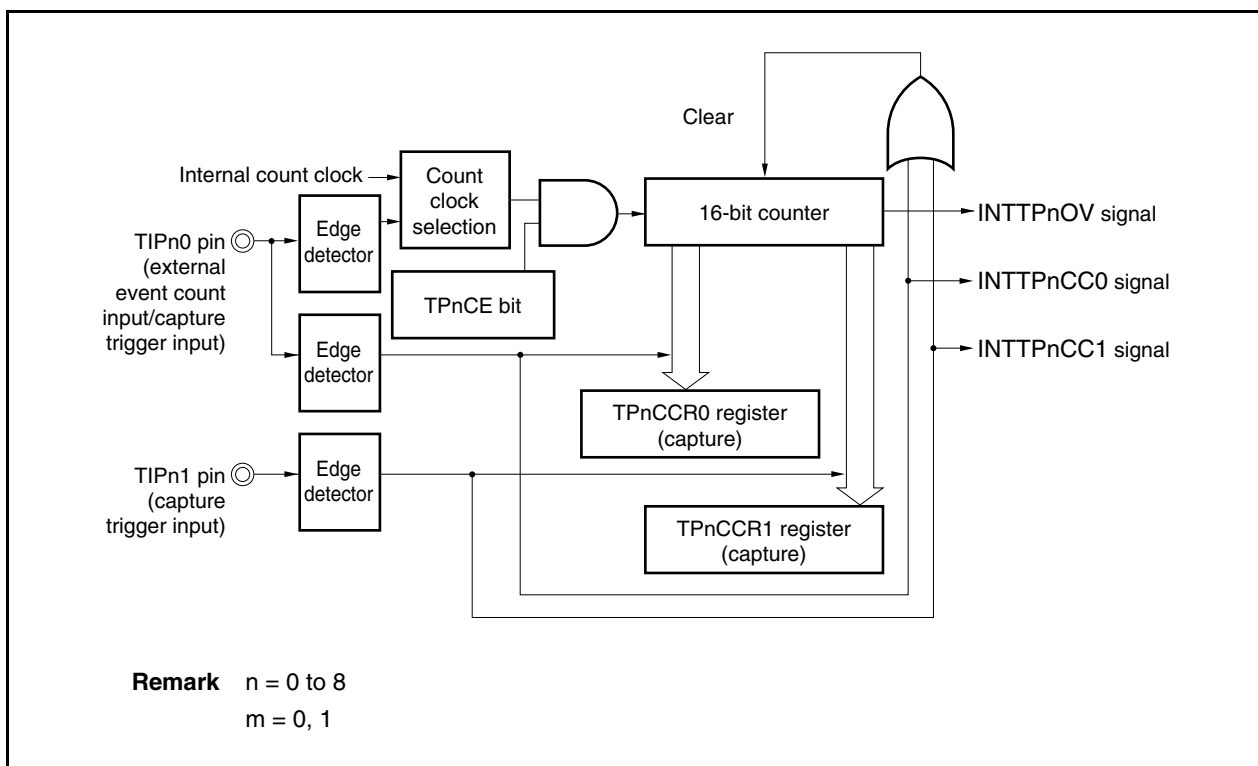
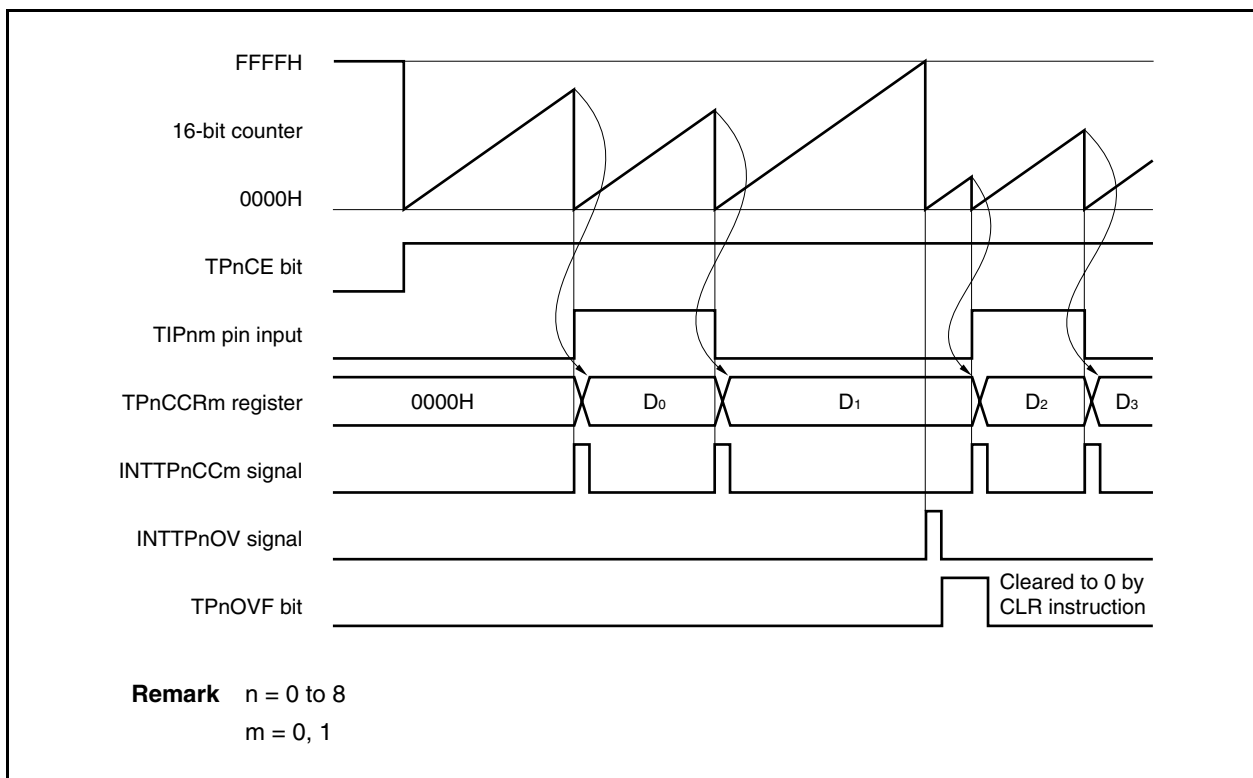


Figure 7-35. Basic Timing in Pulse Width Measurement Mode



When the TPnCE bit is set to 1, the 16-bit counter starts counting. When the valid edge input to the TIPnm pin is later detected, the count value of the 16-bit counter is stored in the TPnCCRm register, the 16-bit counter is cleared to 0000H, and a capture interrupt request signal (INTTPnCCm) is generated.

The pulse width is calculated as follows.

$$\text{Pulse width} = \text{Captured value} \times \text{Count clock cycle}$$

If the valid edge is not input to the TIPnm pin even when the 16-bit counter counted up to FFFFH, an overflow interrupt request signal (INTTPnOV) is generated at the next count clock, and the counter is cleared to 0000H and continues counting. At this time, the overflow flag (TPnOPT0.TPnOVF bit) is also set to 1. Clear the overflow flag to 0 by executing the CLR instruction via software.

If the overflow flag is set to 1, the pulse width can be calculated as follows.

$$\text{Pulse width} = (10000\text{H} \times \text{TPnOVF bit set (1) count} + \text{Captured value}) \times \text{Count clock cycle}$$

**Remark** n = 0 to 8  
m = 0, 1

Figure 7-36. Register Setting in Pulse Width Measurement Mode (1/2)

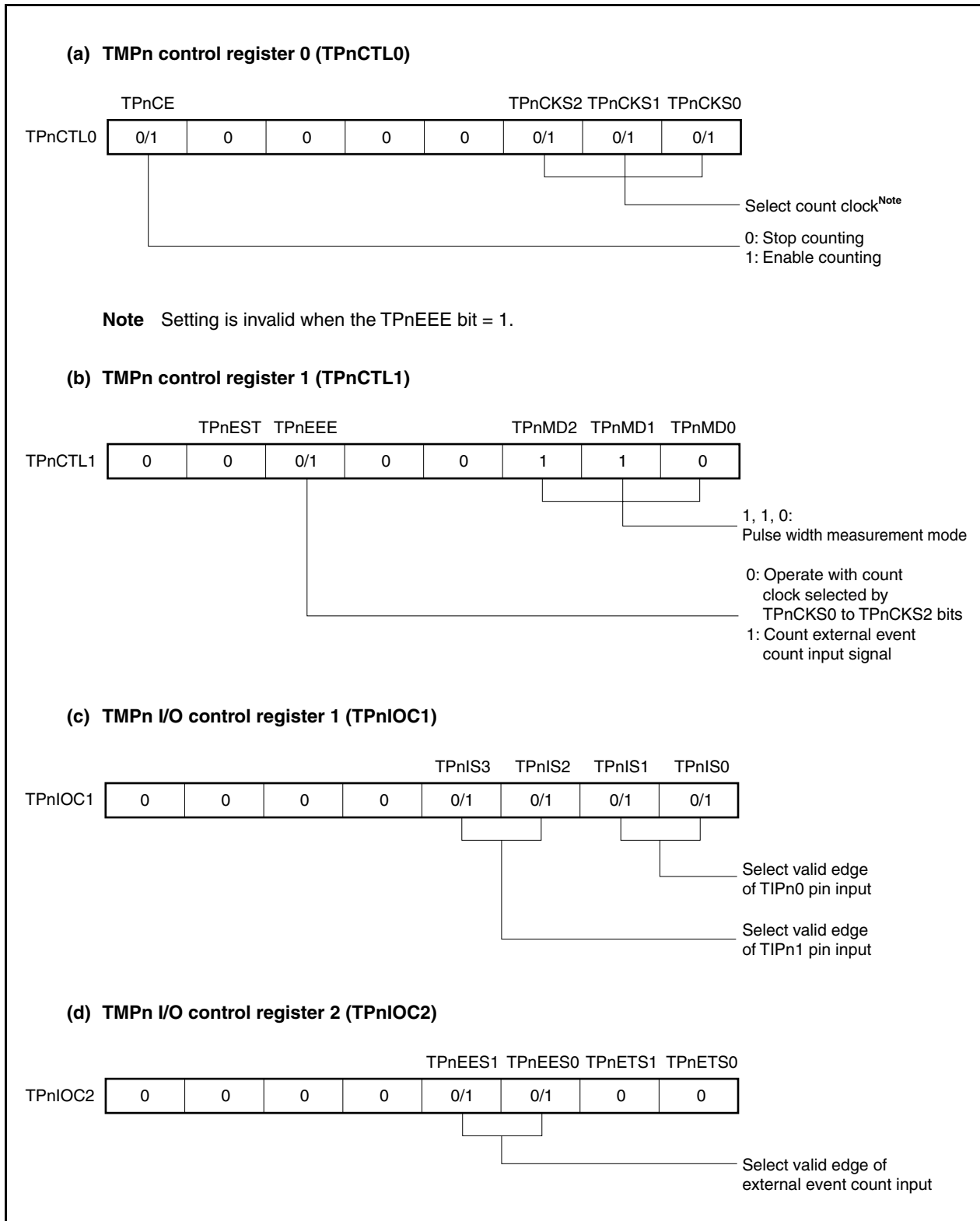
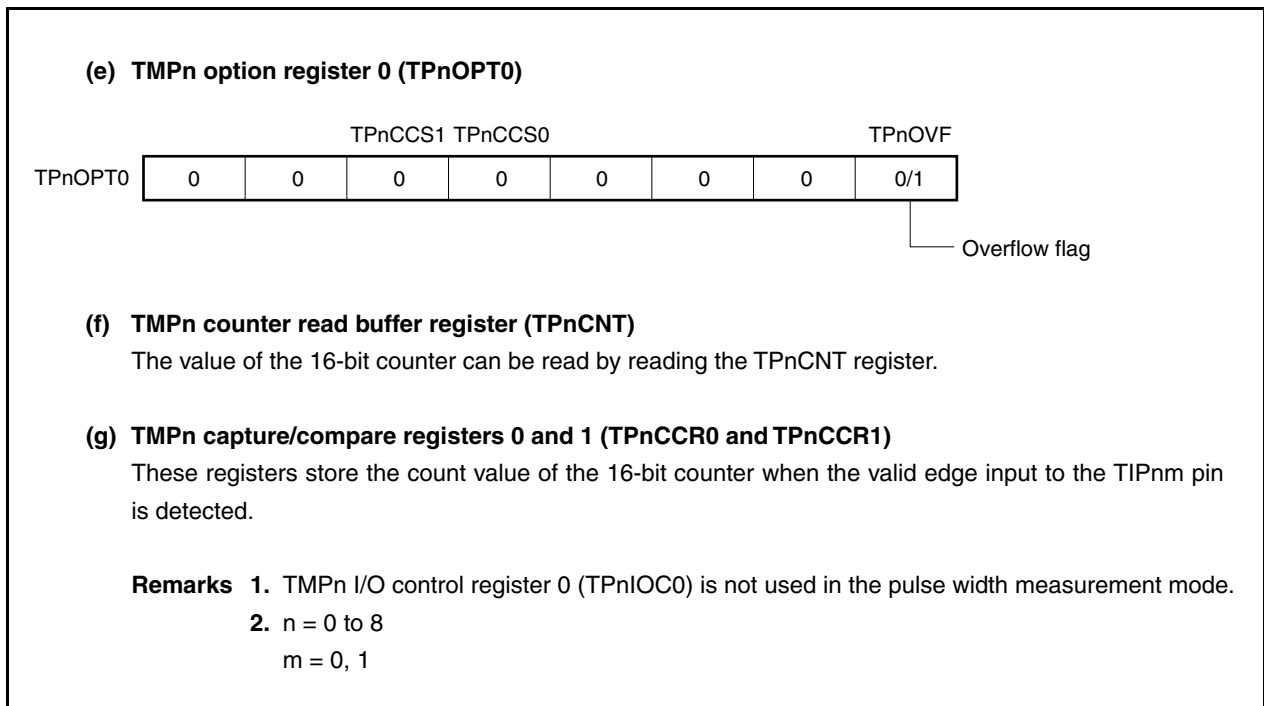


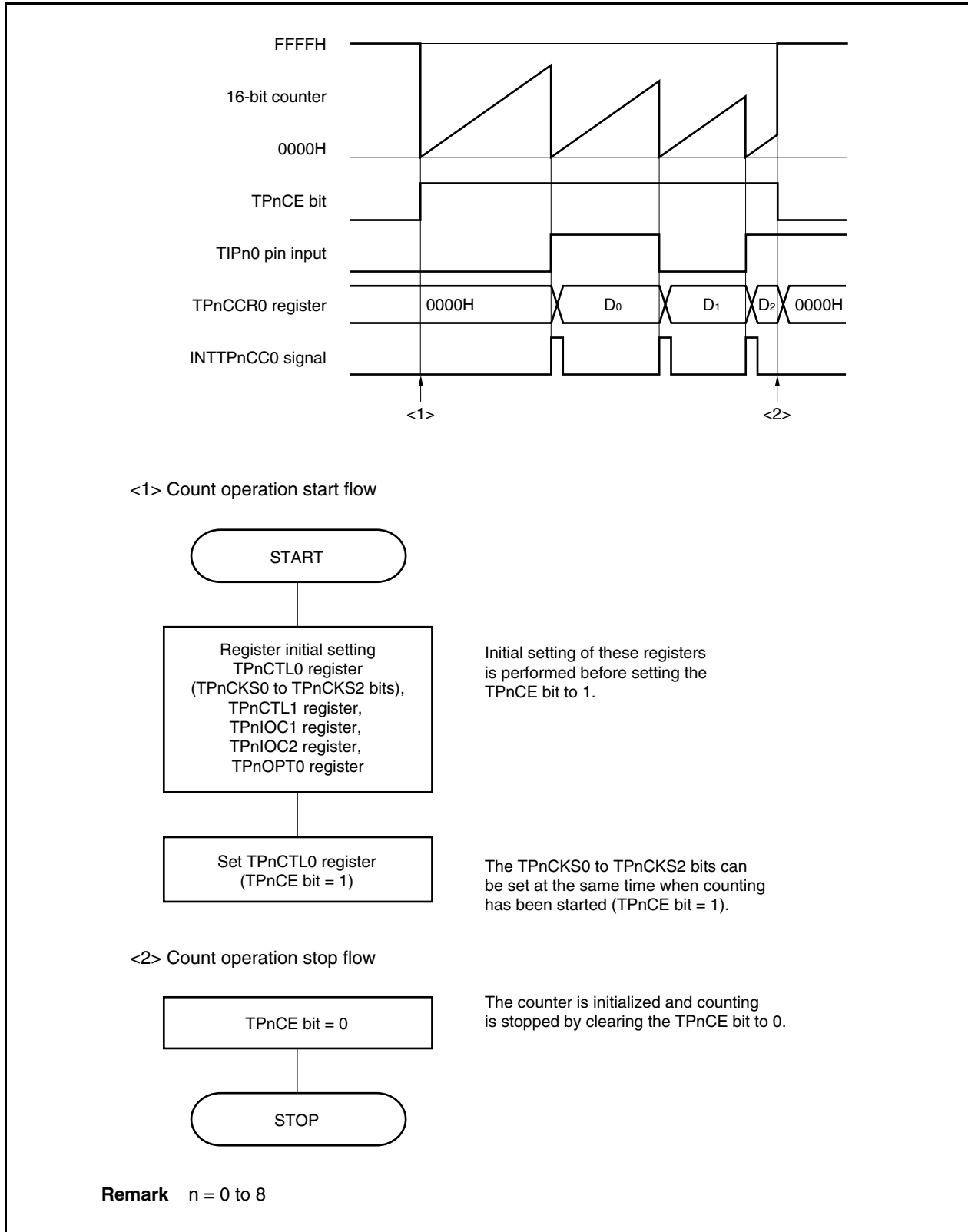


Figure 7-36. Register Setting in Pulse Width Measurement Mode (2/2)



(1) Operation flow in pulse width measurement mode

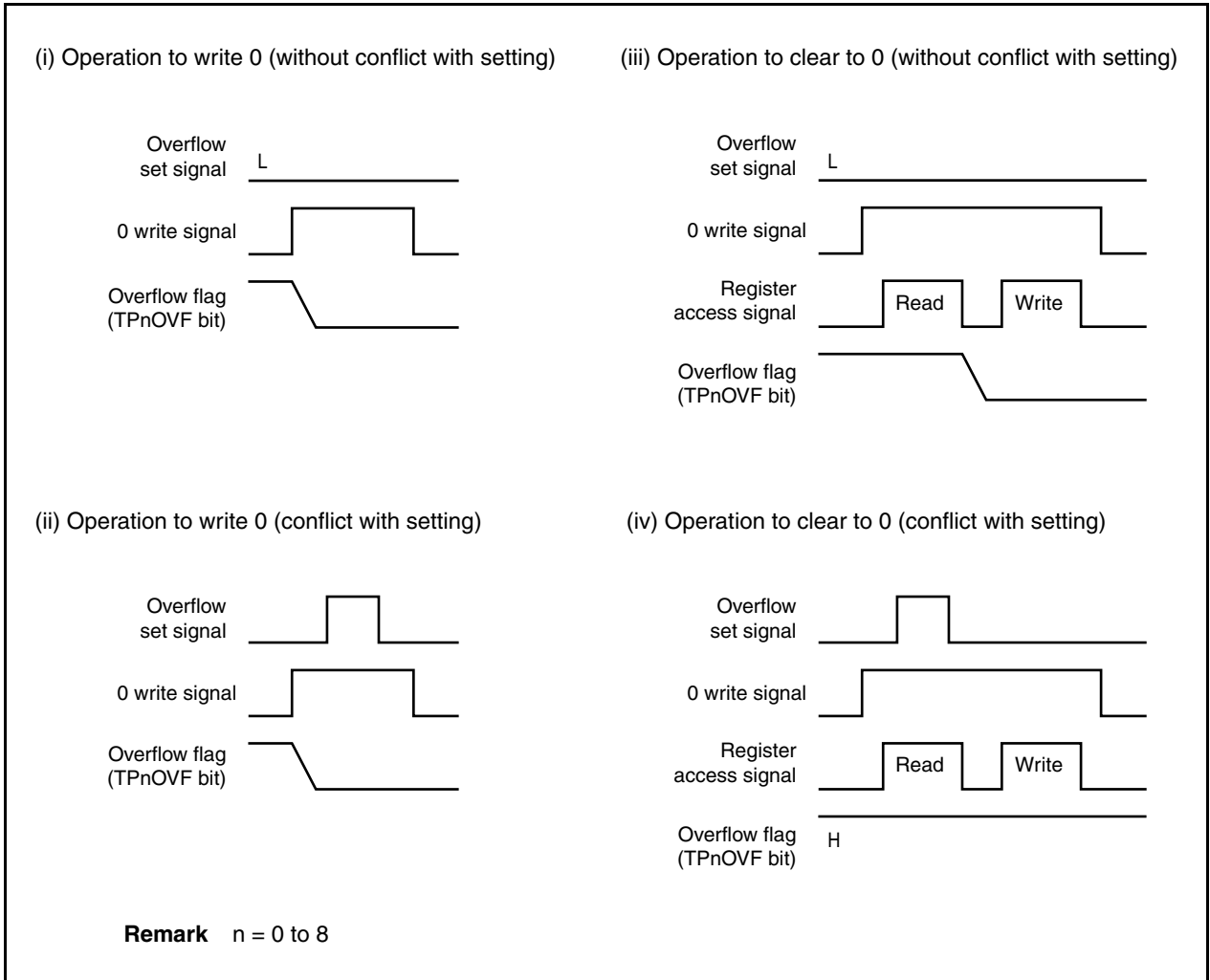
Figure 7-37. Software Processing Flow in Pulse Width Measurement Mode



(2) Operation timing in pulse width measurement mode

(a) Clearing overflow flag

The overflow flag can be cleared to 0 by clearing the TPnOVF bit to 0 with the CLR instruction and by writing 8-bit data (bit 0 is 0) to the TPnOPT0 register. To accurately detect an overflow, read the TPnOVF bit when it is 1, and then clear the overflow flag by using a bit manipulation instruction.



To clear the overflow flag to 0, read the overflow flag to check if it is set to 1, and clear it with the CLR instruction. If 0 is written to the overflow flag without checking if the flag is 1, the set information of overflow may be erased by writing 0 ((ii) in the above chart). Therefore, software may judge that no overflow has occurred even when an overflow actually has occurred.

If execution of the CLR instruction conflicts with occurrence of an overflow when the overflow flag is cleared to 0 with the CLR instruction, the overflow flag remains set even after execution of the clear instruction.

### 7.5.8 Timer output operations

The following table shows the operations and output levels of the TOPn0 and TOPn1 pins.

**Table 7-4. Timer Output Control in Each Mode**

| Operation Mode                     | TOPn1 Pin   | TOPn0 Pin          |
|------------------------------------|---|--------------------|
| Interval timer mode                | Square wave output                                      |                    |
| External event count mode          | Square wave output                                      | –                  |
| External trigger pulse output mode | External trigger pulse output                           | Square wave output |
| One-shot pulse output mode         | One-shot pulse output                                   |                    |
| PWM output mode                    | PWM output  |                    |
| Free-running timer mode            | Square wave output (only when compare function is used) |                    |
| Pulse width measurement mode       | –   |                    |

**Remark** n = 0 to 8

**Table 7-5. Truth Table of TOPn0 and TOPn1 Pins Under Control of Timer Output Control Bits**

| TPnIOC0.TPnOLm Bit | TPnIOC0.TPnOEm Bit | TPnCTL0.TPnCE Bit | Level of TOPnm Pin  |
|--------------------|--------------------|-------------------|---|
| 0                  | 0                  | ×                 | Low-level output  |
|                    | 1                  | 0                 | Low-level output  |
|                    |                    | 1                 | Low level immediately before counting, high level after counting is started |
| 1                  | 0                  | ×                 | High-level output   |
|                    | 1                  | 0                 | High-level output   |
|                    |                    | 1                 | High level immediately before counting, low level after counting is started |

**Remark** n = 0 to 8  
m = 0, 1

## 7.6 Selector Function

In the V850ES/JJ3, the capture trigger input for TMP can be selected from the input signal via the port/timer alternate-function pin and the peripheral I/O (TMP/UARTA) input signal.

This function makes the following possible.

- The TIP10 and TIP11 input signals for TMP1 can be selected from the signals via the port/timer alternate-function pins (TIP10 and TIP11) and the signals via the UARTA reception alternate-function pins (RXDA0 and RXDA1). Similarly, the TIP31 input signal for TMP3 can be selected from the signal via the port/timer alternate-function pin (TIP31) and the signal via the UARTA reception alternate-function pin (RXDA3).  
→ When the RXDA0, RXDA1, or RXDA3 signal for UARTA0, for UARTA1, or UARTA3 is selected, the baud rate error of the UARTA LIN reception transfer rate can be calculated.

**Cautions 1. When using the selector function, be sure to set the port/timer alternate function pins for TMP to be connected to the capture trigger input.**

**2. Disable the peripheral I/Os to be connected (TMP/UARTA) before setting the selector function.**

The capture trigger input can be selected using the following register.

**(1) Selector operation control register 0 (SELCNT0)**

The SELCNT0 register is an 8-bit register that selects the capture trigger for TMP1 and TMP3.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF308H

|         |   |       |   |       |       |   |   |   |
|---------|---|-------|---|-------|-------|---|---|---|
|         | 7 | <6>   | 5 | <4>   | <3>   | 2 | 1 | 0 |
| SELCNT0 | 0 | ISEL6 | 0 | ISEL4 | ISEL3 | 0 | 0 | 0 |

|       |  |
|-------|--|
| ISEL6 | Selection of TIP31 input signal (TMP3) |
| 0     | TIP31 pin input                        |
| 1     | RXDA3 pin input                        |

|       |  |
|-------|--|
| ISEL4 | Selection of TIP11 input signal (TMP1) |
| 0     | TIP11 pin input                        |
| 1     | RXDA1 pin input                        |

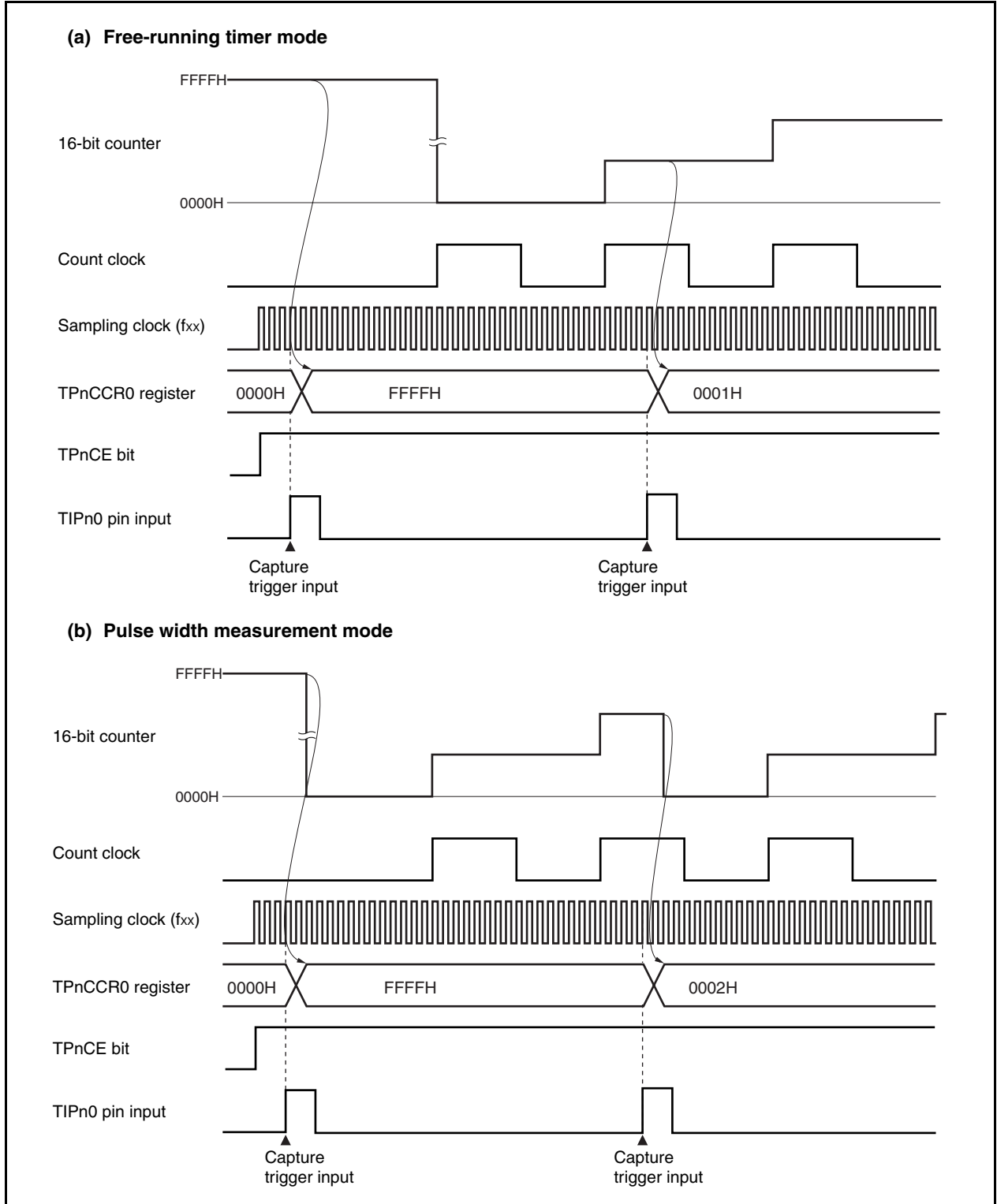
|       |  |
|-------|--|
| ISEL3 | Selection of TIP10 input signal (TMP1) |
| 0     | TIP10 pin input                        |
| 1     | RXDA0 pin input                        |

- Cautions**
1. When setting the ISEL3, ISEL4, or ISEL6 bit to 1, be sure to set the corresponding alternate-function pin to the capture trigger input.
  2. Be sure to clear bits 7, 5, and 2 to 0 to "0".

7.7 Cautions

(1) Capture operation

When the capture operation is used and a slow clock is selected as the count clock, FFFFH, not 0000H, may be captured in the TPnCCR0 and TPnCCR1 registers if the capture trigger is input immediately after the TPnCE bit is set to 1.



## CHAPTER 8 16-BIT TIMER/EVENT COUNTER Q (TMQ)

Timer Q (TMQ) is a 16-bit timer/event counter.  
The V850ES/JJ3 incorporates TMQ0.

### 8.1 Overview

An outline of TMQ0 is shown below.

- Clock selection: 8 ways
- Capture/trigger input pins: 4
- External event count input pins: 1
- External trigger input pins: 1
- Timer/counters: 1
- Capture/compare registers: 4
- Capture/compare match interrupt request signals: 4
- Timer output pins: 4

### 8.2 Functions

TMQ0 has the following functions.

- Interval timer
- External event counter
- External trigger pulse output
- One-shot pulse output
- PWM output
- Free-running timer
- Pulse width measurement



### 8.3 Configuration

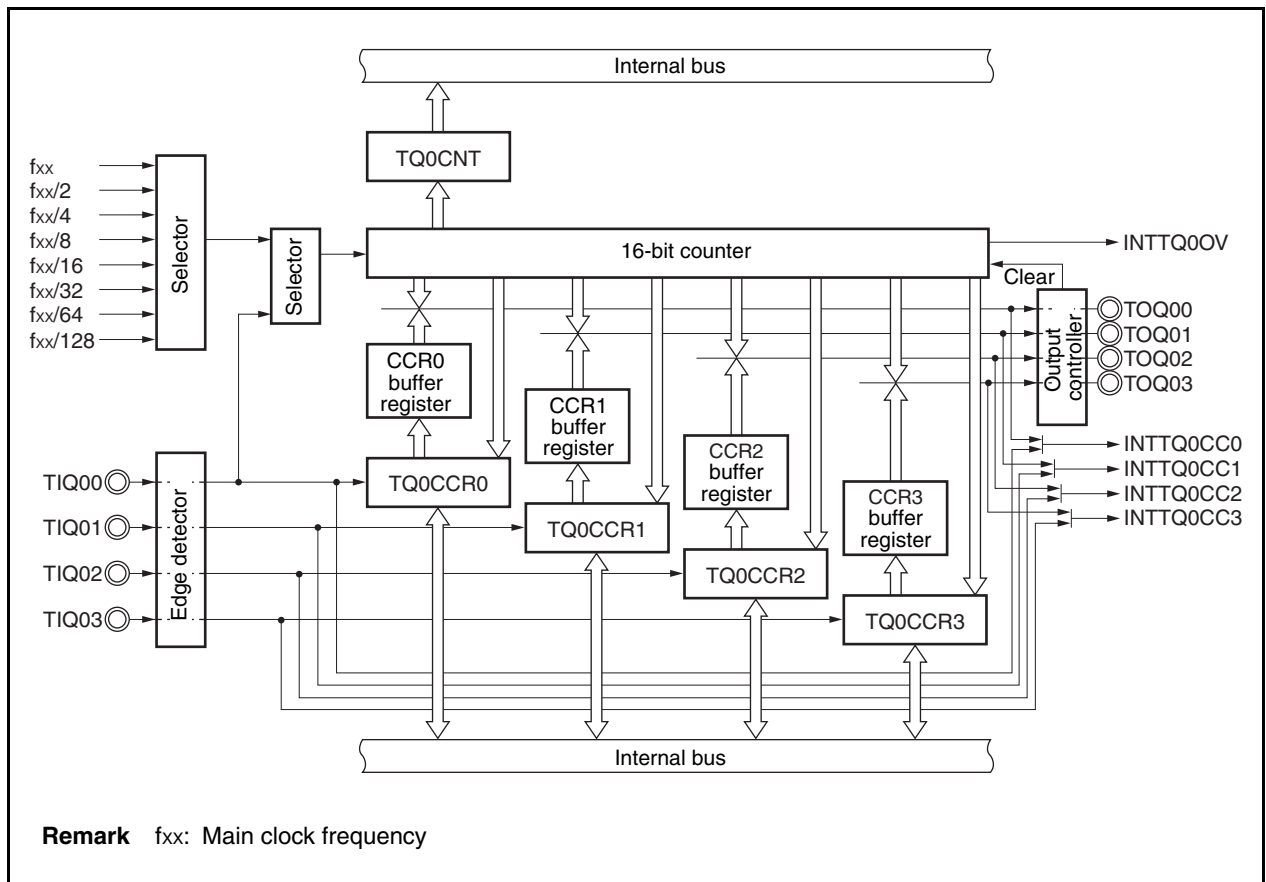
TMQ0 includes the following hardware.

**Table 8-1. Configuration of TMQ0**

| Item                                | Configuration  |
|-------------------------------------|--|
| Timer register                      | 16-bit counter   |
| Registers                           | TMQ0 capture/compare registers 0 to 3 (TQ0CCR0 to TQ0CCR3)<br>TMQ0 counter read buffer register (TQ0CNT)<br>CCR0 to CCR3 buffer registers    |
| Timer inputs                        | 4 (TIQ00 <sup>Note 1</sup> to TIQ03 pins)  |
| Timer outputs                       | 4 (TOQ00 to TOQ03 pins)  |
| Control registers <sup>Note 2</sup> | TMQ0 control registers 0, 1 (TQ0CTL0, TQ0CTL1)<br>TMQ0 I/O control registers 0 to 2 (TQ0IOC0 to TQ0IOC2)<br>TMQ0 option register 0 (TQ0OPT0) |

- Notes 1.** The TIQ00 pin functions alternately as a capture trigger input signal, external event count input signal, and external trigger input signal.
- 2.** When using the functions of the TIQ00 to TIQ03 and TOQ00 to TOQ03 pins, see **Table 4-19 Using Port Pins as Alternate-Function Pins.**

**Figure 8-1. Block Diagram of TMQ0**



**(1) 16-bit counter**

This 16-bit counter can count internal clocks or external events.

The count value of this counter can be read by using the TQ0CNT register.

When the TQ0CTL0.TQ0CE bit = 0, the value of the 16-bit counter is FFFFH. If the TQ0CNT register is read at this time, 0000H is read.

Reset sets the TQ0CE bit to 0. Therefore, the 16-bit counter is set to FFFFH.

**(2) CCR0 buffer register**

This is a 16-bit compare register that compares the count value of the 16-bit counter.

When the TQ0CCR0 register is used as a compare register, the value written to the TQ0CCR0 register is transferred to the CCR0 buffer register. When the count value of the 16-bit counter matches the value of the CCR0 buffer register, a compare match interrupt request signal (INTTQ0CC0) is generated.

The CCR0 buffer register cannot be read or written directly.

The CCR0 buffer register is cleared to 0000H after reset, as the TQ0CCR0 register is cleared to 0000H.

**(3) CCR1 buffer register**

This is a 16-bit compare register that compares the count value of the 16-bit counter.

When the TQ0CCR1 register is used as a compare register, the value written to the TQ0CCR1 register is transferred to the CCR1 buffer register. When the count value of the 16-bit counter matches the value of the CCR1 buffer register, a compare match interrupt request signal (INTTQ0CC1) is generated.

The CCR1 buffer register cannot be read or written directly.

The CCR1 buffer register is cleared to 0000H after reset, as the TQ0CCR1 register is cleared to 0000H.

**(4) CCR2 buffer register**

This is a 16-bit compare register that compares the count value of the 16-bit counter.

When the TQ0CCR2 register is used as a compare register, the value written to the TQ0CCR2 register is transferred to the CCR2 buffer register. When the count value of the 16-bit counter matches the value of the CCR2 buffer register, a compare match interrupt request signal (INTTQ0CC2) is generated.

The CCR2 buffer register cannot be read or written directly.

The CCR2 buffer register is cleared to 0000H after reset, as the TQ0CCR2 register is cleared to 0000H.

**(5) CCR3 buffer register**

This is a 16-bit compare register that compares the count value of the 16-bit counter.

When the TQ0CCR3 register is used as a compare register, the value written to the TQ0CCR3 register is transferred to the CCR3 buffer register. When the count value of the 16-bit counter matches the value of the CCR3 buffer register, a compare match interrupt request signal (INTTQ0CC3) is generated.

The CCR3 buffer register cannot be read or written directly.

The CCR3 buffer register is cleared to 0000H after reset, as the TQ0CCR3 register is cleared to 0000H.

**(6) Edge detector**

This circuit detects the valid edges input to the TIQ00 and TIQ03 pins. No edge, rising edge, falling edge, or both the rising and falling edges can be selected as the valid edge by using the TQ0IOC1 and TQ0IOC2 registers.

**(7) Output controller**

This circuit controls the output of the TOQ00 to TOQ03 pins. The output controller is controlled by the TQ0IOC0 register.

**(8) Selector**

This selector selects the count clock for the 16-bit counter. Eight types of internal clocks or an external event can be selected as the count clock.

## 8.4 Registers

The registers that control TMQ0 are as follows.

- TMQ0 control register 0 (TQ0CTL0)
- TMQ0 control register 1 (TQ0CTL1)
- TMQ0 I/O control register 0 (TQ0IOC0)
- TMQ0 I/O control register 1 (TQ0IOC1)
- TMQ0 I/O control register 2 (TQ0IOC2)
- TMQ0 option register 0 (TQ0OPT0)
- TMQ0 capture/compare register 0 (TQ0CCR0)
- TMQ0 capture/compare register 1 (TQ0CCR1)
- TMQ0 capture/compare register 2 (TQ0CCR2)
- TMQ0 capture/compare register 3 (TQ0CCR3)
- TMQ0 counter read buffer register (TQ0CNT)

**Remark** When using the functions of the TIQ00 to TIQ03 and TOQ00 to TOQ03 pins, see **Table 4-19 Using Port Pins as Alternate-Function Pins**.

**(1) TMQ0 control register 0 (TQ0CTL0)**

The TQ0CTL0 register is an 8-bit register that controls the operation of TMQ0.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

The same value can always be written to the TQ0CTL0 register by software.

After reset: 00H    R/W    Address:    FFFFF540H

|         |       |   |   |   |   |         |         |         |
|---------|-------|---|---|---|---|---------|---------|---------|
|         | <7>   | 6 | 5 | 4 | 3 | 2       | 1       | 0       |
| TQ0CTL0 | TQ0CE | 0 | 0 | 0 | 0 | TQ0CKS2 | TQ0CKS1 | TQ0CKS0 |

|       |   |
|-------|---|
| TQ0CE | TMQ0 operation control  |
| 0     | TMQ0 operation disabled (TMQ0 reset asynchronously <sup>Note</sup> ). |
| 1     | TMQ0 operation enabled. TMQ0 operation started.                       |

|         |         |         |                                |
|---------|---------|---------|--------------------------------|
| TQ0CKS2 | TQ0CKS1 | TQ0CKS0 | Internal count clock selection |
| 0       | 0       | 0       | f <sub>xx</sub>                |
| 0       | 0       | 1       | f <sub>xx</sub> /2             |
| 0       | 1       | 0       | f <sub>xx</sub> /4             |
| 0       | 1       | 1       | f <sub>xx</sub> /8             |
| 1       | 0       | 0       | f <sub>xx</sub> /16            |
| 1       | 0       | 1       | f <sub>xx</sub> /32            |
| 1       | 1       | 0       | f <sub>xx</sub> /64            |
| 1       | 1       | 1       | f <sub>xx</sub> /128           |

**Note** TQ0OPT0.TQ0OVF bit, 16-bit counter, timer output (TOQ00 to TOQ03 pins)

- Cautions**
1. Set the TQ0CKS2 to TQ0CKS0 bits when the TQ0CE bit = 0. When the value of the TQ0CE bit is changed from 0 to 1, the TQ0CKS2 to TQ0CKS0 bits can be set simultaneously.
  2. Be sure to clear bits 3 to 6 to “0”.

**Remark** f<sub>xx</sub>: Main clock frequency

**(2) TMQ0 control register 1 (TQ0CTL1)**

The TQ0CTL1 register is an 8-bit register that controls the operation of TMQ0.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF541H

|         |   |        |        |   |   |        |        |        |
|---------|---|--------|--------|---|---|--------|--------|--------|
|         | 7 | <6>    | <5>    | 4 | 3 | 2      | 1      | 0      |
| TQ0CTL1 | 0 | TQ0EST | TQ0EEE | 0 | 0 | TQ0MD2 | TQ0MD1 | TQ0MD0 |

|        |   |
|--------|---|
| TQ0EST | Software trigger control  |
| 0      | –   |
| 1      | Generate a valid signal for external trigger input.<br><ul style="list-style-type: none"> <li>In one-shot pulse output mode: A one-shot pulse is output with writing 1 to the TQ0EST bit as the trigger.</li> <li>In external trigger pulse output mode: A PWM waveform is output with writing 1 to the TQ0EST bit as the trigger.</li> </ul> |

|   |  |
|---|--|
| TQ0EEE  | Count clock selection  |
| 0   | Disable operation with external event count input.<br>(Perform counting with the count clock selected by the TQ0CTL0.TQ0CK0 to TQ0CK2 bits.) |
| 1   | Enable operation with external event count input.<br>(Perform counting at the valid edge of the external event count input signal.)          |
| The TQ0EEE bit selects whether counting is performed with the internal count clock or the valid edge of the external event count input. |  |

|        |        |        |                                    |
|--------|--------|--------|------------------------------------|
| TQ0MD2 | TQ0MD1 | TQ0MD0 | Timer mode selection               |
| 0      | 0      | 0      | Interval timer mode                |
| 0      | 0      | 1      | External event count mode          |
| 0      | 1      | 0      | External trigger pulse output mode |
| 0      | 1      | 1      | One-shot pulse output mode         |
| 1      | 0      | 0      | PWM output mode                    |
| 1      | 0      | 1      | Free-running timer mode            |
| 1      | 1      | 0      | Pulse width measurement mode       |
| 1      | 1      | 1      | Setting prohibited                 |

- Cautions**
1. The TQ0EST bit is valid only in the external trigger pulse output mode or one-shot pulse output mode. In any other mode, writing 1 to this bit is ignored.
  2. External event count input is selected in the external event count mode regardless of the value of the TQ0EEE bit.
  3. Set the TQ0EEE and TQ0MD2 to TQ0MD0 bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) The operation is not guaranteed when rewriting is performed with the TQ0CE bit = 1. If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.
  4. Be sure to clear bits 3, 4, and 7 to “0”.

**(3) TMQ0 I/O control register 0 (TQ0IOC0)**

The TQ0IOC0 register is an 8-bit register that controls the timer output (TOQ00 to TOQ03 pins).

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF542H

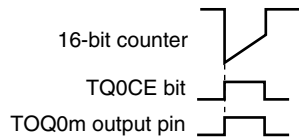
|         |        |        |        |        |        |        |        |        |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|
|         | 7      | <6>    | 5      | <4>    | 3      | <2>    | 1      | <0>    |
| TQ0IOC0 | TQ0OL3 | TQ0OE3 | TQ0OL2 | TQ0OE2 | TQ0OL1 | TQ0OE1 | TQ0OL0 | TQ0OE0 |

|        |   |
|--------|---|
| TQ0OLm | TOQ0m pin output level setting (m = 0 to 3) <sup>Note</sup> |
| 0      | TOQ0m pin output starts at high level                       |
| 1      | TOQ0m pin output starts at low level                        |

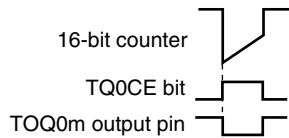
|        |  |
|--------|--|
| TQ0OEm | TOQ0m pin output setting (m = 0 to 3)  |
| 0      | Timer output disabled<br><ul style="list-style-type: none"> <li>• When TQ0OLm bit = 0: Low level is output from the TOQ0m pin</li> <li>• When TQ0OLm bit = 1: High level is output from the TOQ0m pin</li> </ul> |
| 1      | Timer output enabled (a square wave is output from the TOQ0m pin).   |

**Note** The output level of the timer output pin (TOQ0m) specified by the TQ0OLm bit is shown below.

• When TQ0OLm bit = 0



• When TQ0OLm bit = 1



**Cautions** 1. Rewrite the TQ0OLm and TQ0OEm bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.

2. Even if the TQ0OLm bit is manipulated when the TQ0CE and TQ0OEm bits are 0, the TOQ0m pin output level varies.

**Remark** m = 0 to 3

**(4) TMQ0 I/O control register 1 (TQ0IOC1)**

The TQ0IOC1 register is an 8-bit register that controls the valid edge of the capture trigger input signals (TIQ00 to TIQ03 pins).

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address:    FFFFF543H

|         |        |        |        |        |        |        |        |        |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|
|         | 7      | 6      | 5      | 4      | 3      | 2      | 1      | 0      |
| TQ0IOC1 | TQ0IS7 | TQ0IS6 | TQ0IS5 | TQ0IS4 | TQ0IS3 | TQ0IS2 | TQ0IS1 | TQ0IS0 |

| TQ0IS7 | TQ0IS6 | Capture trigger input signal (TIQ03 pin) valid edge setting |
|--------|--------|---|
| 0      | 0      | No edge detection (capture operation invalid)               |
| 0      | 1      | Detection of rising edge                                    |
| 1      | 0      | Detection of falling edge                                   |
| 1      | 1      | Detection of both edges                                     |

| TQ0IS5 | TQ0IS4 | Capture trigger input signal (TIQ02 pin) valid edge detection |
|--------|--------|---|
| 0      | 0      | No edge detection (capture operation invalid)                 |
| 0      | 1      | Detection of rising edge                                      |
| 1      | 0      | Detection of falling edge                                     |
| 1      | 1      | Detection of both edges                                       |

| TQ0IS3 | TQ0IS2 | Capture trigger input signal (TIQ01 pin) valid edge setting |
|--------|--------|---|
| 0      | 0      | No edge detection (capture operation invalid)               |
| 0      | 1      | Detection of rising edge                                    |
| 1      | 0      | Detection of falling edge                                   |
| 1      | 1      | Detection of both edges                                     |

| TQ0IS1 | TQ0IS0 | Capture trigger input signal (TIQ00 pin) valid edge setting |
|--------|--------|---|
| 0      | 0      | No edge detection (capture operation invalid)               |
| 0      | 1      | Detection of rising edge                                    |
| 1      | 0      | Detection of falling edge                                   |
| 1      | 1      | Detection of both edges                                     |

- Cautions**
1. Rewrite the TQ0IS7 to TQ0IS0 bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.
  2. The TQ0IS7 to TQ0IS0 bits are valid only in the free-running timer mode and the pulse width measurement mode. In all other modes, a capture operation is not possible.

**(5) TMQ0 I/O control register 2 (TQ0IOC2)**

The TQ0IOC2 register is an 8-bit register that controls the valid edge of the external event count input signal (TIQ00 pin) and external trigger input signal (TIQ00 pin).

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address:    FFFFF544H

|         |   |   |   |   |         |         |         |         |
|---------|---|---|---|---|---------|---------|---------|---------|
|         | 7 | 6 | 5 | 4 | 3       | 2       | 1       | 0       |
| TQ0IOC2 | 0 | 0 | 0 | 0 | TQ0EES1 | TQ0EES0 | TQ0ETS1 | TQ0ETS0 |

| TQ0EES1 | TQ0EES0 | External event count input signal (TIQ00 pin) valid edge setting |
|---------|---------|--|
| 0       | 0       | No edge detection (external event count invalid)                 |
| 0       | 1       | Detection of rising edge   |
| 1       | 0       | Detection of falling edge  |
| 1       | 1       | Detection of both edges  |

| TQ0ETS1 | TQ0ETS0 | External trigger input signal (TIQ00 pin) valid edge setting |
|---------|---------|--|
| 0       | 0       | No edge detection (external trigger invalid)                 |
| 0       | 1       | Detection of rising edge                                     |
| 1       | 0       | Detection of falling edge                                    |
| 1       | 1       | Detection of both edges                                      |

- Cautions**
1. Rewrite the TQ0EES1, TQ0EES0, TQ0ETS1, and TQ0ETS0 bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.
  2. The TQ0EES1 and TQ0EES0 bits are valid only when the TQ0CTL1.TQ0EEE bit = 1 or when the external event count mode (TQ0CTL1.TQ0MD2 to TQ0CTL1.TQ0MD0 bits = 001) has been set.
  3. The TQ0ETS1 and TQ0ETS0 bits are valid only when the external trigger pulse output mode (TQ0CTL1.TQ0MD2 to TQ0CTL1.TQ0MD0 bits = 010) or the one-shot pulse output mode (TQ0CTL1.TQ0MD2 to TQ0CTL1.TQ0MD0 = 011) is set.



**(6) TMQ0 option register 0 (TQ0OPT0)**

The TQ0OPT0 register is an 8-bit register used to set the capture/compare operation and detect an overflow. This register can be read or written in 8-bit or 1-bit units. Reset sets this register to 00H.

|                  |         |                   |         |         |   |   |   |        |
|------------------|---------|-------------------|---------|---------|---|---|---|--------|
| After reset: 00H | R/W     | Address: FFFF545H |         |         |   |   |   |        |
| TQ0OPT0          | 7       | 6                 | 5       | 4       | 3 | 2 | 1 | <0>    |
|                  | TQ0CCS3 | TQ0CCS2           | TQ0CCS1 | TQ0CCS0 | 0 | 0 | 0 | TQ0OVF |

|   |  |
|---|--|
| TQ0CCSm   | TQ0CCRm register capture/compare selection |
| 0   | Compare register selected                  |
| 1   | Capture register selected                  |
| The TQ0CCSm bit setting is valid only in the free-running timer mode. |  |

|   |   |
|---|---|
| TQ0OVF  | TMQ0 overflow detection                       |
| Set (1)   | Overflow occurred                             |
| Reset (0)   | TQ0OVF bit 0 written or TQ0CTL0.TQ0CE bit = 0 |
| <ul style="list-style-type: none"> <li>• The TQ0OVF bit is set when the 16-bit counter count value overflows from FFFFH to 0000H in the free-running timer mode or the pulse width measurement mode.</li> <li>• An interrupt request signal (INTTQ0OV) is generated at the same time that the TQ0OVF bit is set to 1. The INTTQ0OV signal is not generated in modes other than the free-running timer mode and the pulse width measurement mode.</li> <li>• The TQ0OVF bit is not cleared even when the TQ0OVF bit or the TQ0OPT0 register are read when the TQ0OVF bit = 1.</li> <li>• The TQ0OVF bit can be both read and written, but the TQ0OVF bit cannot be set to 1 by software. Writing 1 has no influence on the operation of TMQ0.</li> </ul> |   |

**Cautions**

1. Rewrite the TQ0CCS3 to TQ0CCS0 bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.
2. Be sure to clear bits 1 to 3 to "0".

**Remark** m = 0 to 3

**(7) TMQ0 capture/compare register 0 (TQ0CCR0)**

The TQ0CCR0 register can be used as a capture register or a compare register depending on the mode. This register can be used as a capture register or a compare register only in the free-running timer mode, depending on the setting of the TQ0OPT0.TQ0CCS0 bit. In the pulse width measurement mode, the TQ0CCR0 register can be used only as a capture register. In any other mode, this register can be used only as a compare register.

The TQ0CCR0 register can be read or written during operation.

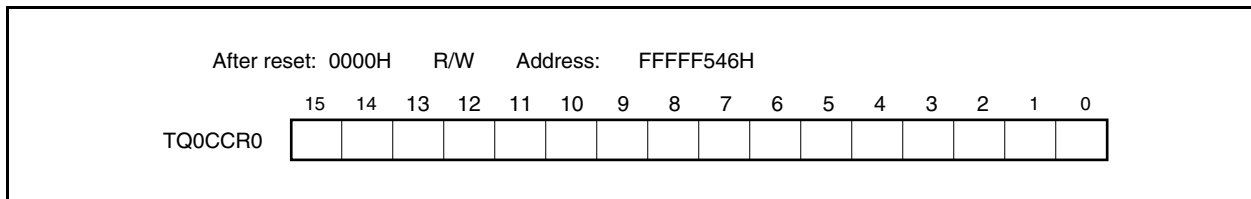
This register can be read or written in 16-bit units.

Reset sets this register to 0000H.

**Caution** Accessing the TQ0CCR0 register is prohibited in the following statuses. For details, see 3.4.8

**(2) Accessing specific on-chip peripheral I/O registers.**

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock



**(a) Function as compare register**

The TQ0CCR0 register can be rewritten even when the TQ0CTL0.TQ0CE bit = 1.

The set value of the TQ0CCR0 register is transferred to the CCR0 buffer register. When the value of the 16-bit counter matches the value of the CCR0 buffer register, a compare match interrupt request signal (INTTQ0CC0) is generated. If TOQ00 pin output is enabled at this time, the output of the TOQ00 pin is inverted.

When the TQ0CCR0 register is used as a cycle register in the interval timer mode, external event count mode, external trigger pulse output mode, one-shot pulse output mode, or PWM output mode, the value of the 16-bit counter is cleared (0000H) if its count value matches the value of the CCR0 buffer register.

**(b) Function as capture register**

When the TQ0CCR0 register is used as a capture register in the free-running timer mode, the count value of the 16-bit counter is stored in the TQ0CCR0 register if the valid edge of the capture trigger input pin (TIQ00 pin) is detected. In the pulse-width measurement mode, the count value of the 16-bit counter is stored in the TQ0CCR0 register and the 16-bit counter is cleared (0000H) if the valid edge of the capture trigger input pin (TIQ00 pin) is detected.

Even if the capture operation and reading the TQ0CCR0 register conflict, the correct value of the TQ0CCR0 register can be read.

The following table shows the functions of the capture/compare register in each mode, and how to write data to the compare register.

**Table 8-2. Function of Capture/Compare Register in Each Mode and How to Write Compare Register**

| Operation Mode                | Capture/Compare Register | How to Write Compare Register |
|-------------------------------|--------------------------|-------------------------------|
| Interval timer                | Compare register         | Anytime write                 |
| External event counter        | Compare register         | Anytime write                 |
| External trigger pulse output | Compare register         | Batch write                   |
| One-shot pulse output         | Compare register         | Anytime write                 |
| PWM output                    | Compare register         | Batch write                   |
| Free-running timer            | Capture/compare register | Anytime write                 |
| Pulse width measurement       | Capture register         | –                             |

**(8) TMQ0 capture/compare register 1 (TQ0CCR1)**

The TQ0CCR1 register can be used as a capture register or a compare register depending on the mode.

This register can be used as a capture register or a compare register only in the free-running timer mode, depending on the setting of the TQ0OPT0.TQ0CCS1 bit. In the pulse width measurement mode, the TQ0CCR1 register can be used only as a capture register. In any other mode, this register can be used only as a compare register.

The TQ0CCR1 register can be read or written during operation.

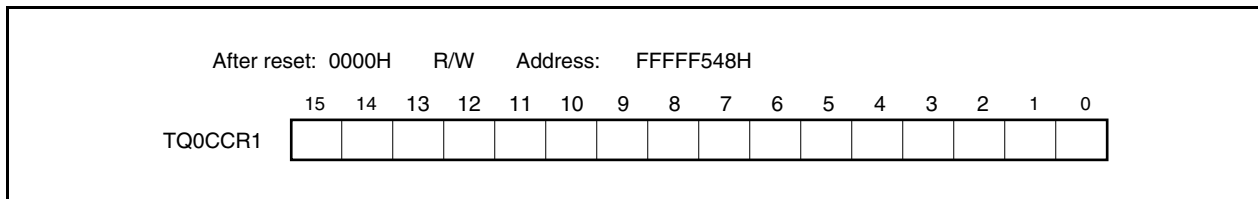
This register can be read or written in 16-bit units.

Reset sets this register to 0000H.

**Caution** Accessing the TQ0CCR1 register is prohibited in the following statuses. For details, see 3.4.8

(2) Accessing specific on-chip peripheral I/O registers.

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock



**(a) Function as compare register**

The TQ0CCR1 register can be rewritten even when the TQ0CTL0.TQ0CE bit = 1.

The set value of the TQ0CCR1 register is transferred to the CCR1 buffer register. When the value of the 16-bit counter matches the value of the CCR1 buffer register, a compare match interrupt request signal (INTTQ0CC1) is generated. If TOQ01 pin output is enabled at this time, the output of the TOQ01 pin is inverted.

**(b) Function as capture register**

When the TQ0CCR1 register is used as a capture register in the free-running timer mode, the count value of the 16-bit counter is stored in the TQ0CCR1 register if the valid edge of the capture trigger input pin (TIQ01 pin) is detected. In the pulse-width measurement mode, the count value of the 16-bit counter is stored in the TQ0CCR1 register and the 16-bit counter is cleared (0000H) if the valid edge of the capture trigger input pin (TIQ01 pin) is detected.

Even if the capture operation and reading the TQ0CCR1 register conflict, the correct value of the TQ0CCR1 register can be read.

The following table shows the functions of the capture/compare register in each mode, and how to write data to the compare register.

**Table 8-3. Function of Capture/Compare Register in Each Mode and How to Write Compare Register**

| Operation Mode                | Capture/Compare Register | How to Write Compare Register |
|-------------------------------|--------------------------|-------------------------------|
| Interval timer                | Compare register         | Anytime write                 |
| External event counter        | Compare register         | Anytime write                 |
| External trigger pulse output | Compare register         | Batch write                   |
| One-shot pulse output         | Compare register         | Anytime write                 |
| PWM output                    | Compare register         | Batch write                   |
| Free-running timer            | Capture/compare register | Anytime write                 |
| Pulse width measurement       | Capture register         | –                             |

**(9) TMQ0 capture/compare register 2 (TQ0CCR2)**

The TQ0CCR2 register can be used as a capture register or a compare register depending on the mode.

This register can be used as a capture register or a compare register only in the free-running timer mode, depending on the setting of the TQ0OPT0.TQ0CCS2 bit. In the pulse width measurement mode, the TQ0CCR2 register can be used only as a capture register. In any other mode, this register can be used only as a compare register.

The TQ0CCR2 register can be read or written during operation.

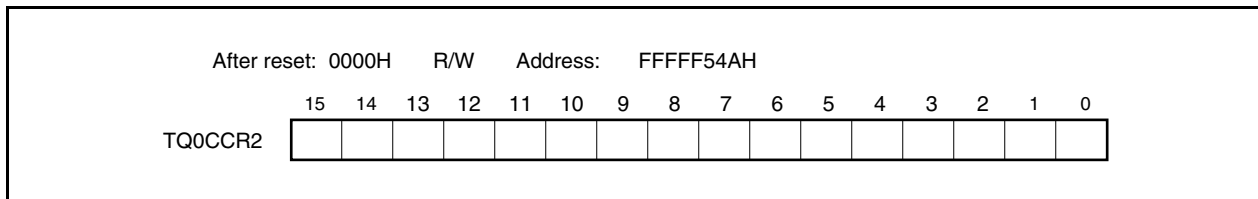
This register can be read or written in 16-bit units.

Reset sets this register to 0000H.

**Caution** Accessing the TQ0CCR2 register is prohibited in the following statuses. For details, see 3.4.8

(2) Accessing specific on-chip peripheral I/O registers.

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock



**(a) Function as compare register**

The TQ0CCR2 register can be rewritten even when the TQ0CTL0.TQ0CE bit = 1.

The set value of the TQ0CCR2 register is transferred to the CCR2 buffer register. When the value of the 16-bit counter matches the value of the CCR2 buffer register, a compare match interrupt request signal (INTTQ0CC2) is generated. If TOQ02 pin output is enabled at this time, the output of the TOQ02 pin is inverted.

**(b) Function as capture register**

When the TQ0CCR2 register is used as a capture register in the free-running timer mode, the count value of the 16-bit counter is stored in the TQ0CCR2 register if the valid edge of the capture trigger input pin (TIQ02 pin) is detected. In the pulse-width measurement mode, the count value of the 16-bit counter is stored in the TQ0CCR2 register and the 16-bit counter is cleared (0000H) if the valid edge of the capture trigger input pin (TIQ02 pin) is detected.

Even if the capture operation and reading the TQ0CCR2 register conflict, the correct value of the TQ0CCR2 register can be read.

The following table shows the functions of the capture/compare register in each mode, and how to write data to the compare register.

**Table 8-4. Function of Capture/Compare Register in Each Mode and How to Write Compare Register**

| Operation Mode                | Capture/Compare Register | How to Write Compare Register |
|-------------------------------|--------------------------|-------------------------------|
| Interval timer                | Compare register         | Anytime write                 |
| External event counter        | Compare register         | Anytime write                 |
| External trigger pulse output | Compare register         | Batch write                   |
| One-shot pulse output         | Compare register         | Anytime write                 |
| PWM output                    | Compare register         | Batch write                   |
| Free-running timer            | Capture/compare register | Anytime write                 |
| Pulse width measurement       | Capture register         | –                             |

**(10) TMQ0 capture/compare register 3 (TQ0CCR3)**

The TQ0CCR3 register can be used as a capture register or a compare register depending on the mode.

This register can be used as a capture register or a compare register only in the free-running timer mode, depending on the setting of the TQ0OPT0.TQ0CCS3 bit. In the pulse width measurement mode, the TQ0CCR3 register can be used only as a capture register. In any other mode, this register can be used only as a compare register.

The TQ0CCR3 register can be read or written during operation.

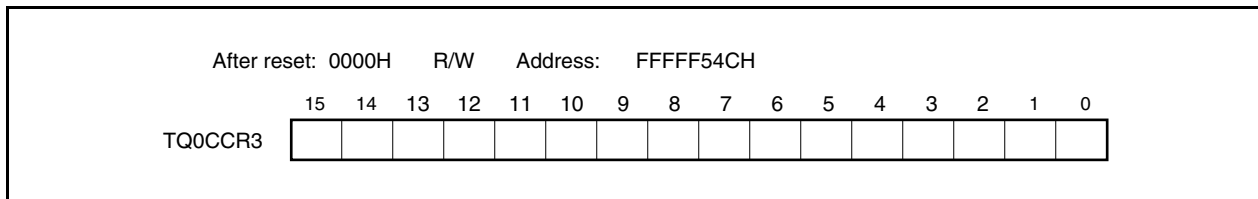
This register can be read or written in 16-bit units.

Reset sets this register to 0000H.

**Caution** Accessing the TQ0CCR3 register is prohibited in the following statuses. For details, see 3.4.8

(2) Accessing specific on-chip peripheral I/O registers.

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock





**(a) Function as compare register**

The TQ0CCR3 register can be rewritten even when the TQ0CTL0.TQ0CE bit = 1.

The set value of the TQ0CCR3 register is transferred to the CCR3 buffer register. When the value of the 16-bit counter matches the value of the CCR3 buffer register, a compare match interrupt request signal (INTTQ0CC3) is generated. If TOQ03 pin output is enabled at this time, the output of the TOQ03 pin is inverted.

**(b) Function as capture register**

When the TQ0CCR3 register is used as a capture register in the free-running timer mode, the count value of the 16-bit counter is stored in the TQ0CCR3 register if the valid edge of the capture trigger input pin (TIQ03 pin) is detected. In the pulse-width measurement mode, the count value of the 16-bit counter is stored in the TQ0CCR3 register and the 16-bit counter is cleared (0000H) if the valid edge of the capture trigger input pin (TIQ03 pin) is detected.

Even if the capture operation and reading the TQ0CCR3 register conflict, the correct value of the TQ0CCR3 register can be read.

The following table shows the functions of the capture/compare register in each mode, and how to write data to the compare register.

**Table 8-5. Function of Capture/Compare Register in Each Mode and How to Write Compare Register**

| Operation Mode                | Capture/Compare Register | How to Write Compare Register |
|-------------------------------|--------------------------|-------------------------------|
| Interval timer                | Compare register         | Anytime write                 |
| External event counter        | Compare register         | Anytime write                 |
| External trigger pulse output | Compare register         | Batch write                   |
| One-shot pulse output         | Compare register         | Anytime write                 |
| PWM output                    | Compare register         | Batch write                   |
| Free-running timer            | Capture/compare register | Anytime write                 |
| Pulse width measurement       | Capture register         | –                             |

**(11) TMQ0 counter read buffer register (TQ0CNT)**

The TQ0CNT register is a read buffer register that can read the count value of the 16-bit counter.

If this register is read when the TQ0CTL0.TQ0CE bit = 1, the count value of the 16-bit timer can be read.

This register is read-only, in 16-bit units.

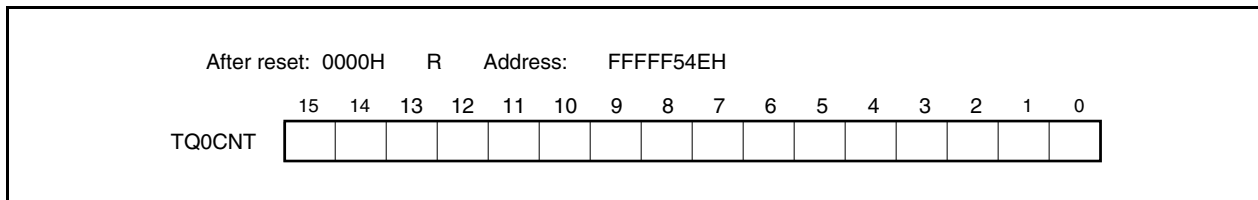
The value of the TQ0CNT register is cleared to 0000H when the TQ0CE bit = 0. If the TQ0CNT register is read at this time, the value of the 16-bit counter (FFFFH) is not read, but 0000H is read.

The value of the TQ0CNT register is cleared to 0000H after reset, as the TQ0CE bit is cleared to 0.

**Caution** Accessing the TQ0CNT register is prohibited in the following statuses. For details, see 3.4.8

**(2) Accessing specific on-chip peripheral I/O registers.**

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock



## 8.5 Operation

TMQ0 can perform the following operations.

| Operation  | TQ0CTL1.TQ0EST Bit<br>(Software Trigger Bit) | TIQ00 Pin<br>(External Trigger Input) | Capture/Compare<br>Register Setting | Compare Register<br>Write |
|--|--|---------------------------------------|-------------------------------------|---------------------------|
| Interval timer mode                                  | Invalid                                      | Invalid                               | Compare only                        | Anytime write             |
| External event count mode <sup>Note 1</sup>          | Invalid                                      | Invalid                               | Compare only                        | Anytime write             |
| External trigger pulse output mode <sup>Note 2</sup> | Valid  | Valid                                 | Compare only                        | Batch write               |
| One-shot pulse output mode <sup>Note 2</sup>         | Valid  | Valid                                 | Compare only                        | Anytime write             |
| PWM output mode                                      | Invalid                                      | Invalid                               | Compare only                        | Batch write               |
| Free-running timer mode                              | Invalid                                      | Invalid                               | Switching enabled                   | Anytime write             |
| Pulse width measurement mode <sup>Note 2</sup>       | Invalid                                      | Invalid                               | Capture only                        | Not applicable            |

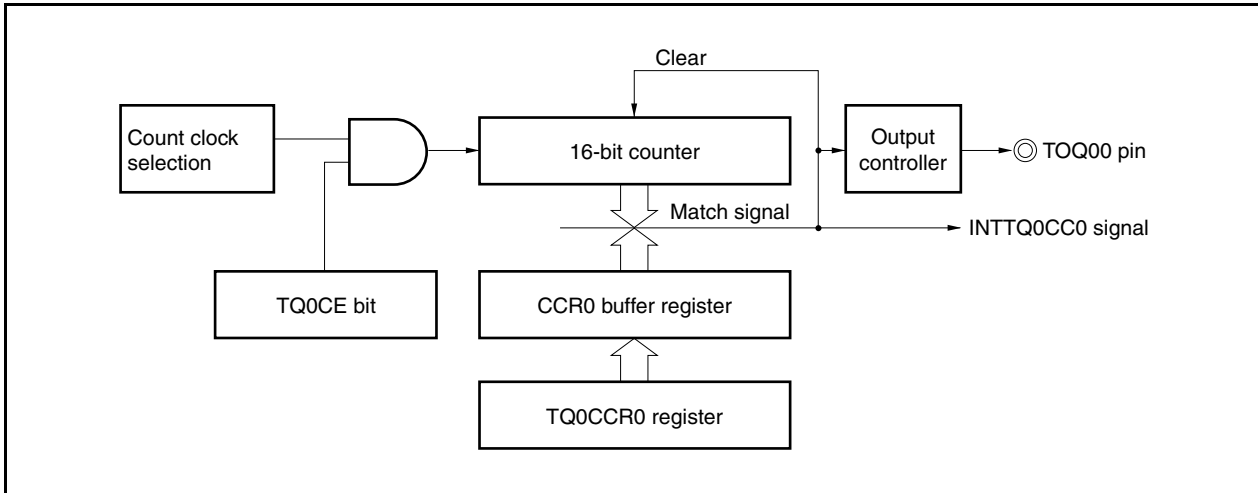
- Notes 1.** To use the external event count mode, specify that the valid edge of the TIQ00 pin capture trigger input is not detected (by clearing the TQ0IOC1.TQ0IS1 and TQ0IOC1.TQ0IS0 bits to "00").
- 2.** When using the external trigger pulse output mode, one-shot pulse output mode, and pulse width measurement mode, select the internal clock as the count clock (by clearing the TQ0CTL1.TQ0EEE bit to 0).

**8.5.1 Interval timer mode (TQ0MD2 to TQ0MD0 bits = 000)**

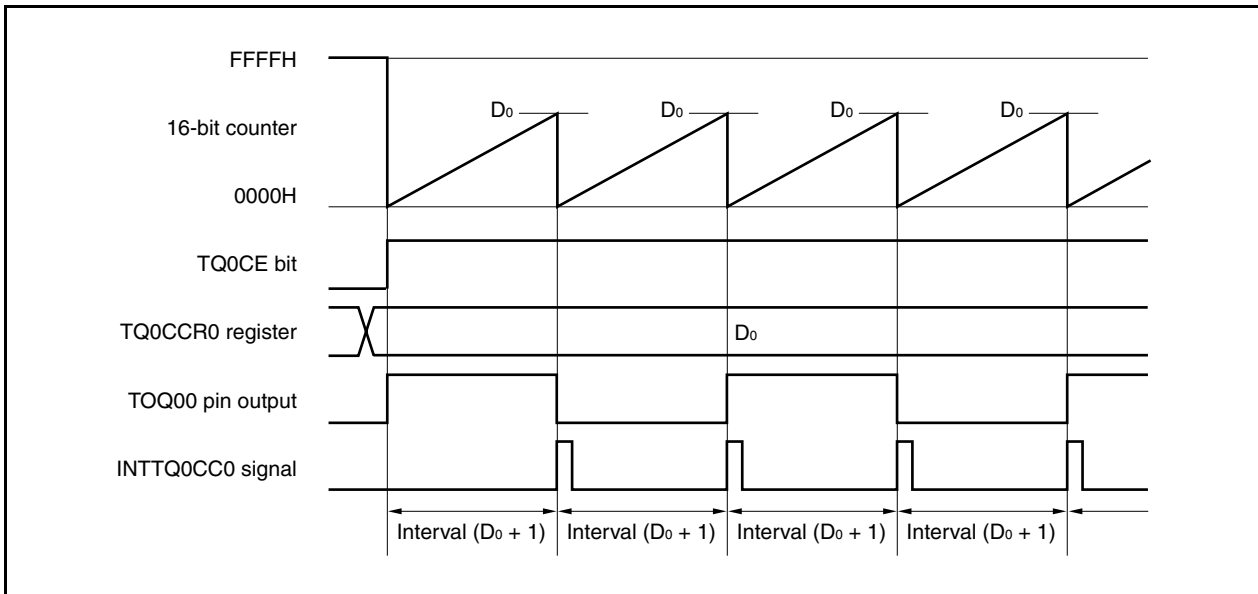
In the interval timer mode, an interrupt request signal (INTTQ0CC0) is generated at the specified interval if the TQ0CTL0.TQ0CE bit is set to 1. A square wave whose half cycle is equal to the interval can be output from the TOQ00 pin.

Usually, the TQ0CCR1 to TQ0CCR3 registers are not used in the interval timer mode.

**Figure 8-2. Configuration of Interval Timer**



**Figure 8-3. Basic Timing of Operation in Interval Timer Mode**



When the TQ0CE bit is set to 1, the value of the 16-bit counter is cleared from FFFFH to 0000H in synchronization with the count clock, and the counter starts counting. At this time, the output of the TOQ00 pin is inverted. Additionally, the set value of the TQ0CCR0 register is transferred to the CCR0 buffer register.

When the count value of the 16-bit counter matches the value of the CCR0 buffer register, the 16-bit counter is cleared to 0000H, the output of the TOQ00 pin is inverted, and a compare match interrupt request signal (INTTQ0CC0) is generated.

The interval can be calculated by the following expression.

$$\text{Interval} = (\text{Set value of TQ0CCR0 register} + 1) \times \text{Count clock cycle}$$

Figure 8-4. Register Setting for Interval Timer Mode Operation (1/2)

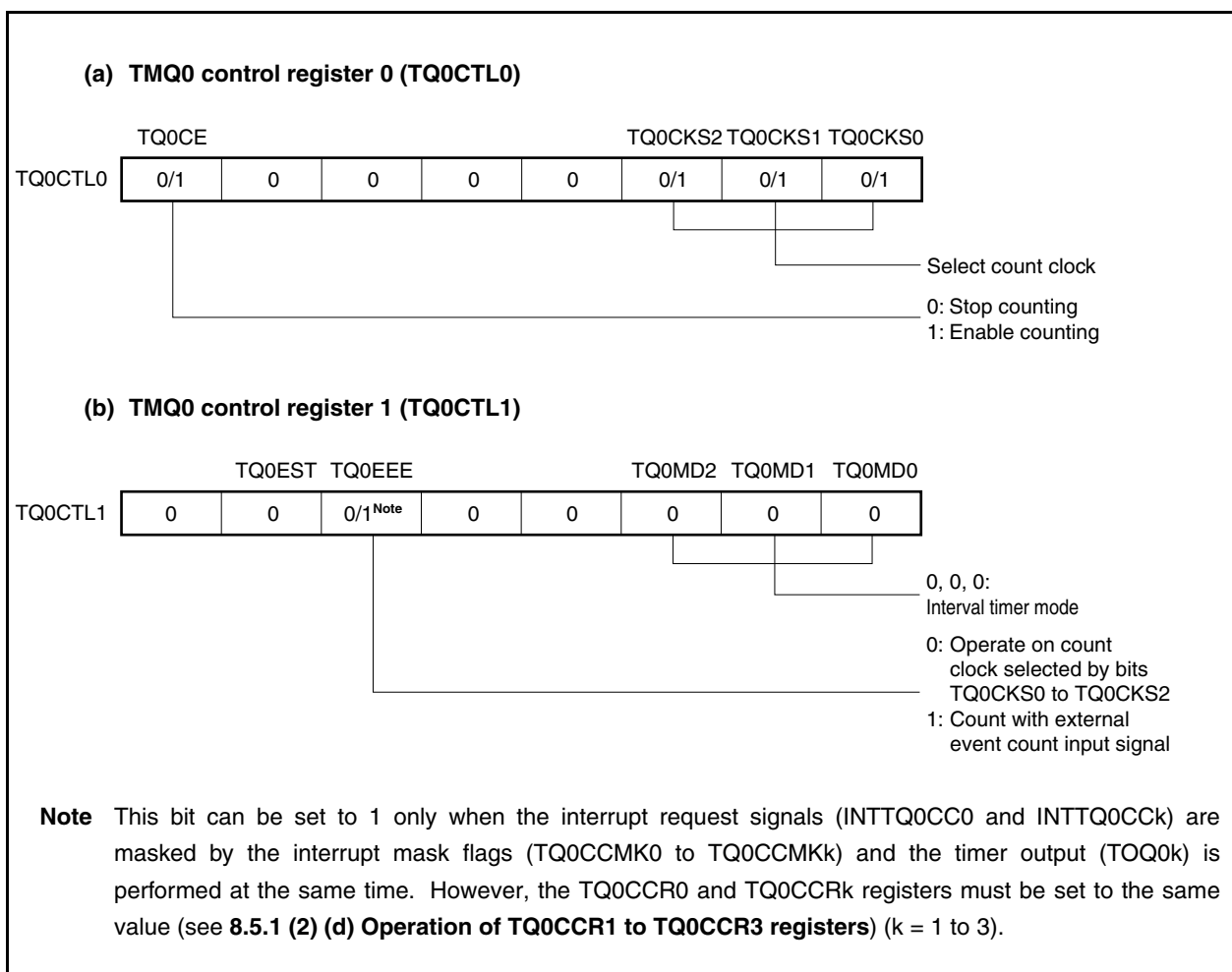
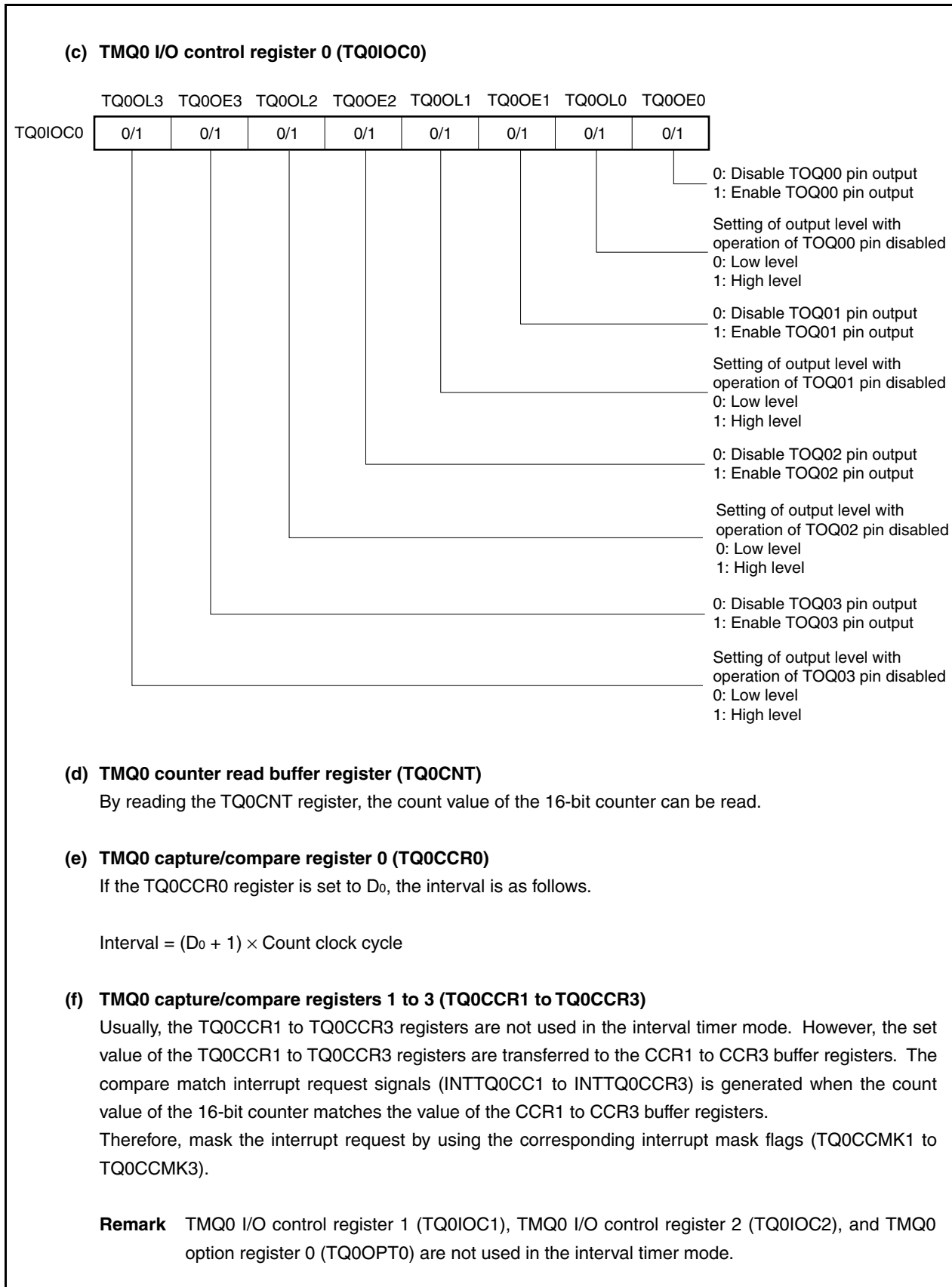
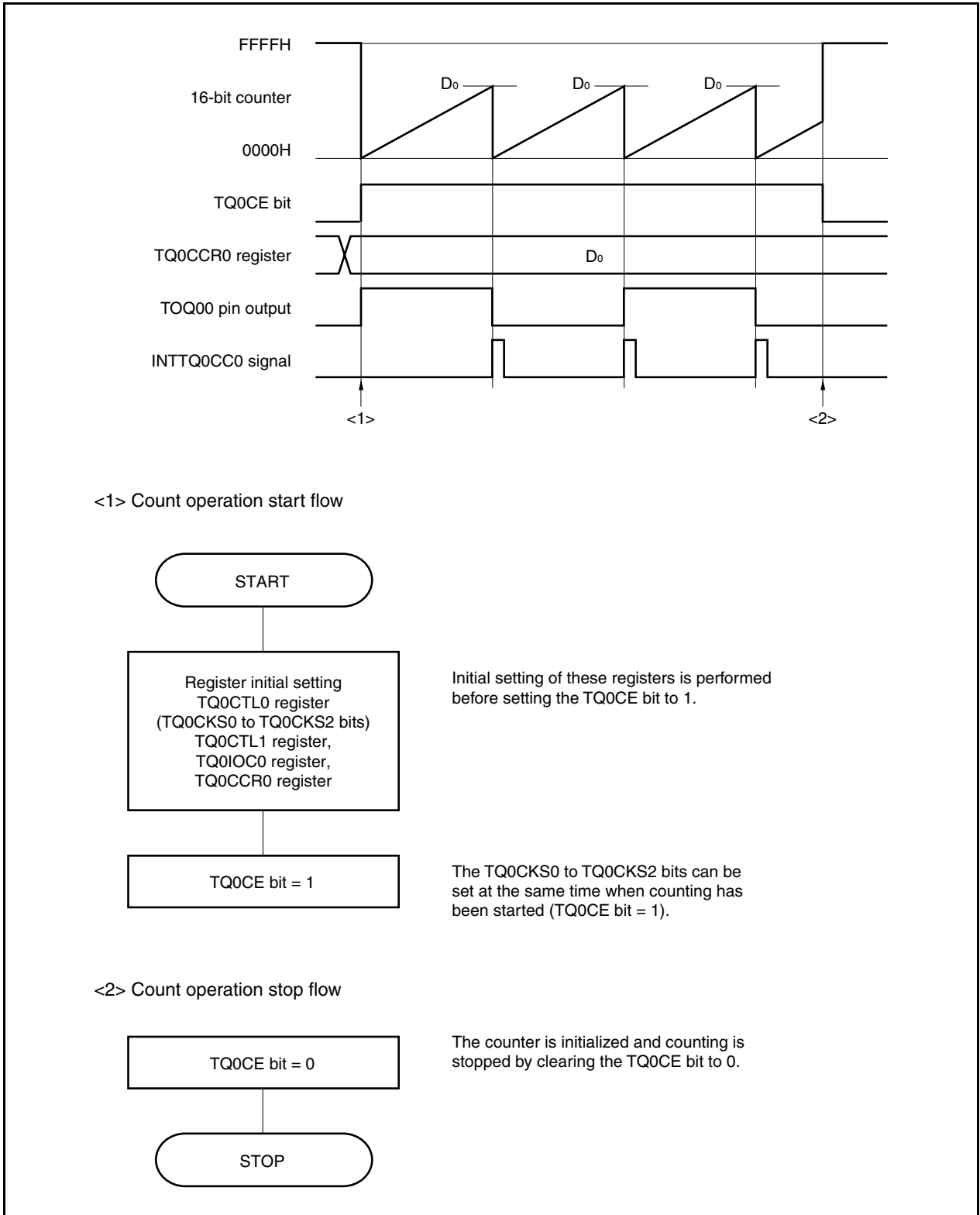


Figure 8-4. Register Setting for Interval Timer Mode Operation (2/2)



(1) Interval timer mode operation flow

Figure 8-5. Software Processing Flow in Interval Timer Mode

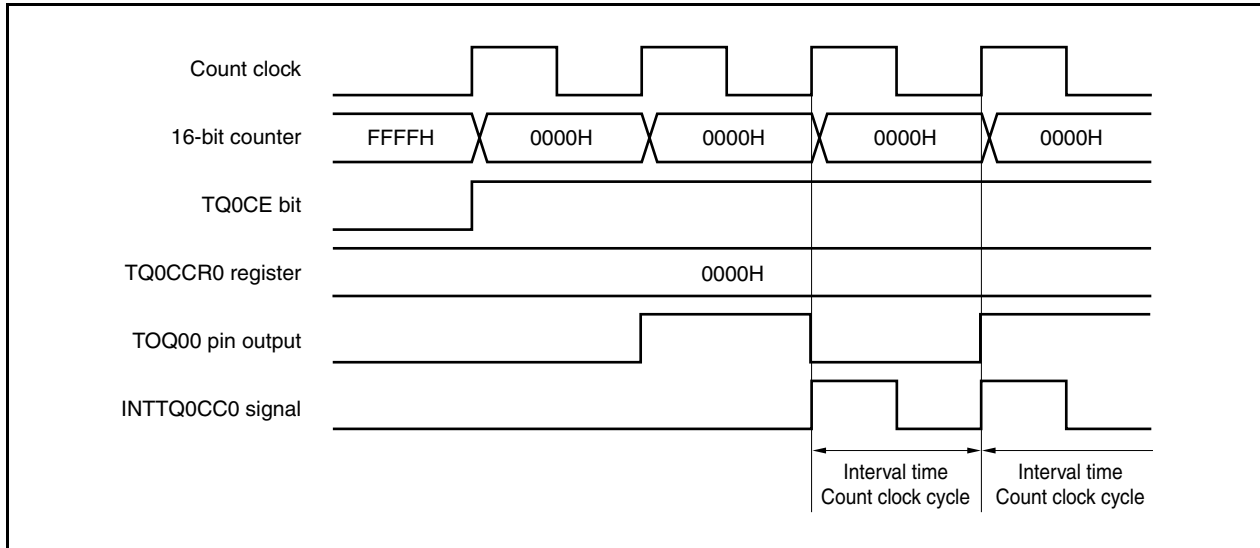


(2) Interval timer mode operation timing

(a) Operation if TQ0CCR0 register is set to 0000H

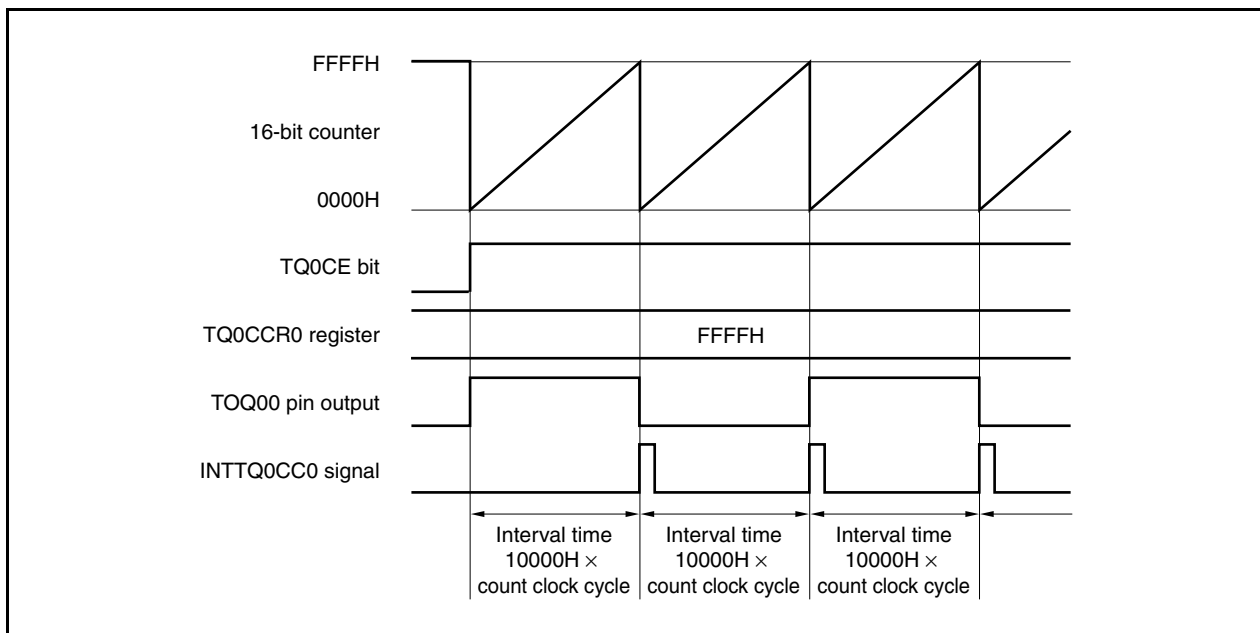
If the TQ0CCR0 register is set to 0000H, the INTTQ0CC0 signal is generated at each count clock subsequent to the first count clock, and the output of the TOQ00 pin is inverted.

The value of the 16-bit counter is always 0000H.



(b) Operation if TQ0CCR0 register is set to FFFFH

If the TQ0CCR0 register is set to FFFFH, the 16-bit counter counts up to FFFFH. The counter is cleared to 0000H in synchronization with the next count-up timing. The INTTQ0CC0 signal is generated and the output of the TOQ00 pin is inverted. At this time, an overflow interrupt request signal (INTTQ0OV) is not generated, nor is the overflow flag (TQ0OPT0.TQ0OVF bit) set to 1.

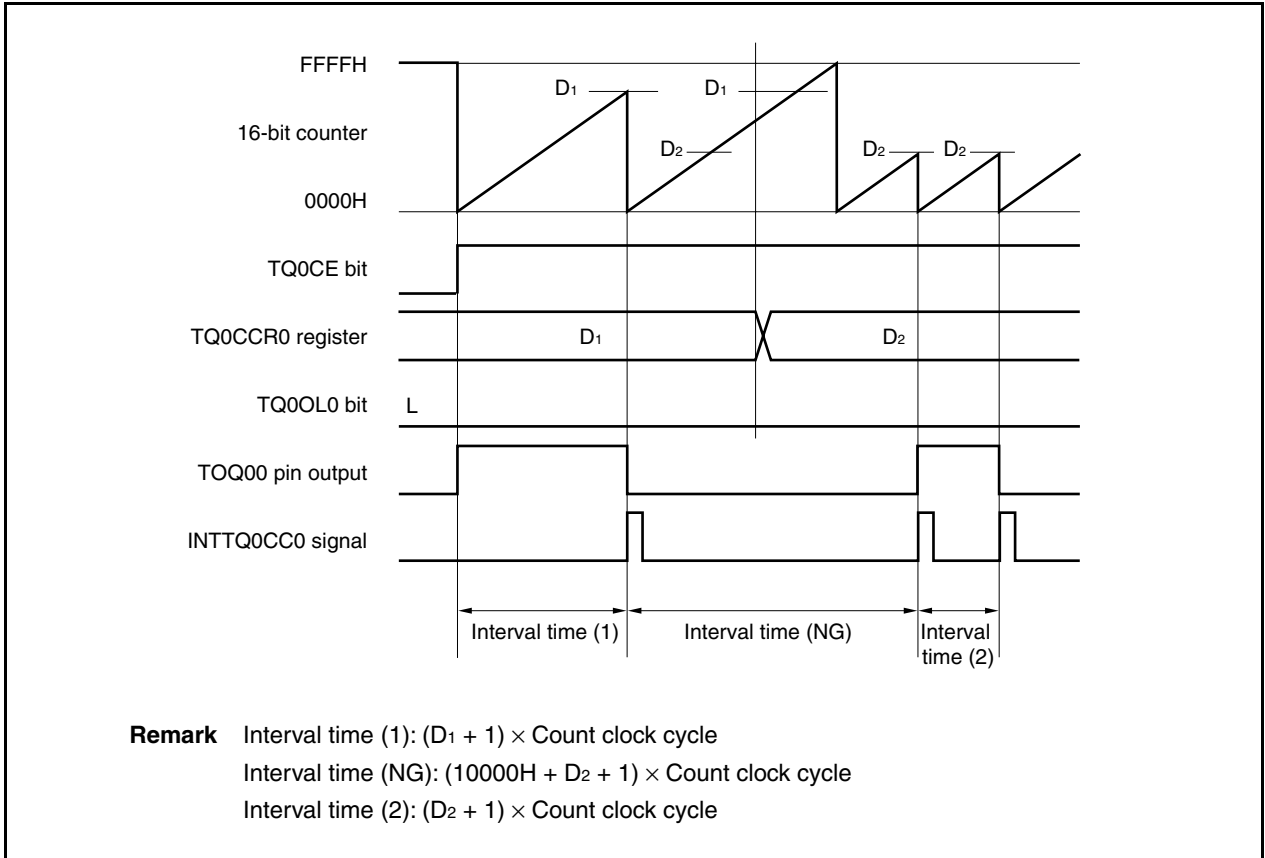




**(c) Notes on rewriting TQ0CCR0 register**

To change the value of the TQ0CCR0 register to a smaller value, stop counting once and then change the set value.

If the value of the TQ0CCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.



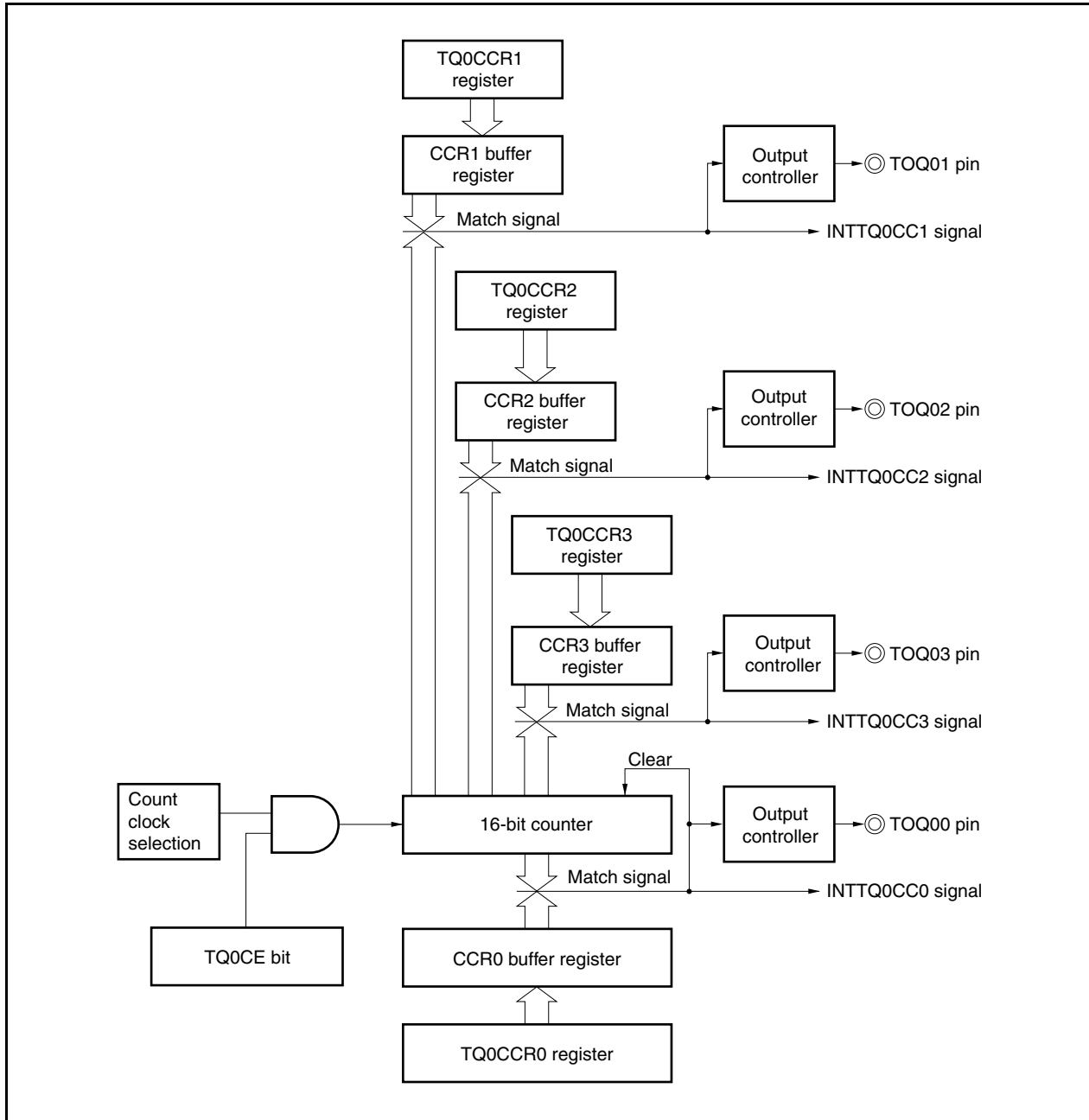
If the value of the TQ0CCR0 register is changed from D<sub>1</sub> to D<sub>2</sub> while the count value is greater than D<sub>2</sub> but less than D<sub>1</sub>, the count value is transferred to the CCR0 buffer register as soon as the TQ0CCR0 register has been rewritten. Consequently, the value of the 16-bit counter that is compared is D<sub>2</sub>.

Because the count value has already exceeded D<sub>2</sub>, however, the 16-bit counter counts up to FFFFH, overflows, and then counts up again from 0000H. When the count value matches D<sub>2</sub>, the INTTQ0CC0 signal is generated and the output of the TOQ00 pin is inverted.

Therefore, the INTTQ0CC0 signal may not be generated at the interval time " $(D_1 + 1) \times \text{Count clock cycle}$ " or " $(D_2 + 1) \times \text{Count clock cycle}$ " originally expected, but may be generated at an interval of " $(10000H + D_2 + 1) \times \text{Count clock period}$ ".

(d) Operation of TQ0CCR1 to TQ0CCR3 registers

Figure 8-6. Configuration of TQ0CCR1 to TQ0CCR3 Registers

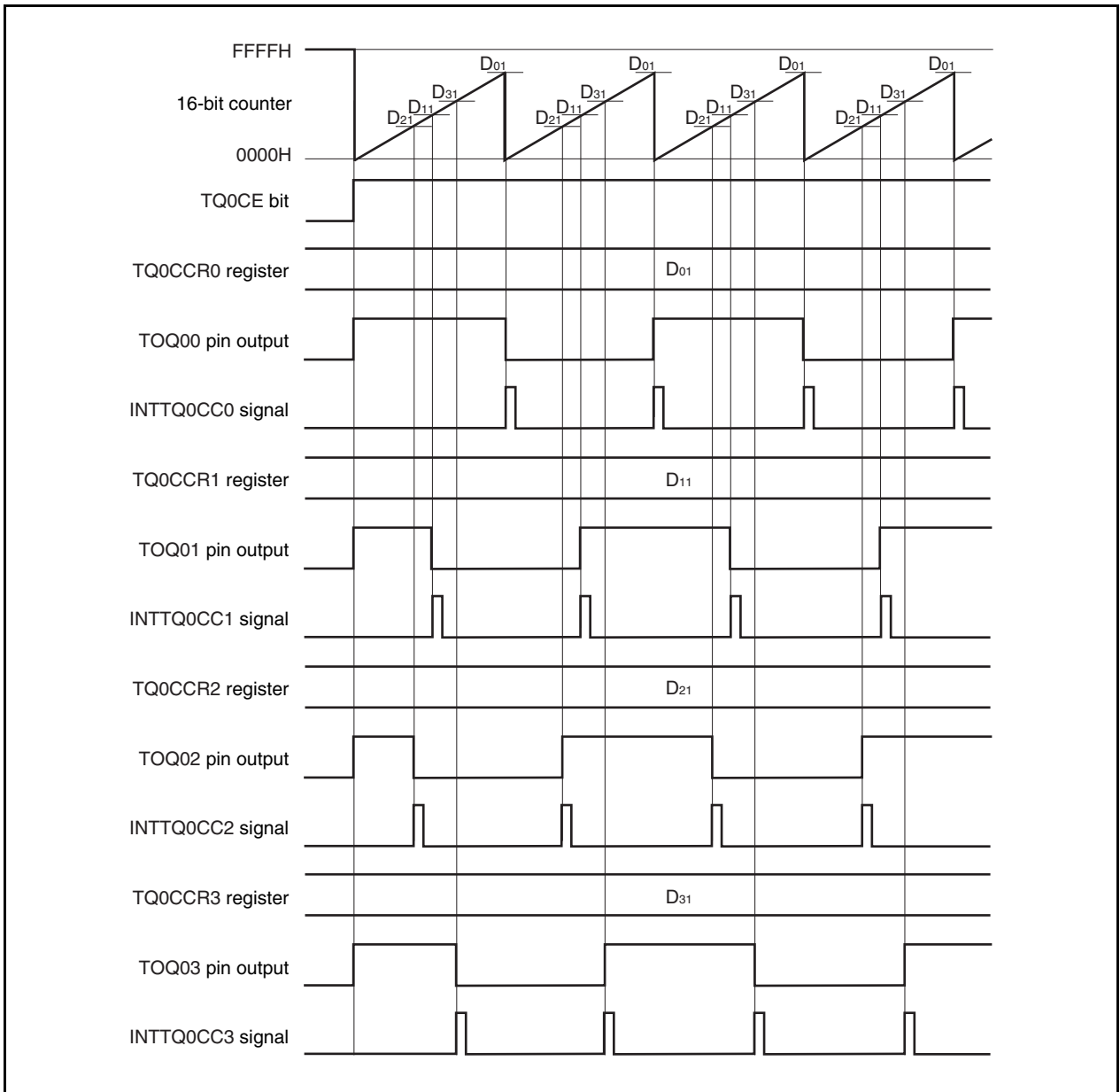


If the set value of the TQ0CCRk register is less than the set value of the TQ0CCR0 register, the INTTQ0CCk signal is generated once per cycle. At the same time, the output of the TOPQ0k pin is inverted.

The TOQ0k pin outputs a square wave with the same cycle as that output by the TOQ00 pin.

**Remark** k = 1 to 3

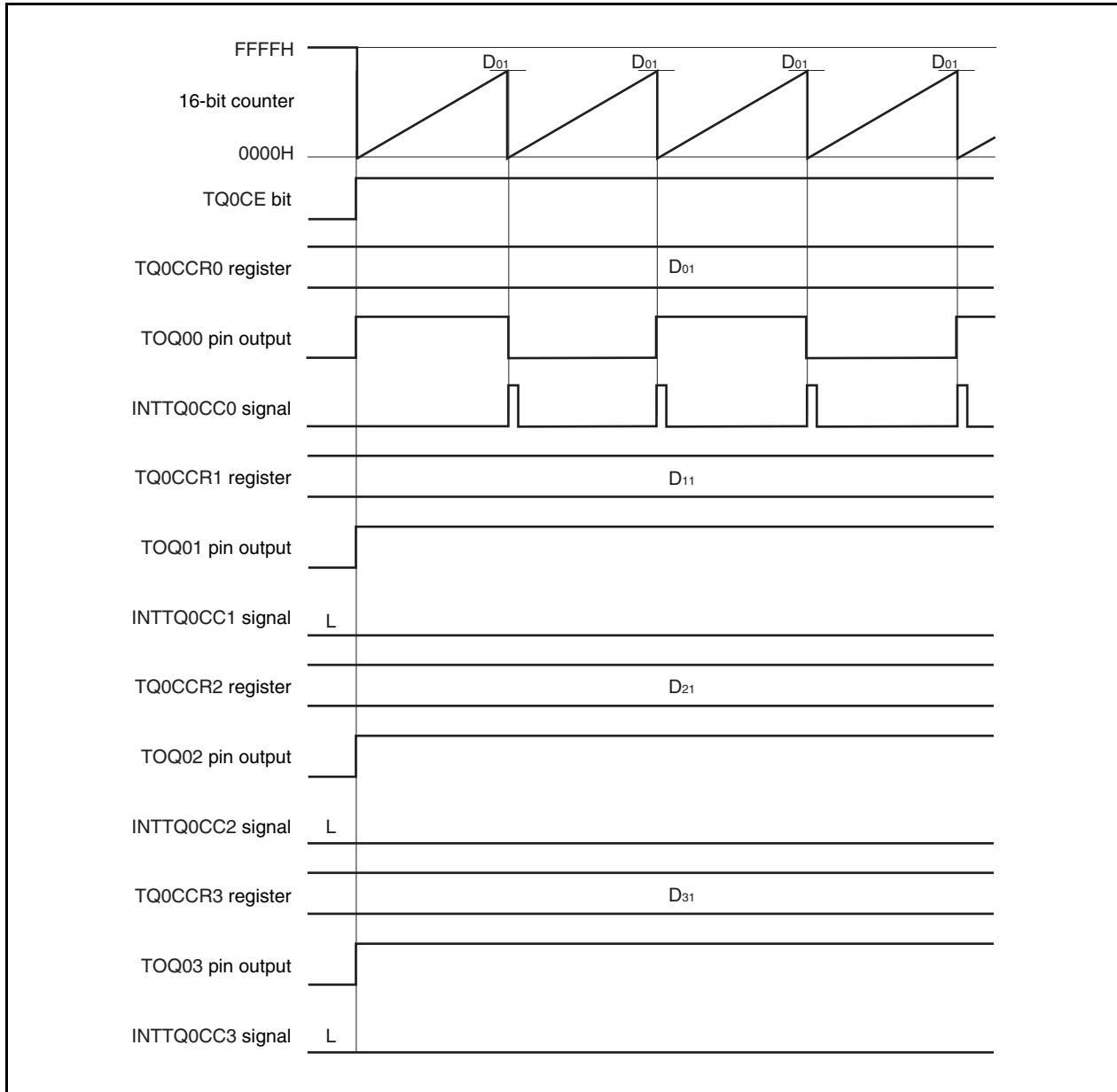
**Figure 8-7. Timing Chart When  $D_{01} \geq D_{k1}$**



If the set value of the TQ0CCRk register is greater than the set value of the TQ0CCR0 register, the count value of the 16-bit counter does not match the value of the TQ0CCRk register. Consequently, the INTTQ0CCk signal is not generated, nor is the output of the TOQ0k pin changed.

**Remark** k = 1 to 3

**Figure 8-8. Timing Chart When  $D_{01} < D_{k1}$**

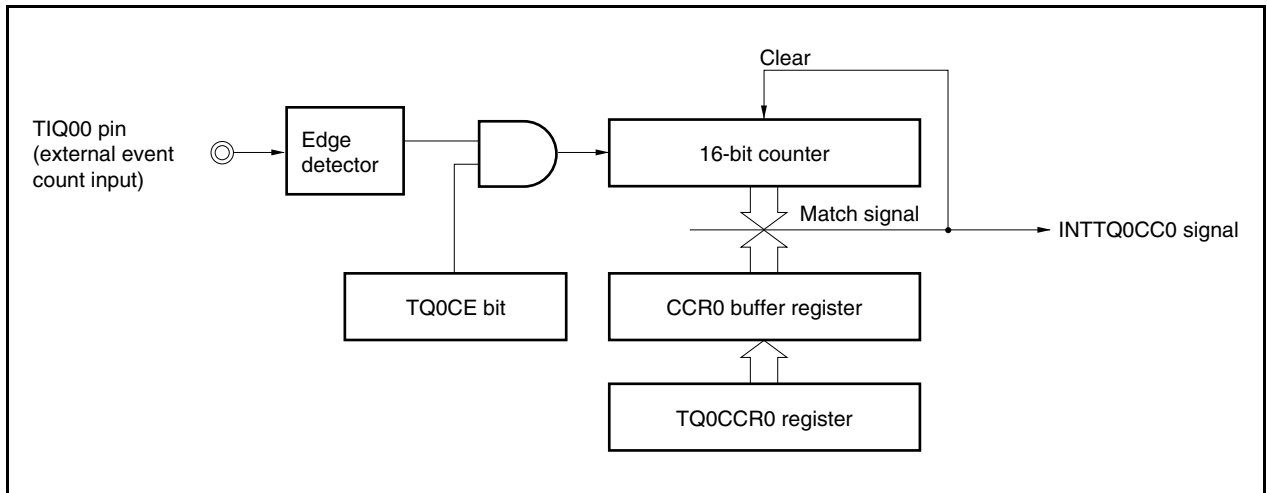


**8.5.2 External event count mode (TQ0MD2 to TQ0MD0 bits = 001)**

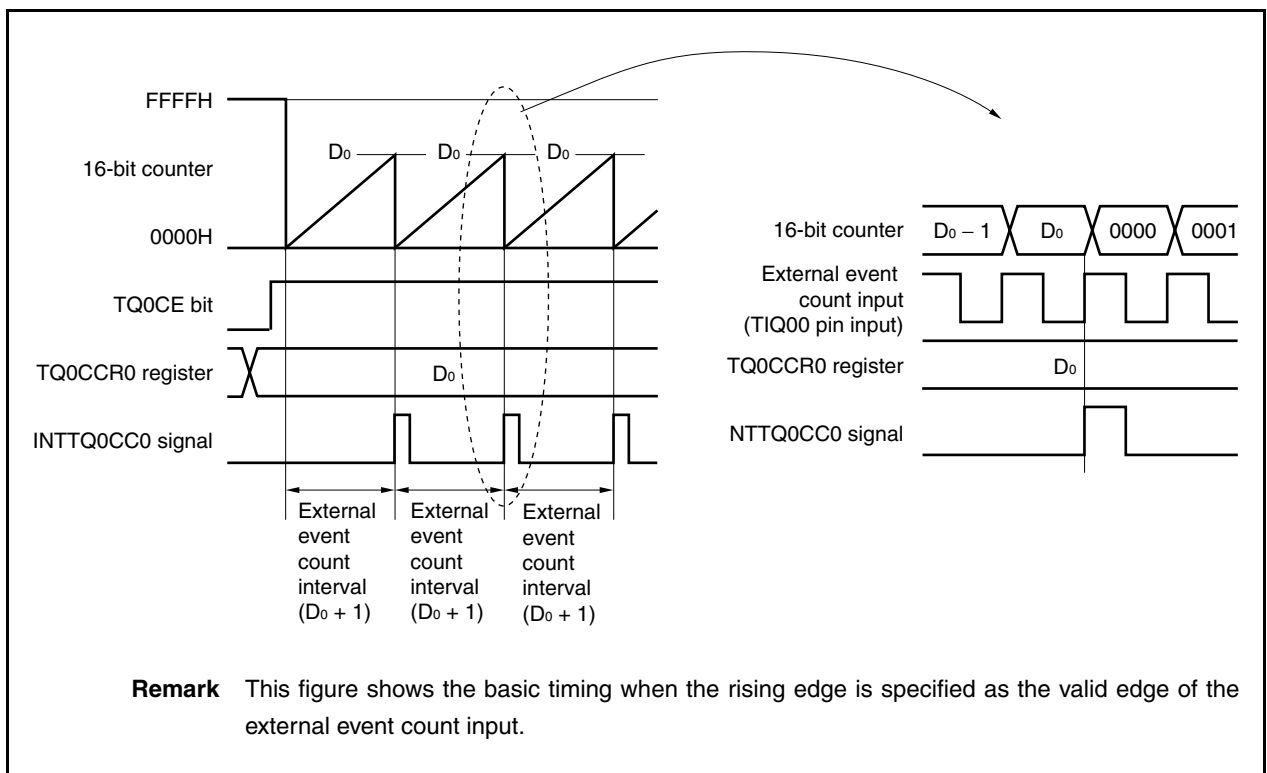
In the external event count mode, the valid edge of the external event count input is counted when the TQ0CTL0.TQ0CE bit is set to 1, and an interrupt request signal (INTTQ0CC0) is generated each time the specified number of edges have been counted. The TQ0Q0 pin cannot be used.

Usually, the TQ0CCR1 to TQ0CCR3 registers are not used in the external event count mode.

**Figure 8-9. Configuration in External Event Count Mode**



**Figure 8-10. Basic Timing in External Event Count Mode**



When the TQ0CE bit is set to 1, the value of the 16-bit counter is cleared from FFFFH to 0000H. The counter counts each time the valid edge of external event count input is detected. Additionally, the set value of the TQ0CCR0 register is transferred to the CCR0 buffer register.

When the count value of the 16-bit counter matches the value of the CCR0 buffer register, the 16-bit counter is cleared to 0000H, and a compare match interrupt request signal (INTTQ0CC0) is generated.

The INTTQ0CC0 signal is generated each time the valid edge of the external event count input has been detected (set value of TQ0CCR0 register + 1) times.

**Figure 8-11. Register Setting for Operation in External Event Count Mode (1/2)**

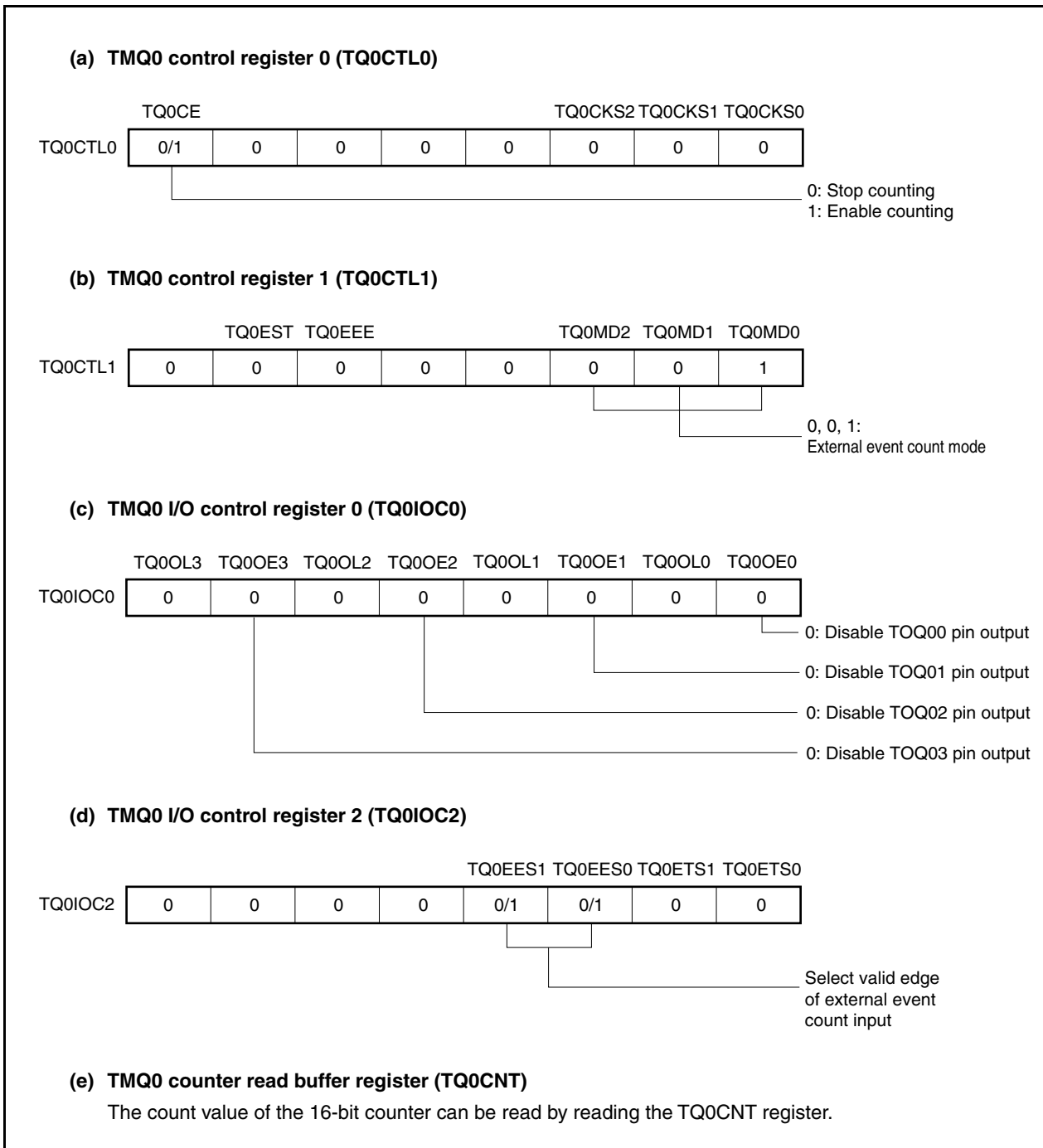


Figure 8-11. Register Setting for Operation in External Event Count Mode (2/2)

**(f) TMQ0 capture/compare register 0 (TQ0CCR0)**

If  $D_0$  is set to the TQ0CCR0 register, the counter is cleared and a compare match interrupt request signal (INTTQ0CC0) is generated when the number of external event counts reaches ( $D_0 + 1$ ).

**(g) TMQ0 capture/compare registers 1 to 3 (TQ0CCR1 to TQ0CCR3)**

Usually, the TQ0CCR1 to TQ0CCR3 registers are not used in the external event count mode. However, the set value of the TQ0CCR1 to TQ0CCR3 registers are transferred to the CCR1 to CCR3 buffer registers. When the count value of the 16-bit counter matches the value of the CCR1 to CCR3 buffer registers, compare match interrupt request signals (INTTQ0CC1 to INTTQ0CC3) are generated.

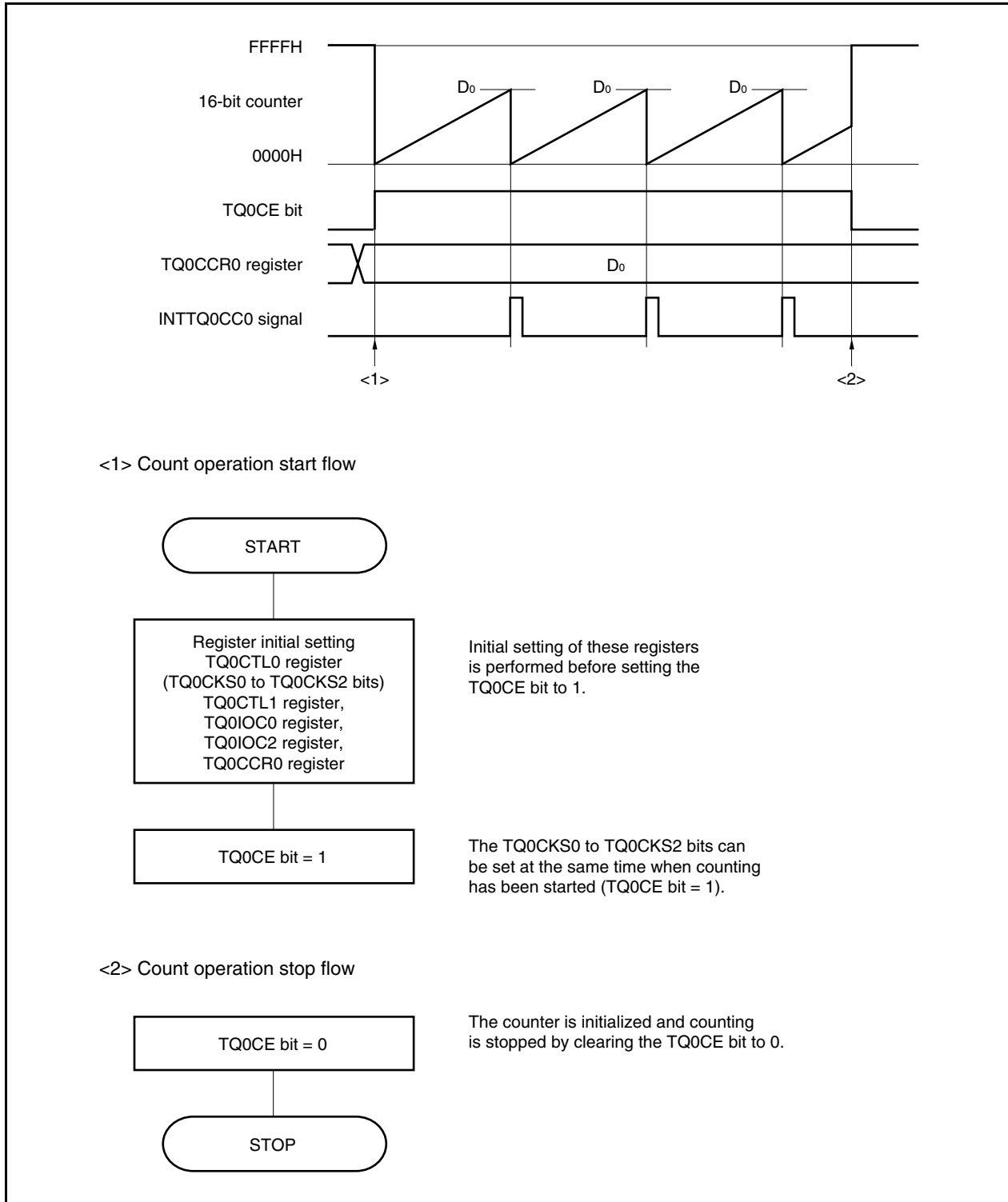
Therefore, mask the interrupt signal by using the interrupt mask flags (TQ0CCMK1 to TQ0CCMK3).

**Caution** When an external clock is used as the count clock, the external clock can be input only from the TIQ00 pin. At this time, set the TQ0IOC1.TQ0IS1 and TQ0IOC1.TQ0IS0 bits to 00 (capture trigger input (TIQ00 pin): no edge detection).

**Remark** The TMQ0 I/O control register 1 (TQ0IOC1) and TMQ0 option register 0 (TQ0OPT0) are not used in the external event count mode.

(1) External event count mode operation flow

Figure 8-12. Flow of Software Processing in External Event Count Mode





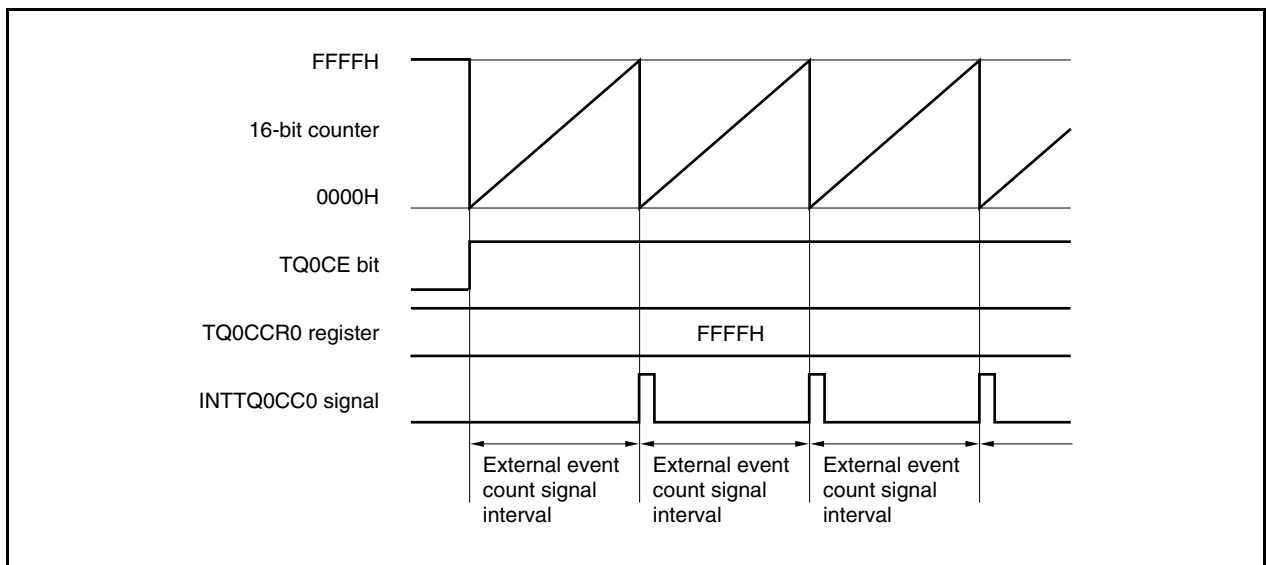
## (2) Operation timing in external event count mode

**Cautions** 1. In the external event count mode, do not set the TQ0CCR0 register to 0000H.

2. In the external event count mode, use of the timer output is disabled. If performing timer output using external event count input, set the interval timer mode, and select the operation enabled by the external event count input for the count clock (TQ0CTL1.TQ0MD2 to TQ0CTL1.TQ0MD0 bits = 000, TQ0CTL1.TQ0EEE bit = 1).

## (a) Operation if TQ0CCR0 register is set to FFFFH

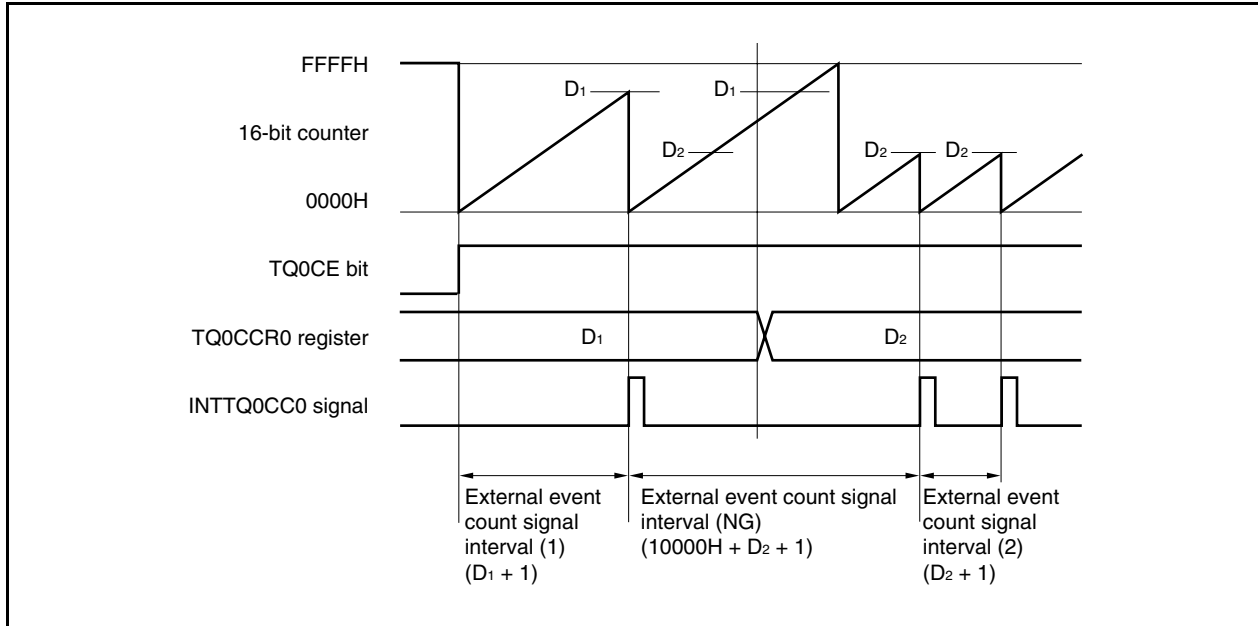
If the TQ0CCR0 register is set to FFFFH, the 16-bit counter counts to FFFFH each time the valid edge of the external event count signal has been detected. The 16-bit counter is cleared to 0000H in synchronization with the next count-up timing, and the INTTQ0CC0 signal is generated. At this time, the TQ0OPT0.TQ0OVF bit is not set.



**(b) Notes on rewriting the TQ0CCR0 register**

To change the value of the TQ0CCR0 register to a smaller value, stop counting once and then change the set value.

If the value of the TQ0CCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.



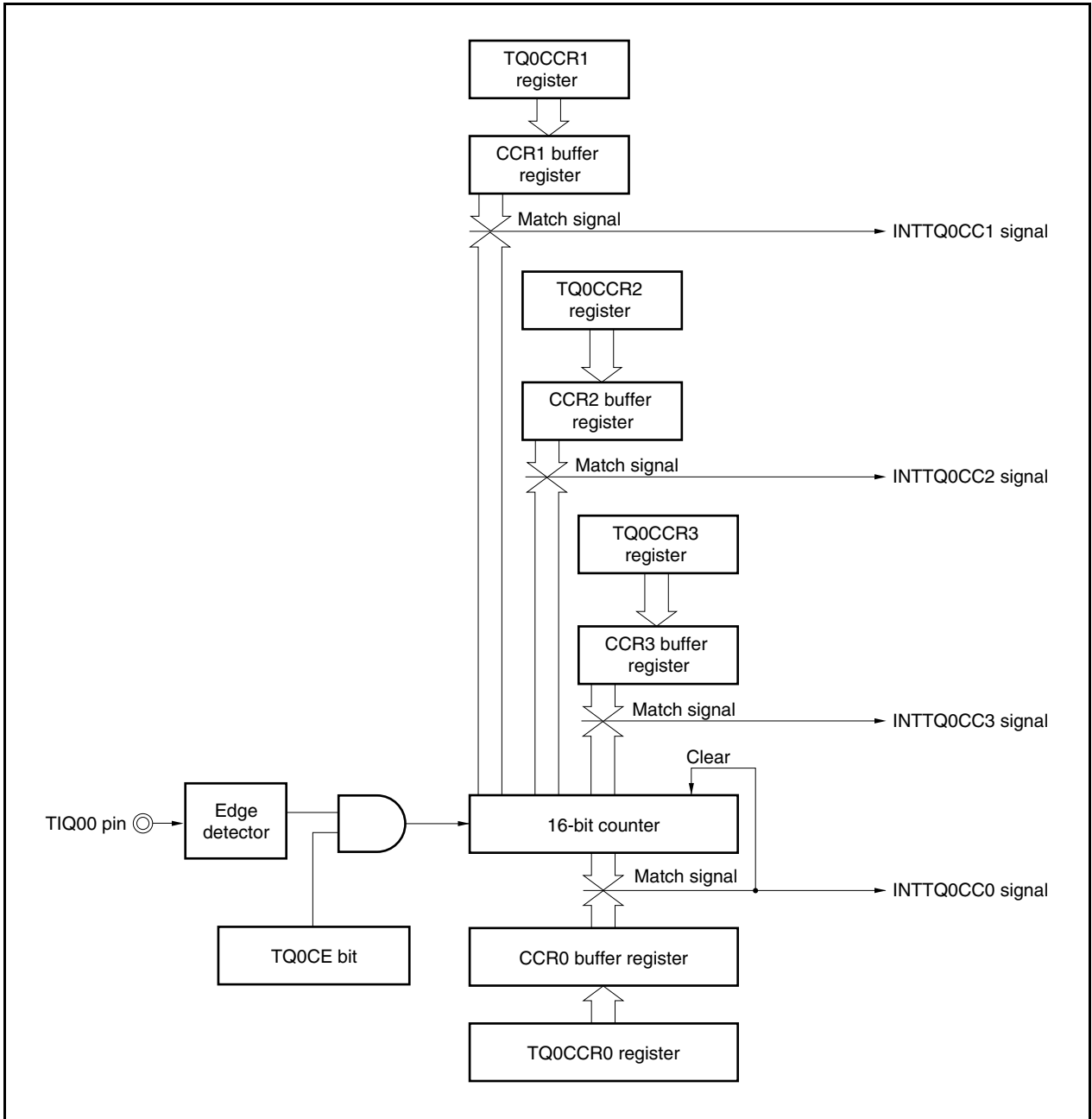
If the value of the TQ0CCR0 register is changed from  $D_1$  to  $D_2$  while the count value is greater than  $D_2$  but less than  $D_1$ , the count value is transferred to the CCR0 buffer register as soon as the TQ0CCR0 register has been rewritten. Consequently, the value that is compared with the 16-bit counter is  $D_2$ .

Because the count value has already exceeded  $D_2$ , however, the 16-bit counter counts up to FFFFH, overflows, and then counts up again from 0000H. When the count value matches  $D_2$ , the INTTQ0CC0 signal is generated.

Therefore, the INTTQ0CC0 signal may not be generated at the valid edge count of " $(D_1 + 1)$  times" or " $(D_2 + 1)$  times" originally expected, but may be generated at the valid edge count of " $(10000H + D_2 + 1)$  times".

(c) Operation of TQ0CCR1 to TQ0CCR3 registers

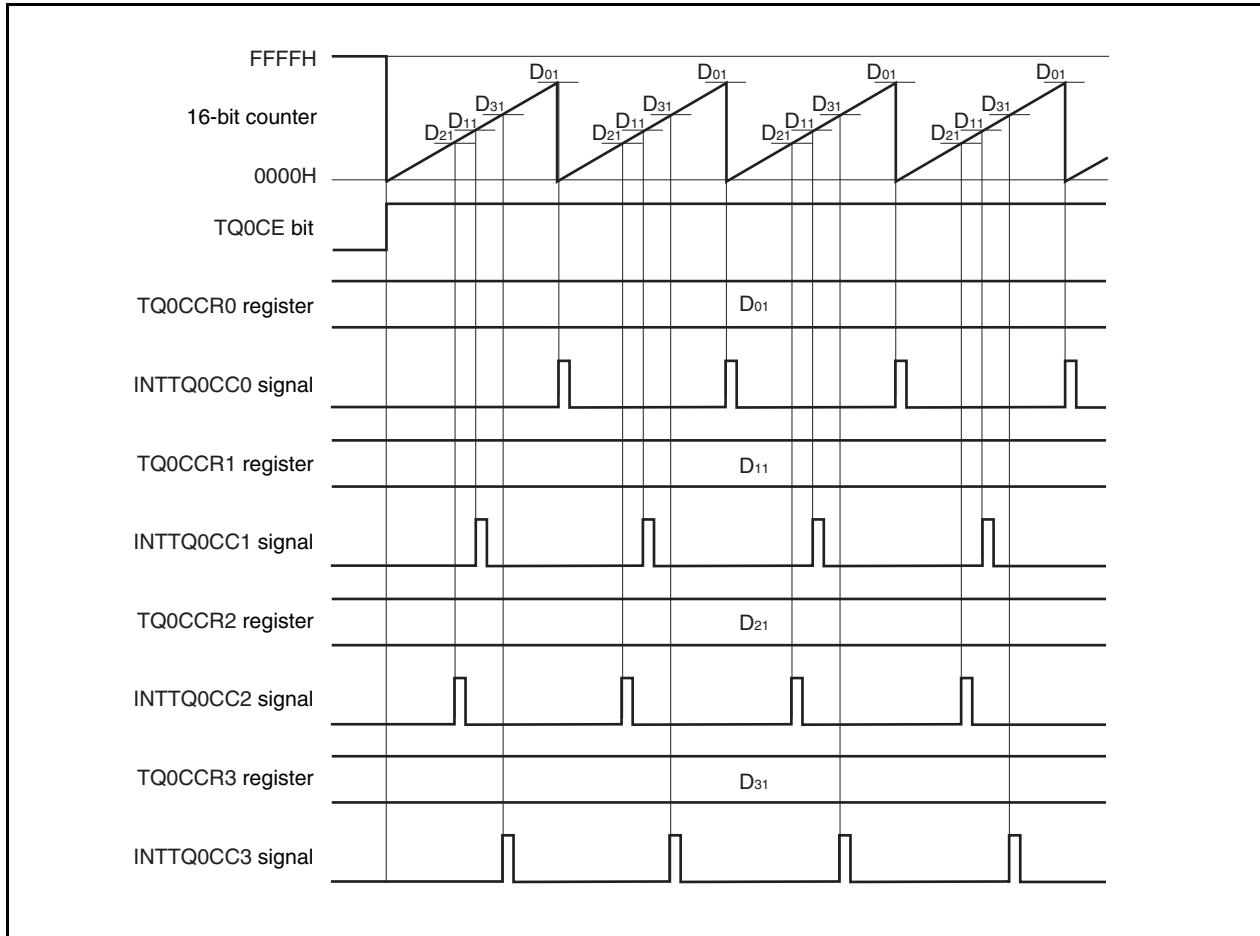
Figure 8-13. Configuration of TQ0CCR1 to TQ0CCR3 Registers



If the set value of the TQ0CCRk register is smaller than the set value of the TQ0CCR0 register, the INTTQ0CCk signal is generated once per cycle.

**Remark** k = 1 to 3

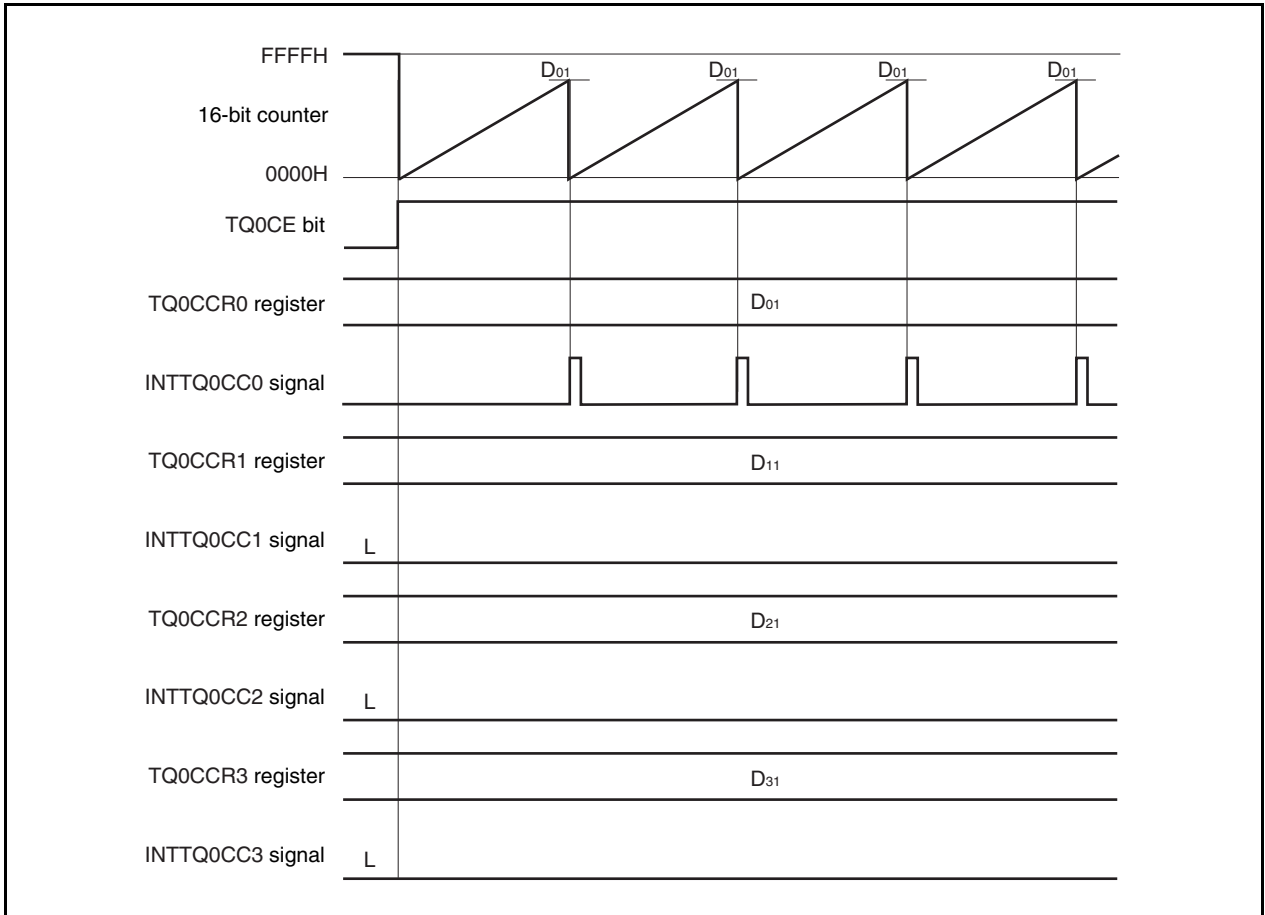
**Figure 8-14. Timing Chart When  $D_{01} \geq D_{k1}$**



If the set value of the TQ0CCRk register is greater than the set value of the TQ0CCR0 register, the INTTQ0CCk signal is not generated because the count value of the 16-bit counter and the value of the TQ0CCRk register do not match.

**Remark** k = 1 to 3

**Figure 8-15. Timing Chart When  $D_{01} < D_{k1}$**



**8.5.3 External trigger pulse output mode (TQ0MD2 to TQ0MD0 bits = 010)**

In the external trigger pulse output mode, 16-bit timer/event counter Q waits for a trigger when the TQ0CTL0.TQ0CE bit is set to 1. When the valid edge of an external trigger input signal is detected, 16-bit timer/event counter Q starts counting, and outputs a PWM waveform from the TOQ01 to TOQ03 pins.

Pulses can also be output by generating a software trigger instead of using the external trigger. When using a software trigger, a square wave that has one cycle of the PWM waveform as half its cycle can also be output from the TOQ00 pin.

**Figure 8-16. Configuration in External Trigger Pulse Output Mode**

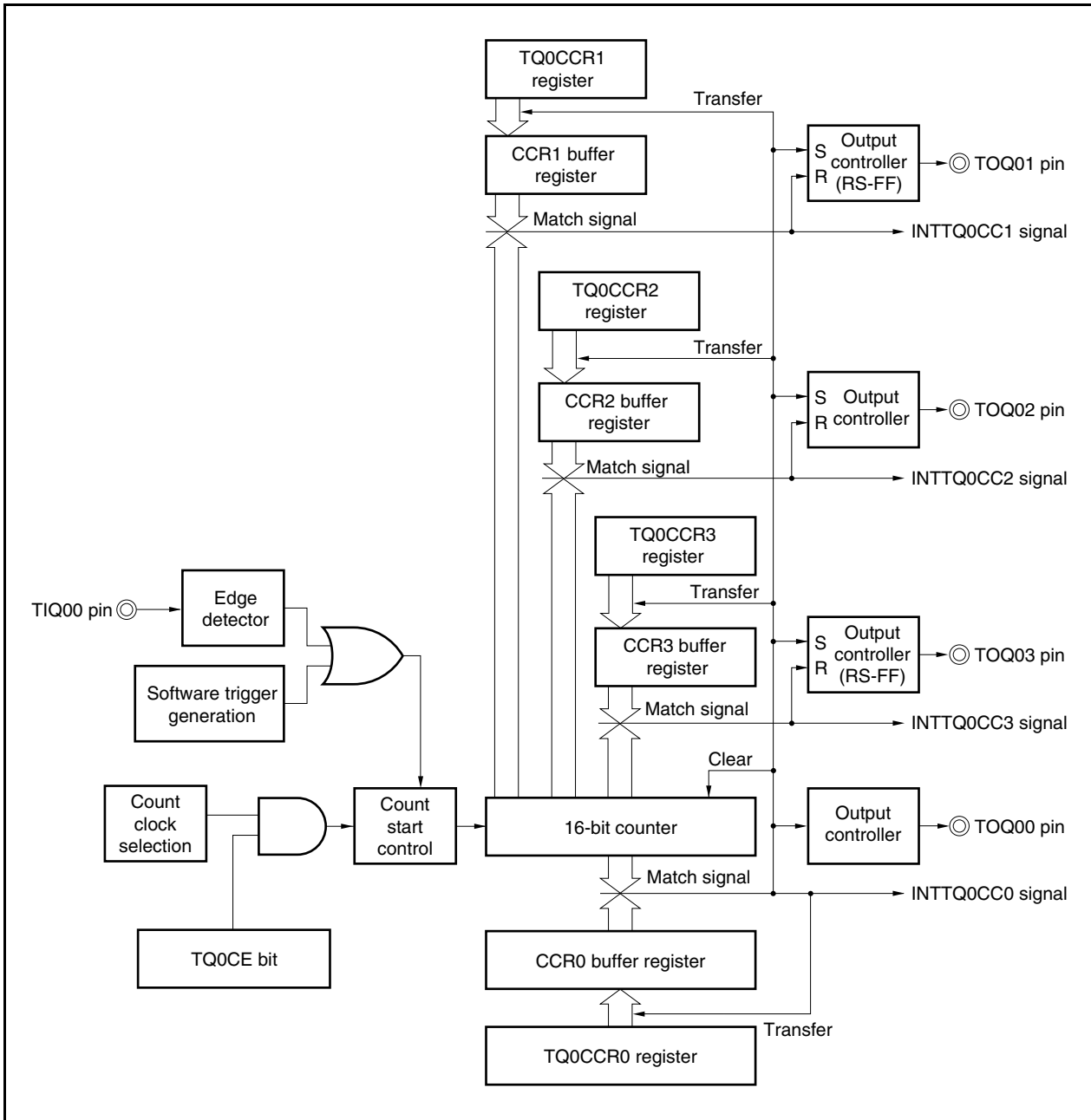
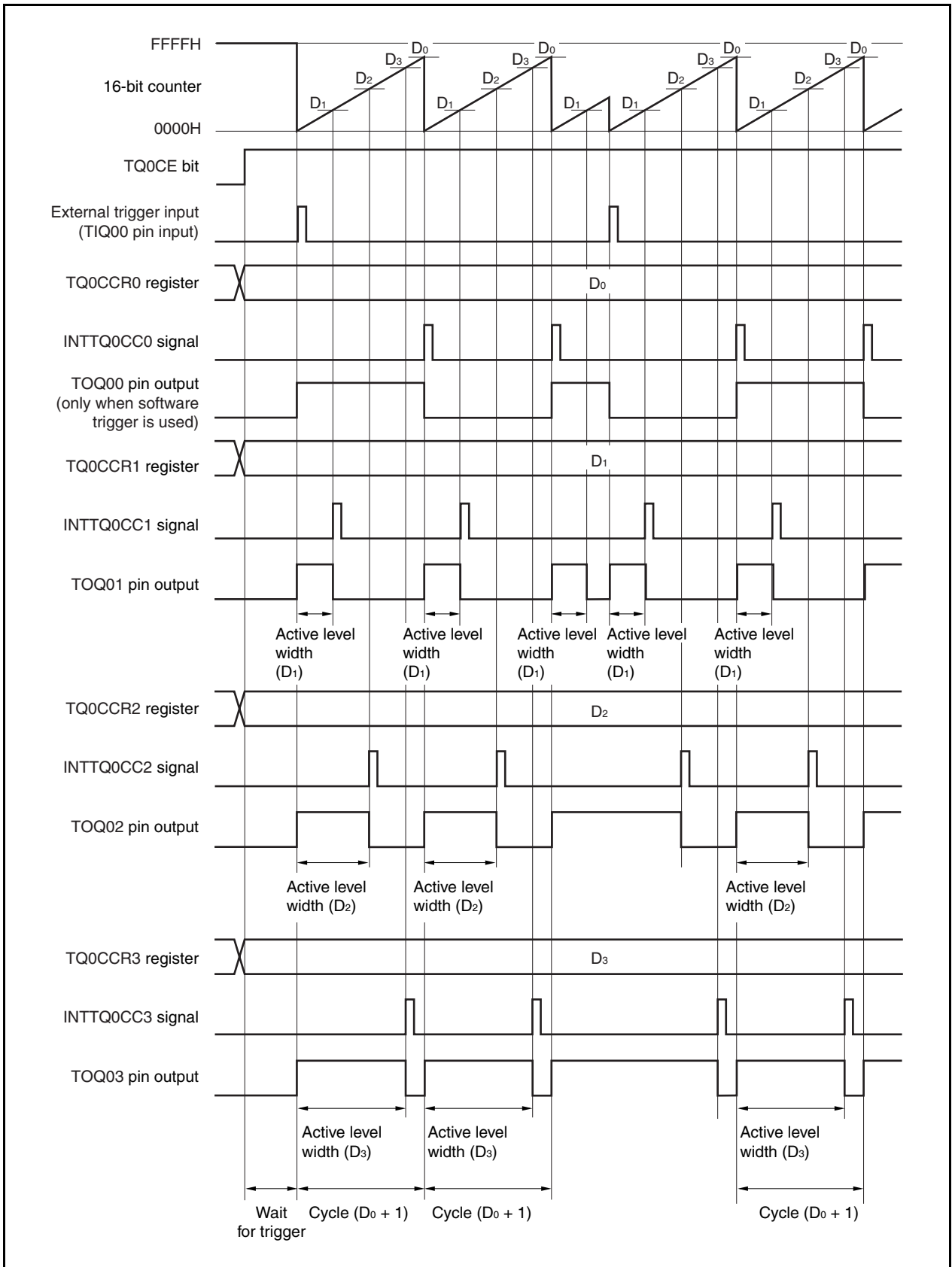


Figure 8-17. Basic Timing in External Trigger Pulse Output Mode



16-bit timer/event counter Q waits for a trigger when the TQ0CE bit is set to 1. When the trigger is generated, the 16-bit counter is cleared from FFFFH to 0000H, starts counting at the same time, and outputs a PWM waveform from the TOQ0k pin. If the trigger is generated again while the counter is operating, the counter is cleared to 0000H and restarted. (The output of the TOQ00 pin is inverted. The TOQ0k pin outputs a high-level regardless of the status (high/low) when a trigger is generated.)

The active level width, cycle, and duty factor of the PWM waveform can be calculated as follows.

$$\text{Active level width} = (\text{Set value of TQ0CCRk register}) \times \text{Count clock cycle}$$

$$\text{Cycle} = (\text{Set value of TQ0CCR0 register} + 1) \times \text{Count clock cycle}$$

$$\text{Duty factor} = (\text{Set value of TQ0CCRk register}) / (\text{Set value of TQ0CCR0 register} + 1)$$

The compare match request signal INTTQ0CC0 is generated when the 16-bit counter counts next time after its count value matches the value of the CCR0 buffer register, and the 16-bit counter is cleared to 0000H. The compare match interrupt request signal INTTQ0CCk is generated when the count value of the 16-bit counter matches the value of the CCRk buffer register.

The value set to the TQ0CCRm register is transferred to the CCRm buffer register when the count value of the 16-bit counter matches the value of the CCR0 buffer register and the 16-bit counter is cleared to 0000H.

The valid edge of an external trigger input signal, or setting the software trigger (TQ0CTL1.TQ0EST bit) to 1 is used as the trigger.

**Remark** k = 1 to 3, m = 0 to 3

**Figure 8-18. Register Setting for Operation in External Trigger Pulse Output Mode (1/3)**

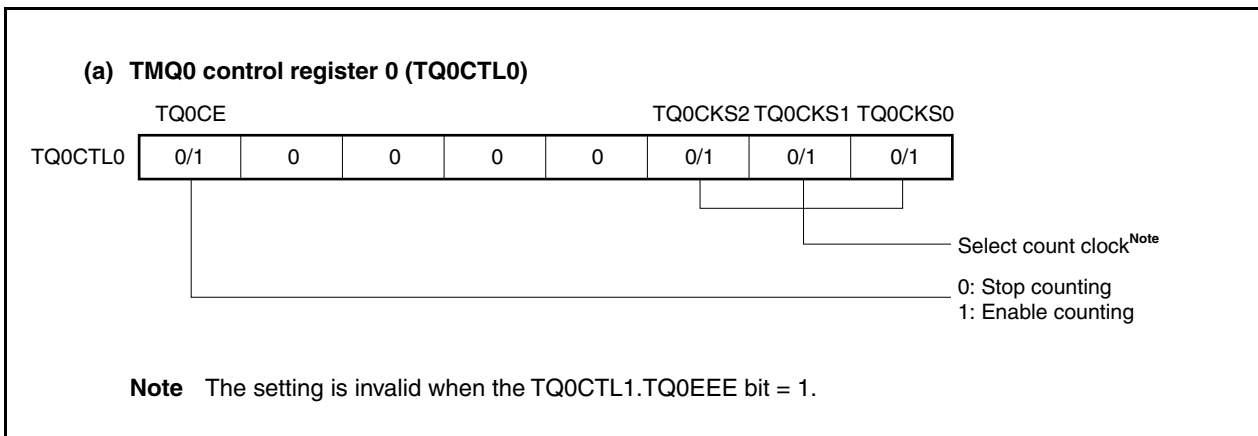




Figure 8-18. Register Setting for Operation in External Trigger Pulse Output Mode (2/3)

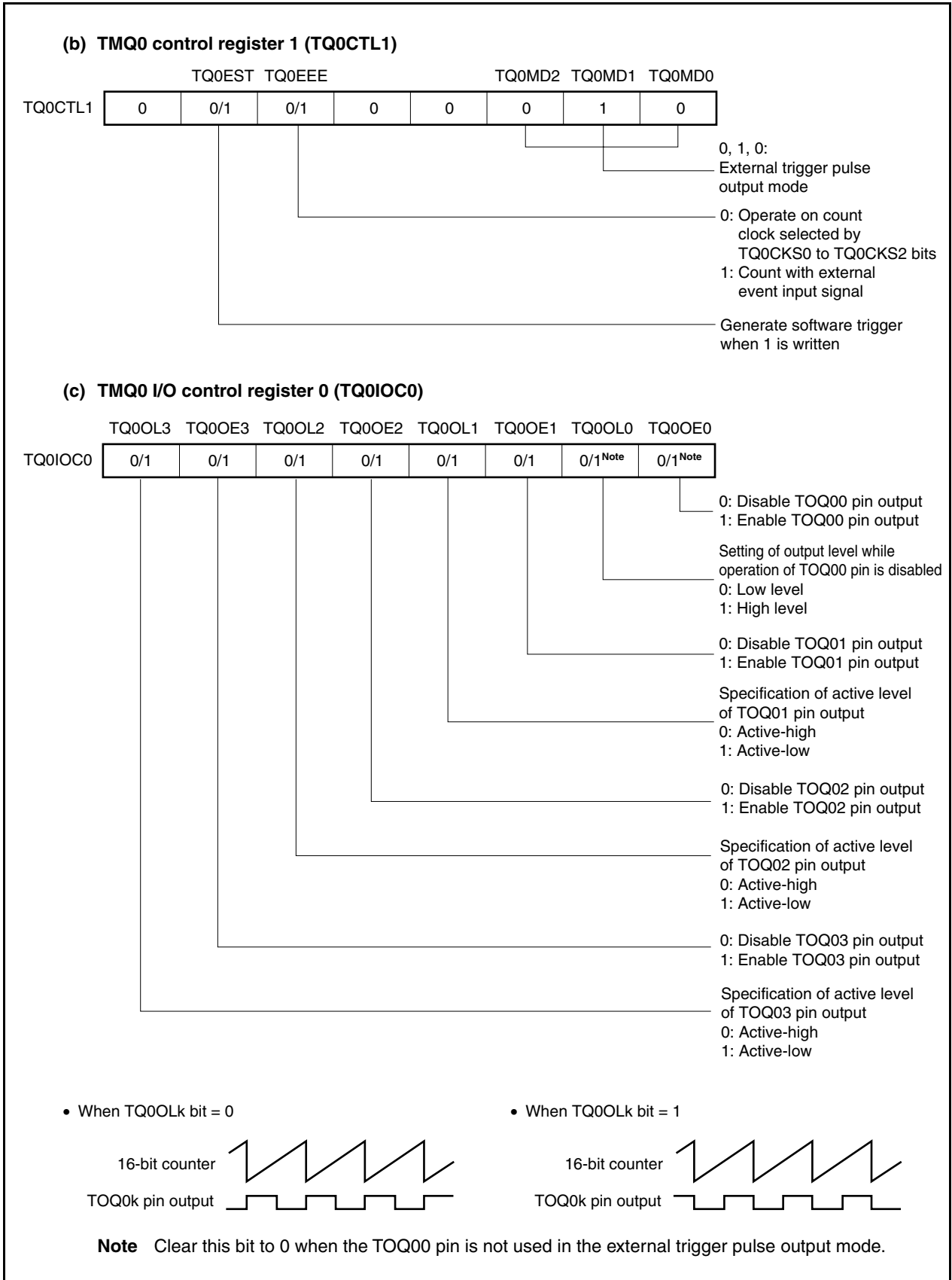
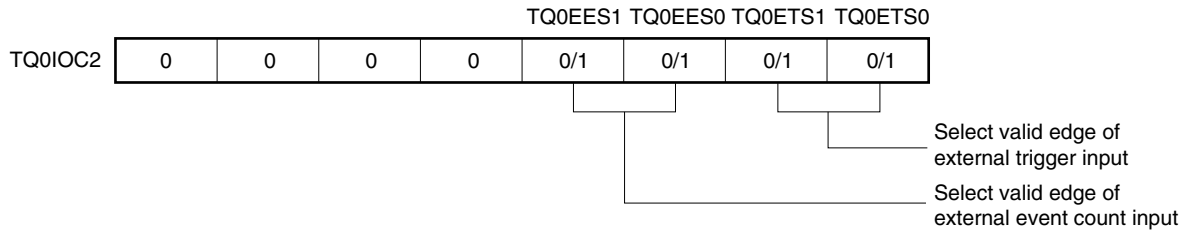


Figure 8-18. Register Setting for Operation in External Trigger Pulse Output Mode (3/3)

**(d) TMQ0 I/O control register 2 (TQ0IOC2)****(e) TMQ0 counter read buffer register (TQ0CNT)**

The value of the 16-bit counter can be read by reading the TQ0CNT register.

**(f) TMQ0 capture/compare registers 0 to 3 (TQ0CCR0 to TQ0CCR3)**

If  $D_0$  is set to the TQ0CCR0 register,  $D_1$  to the TQ0CCR1 register,  $D_2$  to the TQ0CCR2 register, and  $D_3$  to the TQ0CCR3 register, the cycle and active level of the PWM waveform are as follows.

$$\text{Cycle} = (D_0 + 1) \times \text{Count clock cycle}$$

$$\text{TOQ01 pin PWM waveform active level width} = D_1 \times \text{Count clock cycle}$$

$$\text{TOQ02 pin PWM waveform active level width} = D_2 \times \text{Count clock cycle}$$

$$\text{TOQ03 pin PWM waveform active level width} = D_3 \times \text{Count clock cycle}$$

- Remarks**
1. TMQ0 I/O control register 1 (TQ0IOC1) and TMQ0 option register 0 (TQ0OPT0) are not used in the external trigger pulse output mode.
  2. Updating TMQ0 capture/compare register 2 (TQ0CCR2) and TMQ0 capture/compare register 3 (TQ0CCR3) is validated by writing TMQ0 capture/compare register 1 (TQ0CCR1).

(1) Operation flow in external trigger pulse output mode

Figure 8-19. Software Processing Flow in External Trigger Pulse Output Mode (1/2)

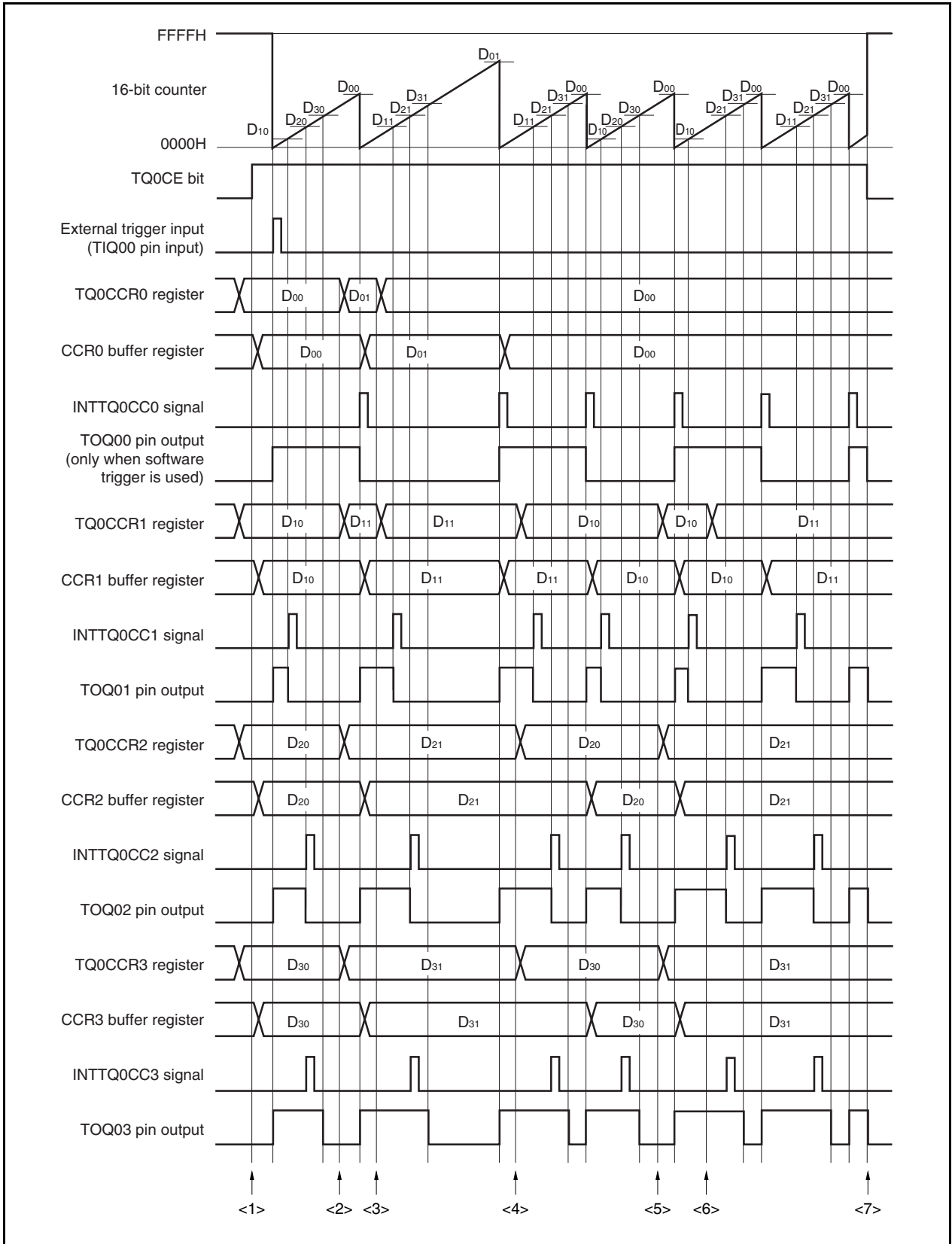
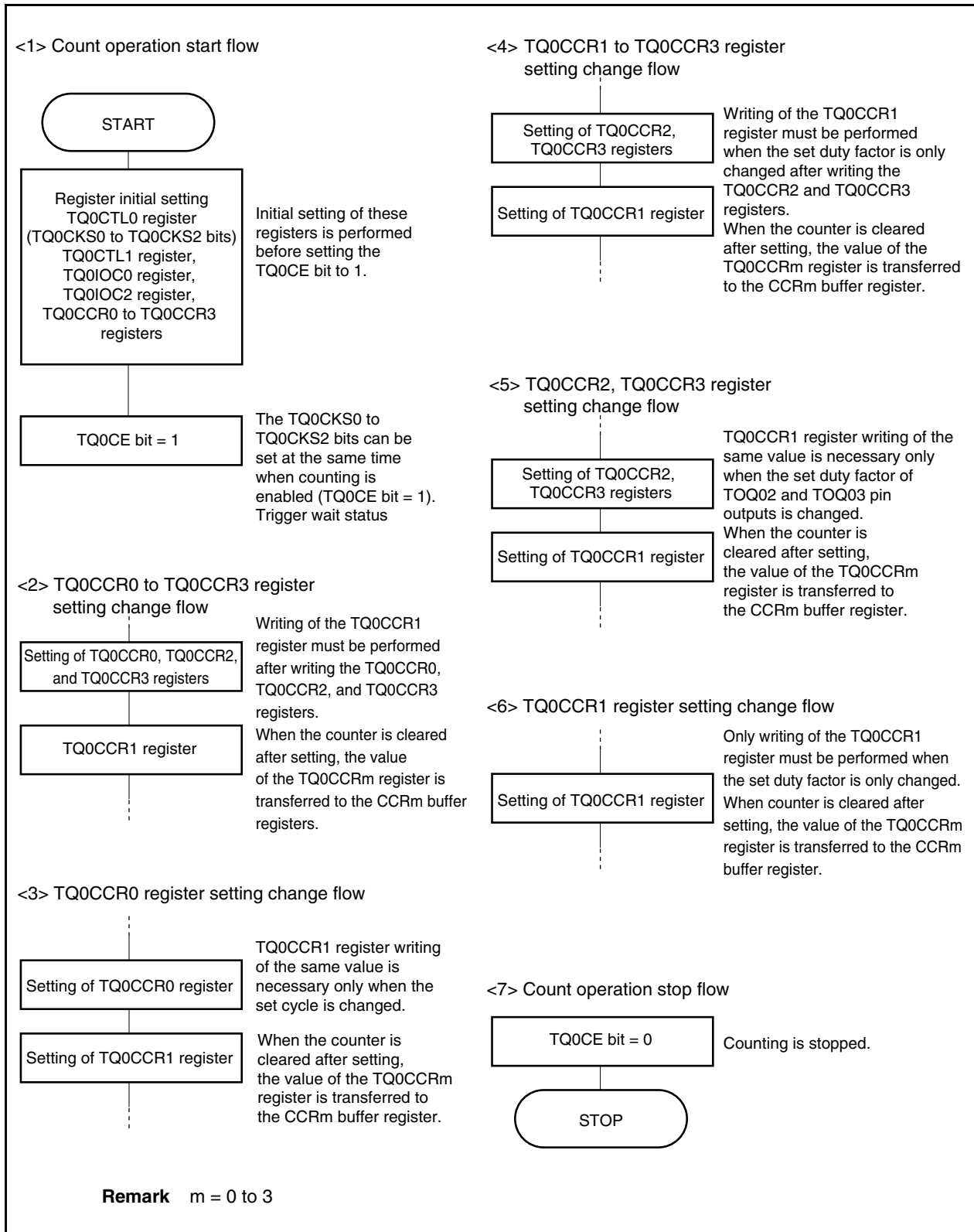


Figure 8-19. Software Processing Flow in External Trigger Pulse Output Mode (2/2)

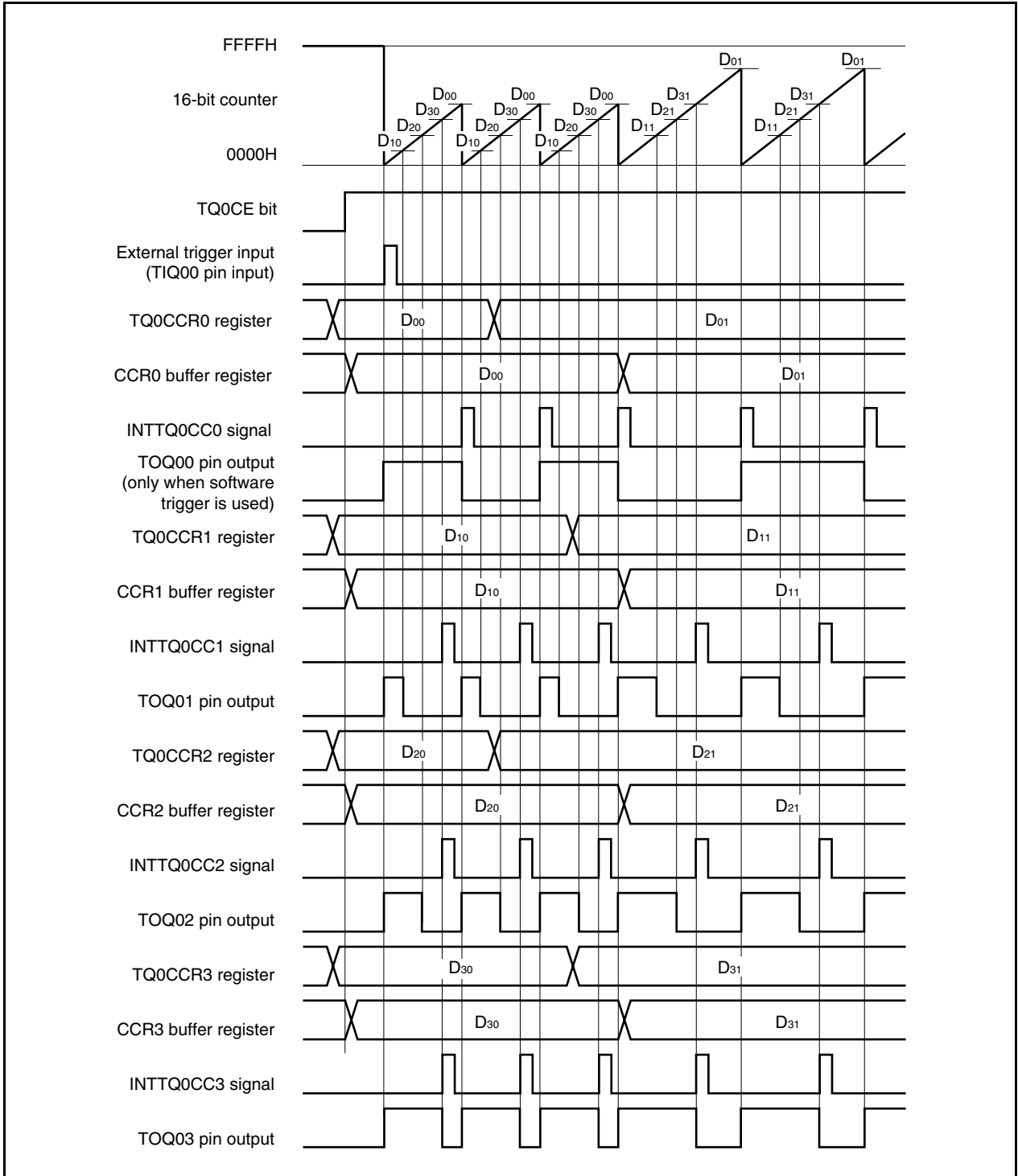


(2) External trigger pulse output mode operation timing

(a) Note on changing pulse width during operation

To change the PWM waveform while the counter is operating, write the TQ0CCR1 register last.

Rewrite the TQ0CCRk register after writing the TQ0CCR1 register after the INTTQ0CC0 signal is detected.



In order to transfer data from the TQ0CCRm register to the CCRm buffer register, the TQ0CCR1 register must be written.

To change both the cycle and active level width of the PWM waveform at this time, first set the cycle to the TQ0CCR0 register, set the active level width to the TQ0CCR2 and TQ0CCR3 registers, and then set an active level to the TQ0CCR1 register.

To change only the cycle of the PWM waveform, first set the cycle to the TQ0CCR0 register, and then write the same value to the TQ0CCR1 register.

To change only the active level width (duty factor) of the PWM waveform, first set an active level to the TQ0CCR2 and TQ0CCR3 registers and then set an active level to the TQ0CCR1 register.

To change only the active level width (duty factor) of the PWM waveform output by the TOQ01 pin, only the TQ0CCR1 register has to be set.

To change only the active level width (duty factor) of the PWM waveform output by the TOQ02 and TOQ03 pins, first set an active level width to the TQ0CCR2 and TQ0CCR3 registers, and then write the same value to the TQ0CCR1 register.

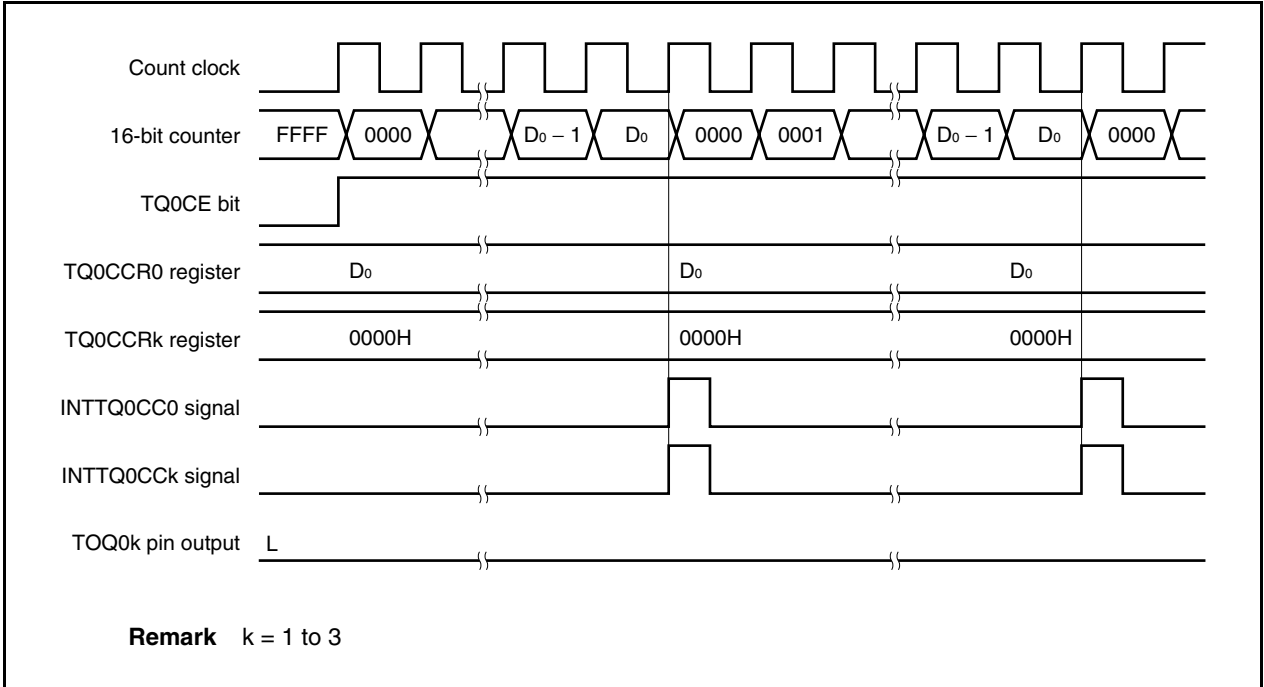
After data is written to the TQ0CCR1 register, the value written to the TQ0CCRm register is transferred to the CCRm buffer register in synchronization with clearing of the 16-bit counter, and is used as the value compared with the 16-bit counter.

To write the TQ0CCR0 to TQ0CCR3 registers again after writing the TQ0CCR1 register once, do so after the INTTQ0CC0 signal is generated. Otherwise, the value of the CCRm buffer register may become undefined because timing of transferring data from the TQ0CCRm register to the CCRm buffer register conflicts with writing the TQ0CCRm register.

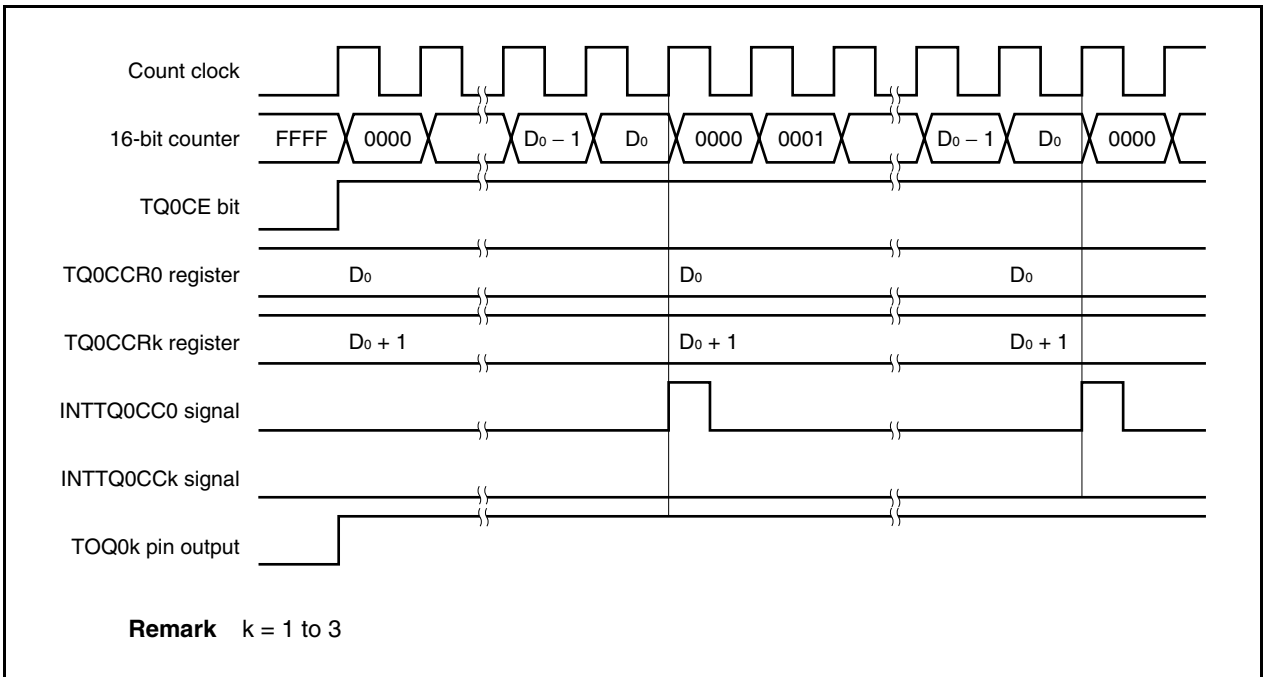
**Remark** m = 0 to 3

**(b) 0%/100% output of PWM waveform**

To output a 0% waveform, set the TQ0CCRk register to 0000H. If the set value of the TQ0CCR0 register is FFFFH, the INTTQ0CCK signal is generated periodically.

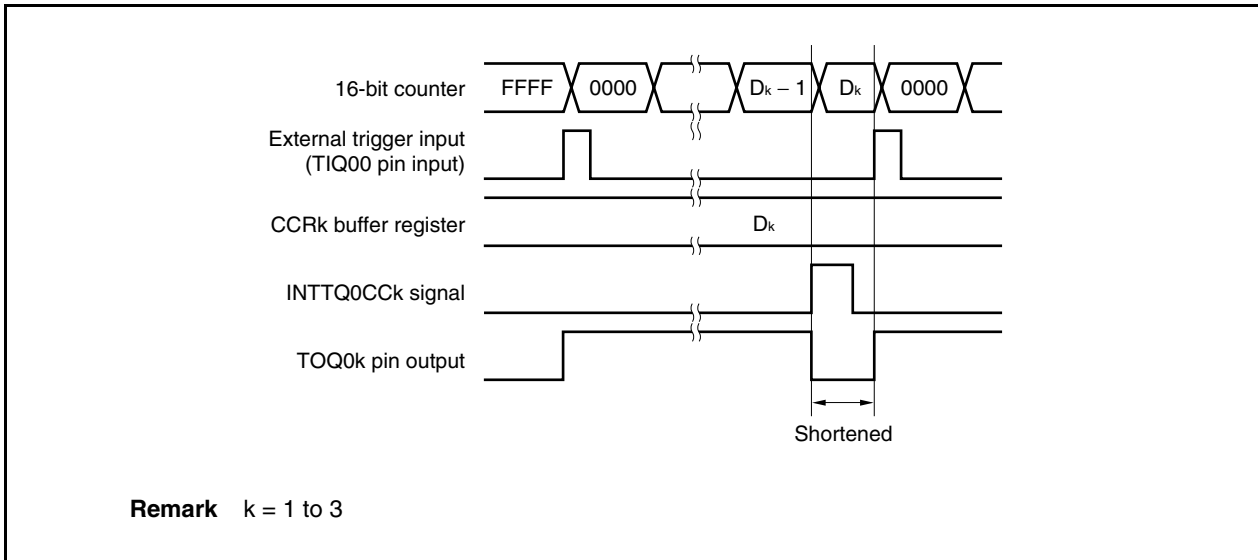


To output a 100% waveform, set a value of (set value of TQ0CCR0 register + 1) to the TQ0CCRk register. If the set value of the TQ0CCR0 register is FFFFH, 100% output cannot be produced.

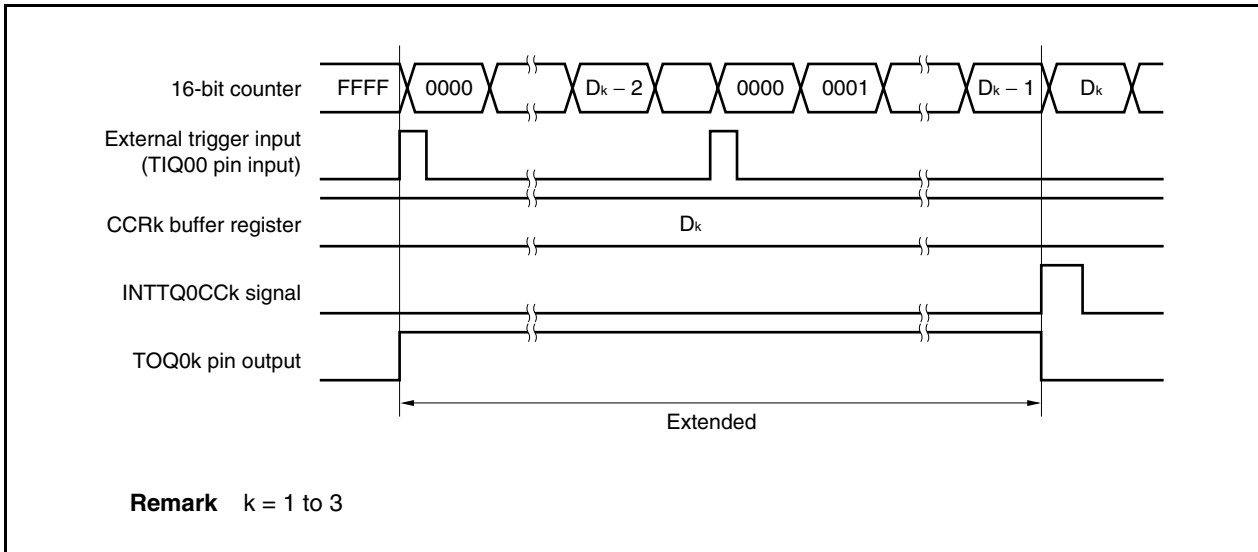


**(c) Conflict between trigger detection and match with CCRk buffer register**

If the trigger is detected immediately after the INTTQ0CCk signal is generated, the 16-bit counter is immediately cleared to 0000H, the output signal of the TOQ0k is asserted, and the counter continues counting. Consequently, the inactive period of the PWM waveform is shortened.



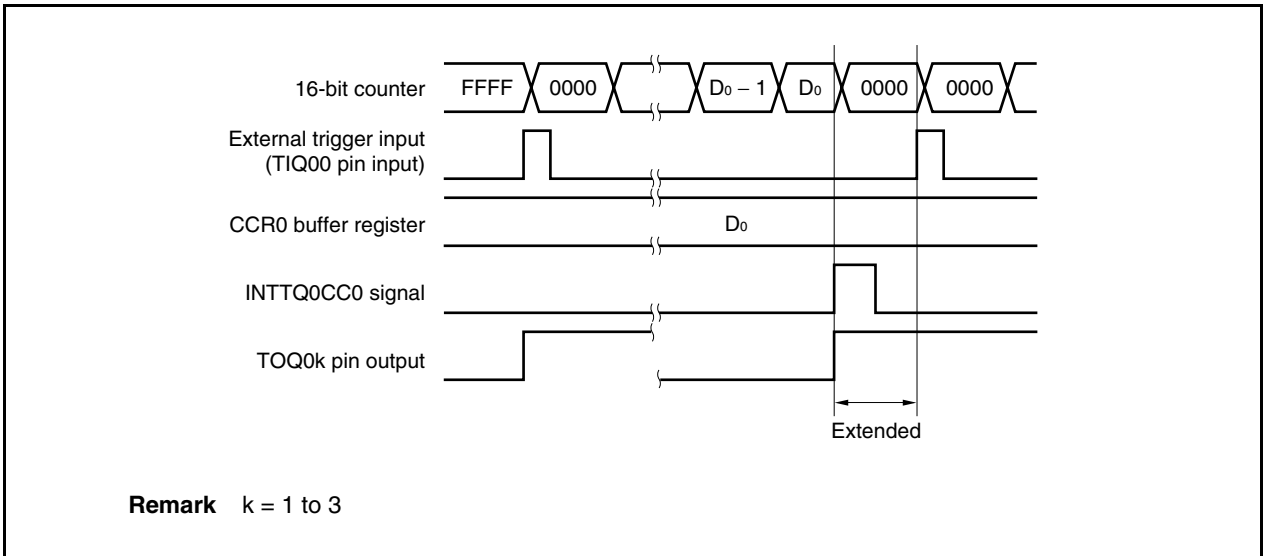
If the trigger is detected immediately before the INTTQ0CCk signal is generated, the INTTQ0CCk signal is not generated, and the 16-bit counter is cleared to 0000H and continues counting. The output signal of the TOQ0k pin remains active. Consequently, the active period of the PWM waveform is extended.



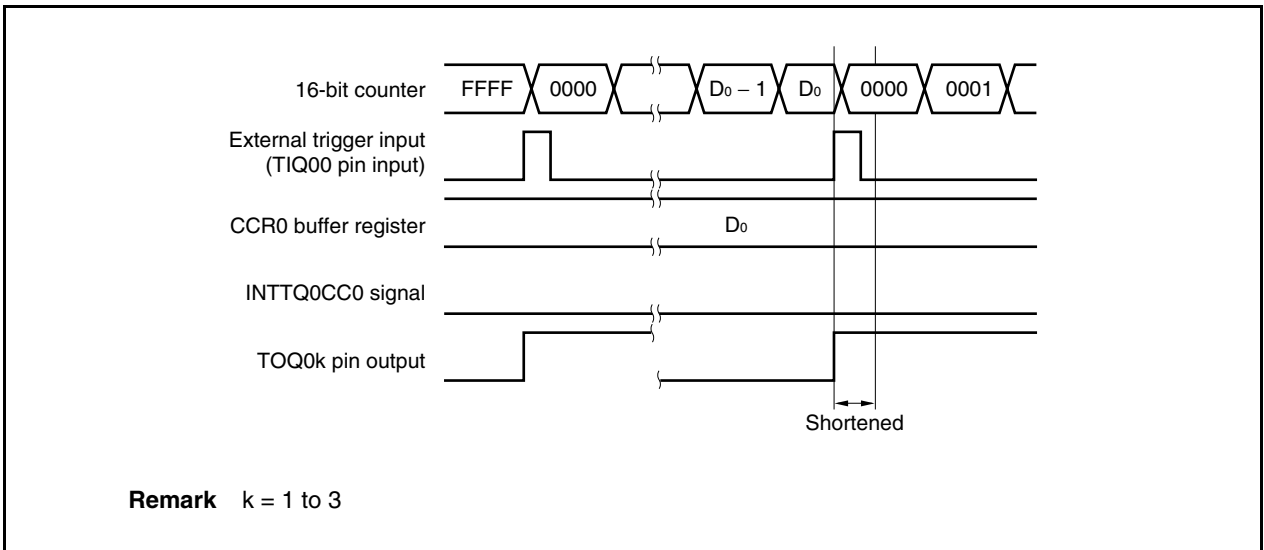


**(d) Conflict between trigger detection and match with CCR0 buffer register**

If the trigger is detected immediately after the INTTQ0CC0 signal is generated, the 16-bit counter is cleared to 0000H and continues counting up. Therefore, the active period of the TOQ0k pin is extended by time from generation of the INTTQ0CC0 signal to trigger detection.

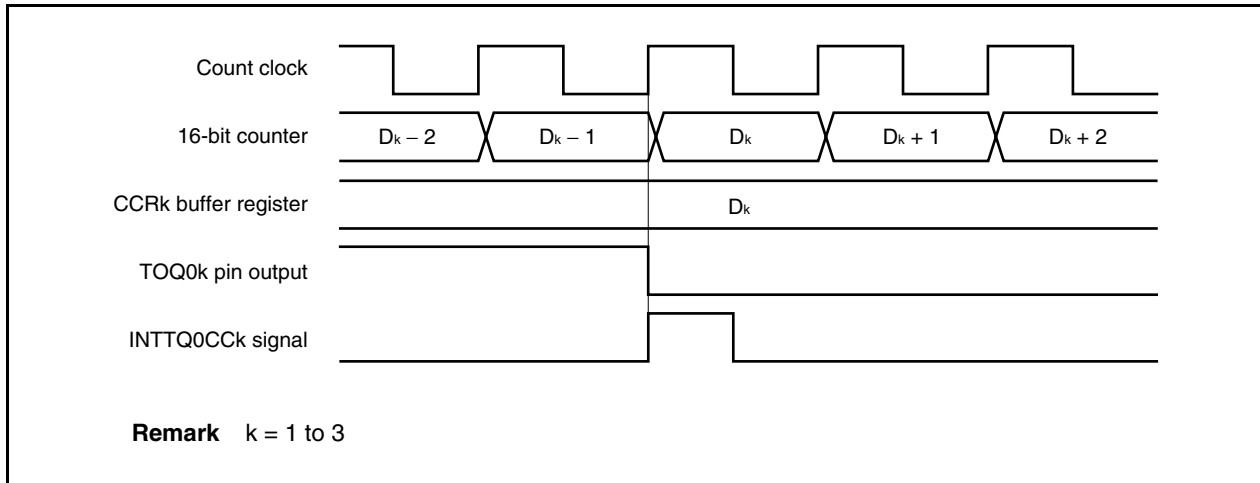


If the trigger is detected immediately before the INTTQ0CC0 signal is generated, the INTTQ0CC0 signal is not generated. The 16-bit counter is cleared to 0000H, the TOQ0k pin is asserted, and the counter continues counting. Consequently, the inactive period of the PWM waveform is shortened.



**(e) Generation timing of compare match interrupt request signal (INTTQ0CCK)**

The timing of generation of the INTTQ0CCK signal in the external trigger pulse output mode differs from the timing of other INTTQ0CCK signals; the INTTQ0CCK signal is generated when the count value of the 16-bit counter matches the value of the CCRk buffer register.



Usually, the INTTQ0CCK signal is generated in synchronization with the next count up after the count value of the 16-bit counter matches the value of the CCRk buffer register.

In the external trigger pulse output mode, however, it is generated one clock earlier. This is because the timing is changed to match the timing of changing the output signal of the TOQ0k pin.

**8.5.4 One-shot pulse output mode (TQ0MD2 to TQ0MD0 bits = 011)**

In the one-shot pulse output mode, 16-bit timer/event counter Q waits for a trigger when the TQ0CTL0.TQ0CE bit is set to 1. When the valid edge of an external trigger input is detected, 16-bit timer/event counter Q starts counting, and outputs a one-shot pulse from the TOQ01 to TOQ03 pins.

Instead of the external trigger, a software trigger can also be generated to output the pulse. When the software trigger is used, the TOQ00 pin outputs the active level while the 16-bit counter is counting, and the inactive level when the counter is stopped (waiting for a trigger).

**Figure 8-20. Configuration in One-Shot Pulse Output Mode**

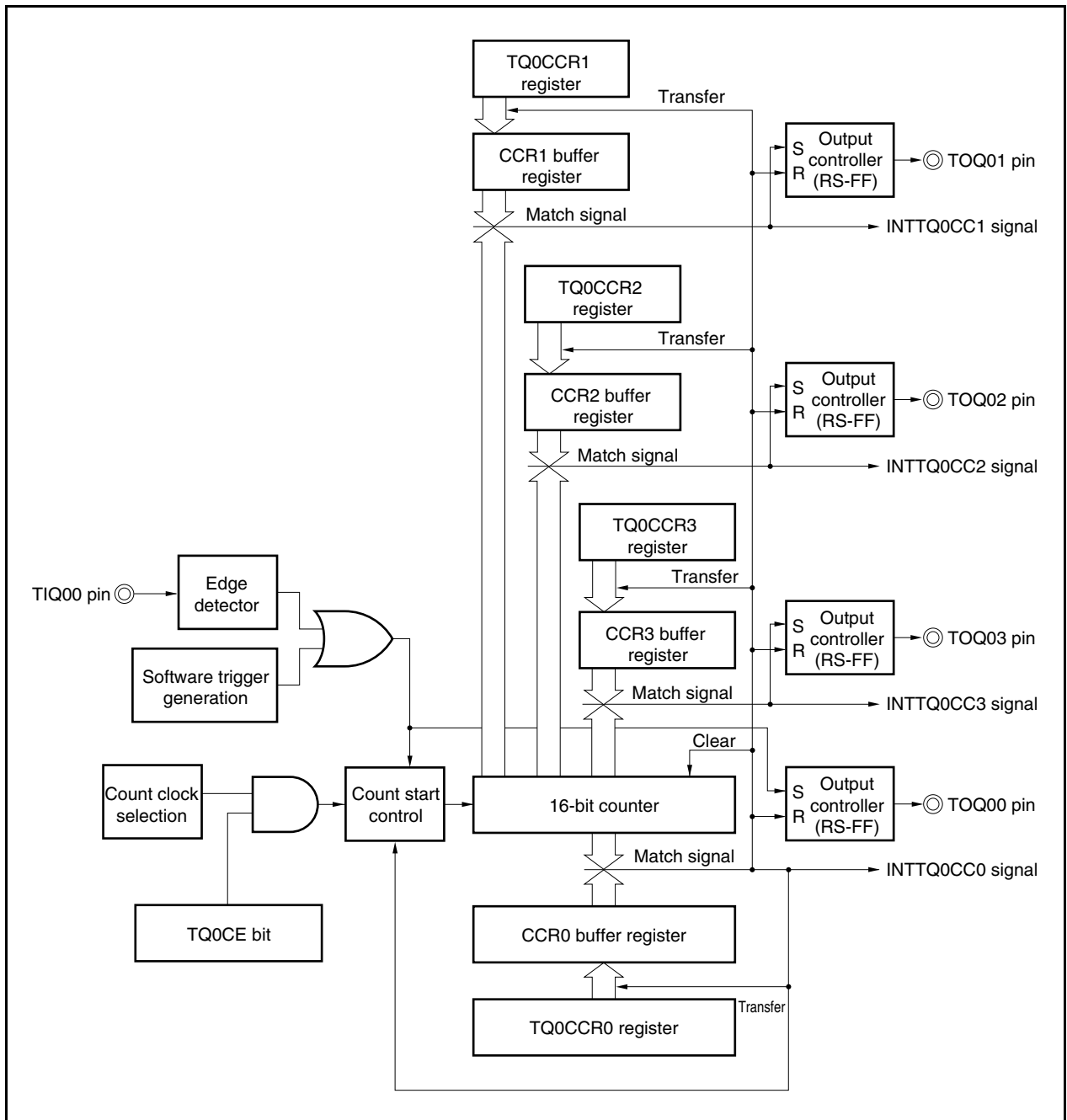
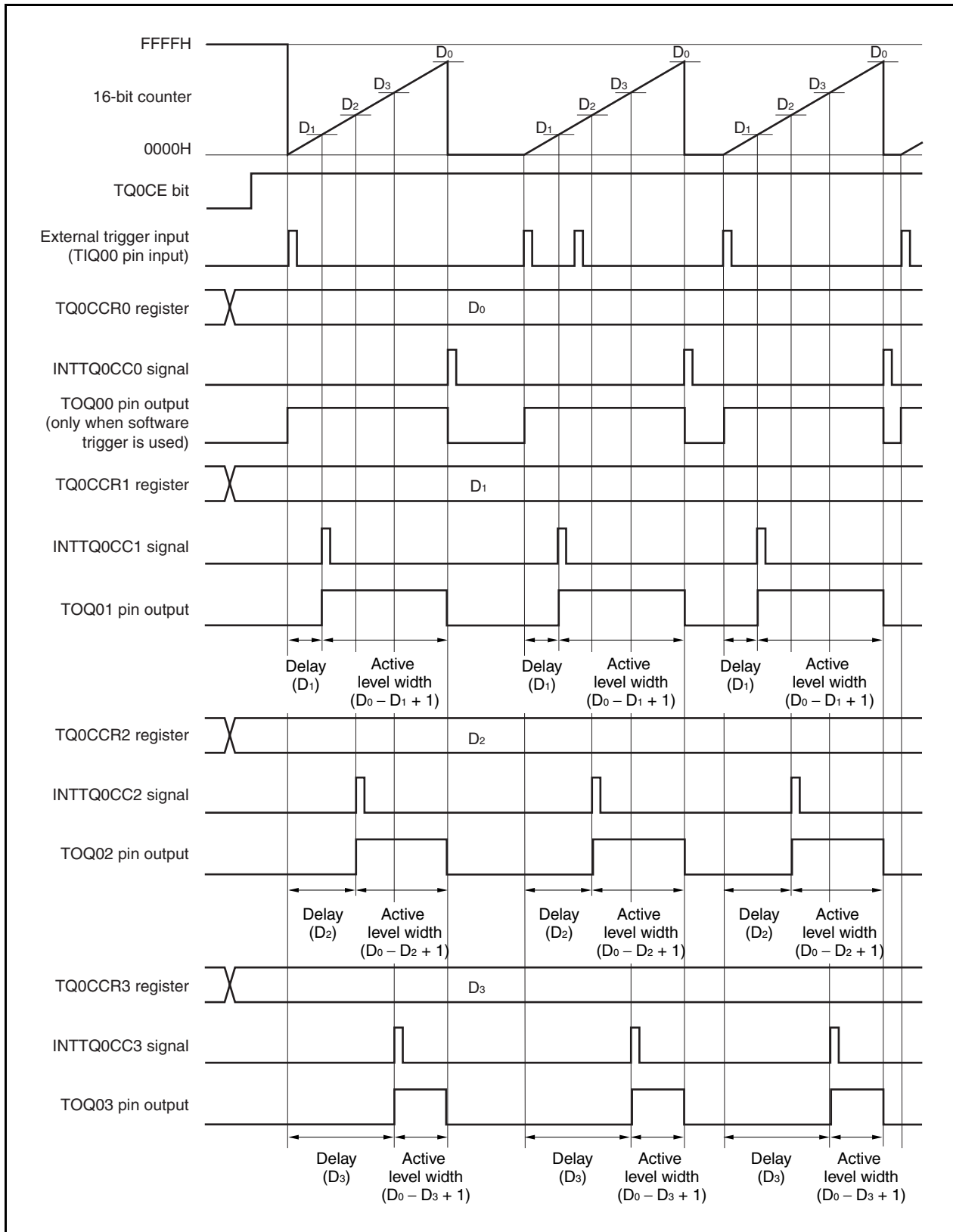


Figure 8-21. Basic Timing in One-Shot Pulse Output Mode



When the TQ0CE bit is set to 1, 16-bit timer/event counter Q waits for a trigger. When the trigger is generated, the 16-bit counter is cleared from FFFFH to 0000H, starts counting, and outputs a one-shot pulse from the TOQ0k pin. After the one-shot pulse is output, the 16-bit counter is set to FFFFH, stops counting, and waits for a trigger. If a trigger is generated again while the one-shot pulse is being output, it is ignored.

The output delay period and active level width of the one-shot pulse can be calculated as follows.

$$\text{Output delay period} = (\text{Set value of TQ0CCRk register}) \times \text{Count clock cycle}$$

$$\text{Active level width} = (\text{Set value of TQ0CCR0 register} - \text{Set value of TQ0CCRk register} + 1) \times \text{Count clock cycle}$$

The compare match interrupt request signal INTTQ0CC0 is generated when the 16-bit counter counts after its count value matches the value of the CCR0 buffer register. The compare match interrupt request signal INTTQ0CCk is generated when the count value of the 16-bit counter matches the value of the CCRk buffer register.

The valid edge of an external trigger input or setting the software trigger (TQ0CTL1.TQ0EST bit) to 1 is used as the trigger.

**Remark** k = 1 to 3

**Figure 8-22. Register Setting for Operation in One-Shot Pulse Output Mode (1/3)**

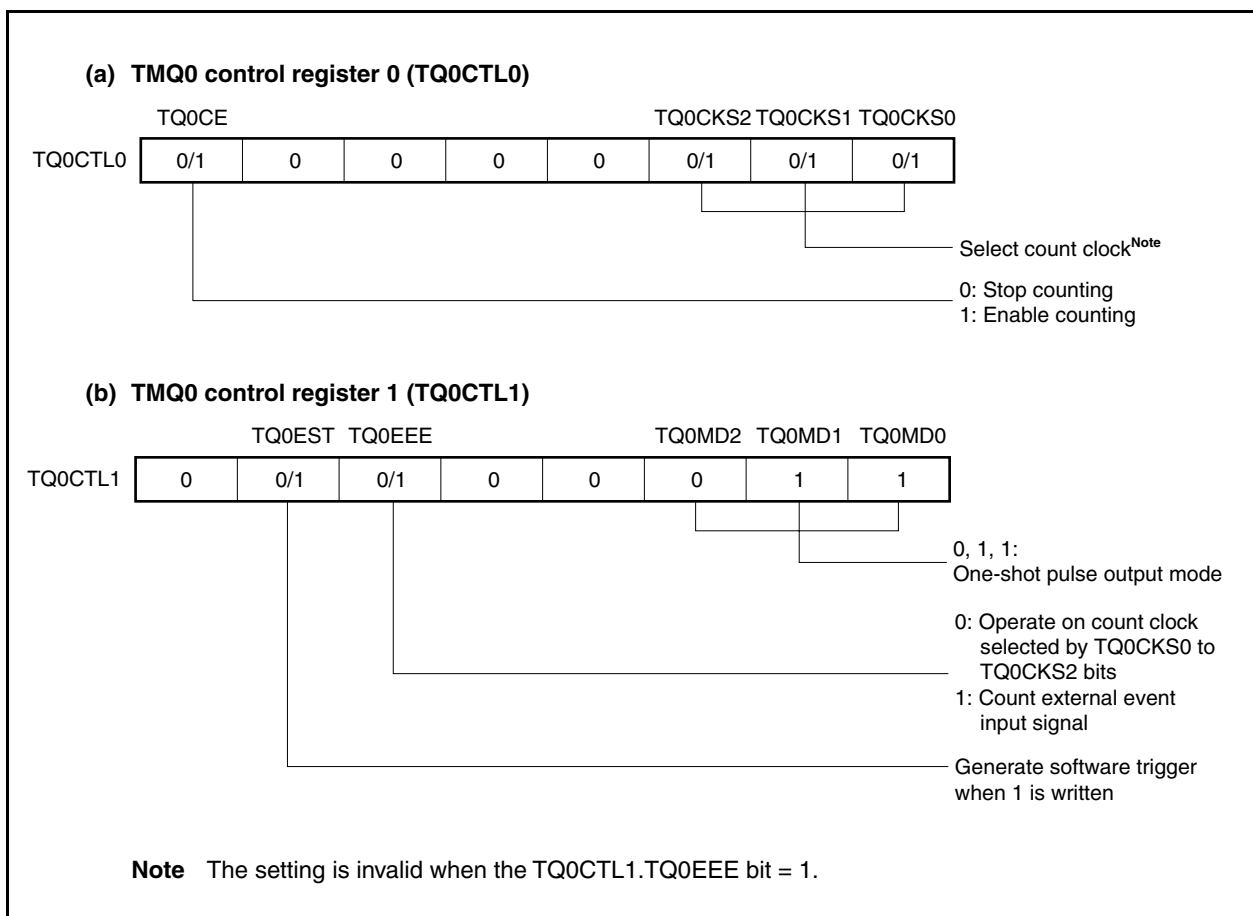


Figure 8-22. Register Setting for Operation in One-Shot Pulse Output Mode (2/3)

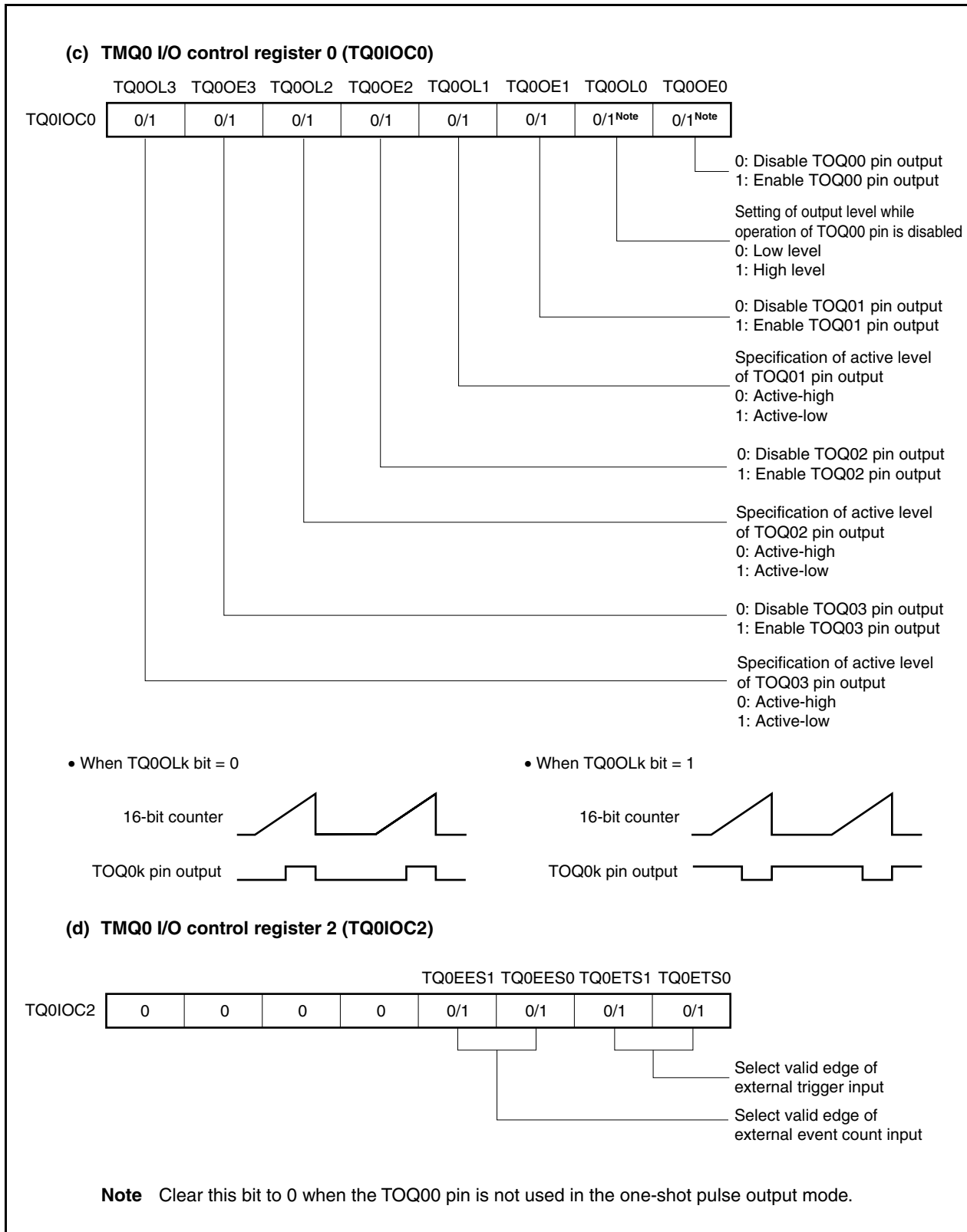


Figure 8-22. Register Setting for Operation in One-Shot Pulse Output Mode (3/3)

**(e) TMQ0 counter read buffer register (TQ0CNT)**

The value of the 16-bit counter can be read by reading the TQ0CNT register.

**(f) TMQ0 capture/compare registers 0 to 3 (TQ0CCR0 to TQ0CCR3)**

If  $D_0$  is set to the TQ0CCR0 register and  $D_k$  to the TQ0CCRk register, the active level width and output delay period of the one-shot pulse are as follows.

Active level width =  $(D_0 - D_k + 1) \times \text{Count clock cycle}$

Output delay period =  $(D_k) \times \text{Count clock cycle}$

**Caution** One-shot pulses are not output even in the one-shot pulse output mode, if the value set in the TQ0CCRk register is greater than that set in the TQ0CCR0 register.

**Remarks** 1. TMQ0 I/O control register 1 (TQ0IOC1) and TMQ0 option register 0 (TQ0OPT0) are not used in the one-shot pulse output mode.

2.  $k = 1$  to 3

(1) Operation flow in one-shot pulse output mode

Figure 8-23. Software Processing Flow in One-Shot Pulse Output Mode (1/2)

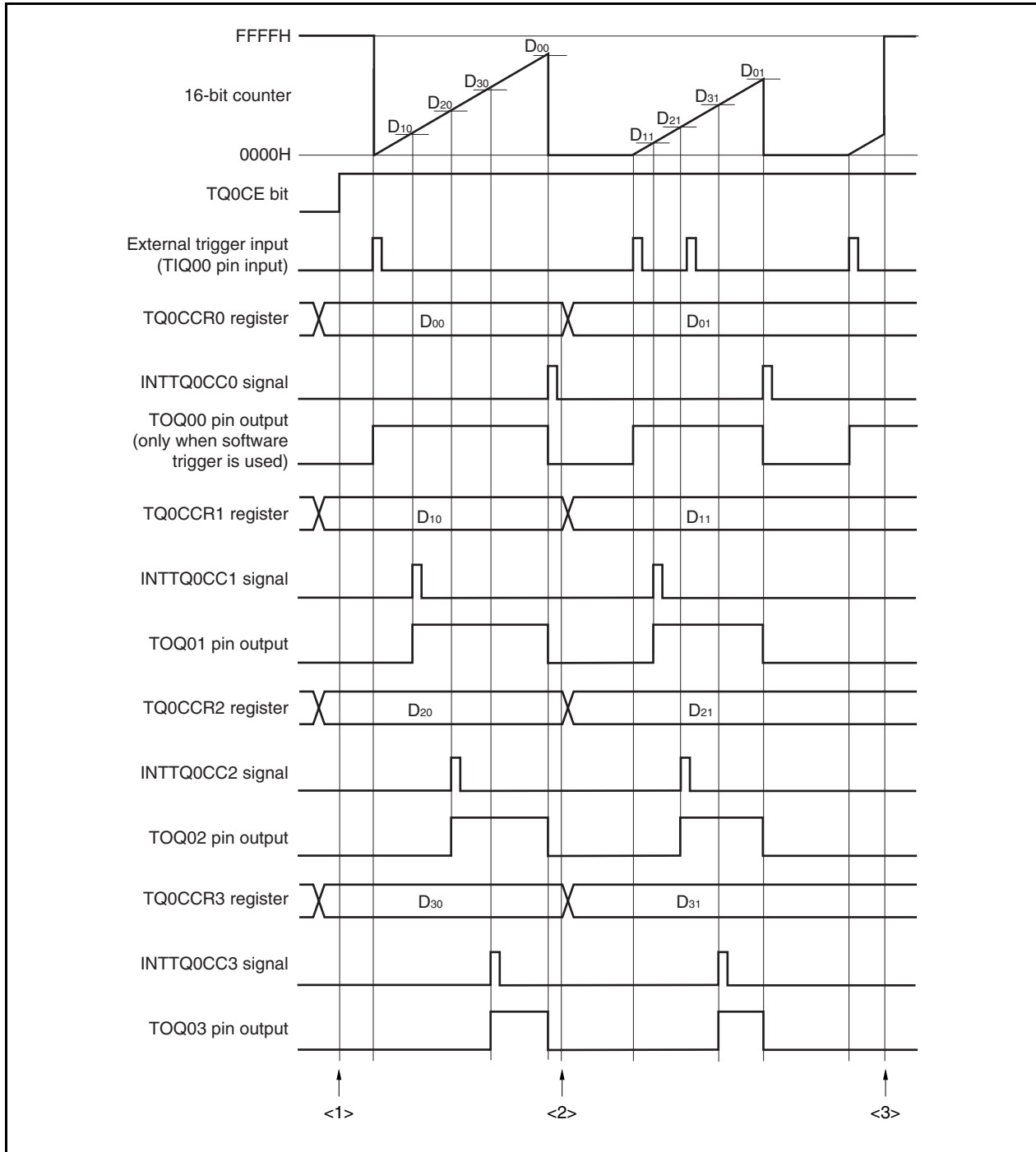
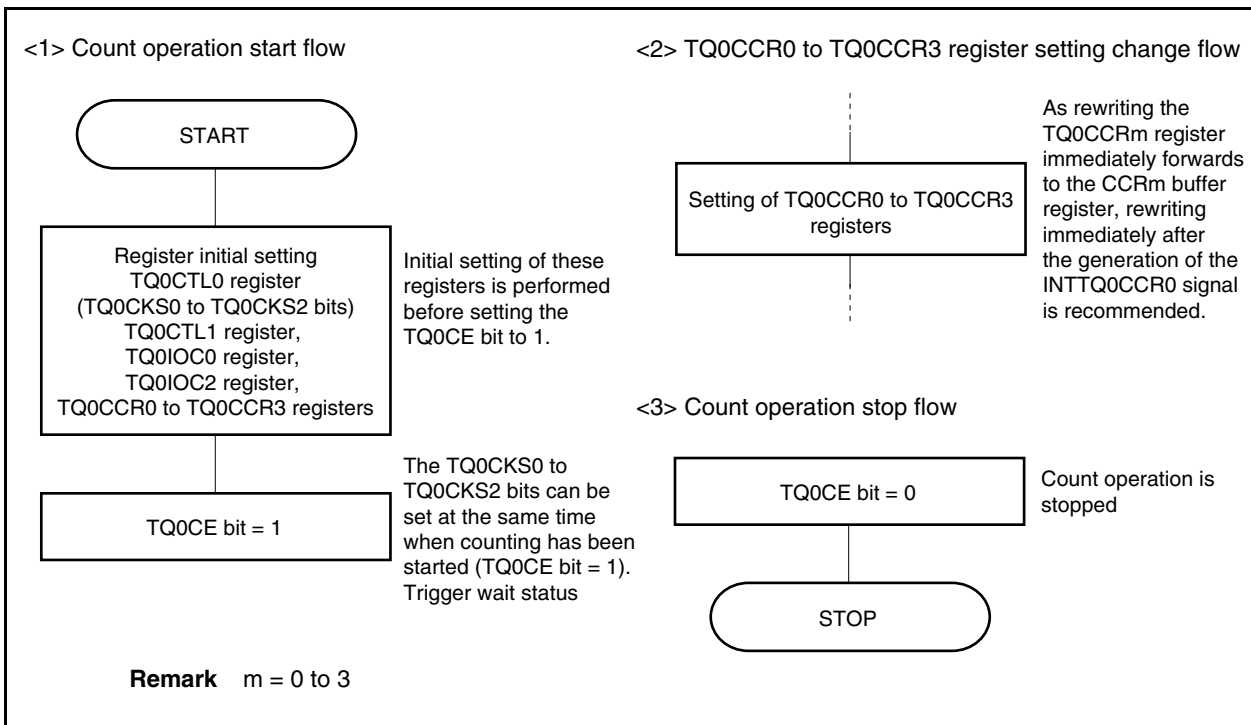




Figure 8-23. Software Processing Flow in One-Shot Pulse Output Mode (2/2)

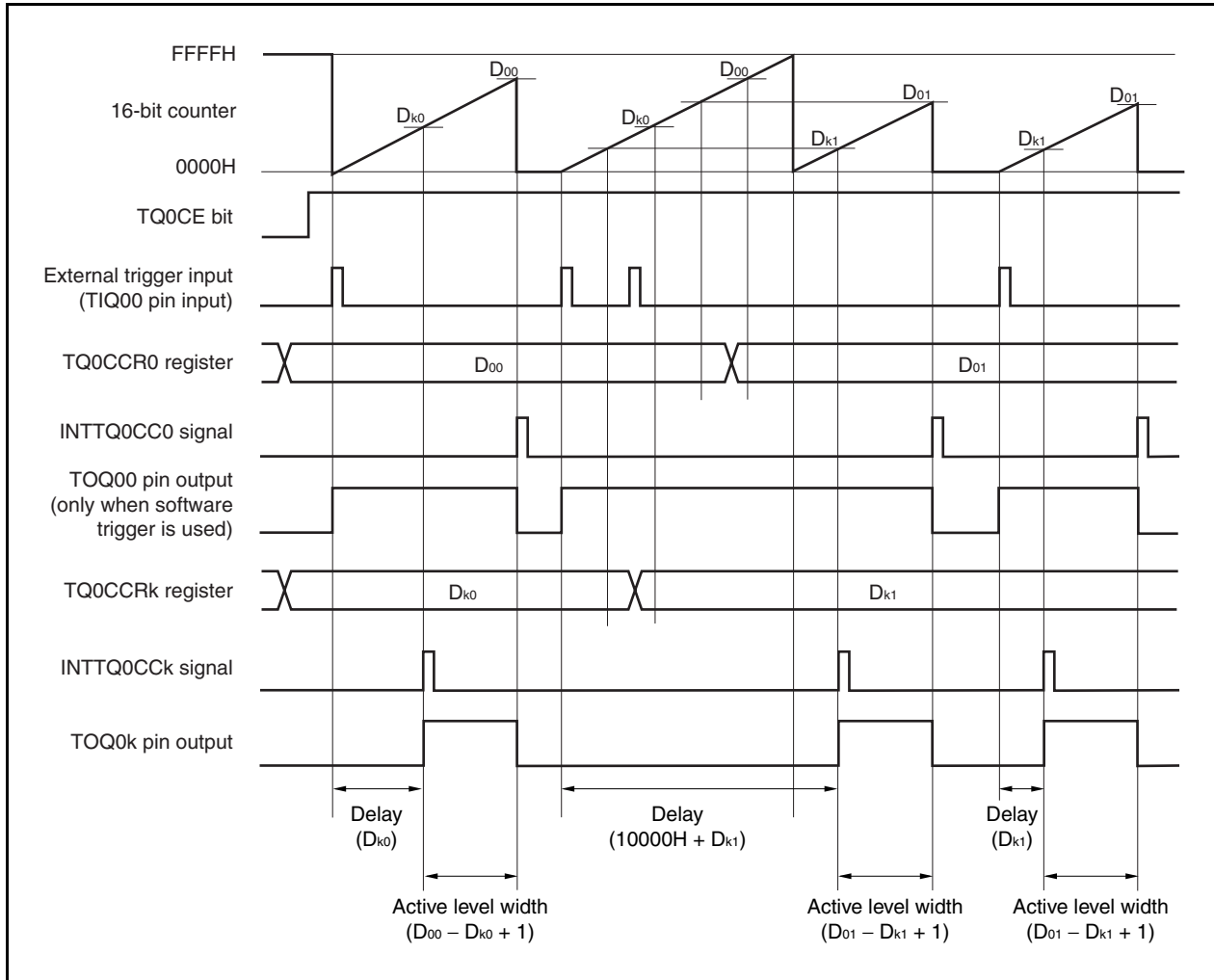


(2) Operation timing in one-shot pulse output mode

(a) Note on rewriting TQ0CCRm register

To change the set value of the TQ0CCRm register to a smaller value, stop counting once, and then change the set value.

If the value of the TQ0CCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.



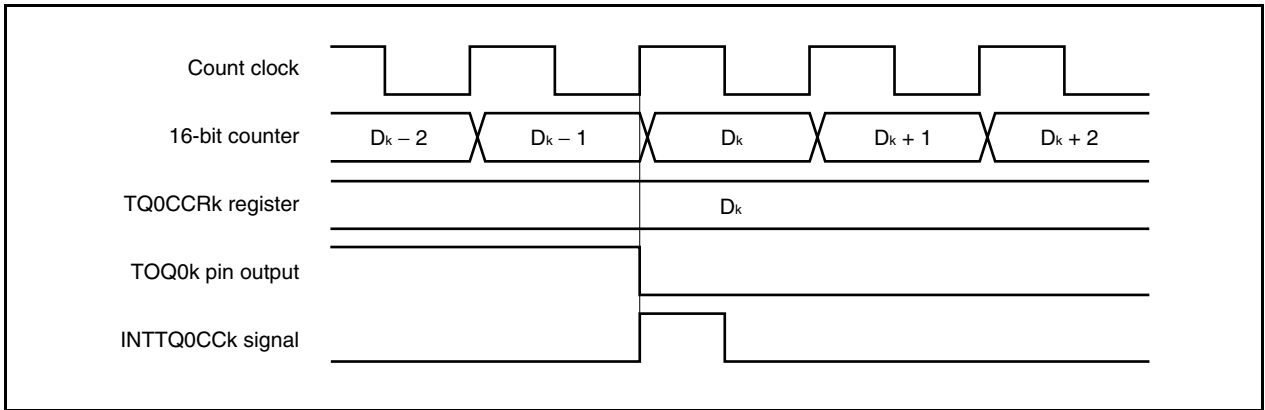
When the TQ0CCR0 register is rewritten from D<sub>00</sub> to D<sub>01</sub> and the TQ0CCRk register from D<sub>k0</sub> to D<sub>k1</sub> where D<sub>00</sub> > D<sub>01</sub> and D<sub>k0</sub> > D<sub>k1</sub>, if the TQ0CCRk register is rewritten when the count value of the 16-bit counter is greater than D<sub>k1</sub> and less than D<sub>k0</sub> and if the TQ0CCR0 register is rewritten when the count value is greater than D<sub>01</sub> and less than D<sub>00</sub>, each set value is reflected as soon as the register has been rewritten and compared with the count value. The counter counts up to FFFFH and then counts up again from 0000H. When the count value matches D<sub>k1</sub>, the counter generates the INTTQ0CCk signal and asserts the TOQ0k pin. When the count value matches D<sub>01</sub>, the counter generates the INTTQ0CC0 signal, deasserts the TOQ0k pin, and stops counting.

Therefore, the counter may output a pulse with a delay period or active period different from that of the one-shot pulse that is originally expected.

**Remark** k = 1 to 3

**(b) Generation timing of compare match interrupt request signal (INTTQ0CCk)**

The generation timing of the INTTQ0CCk signal in the one-shot pulse output mode is different from other INTTQ0CCk signals; the INTTQ0CCk signal is generated when the count value of the 16-bit counter matches the value of the TQ0CCRk register.



Usually, the INTTQ0CCk signal is generated when the 16-bit counter counts up next time after its count value matches the value of the TQ0CCRk register.

In the one-shot pulse output mode, however, it is generated one clock earlier. This is because the timing is changed to match the change timing of the TOQ0k pin.

**Remark**  $k = 1$  to 3

8.5.5 PWM output mode (TQ0MD2 to TQ0MD0 bits = 100)

In the PWM output mode, a PWM waveform is output from the TOQ01 to TOQ03 pins when the TQ0CTL0.TQ0CE bit is set to 1.

In addition, a pulse with one cycle of the PWM waveform as half its cycle is output from the TOQ00 pin.

Figure 8-24. Configuration in PWM Output Mode

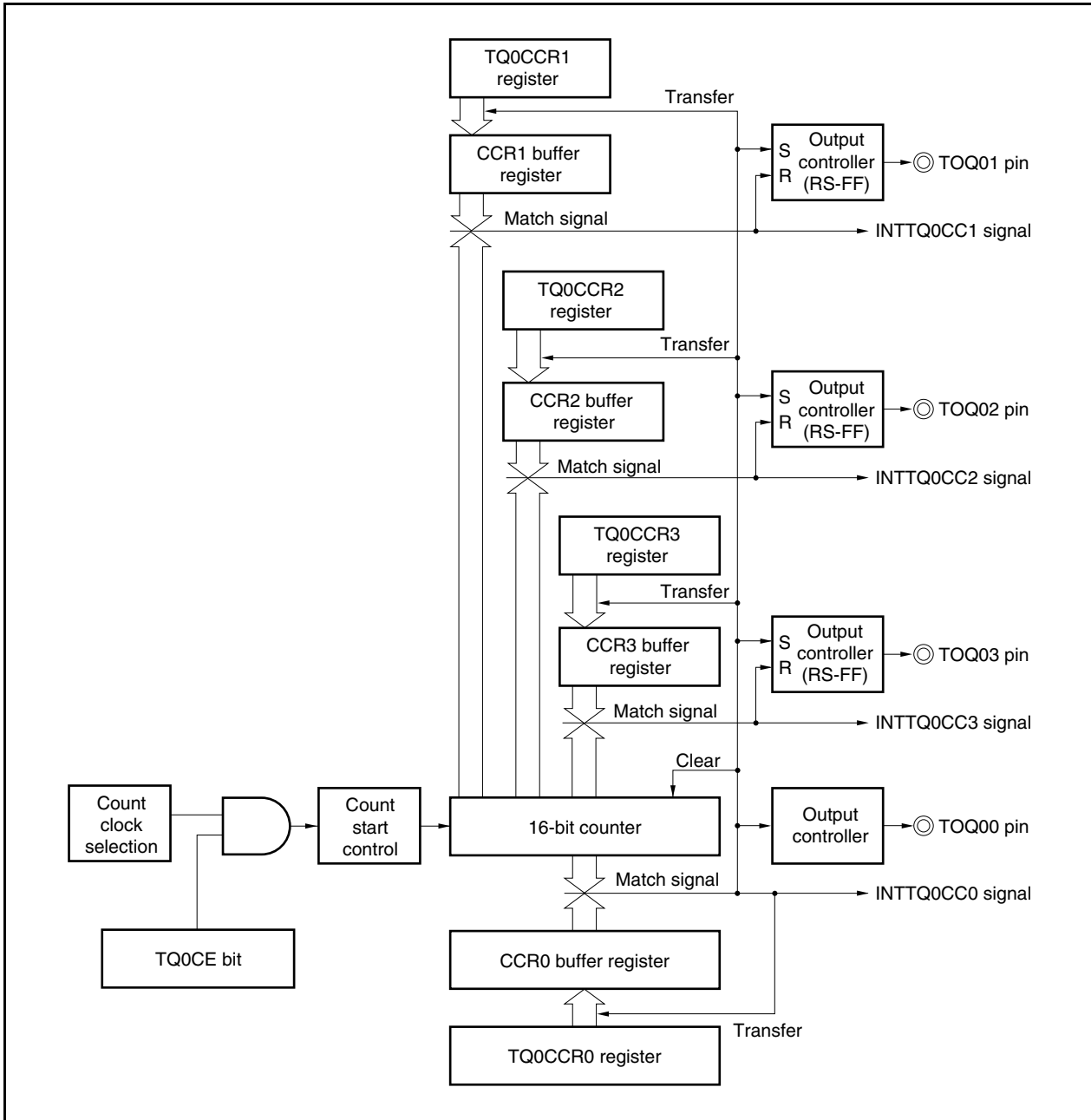
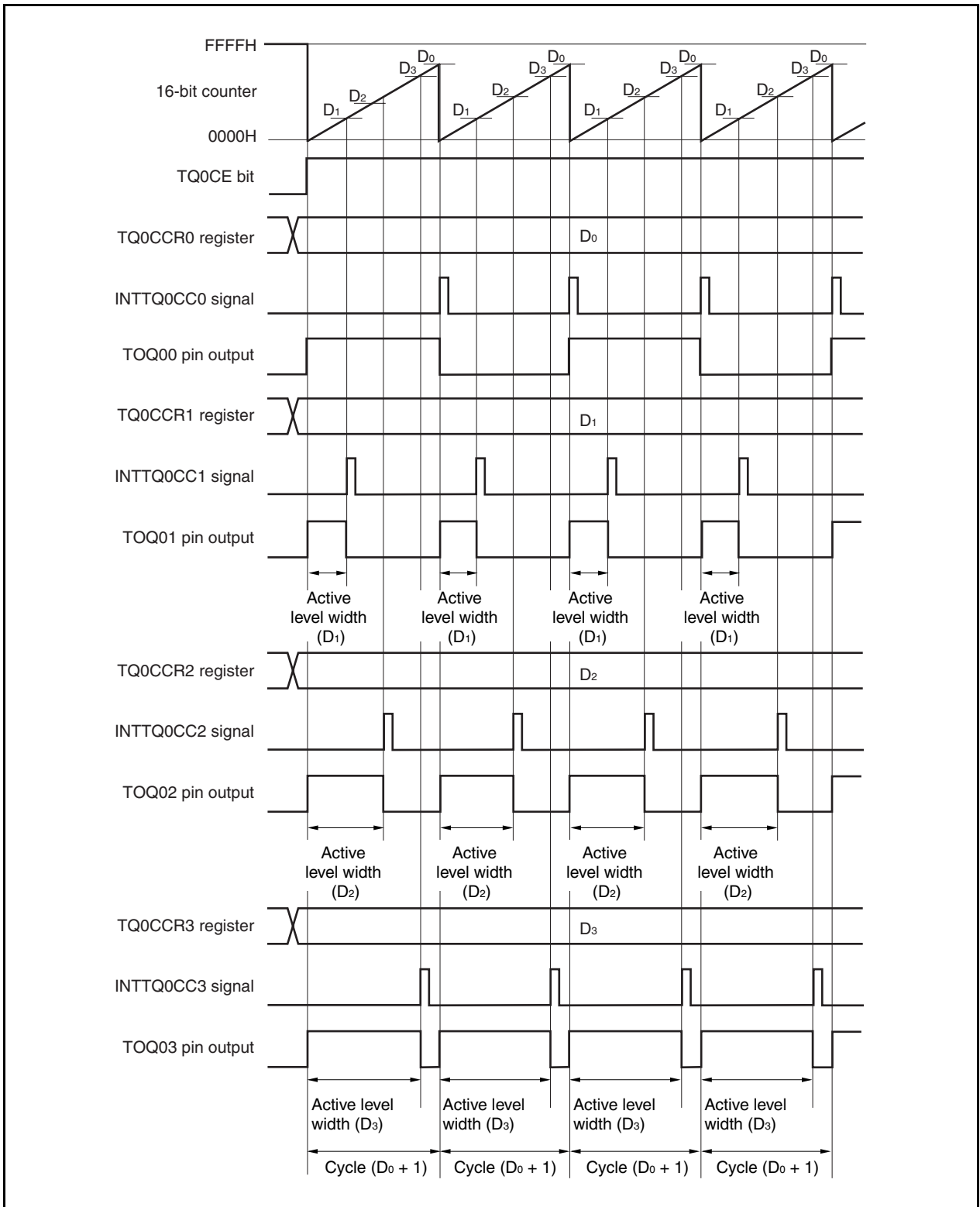


Figure 8-25. Basic Timing in PWM Output Mode



When the TQ0CE bit is set to 1, the 16-bit counter is cleared from FFFFH to 0000H, starts counting, and outputs PWM waveform from the TOQ0k pin.

The active level width, cycle, and duty factor of the PWM waveform can be calculated as follows.

$$\text{Active level width} = (\text{Set value of TQ0CCRk register}) \times \text{Count clock cycle}$$

$$\text{Cycle} = (\text{Set value of TQ0CCR0 register} + 1) \times \text{Count clock cycle}$$

$$\text{Duty factor} = (\text{Set value of TQ0CCRk register}) / (\text{Set value of TQ0CCR0 register} + 1)$$

The PWM waveform can be changed by rewriting the TQ0CCRm register while the counter is operating. The newly written value is reflected when the count value of the 16-bit counter matches the value of the CCR0 buffer register and the 16-bit counter is cleared to 0000H.

The compare match interrupt request signal INTTQ0CC0 is generated when the 16-bit counter counts next time after its count value matches the value of the CCR0 buffer register, and the 16-bit counter is cleared to 0000H. The compare match interrupt request signal INTTQ0CCK is generated when the count value of the 16-bit counter matches the value of the CCRk buffer register.

**Remark** k = 1 to 3, m = 0 to 3

**Figure 8-26. Register Setting for Operation in PWM Output Mode (1/3)**

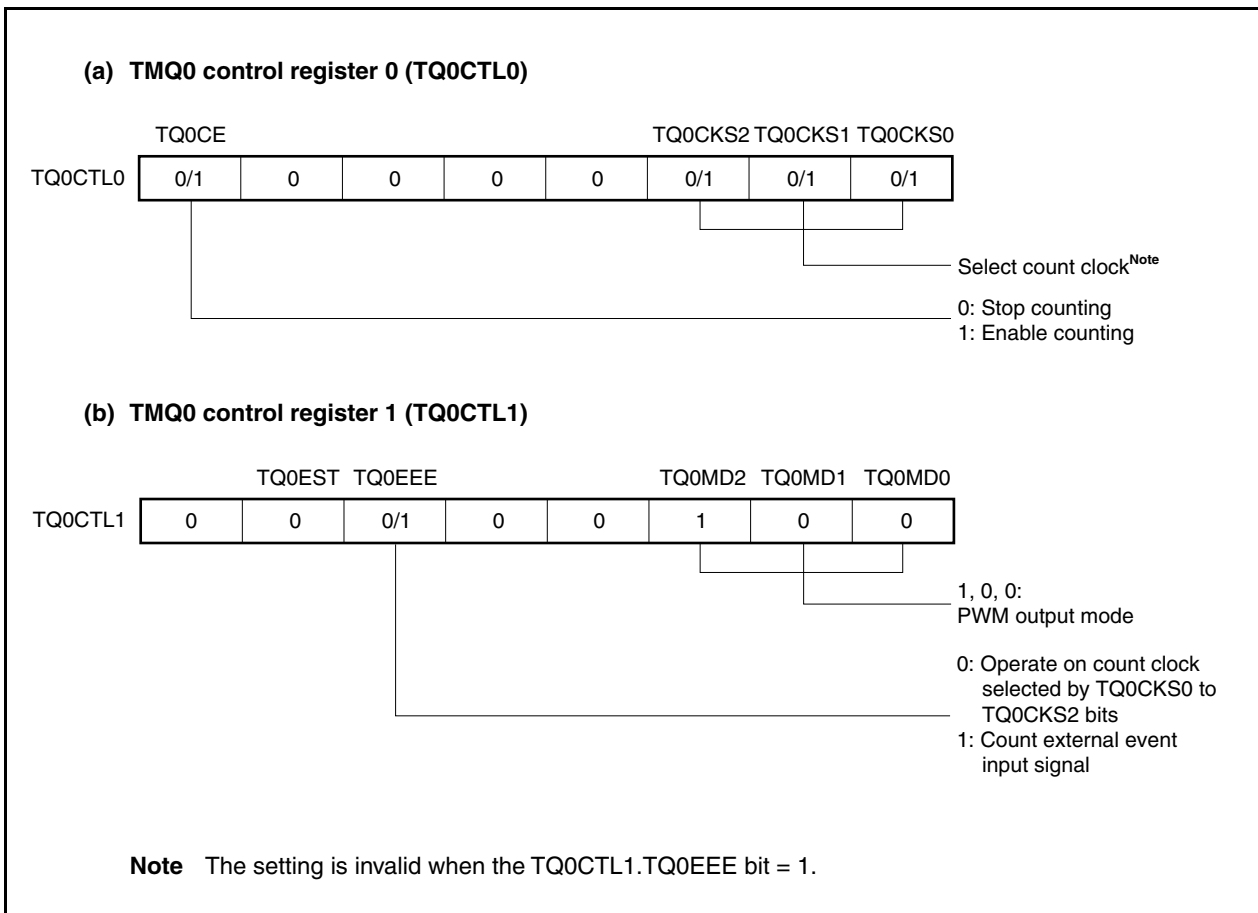


Figure 8-26. Register Setting for Operation in PWM Output Mode (2/3)

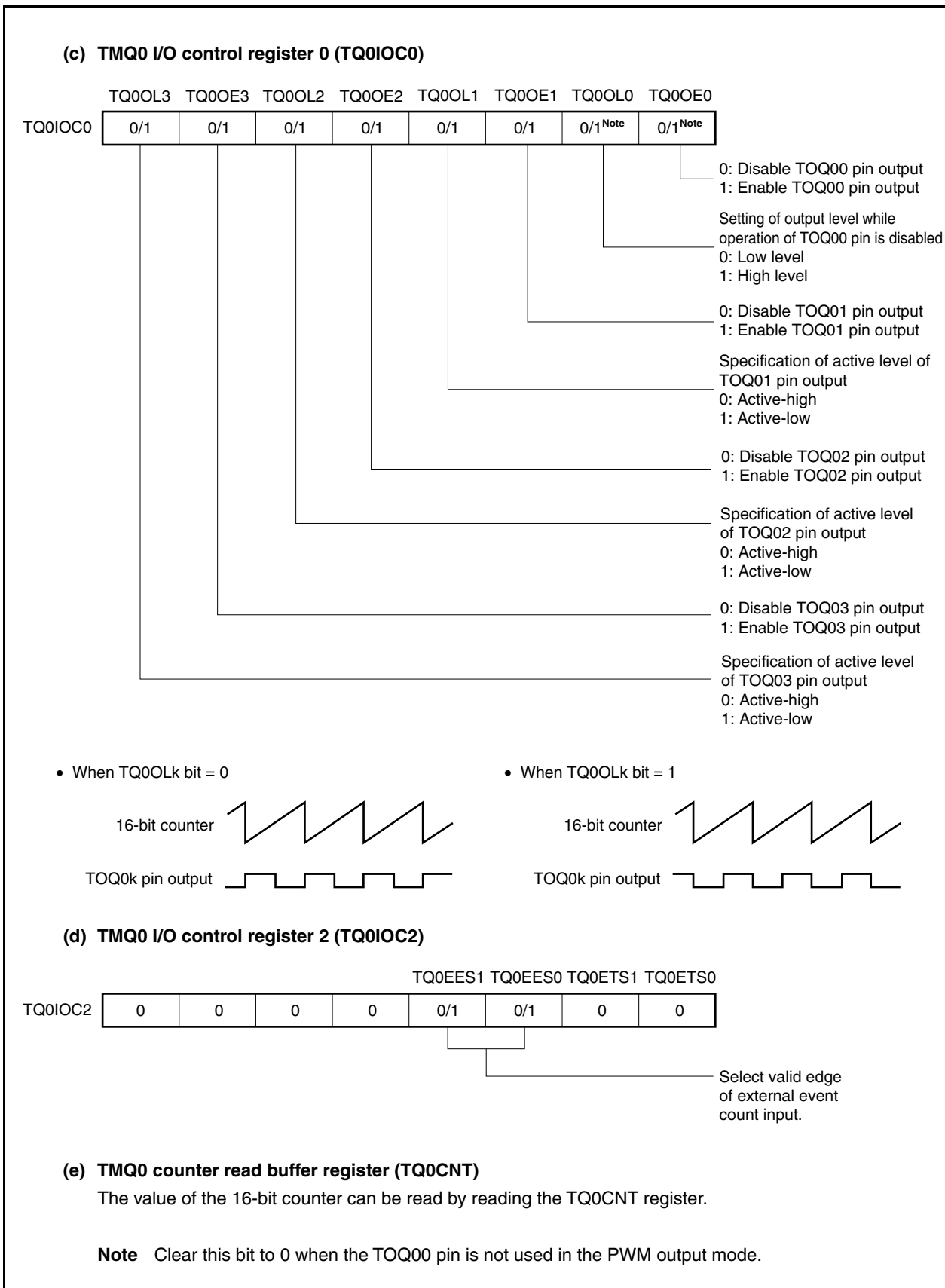


Figure 8-26. Register Setting for Operation in PWM Output Mode (3/3)

**(f) TMQ0 capture/compare registers 0 to 3 (TQ0CCR0 to TQ0CCR3)**

If  $D_0$  is set to the TQ0CCR0 register and  $D_k$  to the TQ0CCR1 register, the cycle and active level of the PWM waveform are as follows.

$$\text{Cycle} = (D_0 + 1) \times \text{Count clock cycle}$$

$$\text{Active level width} = D_k \times \text{Count clock cycle}$$

- Remarks**
1. TMQ0 I/O control register 1 (TQ0IOC1) and TMQ0 option register 0 (TQ0OPT0) are not used in the PWM output mode.
  2. Updating the TMQ0 capture/compare register 2 (TQ0CCR2) and TMQ0 capture/compare register 3 (TQ0CCR3) is validated by writing the TMQ0 capture/compare register 1 (TQ0CCR1).



(1) Operation flow in PWM output mode

Figure 8-27. Software Processing Flow in PWM Output Mode (1/2)

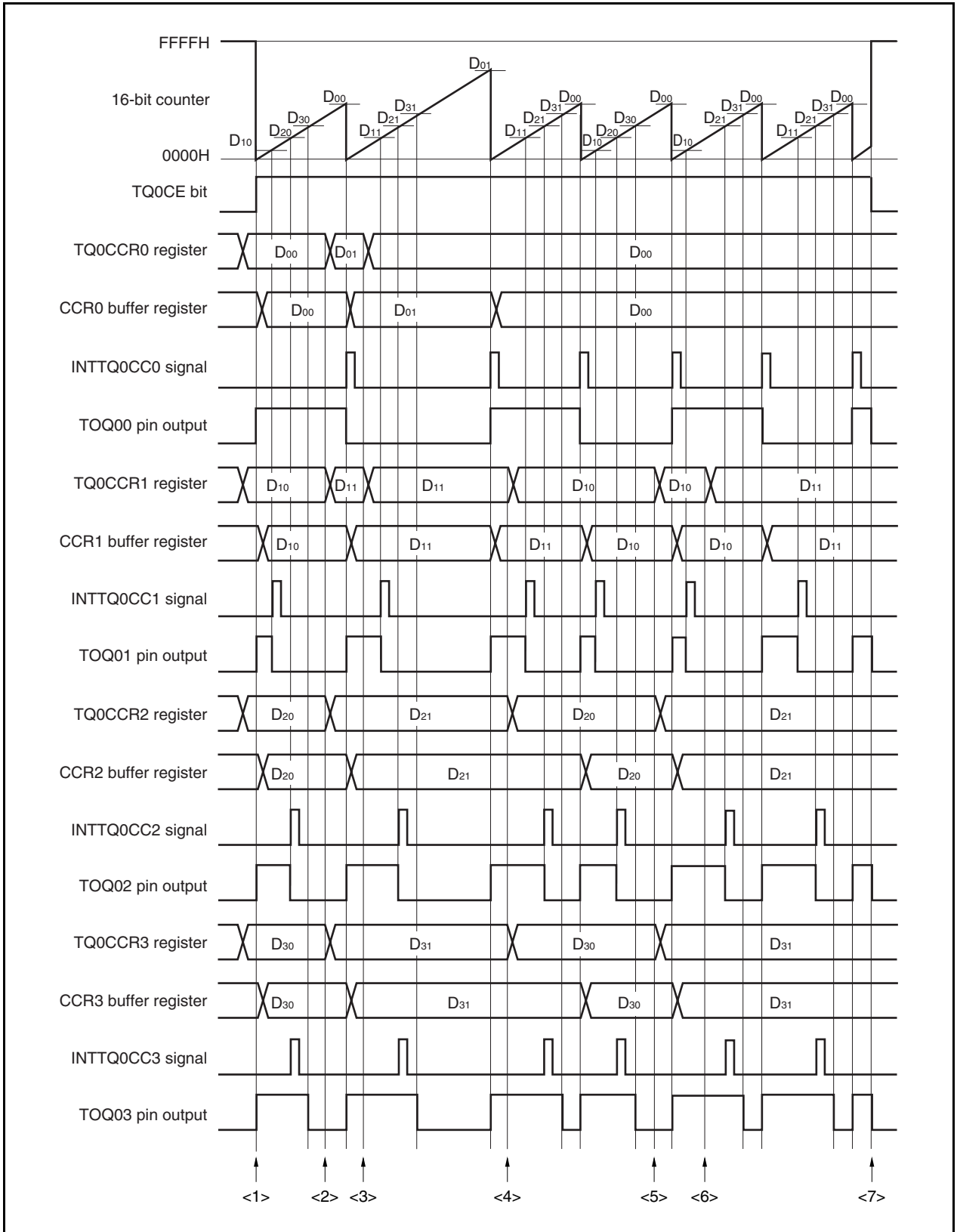
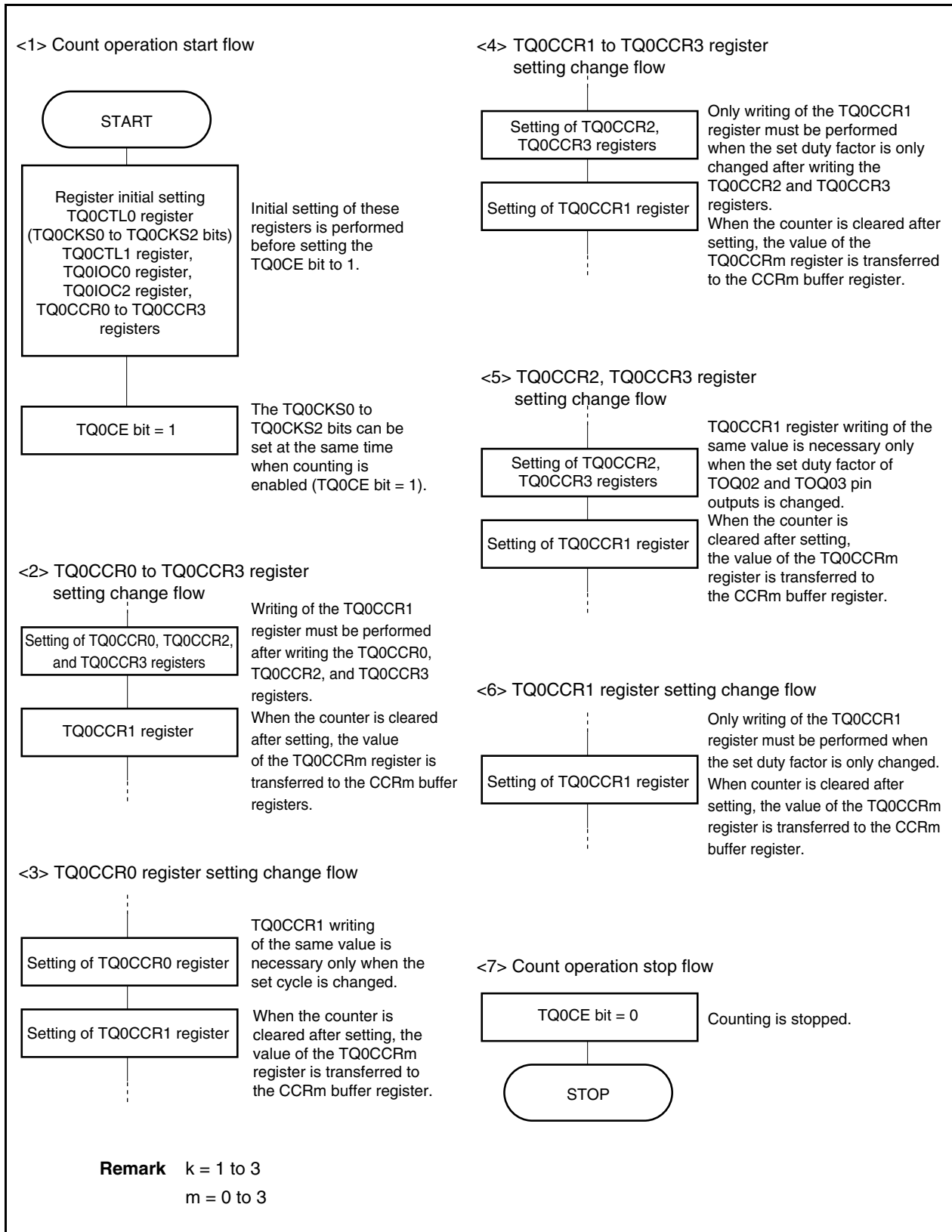


Figure 8-27. Software Processing Flow in PWM Output Mode (2/2)

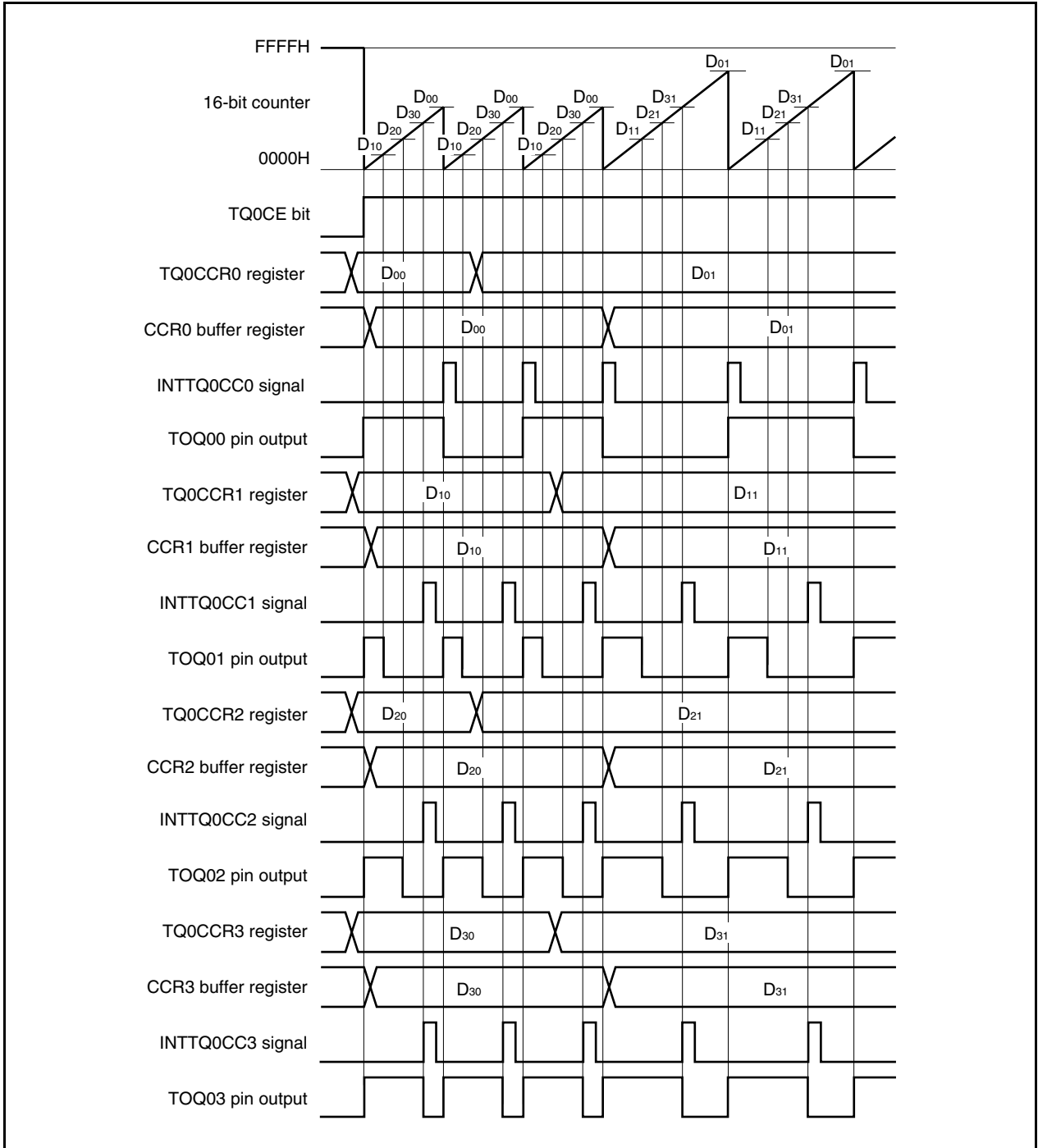


(2) PWM output mode operation timing

(a) Changing pulse width during operation

To change the PWM waveform while the counter is operating, write the TQ0CCR1 register last.

Rewrite the TQ0CCRk register after writing the TQ0CCR1 register after the INTTQ0CC1 signal is detected.



To transfer data from the TQ0CCRm register to the CCRm buffer register, the TQ0CCR1 register must be written.

To change both the cycle and active level of the PWM waveform at this time, first set the cycle to the TQ0CCR0 register, set the active level width to the TQ0CCR2 and TQ0CCR3 registers, and then set an active level width to the TQ0CCR1 register.

To change only the active level width (duty factor) of PWM wave, first set the active level to the TQ0CCR2 and TQ0CCR3 registers, and then set an active level to the TQ0CCR1 register.

To change only the active level width (duty factor) of the PWM waveform output by the TOQ01 pin, only the TQ0CCR1 register has to be set.

To change only the active level width (duty factor) of the PWM waveform output by the TOQ02 and TOQ03 pins, first set an active level width to the TQ0CCR2 and TQ0CCR3 registers, and then write the same value to the TQ0CCR1 register.

After the TQ0CCR1 register is written, the value written to the TQ0CCRm register is transferred to the CCRm buffer register in synchronization with the timing of clearing the 16-bit counter, and is used as a value to be compared with the value of the 16-bit counter.

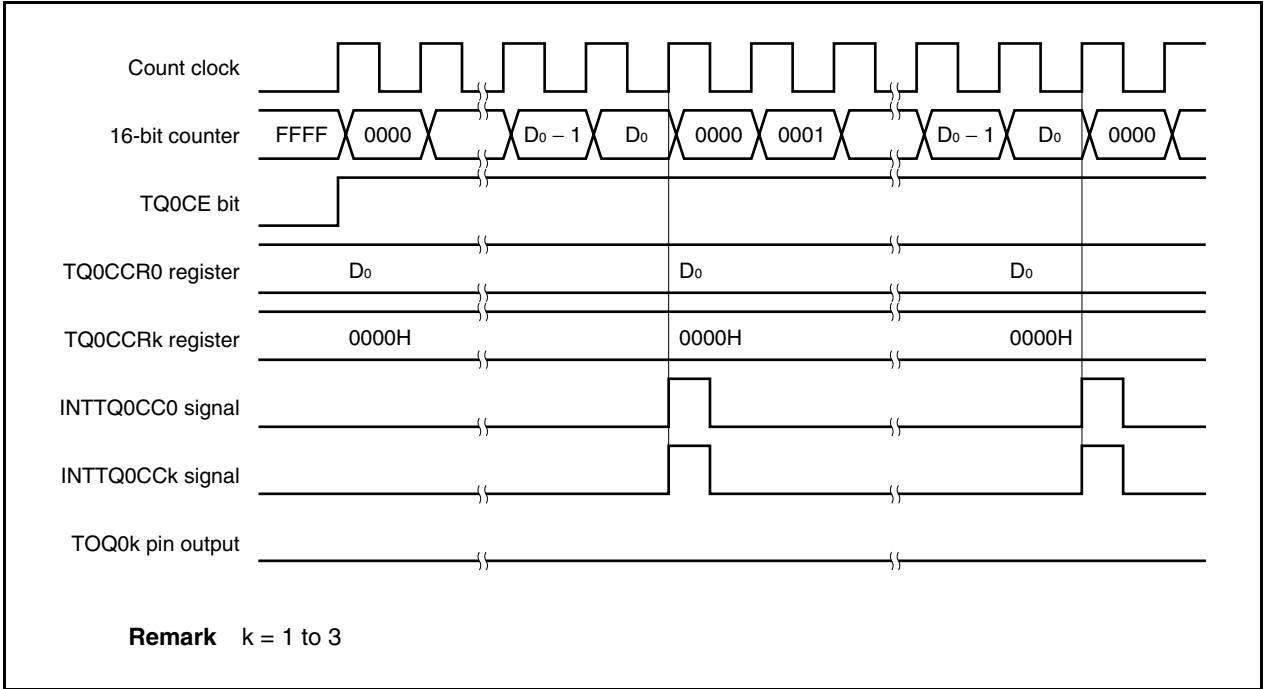
To change only the cycle of the PWM waveform, first set a cycle to the TQ0CCR0 register, and then write the same value to the TQ0CCR1 register.

To write the TQ0CCR0 to TQ0CCR3 registers again after writing the TQ0CCR1 register once, do so after the INTTQ0CC0 signal is generated. Otherwise, the value of the CCRm buffer register may become undefined because the timing of transferring data from the TQ0CCRm register to the CCRm buffer register conflicts with writing the TQ0CCRm register.

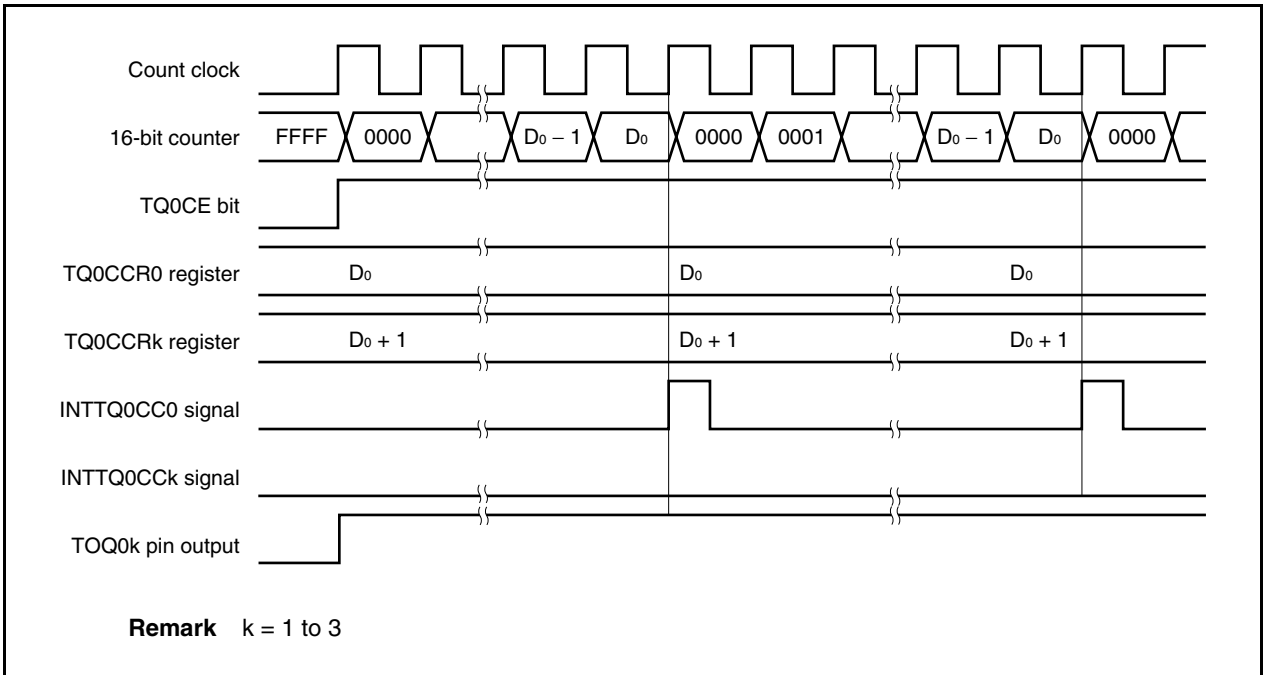
**Remark** m = 0 to 3

**(b) 0%/100% output of PWM waveform**

To output a 0% waveform, set the TQ0CCRk register to 0000H. If the set value of the TQ0CCR0 register is FFFFH, the INTTQ0CCk signal is generated periodically.

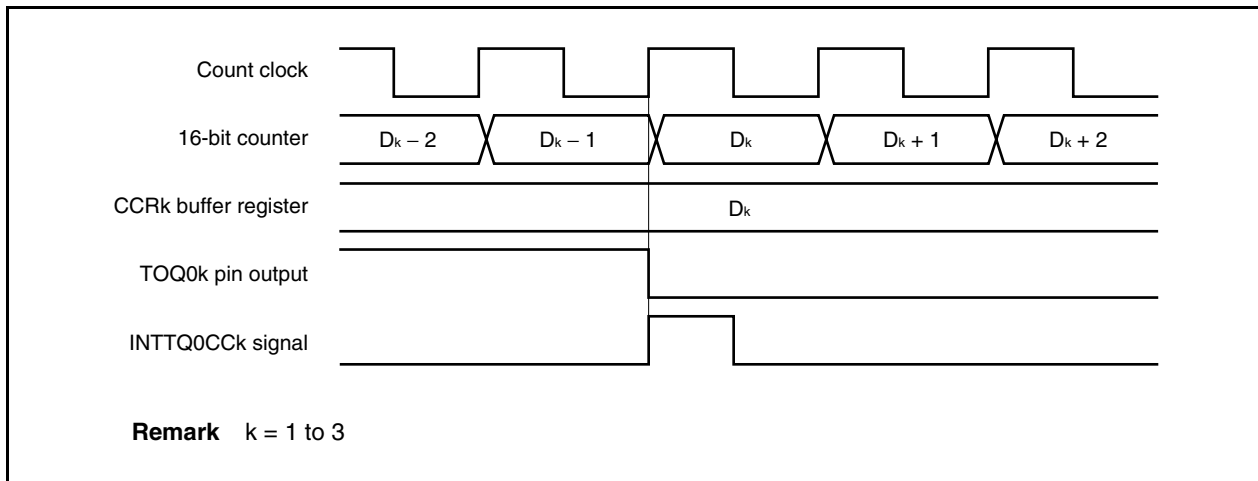


To output a 100% waveform, set a value of (set value of TQ0CCR0 register + 1) to the TQ0CCRk register. If the set value of the TQ0CCR0 register is FFFFH, 100% output cannot be produced.



**(c) Generation timing of compare match interrupt request signal (INTTQ0CCK)**

The timing of generation of the INTTQ0CCK signal in the PWM output mode differs from the timing of other INTTQ0CCK signals; the INTTQ0CCK signal is generated when the count value of the 16-bit counter matches the value of the TQ0CCRk register.



Usually, the INTTQ0CCK signal is generated in synchronization with the next counting up after the count value of the 16-bit counter matches the value of the TQ0CCRk register.

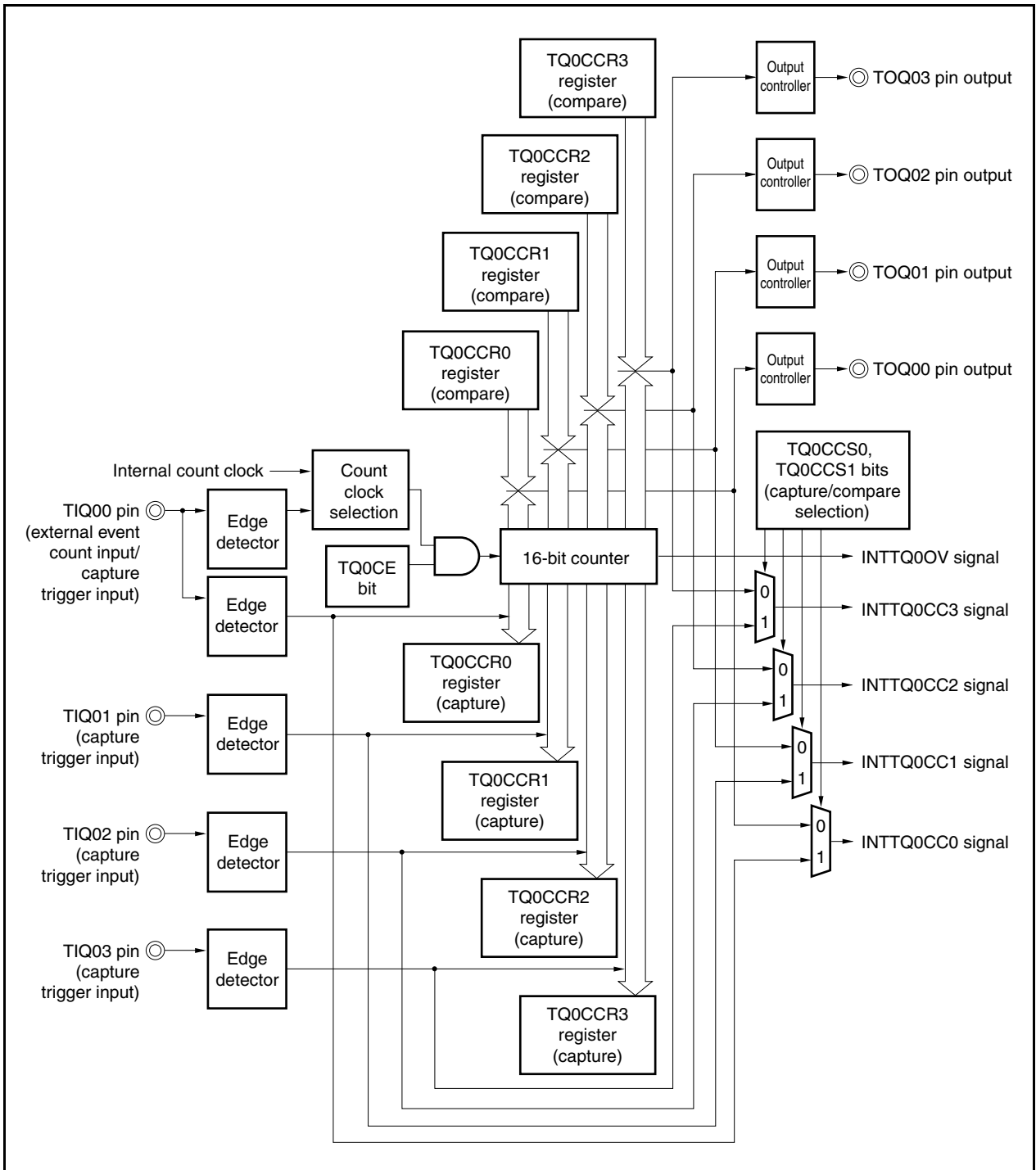
In the PWM output mode, however, it is generated one clock earlier. This is because the timing is changed to match the change timing of the output signal of the TOQ0k pin.

**8.5.6 Free-running timer mode (TQ0MD2 to TQ0MD0 bits = 101)**

In the free-running timer mode, 16-bit timer/event counter Q starts counting when the TQ0CTL0.TQ0CE bit is set to 1. At this time, the TQ0CCRm register can be used as a compare register or a capture register, depending on the setting of the TQ0OPT0.TQ0CCS0 and TQ0OPT0.TQ0CCS1 bits.

**Remark** m = 0 to 3

**Figure 8-28. Configuration in Free-Running Timer Mode**

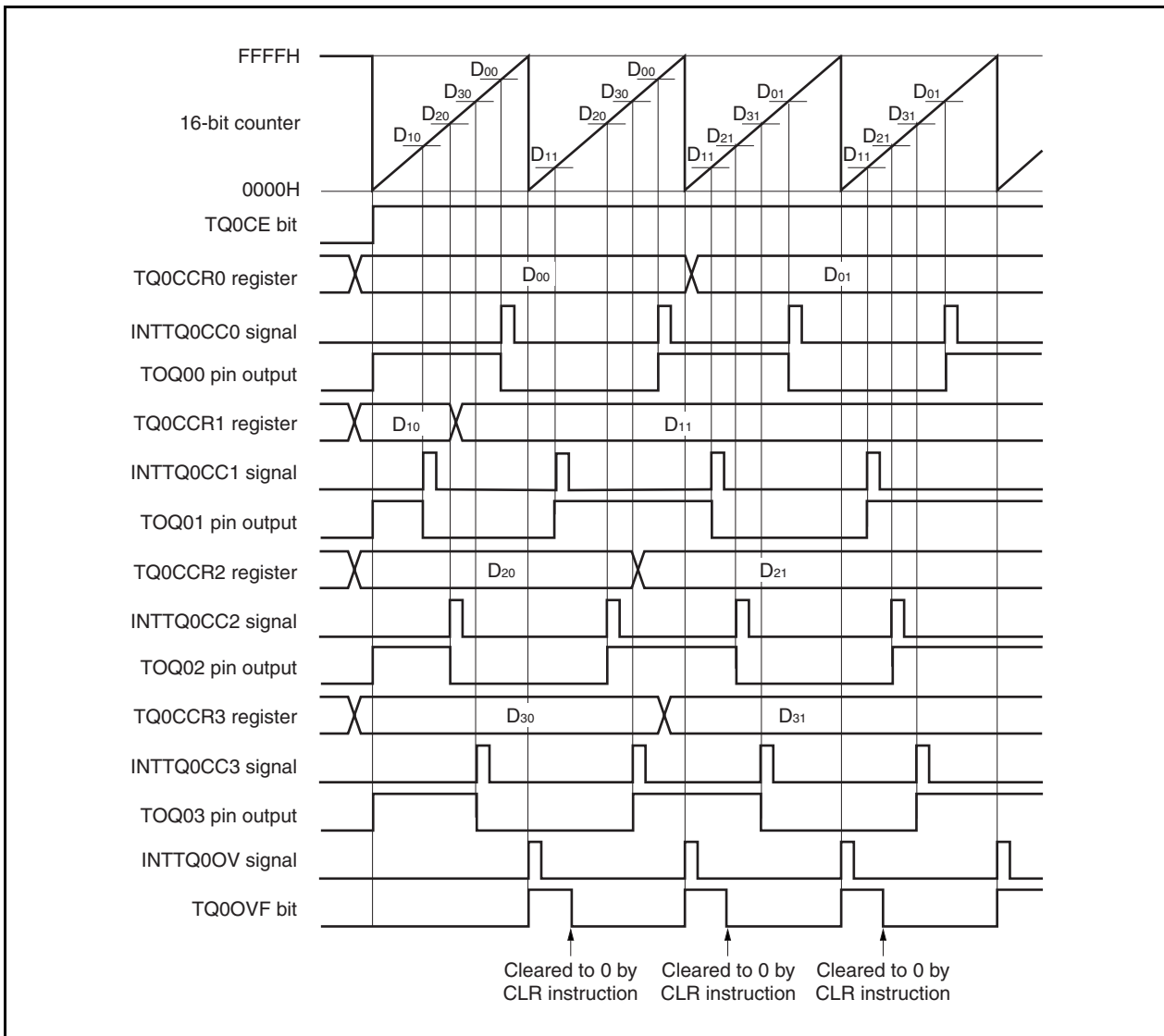


When the TQ0CE bit is set to 1, 16-bit timer/event counter Q starts counting, and the output signals of the TOQ00 to TOQ03 pins are inverted. When the count value of the 16-bit counter later matches the set value of the TQ0CCRm register, a compare match interrupt request signal (INTTQ0CCm) is generated, and the output signal of the TOQ0m pin is inverted.

The 16-bit counter continues counting in synchronization with the count clock. When it counts up to FFFFH, it generates an overflow interrupt request signal (INTTQ0OV) at the next clock, is cleared to 0000H, and continues counting. At this time, the overflow flag (TQ0OPT0.TQ0OVF bit) is also set to 1. Clear the overflow flag to 0 by executing the CLR instruction by software.

The TQ0CCRm register can be rewritten while the counter is operating. If it is rewritten, the new value is reflected at that time, and compared with the count value.

**Figure 8-29. Basic Timing in Free-Running Timer Mode (Compare Function)**





When the TQ0CE bit is set to 1, the 16-bit counter starts counting. When the valid edge input to the TIQ0m pin is detected, the count value of the 16-bit counter is stored in the TQ0CCRm register, and a capture interrupt request signal (INTTQ0CCm) is generated.

The 16-bit counter continues counting in synchronization with the count clock. When it counts up to FFFFH, it generates an overflow interrupt request signal (INTTQ0OV) at the next clock, is cleared to 0000H, and continues counting. At this time, the overflow flag (TQ0OVF bit) is also set to 1. Clear the overflow flag to 0 by executing the CLR instruction by software.

Figure 8-30. Basic Timing in Free-Running Timer Mode (Capture Function)

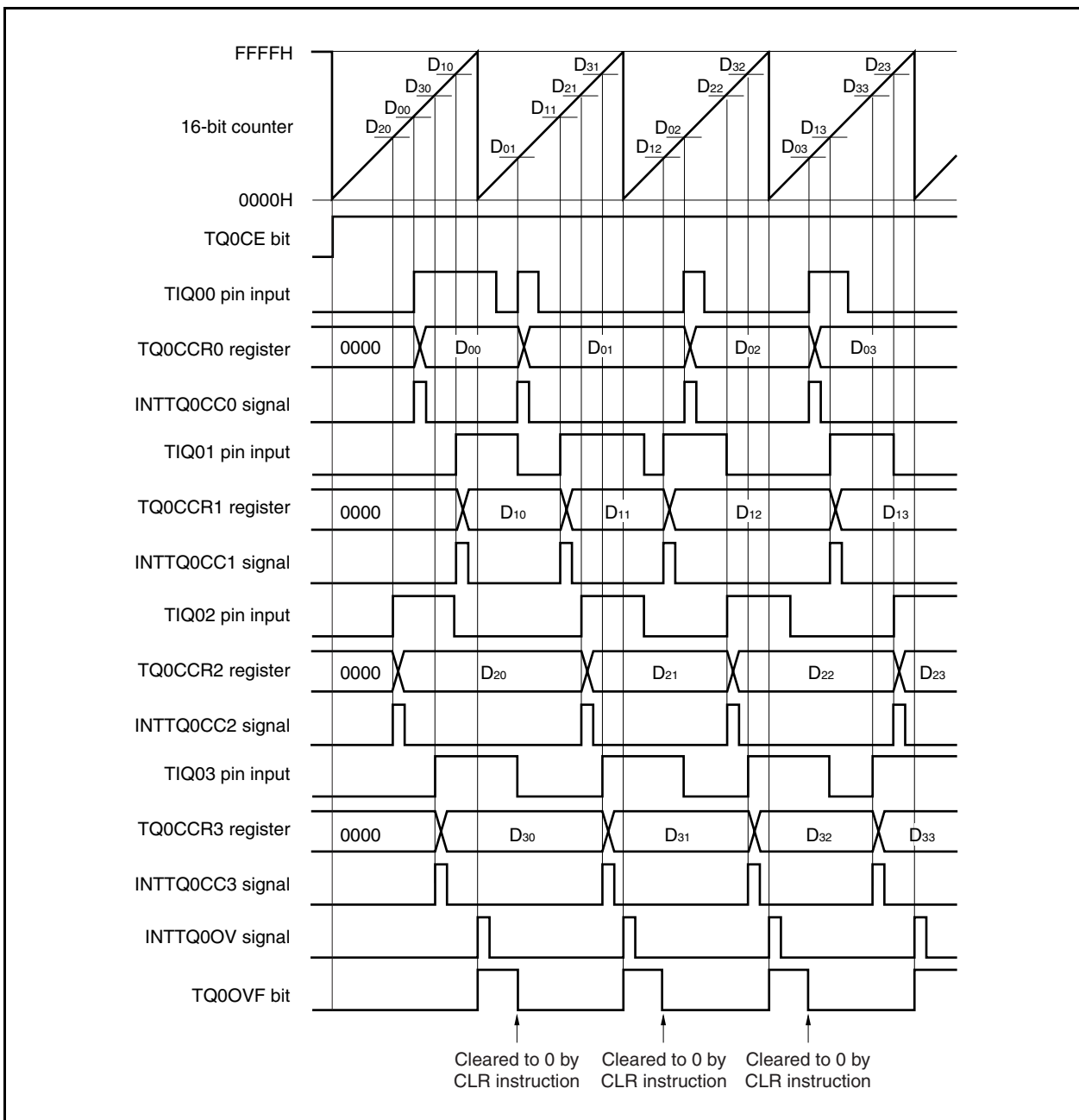


Figure 8-31. Register Setting in Free-Running Timer Mode (1/3)

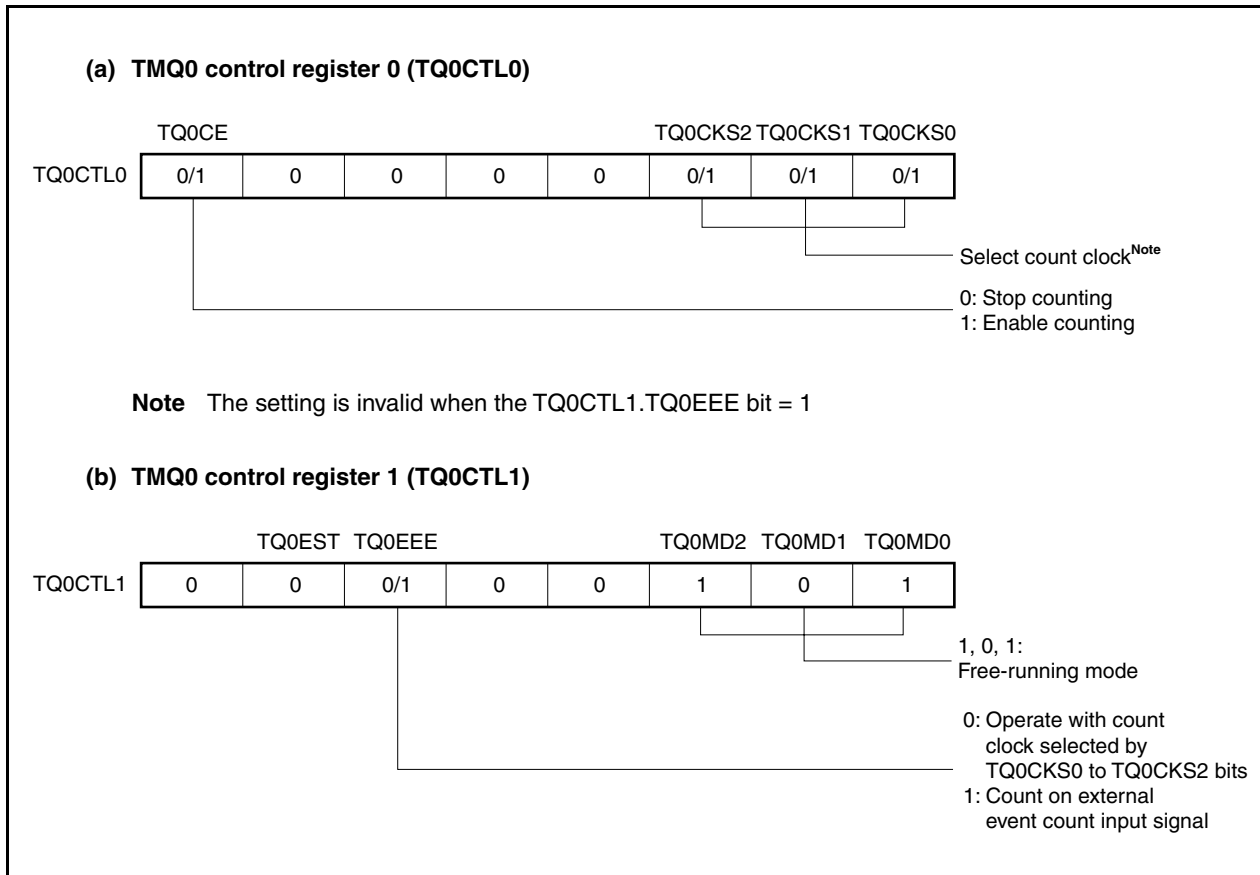


Figure 8-31. Register Setting in Free-Running Timer Mode (2/3)

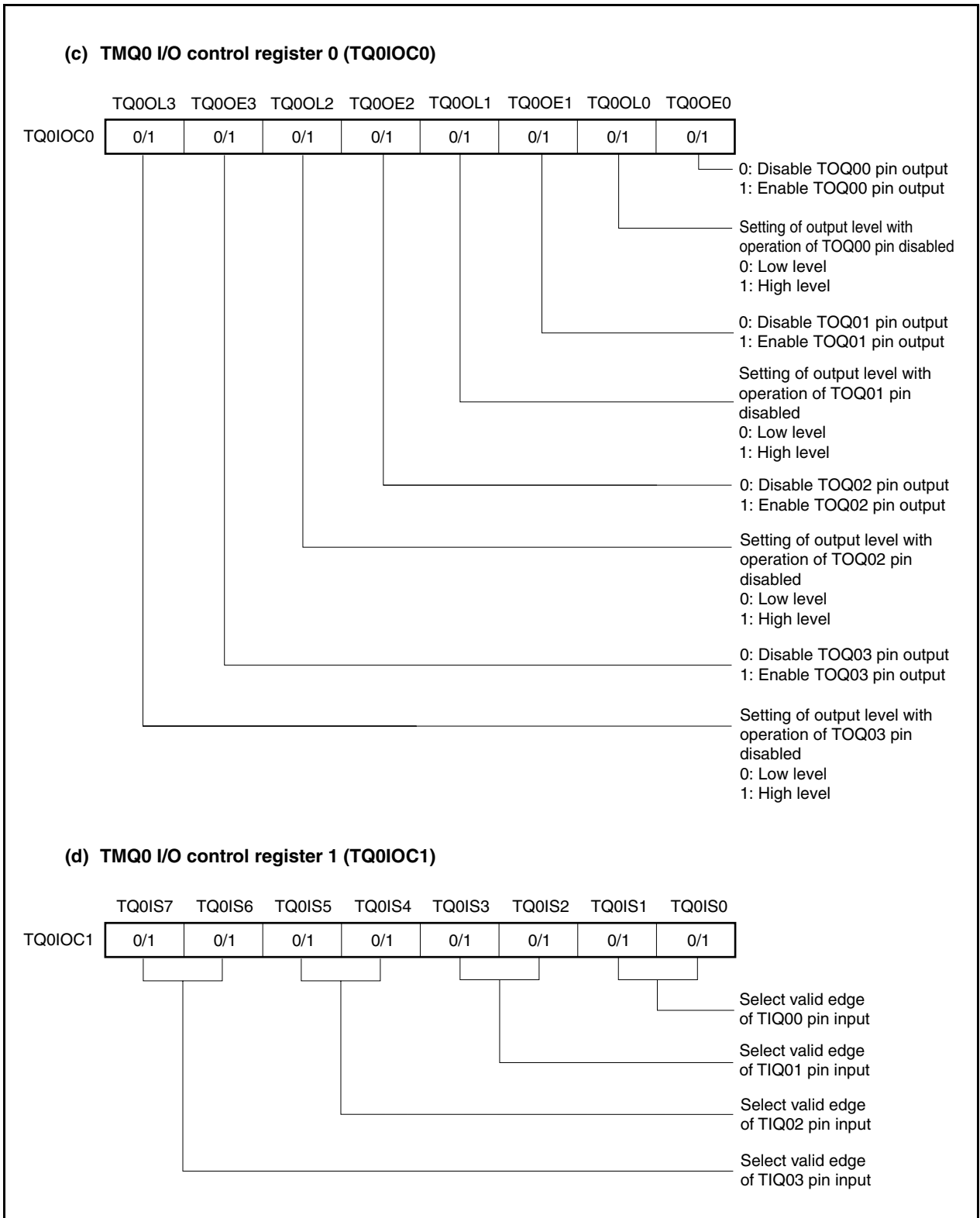
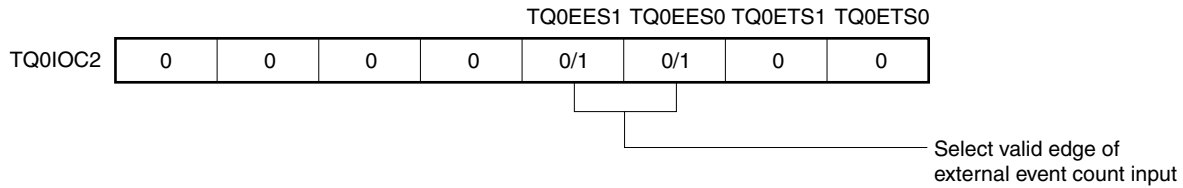
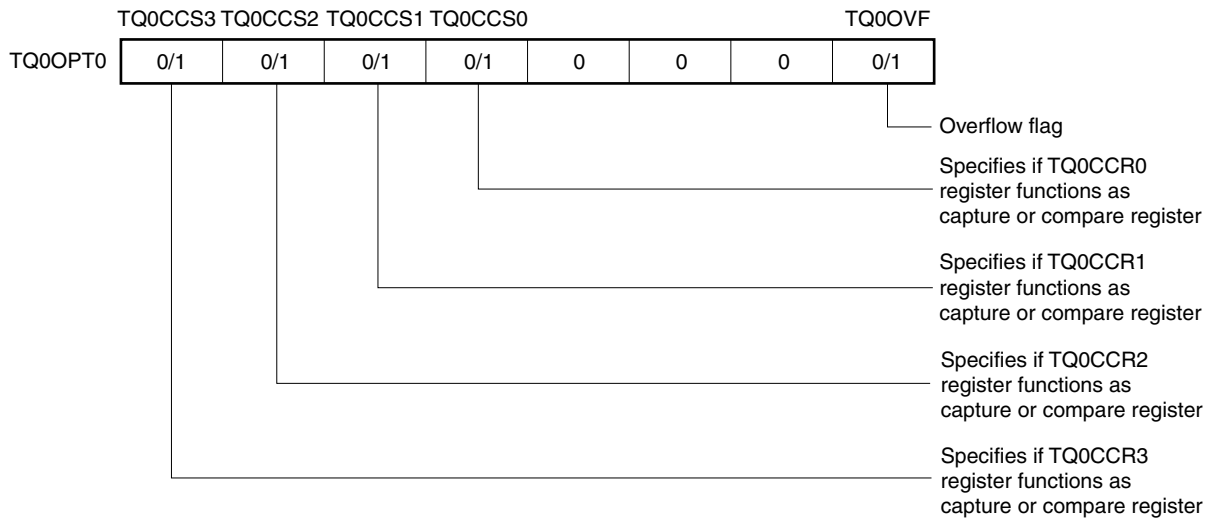


Figure 8-31. Register Setting in Free-Running Timer Mode (3/3)

(e) TMQ0 I/O control register 2 (TQ0IOC2)



(f) TMQ0 option register 0 (TQ0OPT0)



(g) TMQ0 counter read buffer register (TQ0CNT)

The value of the 16-bit counter can be read by reading the TQ0CNT register.

(h) TMQ0 capture/compare registers 0 to 3 (TQ0CCR0 to TQ0CCR3)

These registers function as capture registers or compare registers depending on the setting of the TQ0OPT0.TQ0CCSm bit.

When the registers function as capture registers, they store the count value of the 16-bit counter when the valid edge input to the TIQ0m pin is detected.

When the registers function as compare registers and when D<sub>m</sub> is set to the TQ0CCRm register, the INTTQ0CCm signal is generated when the counter reaches (D<sub>m</sub> + 1), and the output signal of the TOQ0m pin is inverted.

**Remark** m = 0 to 3

(1) Operation flow in free-running timer mode

(a) When using capture/compare register as compare register

Figure 8-32. Software Processing Flow in Free-Running Timer Mode (Compare Function) (1/2)

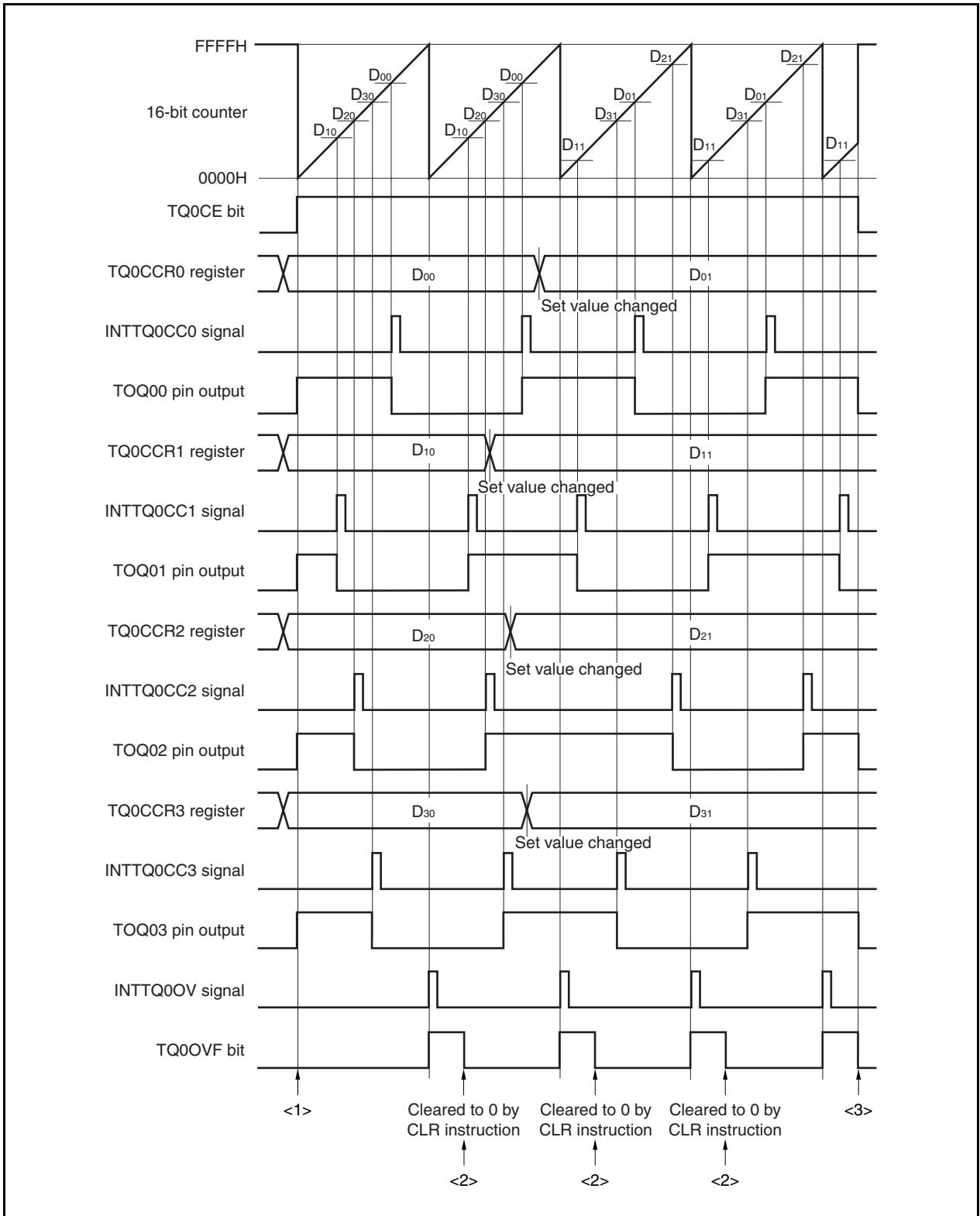
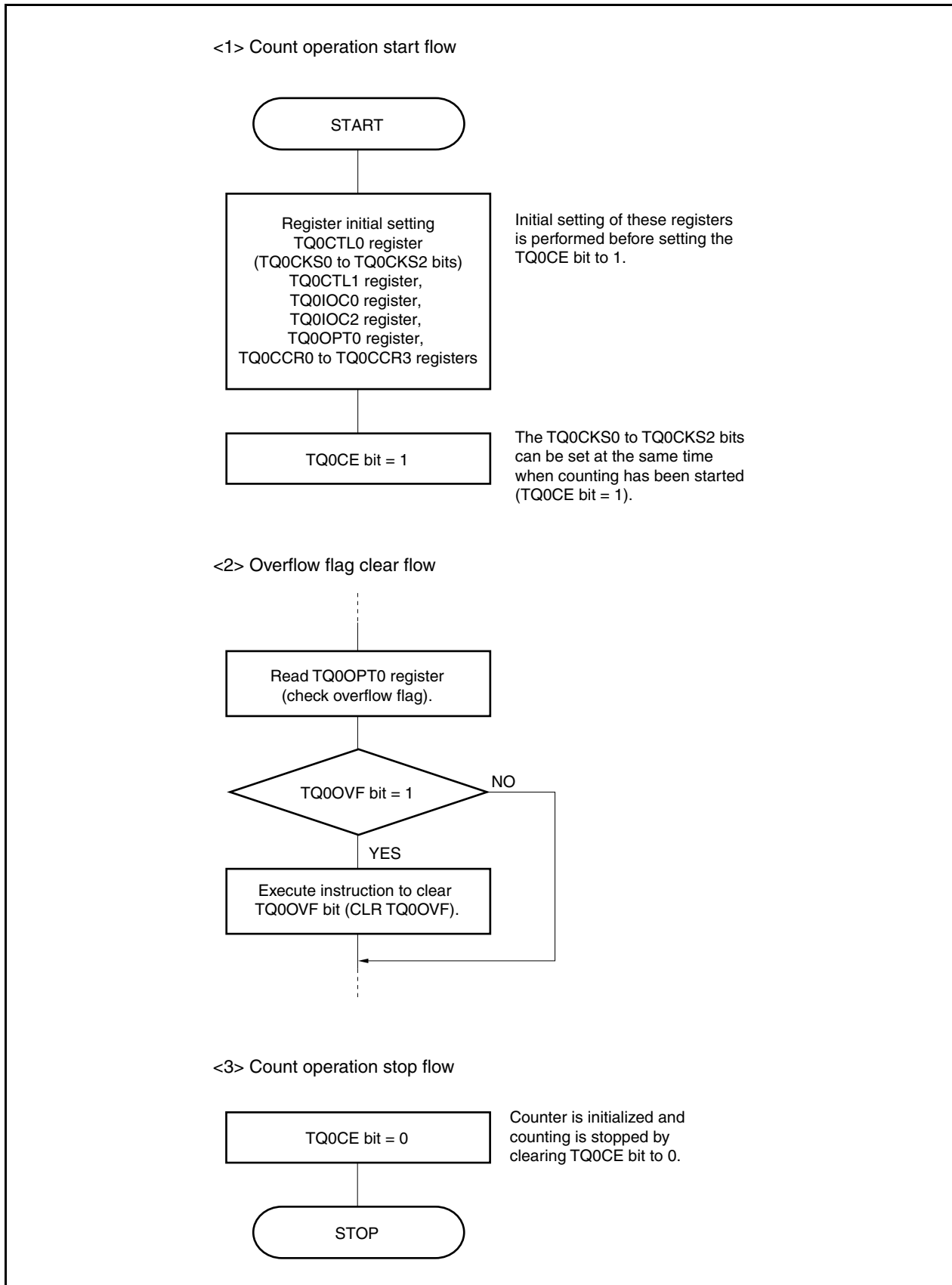


Figure 8-32. Software Processing Flow in Free-Running Timer Mode (Compare Function) (2/2)



(b) When using capture/compare register as capture register

Figure 8-33. Software Processing Flow in Free-Running Timer Mode (Capture Function) (1/2)

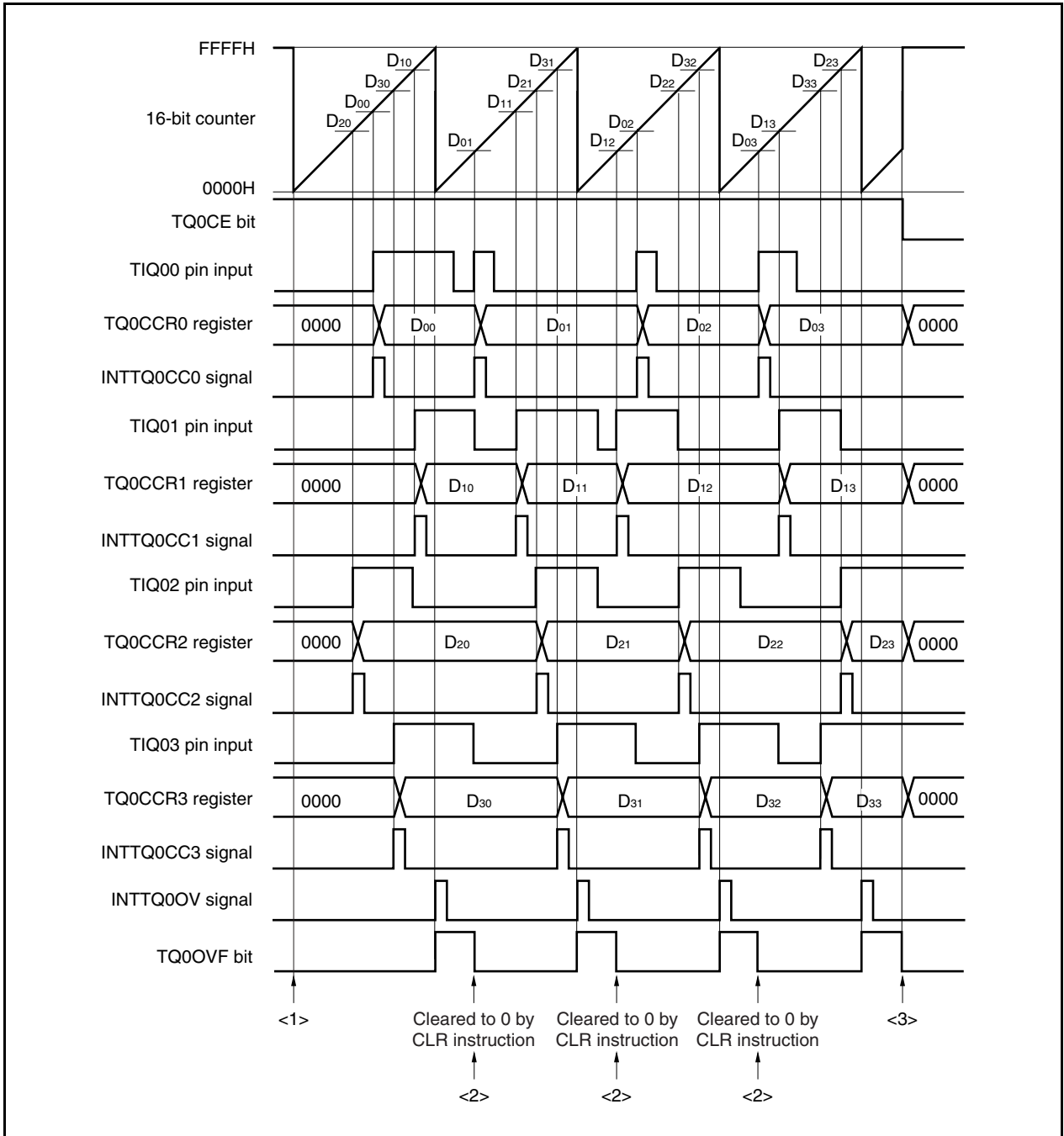
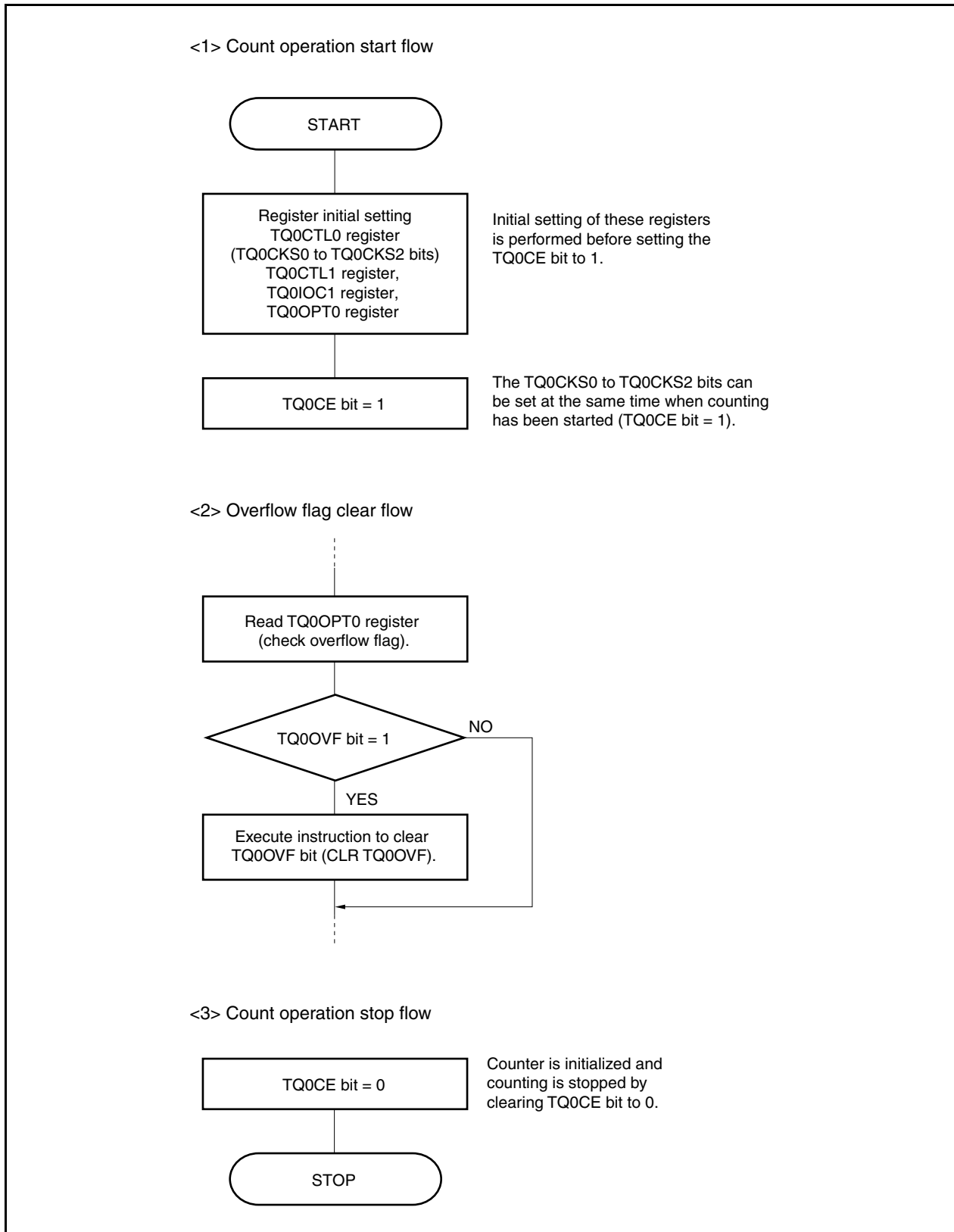


Figure 8-33. Software Processing Flow in Free-Running Timer Mode (Capture Function) (2/2)

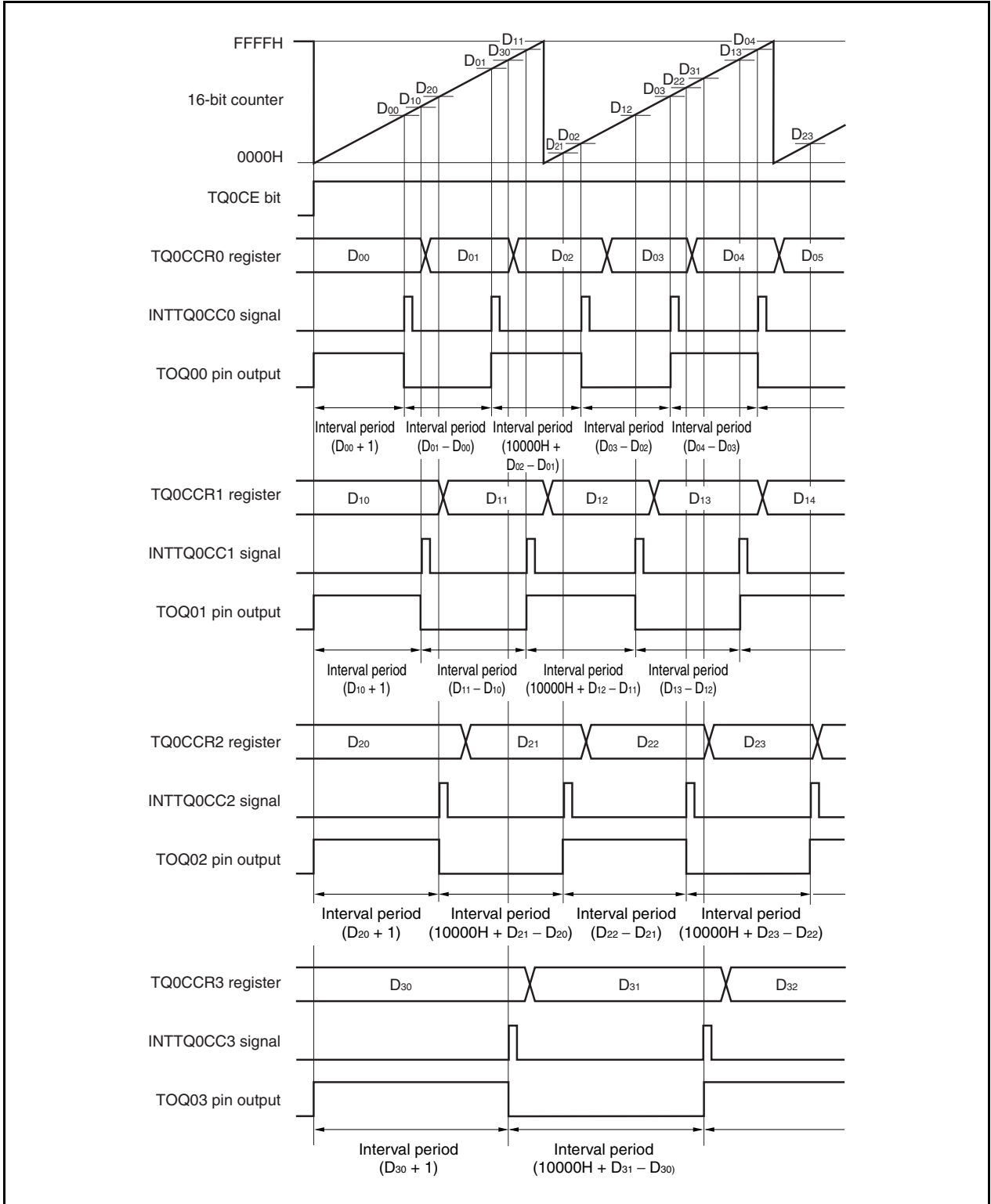




(2) Operation timing in free-running timer mode

(a) Interval operation with compare register

When 16-bit timer/event counter Q is used as an interval timer with the TQ0CCRm register used as a compare register, software processing is necessary for setting a comparison value to generate the next interrupt request signal each time the INTTQ0CCm signal has been detected.



When performing an interval operation in the free-running timer mode, two intervals can be set with one channel.

To perform the interval operation, the value of the corresponding TQ0CCR<sub>m</sub> register must be re-set in the interrupt servicing that is executed when the INTTQ0CC<sub>m</sub> signal is detected.

The set value for re-setting the TQ0CCR<sub>m</sub> register can be calculated by the following expression, where "D<sub>m</sub>" is the interval period.

Compare register default value:  $D_m - 1$

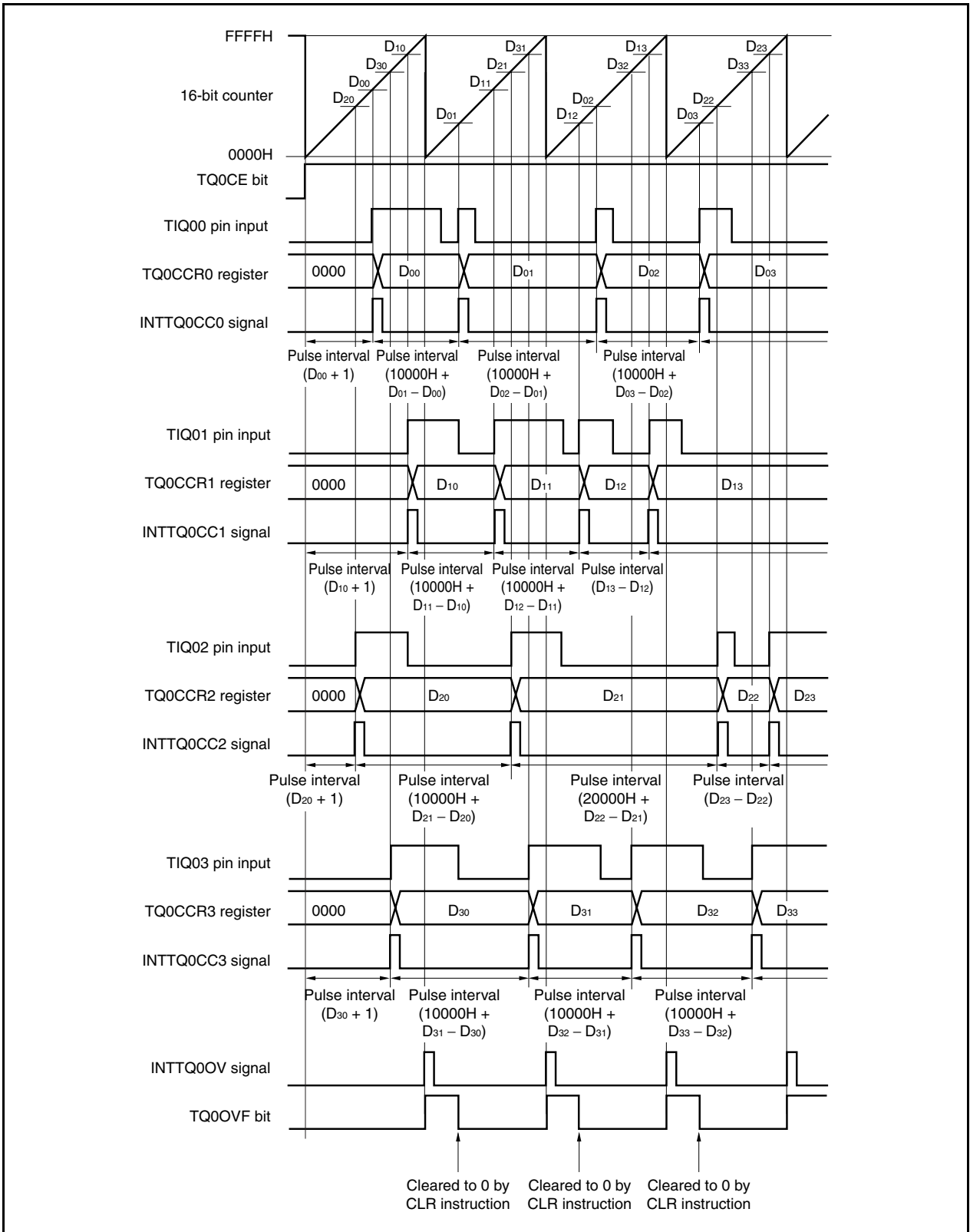
Value set to compare register second and subsequent time: Previous set value +  $D_m$

(If the calculation result is greater than FFFFH, subtract 10000H from the result and set this value to the register.)

**Remark** m = 0 to 3

**(b) Pulse width measurement with capture register**

When pulse width measurement is performed with the TQ0CCRm register used as a capture register, software processing is necessary for reading the capture register each time the INTTQ0CCm signal has been detected and for calculating an interval.



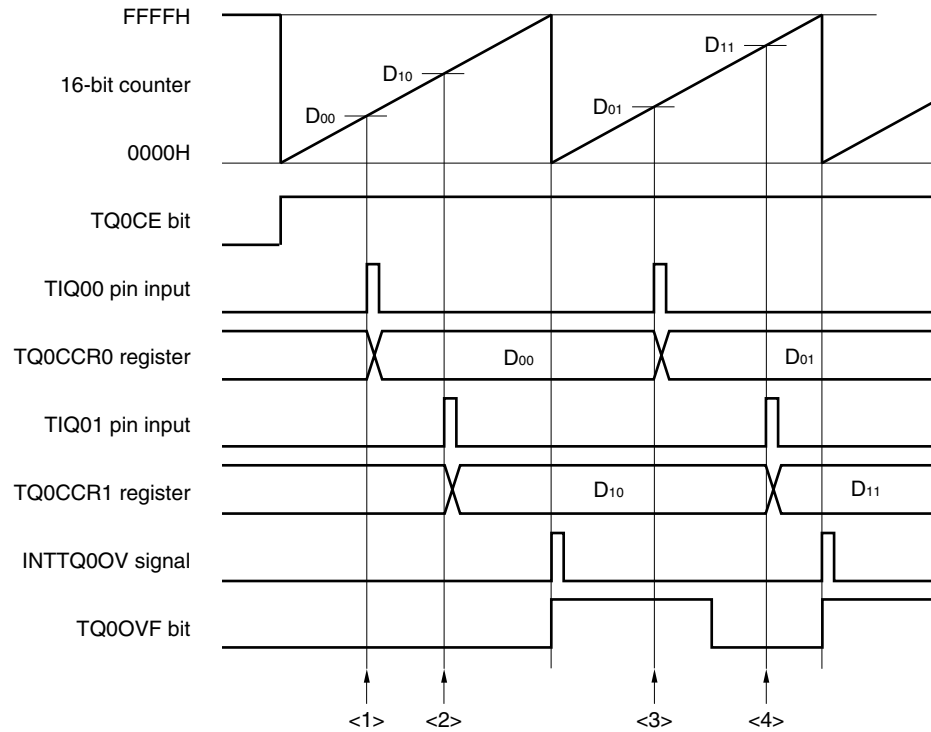
When executing pulse width measurement in the free-running timer mode, four pulse widths can be measured with one channel.

To measure a pulse width, the pulse width can be calculated by reading the value of the TQ0CCRm register in synchronization with the INTTQ0CCm signal, and calculating the difference between the read value and the previously read value.

**Remark** m = 0 to 3

**(c) Processing of overflow when two or more capture registers are used**

Care must be exercised in processing the overflow flag when two capture registers are used. First, an example of incorrect processing is shown below.

**Example of incorrect processing when two or more capture registers are used**

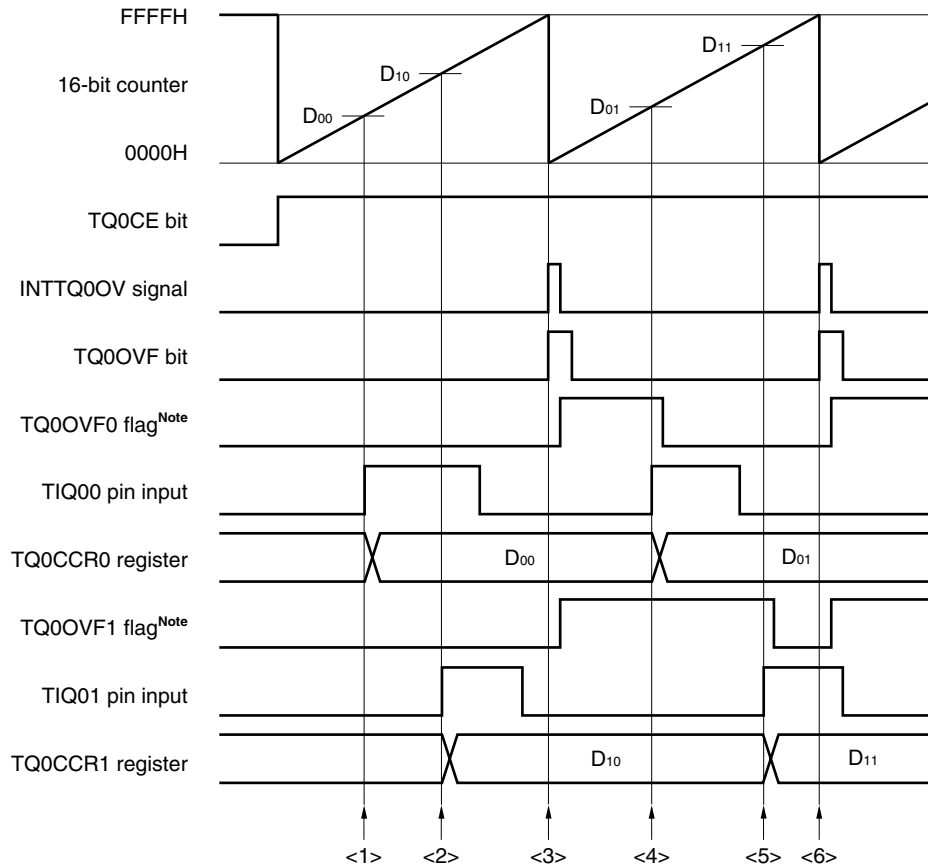
The following problem may occur when two pulse widths are measured in the free-running timer mode.

- <1> Read the TQ0CCR0 register (setting of the default value of the TIQ00 pin input).
- <2> Read the TQ0CCR1 register (setting of the default value of the TIQ01 pin input).
- <3> Read the TQ0CCR0 register.  
Read the overflow flag. If the overflow flag is 1, clear it to 0.  
Because the overflow flag is 1, the pulse width can be calculated by  $(10000H + D_{01} - D_{00})$ .
- <4> Read the TQ0CCR1 register.  
Read the overflow flag. Because the flag is cleared in <3>, 0 is read.  
Because the overflow flag is 0, the pulse width can be calculated by  $(D_{11} - D_{10})$  (incorrect).

When two capture registers are used, and if the overflow flag is cleared to 0 by one capture register, the other capture register may not obtain the correct pulse width.

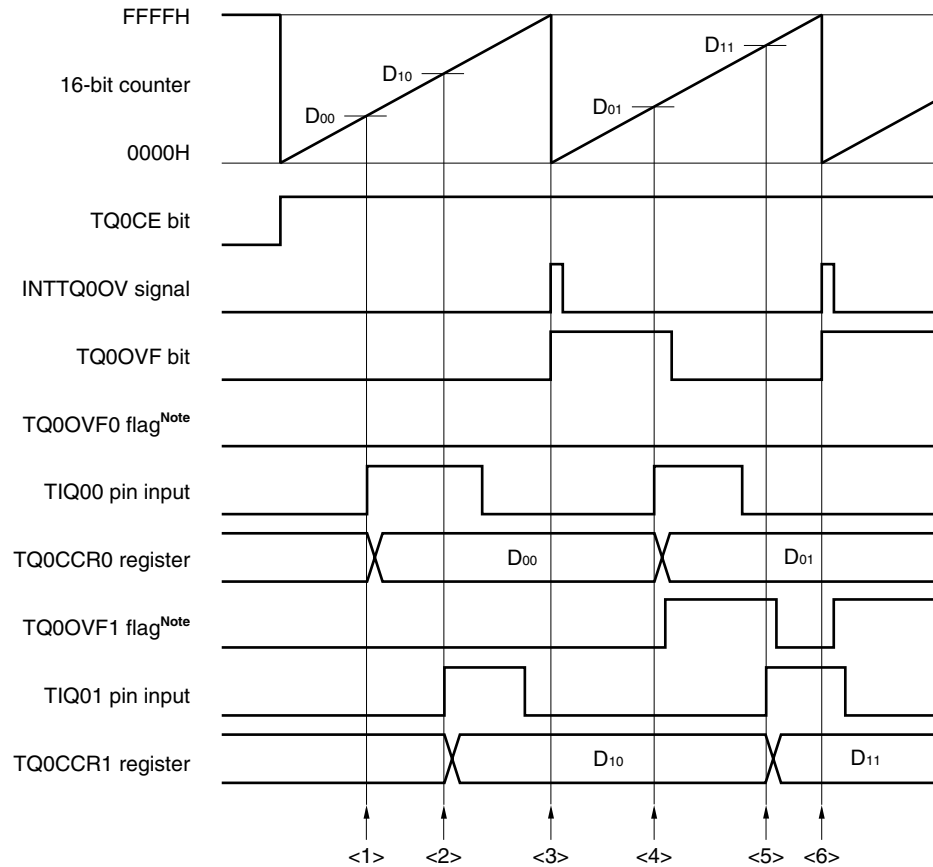
Use software when using two capture registers. An example of how to use software is shown below.

### Example when two capture registers are used (using overflow interrupt)



**Note** The TQ0OVF0 and TQ0OVF1 flags are set on the internal RAM by software.

- <1> Read the TQ0CCR0 register (setting of the default value of the TIQ00 pin input).
- <2> Read the TQ0CCR1 register (setting of the default value of the TIQ01 pin input).
- <3> An overflow occurs. Set the TQ0OVF0 and TQ0OVF1 flags to 1 in the overflow interrupt servicing, and clear the overflow flag to 0.
- <4> Read the TQ0CCR0 register.  
Read the TQ0OVF0 flag. If the TQ0OVF0 flag is 1, clear it to 0.  
Because the TQ0OVF0 flag is 1, the pulse width can be calculated by  $(10000H + D_{01} - D_{00})$ .
- <5> Read the TQ0CCR1 register.  
Read the TQ0OVF1 flag. If the TQ0OVF1 flag is 1, clear it to 0 (the TQ0OVF0 flag is cleared in <4>, and the TQ0OVF1 flag remains 1).  
Because the TQ0OVF1 flag is 1, the pulse width can be calculated by  $(10000H + D_{11} - D_{10})$  (correct).
- <6> Same as <3>

**Example when two capture registers are used (without using overflow interrupt)**

**Note** The TQ0OVF0 and TQ0OVF1 flags are set on the internal RAM by software.

<1> Read the TQ0CCR0 register (setting of the default value of the TIQ00 pin input).

<2> Read the TQ0CCR1 register (setting of the default value of the TIQ01 pin input).

<3> An overflow occurs. Nothing is done by software.

<4> Read the TQ0CCR0 register.

Read the overflow flag. If the overflow flag is 1, set only the TQ0OVF1 flag to 1, and clear the overflow flag to 0.

Because the overflow flag is 1, the pulse width can be calculated by  $(10000H + D_{01} - D_{00})$ .

<5> Read the TQ0CCR1 register.

Read the overflow flag. Because the overflow flag is cleared in <4>, 0 is read.

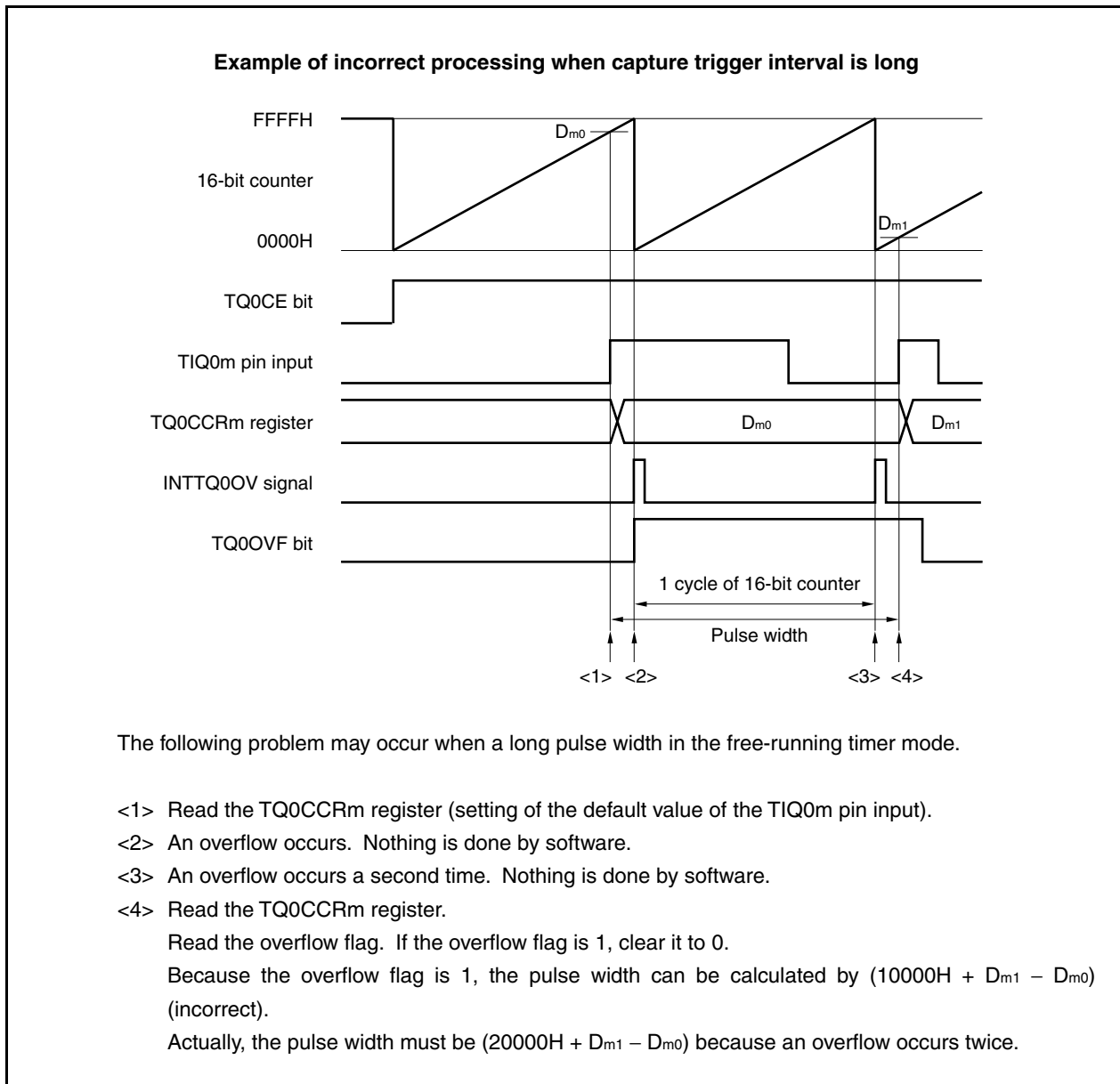
Read the TQ0OVF1 flag. If the TQ0OVF1 flag is 1, clear it to 0.

Because the TQ0OVF1 flag is 1, the pulse width can be calculated by  $(10000H + D_{11} - D_{10})$  (correct).

<6> Same as <3>

**(d) Processing of overflow if capture trigger interval is long**

If the pulse width is greater than one cycle of the 16-bit counter, care must be exercised because an overflow may occur more than once from the first capture trigger to the next. First, an example of incorrect processing is shown below.

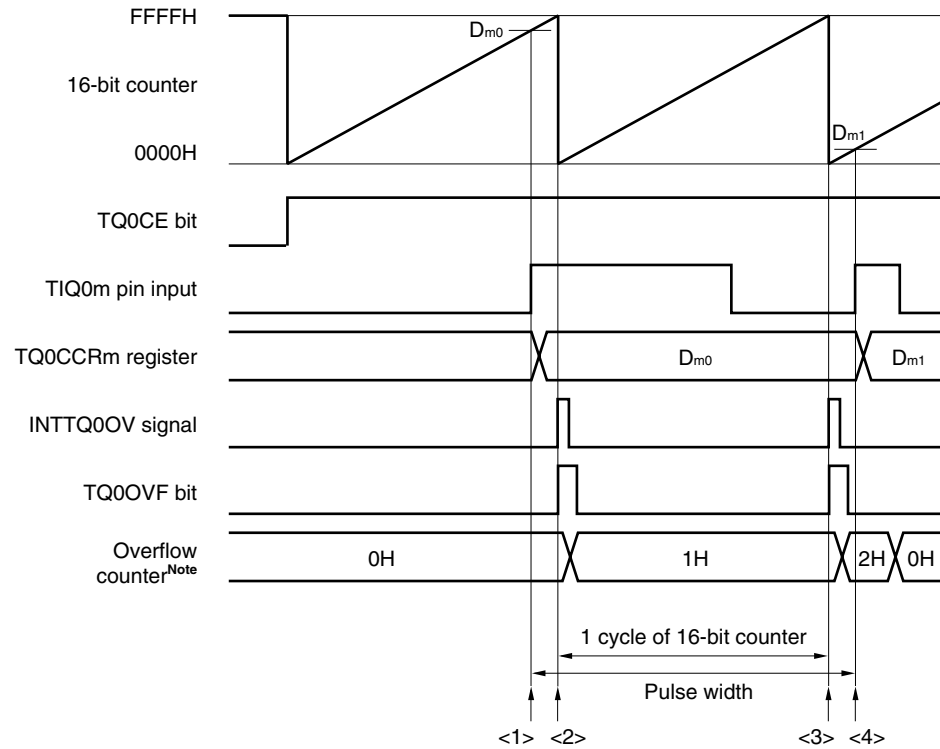


If an overflow occurs twice or more when the capture trigger interval is long, the correct pulse width may not be obtained.

If the capture trigger interval is long, slow the count clock to lengthen one cycle of the 16-bit counter, or use software. An example of how to use software is shown next.



## Example when capture trigger interval is long

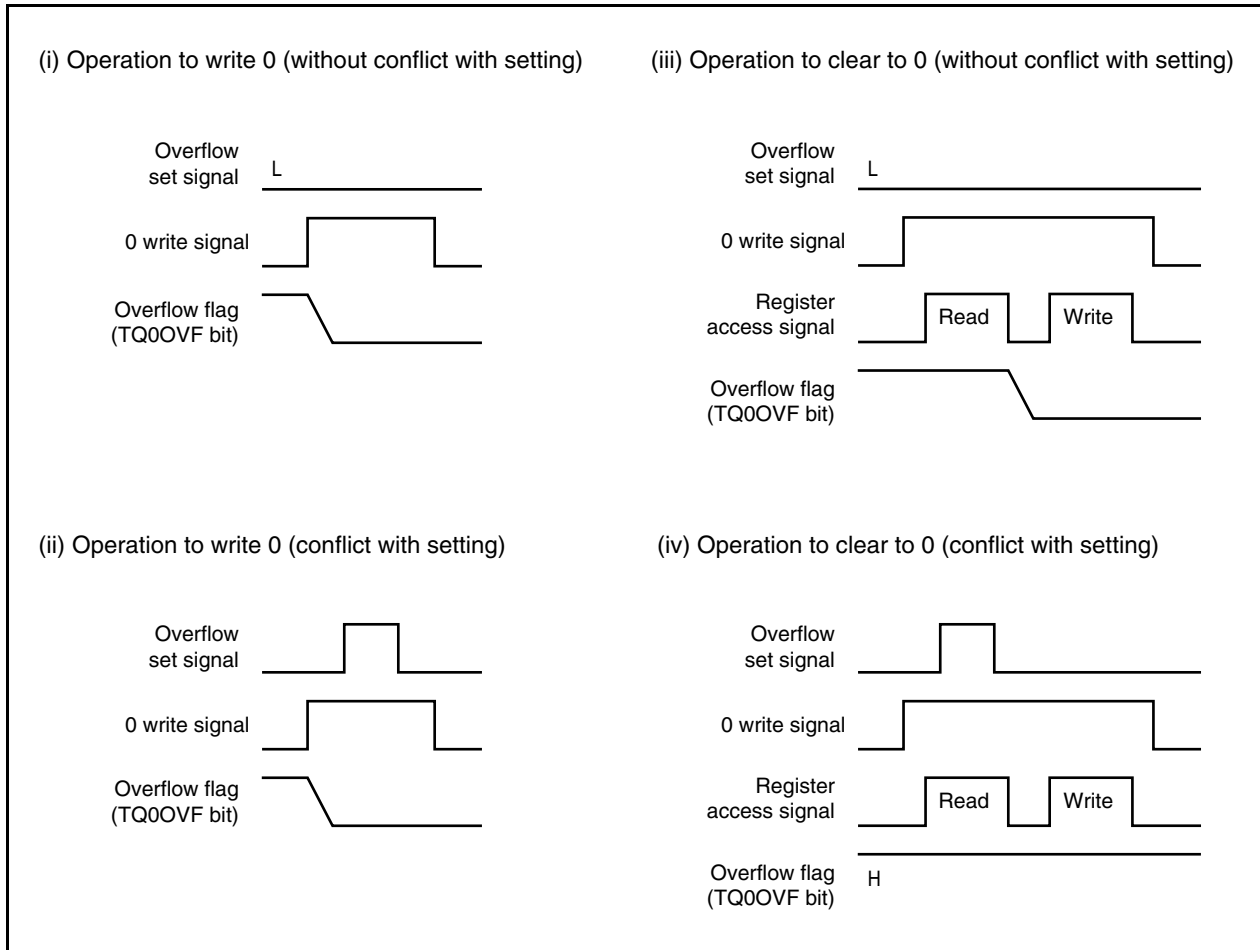


**Note** The overflow counter is set arbitrarily by software on the internal RAM.

- <1> Read the TQ0CCRm register (setting of the default value of the TIQ0m pin input).
- <2> An overflow occurs. Increment the overflow counter and clear the overflow flag to 0 in the overflow interrupt servicing.
- <3> An overflow occurs a second time. Increment (+1) the overflow counter and clear the overflow flag to 0 in the overflow interrupt servicing.
- <4> Read the TQ0CCRm register.  
Read the overflow counter.  
→ When the overflow counter is "N", the pulse width can be calculated by  $(N \times 10000H + D_{m1} - D_{m0})$ .  
In this example, the pulse width is  $(20000H + D_{m1} - D_{m0})$  because an overflow occurs twice.  
Clear the overflow counter (0H).

**(e) Clearing overflow flag**

The overflow flag can be cleared to 0 by clearing the TQ0OVF bit to 0 with the CLR instruction and by writing 8-bit data (bit 0 is 0) to the TQ0OPT0 register. To accurately detect an overflow, read the TQ0OVF bit when it is 1, and then clear the overflow flag by using a bit manipulation instruction.



To clear the overflow flag to 0, read the overflow flag to check if it is set to 1, and clear it with the CLR instruction. If 0 is written to the overflow flag without checking if the flag is 1, the set information of overflow may be erased by writing 0 ((ii) in the above chart). Therefore, software may judge that no overflow has occurred even when an overflow actually has occurred.

If execution of the CLR instruction conflicts with occurrence of an overflow when the overflow flag is cleared to 0 with the CLR instruction, the overflow flag remains set even after execution of the clear instruction.

**8.5.7 Pulse width measurement mode (TQ0MD2 to TQ0MD0 bits = 110)**

In the pulse width measurement mode, 16-bit timer/event counter Q starts counting when the TQ0CTL0.TQ0CE bit is set to 1. Each time the valid edge input to the TIQ0m pin has been detected, the count value of the 16-bit counter is stored in the TQ0CCRm register, and the 16-bit counter is cleared to 0000H.

The interval of the valid edge can be measured by reading the TQ0CCRm register after a capture interrupt request signal (INTTQ0CCm) occurs.

Select either of the TIQ00 to TIQ03 pins as the capture trigger input pin. Specify "No edge detected" by using the TQ0IOC1 register for the unused pins.

When an external clock is used as the count clock, measure the pulse width of the TIQ0k pin because the external clock is fixed to the TIQ00 pin. At this time, clear the TQ0IOC1.TQ0IS1 and TQ0IOC1.TQ0IS0 bits to 00 (capture trigger input (TIQ00 pin): No edge detected).

**Remark** m = 0 to 3  
k = 1 to 3

**Figure 8-34. Configuration in Pulse Width Measurement Mode**

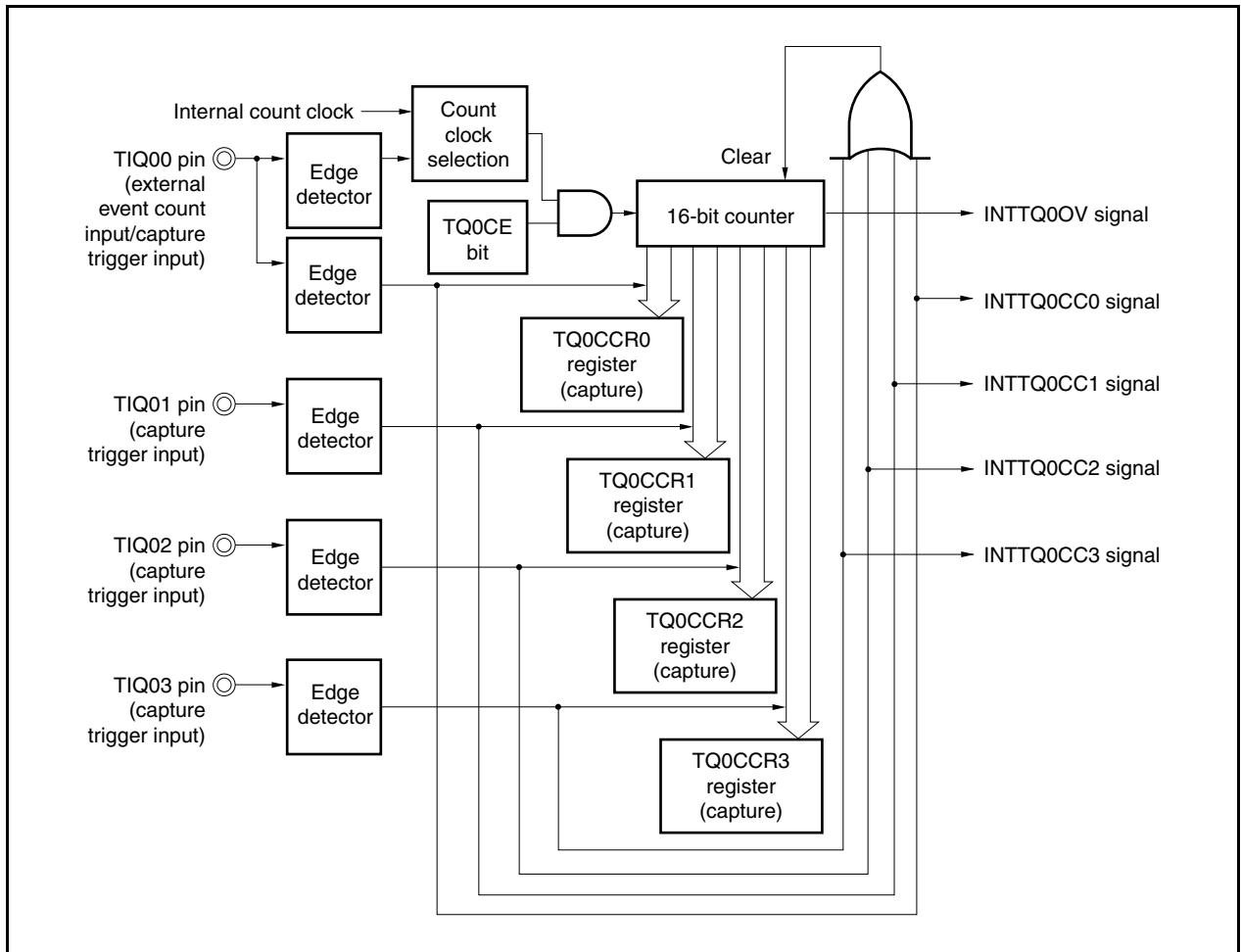
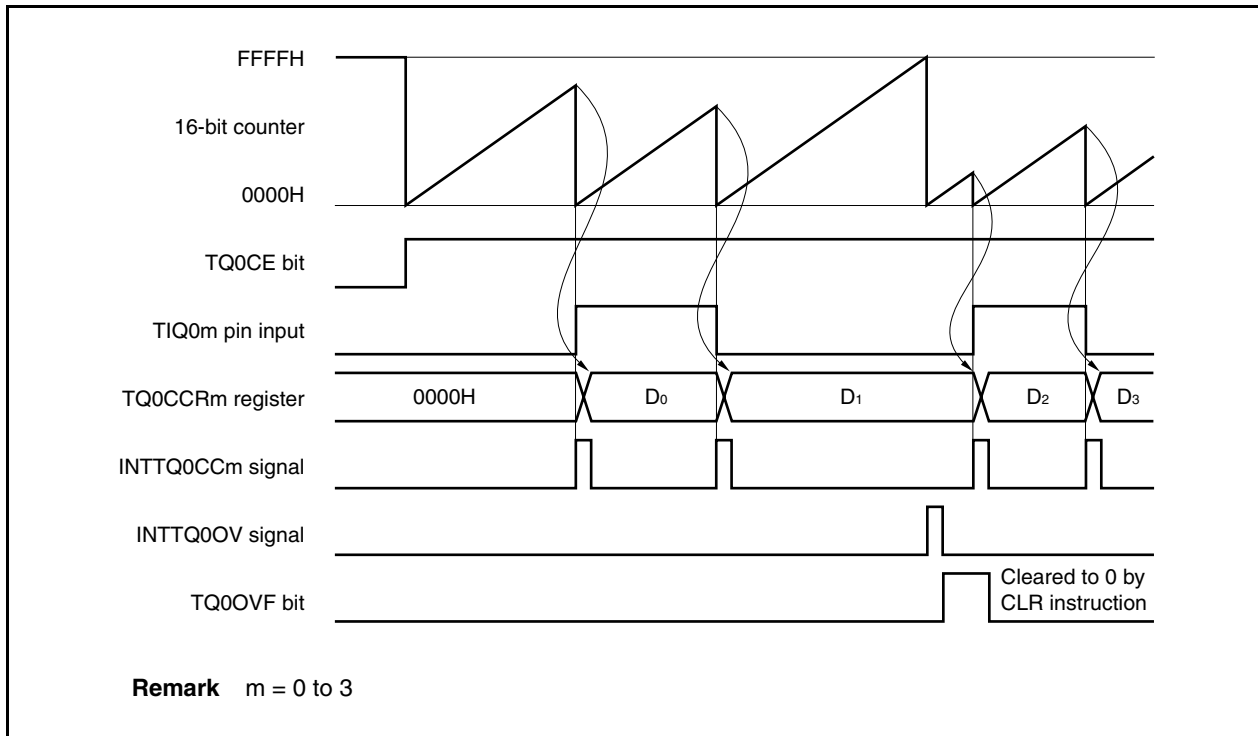


Figure 8-35. Basic Timing in Pulse Width Measurement Mode



When the TQ0CE bit is set to 1, the 16-bit counter starts counting. When the valid edge input to the TIQ0m pin is later detected, the count value of the 16-bit counter is stored in the TQ0CCRm register, the 16-bit counter is cleared to 0000H, and a capture interrupt request signal (INTTQ0CCm) is generated.

The pulse width is calculated as follows.

$$\text{Pulse width} = \text{Captured value} \times \text{Count clock cycle}$$

If the valid edge is not input to the TIQ0m pin even when the 16-bit counter counted up to FFFFH, an overflow interrupt request signal (INTTQ0OV) is generated at the next count clock, and the counter is cleared to 0000H and continues counting. At this time, the overflow flag (TQ0OPT0.TQ0OVF bit) is also set to 1. Clear the overflow flag to 0 by executing the CLR instruction via software.

If the overflow flag is set to 1, the pulse width can be calculated as follows.

$$\text{Pulse width} = (10000\text{H} \times \text{TQ0OVF bit set (1) count} + \text{Captured value}) \times \text{Count clock cycle}$$

**Remark** m = 0 to 3

Figure 8-36. Register Setting in Pulse Width Measurement Mode (1/2)

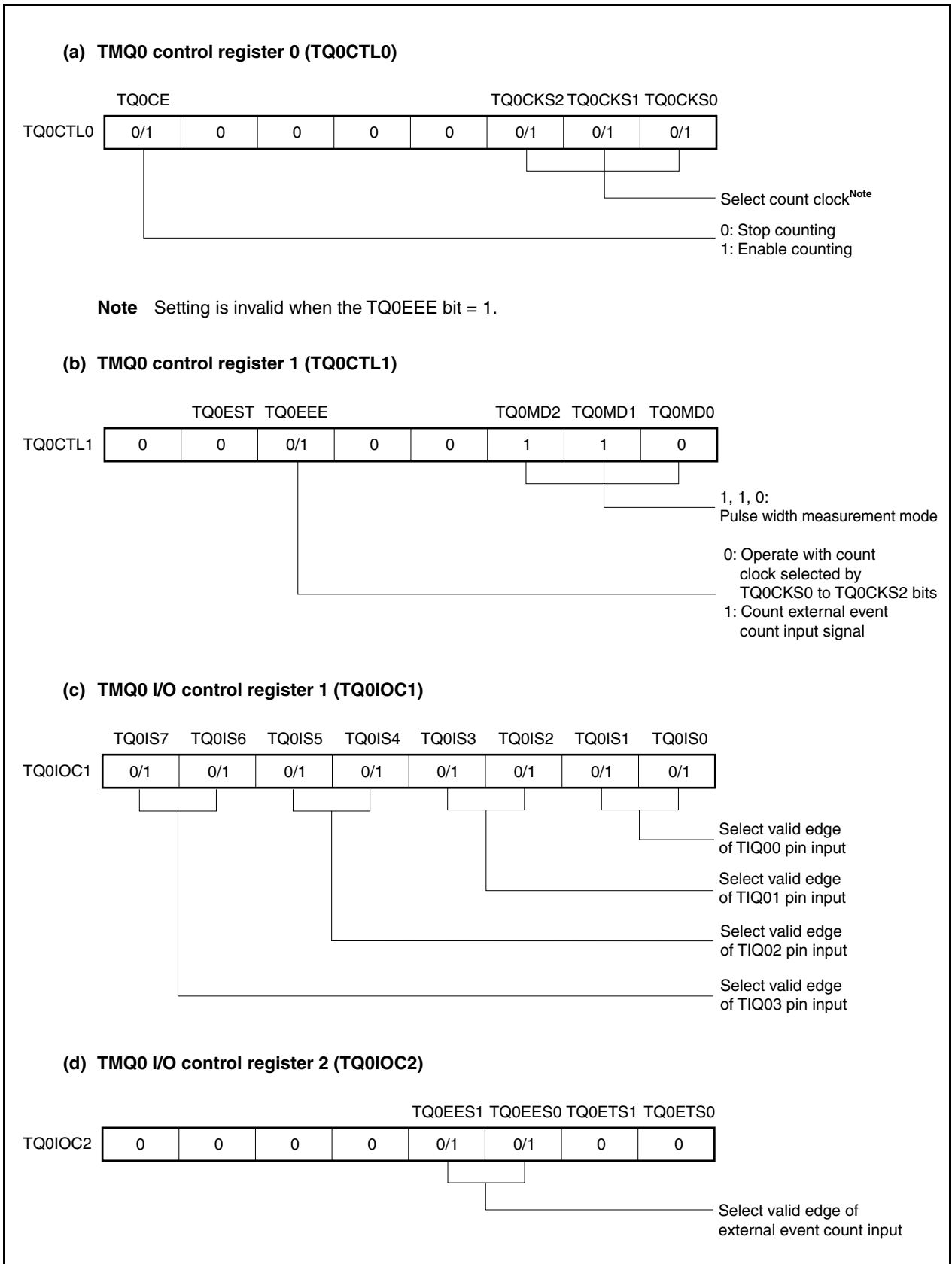
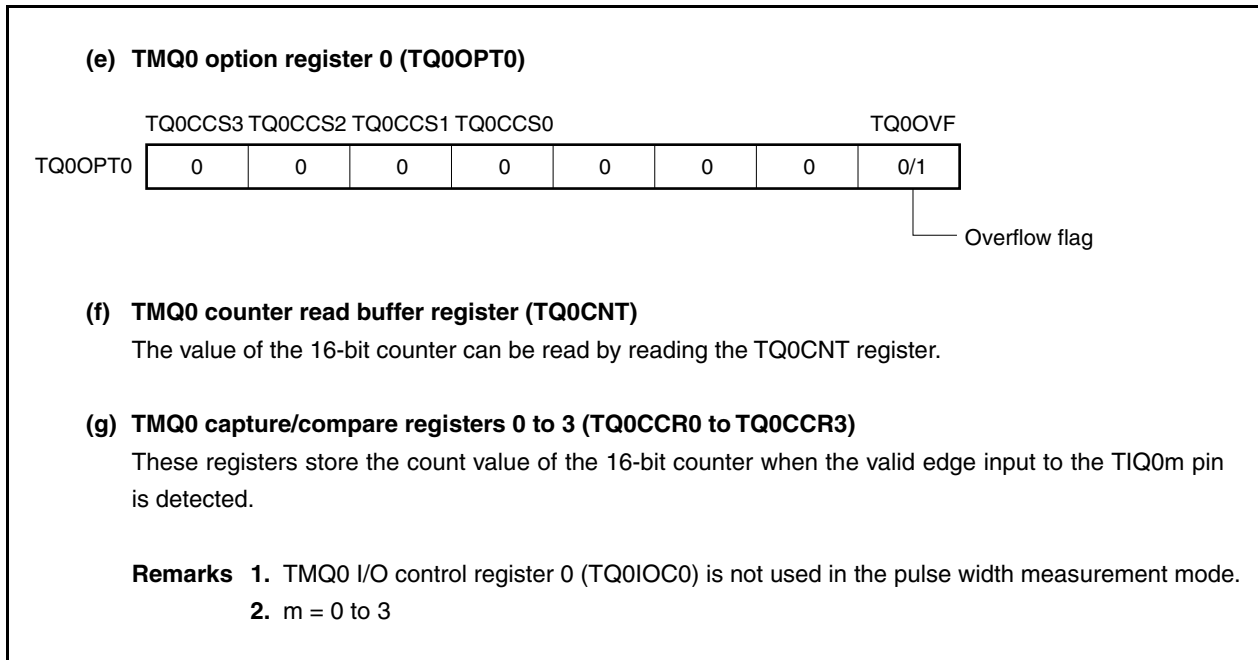
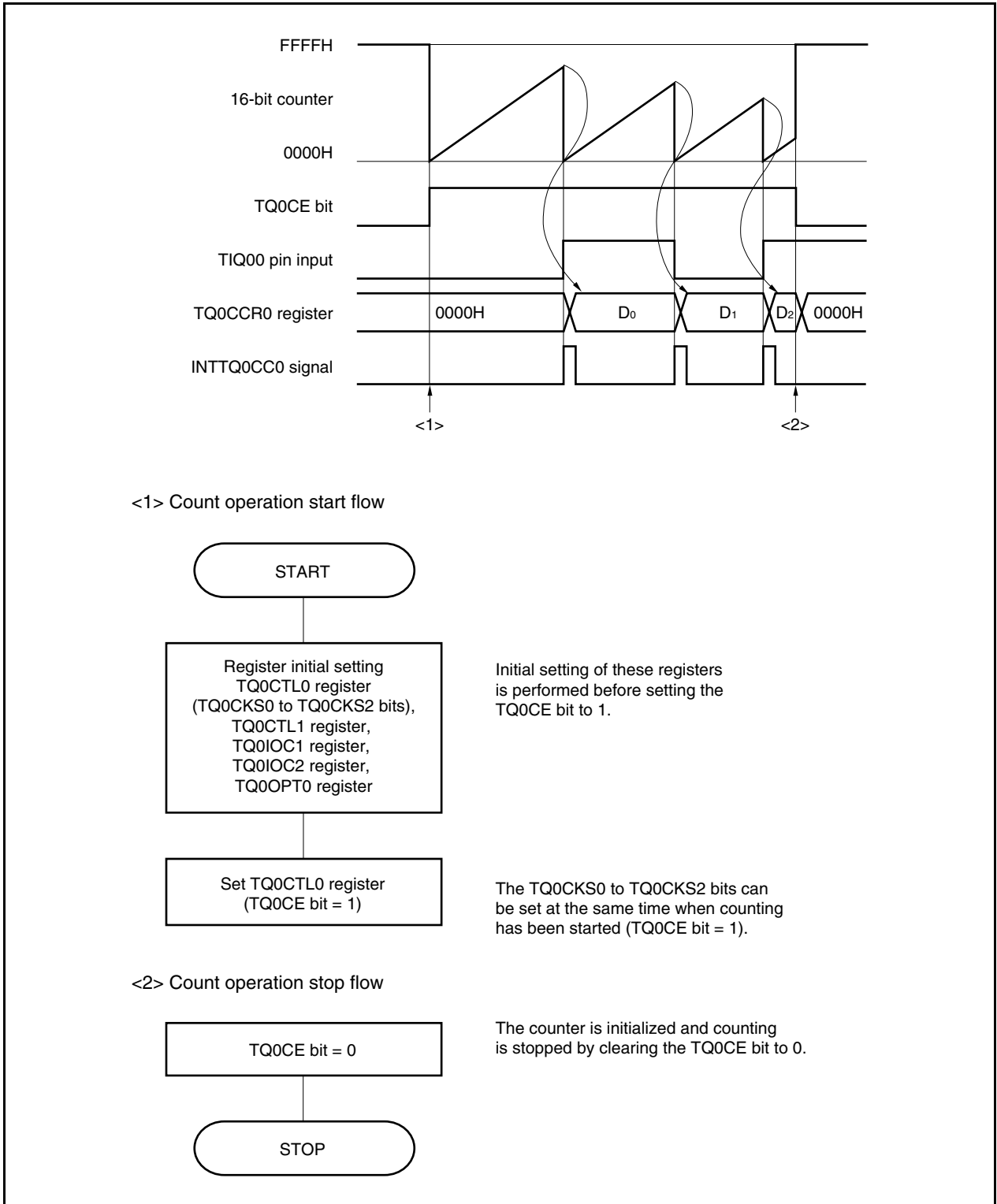


Figure 8-36. Register Setting in Pulse Width Measurement Mode (2/2)



(1) Operation flow in pulse width measurement mode

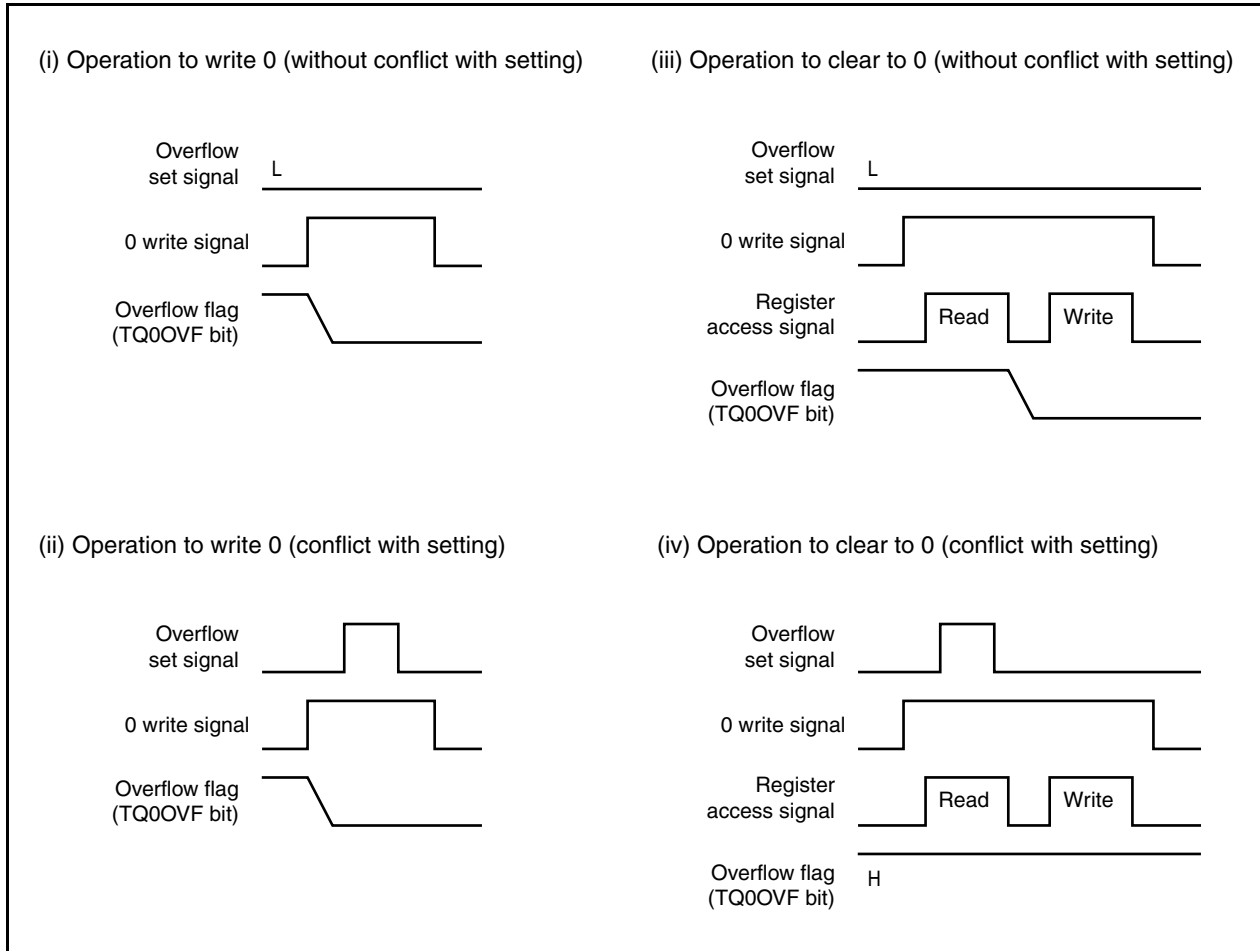
Figure 8-37. Software Processing Flow in Pulse Width Measurement Mode



(2) Operation timing in pulse width measurement mode

(a) Clearing overflow flag

The overflow flag can be cleared to 0 by clearing the TQ0OVF bit to 0 with the CLR instruction and by writing 8-bit data (bit 0 is 0) to the TQ0OPT0 register. To accurately detect an overflow, read the TQ0OVF bit when it is 1, and then clear the overflow flag by using a bit manipulation instruction.



To clear the overflow flag to 0, read the overflow flag to check if it is set to 1, and clear it with the CLR instruction. If 0 is written to the overflow flag without checking if the flag is 1, the set information of overflow may be erased by writing 0 ((ii) in the above chart). Therefore, software may judge that no overflow has occurred even when an overflow actually has occurred.

If execution of the CLR instruction conflicts with occurrence of an overflow when the overflow flag is cleared to 0 with the CLR instruction, the overflow flag remains set even after execution of the clear instruction.



**8.5.8 Timer output operations**

The following table shows the operations and output levels of the TOQ00 to TOQ03 pins.

**Table 8-6. Timer Output Control in Each Mode**

| Operation Mode                     | TOQ00 Pin   | TOQ01 Pin                     | TOQ02 Pin                     | TOQ03 Pin                     |
|------------------------------------|---|-------------------------------|-------------------------------|-------------------------------|
| Interval timer mode                | Square wave output                                      |                               |                               |                               |
| External event count mode          | Square wave output                                      | -                             |                               |                               |
| External trigger pulse output mode | Square wave output                                      | External trigger pulse output | External trigger pulse output | External trigger pulse output |
| One-shot pulse output mode         |   | One-shot pulse output         | One-shot pulse output         | One-shot pulse output         |
| PWM output mode                    |   | PWM output                    | PWM output                    | PWM output                    |
| Free-running timer mode            | Square wave output (only when compare function is used) |                               |                               |                               |
| Pulse width measurement mode       | -   |                               |                               |                               |

**Table 8-7. Truth Table of TOQ00 to TOQ03 Pins Under Control of Timer Output Control Bits**

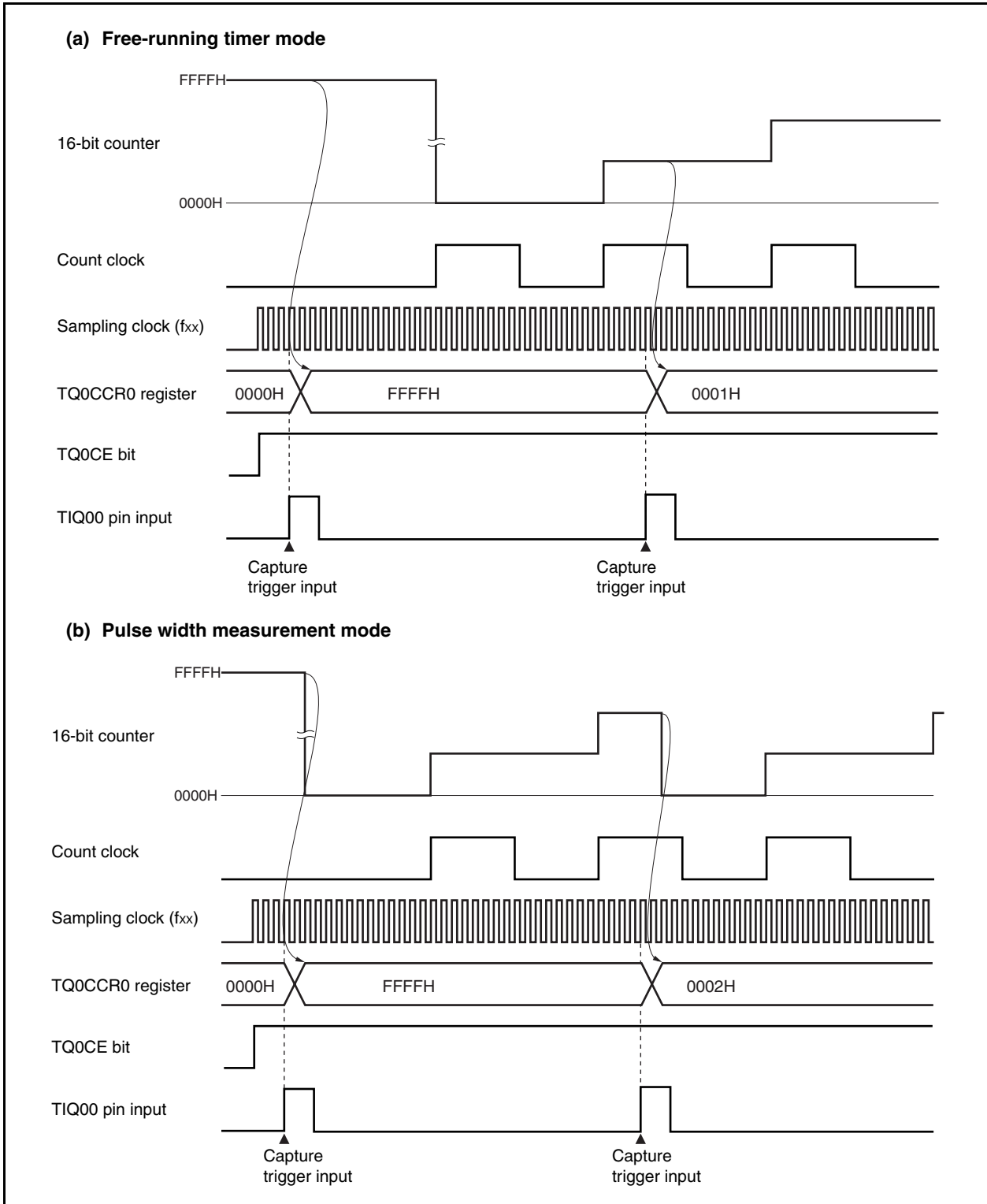
| TQ0IOC0.TQ0OLm Bit | TQ0IOC0.TQ0OEm Bit | TQ0CTL0.TQ0CE Bit | Level of TOQ0m Pin  |
|--------------------|--------------------|-------------------|---|
| 0                  | 0                  | ×                 | Low-level output  |
|                    | 1                  | 0                 | Low-level output  |
|                    |                    | 1                 | Low level immediately before counting, high level after counting is started |
| 1                  | 0                  | ×                 | High-level output   |
|                    | 1                  | 0                 | High-level output   |
|                    |                    | 1                 | High level immediately before counting, low level after counting is started |

**Remark** m = 0 to 3

8.6 Cautions

(1) Capture operation

When the capture operation is used and a slow clock is selected as the count clock, FFFFH, not 0000H, may be captured in the TQ0CCR0, TQ0CCR1, TQ0CCR2, and TQ0CCR3 registers if the capture trigger is input immediately after the TQ0CE bit is set to 1.



## CHAPTER 9 16-BIT INTERVAL TIMER M (TMM)

### 9.1 Overview

- Interval function
- 8 clocks selectable
- 16-bit counter × 1  
(The 16-bit counter cannot be read during timer count operation.)
- Compare register × 1  
(The compare register cannot be written during timer counter operation.)
- Compare match interrupt × 1

Timer M supports only the clear & start mode. The free-running timer mode is not supported.

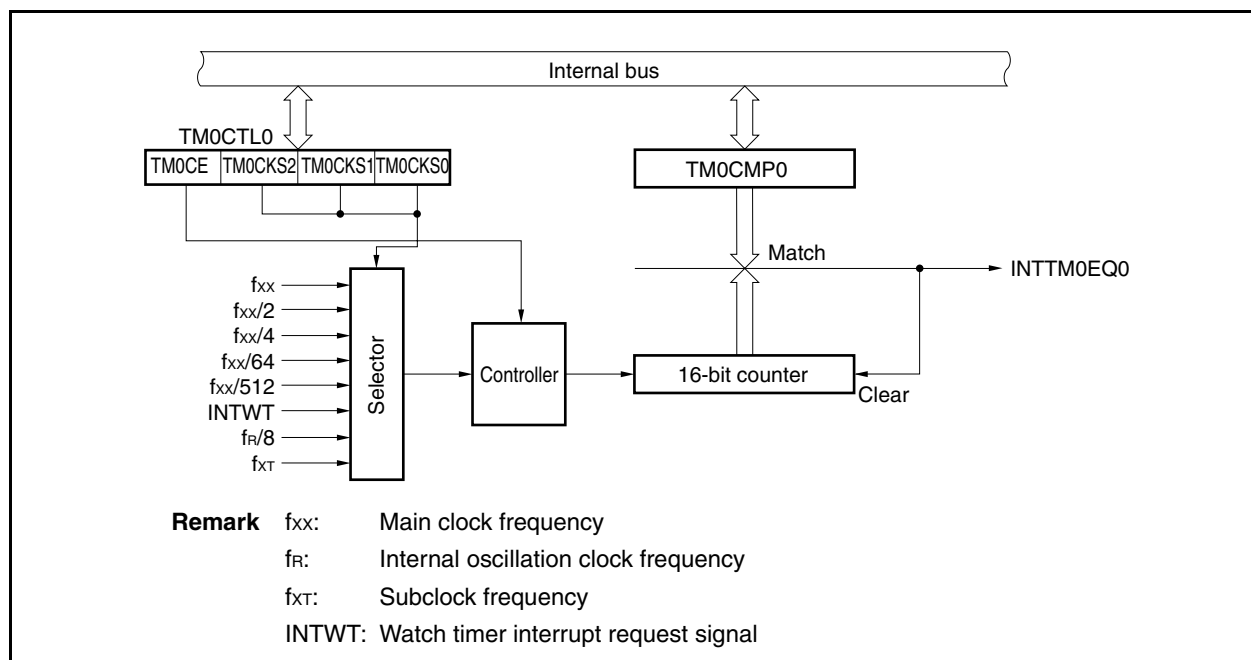
## 9.2 Configuration

TMM0 includes the following hardware.

**Table 9-1. Configuration of TMM0**

| Item             | Configuration                     |
|------------------|-----------------------------------|
| Timer register   | 16-bit counter                    |
| Register         | TMM0 compare register 0 (TM0CMP0) |
| Control register | TMM0 control register 0 (TM0CTL0) |

**Figure 9-1. Block Diagram of TMM0**

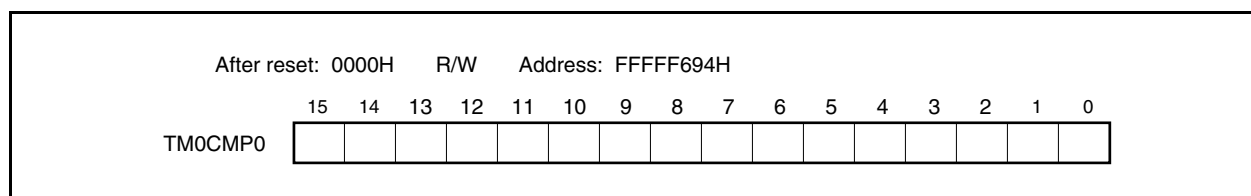


**(1) 16-bit counter**

This is a 16-bit counter that counts the internal clock.  
The 16-bit counter cannot be read or written.

**(2) TMM0 compare register 0 (TM0CMP0)**

The TM0CMP0 register is a 16-bit compare register.  
This register can be read or written in 16-bit units.  
Reset sets this register to 0000H.  
The same value can always be written to the TM0CMP0 register by software.  
TM0CMP0 register rewrite is prohibited when the TM0CTL0.TM0CE bit = 1.



### 9.3 Register

#### (1) TMM0 control register (TM0CTL0)

The TM0CTL0 register is an 8-bit register that controls the TMM0 operation.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

The same value can always be written to the TM0CTL0 register by software.

After reset: 00H    R/W    Address: FFFFF690H

|         |       |   |   |   |   |         |         |         |
|---------|-------|---|---|---|---|---------|---------|---------|
|         | <7>   | 6 | 5 | 4 | 3 | 2       | 1       | 0       |
| TM0CTL0 | TMOCE | 0 | 0 | 0 | 0 | TM0CKS2 | TM0CKS1 | TM0CKS0 |

| TMOCE   | Internal clock operation enable/disable specification   |
|---|---|
| 0   | TMM0 operation disabled (16-bit counter reset asynchronously). Operation clock application stopped. |
| 1   | TMM0 operation enabled. Operation clock application started. TMM0 operation started.                |
| The internal clock control and internal circuit reset for TMM0 are performed asynchronously with the TMOCE bit. When the TMOCE bit is cleared to 0, the internal clock of TMM0 is disabled (fixed to low level) and 16-bit counter is reset asynchronously. |   |

| TM0CKS2 | TM0CKS1 | TM0CKS0 | Count clock selection |
|---------|---------|---------|-----------------------|
| 0       | 0       | 0       | f <sub>xx</sub>       |
| 0       | 0       | 1       | f <sub>xx</sub> /2    |
| 0       | 1       | 0       | f <sub>xx</sub> /4    |
| 0       | 1       | 1       | f <sub>xx</sub> /64   |
| 1       | 0       | 0       | f <sub>xx</sub> /512  |
| 1       | 0       | 1       | INTWT                 |
| 1       | 1       | 0       | f <sub>R</sub> /8     |
| 1       | 1       | 1       | f <sub>XT</sub>       |

**Cautions 1. Set the TM0CKS2 to TM0CKS0 bits when TMOCE bit = 0.**

**When changing the value of TMOCE from 0 to 1, it is not possible to set the value of the TM0CKS2 to TM0CKS0 bits simultaneously.**

**2. Be sure to clear bits 3 to 6 to “0”.**

**Remark** f<sub>xx</sub>: Main clock frequency  
 f<sub>R</sub>: Internal oscillation clock frequency  
 f<sub>XT</sub>: Subclock frequency

## 9.4 Operation

**Caution** Do not set the TM0CMP0 register to FFFFH.

### 9.4.1 Interval timer mode

In the interval timer mode, an interrupt request signal (INTTM0EQ0) is generated at the specified interval if the TMOCTL0.TM0CE bit is set to 1.

Figure 9-2. Configuration of Interval Timer

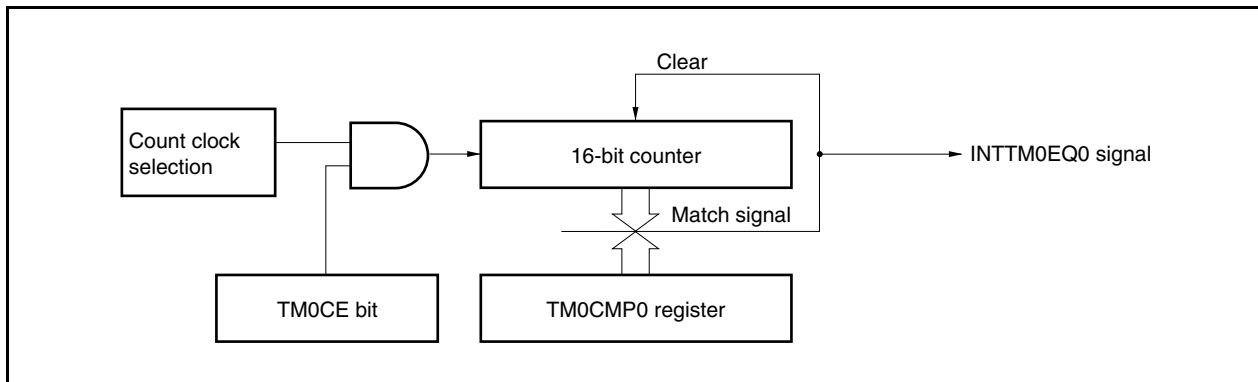
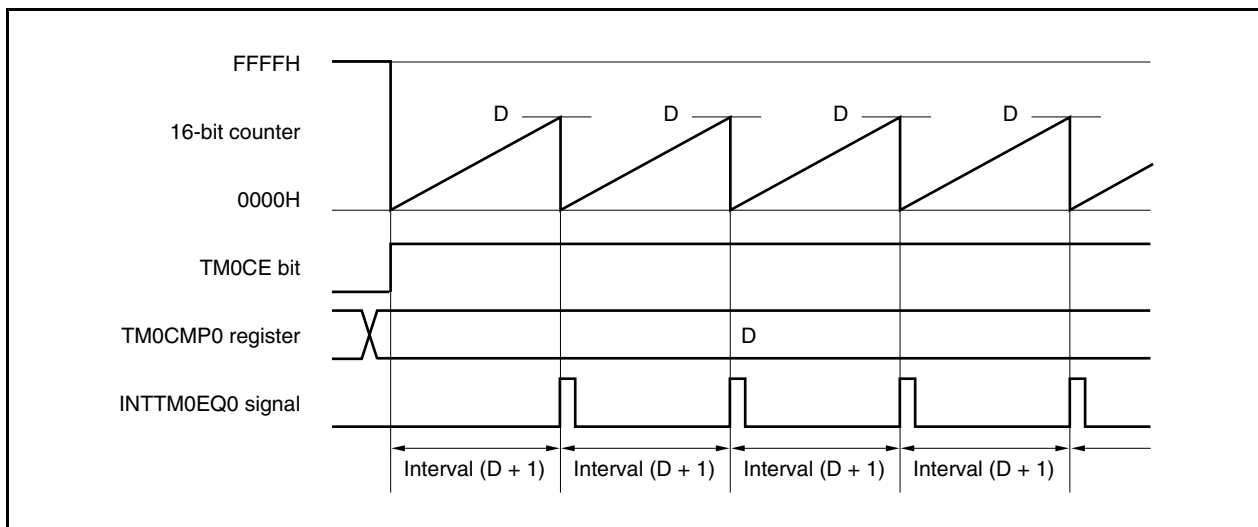


Figure 9-3. Basic Timing of Operation in Interval Timer Mode



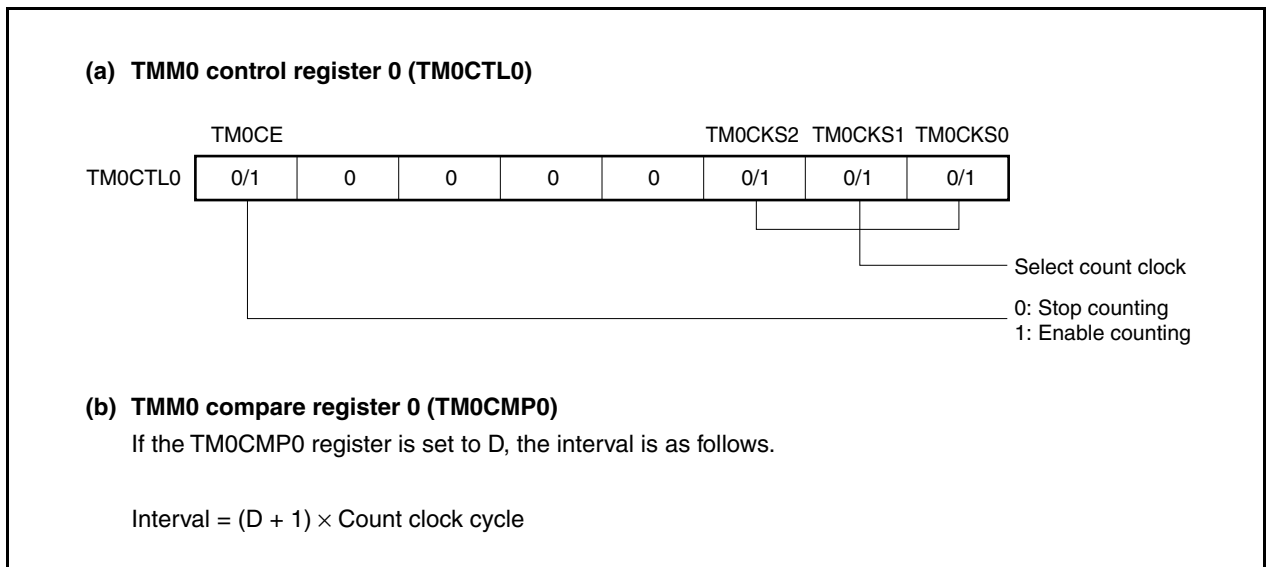
When the TM0CE bit is set to 1, the value of the 16-bit counter is cleared from FFFFH to 0000H in synchronization with the count clock, and the counter starts counting.

When the count value of the 16-bit counter matches the value of the TM0CMP0 register, the 16-bit counter is cleared to 0000H and a compare match interrupt request signal (INTTM0EQ0) is generated.

The interval can be calculated by the following expression.

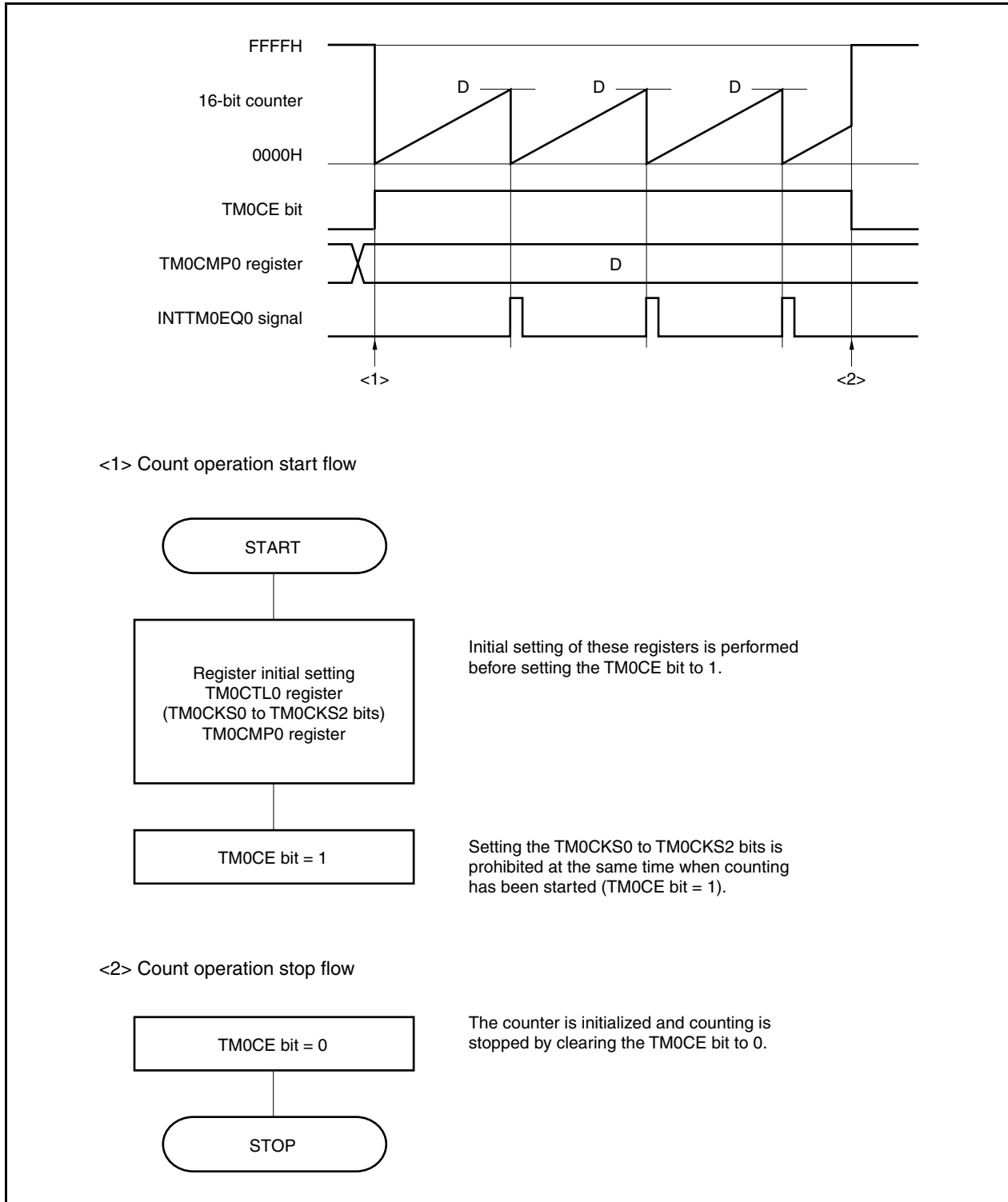
$$\text{Interval} = (\text{Set value of TM0CMP0 register} + 1) \times \text{Count clock cycle}$$

Figure 9-4. Register Setting for Interval Timer Mode Operation



(1) Interval timer mode operation flow

Figure 9-5. Software Processing Flow in Interval Timer Mode



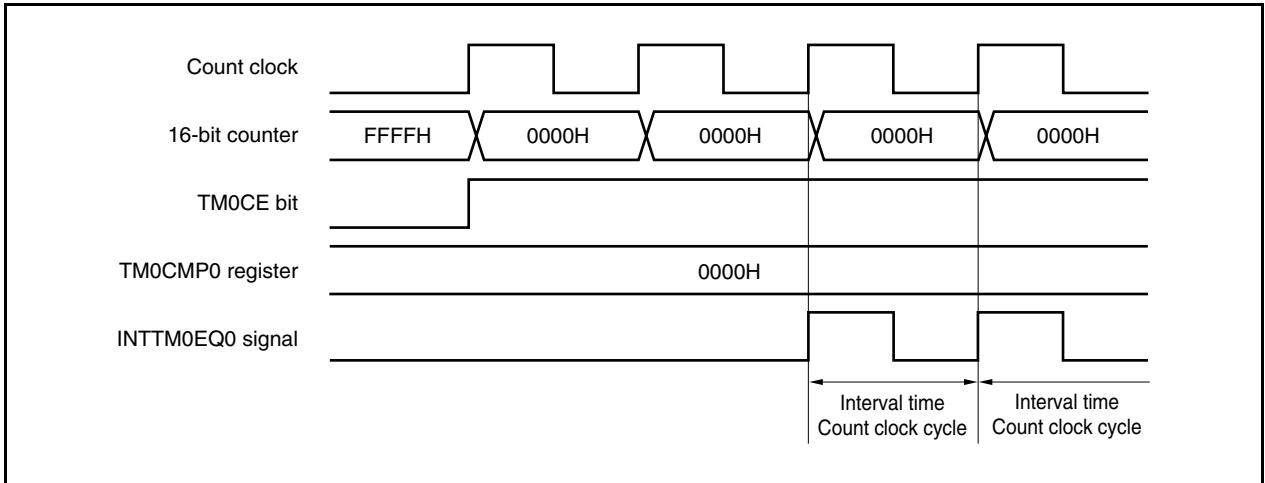


(2) Interval timer mode operation timing

**Caution** Do not set the TM0CMP0 register to FFFFH.

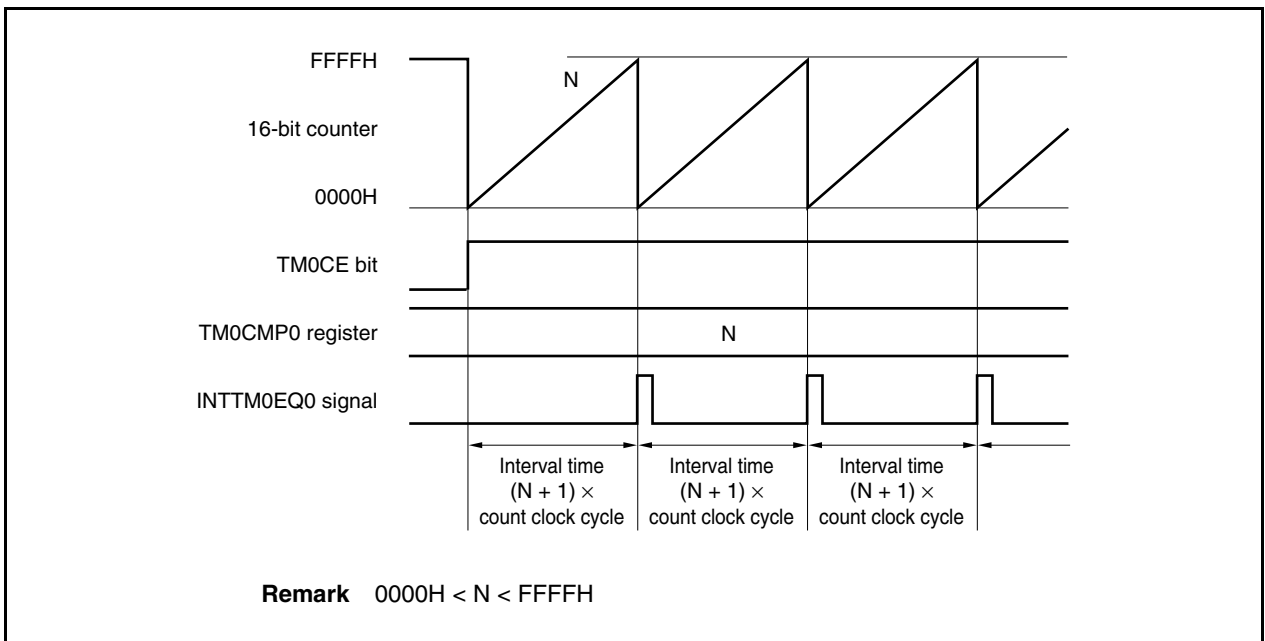
(a) Operation if TM0CMP0 register is set to 0000H

If the TM0CMP0 register is set to 0000H, the INTTM0EQ0 signal is generated at each count clock. The value of the 16-bit counter is always 0000H.



(b) Operation if TM0CMP0 register is set to N

If the TM0CMP0 register is set to N, the 16-bit counter counts up to N. The counter is cleared to 0000H in synchronization with the next count-up timing and the INTTM0EQ0 signal is generated.



### 9.4.2 Cautions

- (1) It takes the 16-bit counter up to the following time to start counting after the TM0CTL0.TM0CE bit is set to 1, depending on the count clock selected.

| Selected Count Clock | Maximum Time Before Counting Start |
|----------------------|------------------------------------|
| $f_{xx}$             | $2/f_{xx}$                         |
| $f_{xx}/2$           | $6/f_{xx}$                         |
| $f_{xx}/4$           | $24/f_{xx}$                        |
| $f_{xx}/64$          | $128/f_{xx}$                       |
| $f_{xx}/512$         | $1024/f_{xx}$                      |
| INTWT                | Second rising edge of INTWT signal |
| $f_R/8$              | $16/f_R$                           |
| $f_{XT}$             | $2/f_{XT}$                         |

- (2) Rewriting the TM0CMP0 and TM0CTL0 registers is prohibited while TMM0 is operating. If these registers are rewritten while the TM0CE bit is 1, the operation cannot be guaranteed. If they are rewritten by mistake, clear the TM0CTL0.TM0CE bit to 0, and re-set the registers.

## CHAPTER 10 WATCH TIMER FUNCTIONS

### 10.1 Functions

The watch timer has the following functions.

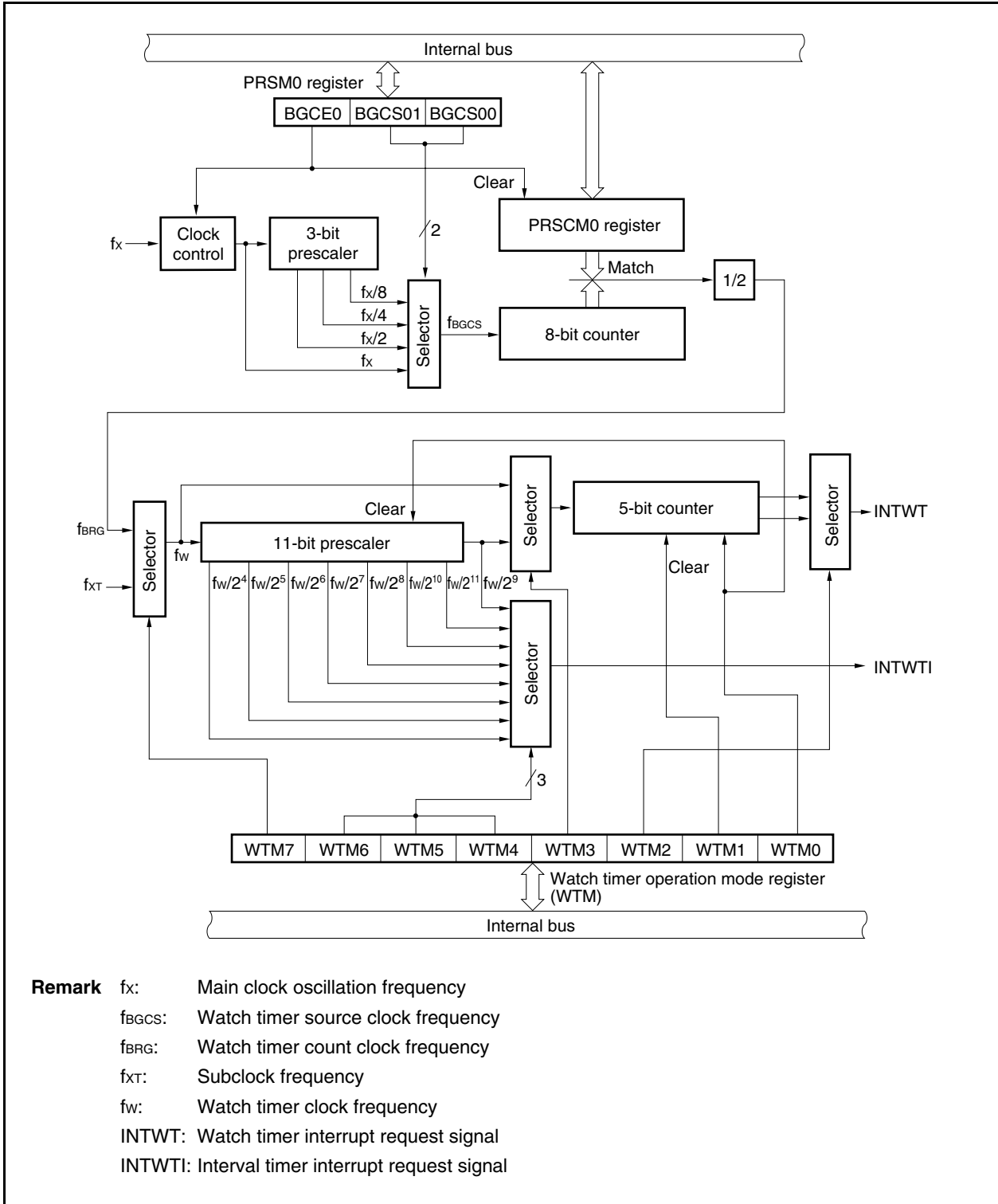
- Watch timer: An interrupt request signal (INTWT) is generated at intervals of 0.5 or 0.25 seconds by using the main clock or subclock.
- Interval timer: An interrupt request signal (INTWTI) is generated at set intervals.

The watch timer and interval timer functions can be used at the same time.

## 10.2 Configuration

The block diagram of the watch timer is shown below.

Figure 10-1. Block Diagram of Watch Timer



**(1) Clock control**

This block controls supplying and stopping the operating clock ( $f_x$ ) when the watch timer operates on the main clock.

**(2) 3-bit prescaler**

This prescaler divides  $f_x$  to generate  $f_x/2$ ,  $f_x/4$ , or  $f_x/8$ .

**(3) 8-bit counter**

This 8-bit counter counts the source clock ( $f_{BGS}$ ).

**(4) 11-bit prescaler**

This prescaler divides  $f_w$  to generate a clock of  $f_w/2^4$  to  $f_w/2^{11}$ .

**(5) 5-bit counter**

This counter counts  $f_w$  or  $f_w/2^9$ , and generates a watch timer interrupt request signal at intervals of  $2^4/f_w$ ,  $2^5/f_w$ ,  $2^{12}/f_w$ , or  $2^{14}/f_w$ .

**(6) Selector**

The watch timer has the following five selectors.

- Selector that selects one of  $f_x$ ,  $f_x/2$ ,  $f_x/4$ , or  $f_x/8$  as the source clock of the watch timer
- Selector that selects the main clock ( $f_x$ ) or subclock ( $f_{XT}$ ) as the clock of the watch timer
- Selector that selects  $f_w$  or  $f_w/2^9$  as the count clock frequency of the 5-bit counter
- Selector that selects  $2^4/f_w$ ,  $2^9/f_w$ ,  $2^5/f_w$ , or  $2^{14}/f_w$  as the INTWT signal generation time interval
- Selector that selects  $2^4/f_w$  to  $2^{11}/f_w$  as the interval timer interrupt request signal (INTWTI) generation time interval

**(7) PRSCM register**

This is an 8-bit compare register that sets the interval time.

**(8) PRSM register**

This register controls clock supply to the watch timer.

**(9) WTM register**

This is an 8-bit register that controls the operation of the watch timer/interval timer, and sets the interrupt request signal generation interval.

### 10.3 Control Registers

The following registers are provided for the watch timer.

- Prescaler mode register 0 (PRSM0)
- Prescaler compare register 0 (PRSCM0)
- Watch timer operation mode register (WTM)

#### (1) Prescaler mode register 0 (PRSM0)

The PRSM0 register controls the generation of the watch timer count clock.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF8B0H

|       |   |   |   |       |   |   |        |        |
|-------|---|---|---|-------|---|---|--------|--------|
|       | 7 | 6 | 5 | <4>   | 3 | 2 | 1      | 0      |
| PRSM0 | 0 | 0 | 0 | BGCE0 | 0 | 0 | BGCS01 | BGCS00 |

|       |                             |  |
|-------|-----------------------------|--|
| BGCE0 | Main clock operation enable |  |
| 0     | Disabled                    |  |
| 1     | Enabled                     |  |

|        |        |  |             |           |
|--------|--------|--|-------------|-----------|
| BGCS01 | BGCS00 | Selection of watch timer source clock ( $f_{BGCS}$ ) |             |           |
|        |        |  | 5 MHz       | 4 MHz     |
| 0      | 0      | $f_x$  | 200 ns      | 250 ns    |
| 0      | 1      | $f_x/2$  | 400 ns      | 500 ns    |
| 1      | 0      | $f_x/4$  | 800 ns      | 1 $\mu$ s |
| 1      | 1      | $f_x/8$  | 1.6 $\mu$ s | 2 $\mu$ s |

- Cautions**
1. Do not change the values of the BGCS00 and BGCS01 bits during watch timer operation.
  2. Set the PRSM0 register before setting the BGCE0 bit to 1.
  3. Set the PRSM0 and PRSCM0 registers according to the main clock frequency that is used so as to obtain an  $f_{BRG}$  frequency of 32.768 kHz.

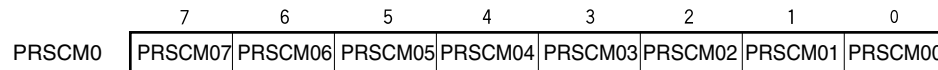
**(2) Prescaler compare register 0 (PRSCM0)**

The PRSCM0 register is an 8-bit compare register.

This register can be read or written in 8-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFF8B1H



- Cautions**
1. Do not rewrite the PRSCM0 register during watch timer operation.
  2. Set the PRSCM0 register before setting the PRSM0.BGCE0 bit to 1.
  3. Set the PRSM0 and PRSCM0 registers according to the main clock frequency that is used so as to obtain an  $f_{BRG}$  frequency of 32.768 kHz.

The calculation for  $f_{BRG}$  is shown below.

$$f_{BRG} = f_{BGCS}/2N$$

**Remark**  $f_{BGCS}$ : Watch timer source clock set by the PRSM0 register

N: Set value of PRSCM0 register = 1 to 256

However, N = 256 only when PRSCM0 register is set to 00H.

**(3) Watch timer operation mode register (WTM)**

The WTM register enables or disables the count clock and operation of the watch timer, sets the interval time of the prescaler, controls the operation of the 5-bit counter, and sets the set time of the watch flag.

Set the PRSM0 register before setting the WTM register.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

(1/2)

After reset: 00H    R/W    Address: FFFFF680H

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| 7    | 6    | 5    | 4    | 3    | 2    | <1>  | <0>  |
| WTM7 | WTM6 | WTM5 | WTM4 | WTM3 | WTM2 | WTM1 | WTM0 |

| WTM7 | WTM6 | WTM5 | WTM4 | Selection of interval time of prescaler   |
|------|------|------|------|---|
| 0    | 0    | 0    | 0    | $2^4/f_w$ (488 $\mu$ s: $f_w = f_{XT}$ )  |
| 0    | 0    | 0    | 1    | $2^5/f_w$ (977 $\mu$ s: $f_w = f_{XT}$ )  |
| 0    | 0    | 1    | 0    | $2^6/f_w$ (1.95 ms: $f_w = f_{XT}$ )      |
| 0    | 0    | 1    | 1    | $2^7/f_w$ (3.91 ms: $f_w = f_{XT}$ )      |
| 0    | 1    | 0    | 0    | $2^8/f_w$ (7.81 ms: $f_w = f_{XT}$ )      |
| 0    | 1    | 0    | 1    | $2^9/f_w$ (15.6 ms: $f_w = f_{XT}$ )      |
| 0    | 1    | 1    | 0    | $2^{10}/f_w$ (31.3 ms: $f_w = f_{XT}$ )   |
| 0    | 1    | 1    | 1    | $2^{11}/f_w$ (62.5 ms: $f_w = f_{XT}$ )   |
| 1    | 0    | 0    | 0    | $2^4/f_w$ (488 $\mu$ s: $f_w = f_{BRG}$ ) |
| 1    | 0    | 0    | 1    | $2^5/f_w$ (977 $\mu$ s: $f_w = f_{BRG}$ ) |
| 1    | 0    | 1    | 0    | $2^6/f_w$ (1.95 ms: $f_w = f_{BRG}$ )     |
| 1    | 0    | 1    | 1    | $2^7/f_w$ (3.90 ms: $f_w = f_{BRG}$ )     |
| 1    | 1    | 0    | 0    | $2^8/f_w$ (7.81 ms: $f_w = f_{BRG}$ )     |
| 1    | 1    | 0    | 1    | $2^9/f_w$ (15.6 ms: $f_w = f_{BRG}$ )     |
| 1    | 1    | 1    | 0    | $2^{10}/f_w$ (31.2 ms: $f_w = f_{BRG}$ )  |
| 1    | 1    | 1    | 1    | $2^{11}/f_w$ (62.5 ms: $f_w = f_{BRG}$ )  |



| WTM7 | WTM3 | WTM2 | Selection of set time of watch flag       |
|------|------|------|---|
| 0    | 0    | 0    | $2^{14}/f_w$ (0.5 s: $f_w = f_{XT}$ )     |
| 0    | 0    | 1    | $2^{13}/f_w$ (0.25 s: $f_w = f_{XT}$ )    |
| 0    | 1    | 0    | $2^5/f_w$ (977 $\mu$ s: $f_w = f_{XT}$ )  |
| 0    | 1    | 1    | $2^4/f_w$ (488 $\mu$ s: $f_w = f_{XT}$ )  |
| 1    | 0    | 0    | $2^{14}/f_w$ (0.5 s: $f_w = f_{BRG}$ )    |
| 1    | 0    | 1    | $2^{13}/f_w$ (0.25 s: $f_w = f_{BRG}$ )   |
| 1    | 1    | 0    | $2^5/f_w$ (977 $\mu$ s: $f_w = f_{BRG}$ ) |
| 1    | 1    | 1    | $2^4/f_w$ (488 $\mu$ s: $f_w = f_{BRG}$ ) |

| WTM1 | Control of 5-bit counter operation |
|------|------------------------------------|
| 0    | Clears after operation stops       |
| 1    | Starts                             |

| WTM0 | Watch timer operation enable                              |
|------|---|
| 0    | Stops operation (clears both prescaler and 5-bit counter) |
| 1    | Enables operation   |

**Caution** Rewrite the WTM2 to WTM7 bits while both the WTM0 and WTM1 bits are 0.

**Remarks**

1.  $f_w$ : Watch timer clock frequency
2. Values in parentheses apply to operation with  $f_w = 32.768$  kHz

## 10.4 Operation

### 10.4.1 Operation as watch timer

The watch timer generates an interrupt request signal (INTWT) at fixed time intervals. The watch timer operates using time intervals of 0.25 or 0.5 seconds with the subclock (32.768 kHz) or main clock.

The count operation starts when the WTM.WTM1 and WTM.WTM0 bits are set to 11. When the WTM0 bit is cleared to 0, the 11-bit prescaler and 5-bit counter are cleared and the count operation stops.

The time of the watch timer can be adjusted by clearing the WTM1 bit to 0 and then the 5-bit counter when operating at the same time as the interval timer. At this time, an error of up to 15.6 ms may occur for the watch timer, but the interval timer is not affected.

If the main clock is used as the count clock of the watch timer, set the count clock using the PRSM0.BGCS01 and BGCS00 bits, the 8-bit comparison value using the PRSCM0 register, and the count clock frequency ( $f_{BRG}$ ) of the watch timer to 32.768 kHz.

When the PRSM0.BGCE0 bit is set (1),  $f_{BRG}$  is supplied to the watch timer.

$f_{BRG}$  can be calculated by the following expression.

$$f_{BRG} = f_x / (2^{m+1} \times N)$$

To set  $f_{BRG}$  to 32.768 kHz, perform the following calculation and set the BGCS01 and BGCS00 bits and the PRSCM0 register.

- <1> Set  $N = f_x / 65,536$ . Set  $m = 0$ .
- <2> When the value resulting from rounding up the first decimal place of  $N$  is even, set  $N$  before the roundup as  $N/2$  and  $m$  as  $m + 1$ .
- <3> Repeat <2> until  $N$  is odd or  $m = 3$ .
- <4> Set the value resulting from rounding up the first decimal place of  $N$  to the PRSCM0 register and  $m$  to the BGCS01 and BGCS00 bits.

Example: When  $f_x = 4.00$  MHz

$$\text{<1> } N = 4,000,000 / 65,536 = 61.03\dots, m = 0$$

<2>, <3> Because  $N$  (round up the first decimal place) is odd,  $N = 61$ ,  $m = 0$ .

<4> Set value of PRSCM0 register: 3DH (61), set value of BGCS01 and BGCS00 bits: 00

At this time, the actual  $f_{BRG}$  frequency is as follows.

$$\begin{aligned} f_{BRG} &= f_x / (2^{m+1} \times N) = 4,000,000 / (2 \times 61) \\ &= 32.787 \text{ kHz} \end{aligned}$$

**Remark**  $m$ : Division value (set value of BGCS01 and BGCS00 bits) = 0 to 3

$N$ : Set value of PRSCM0 register = 1 to 256

However,  $N = 256$  only when PRSCM0 register is set to 00H.

$f_x$ : Main clock oscillation frequency

### 10.4.2 Operation as interval timer

The watch timer can also be used as an interval timer that repeatedly generates an interrupt request signal (INTWTI) at intervals specified by a preset count value.

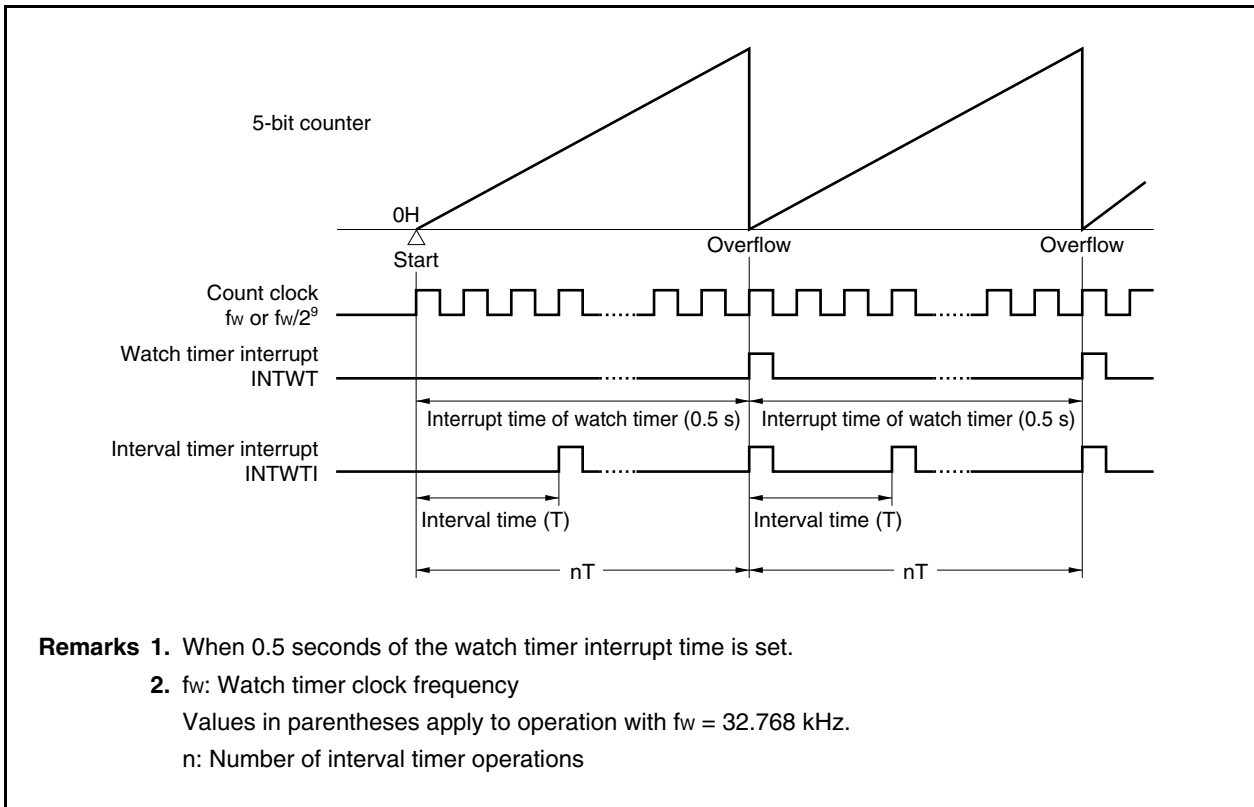
The interval time can be selected by the WTM4 to WTM7 bits of the WTM register.

**Table 10-1. Interval Time of Interval Timer**

| WTM7 | WTM6 | WTM5 | WTM4 | Interval Time        |   |
|------|------|------|------|----------------------|---|
| 0    | 0    | 0    | 0    | $2^1 \times 1/fw$    | 488 $\mu$ s (operating at $f_w = f_{XT} = 32.768$ kHz)  |
| 0    | 0    | 0    | 1    | $2^5 \times 1/fw$    | 977 $\mu$ s (operating at $f_w = f_{XT} = 32.768$ kHz)  |
| 0    | 0    | 1    | 0    | $2^6 \times 1/fw$    | 1.95 ms (operating at $f_w = f_{XT} = 32.768$ kHz)      |
| 0    | 0    | 1    | 1    | $2^7 \times 1/fw$    | 3.91 ms (operating at $f_w = f_{XT} = 32.768$ kHz)      |
| 0    | 1    | 0    | 0    | $2^8 \times 1/fw$    | 7.81 ms (operating at $f_w = f_{XT} = 32.768$ kHz)      |
| 0    | 1    | 0    | 1    | $2^9 \times 1/fw$    | 15.6 ms (operating at $f_w = f_{XT} = 32.768$ kHz)      |
| 0    | 1    | 1    | 0    | $2^{10} \times 1/fw$ | 31.3 ms (operating at $f_w = f_{XT} = 32.768$ kHz)      |
| 0    | 1    | 1    | 1    | $2^{11} \times 1/fw$ | 62.5 ms (operating at $f_w = f_{XT} = 32.768$ kHz)      |
| 1    | 0    | 0    | 0    | $2^4 \times 1/fw$    | 488 $\mu$ s (operating at $f_w = f_{BRG} = 32.768$ kHz) |
| 1    | 0    | 0    | 1    | $2^5 \times 1/fw$    | 977 $\mu$ s (operating at $f_w = f_{BRG} = 32.768$ kHz) |
| 1    | 0    | 1    | 0    | $2^6 \times 1/fw$    | 1.95 ms (operating at $f_w = f_{BRG} = 32.768$ kHz)     |
| 1    | 0    | 1    | 1    | $2^7 \times 1/fw$    | 3.91 ms (operating at $f_w = f_{BRG} = 32.768$ kHz)     |
| 1    | 1    | 0    | 0    | $2^8 \times 1/fw$    | 7.81 ms (operating at $f_w = f_{BRG} = 32.768$ kHz)     |
| 1    | 1    | 0    | 1    | $2^9 \times 1/fw$    | 15.6 ms (operating at $f_w = f_{BRG} = 32.768$ kHz)     |
| 1    | 1    | 1    | 0    | $2^{10} \times 1/fw$ | 31.3 ms (operating at $f_w = f_{BRG} = 32.768$ kHz)     |
| 1    | 1    | 1    | 1    | $2^{11} \times 1/fw$ | 62.5 ms (operating at $f_w = f_{BRG} = 32.768$ kHz)     |

**Remark** fw: Watch timer clock frequency

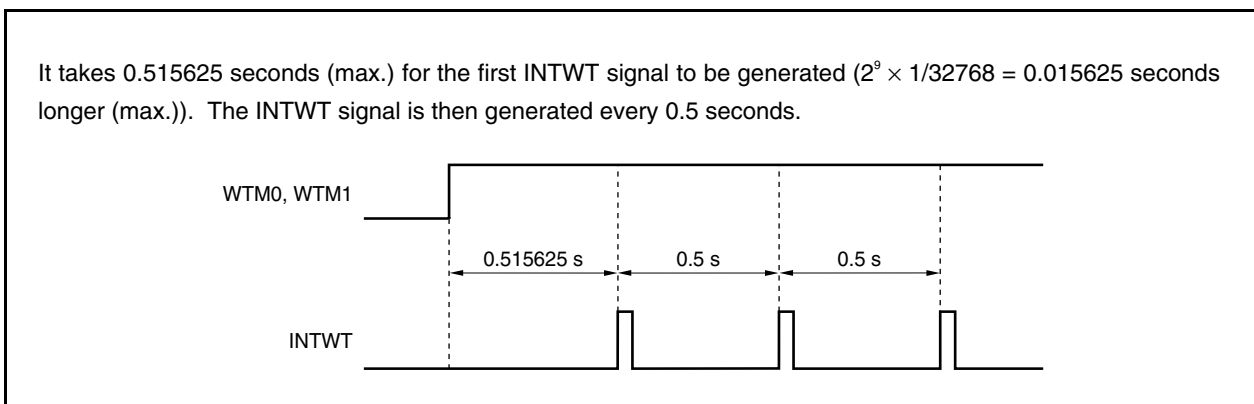
Figure 10-2. Operation Timing of Watch Timer/Interval Timer



10.4.3 Cautions

Some time is required before the first watch timer interrupt request signal (INTWT) is generated after operation is enabled (WTM.WTM1 and WTM.WTM0 bits = 1).

Figure 10-3. Example of Generation of Watch Timer Interrupt Request Signal (INTWT)  
(When Interrupt Cycle = 0.5 s)



## CHAPTER 11 FUNCTIONS OF WATCHDOG TIMER 2

### 11.1 Functions

Watchdog timer 2 has the following functions.

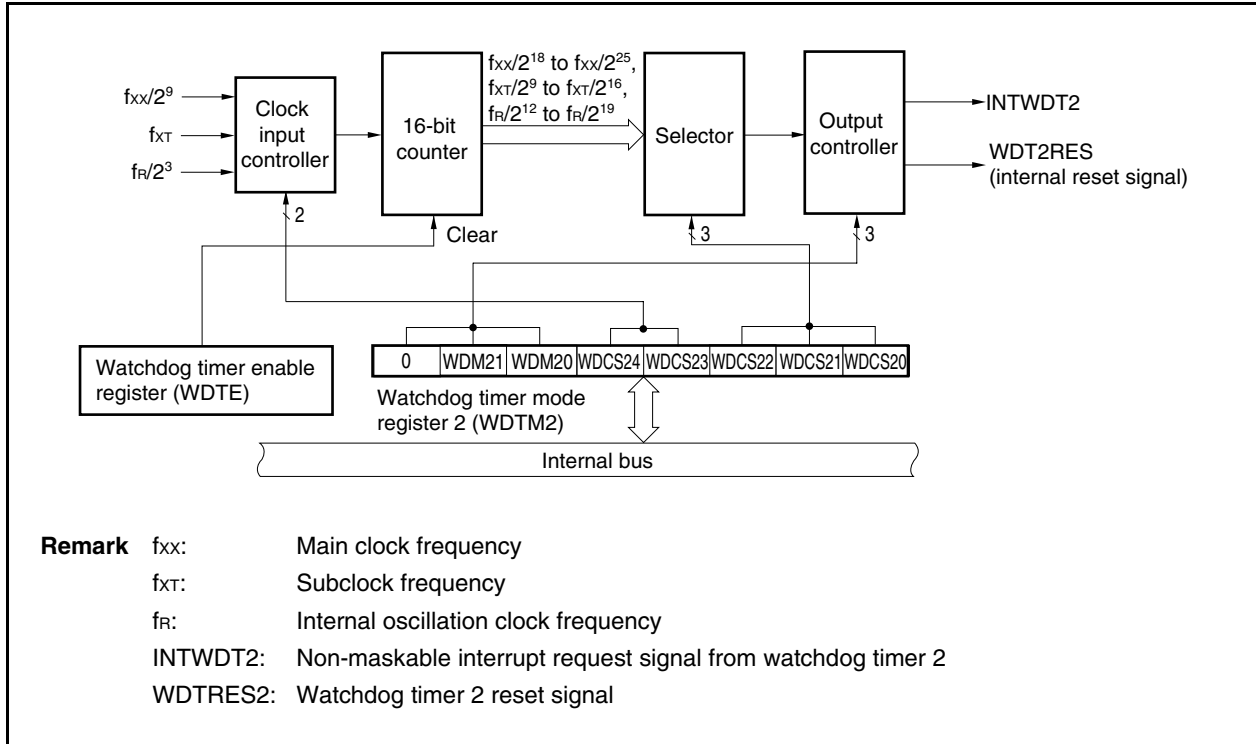
- Default-start watchdog timer<sup>Note 1</sup>
  - Reset mode: Reset operation upon overflow of watchdog timer 2 (generation of WDT2RES signal)
  - Non-maskable interrupt request mode: NMI operation upon overflow of watchdog timer 2 (generation of INTWDT2 signal)<sup>Note 2</sup>
- Input selectable from main clock, internal oscillation clock, and subclock as the source clock

- Notes**
1. Watchdog timer 2 automatically starts in the reset mode following reset release.  
When watchdog timer 2 is not used, either stop its operation before reset is executed via this function, or clear watchdog timer 2 once and stop it within the next interval time.  
Also, write to the WDTM2 register for verification purposes only once, even if the default settings (reset mode, interval time:  $f_{R}/2^{19}$ ) do not need to be changed.
  2. For the non-maskable interrupt servicing due to a non-maskable interrupt request signal (INTWDT2), see **19.2.2 (2) From INTWDT2 signal**.

## 11.2 Configuration

The following shows the block diagram of watchdog timer 2.

Figure 11-1. Block Diagram of Watchdog Timer 2



Watchdog timer 2 includes the following hardware.

Table 11-1. Configuration of Watchdog Timer 2

| Item              | Configuration   |
|-------------------|---|
| Control registers | Watchdog timer mode register 2 (WDTM2)<br>Watchdog timer enable register (WDTE) |

### 11.3 Registers

#### (1) Watchdog timer mode register 2 (WDTM2)

The WDTM2 register sets the overflow time and operation clock of watchdog timer 2.

This register can be read or written in 8-bit units. This register can be read any number of times, but it can be written only once following reset release.

Reset sets this register to 67H.

**Caution** Accessing the WDTM2 register is prohibited in the following statuses. For details, see 3.4.8 (2) Accessing specific on-chip peripheral I/O registers.

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock

After reset: 67H    R/W    Address: FFFFF6D0H

|       |   |       |       |        |        |        |        |        |
|-------|---|-------|-------|--------|--------|--------|--------|--------|
| WDTM2 | 7 | 6     | 5     | 4      | 3      | 2      | 1      | 0      |
|       | 0 | WDM21 | WDM20 | WDCS24 | WDCS23 | WDCS22 | WDCS21 | WDCS20 |

|       |       |   |
|-------|-------|---|
| WDM21 | WDM20 | Selection of operation mode of watchdog timer 2                       |
| 0     | 0     | Stops operation   |
| 0     | 1     | Non-maskable interrupt request mode<br>(generation of INTWDT2 signal) |
| 1     | –     | Reset mode (generation of WDT2RES signal)                             |

**Cautions**

1. For details of the WDCS20 to WDCS24 bits, see Table 11-2 Watchdog Timer 2 Clock Selection.
2. Although watchdog timer 2 can be stopped just by stopping the operation of the internal oscillator, clear the WDTM2 register to 00H to securely stop the timer (to avoid selection of the main clock or subclock due to an erroneous write operation).
3. If the WDTM2 register is rewritten twice after reset, an overflow signal is forcibly generated and the counter is reset.
4. To intentionally generate an overflow signal, write data to the WDTM2 register only twice, or write a value other than “ACH” to the WDTE register only once.  
However, when watchdog timer 2 is set to stop operation, an overflow signal is not generated even if data is written to the WDTM2 register only twice, or a value other than “ACH” is written to the WDTE register only once.
5. To stop the operation of watchdog timer 2, set the RCM.RSTP bit to 1 (to stop the internal oscillator) and write 00H in the WDTM2 register. If the RCM.RSTP bit cannot be set to 1, set the WDCS23 bit to 1 ( $2^0/f_{xx}$  is selected and the clock can be stopped in the IDLE1, IDLW2, sub-IDLE, and subclock operation modes).

Table 11-2. Watchdog Timer 2 Clock Selection

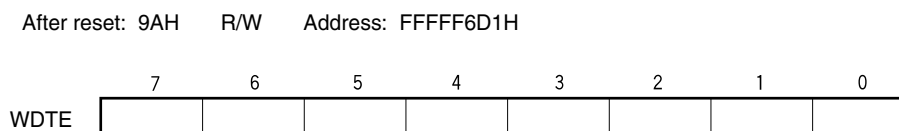
| WDCS24 | WDCS23 | WDCS22 | WDCS21 | WDCS20 | Selected Clock  | 100 kHz (MIN.)                | 220 kHz (TYP.)            | 400 kHz (MAX.)            |
|--------|--------|--------|--------|--------|-----------------|-------------------------------|---------------------------|---------------------------|
| 0      | 0      | 0      | 0      | 0      | $2^{12}/f_R$    | 41.0 ms                       | 18.6 ms                   | 10.2 ms                   |
| 0      | 0      | 0      | 0      | 1      | $2^{13}/f_R$    | 81.9 ms                       | 37.2 ms                   | 20.5 ms                   |
| 0      | 0      | 0      | 1      | 0      | $2^{14}/f_R$    | 163.8 ms                      | 74.5 ms                   | 41.0 ms                   |
| 0      | 0      | 0      | 1      | 1      | $2^{15}/f_R$    | 327.7 ms                      | 148.9 ms                  | 81.9 ms                   |
| 0      | 0      | 1      | 0      | 0      | $2^{16}/f_R$    | 655.4 ms                      | 297.9 ms                  | 163.8 ms                  |
| 0      | 0      | 1      | 0      | 1      | $2^{17}/f_R$    | 1,310.7 ms                    | 595.8 ms                  | 327.7 ms                  |
| 0      | 0      | 1      | 1      | 0      | $2^{18}/f_R$    | 2,621.4 ms                    | 1,191.6 ms                | 655.4 ms                  |
| 0      | 0      | 1      | 1      | 1      | $2^{19}/f_R$    | 5,242.9 ms                    | 2,383.1 ms                | 1,310.7 ms                |
|        |        |        |        |        |                 | $f_{xx} = 32 \text{ MHz}$     | $f_{xx} = 20 \text{ MHz}$ | $f_{xx} = 10 \text{ MHz}$ |
| 0      | 1      | 0      | 0      | 0      | $2^{18}/f_{xx}$ | 8.2 ms                        | 13.1 ms                   | 26.2 ms                   |
| 0      | 1      | 0      | 0      | 1      | $2^{19}/f_{xx}$ | 16.4 ms                       | 26.2 ms                   | 52.4 ms                   |
| 0      | 1      | 0      | 1      | 0      | $2^{20}/f_{xx}$ | 32.8 ms                       | 52.4 ms                   | 104.9 ms                  |
| 0      | 1      | 0      | 1      | 1      | $2^{21}/f_{xx}$ | 65.5 ms                       | 104.9 ms                  | 209.7 ms                  |
| 0      | 1      | 1      | 0      | 0      | $2^{22}/f_{xx}$ | 131.1 ms                      | 209.7 ms                  | 419.4 ms                  |
| 0      | 1      | 1      | 0      | 1      | $2^{23}/f_{xx}$ | 262.1 ms                      | 419.4 ms                  | 838.9 ms                  |
| 0      | 1      | 1      | 1      | 0      | $2^{24}/f_{xx}$ | 524.3 ms                      | 838.9 ms                  | 1,677.7 ms                |
| 0      | 1      | 1      | 1      | 1      | $2^{25}/f_{xx}$ | 1,048.6 ms                    | 1,677.7 ms                | 3,355.4 ms                |
|        |        |        |        |        |                 | $f_{XT} = 32.768 \text{ kHz}$ |                           |                           |
| 1      | ×      | 0      | 0      | 0      | $2^9/f_{XT}$    | 15.625 ms                     |                           |                           |
| 1      | ×      | 0      | 0      | 1      | $2^{10}/f_{XT}$ | 31.25 ms                      |                           |                           |
| 1      | ×      | 0      | 1      | 0      | $2^{11}/f_{XT}$ | 62.5 ms                       |                           |                           |
| 1      | ×      | 0      | 1      | 1      | $2^{12}/f_{XT}$ | 125 ms                        |                           |                           |
| 1      | ×      | 1      | 0      | 0      | $2^{13}/f_{XT}$ | 250 ms                        |                           |                           |
| 1      | ×      | 1      | 0      | 1      | $2^{14}/f_{XT}$ | 500 ms                        |                           |                           |
| 1      | ×      | 1      | 1      | 0      | $2^{15}/f_{XT}$ | 1,000 ms                      |                           |                           |
| 1      | ×      | 1      | 1      | 1      | $2^{16}/f_{XT}$ | 2,000 ms                      |                           |                           |

**(2) Watchdog timer enable register (WDTE)**

The counter of watchdog timer 2 is cleared and counting restarted by writing "ACH" to the WDTE register.

The WDTE register can be read or written in 8-bit units.

Reset sets this register to 9AH.



- Cautions**
1. When a value other than "ACH" is written to the WDTE register, an overflow signal is forcibly output.
  2. When a 1-bit memory manipulation instruction is executed for the WDTE register, an overflow signal is forcibly output.
  3. To intentionally generate an overflow signal, write a value other than "ACH" to the WDTE register only once, or write data to the WDTM2 register only twice.  
However, when the watchdog timer 2 is set to stop operation, an overflow signal is not generated even if data is written to the WDTM2 register only twice, or a value other than "ACH" is written to the WDTE register only once.
  4. The read value of the WDTE register is "9AH" (which differs from written value "ACH").



## 11.4 Operation

Watchdog timer 2 automatically starts in the reset mode following reset release.

The WDTM2 register can be written to only once following reset using byte access. To use watchdog timer 2, write the operation mode and the interval time to the WDTM2 register using an 8-bit memory manipulation instruction. After this, the operation of watchdog timer 2 cannot be stopped.

The WDCS24 to WDCS20 bits of the WDTM2 register are used to select the watchdog timer 2 loop detection time interval.

Writing ACH to the WDTE register clears the counter of watchdog timer 2 and starts the count operation again. After the count operation has started, write ACH to WDTE within the loop detection time interval.

If the time interval expires without ACH being written to the WDTE register, a reset signal (WDT2RES) or a non-maskable interrupt request signal (INTWDT2) is generated, depending on the set values of the WDM21 and WDTM2.WDM20 bits.

When the WDTM2.WDM21 bit is set to 1 (reset mode), if a WDT overflow occurs during oscillation stabilization after a reset or standby is released, no internal reset will occur and the CPU clock will switch to the internal oscillation clock.

To not use watchdog timer 2, write 00H to the WDTM2 register.

For the non-maskable interrupt servicing while the non-maskable interrupt request mode is set, see **19.2.2 (2) From INTWDT2 signal**.

## CHAPTER 12 REAL-TIME OUTPUT FUNCTION (RTO)

### 12.1 Function

The real-time output function transfers preset data to the RTBLn and RTBHn registers, and then transfers this data by hardware to an external device via the output latches, upon occurrence of a timer interrupt. The pins through which the data is output to an external device constitute a port called the real-time output function (RTO).

Because RTO can output signals without jitter, it is suitable for controlling a stepper motor.

In the V850ES/JJ3, two 6-bit real-time output port channels are provided.

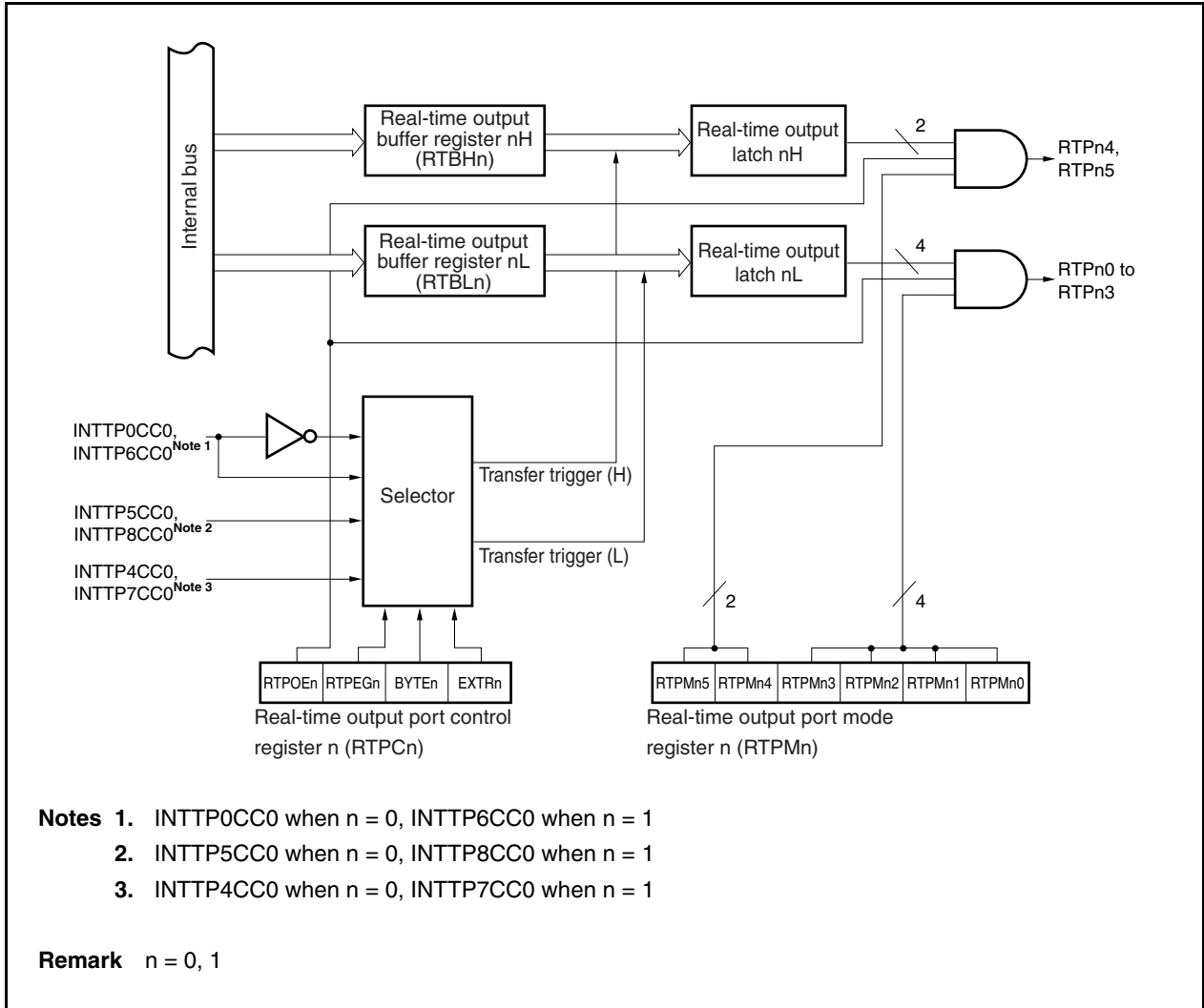
The real-time output port can be set to the port mode or real-time output port mode in 1-bit units.

**Remark** n = 0, 1

### 12.2 Configuration

The block diagram of RTO is shown below.

**Figure 12-1. Block Diagram of RTO**



RTO includes the following hardware.

**Table 12-1. Configuration of RTO**

| Item              | Configuration   |
|-------------------|---|
| Registers         | Real-time output buffer registers nL, nH (RTBLn, RTBHn)   |
| Control registers | Real-time output port mode register n (RTPMn)<br>Real-time output port control register n (RTPCn) |

**(1) Real-time output buffer registers nL, nH (RTBLn, RTBHn)**

The RTBLn and RTBHn registers are 4-bit registers that hold preset output data.

These registers are mapped to independent addresses in the peripheral I/O register area.

These registers can be read or written in 8-bit or 1-bit units.

Reset sets these registers to 00H.

If an operation mode of 4 bits × 1 channel or 2 bits × 1 channel is specified (RTPCn.BYTE<sub>n</sub> bit = 0), data can be individually set to the RTBLn and RTBHn registers. The data of both these registers can be read at once by specifying the address of either of these registers.

If an operation mode of 6 bits × 1 channel is specified (BYTE<sub>n</sub> bit = 1), 8-bit data can be set to both the RTBLn and RTBHn registers by writing the data to either of these registers. Moreover, the data of both these registers can be read at once by specifying the address of either of these registers.

Table 12-2 shows the operation when the RTBLn and RTBHn registers are manipulated.

After reset: 00H    R/W    Address: RTBL0 FFFFF6E0H, RTBH0 FFFFF6E2H,  
RTBL1 FFFFF6F0H, RTBH1 FFFFF6F2H

|       |       |   |        |        |        |        |        |        |
|-------|-------|---|--------|--------|--------|--------|--------|--------|
|       | 7     | 6 | 5      | 4      | 3      | 2      | 1      | 0      |
| RTBLn | ----- |   |        |        | RTBLn3 | RTBLn2 | RTBLn1 | RTBLn0 |
| RTBHn | 0     | 0 | RTBHn5 | RTBHn4 | -----  |        |        |        |

**Cautions**

1. When writing to bits 6 and 7 of the RTBHn register, always write 0.
2. Accessing the RTBLn and RTBHn registers is prohibited in the following statuses. For details, see 3.4.8 (2) Accessing specific on-chip peripheral I/O registers.
  - When the CPU operates with the subclock and the main clock oscillation is stopped
  - When the CPU operates with the internal oscillation clock

**Remark**    n = 0, 1

**Table 12-2. Operation During Manipulation of RTBLn and RTBHn Registers**

| Operation Mode                            | Register to Be Manipulated | Read          |              | Write <sup>Note</sup> |              |
|---|----------------------------|---------------|--------------|-----------------------|--------------|
|   |                            | Higher 4 Bits | Lower 4 Bits | Higher 4 Bits         | Lower 4 Bits |
| 4 bits × 1 channel,<br>2 bits × 1 channel | RTBLn                      | RTBHn         | RTBLn        | Invalid               | RTBLn        |
|   | RTBHn                      | RTBHn         | RTBLn        | RTBHn                 | Invalid      |
| 6 bits × 1 channel                        | RTBLn                      | RTBHn         | RTBLn        | RTBHn                 | RTBLn        |
|   | RTBHn                      | RTBHn         | RTBLn        | RTBHn                 | RTBLn        |

**Note** After setting the real-time output port, set output data to the RTBLn and RTBHn registers by the time a real-time output trigger is generated.

### 12.3 Registers

RTO is controlled using the following two registers.

- Real-time output port mode register n (RTPMn)
- Real-time output port control register n (RTPCn)

#### (1) Real-time output port mode register n (RTPMn)

The RTPMn register selects the real-time output port mode or port mode in 1-bit units.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

|                     |   |     |   |        |        |        |        |        |
|---------------------|---|-----|---|--------|--------|--------|--------|--------|
| After reset: 00H    |   | R/W | Address: RTPM0 FFFFF6E4H, RTPM1 FFFFF6F4H |        |        |        |        |        |
| RTPMn<br>(n = 0, 1) | 7 | 6   | 5   | 4      | 3      | 2      | 1      | 0      |
|                     | 0 | 0   | RTPMn5                                    | RTPMn4 | RTPMn3 | RTPMn2 | RTPMn1 | RTPMn0 |

|        |   |
|--------|---|
| RTPMnm | Control of real-time output port (m = 0 to 5) |
| 0      | Real-time output disabled                     |
| 1      | Real-time output enabled                      |

**Cautions**

1. By enabling the real-time output operation (RTPCn.RTPOEn bit = 1), the bits enabled to real-time output among the RTPn0 to RTPn5 signals perform real-time output, and the bits set to port mode output 0.
2. If real-time output is disabled (RTPOEn bit = 0), the real-time output pins (RTPn0 to RTPn5) all output 0, regardless of the RTPMn register setting.
3. In order to use this register as the real-time output pins (RTPn0 to RTPn5), set these pins as real-time output port pins using the PMC and PFC registers.

**(2) Real-time output port control register n (RTPCn)**

The RTPCn register is a register that sets the operation mode and output trigger of the real-time output port. The relationship between the operation mode and output trigger of the real-time output port is as shown in Tables 12-3 and 12-4.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: RTPC0 FFFFF6E5H, RTPC1 FFFFF6F5H

|                     |        |        |       |       |   |   |   |
|---------------------|--------|--------|-------|-------|---|---|---|
| <7>                 | 6      | 5      | 4     | 3     | 2 | 1 | 0 |
| RTPCn<br>(n = 0, 1) | RTPOEn | RTPEGn | BYTEn | EXTRn | 0 | 0 | 0 |

|        |                                       |
|--------|---------------------------------------|
| RTPOEn | Control of real-time output operation |
| 0      | Disables operation <sup>Note 1</sup>  |
| 1      | Enables operation                     |

|        |   |
|--------|---|
| RTPEGn | Valid edge of INTTPaCC0 (n = 0, a = 0, 4, 5) and<br>INTTPbCC0 (n = 1, b = 6 to 8) signals |
| 0      | Falling edge <sup>Note 2</sup>  |
| 1      | Rising edge   |

|       |   |
|-------|---|
| BYTEn | Specification of channel configuration for real-time output |
| 0     | 4 bits × 2 channels, 2 bits × 2 channels                    |
| 1     | 6 bits × 2 channels   |

**Notes**

1. When the real-time output operation is disabled (RTPOEn bit = 0), all the bits of the real-time output signals (RTPn0 to RTPn5) output "0".
2. The INTTP0CC0 and INTTP6CC0 signals are output for 1 clock of the count clock selected by TMP0 or TMP6.

**Caution** Set the RTPEGn, BYTEn, and EXTRn bits only when RTPOEn bit = 0.

**Table 12-3. Operation Modes and Output Triggers of Real-Time Output Port (n = 0)**

| BYTE0 | EXTR0 | Operation Mode      | RTBH0 (RTP04, RTP05) | RTBL0 (RTP00 to RTP03) |
|-------|-------|---------------------|----------------------|------------------------|
| 0     | 0     | 4 bits × 1 channel, | INTTP5CC0            | INTTP4CC0              |
|       | 1     | 2 bits × 1 channel  | INTTP4CC0            | INTTP0CC0              |
| 1     | 0     | 6 bits × 1 channel  | INTTP4CC0            |                        |
|       | 1     |                     | INTTP0CC0            |                        |

**Table 12-4. Operation Modes and Output Triggers of Real-Time Output Port (n = 1)**

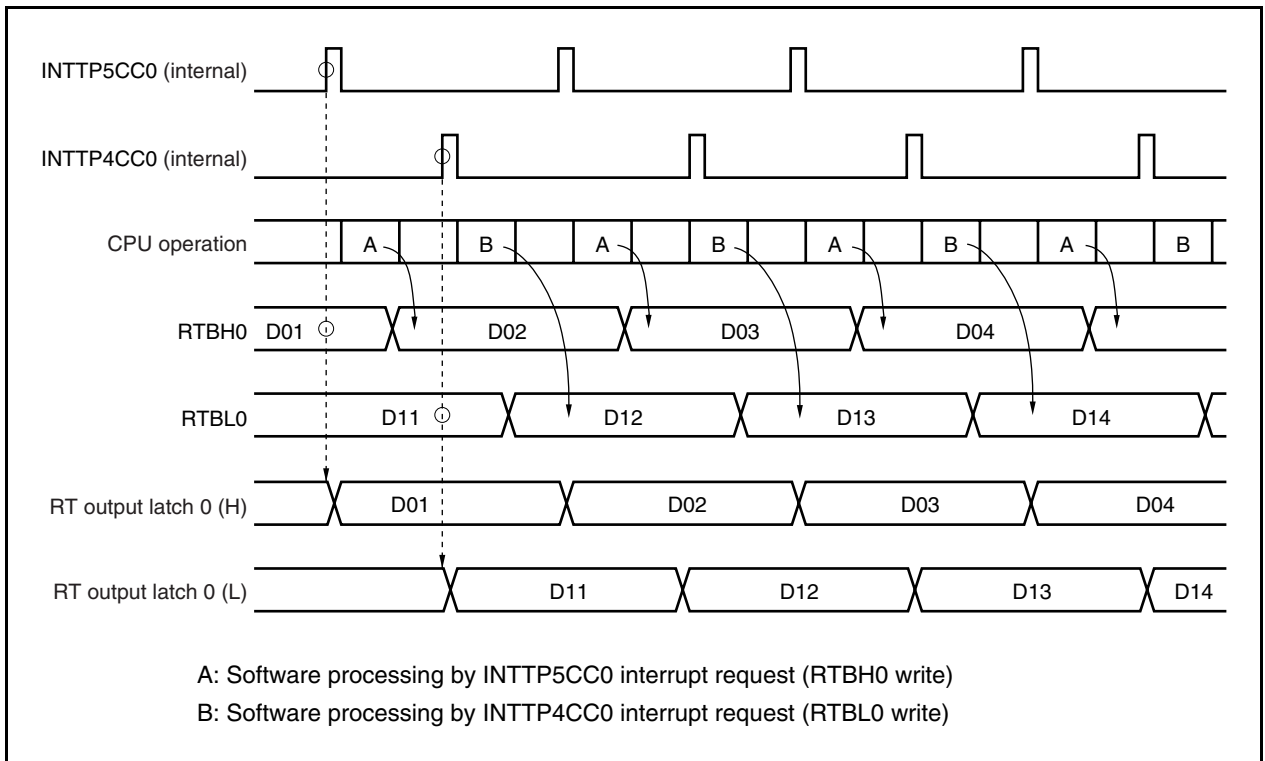
| BYTE1 | EXTR1 | Operation Mode      | RTBH1 (RTP14, RTP15) | RTBL1 (RTP10 to RTP13) |
|-------|-------|---------------------|----------------------|------------------------|
| 0     | 0     | 4 bits × 1 channel, | INTTP8CC0            | INTTP7CC0              |
|       | 1     | 2 bits × 1 channel  | INTTP7CC0            | INTTP6CC0              |
| 1     | 0     | 6 bits × 1 channel  | INTTP7CC0            |                        |
|       | 1     |                     | INTTP6CC0            |                        |

### 12.4 Operation

If the real-time output operation is enabled by setting the RTPCn.RTPOEn bit to 1, the data of the RTBHn and RTBLn registers is transferred to the real-time output latch in synchronization with the generation of the selected transfer trigger (set by the RTPCn.EXTRn and RTPCn.BYTEn bits). Of the transferred data, only the data of the bits for which real-time output is enabled by the RTPMn register is output from the RTPn0 to RTPn5 bits. The bits for which real-time output is disabled by the RTPMn register output 0.

If the real-time output operation is disabled by clearing the RTPOEn bit to 0, the RTPn0 to RTPn5 signals output 0 regardless of the setting of the RTPMn register.

**Figure 12-2. Example of Operation Timing of RTO0 (When EXTR0 Bit = 0, BYTE0 Bit = 0)**



**Remark** For the operation during standby, see **CHAPTER 21 STANDBY FUNCTION**.

## 12.5 Usage

- (1) Disable real-time output.  
Clear the RTPCn.RTPOEn bit to 0.
- (2) Perform initialization as follows.
  - Set the alternate-function pins of port 5  
Set the PFC5.PFC5m bit and PFCE5.PFCE5m bit to 1, and then set the PMC5.PMC5m bit to 1 (m = 0 to 5).
  - Specify the real-time output port mode or port mode in 1-bit units.  
Set the RTPMn register.
  - Channel configuration: Select the trigger and valid edge.  
Set the RTPCn.EXTRn, RTPCn.BYTEn, and RTPCn.RTPEGn bits.
  - Set the initial values to the RTBHn and RTBLn registers<sup>Note 1</sup>.
- (3) Enable real-time output.  
Set the RTPOEn bit = 1.
- (4) Set the next output value to the RTBHn and RTBLn registers by the time the selected transfer trigger is generated<sup>Note 2</sup>.
- (5) Set the next real-time output value to the RTBHn and RTBLn registers via interrupt servicing corresponding to the selected trigger.

**Notes 1.** If the RTBHn and RTBLn registers are written when the RTPOEn bit = 0, that value is transferred to real-time output latches nH and nL, respectively.

**2.** Even if the RTBHn and RTBLn registers are written when the RTPOEn bit = 1, data is not transferred to real-time output latches nH and nL.

## 12.6 Cautions

- (1) Prevent the following conflicts by software.
  - Conflict between real-time output disable/enable switching (RTPOEn bit) and selected real-time output trigger.
  - Conflict between writing to the RTBHn and RTBLn registers in the real-time output enabled status and the selected real-time output trigger.
- (2) Before performing initialization, disable real-time output (RTPOEn bit = 0).
- (3) Once real-time output has been disabled (RTPOEn bit = 0), be sure to initialize the RTBHn and RTBLn registers before enabling real-time output again (RTPOEn bit = 0 → 1).



## CHAPTER 13 A/D CONVERTER

### 13.1 Overview

The A/D converter converts analog input signals into digital values, has a resolution of 10 bits, and can handle 16 analog input signal channels (ANI0 to ANI15).

The A/D converter has the following features.

- 10-bit resolution
- 16 channels
- Successive approximation method
- Operating voltage:  $AV_{REF0} = 3.0$  to  $3.6$  V
- Analog input voltage:  $0$  V to  $AV_{REF0}$
- The following functions are provided as operation modes.
  - Continuous select mode
  - Continuous scan mode
  - One-shot select mode
  - One-shot scan mode
- The following functions are provided as trigger modes.
  - Software trigger mode
  - External trigger mode (external, 1)
  - Timer trigger mode
- Power-fail monitor function (conversion result compare function)

### 13.2 Functions

#### (1) 10-bit resolution A/D conversion

An analog input channel is selected from ANI0 to ANI15, and an A/D conversion operation is repeated at a resolution of 10 bits. Each time A/D conversion has been completed, an interrupt request signal (INTAD) is generated.

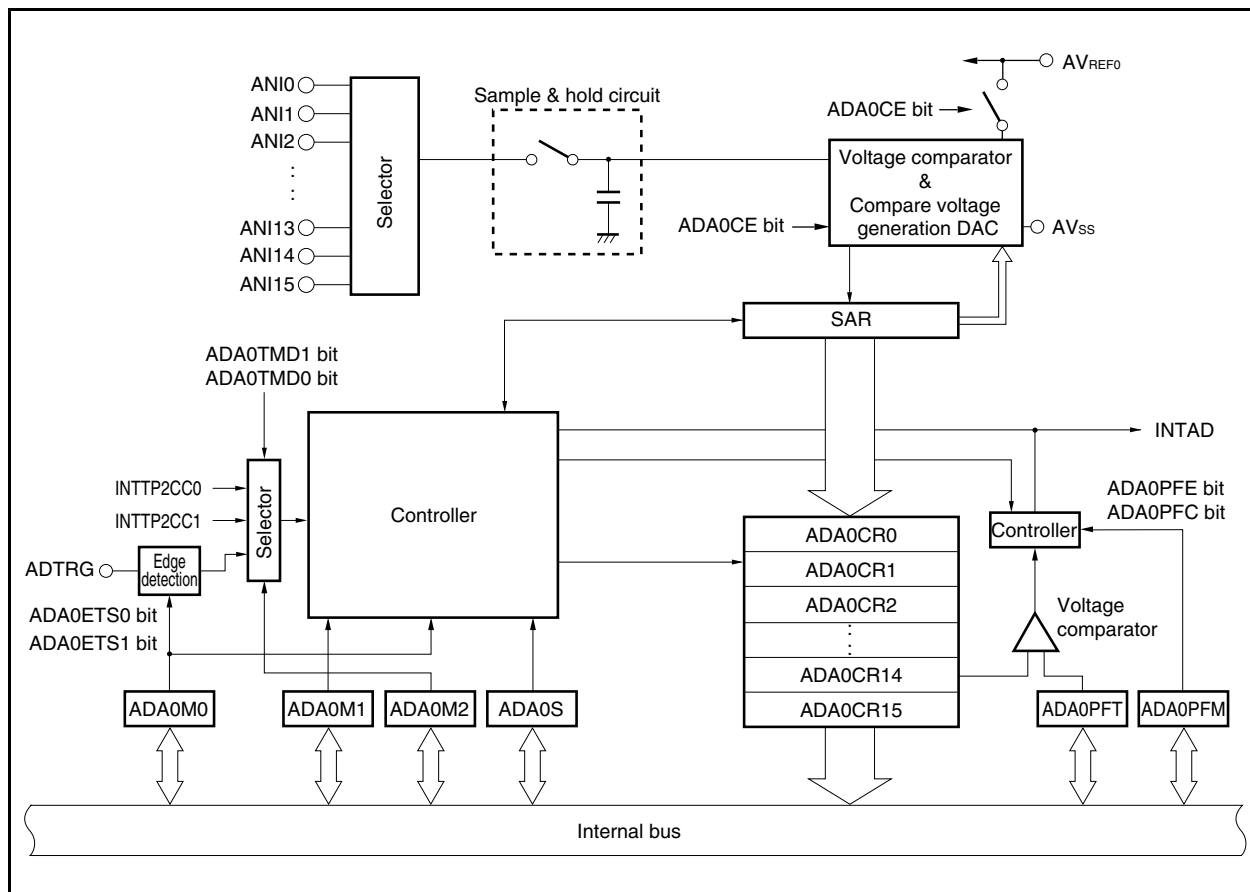
#### (2) Power-fail detection function

This function is used to detect a drop in the battery voltage. The result of A/D conversion (the value of the ADA0CRnH register) is compared with the value of the ADA0PFT register, and the INTAD signal is generated only when a specified comparison condition is satisfied ( $n = 0$  to  $15$ ).

### 13.3 Configuration

The block diagram of the A/D converter is shown below.

**Figure 13-1. Block Diagram of A/D Converter**



The A/D converter includes the following hardware.

**Table 13-1. Configuration of A/D Converter**

| Item              | Configuration   |
|-------------------|---|
| Analog inputs     | 16 channels (ANI0 to ANI15 pins)  |
| Registers         | Successive approximation register (SAR)<br>A/D conversion result registers 0 to 15 (ADA0CR0 to ADA0CR15)<br>A/D conversion result registers 0H to 15H (ADCR0H to ADCR15H): Only higher 8 bits can be read               |
| Control registers | A/D converter mode registers 0 to 2 (ADA0M0 to ADA0M2)<br>A/D converter channel specification register 0 (ADA0S)<br>Power fail compare mode register (ADA0PFT)<br>Power fail compare threshold value register (ADA0PFC) |

**(1) Successive approximation register (SAR)**

The SAR register compares the voltage value of the analog input signal with the output voltage (compare voltage) value of the compare voltage generation DAC, and holds the comparison result starting from the most significant bit (MSB).

When the comparison result has been held down to the least significant bit (LSB) (i.e., when A/D conversion is complete), the contents of the SAR register are transferred to the ADA0CRn register.

**Remark** n = 0 to 15

**(2) A/D conversion result register n (ADA0CRn), A/D conversion result register nH (ADA0CRnH)**

The ADA0CRn register is a 16-bit register that stores the A/D conversion result. ADA0ARn consist of 16 registers and the A/D conversion result is stored in the 10 higher bits of the ADA0CRn register corresponding to analog input. (The lower 6 bits are fixed to 0.)

**(3) A/D converter mode register 0 (ADA0M0)**

This register specifies the operation mode and controls the conversion operation by the A/D converter.

**(4) A/D converter mode register 1 (ADA0M1)**

This register sets the conversion time of the analog input signal to be converted.

**(5) A/D converter mode register 2 (ADA0M2)**

This register sets the hardware trigger mode.

**(6) A/D converter channel specification register (ADA0S)**

This register sets the input port that inputs the analog voltage to be converted.

**(7) Power-fail compare mode register (ADA0PFM)**

This register sets the power-fail monitor mode.

**(8) Power-fail compare threshold value register (ADA0PFT)**

The ADA0PFT register sets a threshold value that is compared with the value of A/D conversion result register nH (ADA0CRnH). The 8-bit data set to the ADA0PFT register is compared with the higher 8 bits of the A/D conversion result register (ADA0CRnH).

**(9) Controller**

The controller compares the result of the A/D conversion (the value of the ADA0CRnH register) with the value of the ADA0PFT register when A/D conversion is completed or when the power-fail detection function is used, and generates the INTAD signal only when a specified comparison condition is satisfied.

**(10) Sample & hold circuit**

The sample & hold circuit samples each of the analog input signals selected by the input circuit and sends the sampled data to the voltage comparator. This circuit also holds the sampled analog input signal voltage during A/D conversion.

**(11) Voltage comparator**

The voltage comparator compares a voltage value that has been sampled and held with the output voltage value of the compare voltage generation DAC.

**(12) Compare voltage generation DAC**

This compare voltage generation DAC is connected between  $AV_{REF0}$  and  $AV_{SS}$  and generates a voltage for comparison with the analog input signal.

**(13) ANI0 to ANI15 pins**

These are analog input pins for the 16 A/D converter channels and are used to input analog signals to be converted into digital signals. Pins other than the one selected as the analog input by the ADA0S register can be used as input port pins.

**Caution** Make sure that the voltages input to the ANI0 to ANI15 pins do not exceed the rated values. In particular if a voltage of  $AV_{REF0}$  or higher is input to a channel, the conversion value of that channel becomes undefined, and the conversion values of the other channels may also be affected.

**(14)  $AV_{REF0}$  pin**

This is the pin used to input the reference voltage of the A/D converter. Always make the potential at this pin the same as that at the  $V_{DD}$  pin even when the A/D converter is not used. The signals input to the ANI0 to ANI15 pins are converted to digital signals based on the voltage applied between the  $AV_{REF0}$  and  $AV_{SS}$  pins.

**(15)  $AV_{SS}$  pin**

This is the ground pin of the A/D converter. Always make the potential at this pin the same as that at the  $V_{SS}$  pin even when the A/D converter is not used.

### 13.4 Registers

The A/D converter is controlled by the following registers.

- A/D converter mode registers 0, 1, 2 (ADA0M0, ADA0M1, ADA0M2)
- A/D converter channel specification register 0 (ADA0S)
- Power-fail compare mode register (ADA0PFM)

The following registers are also used.

- A/D conversion result register n (ADA0CRn)
- A/D conversion result register nH (ADA0CRnH)
- Power-fail compare threshold value register (ADA0PFT)

#### (1) A/D converter mode register 0 (ADA0M0)

The ADA0M0 register is an 8-bit register that specifies the operation mode and controls conversion operations. This register can be read or written in 8-bit or 1-bit units. However, ADA0EF bit is read-only. Reset sets this register to 00H.

(1/2)

|                  |          |                        |  |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|------------------|----------|------------------------|--|---------|----------|----------|---------|--------|-------------------|--|--|--|--|--|--|--|
| After reset: 00H |          |                        |  |         |          |          |         | R/W    | Address: FFFF200H |  |  |  |  |  |  |  |
|                  | <7>      | 6                      | 5  | 4       | 3        | 2        | 1       | <0>    |                   |  |  |  |  |  |  |  |
| ADA0M0           | ADA0CE   | 0                      | ADA0MD1  | ADA0MD0 | ADA0ETS1 | ADA0ETS0 | ADA0TMD | ADA0EF |                   |  |  |  |  |  |  |  |
|                  | ADA0CE   | A/D conversion control |  |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 0        | Stops A/D conversion   |  |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 1        | Enables A/D conversion |  |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | ADA0MD1  | ADA0MD0                | Specification of A/D converter operation mode                  |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 0        | 0                      | Continuous select mode   |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 0        | 1                      | Continuous scan mode   |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 1        | 0                      | One-shot select mode   |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 1        | 1                      | One-shot scan mode   |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | ADA0ETS1 | ADA0ETS0               | Specification of external trigger (ADTRG pin) input valid edge |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 0        | 0                      | No edge detection  |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 0        | 1                      | Falling edge detection   |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 1        | 0                      | Rising edge detection  |         |          |          |         |        |                   |  |  |  |  |  |  |  |
|                  | 1        | 1                      | Detection of both rising and falling edges                     |         |          |          |         |        |                   |  |  |  |  |  |  |  |

| ADA0TMD | Trigger mode specification               |
|---------|--|
| 0       | Software trigger mode                    |
| 1       | External trigger mode/timer trigger mode |

| ADA0EF | A/D converter status display |
|--------|------------------------------|
| 0      | A/D conversion stopped       |
| 1      | A/D conversion in progress   |

- Cautions**
1. Accessing the ADA0M0 register is prohibited in the following statuses. For details, see 3.4.8 (2) Accessing specific on-chip peripheral I/O registers.
    - When the CPU operates with the subclock and the main clock oscillation is stopped
    - When the CPU operates with the internal oscillation clock
  2. A write operation to bit 0 is ignored.
  3. Changing the ADA0M1.ADA0FR2 to ADA0M1.ADA0FR0 bits is prohibited while A/D conversion is enabled (ADA0CE bit = 1).
  4. When writing data to the ADA0M0, ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register in the following modes, stop the A/D conversion by clearing the ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.
    - Normal conversion mode
    - One-shot select mode/one-shot scan mode in high-speed conversion mode
 If the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers are written in the other modes during A/D conversion (ADA0EF bit = 1), the following will be performed according to the mode.
    - In software trigger mode  
A/D conversion is stopped and started again from the beginning.
    - In hardware trigger mode  
A/D conversion is stopped, and the trigger standby status is set.
  5. To select the external trigger mode/timer trigger mode (ADA0TMD bit = 1), set the high-speed conversion mode (ADA0M1.ADA0HS1 bit = 1). Do not input a trigger during stabilization time that is inserted once after the A/D conversion operation is enabled (ADA0CE bit = 1).
  6. When not using the A/D converter, stop the operation by setting the ADA0CE bit to 0 to reduce the power consumption.

**(2) A/D converter mode register 1 (ADA0M1)**

The ADA0M1 register is an 8-bit register that specifies the conversion time.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF201H

|        |         |   |   |   |         |         |         |         |
|--------|---------|---|---|---|---------|---------|---------|---------|
|        | 7       | 6 | 5 | 4 | 3       | 2       | 1       | 0       |
| ADA0M1 | ADA0HS1 | 0 | 0 | 0 | ADA0FR3 | ADA0FR2 | ADA0FR1 | ADA0FR0 |

|         |   |
|---------|---|
| ADA0HS1 | Specification of normal conversion mode/high-speed mode (A/D conversion time) |
| 0       | Normal conversion mode  |
| 1       | High-speed conversion mode  |

- Cautions**
1. Changing the ADA0M1 register is prohibited while A/D conversion is enabled (ADA0M0.ADA0CE bit = 1).
  2. To select the external trigger mode/timer trigger mode (ADA0M0.ADA0TMD bit = 1), set the high-speed conversion mode (ADA0HS1 bit = 1). Do not input a trigger during stabilization time that is inserted once after the A/D conversion operation is enabled (ADA0CE bit = 1).
  3. Be sure to clear bits 6 to 4 to "0".

**Remark** For A/D conversion time setting examples, see **Tables 13-2** and **13-3**.

Table 13-2. Conversion Time Selection in Normal Conversion Mode (ADA0HS1 Bit = 0)

| ADA0FR3 to<br>ADA0FR0 Bits | A/D Conversion Time                                    |                           |                           |                           |                          |                             |
|----------------------------|--|---------------------------|---------------------------|---------------------------|--------------------------|-----------------------------|
|                            | Stabilization Time<br>+ Conversion Time<br>+ Wait Time | $f_{xx} = 32 \text{ MHz}$ | $f_{xx} = 20 \text{ MHz}$ | $f_{xx} = 16 \text{ MHz}$ | $f_{xx} = 4 \text{ MHz}$ | Trigger<br>Response<br>Time |
| 0000                       | $13/f_{xx} + 26/f_{xx} + 26/f_{xx}$                    | Setting prohibited        | Setting prohibited        | Setting prohibited        | $16.25 \mu\text{s}$      | $4/f_{xx}$                  |
| 0001                       | $26/f_{xx} + 52/f_{xx} + 52/f_{xx}$                    | Setting prohibited        | $6.5 \mu\text{s}$         | $8.125 \mu\text{s}$       | Setting prohibited       | $5/f_{xx}$                  |
| 0010                       | $39/f_{xx} + 78/f_{xx} + 78/f_{xx}$                    | Setting prohibited        | $9.75 \mu\text{s}$        | $12.1875 \mu\text{s}$     | Setting prohibited       | $6/f_{xx}$                  |
| 0011                       | $50/f_{xx} + 104/f_{xx} + 104/f_{xx}$                  | $8.0625 \mu\text{s}$      | $12.9 \mu\text{s}$        | $16.125 \mu\text{s}$      | Setting prohibited       | $7/f_{xx}$                  |
| 0100                       | $50/f_{xx} + 130/f_{xx} + 130/f_{xx}$                  | $9.6875 \mu\text{s}$      | $15.5 \mu\text{s}$        | $19.375 \mu\text{s}$      | Setting prohibited       | $8/f_{xx}$                  |
| 0101                       | $50/f_{xx} + 156/f_{xx} + 156/f_{xx}$                  | $11.3125 \mu\text{s}$     | $18.1 \mu\text{s}$        | $22.625 \mu\text{s}$      | Setting prohibited       | $9/f_{xx}$                  |
| 0110                       | $50/f_{xx} + 182/f_{xx} + 182/f_{xx}$                  | $12.9375 \mu\text{s}$     | $20.7 \mu\text{s}$        | Setting prohibited        | Setting prohibited       | $10/f_{xx}$                 |
| 0111                       | $50/f_{xx} + 208/f_{xx} + 208/f_{xx}$                  | $14.5625 \mu\text{s}$     | $23.3 \mu\text{s}$        | Setting prohibited        | Setting prohibited       | $11/f_{xx}$                 |
| 1000                       | $50/f_{xx} + 234/f_{xx} + 234/f_{xx}$                  | $16.1875 \mu\text{s}$     | Setting prohibited        | Setting prohibited        | Setting prohibited       | $12/f_{xx}$                 |
| 1001                       | $50/f_{xx} + 260/f_{xx} + 260/f_{xx}$                  | $17.8125 \mu\text{s}$     | Setting prohibited        | Setting prohibited        | Setting prohibited       | $13/f_{xx}$                 |
| 1010                       | $50/f_{xx} + 286/f_{xx} + 286/f_{xx}$                  | $19.4375 \mu\text{s}$     | Setting prohibited        | Setting prohibited        | Setting prohibited       | $14/f_{xx}$                 |
| 1011                       | $50/f_{xx} + 312/f_{xx} + 312/f_{xx}$                  | $21.0625 \mu\text{s}$     | Setting prohibited        | Setting prohibited        | Setting prohibited       | $15/f_{xx}$                 |
| Other than above           | Setting prohibited                                     |                           |                           |                           |                          |                             |

**Remark** Stabilization time: A/D converter setup time ( $1 \mu\text{s}$  or longer)  
 Conversion time: Actual A/D conversion time ( $2.6$  to  $10.4 \mu\text{s}$ )  
 Wait time: Wait time inserted before the next conversion  
 Trigger response time: If a software trigger, external trigger, or timer trigger is generated after the stabilization time, it is inserted before the conversion time.

In the normal conversion mode, the conversion is started after the stabilization time elapsed from the ADA0M0.ADA0CE bit is set to 1, and A/D conversion is performed only during the conversion time ( $2.6$  to  $10.4 \mu\text{s}$ ). Operation is stopped after the conversion ends and the A/D conversion end interrupt request signal (INTAD) is generated after the wait time is elapsed.

Because the conversion operation is stopped during the wait time, operation current can be reduced.

**Cautions** 1. Set as  $2.6 \mu\text{s} \leq \text{conversion time} \leq 10.4 \mu\text{s}$ .

2. During A/D conversion, if the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers are written or trigger is input, reconversion is carried out. However, if the stabilization time end timing conflicts with the writing to these registers, or if the stabilization time end timing conflicts with the trigger input, the stabilization time of 64 clocks is reinserted.

If a conflict occurs again with the reinserted stabilization time end timing, the stabilization time is reinserted. Therefore do not set the trigger input interval and control register write interval to 64 clocks or below.



Table 13-3. Conversion Time Selection in High-Speed Conversion Mode (ADA0HS1 Bit = 1)

| ADA0FR3 to<br>ADA0FR0 Bits | A/D Conversion Time                         |                            |                          |                           |                         |                             |
|----------------------------|---|----------------------------|--------------------------|---------------------------|-------------------------|-----------------------------|
|                            | Conversion Time<br>(+ Stabilization Time)   | f <sub>xx</sub> = 32 MHz   | f <sub>xx</sub> = 20 MHz | f <sub>xx</sub> = 16 MHz  | f <sub>xx</sub> = 4 MHz | Trigger<br>Response<br>Time |
| 0000                       | 26/f <sub>xx</sub> (+ 13/f <sub>xx</sub> )  | Setting prohibited         | Setting prohibited       | Setting prohibited        | 6.5 μs<br>(+ 3.25 μs)   | 4/f <sub>xx</sub>           |
| 0010                       | 52/f <sub>xx</sub> (+ 26/f <sub>xx</sub> )  | Setting prohibited         | 2.6 μs<br>(+ 1.3 μs)     | 3.25 μs<br>(+ 1.625 μs)   | Setting prohibited      | 5/f <sub>xx</sub>           |
| 0010                       | 78/f <sub>xx</sub> (+ 39/f <sub>xx</sub> )  | Setting prohibited         | 3.9 μs<br>(+ 1.95 μs)    | 4.875 μs<br>(+ 2.4375 μs) | Setting prohibited      | 6/f <sub>xx</sub>           |
| 0011                       | 104/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 3.25 μs<br>(+ 1.5625 μs)   | 5.2 μs<br>(+ 2.5 μs)     | 6.5 μs<br>(+ 3.125 μs)    | Setting prohibited      | 7/f <sub>xx</sub>           |
| 0100                       | 130/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 4.0625 μs<br>(+ 1.5625 μs) | 6.5 μs<br>(+ 2.5 μs)     | 8.125 μs<br>(+ 3.125 μs)  | Setting prohibited      | 8/f <sub>xx</sub>           |
| 0101                       | 156/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 4.875 μs<br>(+ 1.5625 μs)  | 7.8 μs<br>(+ 2.5 μs)     | 9.75 μs<br>(+ 3.125 μs)   | Setting prohibited      | 9/f <sub>xx</sub>           |
| 0110                       | 182/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 5.6875 μs<br>(+ 1.5625 μs) | 9.1 μs<br>(+ 2.5 μs)     | Setting prohibited        | Setting prohibited      | 10/f <sub>xx</sub>          |
| 0111                       | 208/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 6.5 μs<br>(+ 1.5625 μs)    | 10.4 μs<br>(+ 2.5 μs)    | Setting prohibited        | Setting prohibited      | 11/f <sub>xx</sub>          |
| 1000                       | 234/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 7.3125 μs<br>(+ 1.5625 μs) | Setting prohibited       | Setting prohibited        | Setting prohibited      | 12/f <sub>xx</sub>          |
| 1001                       | 260/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 8.125 μs<br>(+ 1.5625 μs)  | Setting prohibited       | Setting prohibited        | Setting prohibited      | 13/f <sub>xx</sub>          |
| 1010                       | 286/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 8.9375 μs<br>(+ 1.5625 μs) | Setting prohibited       | Setting prohibited        | Setting prohibited      | 14/f <sub>xx</sub>          |
| 1011                       | 312/f <sub>xx</sub> (+ 50/f <sub>xx</sub> ) | 9.75 μs<br>(+ 1.5625 μs)   | Setting prohibited       | Setting prohibited        | Setting prohibited      | 15/f <sub>xx</sub>          |
| Other than above           | Setting prohibited                          |                            |                          |                           |                         |                             |

**Remark** Conversion time: Actual A/D conversion time (2.6 to 10.4 μs)  
 Stabilization time: A/D converter setup time (1 μs or longer)  
 Trigger response time: If a software trigger, external trigger, or timer trigger is generated after the stabilization time, it is inserted before the conversion time.

In the high-speed conversion mode, the conversion is started after the stabilization time elapsed from the ADA0M0.ADA0CE bit is set to 1, and A/D conversion is performed only during the conversion time (2.6 to 10.4 μs). The A/D conversion end interrupt request signal (INTAD) is generated immediately after the conversion ends.

In continuous conversion mode, the stabilization time is inserted only before the first conversion, and not inserted after the second conversion (the A/D converter remains running).

- Cautions**
1. Set as  $2.6 \mu\text{s} \leq \text{conversion time} \leq 10.4 \mu\text{s}$ .
  2. In the high-speed conversion mode, rewriting of the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers and trigger input are prohibited during the stabilization time.

**(3) A/D converter mode register 2 (ADA0M2)**

The ADA0M2 register specifies the hardware trigger mode.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF203H

|        |   |   |   |   |   |   |          |          |
|--------|---|---|---|---|---|---|----------|----------|
|        | 7 | 6 | 5 | 4 | 3 | 2 | 1        | 0        |
| ADA0M2 | 0 | 0 | 0 | 0 | 0 | 0 | ADA0TMD1 | ADA0TMD0 |

| ADA0TMD1 | ADA0TMD0 | Specification of hardware trigger mode                            |
|----------|----------|---|
| 0        | 0        | External trigger mode (when ADTRG pin valid edge detected)        |
| 0        | 1        | Timer trigger mode 0 (when INTTP2CC0 interrupt request generated) |
| 1        | 0        | Timer trigger mode 1 (when INTTP2CC1 interrupt request generated) |
| 1        | 1        | Setting prohibited  |

**Cautions 1.** When writing data to the ADA0M2 register in the following modes, stop the A/D conversion by clearing the AD0M0.ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.

- Normal conversion mode
- One-shot select mode/one-shot scan mode in high-speed conversion mode

**2.** Be sure to clear bits 7 to 2 to “0”.

**(4) A/D converter channel specification register 0 (ADA0S)**

The ADA0S register specifies the pin that inputs the analog voltage to be converted into a digital signal.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H R/W Address: FFFFF202H

|       |   |   |   |   |        |        |        |        |
|-------|---|---|---|---|--------|--------|--------|--------|
|       | 7 | 6 | 5 | 4 | 3      | 2      | 1      | 0      |
| ADA0S | 0 | 0 | 0 | 0 | ADA0S3 | ADA0S2 | ADA0S1 | ADA0S0 |

| ADA0S3 | ADA0S2 | ADA0S1 | ADA0S0 | Select mode | Scan mode     |
|--------|--------|--------|--------|-------------|---------------|
| 0      | 0      | 0      | 0      | ANI0        | ANI0          |
| 0      | 0      | 0      | 1      | ANI1        | ANI0, ANI1    |
| 0      | 0      | 1      | 0      | ANI2        | ANI0 to ANI2  |
| 0      | 0      | 1      | 1      | ANI3        | ANI0 to ANI3  |
| 0      | 1      | 0      | 0      | ANI4        | ANI0 to ANI4  |
| 0      | 1      | 0      | 1      | ANI5        | ANI0 to ANI5  |
| 0      | 1      | 1      | 0      | ANI6        | ANI0 to ANI6  |
| 0      | 1      | 1      | 1      | ANI7        | ANI0 to ANI7  |
| 1      | 0      | 0      | 0      | ANI8        | ANI0 to ANI8  |
| 1      | 0      | 0      | 1      | ANI9        | ANI0 to ANI9  |
| 1      | 0      | 1      | 0      | ANI10       | ANI0 to ANI10 |
| 1      | 0      | 1      | 1      | ANI11       | ANI0 to ANI11 |
| 1      | 1      | 0      | 0      | ANI12       | ANI0 to ANI12 |
| 1      | 1      | 0      | 1      | ANI13       | ANI0 to ANI13 |
| 1      | 1      | 1      | 0      | ANI14       | ANI0 to ANI14 |
| 1      | 1      | 1      | 1      | ANI15       | ANI0 to ANI15 |

**Cautions 1. When writing data to the ADA0S register in the following modes, stop the A/D conversion by clearing the AD0M0.ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.**

- Normal conversion mode
- One-shot select mode/one-shot scan mode in high-speed conversion mode

**2. Be sure to clear bits 7 to 4 to “0”.**

**(5) A/D conversion result registers n, nH (ADA0CRn, ADA0CRnH)**

The ADA0CRn and ADA0CRnH registers store the A/D conversion results.

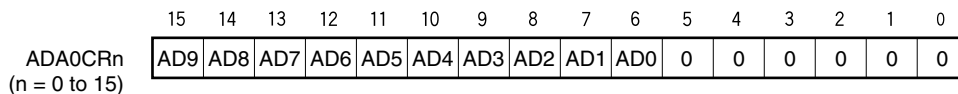
These registers are read-only, in 16-bit or 8-bit units. However, specify the ADA0CRn register for 16-bit access and the ADA0CRnH register for 8-bit access. The 10 bits of the conversion result are read from the higher 10 bits of the ADA0CRn register, and 0 is read from the lower 6 bits. The higher 8 bits of the conversion result are read from the ADA0CRnH register.

**Caution** Accessing the ADA0CRn and ADA0CRnH registers is prohibited in the following statuses.

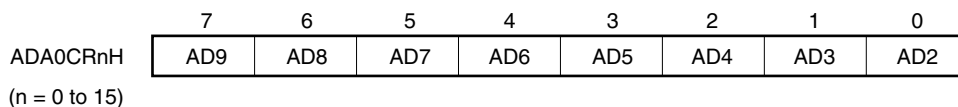
For details, see 3.4.8 (2) Accessing specific on-chip peripheral I/O registers.

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock

After reset: Undefined R Address: ADA0CR0 FFFFFFF210H, ADA0CR1 FFFFFFF212H,  
 ADA0CR2 FFFFFFF214H, ADA0CR3 FFFFFFF216H,  
 ADA0CR4 FFFFFFF218H, ADA0CR5 FFFFFFF21AH,  
 ADA0CR6 FFFFFFF21CH, ADA0CR7 FFFFFFF21EH,  
 ADA0CR8 FFFFFFF220H, ADA0CR9 FFFFFFF222H,  
 ADA0CR10 FFFFFFF224H, ADA0CR11 FFFFFFF226H,  
 ADA0CR12 FFFFFFF228H, ADA0CR13 FFFFFFF22AH,  
 ADA0CR14 FFFFFFF22CH, ADA0CR15 FFFFFFF22EH



After reset: Undefined R Address: ADA0CR0H FFFFFFF211H, ADA0CR1H FFFFFFF213H,  
 ADA0CR2H FFFFFFF215H, ADA0CR3H FFFFFFF217H,  
 ADA0CR4H FFFFFFF219H, ADA0CR5H FFFFFFF21BH,  
 ADA0CR6H FFFFFFF21DH, ADA0CR7H FFFFFFF21FH,  
 ADA0CR8H FFFFFFF221H, ADA0CR9H FFFFFFF223H,  
 ADA0CR10H FFFFFFF225H, ADA0CR11H FFFFFFF227H,  
 ADA0CR12H FFFFFFF229H, ADA0CR13H FFFFFFF22BH,  
 ADA0CR14H FFFFFFF22DH, ADA0CR15H FFFFFFF22FH



**Caution** A write operation to the ADA0M0 and ADA0S registers may cause the contents of the ADA0CRn register to become undefined. After the conversion, read the conversion result before writing to the ADA0M0 and ADA0S registers. Correct conversion results may not be read if a sequence other than the above is used.

The relationship between the analog voltage input to the analog input pins (ANI0 to ANI15) and the A/D conversion result (ADA0CRn register) is as follows.

$$SAR = \text{INT} \left( \frac{V_{IN}}{AV_{REF0}} \times 1,024 + 0.5 \right)$$

$$ADA0CRn^{\text{Note}} = SAR \times 64$$

Or,

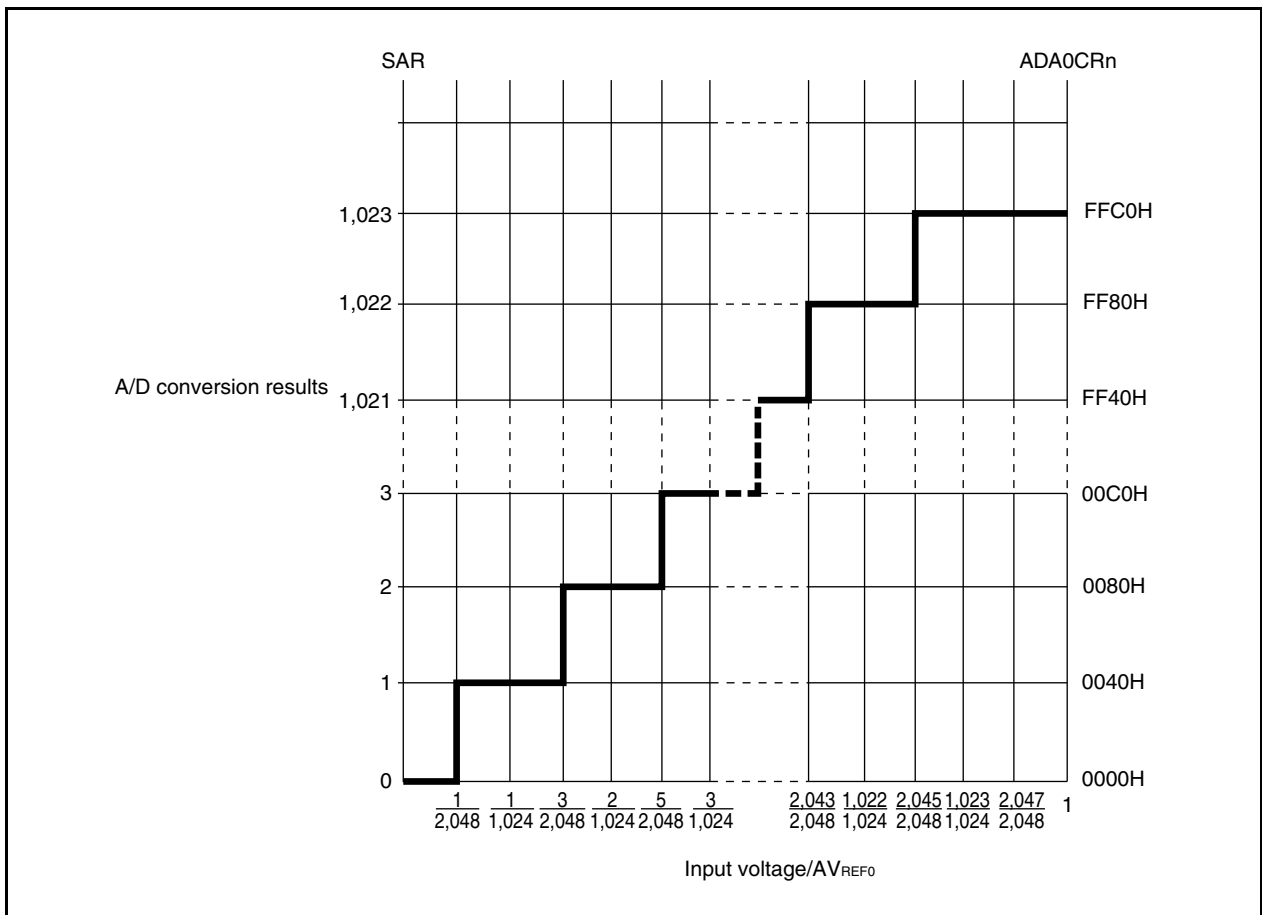
$$(SAR - 0.5) \times \frac{AV_{REF0}}{1,024} \leq V_{IN} < (SAR + 0.5) \times \frac{AV_{REF0}}{1,024}$$

- INT( ): Function that returns the integer of the value in ( )
- V<sub>IN</sub>: Analog input voltage
- AV<sub>REF0</sub>: AV<sub>REF0</sub> pin voltage
- ADA0CR: Value of ADA0CRn register

**Note** The lower 6 bits of the ADA0CRn register are fixed to 0.

The following shows the relationship between the analog input voltage and the A/D conversion results.

**Figure 13-2. Relationship Between Analog Input Voltage and A/D Conversion Results**



**(6) Power-fail compare mode register (ADA0PFM)**

The ADA0PFM register is an 8-bit register that sets the power-fail compare mode.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF204H

|         |         |         |   |   |   |   |   |   |
|---------|---------|---------|---|---|---|---|---|---|
|         | <7>     | 6       | 5 | 4 | 3 | 2 | 1 | 0 |
| ADA0PFM | ADA0PFE | ADA0PFC | 0 | 0 | 0 | 0 | 0 | 0 |

|         |  |
|---------|--|
| ADA0PFE | Selection of power-fail compare enable/disable |
| 0       | Power-fail compare disabled                    |
| 1       | Power-fail compare enabled                     |

|         |  |
|---------|--|
| ADA0PFC | Selection of power-fail compare mode                                       |
| 0       | Generates an interrupt request signal (INTAD) when $ADA0CRnH \geq ADA0PFT$ |
| 1       | Generates an interrupt request signal (INTAD) when $ADA0CRnH < ADA0PFT$    |

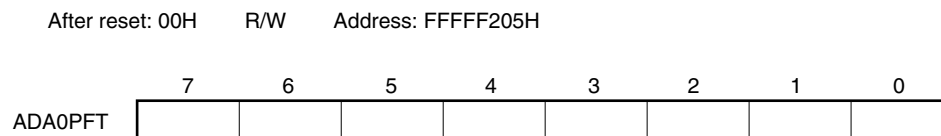
- Cautions 1.** In the select mode, the 8-bit data set to the ADA0PFT register is compared with the value of the ADA0CRnH register specified by the ADA0S register. If the result matches the condition specified by the ADA0PFC bit, the conversion result is stored in the ADA0CRn register and the INTAD signal is generated. If it does not match, however, the interrupt signal is not generated.
- 2.** In the scan mode, the 8-bit data set to the ADA0PFT register is compared with the contents of the ADA0CR0H register. If the result matches the condition specified by the ADA0PFC bit, the conversion result is stored in the ADA0CR0 register and the INTAD signal is generated. If it does not match, however, the INTAD signal is not generated. Regardless of the comparison result, the scan operation is continued and the conversion result is stored in the ADA0CRn register until the scan operation is completed. However, the INTAD signal is not generated after the scan operation has been completed.
- 3.** When writing data to the ADA0PFM register in the following modes, stop the A/D conversion by clearing the AD0M0.ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.
- Normal conversion mode
  - One-shot select mode/one-shot scan mode in high-speed conversion mode

**(7) Power-fail compare threshold value register (ADA0PFT)**

The ADA0PFT register sets the compare value in the power-fail compare mode.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.



**Caution** When writing data to the ADA0PFT register in the following modes, stop the A/D conversion by clearing the AD0M0.ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.

- Normal conversion mode
- One-shot select mode/one-shot scan mode in high-speed conversion mode

## 13.5 Operation

### 13.5.1 Basic operation

- <1> Set the operation mode, trigger mode, and conversion time for executing A/D conversion by using the ADA0M0, ADA0M1, ADA0M2, and ADA0S registers. When the ADA0CE bit of the ADA0M0 register is set, conversion is started in the software trigger mode and the A/D converter waits for a trigger in the external or timer trigger mode.
- <2> When A/D conversion is started, the voltage input to the selected analog input channel is sampled by the sample & hold circuit.
- <3> When the sample & hold circuit samples the input channel for a specific time, it enters the hold status, and holds the input analog voltage until A/D conversion is complete.
- <4> Set bit 9 of the successive approximation register (SAR) to set the compare voltage generation DAC to  $(1/2) AV_{REF0}$ .
- <5> The voltage difference between the voltage of the compare voltage generation DAC and the analog input voltage is compared by the voltage comparator. If the analog input voltage is higher than  $(1/2) AV_{REF0}$ , the MSB of the SAR register remains set. If it is lower than  $(1/2) AV_{REF0}$ , the MSB is reset.
- <6> Next, bit 8 of the SAR register is automatically set and the next comparison is started. Depending on the value of bit 9, to which a result has been already set, the compare voltage generation DAC is selected as follows.
  - Bit 9 = 1:  $(3/4) AV_{REF0}$
  - Bit 9 = 0:  $(1/4) AV_{REF0}$
 This compare voltage and the analog input voltage are compared and, depending on the result, bit 8 is manipulated as follows.  
 Analog input voltage  $\geq$  Compare voltage: Bit 8 = 1  
 Analog input voltage  $\leq$  Compare voltage: Bit 8 = 0
- <7> This comparison is continued to bit 0 of the SAR register.
- <8> When comparison of the 10 bits is complete, the valid digital result is stored in the SAR register, which is then transferred to and stored in the ADA0CRn register. After that, an A/D conversion end interrupt request signal (INTAD) is generated.
- <9> In one-shot select mode, conversion is stopped<sup>Note</sup>. In one-shot scan mode, conversion is stopped after scanning once<sup>Note</sup>. In continuous select mode, repeat steps <2> to <8> until the ADA0M0.ADA0CE bit is cleared to 0. In continuous scan mode, repeat steps <2> to <8> for each channel.

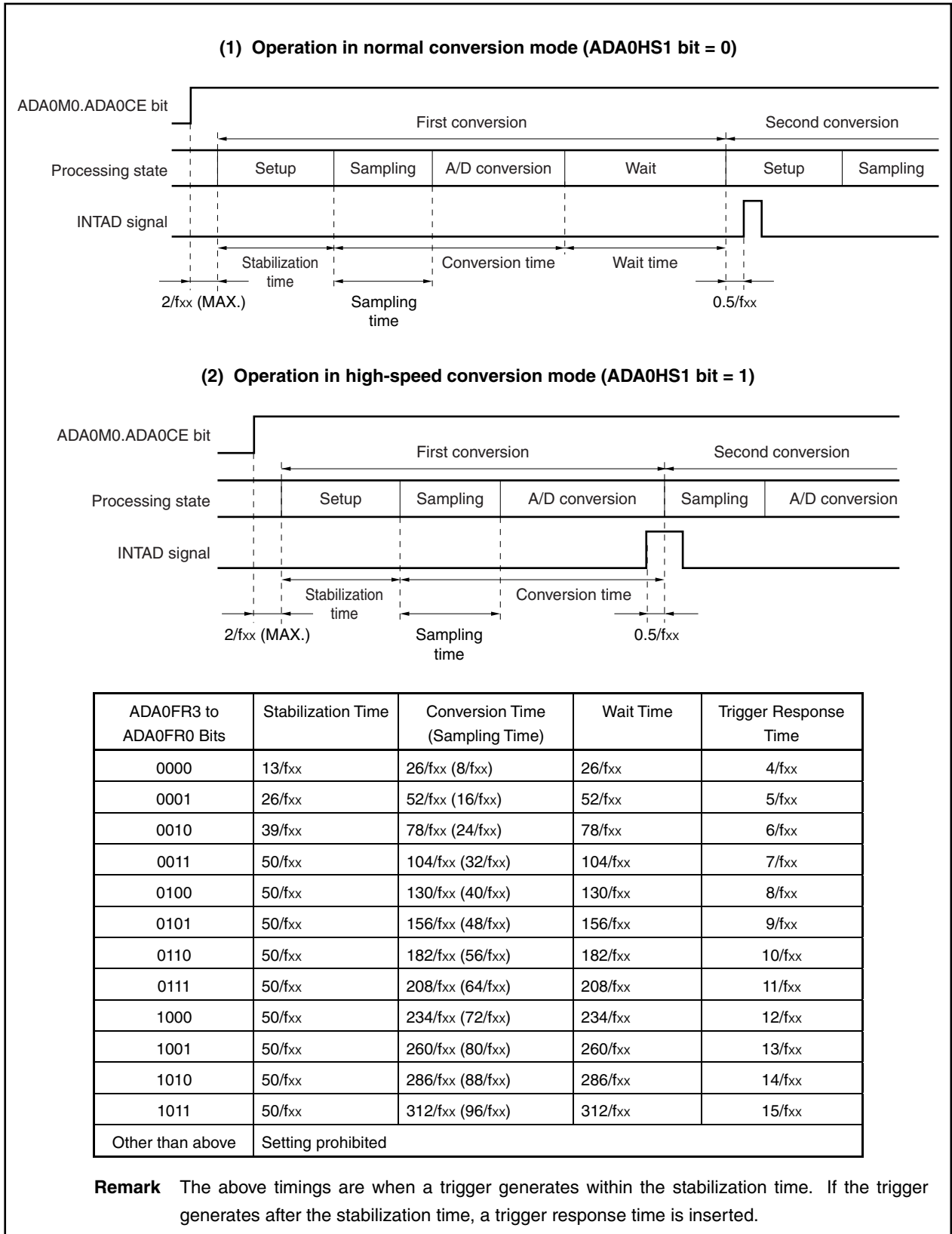
**Note** In the external trigger mode, timer trigger mode 0, or timer trigger mode 1, the trigger standby status is entered.

**Remark** The trigger standby status means the status after the stabilization time has passed.



13.5.2 Conversion operation timing

Figure 13-3. Conversion Operation Timing (Continuous Conversion)



### 13.5.3 Trigger mode

The timing of starting the conversion operation is specified by setting a trigger mode. The trigger mode includes a software trigger mode and hardware trigger modes. The hardware trigger modes include timer trigger modes 0 and 1, and external trigger mode. The ADA0M0.ADA0TMD bit is used to set the trigger mode. The hardware trigger modes are set by the ADA0M2.ADA0TMD1 and ADA0M2.ADA0TMD0 bits.

#### (1) Software trigger mode

When the ADA0M0.ADA0CE bit is set to 1, the signal of the analog input pin (ANI0 to ANI15 pin) specified by the ADA0S register is converted. When conversion is complete, the result is stored in the ADA0CRn register. At the same time, the A/D conversion end interrupt request signal (INTAD) is generated.

If the operation mode specified by the ADA0M0.ADA0MD1 and ADA0M0.ADA0MD0 bits is the continuous select/scan mode, the next conversion is started, unless the ADA0CE bit is cleared to 0 after completion of the first conversion. Conversion is performed once and ends if the operation mode is the one-shot select/scan mode.

When conversion is started, the ADA0M0.ADA0EF bit is set to 1 (indicating that conversion is in progress).

If the ADA0M0, ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register is written during conversion, the conversion is aborted and started again from the beginning. However, writing to these registers is prohibited in the normal conversion mode and one-shot select mode/one-shot scan mode in the high-speed conversion mode.

#### (2) External trigger mode

In this mode, converting the signal of the analog input pin (ANI0 to ANI15) specified by the ADA0S register is started when an external trigger is input (to the ADTRG pin). Which edge of the external trigger is to be detected (i.e., the rising edge, falling edge, or both rising and falling edges) can be specified by using the ADA0M0.ADA0ETS1 and ADA0M0.ATA0ETS0 bits. When the ADA0CE bit is set to 1, the A/D converter waits for the trigger, and starts conversion after the external trigger has been input.

When conversion is completed, the result of conversion is stored in the ADA0CRn register, regardless of whether the continuous select, continuous scan, one-shot select, or one-shot scan mode is set as the operation mode by the ADA0MD1 and ADA0MD0 bits. At the same time, the INTAD signal is generated, and the A/D converter waits for the trigger again.

When conversion is started, the ADA0EF bit is set to 1 (indicating that conversion is in progress). While the A/D converter is waiting for the trigger, however, the ADA0EF bit is cleared to 0 (indicating that conversion is stopped). If the valid trigger is input during the conversion operation, the conversion is aborted and started again from the beginning.

If the ADA0M0, ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register is written during the conversion operation, the conversion is not aborted, and the A/D converter waits for the trigger again. However, writing to these registers is prohibited in the one-shot select mode/one-shot scan mode.

**Caution** To select the external trigger mode, set the high-speed conversion mode. Do not input a trigger during stabilization time that is inserted once after the A/D conversion operation is enabled (ADA0M0.ADA0CE bit = 1).

**Remark** The trigger standby status means the status after the stabilization time has passed.

**(3) Timer trigger mode**

In this mode, converting the signal of the analog input pin (ANI0 to ANI15) specified by the ADA0S register is started by the compare match interrupt request signal (INTTP2CC0 or INTTP2CC1) of the capture/compare register connected to the timer. The INTTP2CC0 or INTTP2CC1 signal is selected by the ADA0TMD1 and ADA0TMD0 bits, and conversion is started at the rising edge of the specified compare match interrupt request signal. When the ADA0CE bit is set to 1, the A/D converter waits for a trigger, and starts conversion when the compare match interrupt request signal of the timer is input.

When conversion is completed, regardless of whether the continuous select, continuous scan, one-shot select, or one-shot scan mode is set as the operation mode by the ADA0MD1 and ADA0MD0 bits, the result of the conversion is stored in the ADA0CRn register. At the same time, the INTAD signal is generated, and the A/D converter waits for the trigger again.

When conversion is started, the ADA0EF bit is set to 1 (indicating that conversion is in progress). While the A/D converter is waiting for the trigger, however, the ADA0EF bit is cleared to 0 (indicating that conversion is stopped). If the valid trigger is input during the conversion operation, the conversion is aborted and started again from the beginning.

If the ADA0M0, ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register is written during conversion, the conversion is stopped and the A/D converter waits for the trigger again. However, writing to these registers is prohibited in the one-shot select mode/one-shot scan mode.

**Caution** To select the timer trigger mode, set the high-speed conversion mode. Do not input a trigger during stabilization time that is inserted once after the A/D conversion operation is enabled (ADA0M0.ADA0CE bit = 1).

**Remark** The trigger standby status means the status after the stabilization time has passed.

**13.5.4 Operation mode**

Four operation modes are available as the modes in which to set the ANI0 to ANI15 pins: continuous select mode, continuous scan mode, one-shot select mode, and one-shot scan mode.

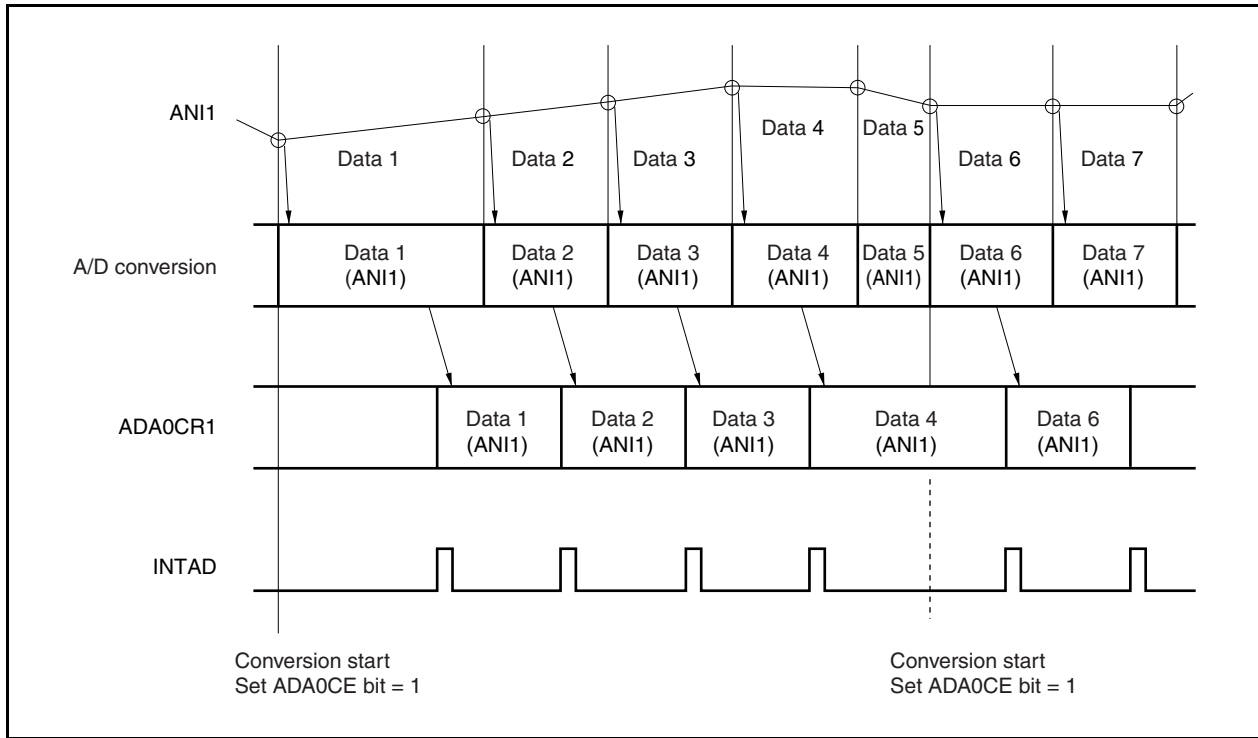
The operation mode is selected by the ADA0M0.ADA0MD1 and ADA0M0.ADA0MD0 bits.

**(1) Continuous select mode**

In this mode, the voltage of one analog input pin selected by the ADA0S register is continuously converted into a digital value.

The conversion result is stored in the ADA0CRn register corresponding to the analog input pin. In this mode, an analog input pin corresponds to an ADA0CRn register on a one-to-one basis. Each time A/D conversion is completed, the A/D conversion end interrupt request signal (INTAD) is generated. After completion of conversion, the next conversion is started, unless the ADA0M0.ADA0CE bit is cleared to 0 (n = 0 to 15).

**Figure 13-4. Timing Example of Continuous Select Mode Operation (ADA0S Register = 01H)**

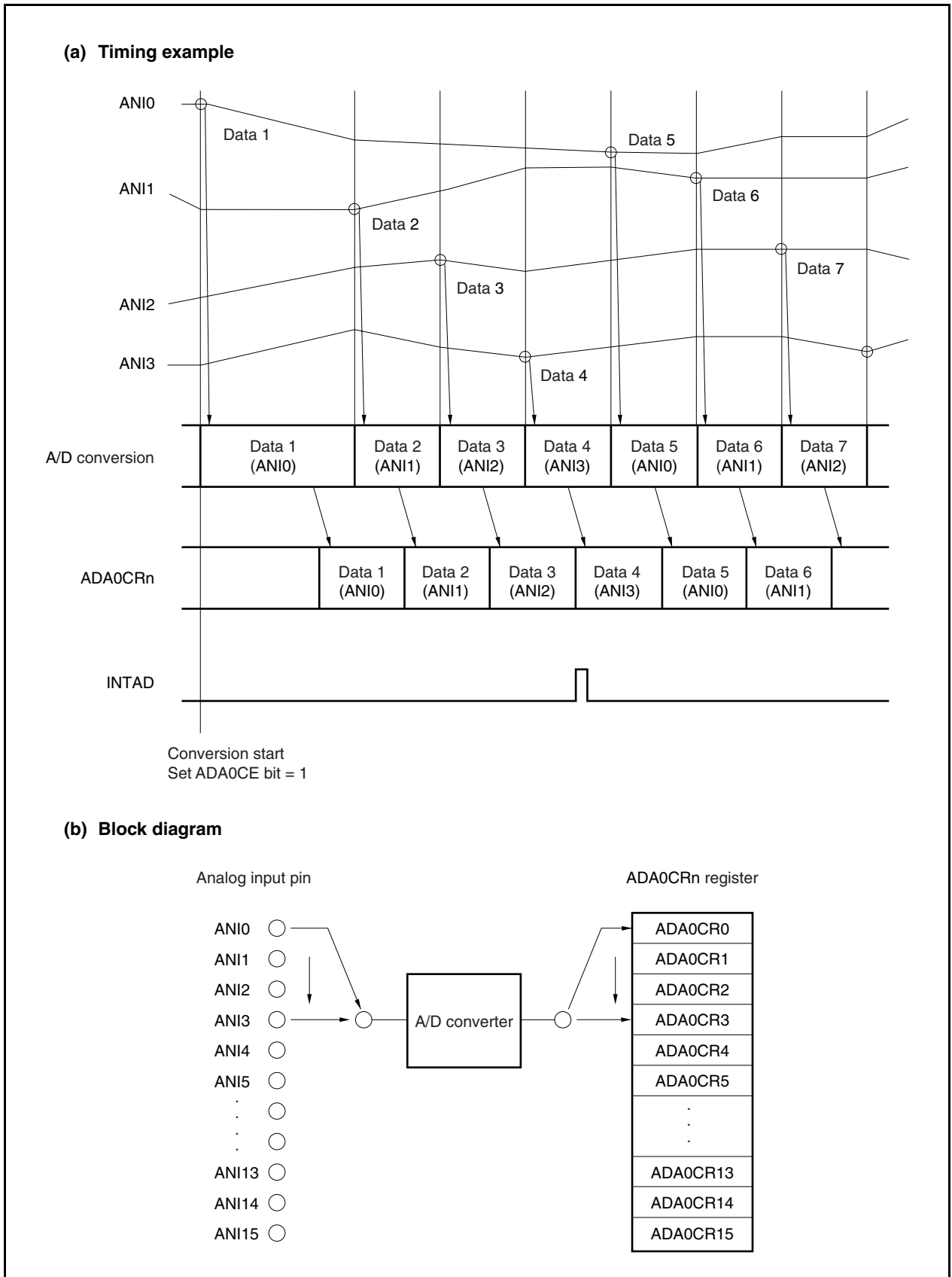


**(2) Continuous scan mode**

In this mode, analog input pins are sequentially selected, from the ANI0 pin to the pin specified by the ADA0S register, and their values are converted into digital values.

The result of each conversion is stored in the ADA0CRn register corresponding to the analog input pin. When conversion of the analog input pin specified by the ADA0S register is complete, the INTAD signal is generated, and A/D conversion is started again from the ANI0 pin, unless the ADA0CE bit is cleared to 0 (n = 0 to 15).

Figure 13-5. Timing Example of Continuous Scan Mode Operation (ADA0S Register = 03H)

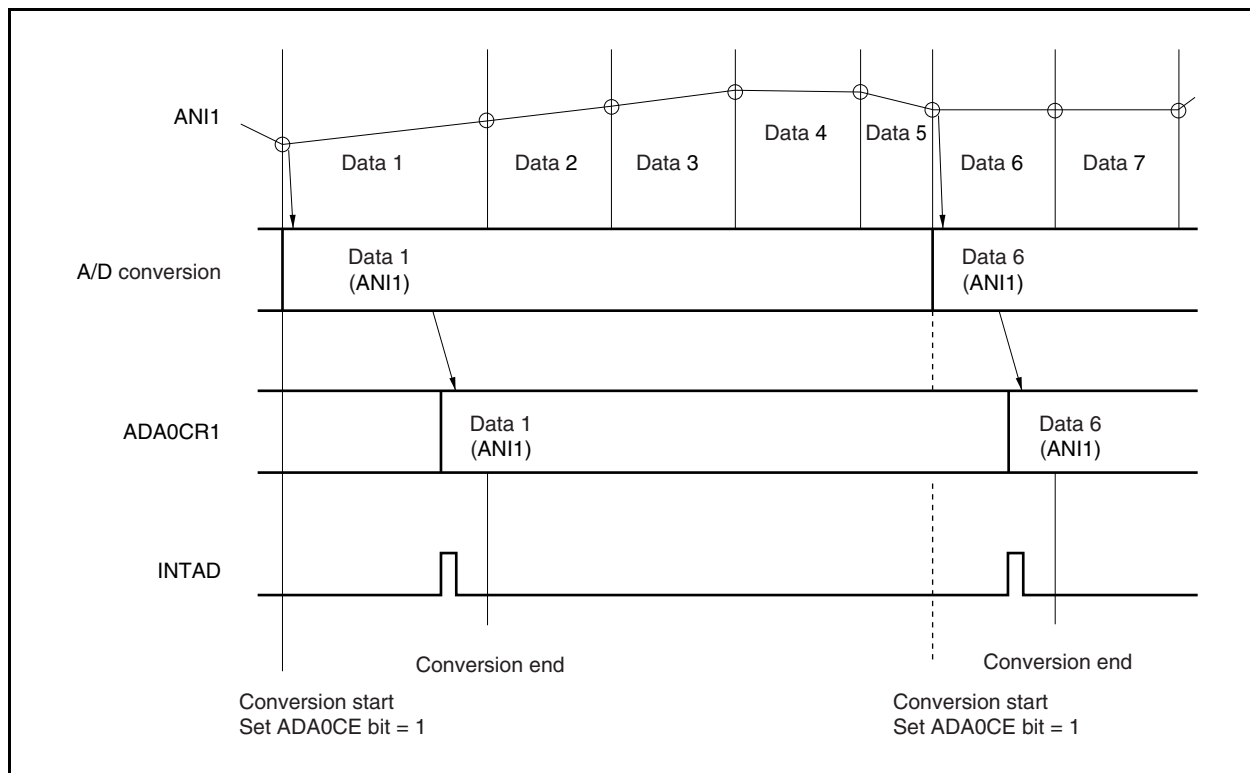


**(3) One-shot select mode**

In this mode, the voltage on the analog input pin specified by the ADA0S register is converted into a digital value only once.

The conversion result is stored in the ADA0CRn register corresponding to the analog input pin. In this mode, an analog input pin and an ADA0CRn register correspond on a one-to-one basis. When A/D conversion has been completed once, the INTAD signal is generated. The A/D conversion operation is stopped after it has been completed (n = 0 to 15).

**Figure 13-6. Timing Example of One-Shot Select Mode Operation (ADA0S Register = 01H)**

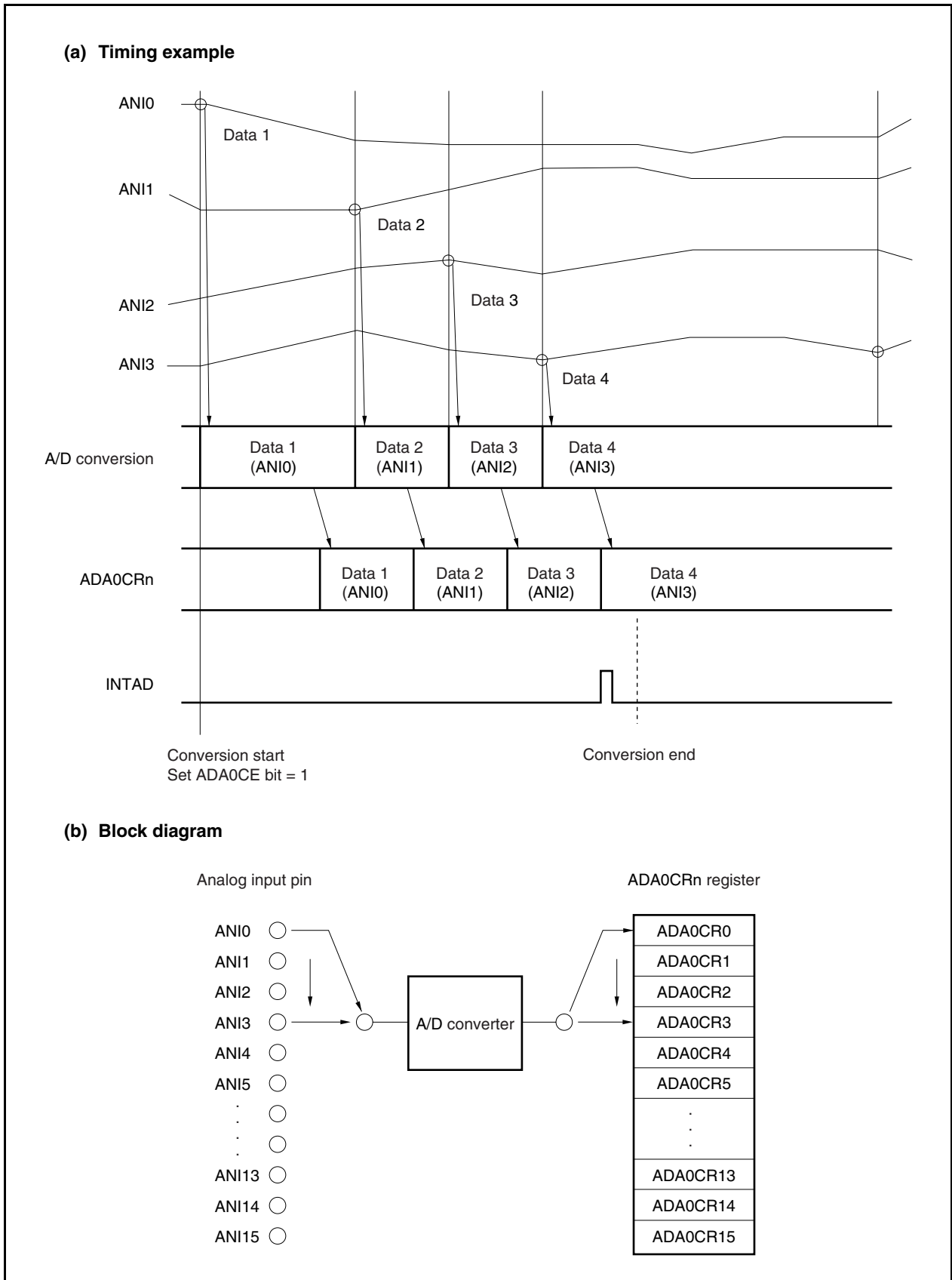


**(4) One-shot scan mode**

In this mode, analog input pins are sequentially selected, from the ANI0 pin to the pin specified by the ADA0S register, and their values are converted into digital values.

Each conversion result is stored in the ADA0CRn register corresponding to the analog input pin. When conversion of the analog input pin specified by the ADA0S register is complete, the INTAD signal is generated. A/D conversion is stopped after it has been completed (n = 0 to 15).

Figure 13-7. Timing Example of One-Shot Scan Mode Operation (ADA0S Register = 03H)



### 13.5.5 Power-fail compare mode

The A/D conversion end interrupt request signal (INTAD) can be controlled as follows by the ADA0PFM and ADA0PFT registers.

- When the ADA0PFM.ADA0PFE bit = 0, the INTAD signal is generated each time conversion is completed (normal use of the A/D converter).
- When the ADA0PFE bit = 1 and when the ADA0PFM.ADA0PFC bit = 0, the value of the ADA0CRnH register is compared with the value of the ADA0PFT register when conversion is completed, and the INTAD signal is generated only if  $ADA0CRnH \geq ADA0PFT$ .
- When the ADA0PFE bit = 1 and when the ADA0PFC bit = 1, the value of the ADA0CRnH register is compared with the value of the ADA0PFT register when conversion is completed, and the INTAD signal is generated only if  $ADA0CRnH < ADA0PFT$ .

**Remark** n = 0 to 15

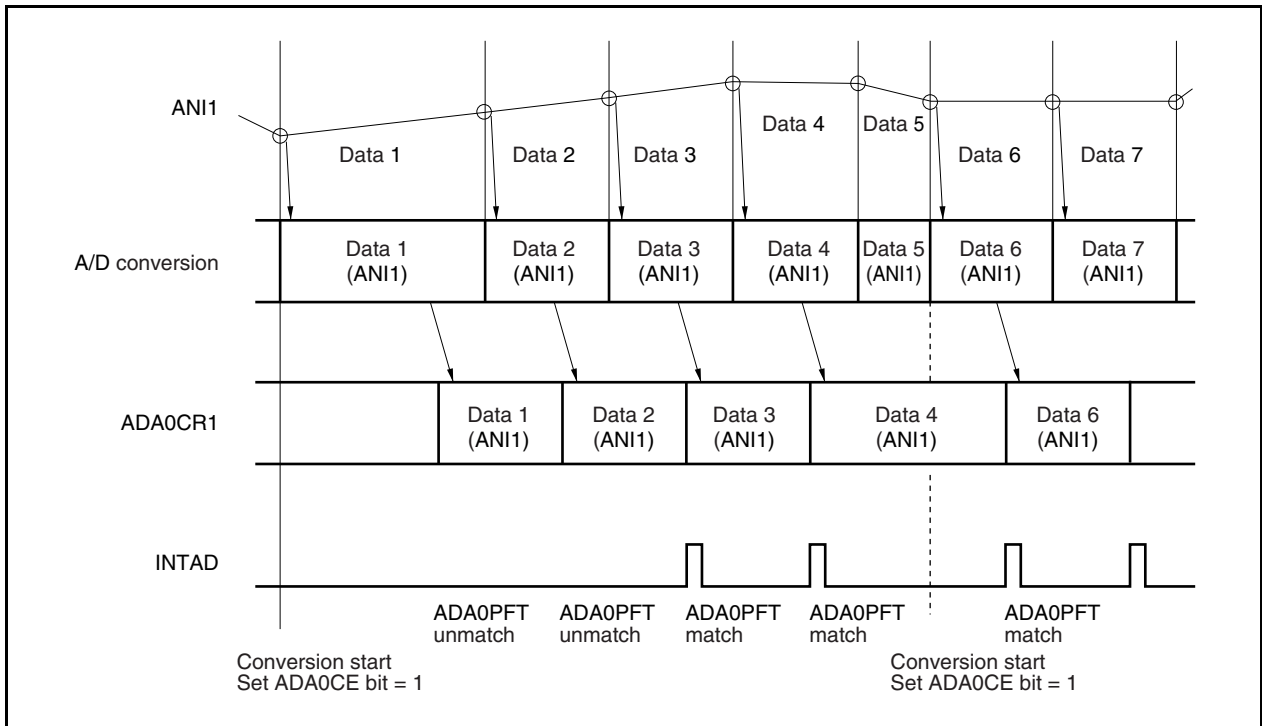
In the power-fail compare mode, four modes are available as modes in which to set the ANI0 to ANI15 pins: continuous select mode, continuous scan mode, one-shot select mode, and one-shot scan mode.



**(1) Continuous select mode**

In this mode, the result of converting the voltage of the analog input pin specified by the ADA0S register is compared with the set value of the ADA0PFT register. If the result of power-fail comparison matches the condition set by the ADA0PFC bit, the conversion result is stored in the ADA0CRn register, and the INTAD signal is generated. If it does not match, the conversion result is stored in the ADA0CRn register, and the INTAD signal is not generated. After completion of the first conversion, the next conversion is started, unless the ADA0M0.ADA0CE bit is cleared to 0 (n = 0 to 15).

**Figure 13-8. Timing Example of Continuous Select Mode Operation  
(When Power-Fail Comparison Is Made: ADA0S Register = 01H)**

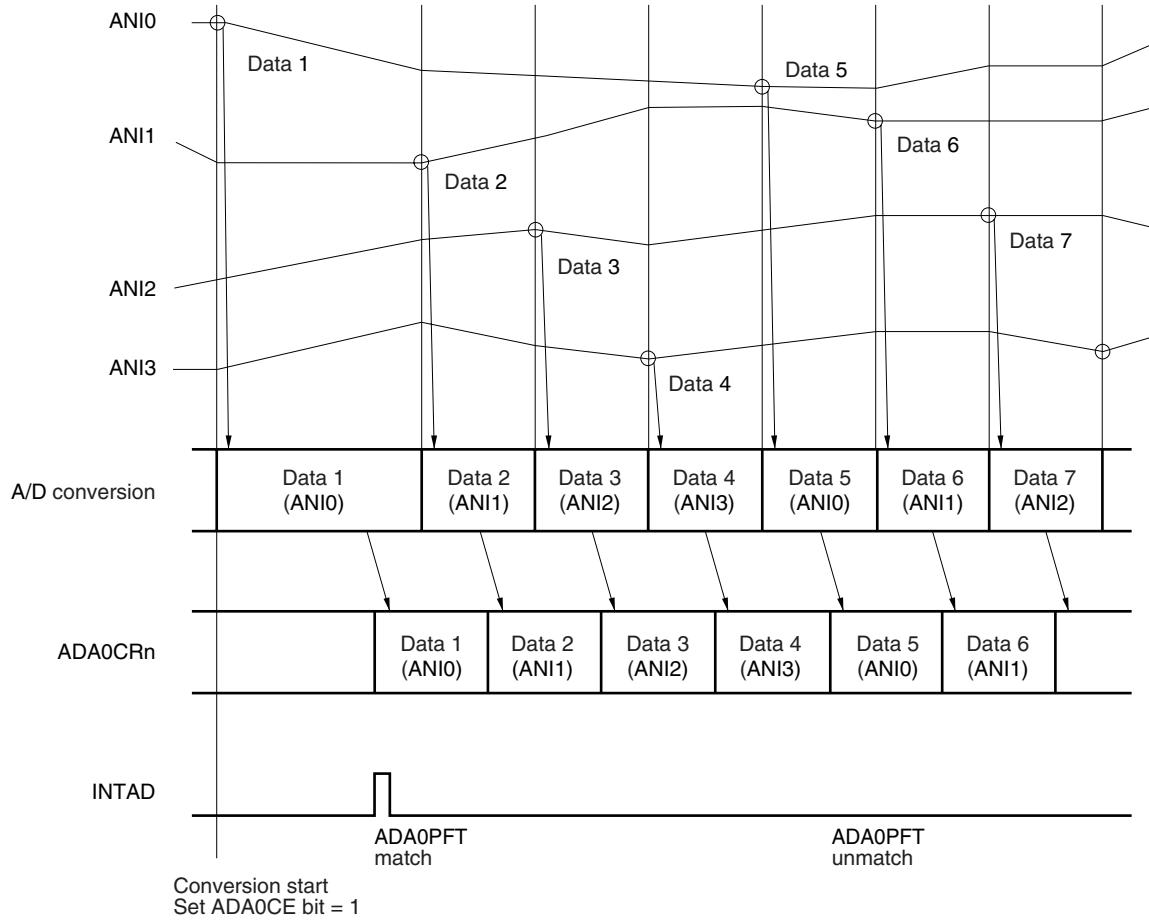
**(2) Continuous scan mode**

In this mode, the results of converting the voltages of the analog input pins sequentially selected from the ANI0 pin to the pin specified by the ADA0S register are stored, and the set value of the ADA0CR0H register of channel 0 is compared with the value of the ADA0PFT register. If the result of power-fail comparison matches the condition set by the ADA0PFC bit, the conversion result is stored in the ADA0CR0 register, and the INTAD signal is generated. If it does not match, the conversion result is stored in the ADA0CR0 register, and the INTAD signal is not generated.

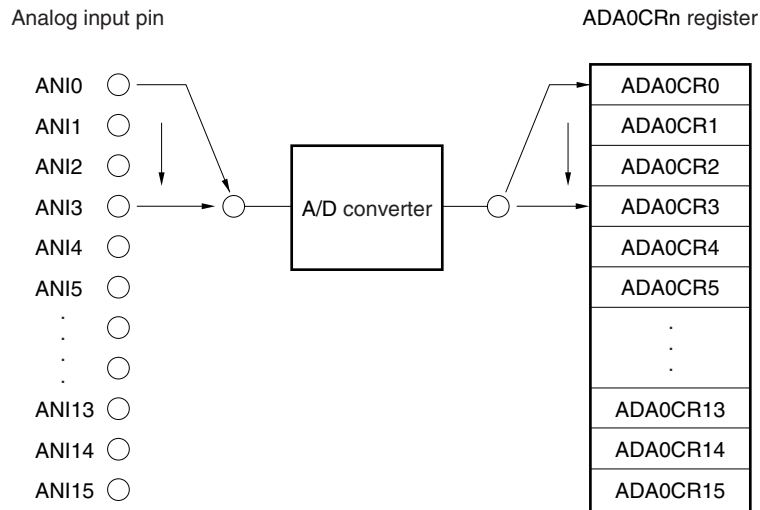
After the result of the first conversion has been stored in the ADA0CR0 register, the results of sequentially converting the voltages on the analog input pins up to the pin specified by the ADA0S register are continuously stored. After completion of conversion, the next conversion is started from the ANI0 pin again, unless the ADA0CE bit is cleared to 0.

**Figure 13-9. Timing Example of Continuous Scan Mode Operation  
(When Power-Fail Comparison Is Made: ADA0S Register = 03H)**

**(a) Timing example**



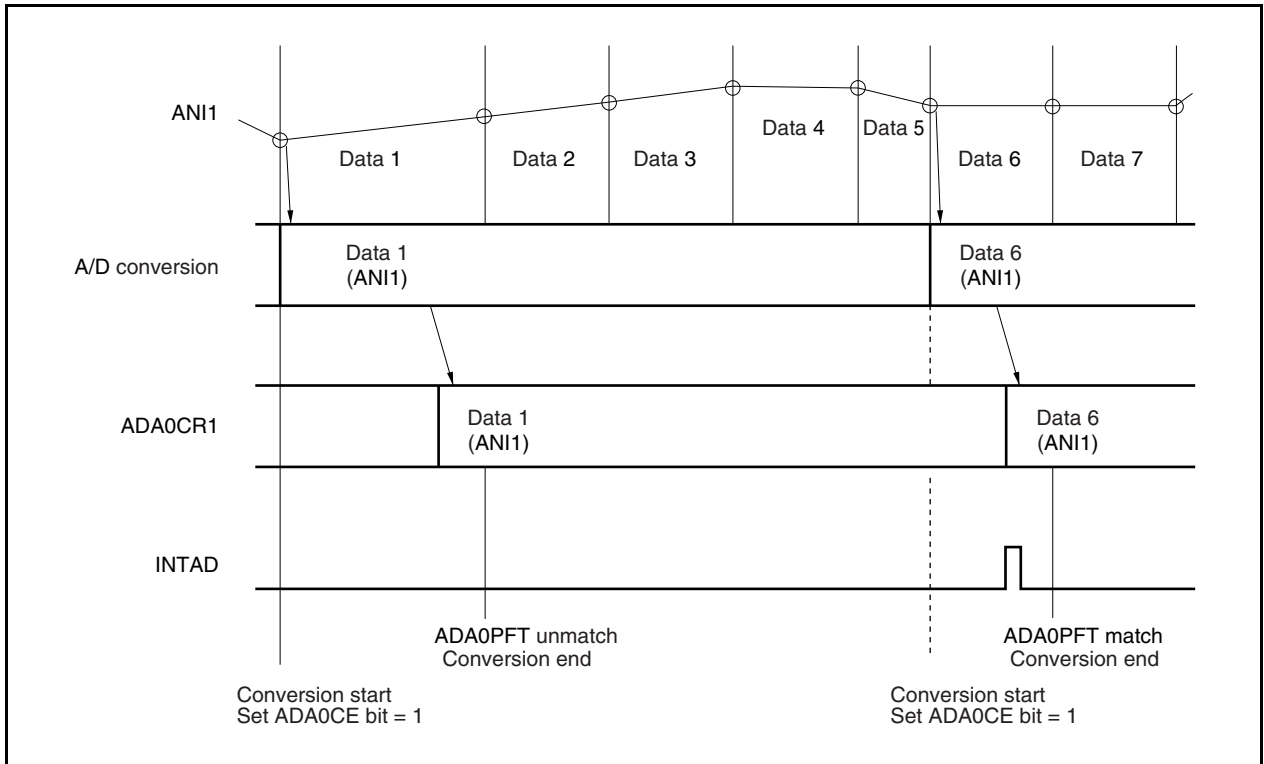
**(b) Block diagram**



**(3) One-shot select mode**

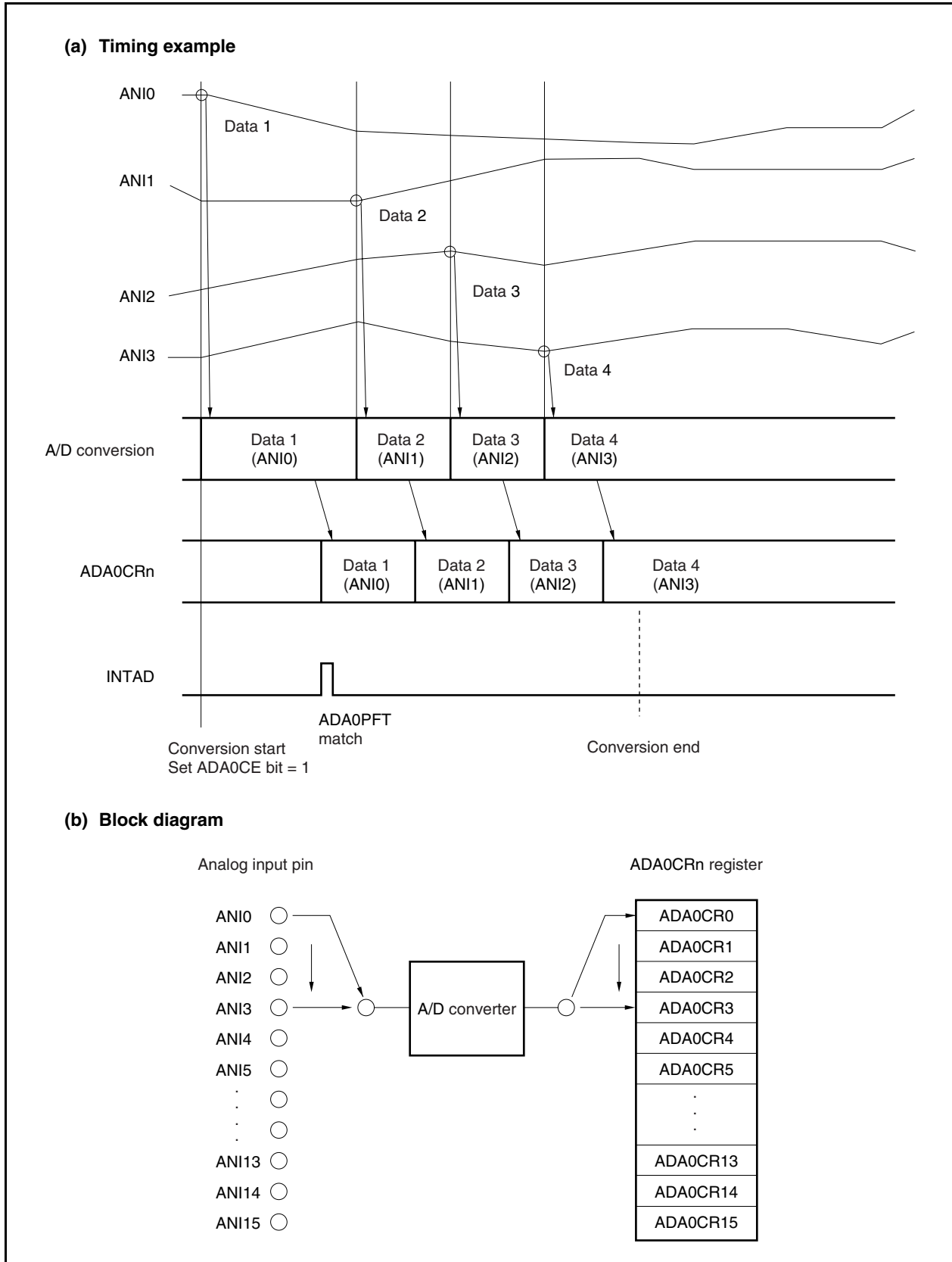
In this mode, the result of converting the voltage of the analog input pin specified by the ADA0S register is compared with the set value of the ADA0PFT register. If the result of power-fail comparison matches the condition set by the ADA0PFC bit, the conversion result is stored in the ADA0CRn register, and the INTAD signal is generated. If it does not match, the conversion result is stored in the ADA0CRn register, and the INTAD signal is not generated. Conversion is stopped after it has been completed.

**Figure 13-10. Timing Example of One-Shot Select Mode Operation  
(When Power-Fail Comparison Is Made: ADA0S Register = 01H)**

**(4) One-shot scan mode**

In this mode, the results of converting the voltages of the analog input pins sequentially selected from the ANI0 pin to the pin specified by the ADA0S register are stored, and the set value of the ADA0CR0H register of channel 0 is compared with the set value of the ADA0PFT register. If the result of power-fail comparison matches the condition set by the ADA0PFC bit, the conversion result is stored in the ADA0CR0 register and the INTAD signal is generated. If it does not match, the conversion result is stored in the ADA0CR0 register, and the INTAD0 signal is not generated. After the result of the first conversion has been stored in the ADA0CR0 register, the results of converting the signals on the analog input pins specified by the ADA0S register are sequentially stored. The conversion is stopped after it has been completed.

**Figure 13-11. Timing Example of One-Shot Scan Mode Operation  
(When Power-Fail Comparison Is Made: ADA0S Register = 03H)**



## 13.6 Cautions

### (1) When A/D converter is not used

When the A/D converter is not used, the power consumption can be reduced by clearing the ADA0M0.ADA0CE bit to 0.

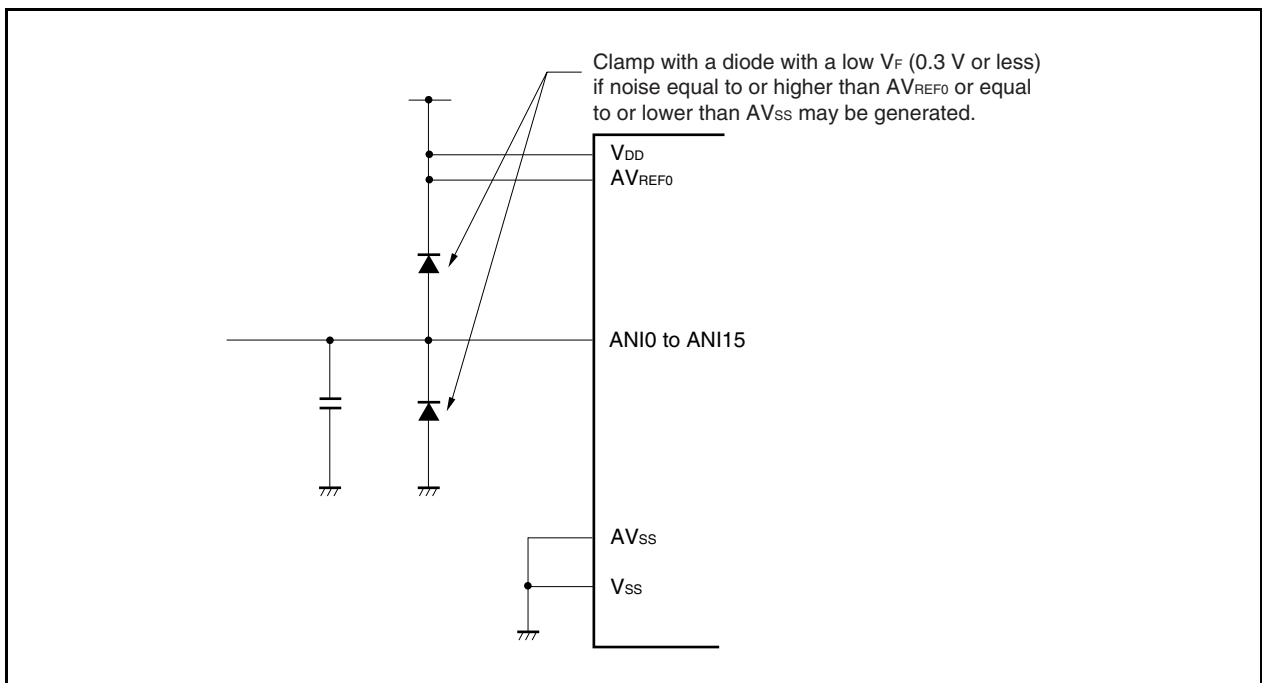
### (2) Input range of ANI0 to ANI15 pins

Input the voltage within the specified range to the ANI0 to ANI15 pins. If a voltage equal to or higher than  $AV_{REF0}$  or equal to or lower than  $AV_{SS}$  (even within the range of the absolute maximum ratings) is input to any of these pins, the conversion value of that channel is undefined, and the conversion value of the other channels may also be affected.

### (3) Countermeasures against noise

To maintain the 10-bit resolution, the ANI0 to ANI15 pins must be effectively protected from noise. The influence of noise increases as the output impedance of the analog input source becomes higher. To lower the noise, connecting an external capacitor as shown in Figure 13-12 is recommended.

Figure 13-12. Processing of Analog Input Pin



### (4) Alternate I/O

The analog input pins (ANI0 to ANI15) function alternately as port pins. When selecting one of the ANI0 to ANI15 pins to execute A/D conversion, do not execute an instruction to read an input port or write to an output port during conversion as the conversion resolution may drop.

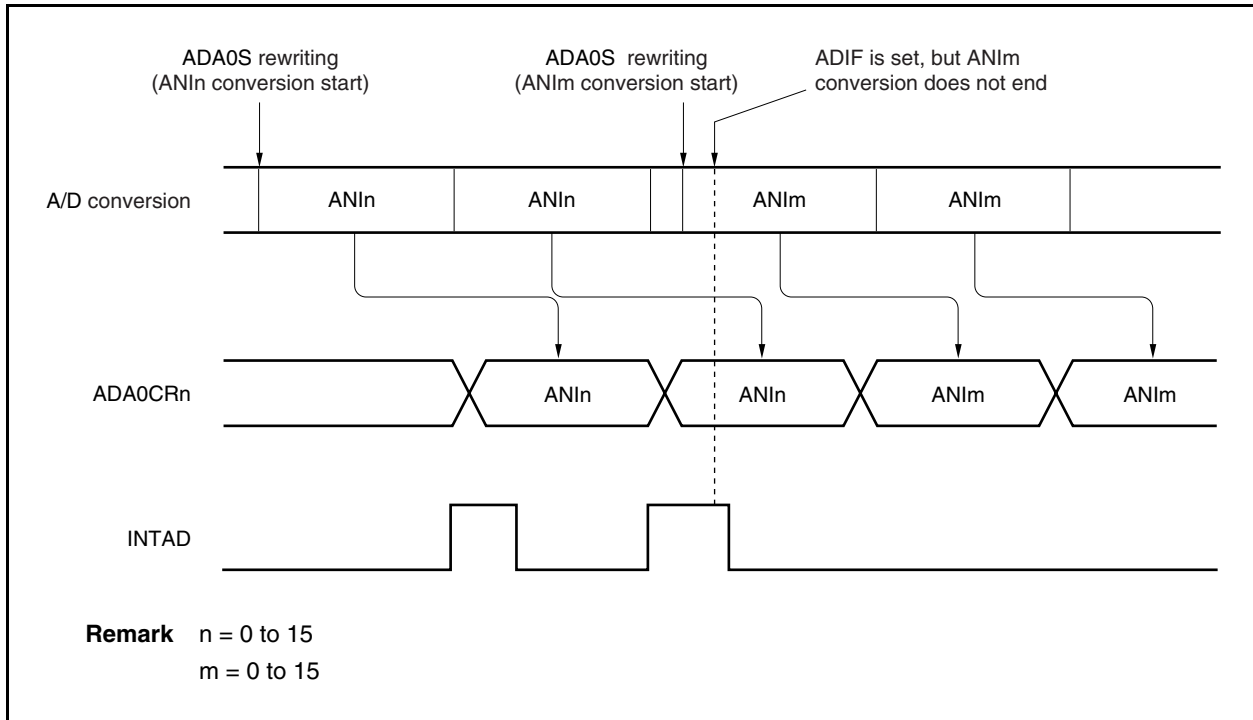
Also the conversion resolution may drop at the pins set as output port pins during A/D conversion if the output current fluctuates due to the effect of the external circuit connected to the port pins.

If a digital pulse is applied to a pin adjacent to the pin whose input signal is being converted, the A/D conversion value may not be as expected due to the influence of coupling noise. Therefore, do not apply a pulse to a pin adjacent to the pin undergoing A/D conversion.

**(5) Interrupt request flag (ADIF)**

The interrupt request flag (ADIF) is not cleared even if the contents of the ADA0S register are changed. If the analog input pin is changed during A/D conversion, therefore, the result of converting the previously selected analog input signal may be stored and the conversion end interrupt request flag may be set immediately before the ADA0S register is rewritten. If the ADIF flag is read immediately after the ADA0S register is rewritten, the ADIF flag may be set even though the A/D conversion of the newly selected analog input pin has not been completed. When A/D conversion is stopped, clear the ADIF flag before resuming conversion.

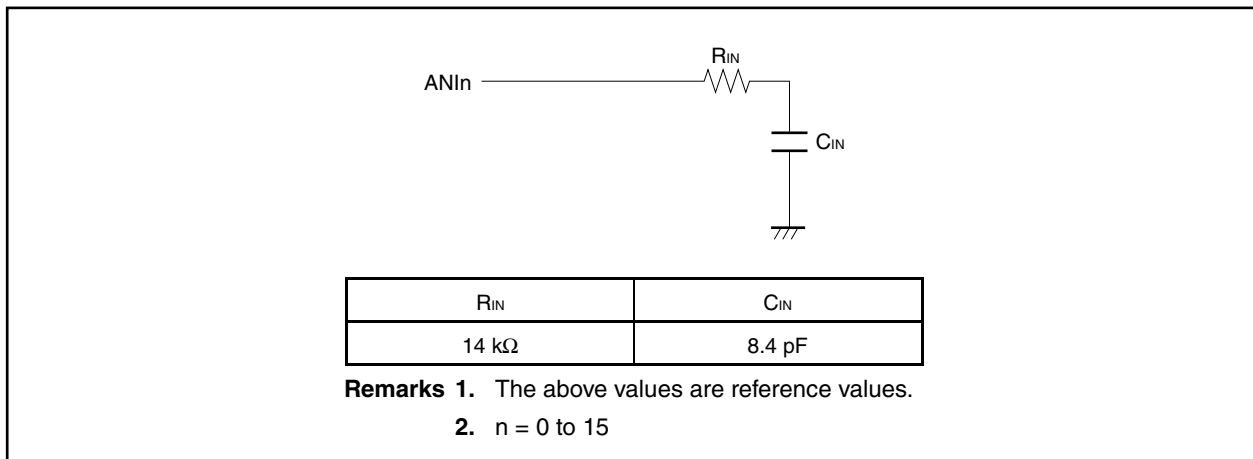
**Figure 13-13. Generation Timing of A/D Conversion End Interrupt Request**



**(6) Internal equivalent circuit**

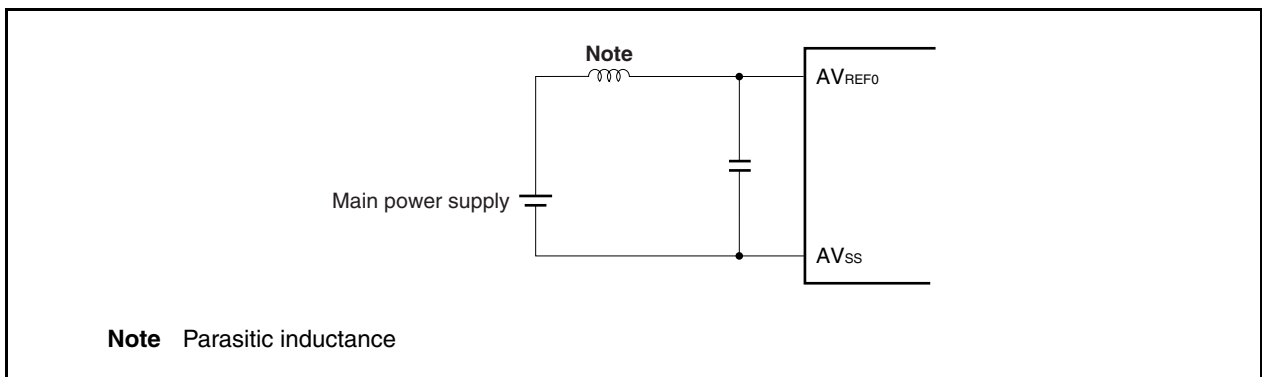
The following shows the equivalent circuit of the analog input block.

**Figure 13-14. Internal Equivalent Circuit of ANIn Pin**



**(7) AV<sub>REF0</sub> pin**

- (a) The AV<sub>REF0</sub> pin is used as the power supply pin of the A/D converter and also supplies power to the alternate-function ports. In an application where a backup power supply is used, be sure to supply the same voltage as V<sub>DD</sub> to the AV<sub>REF0</sub> pin as shown in Figure 13-15.
- (b) The AV<sub>REF0</sub> pin is also used as the reference voltage pin of the A/D converter. If the source supplying power to the AV<sub>REF0</sub> pin has a high impedance or if the power supply has a low current supply capability, the reference voltage may fluctuate due to the current that flows during conversion (especially, immediately after the conversion operation enable bit ADA0CE has been set to 1). As a result, the conversion accuracy may drop. To avoid this, it is recommended to connect a capacitor across the AV<sub>REF0</sub> and AV<sub>SS</sub> pins to suppress the reference voltage fluctuation as shown in Figure 13-15.
- (c) If the source supplying power to the AV<sub>REF0</sub> pin has a high DC resistance (for example, because of insertion of a diode), the voltage when conversion is enabled may be lower than the voltage when conversion is stopped, because of a voltage drop caused by the A/D conversion current.

**Figure 13-15. AV<sub>REF0</sub> Pin Processing Example****(8) Reading ADA0CRn register**

When the ADA0M0 to ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register is written, the contents of the ADA0CRn register may be undefined. Read the conversion result after completion of conversion and before writing to the ADA0M0 to ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register. Also, when an external/timer trigger is acknowledged, the contents of the ADA0CRn register may be undefined. Read the conversion result after completion of conversion and before the next external/timer trigger is acknowledged. The correct conversion result may not be read at a timing different from the above.

**(9) Standby mode**

Because the A/D converter stops operating in the STOP mode, conversion results are invalid, so power consumption can be reduced. Operations are resumed after the STOP mode is released, but the A/D conversion results after the STOP mode is released are invalid. When using the A/D converter after the STOP mode is released, before setting the STOP mode or releasing the STOP mode, clear the ADA0M0.ADA0CE bit to 0 then set the ADA0CE bit to 1 after releasing the STOP mode.

In the IDLE1, IDLE2, or subclock operation mode, operation continues. To lower the power consumption, therefore, clear the ADA0M0.ADA0CE bit to 0. In the IDLE1 and IDLE2 modes, since the analog input voltage value cannot be retained, the A/D conversion results after the IDLE1 and IDLE2 modes are released are invalid. The results of conversions before the IDLE1 and IDLE2 modes were set are valid.

**(10) High-speed conversion mode**

In the high-speed conversion mode, rewriting of the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers and trigger input during the stabilization time are prohibited.

**(11) A/D conversion time**

A/D conversion time is the total time of stabilization time, conversion time, wait time, and trigger response time (for details of these times, refer to **Table 13-2 Conversion Time Selection in Normal Conversion Mode (ADA0HS1 Bit = 0)** and **Table 13-3 Conversion Time Selection in High-Speed Conversion Mode (ADA0HS1 Bit = 1)**).

During A/D conversion in the normal conversion mode, if the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers are written or a trigger is input, reconversion is carried out. However, if the stabilization time end timing conflicts with the writing to these registers, or if the stabilization time end timing conflicts with the trigger input, the stabilization time of 64 clocks is reinserted.

If a conflict occurs again with the reinserted stabilization time end timing, the stabilization time is reinserted. Therefore do not set the trigger input interval and control register write interval to 64 clocks or below.

**(12) Variation of A/D conversion results**

The results of the A/D conversion may vary depending on the fluctuation of the supply voltage, or may be affected by noise. To reduce the variation, take counteractive measures with the program such as averaging the A/D conversion results.

**(13) A/D conversion result hysteresis characteristics**

The successive comparison type A/D converter holds the analog input voltage in the internal sample & hold capacitor and then performs A/D conversion. After the A/D conversion has finished, the analog input voltage remains in the internal sample & hold capacitor. As a result, the following phenomena may occur.

- When the same channel is used for A/D conversions, if the voltage is higher or lower than the previous A/D conversion, then hysteresis characteristics may appear where the conversion result is affected by the previous value. Thus, even if the conversion is performed at the same potential, the result may vary.
- When switching the analog input channel, hysteresis characteristics may appear where the conversion result is affected by the previous channel value. This is because one A/D converter is used for the A/D conversions. Thus, even if the conversion is performed at the same potential, the result may vary.



### 13.7 How to Read A/D Converter Characteristics Table

This section describes the terms related to the A/D converter.

#### (1) Resolution

The minimum analog input voltage that can be recognized, i.e., the ratio of an analog input voltage to 1 bit of digital output is called 1 LSB (least significant bit). The ratio of 1 LSB to the full scale is expressed as %FSR (full-scale range). %FSR is the ratio of a range of convertible analog input voltages expressed as a percentage, and can be expressed as follows, independently of the resolution.

$$\begin{aligned} 1\%FSR &= (\text{Maximum value of convertible analog input voltage} - \text{Minimum value of convertible analog} \\ &\quad \text{input voltage})/100 \\ &= (AV_{REF0} - 0)/100 \\ &= AV_{REF0}/100 \end{aligned}$$

When the resolution is 10 bits, 1 LSB is as follows:

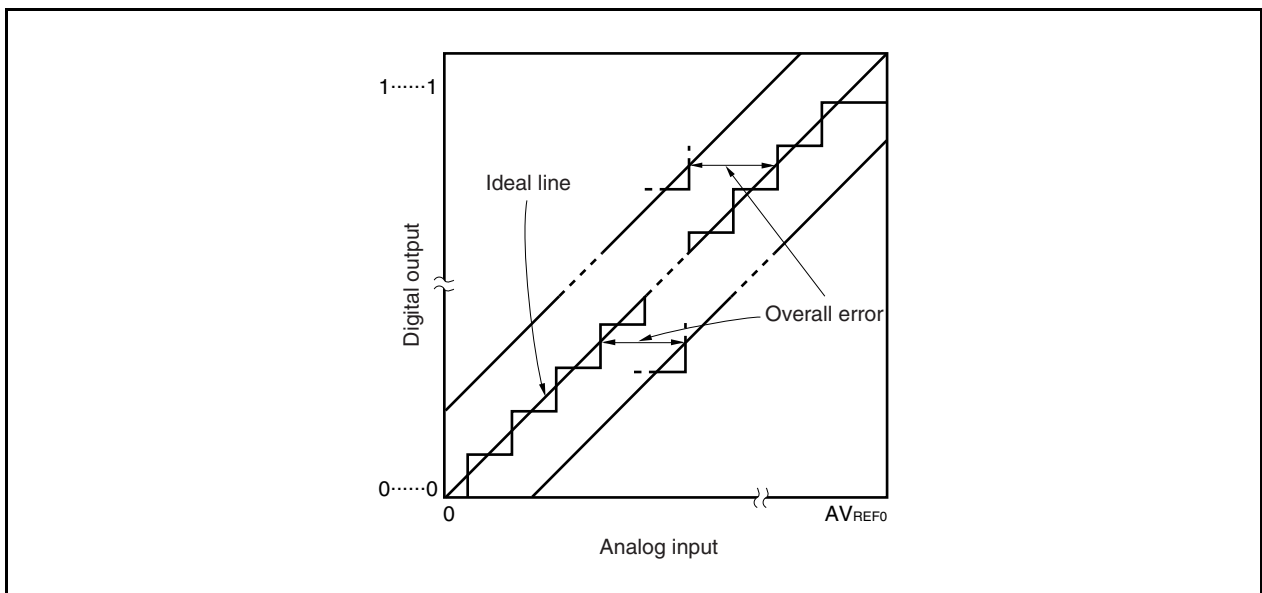
$$\begin{aligned} 1 \text{ LSB} &= 1/2^{10} = 1/1,024 \\ &= 0.098\%FSR \end{aligned}$$

The accuracy is determined by the overall error, independently of the resolution.

#### (2) Overall error

This is the maximum value of the difference between an actually measured value and a theoretical value. It is a total of zero-scale error, full-scale error, linearity error, and a combination of these errors. The overall error in the characteristics table does not include the quantization error.

**Figure 13-16. Overall Error**

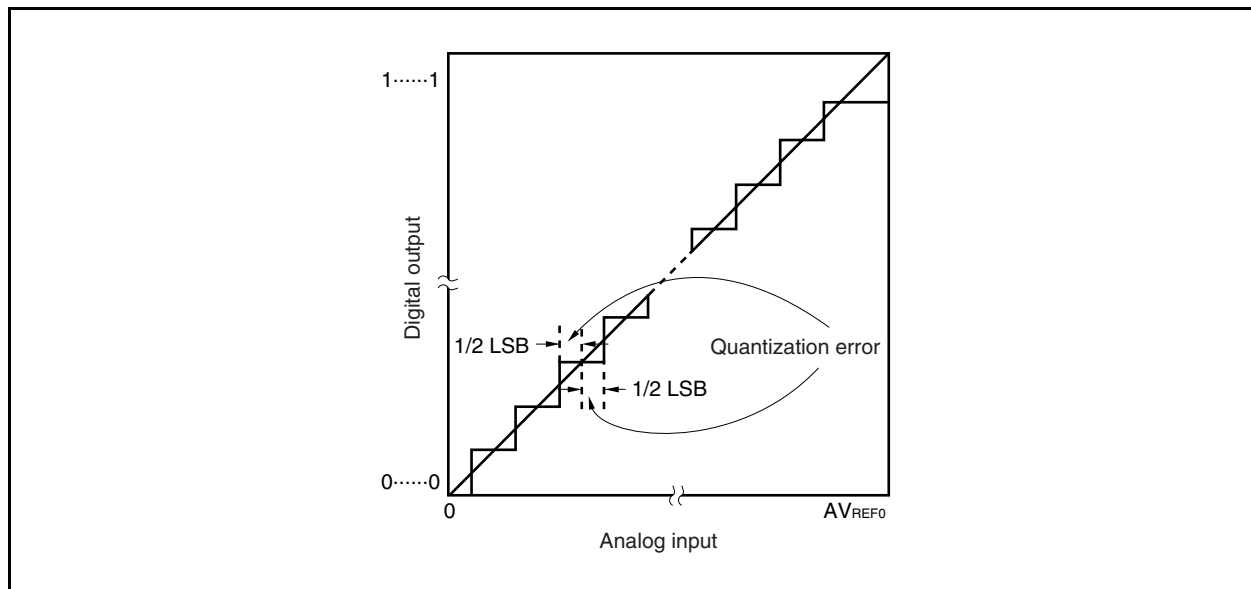


**(3) Quantization error**

This is an error of  $\pm 1/2$  LSB that inevitably occurs when an analog value is converted into a digital value. Because the A/D converter converts analog input voltages in a range of  $\pm 1/2$  LSB into the same digital codes, a quantization error is unavoidable.

This error is not included in the overall error, zero-scale error, full-scale error, integral linearity error, or differential linearity error in the characteristics table.

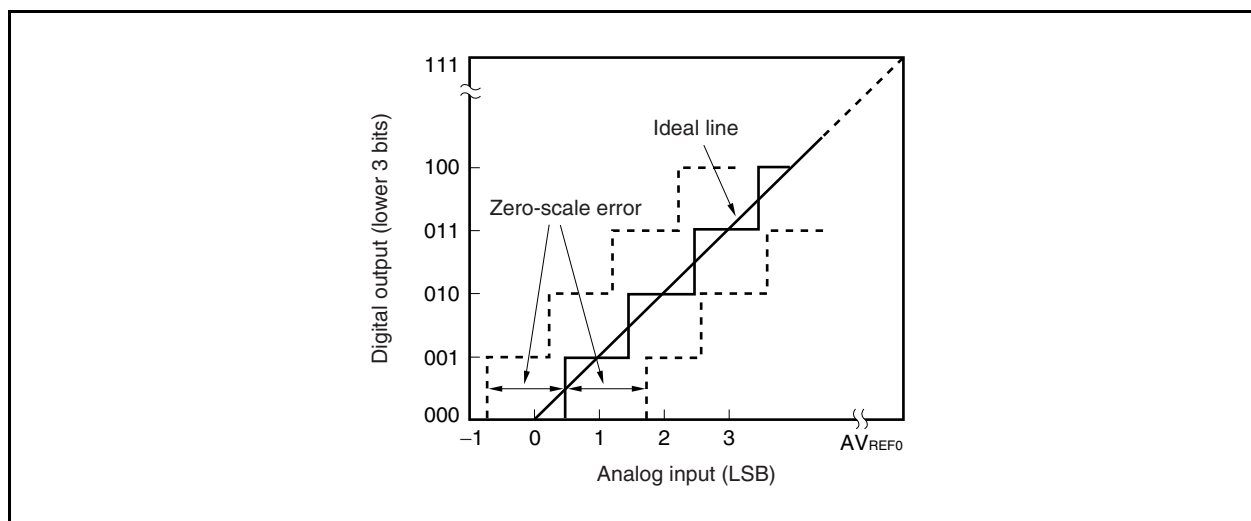
**Figure 13-17. Quantization Error**



**(4) Zero-scale error**

This is the difference between the actually measured analog input voltage and its theoretical value when the digital output changes from 0...000 to 0...001 ( $1/2$  LSB).

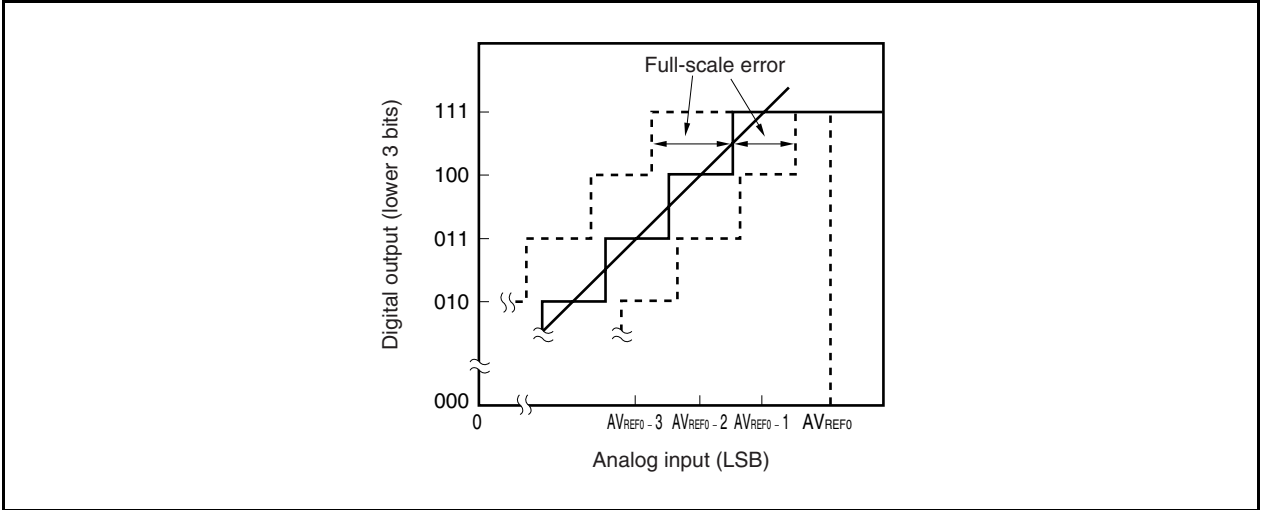
**Figure 13-18. Zero-Scale Error**



**(5) Full-scale error**

This is the difference between the actually measured analog input voltage and its theoretical value when the digital output changes from 1...110 to 1...111 (full scale – 3/2 LSB).

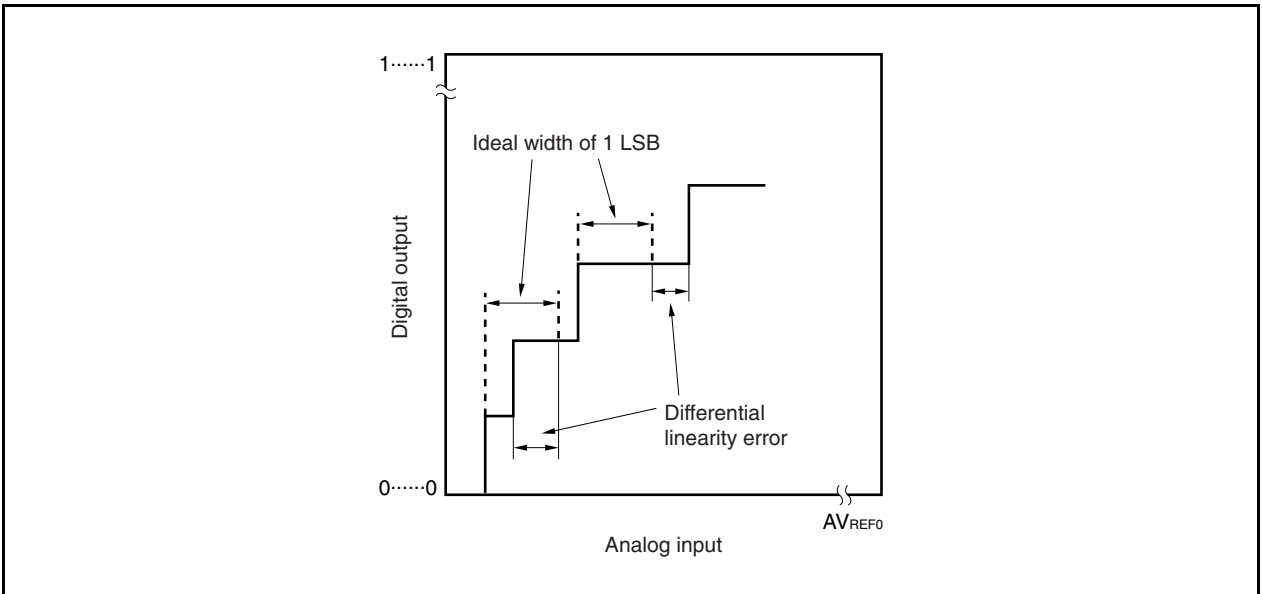
**Figure 13-19. Full-Scale Error**



**(6) Differential linearity error**

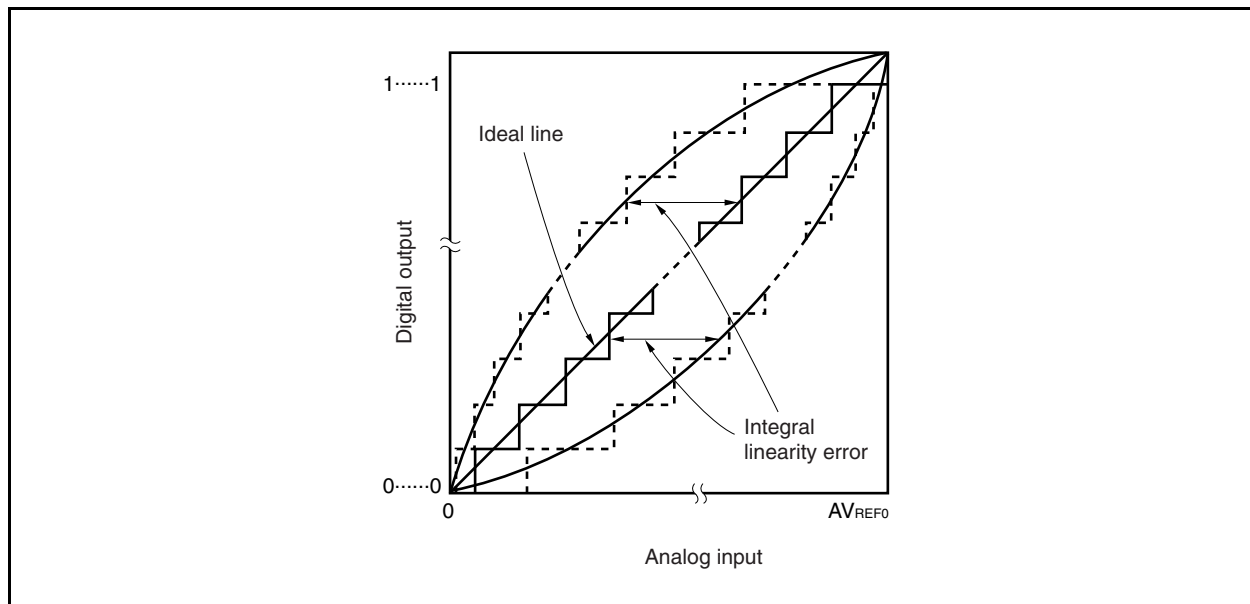
Ideally, the width to output a specific code is 1 LSB. This error indicates the difference between the actually measured value and its theoretical value when a specific code is output. This indicates the basic characteristics of the A/D conversion when the voltage applied to the analog input pins of the same channel is consistently increased bit by bit from  $AV_{SS}$  to  $AV_{REF0}$ . When the input voltage is increased or decreased, or when two or more channels are used, see 13.7 (2) Overall error.

**Figure 13-20. Differential Linearity Error**



**(7) Integral linearity error**

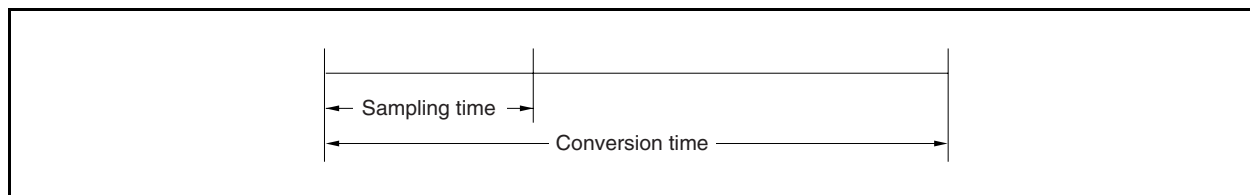
This error indicates the extent to which the conversion characteristics differ from the ideal linear relationship. It indicates the maximum value of the difference between the actually measured value and its theoretical value where the zero-scale error and full-scale error are 0.

**Figure 13-21. Integral Linearity Error****(8) Conversion time**

This is the time required to obtain a digital output after each trigger has been generated. The conversion time in the characteristics table includes the sampling time.

**(9) Sampling time**

This is the time for which the analog switch is ON to load an analog voltage to the sample & hold circuit.

**Figure 13-22. Sampling Time**

## CHAPTER 14 D/A CONVERTER

### 14.1 Functions

The D/A converter has the following functions.

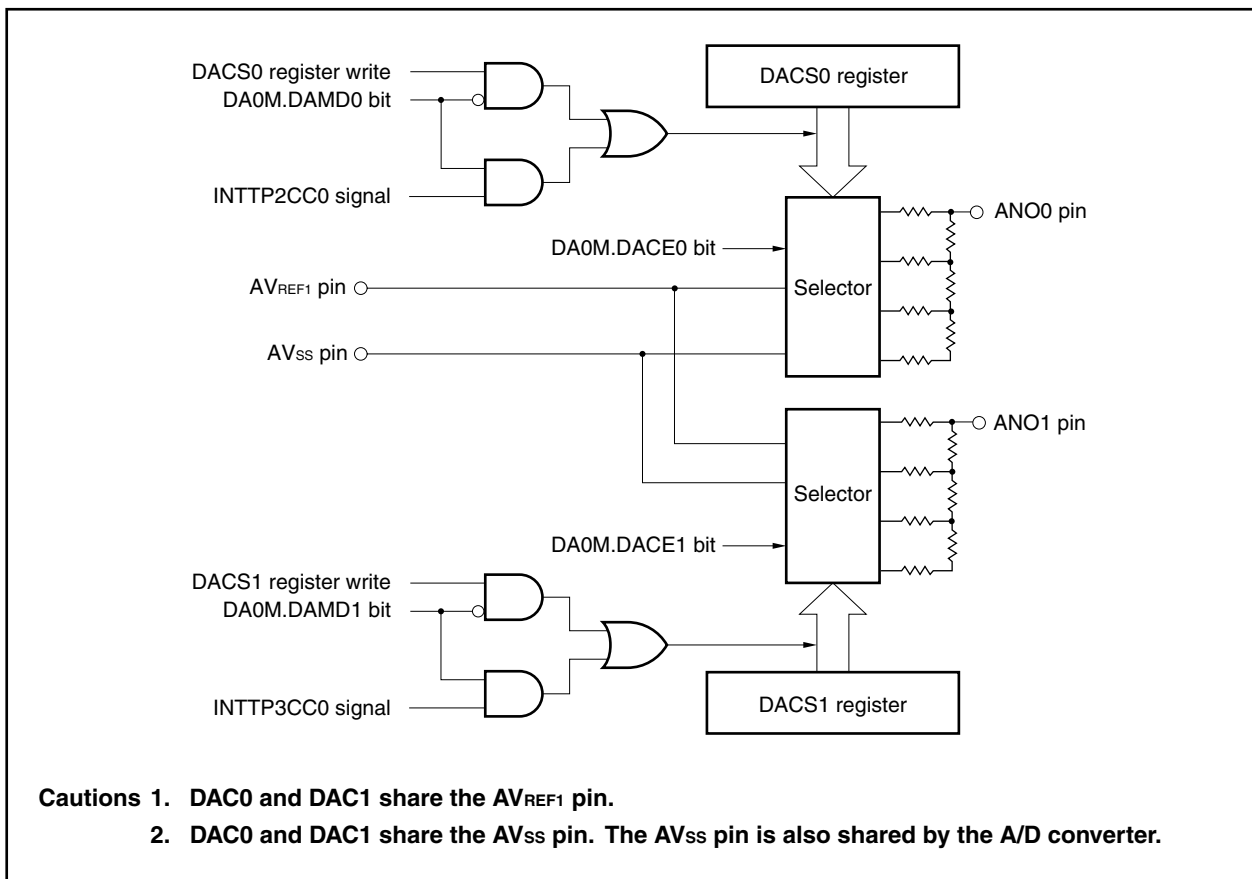
- 8-bit resolution × 2 channels (DA0CS0, DA0CS1)
- R-2R ladder method
- Settling time: 3  $\mu$ s max. (when  $AV_{REF1}$  is 3.0 to 3.6 V and external load is 20 pF)
- Analog output voltage:  $AV_{REF1} \times m/256$  ( $m = 0$  to 255; value set to DA0CSn register)
- Operation modes: Normal mode, real-time output mode

**Remark**  $n = 0, 1$

### 14.2 Configuration

The D/A converter configuration is shown below.

**Figure 14-1. Block Diagram of D/A Converter**



The D/A converter includes the following hardware.

**Table 14-1. Configuration of D/A Converter**

| Item              | Configuration  |
|-------------------|--|
| Control registers | D/A converter mode register (DA0M)<br>D/A conversion value setting registers 0, 1 (DA0CS0, DA0CS1) |

### 14.3 Registers

The registers that control the D/A converter are as follows.

- D/A converter mode register (DA0M)
- D/A conversion value setting registers 0, 1 (DA0CS0, DA0CS1)

#### (1) D/A converter mode register (DA0M)

The DA0M register controls the operation of the D/A converter.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

|                  |   |     |                    |        |   |   |        |        |
|------------------|---|-----|--------------------|--------|---|---|--------|--------|
| After reset: 00H |   | R/W | Address: FFFFF282H |        |   |   |        |        |
|                  | 7 | 6   | <5>                | <4>    | 3 | 2 | 1      | 0      |
| DA0M             | 0 | 0   | DA0CE1             | DA0CE0 | 0 | 0 | DA0MD1 | DA0MD0 |

|        |  |
|--------|--|
| DA0CEn | Control of D/A converter operation enable/disable (n = 0, 1) |
| 0      | Disables operation   |
| 1      | Enables operation  |

|        |  |
|--------|--|
| DA0MDn | Selection of D/A converter operation mode (n = 0, 1) |
| 0      | Normal mode  |
| 1      | Real-time output mode <sup>Note</sup>                |

**Note** The output trigger in the real-time output mode (DA0MDn bit = 1) is as follows.

- When n = 0: INTTP2CC0 signal (see **CHAPTER 7 16-BIT TIMER/EVENT COUNTER P (TMP)**)
- When n = 1: INTTP3CC0 signal (see **CHAPTER 7 16-BIT TIMER/EVENT COUNTER P (TMP)**)

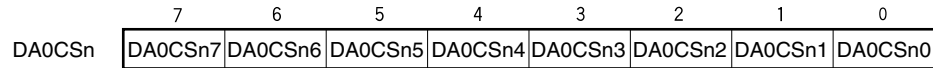
**(2) D/A conversion value setting registers 0, 1 (DA0CS0, DA0CS1)**

The DA0CS0 and DA0CS1 registers set the analog voltage value output to the ANO0 and ANO1 pins.

These registers can be read or written in 8-bit units.

Reset sets these registers to 00H.

After reset: 00H    R/W    Address: DA0CS0 FFFFF280H, DA0CS1 FFFFF281H



**Caution** In the real-time output mode (DA0M.DA0MDn bit = 1), set the DA0CSn register before the INTTP2CC0/INTTP3CC0 signals are generated. D/A conversion starts when the INTTP2CC0/INTTP3CC0 signals are generated.

**Remark** n = 0, 1

## 14.4 Operation

### 14.4.1 Operation in normal mode

D/A conversion is performed using a write operation to the DA0CSn register as the trigger. The setting method is described below.

- <1> Set the DA0M.DA0MDn bit to 0 (normal mode).
- <2> Set the analog voltage value to be output to the ANOn pin to the DA0CSn register. Steps <1> and <2> above constitute the initial settings.
- <3> Set the DA0M.DA0CEn bit to 1 (D/A conversion enable). D/A conversion starts when this setting is performed.
- <4> To perform subsequent D/A conversions, write to the DA0CSn register. The previous D/A conversion result is held until the next D/A conversion is performed.

**Remarks 1.** For the alternate-function pin settings, see **Table 4-19 Using Port Pins as Alternate-Function Pins.**

- 2. n = 0, 1

### 14.4.2 Operation in real-time output mode

D/A conversion is performed using the interrupt request signals (INTTP2CC0 and INTTP3CC0) of TMP2 and TMP3 as triggers.

The setting method is described below.

- <1> Set the DA0M.DA0MDn bit to 1 (real-time output mode).
- <2> Set the analog voltage value to be output to the ANOn pin to the DA0CSn register.
- <3> Set the DA0M.DA0CEn bit to 1 (D/A conversion enable). Steps <1> to <3> above constitute the initial settings.
- <4> Operate TMP2 and TMP3.
- <5> D/A conversion starts when the INTTP2CC0 and INTTP3CC0 signals are generated.
- <6> After that, the value set in DA0CSn register is output every time the INTTP2CC0 and INTTP3CC0 signals are generated.

**Remarks 1.** The output values of the ANO0 and ANO1 pins up to <5> above are undefined.

- 2. For the output values of the ANO0 and ANO1 pins in the HALT, IDLE1, IDLE2, and STOP modes, see **CHAPTER 21 STANDBY FUNCTION.**
- 3. For the alternate-function pin settings, see **Table 4-19 Using Port Pins as Alternate-Function Pins.**

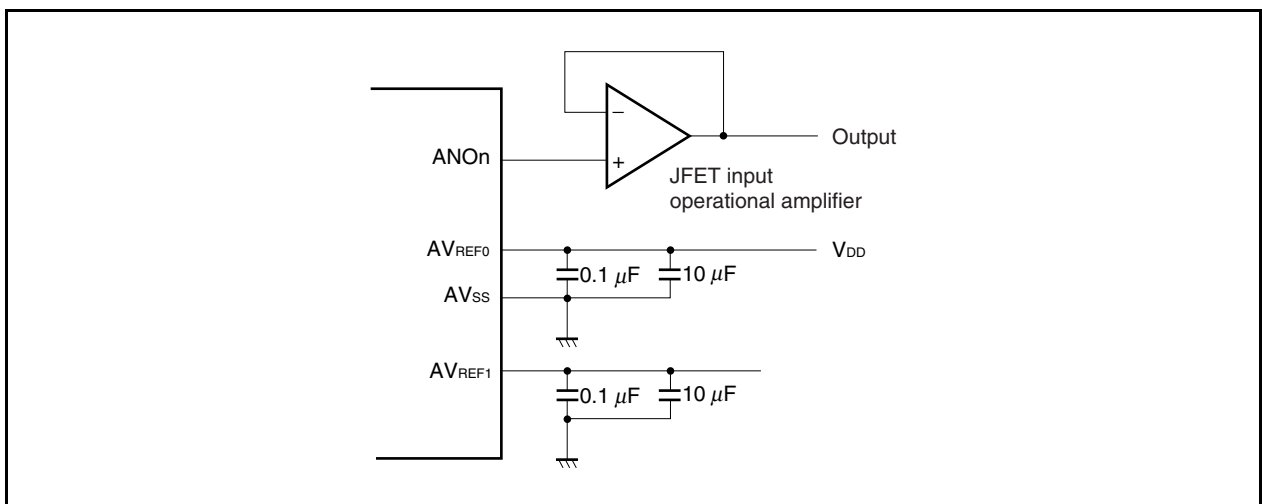


### 14.4.3 Cautions

Observe the following cautions when using the D/A converter of the V850ES/JJ3.

- (1) Do not change the set value of the DA0CSn register while the trigger signal is being issued in the real-time output mode.
- (2) Before changing the operation mode, be sure to clear the DA0M.DA0CEn bit to 0.
- (3) When using one of the P10/AN00 and P11/AN01 pins as an I/O port and the other as a D/A output pin, do so in an application where the port I/O level does not change during D/A output.
- (4) Make sure that  $AV_{REF0} = V_{DD} = AV_{REF1} = 3.0$  to  $3.6$  V. If this range is exceeded, the operation is not guaranteed.
- (5) Apply power to  $AV_{REF1}$  at the same timing as  $AV_{REF0}$ .
- (6) No current can be output from the ANOn pin ( $n = 0, 1$ ) because the output impedance of the D/A converter is high. When connecting a resistor of  $2\text{ M}\Omega$  or less, insert a JFET input operational amplifier between the resistor and the ANOn pin.

**Figure 14-2. External Pin Connection Example**



- (7) Because the D/A converter stops operation in the STOP mode, the ANO0 and ANO1 pins go into a high-impedance state, and the power consumption can be reduced. In the IDLE1, IDLE2, or subclock operation mode, however, the operation continues. To lower the power consumption, therefore, clear the DA0M.DA0CEn bit to 0.

## CHAPTER 15 ASYNCHRONOUS SERIAL INTERFACE A (UARTA)

### 15.1 Mode Switching of UARTA and Other Serial Interfaces

#### 15.1.1 CSIB4 and UARTA0 mode switching

In the V850ES/JJ3, CSIB4 and UARTA0 are alternate functions of the same pin and therefore cannot be used simultaneously. Set UARTA0 in advance, using the PMC3 and PFC3 registers, before use.

**Caution** The transmit/receive operation of CSIB4 and UARTA0 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.

**Figure 15-1. CSIB4 and UARTA0 Mode Switch Settings**

After reset: 0000H    R/W    Address: FFFFF446H, FFFFF447H

|      |    |    |       |       |       |       |       |       |
|------|----|----|-------|-------|-------|-------|-------|-------|
|      | 15 | 14 | 13    | 12    | 11    | 10    | 9     | 8     |
| PMC3 | 0  | 0  | 0     | 0     | 0     | 0     | PMC39 | PMC38 |
|      |    |    |       |       |       |       |       |       |
|      | 7  | 6  | 5     | 4     | 3     | 2     | 1     | 0     |
|      | 0  | 0  | PMC35 | PMC34 | PMC33 | PMC32 | PMC31 | PMC30 |

After reset: 0000H    R/W    Address: FFFFF466H, FFFFF467H

|      |    |    |       |       |       |       |       |       |
|------|----|----|-------|-------|-------|-------|-------|-------|
|      | 15 | 14 | 13    | 12    | 11    | 10    | 9     | 8     |
| PFC3 | 0  | 0  | 0     | 0     | 0     | 0     | PFC39 | PFC38 |
|      |    |    |       |       |       |       |       |       |
|      | 7  | 6  | 5     | 4     | 3     | 2     | 1     | 0     |
|      | 0  | 0  | PFC35 | PFC34 | PFC33 | PFC32 | PFC31 | PFC30 |

After reset: 00H    R/W    Address: FFFFF706H

|        |   |   |   |   |   |        |   |   |
|--------|---|---|---|---|---|--------|---|---|
|        | 7 | 6 | 5 | 4 | 3 | 2      | 1 | 0 |
| PFCE3L | 0 | 0 | 0 | 0 | 0 | PFCE32 | 0 | 0 |

| PMC32 | PFCE32 | PFC32 | Operation mode |
|-------|--------|-------|----------------|
| 0     | ×      | ×     | Port I/O mode  |
| 1     | 0      | 0     | ASCKA0 mode    |
| 1     | 0      | 1     | SCKB4 mode     |

| PMC3n | PFC3n | Operation mode |
|-------|-------|----------------|
| 0     | ×     | Port I/O mode  |
| 1     | 0     | UARTA0 mode    |
| 1     | 1     | CSIB4 mode     |

**Remarks**

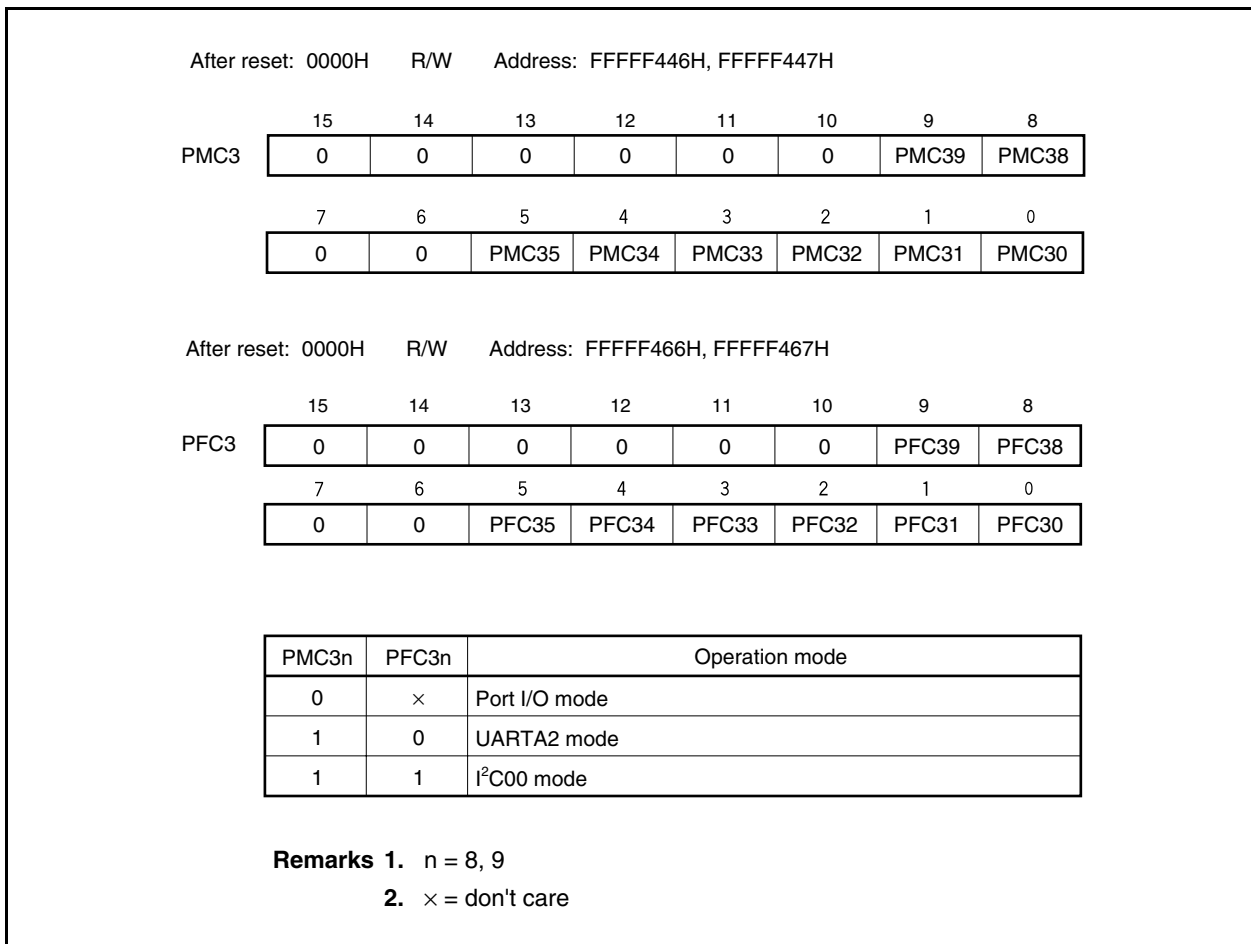
1. n = 0, 1
2. × = don't care

**15.1.2 UARTA2 and I<sup>2</sup>C00 mode switching**

In the V850ES/JJ3, UARTA2 and I<sup>2</sup>C00 are alternate functions of the same pin and therefore cannot be used simultaneously. Set UARTA2 in advance, using the PMC3 and PFC3 registers, before use.

**Caution** The transmit/receive operation of UARTA2 and I<sup>2</sup>C00 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.

**Figure 15-2. UARTA2 and I<sup>2</sup>C00 Mode Switch Settings**

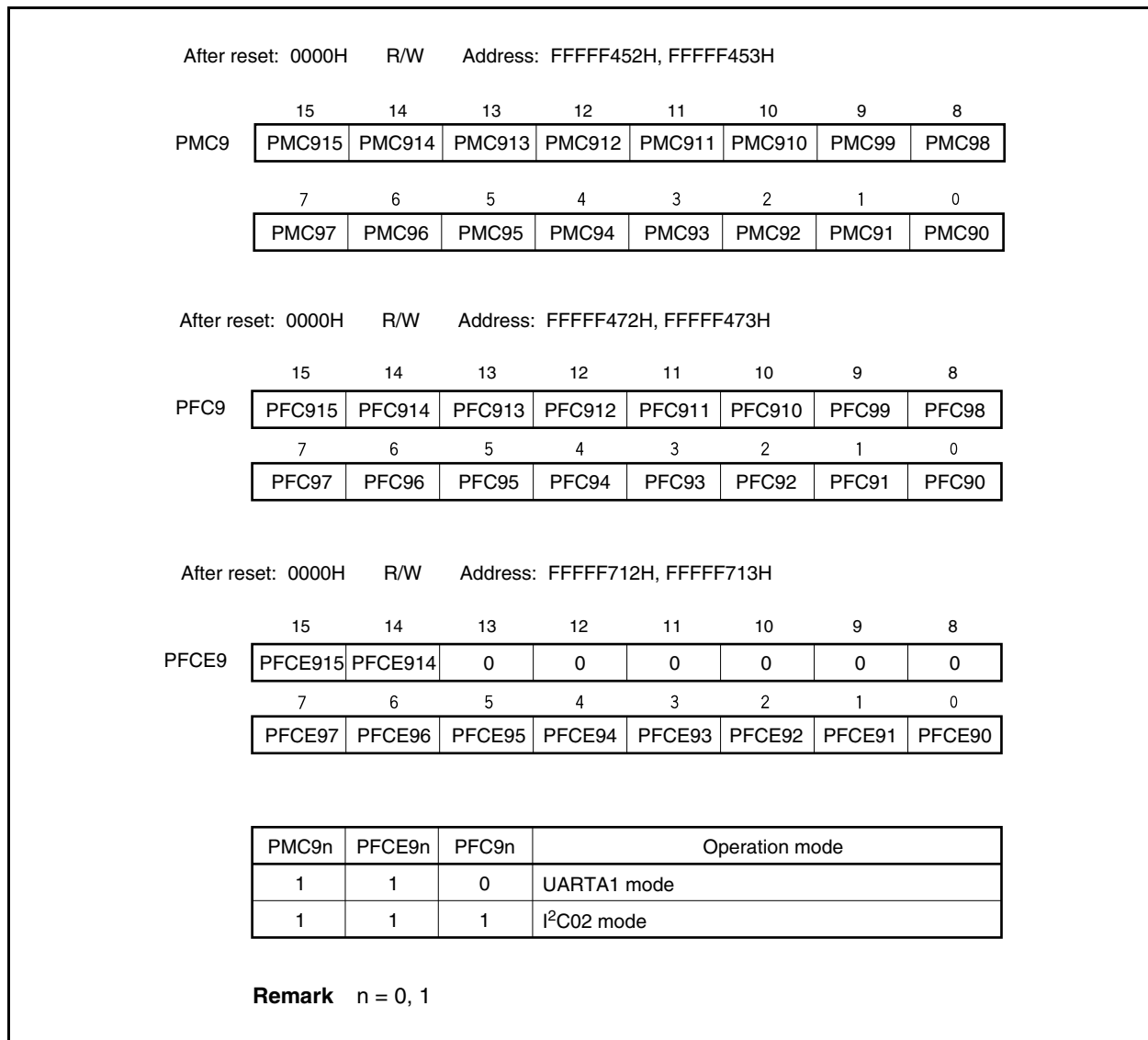


15.1.3 UARTA1 and I<sup>2</sup>C02 mode switching

In the V850ES/JJ3, UARTA1 and I<sup>2</sup>C02 are alternate functions of the same pin and therefore cannot be used simultaneously. Set UARTA1 in advance, using the PMC9, PFC9, and PMCE9 registers, before use.

**Caution** The transmit/receive operation of UARTA1 and I<sup>2</sup>C02 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.

Figure 15-3. UARTA1 and I<sup>2</sup>C02 Mode Switch Settings



## 15.2 Features

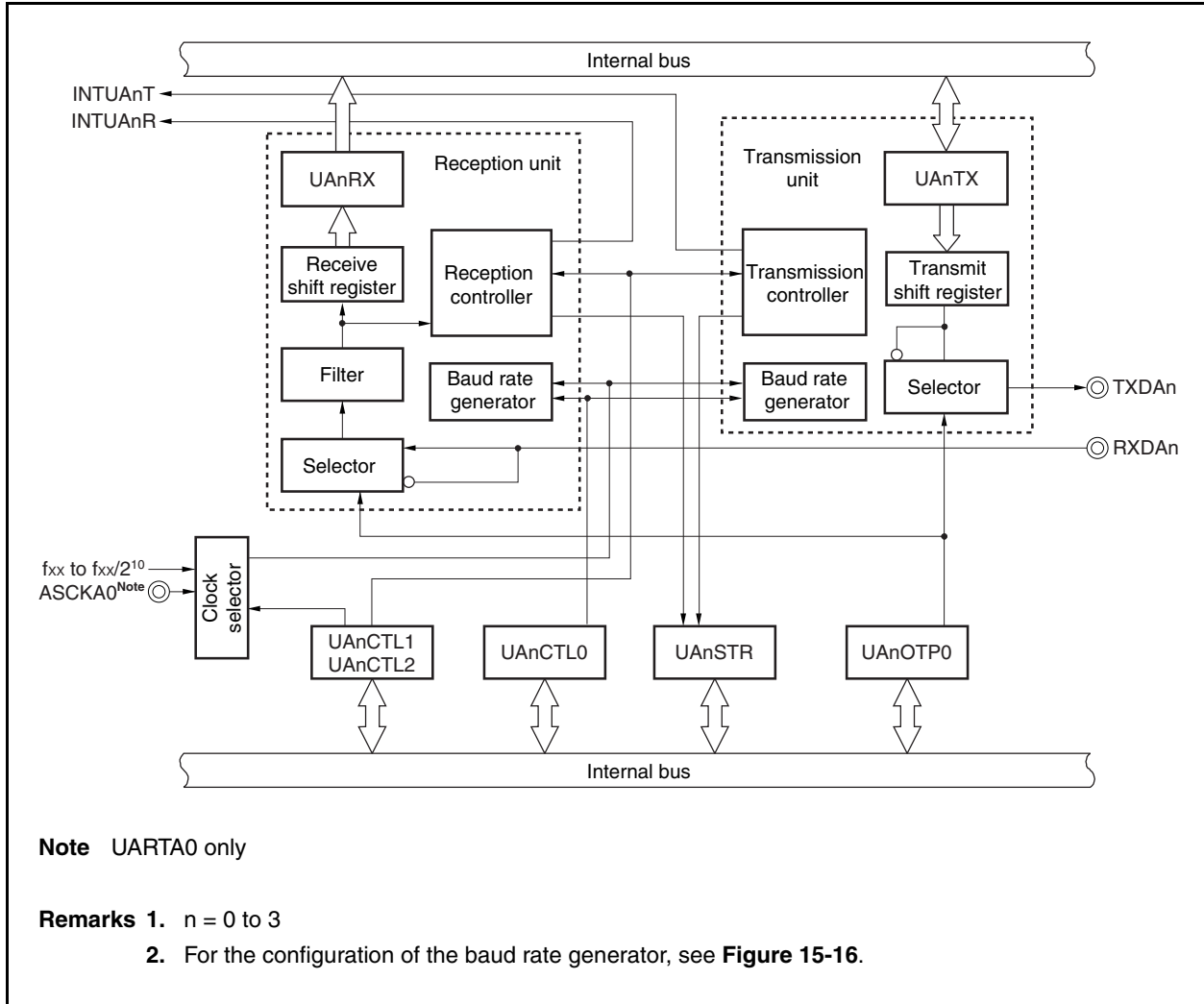
- Transfer rate: 300 bps to 625 kbps (using internal system clock of 32 MHz and dedicated baud rate generator)
- Full-duplex communication: Internal UARTAn receive data register (UAnRX)  
Internal UARTAn transmit data register (UAnTX)
- 2-pin configuration: TXDAn: Transmit data output pin  
RXDAn: Receive data input pin
- Reception error output function
  - Parity error
  - Framing error
  - Overrun error
- Interrupt sources: 2
  - Reception complete interrupt (INTUAnR): This interrupt occurs upon transfer of receive data from the receive shift register to receive data register after serial transfer completion, in the reception enabled status.
  - Transmission enable interrupt (INTUAnT): This interrupt occurs upon transfer of transmit data from the transmit data register to the transmit shift register in the transmission enabled status.
- Character length: 7, 8 bits
- Parity function: Odd, even, 0, none
- Transmission stop bit: 1, 2 bits
- On-chip dedicated baud rate generator
- MSB-/LSB-first transfer selectable
- Transmit/receive data inverted input/output possible
- SBF (Sync Break Field) transmission/reception in the LIN (Local Interconnect Network) communication format possible
  - 13 to 20 bits selectable for SBF transmission
  - Recognition of 11 bits or more possible for SBF reception
  - SBF reception flag provided

**Remark** n = 0 to 3

### 15.3 Configuration

The block diagram of the UARTAn is shown below.

**Figure 15-4. Block Diagram of Asynchronous Serial Interface An**



UARTAn includes the following hardware.

**Table 15-1. Configuration of UARTAn**

| Item      | Configuration  |
|-----------|--|
| Registers | UARTAn control register 0 (UAnCTL0)<br>UARTAn control register 1 (UAnCTL1)<br>UARTAn control register 2 (UAnCTL2)<br>UARTAn option control register 0 (UAnOPT0)<br>UARTAn status register (UAnSTR)<br>UARTAn receive shift register<br>UARTAn receive data register (UAnRX)<br>UARTAn transmit shift register<br>UARTAn transmit data register (UAnTX) |

**(1) UARTAn control register 0 (UAnCTL0)**

The UAnCTL0 register is an 8-bit register used to specify the UARTAn operation.

**(2) UARTAn control register 1 (UAnCTL1)**

The UAnCTL1 register is an 8-bit register used to select the input clock for the UARTAn.

**(3) UARTAn control register 2 (UAnCTL2)**

The UAnCTL2 register is an 8-bit register used to control the baud rate for the UARTAn.

**(4) UARTAn option control register 0 (UAnOPT0)**

The UAnOPT0 register is an 8-bit register used to control serial transfer for the UARTAn.

**(5) UARTAn status register (UAnSTR)**

The UAnSTRn register consists of flags indicating the error contents when a reception error occurs. Each one of the reception error flags is set (to 1) upon occurrence of a reception error.

<R>

**(6) UARTAn receive shift register**

This is a shift register used to convert the serial data input to the RXDAn pin into parallel data. Upon reception of 1 byte of data and detection of the stop bit, the receive data is transferred to the UAnRX register.

This register cannot be manipulated directly.

**(7) UARTAn receive data register (UAnRX)**

The UAnRX register is an 8-bit register that holds receive data. When 7 characters are received, 0 is stored in the highest bit (when data is received LSB first).

In the reception enabled status, receive data is transferred from the UARTAn receive shift register to the UAnRX register in synchronization with the completion of shift-in processing of 1 frame.

Transfer to the UAnRX register also causes the reception complete interrupt request signal (INTUAnR) to be output.

**(8) UARTAn transmit shift register**

The transmit shift register is a shift register used to convert the parallel data transferred from the UAnTX register into serial data.

When 1 byte of data is transferred from the UAnTX register, the shift register data is output from the TXDAn pin.

This register cannot be manipulated directly.

**(9) UARTAn transmit data register (UAnTX)**

The UAnTX register is an 8-bit transmit data buffer. Transmission starts when transmit data is written to the UAnTX register. When data can be written to the UAnTX register (when data of one frame is transferred from the UAnTX register to the UARTAn transmit shift register), the transmission enable interrupt request signal (INTUAnT) is generated.

15.4 Registers

(1) UARTAn control register 0 (UAnCTL0)

The UAnCTL0 register is an 8-bit register that controls the UARTAn serial transfer operation.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 10H.

(1/2)

After reset: 10H    R/W    Address: UA0CTL0 FFFFFFFA00H, UA1CTL0 FFFFFFFA10H,  
 UA2CTL0 FFFFFFFA20H, UA3CTL0 FFFFFFFA30H

|         |                  |                  |                  |                  |          |          |          |          |
|---------|------------------|------------------|------------------|------------------|----------|----------|----------|----------|
|         | <b>&lt;7&gt;</b> | <b>&lt;6&gt;</b> | <b>&lt;5&gt;</b> | <b>&lt;4&gt;</b> | <b>3</b> | <b>2</b> | <b>1</b> | <b>0</b> |
| UAnCTL0 | UAnPWR           | UAnTXE           | UAnRXE           | UAnDIR           | UAnPS1   | UAnPS0   | UAnCL    | UAnSL    |

(n = 0 to 3)

|   |  |
|---|--|
| <b>UAnPWR</b>   | UARTAn operation control                               |
| 0   | Disable UARTAn operation (UARTAn reset asynchronously) |
| 1   | Enable UARTAn operation                                |
| The UARTAn operation is controlled by the UAnPWR bit. The TXDAn pin output is fixed to high level by clearing the UAnPWR bit to 0 (fixed to low level if UAnOPT0.UAnTDL bit = 1). |  |

|  |                                |
|--|--------------------------------|
| <b>UAnTXE</b>  | Transmission operation enable  |
| 0  | Disable transmission operation |
| 1  | Enable transmission operation  |
| <ul style="list-style-type: none"> <li>• To start transmission, set the UAnPWR bit to 1 and then set the UAnTXE bit to 1. To stop, transmission clear the UAnTXE bit to 0 and then UAnPWR bit to 0.</li> <li>• To initialize the transmission unit, clear the UAnTXE bit to 0, wait for two cycles of the base clock, and then set the UAnTXE bit to 1 again. Otherwise, initialization may not be executed (for the base clock, see <b>15.7 (1) (a) Base clock</b>).</li> </ul> |                                |

|  |                             |
|--|-----------------------------|
| <b>UAnRXE</b>  | Reception operation enable  |
| 0  | Disable reception operation |
| 1  | Enable reception operation  |
| <ul style="list-style-type: none"> <li>• To start reception, set the UAnPWR bit to 1 and then set the UAnRXE bit to 1. To stop reception, clear the UAnRXE bit to 0 and then UAnPWR bit to 0.</li> <li>• To initialize the reception unit, clear the UAnRXE bit to 0, wait for two periods of the base clock, and then set the UAnRXE bit to 1 again. Otherwise, initialization may not be executed (for the base clock, see <b>15.7 (1) (a) Base clock</b>).</li> </ul> |                             |



| UAnDIR | Transfer direction selection |
|--------|------------------------------|
| 0      | MSB-first transfer           |
| 1      | LSB-first transfer           |

- This register can be rewritten only when the UAnPWR bit = 0 or the UAnTXE bit = the UAnRXE bit = 0.
- When transmission and reception are performed in the LIN format, set the UAnDIR bit to 1.

| UAnPS1 | UAnPS0 | Parity selection during transmission | Parity selection during reception |
|--------|--------|--------------------------------------|-----------------------------------|
| 0      | 0      | No parity output                     | Reception with no parity          |
| 0      | 1      | 0 parity output                      | Reception with 0 parity           |
| 1      | 0      | Odd parity output                    | Odd parity check                  |
| 1      | 1      | Even parity output                   | Even parity check                 |

- This register is rewritten only when the UAnPWR bit = 0 or the UAnTXE bit = the UAnRXE bit = 0.
- If "Reception with 0 parity" is selected during reception, a parity check is not performed. Therefore, the UAnSTR.UAnPE bit is not set.
- When transmission and reception are performed in the LIN format, clear the UAnPS1 and UAnPS0 bits to 00.

| UAnCL | Specification of data character length of 1 frame of transmit/receive data |
|-------|--|
| 0     | 7 bits   |
| 1     | 8 bits   |

- This register can be rewritten only when the UAnPWR bit = 0 or the UAnTXE bit = the UAnRXE bit = 0.
- When transmission and reception are performed in the LIN format, set the UAnCL bit to 1.

| UAnSL | Specification of length of stop bit for transmit data |
|-------|---|
| 0     | 1 bit   |
| 1     | 2 bits  |

This register can be rewritten only when the UAnPWR bit = 0 or the UAnTXE bit = the UAnRXE bit = 0.

**Remark** For details of parity, see 15.6.9 Parity types and operations.

**(2) UARTAn control register 1 (UAnCTL1)**

For details, see 15.7 (2) **UARTAn control register 1 (UAnCTL1)**.

**(3) UARTAn control register 2 (UAnCTL2)**

For details, see 15.7 (3) **UARTAn control register 2 (UAnCTL2)**.

**(4) UARTAn option control register 0 (UAnOPT0)**

The UAnOPT0 register is an 8-bit register that controls the serial transfer operation of the UARTAn register.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 14H.

(1/2)

After reset: 14H    R/W    Address: UA0OPT0 FFFFA03H, UA1OPT0 FFFFA13H,  
 UA2OPT0 FFFFA23H, UA3OPT0 FFFFA33H

|         |        |        |        |         |         |         |        |        |
|---------|--------|--------|--------|---------|---------|---------|--------|--------|
|         | <7>    | 6      | 5      | 4       | 3       | 2       | 1      | 0      |
| UAnOPT0 | UAnSRF | UAnSRT | UAnSTT | UAnSLS2 | UAnSLS1 | UAnSLS0 | UAnTDL | UAnRDL |

(n = 0 to 3)

|  |  |
|--|--|
| UAnSRF   | SBF reception flag   |
| 0  | When the UAnCTL0.UAnPWR bit = UAnCTL0.UAnRXE bit = 0 are set. Also upon normal end of SBF reception. |
| 1  | During SBF reception   |
| <ul style="list-style-type: none"> <li>• SBF (Sync Break Field) reception is judged during LIN communication.</li> <li>• The UAnSRF bit is held at 1 when an SBF reception error occurs, and then SBF reception is started again.</li> <li>• UAnSRF bit is a read-only bit.</li> </ul> |  |

|   |                       |
|---|-----------------------|
| UAnSRT  | SBF reception trigger |
| 0   | –                     |
| 1   | SBF reception trigger |
| <ul style="list-style-type: none"> <li>• This is the SBF reception trigger bit during LIN communication, and when read, “0” is always read. For SBF reception, set the UAnSRT bit (to 1) to enable SBF reception.</li> <li>• Set the UAnSRT bit after setting the UAnPWR bit = UAnRXE bit = 1.</li> </ul> |                       |

|  |                          |
|--|--------------------------|
| UAnSTT   | SBF transmission trigger |
| 0  | –                        |
| 1  | SBF transmission trigger |
| <ul style="list-style-type: none"> <li>• This is the SBF transmission trigger bit during LIN communication, and when read, “0” is always read.</li> <li>• Set the UAnSTT bit after setting the UAnPWR bit = UAnTXE bit = 1.</li> </ul> |                          |

**Caution** Do not set the UAnSRT and UAnSTT bits (to 1) during SBF reception (UAnSRF bit = 1).

| UAnSLS2 | UAnSLS1 | UAnSLS0 | SBF transmit length selection |
|---------|---------|---------|-------------------------------|
| 1       | 0       | 1       | 13-bit output (reset value)   |
| 1       | 1       | 0       | 14-bit output                 |
| 1       | 1       | 1       | 15-bit output                 |
| 0       | 0       | 0       | 16-bit output                 |
| 0       | 0       | 1       | 17-bit output                 |
| 0       | 1       | 0       | 18-bit output                 |
| 0       | 1       | 1       | 19-bit output                 |
| 1       | 0       | 0       | 20-bit output                 |

This register can be set when the UAnPWR bit = 0 or when the UAnTXE bit = 0.

| UAnTDL | Transmit data level bit          |
|--------|----------------------------------|
| 0      | Normal output of transfer data   |
| 1      | Inverted output of transfer data |

- The output level of the TXDAn pin can be inverted using the UAnTDL bit.
- This register can be set when the UAnPWR bit = 0 or when the UAnTXE bit = 0.

| UAnRDL | Receive data level bit          |
|--------|---------------------------------|
| 0      | Normal input of transfer data   |
| 1      | Inverted input of transfer data |

- The input level of the RXDAn pin can be inverted using the UAnRDL bit.
- This register can be set when the UAnPWR bit = 0 or the UAnRXE bit = 0.

#### (5) UARTAn status register (UAnSTR)

The UAnSTR register is an 8-bit register that displays the UARTAn transfer status and reception error contents. This register can be read or written in 8-bit or 1-bit units, but the UAnTSF bit is a read-only bit, while the UAnPE, UAnFE, and UAnOVE bits can both be read and written. However, these bits can only be cleared by writing 0; they cannot be set by writing 1 (even if 1 is written to them, the value is retained).

The initialization conditions are shown below.

| Register/Bit              | Initialization Conditions   |
|---------------------------|---|
| UAnSTR register           | <ul style="list-style-type: none"> <li>• Reset</li> <li>• UAnCTL0.UAnPWR = 0</li> </ul>   |
| UAnTSF bit                | <ul style="list-style-type: none"> <li>• UAnCTL0.UAnTXE = 0</li> </ul>                    |
| UAnPE, UAnFE, UAnOVE bits | <ul style="list-style-type: none"> <li>• 0 write</li> <li>• UAnCTL0.UAnRXE = 0</li> </ul> |

After reset: 00H R/W Address: UA0STR FFFFFFFA04H, UA1STR FFFFFFFA14H,  
 UA2STR FFFFFFFA24H, UA3STR FFFFFFFA34H

|                        |        |   |   |   |   |       |       |        |
|------------------------|--------|---|---|---|---|-------|-------|--------|
|                        | <7>    | 6 | 5 | 4 | 3 | <2>   | <1>   | <0>    |
| UAnSTR<br>(n = 0 to 3) | UAnTSF | 0 | 0 | 0 | 0 | UAnPE | UAnFE | UAnOVE |

|  |   |
|--|---|
| UAnTSF   | Transfer status flag  |
| 0  | <ul style="list-style-type: none"> <li>When the UAnPWR bit = 0 or the UAnTXE bit = 0 has been set.</li> <li>When, following transfer completion, there was no next data transfer from UAnTX register</li> </ul> |
| 1  | Write to UAnTX register   |
| <p>The UAnTSF bit is always 1 when performing continuous transmission. When initializing the transmission unit, check that the UAnTSF bit = 0 before performing initialization. The transmit data is not guaranteed when initialization is performed while the UAnTSF bit = 1.</p> |   |

|   |  |
|---|--|
| UAnPE   | Parity error flag  |
| 0   | <ul style="list-style-type: none"> <li>When the UAnPWR bit = 0 or the UAnRXE bit = 0 has been set.</li> <li>When 0 has been written</li> </ul> |
| 1   | When parity of data and parity bit do not match during reception.  |
| <ul style="list-style-type: none"> <li>The operation of the UAnPE bit is controlled by the settings of the UAnCTL0.UAnPS1 and UAnCTL0.UAnPS0 bits.</li> <li>The UAnPE bit can be read and written, but it can only be cleared by writing 0 to it, and it cannot be set by writing 1 to it. When 1 is written to this bit, the value is retained.</li> </ul> |  |

|   |   |
|---|---|
| UAnFE   | Framing error flag  |
| 0   | <ul style="list-style-type: none"> <li>When the UAnPWR bit = 0 or the UAnRXE bit = 0 has been set</li> <li>When 0 has been written</li> </ul> |
| 1   | When no stop bit is detected during reception   |
| <ul style="list-style-type: none"> <li>Only the first bit of the receive data stop bits is checked, regardless of the value of the UAnCTL0.UAnSL bit.</li> <li>The UAnFE bit can be both read and written, but it can only be cleared by writing 0 to it, and it cannot be set by writing 1 to it. When 1 is written to this bit, the value is retained.</li> </ul> |   |

|   |  |
|---|--|
| UAnOVE  | Overrun error flag   |
| 0   | <ul style="list-style-type: none"> <li>When the UAnPWR bit = 0 or the UAnRXE bit = 0 has been set.</li> <li>When 0 has been written</li> </ul> |
| 1   | When receive data has been set to the UAnRX register and the next receive operation is completed before that receive data has been read        |
| <ul style="list-style-type: none"> <li>When an overrun error occurs, the data is discarded without the next receive data being written to the receive buffer.</li> <li>The UAnOVE bit can be both read and written, but it can only be cleared by writing 0 to it. When 1 is written to this bit, the value is retained.</li> </ul> |  |

**(6) UARTAn receive data register (UAnRX)**

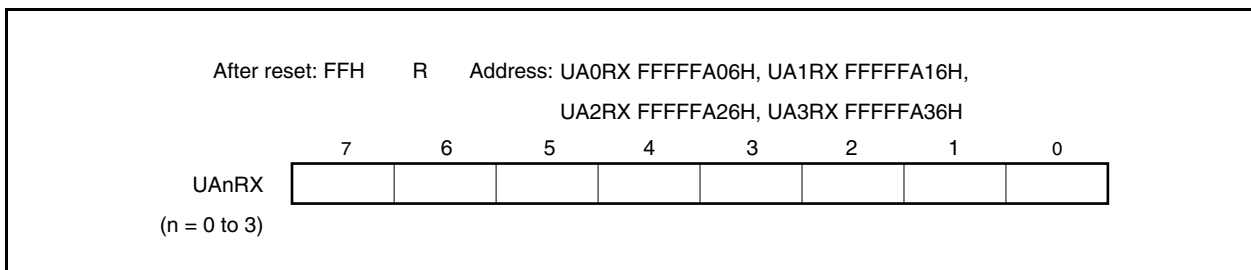
The UAnRX register is an 8-bit buffer register that stores parallel data converted by the receive shift register. The data stored in the receive shift register is transferred to the UAnRX register upon completion of reception of 1 byte of data.

During LSB-first reception when the data length has been specified as 7 bits, the receive data is transferred to bits 6 to 0 of the UAnRX register and the MSB always becomes 0. During MSB-first reception, the receive data is transferred to bits 7 to 1 of the UAnRX register and the LSB always becomes 0.

When an overrun error (UAnOVE) occurs, the receive data at this time is not transferred to the UAnRX register and is discarded.

This register is read-only, in 8-bit units.

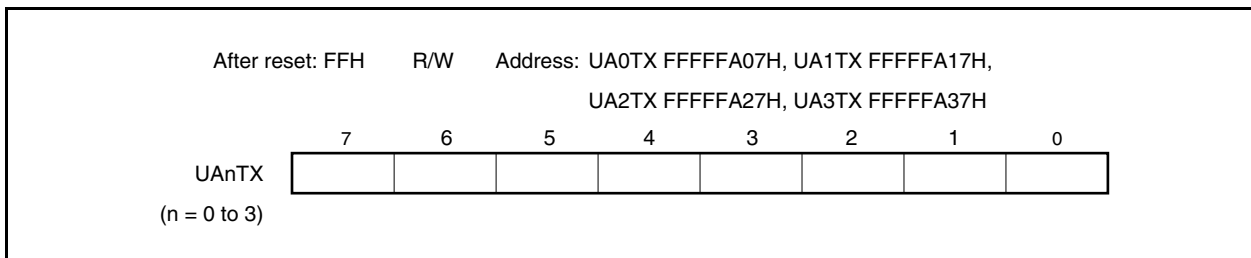
In addition to reset input, the UAnRX register can be set to FFH by clearing the UAnCTL0.UAnPWR bit to 0.

**(7) UARTAn transmit data register (UAnTX)**

The UAnTX register is an 8-bit register used to set transmit data.

This register can be read or written in 8-bit units.

Reset sets this register to FFH.



## 15.5 Interrupt Request Signals

The following two interrupt request signals are generated from UARTAn.

- Reception complete interrupt request signal (INTUAnR)
- Transmission enable interrupt request signal (INTUAnT)

The default priority for these two interrupt request signals is reception complete interrupt request signal then transmission enable interrupt request signal.

**Table 15-2. Interrupts and Their Default Priorities**

| Interrupt           | Priority |
|---------------------|----------|
| Reception complete  | High     |
| Transmission enable | Low      |

### (1) Reception complete interrupt request signal (INTUAnR)

A reception complete interrupt request signal is output when data is shifted into the receive shift register and transferred to the UAnRX register in the reception enabled status.

A reception complete interrupt request signal is also output when a reception error occurs. Therefore, when a reception complete interrupt request signal is acknowledged and the data is read, read the UAnSTR register and check that the reception result is not an error.

No reception complete interrupt request signal is generated in the reception disabled status.

### (2) Transmission enable interrupt request signal (INTUAnT)

If transmit data is transferred from the UAnTX register to the UARTAn transmit shift register with transmission enabled, the transmission enable interrupt request signal is generated.

## 15.6 Operation

### 15.6.1 Data format

Full-duplex serial data reception and transmission is performed.

As shown in Figure 15-5, one data frame of transmit/receive data consists of a start bit, character bits, parity bit, and stop bit(s).

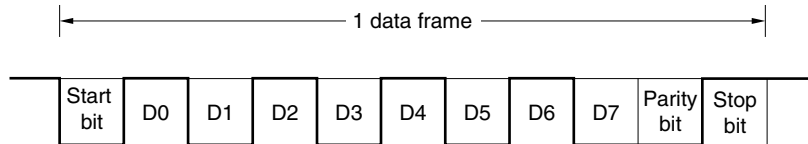
Specification of the character bit length within 1 data frame, parity selection, specification of the stop bit length, and specification of MSB/LSB-first transfer are performed using the UAnCTL0 register.

Moreover, control of UART output/inverted output for the TXDAn bit is performed using the UAnOPT0.UAnTDL bit.

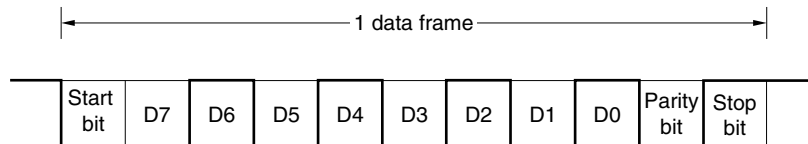
- Start bit ..... 1 bit
- Character bits..... 7 bits/8 bits
- Parity bit ..... Even parity/odd parity/0 parity/no parity
- Stop bit..... 1 bit/2 bits

Figure 15-5. UARTA Transmit/Receive Data Format

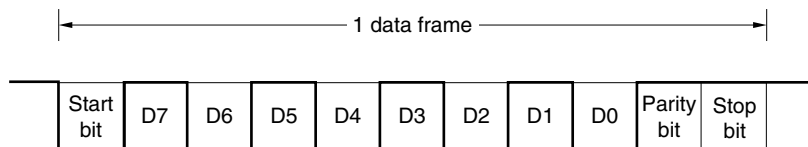
(a) 8-bit data length, LSB first, even parity, 1 stop bit, transfer data: 55H



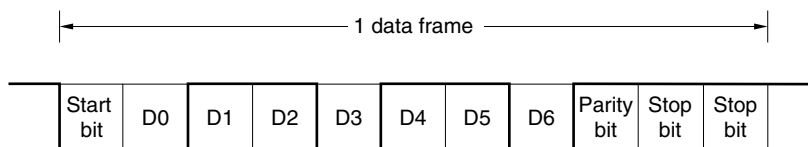
(b) 8-bit data length, MSB first, even parity, 1 stop bit, transfer data: 55H



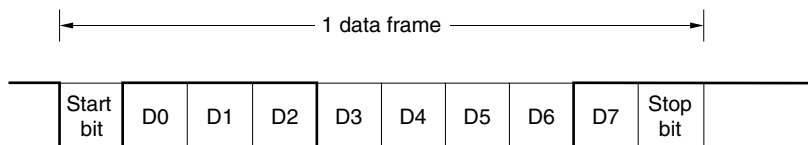
(c) 8-bit data length, MSB first, even parity, 1 stop bit, transfer data: 55H, TXDAn inversion



(d) 7-bit data length, LSB first, odd parity, 2 stop bits, transfer data: 36H



(e) 8-bit data length, LSB first, no parity, 1 stop bit, transfer data: 87H





### 15.6.2 SBF transmission/reception format

The V850ES/JJ3 has an SBF (Sync Break Field) transmission/reception control function to enable use of the LIN function.

**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 15-6 and 15-7 outline the transmission and reception manipulations of LIN.

**Figure 15-6. LIN Transmission Manipulation Outline**

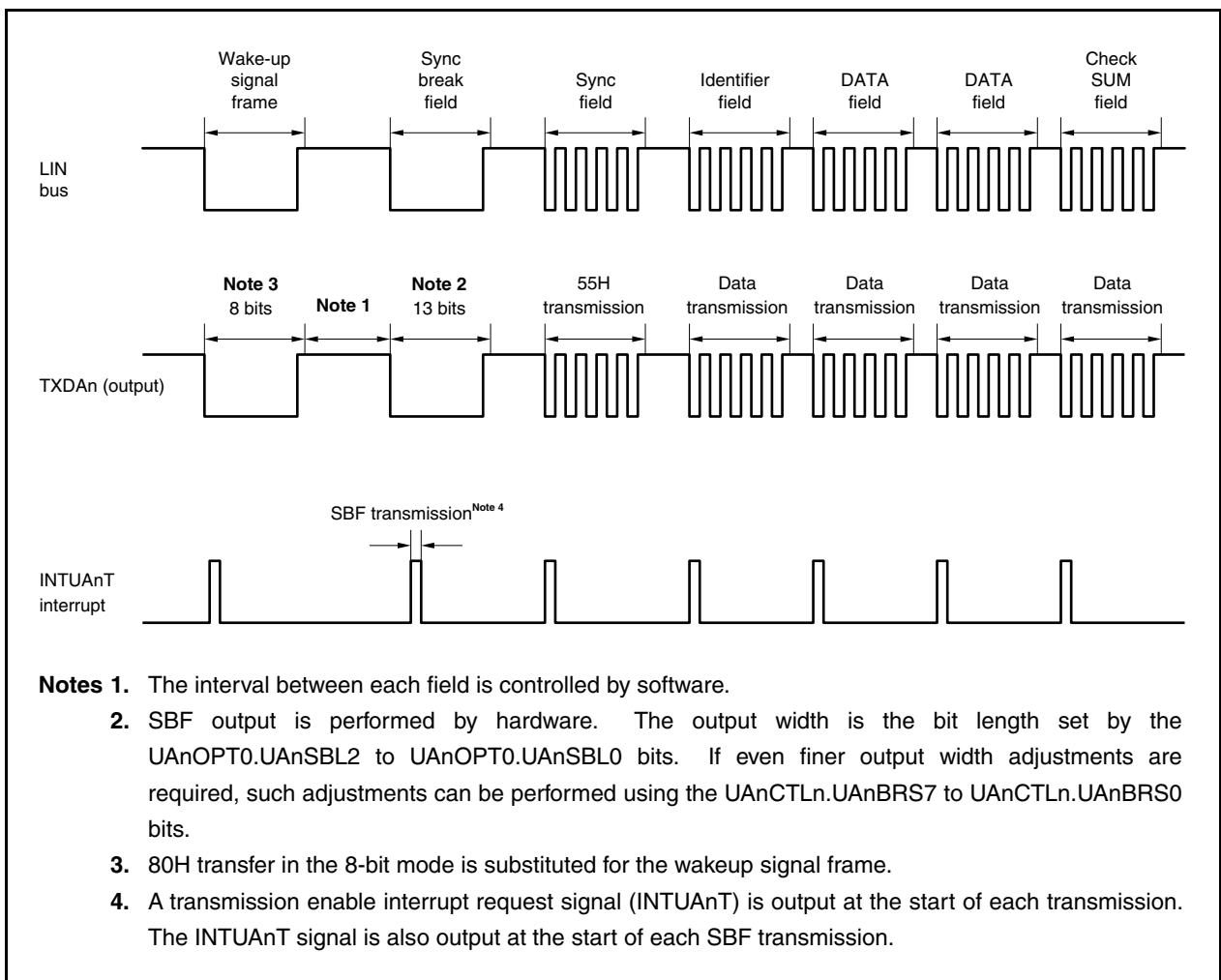
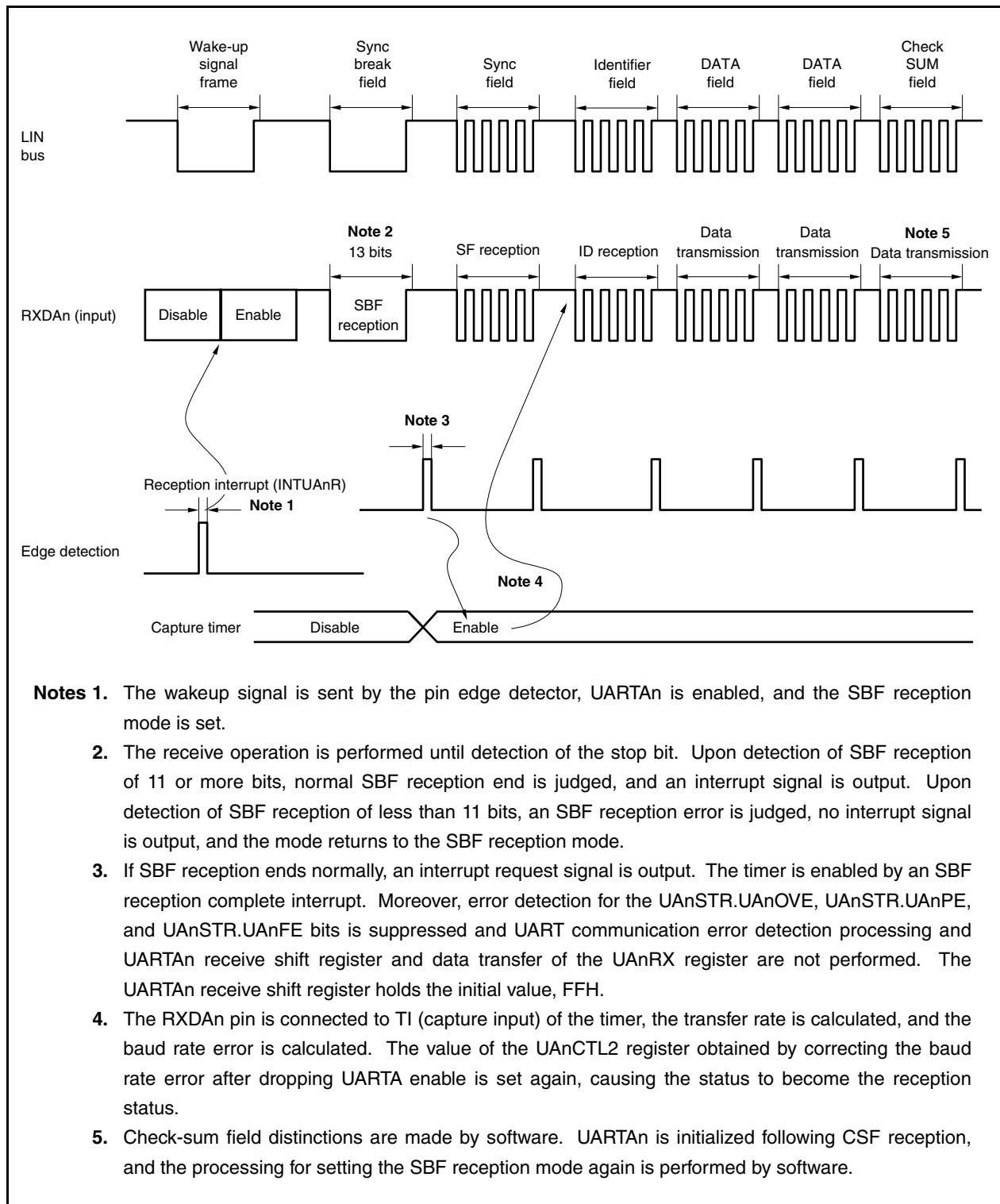


Figure 15-7. LIN Reception Manipulation Outline



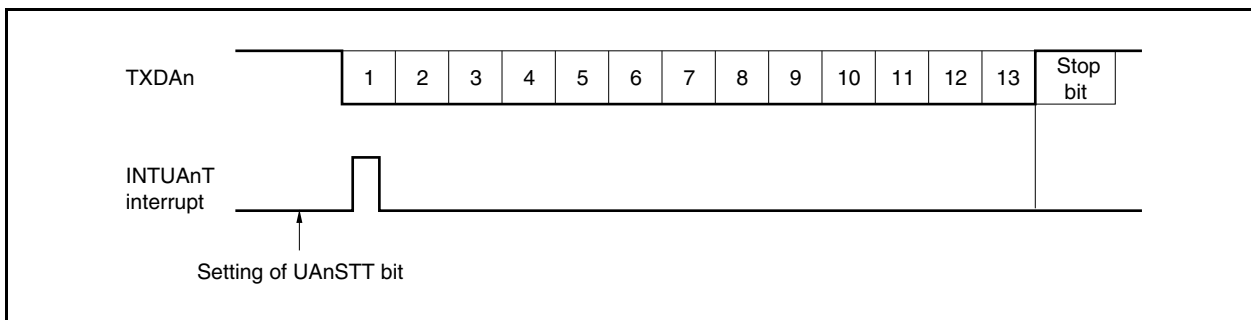
### 15.6.3 SBF transmission

When the UAnCTL0.UAnPWR bit = UAnCTL0.UAnTXE bit = 1, the transmission enabled status is entered, and SBF transmission is started by setting (to 1) the SBF transmission trigger (UAnOPT0.UAnSTT bit).

Thereafter, a low level the width of bits 13 to 20 specified by the UAnOPT0.UAnSLS2 to UAnOPT0.UAnSLS0 bits is output. A transmission enable interrupt request signal (INTUAnT) is generated upon SBF transmission start. Following the end of SBF transmission, the UAnSTT bit is automatically cleared. Thereafter, the UART transmission mode is restored.

Transmission is suspended until the data to be transmitted next is written to the UAnTX register, or until the SBF transmission trigger (UAnSTT bit) is set.

Figure 15-8. SBF Transmission



### 15.6.4 SBF reception

The reception enabled status is achieved by setting the UAnCTL0.UAnPWR bit to 1 and then setting the UAnCTL0.UAnRXE bit to 1.

The SBF reception wait status is set by setting the SBF reception trigger (UAnOPT0.UAnSTR bit) to 1.

In the SBF reception wait status, similarly to the UART reception wait status, the RXDAn pin is monitored and start bit detection is performed.

Following detection of the start bit, reception is started and the internal counter counts up according to the set baud rate.

When a stop bit is received, if the SBF width is 11 or more bits, normal processing is judged and a reception complete interrupt request signal (INTUAnR) is output. The UAnOPT0.UAnSRF bit is automatically cleared and SBF reception ends. Error detection for the UAnSTR.UAnOVE, UAnSTR.UAnPE, and UAnSTR.UAnFE bits is suppressed and UART communication error detection processing is not performed. Moreover, data transfer of the UARTAn reception shift register and UAnRX register is not performed and FFH, the initial value, is held. If the SBF width is 10 or fewer bits, reception is terminated as error processing without outputting an interrupt, and the SBF reception mode is returned to. The UAnSRF bit is not cleared at this time.

- Cautions**
1. If SBF is transmitted during a data reception, a framing error occurs.
  2. Do not set the SBF reception trigger bit (UAnSRT) and SBF transmission trigger bit (UAnSTT) to 1 during an SBF reception (UAnSRF = 1).

Figure 15-9. SBF Reception (1/2)

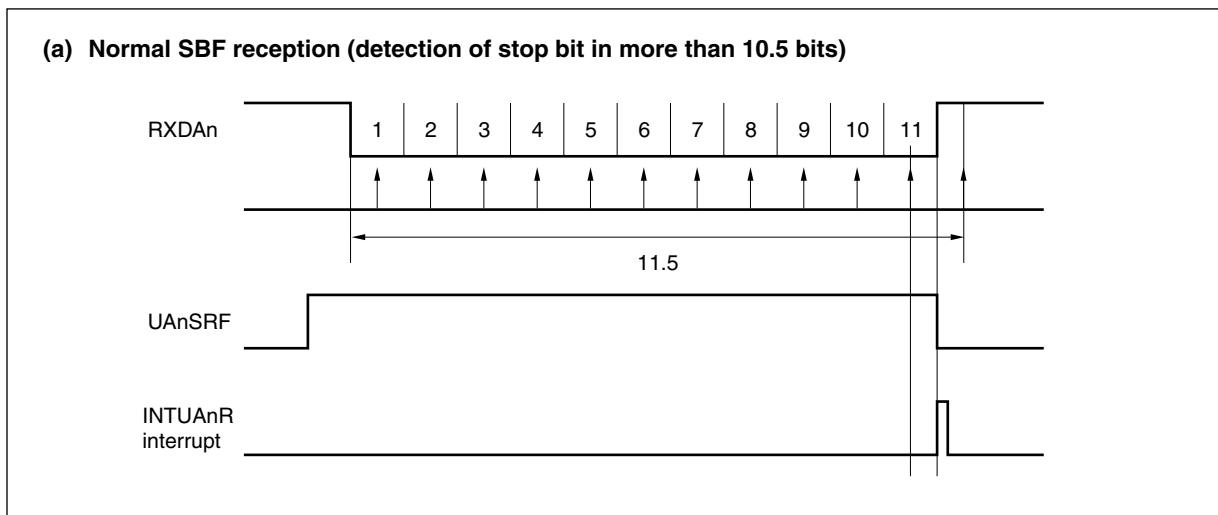
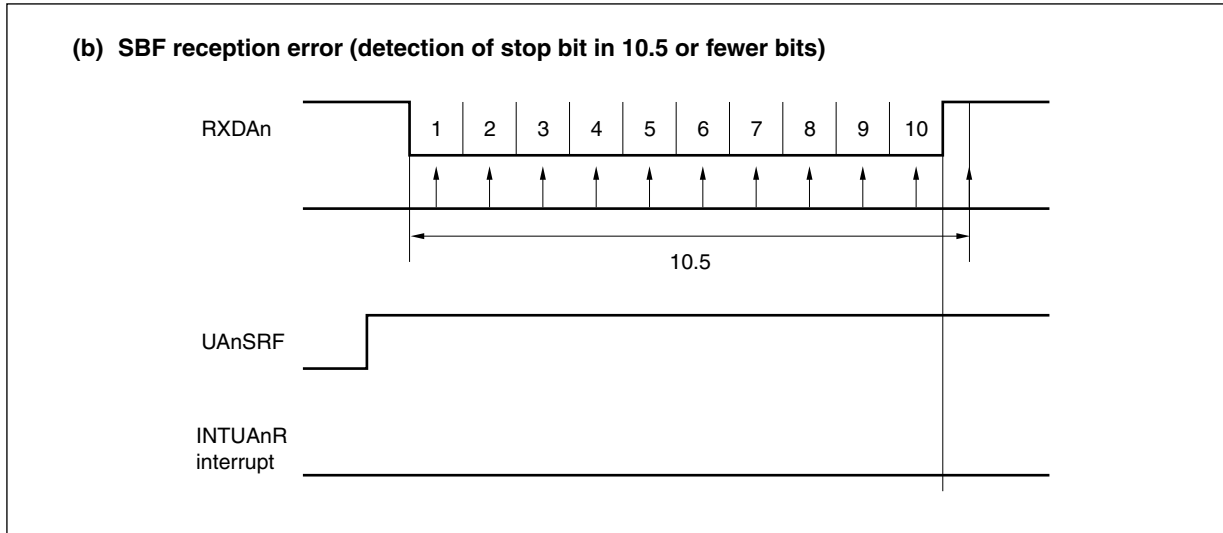


Figure 15-9. SBF Reception (2/2)



**15.6.5 UART transmission**

A high level is output to the TXDAn pin by setting the UAnCTL0.UAnPWR bit to 1.

Next, the transmission enabled status is set by setting the UAnCTL0.UAnTXE bit to 1, and transmission is started by writing transmit data to the UAnTX register. The start bit, parity bit, and stop bit are automatically added.

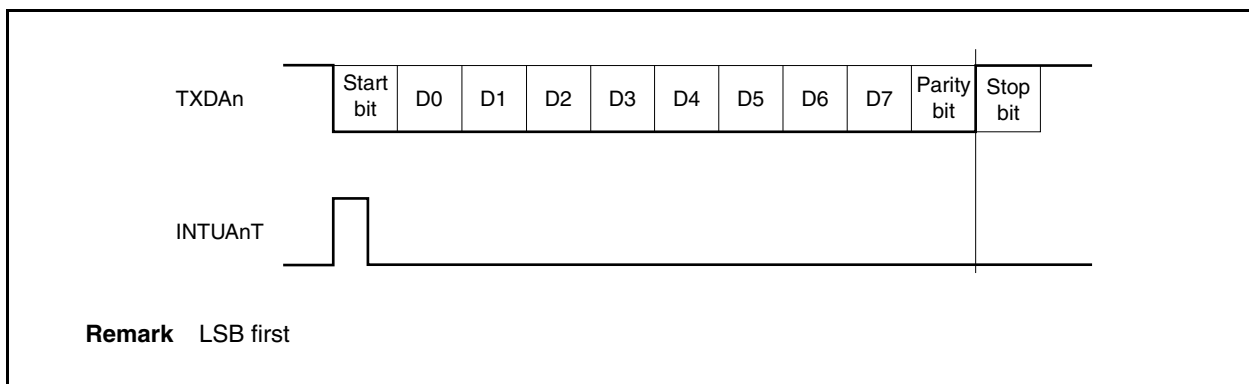
Since the CTS (transmit enable signal) input pin is not provided in UARTAn, use a port to check that reception is enabled at the transmit destination.

The data in the UAnTX register is transferred to the UARTAn transmit shift register upon the start of the transmit operation.

A transmission enable interrupt request signal (INTUAnT) is generated upon completion of transmission of the data of the UAnTX register to the UARTAn transmit shift register, and thereafter the contents of the UARTAn transmit shift register are output to the TXDAn pin.

Write of the next transmit data to the UAnTX register is enabled after the INTUAnT signal is generated.

**Figure 15-10. UART Transmission**



### 15.6.6 Continuous transmission procedure

UARTAn can write the next transmit data to the UAnTX register when the UARTAn transmit shift register starts the shift operation. The transmit timing of the UARTAn transmit shift register can be judged from the transmission enable interrupt request signal (INTUAnT).

An efficient communication rate is realized by writing the data to be transmitted next to the UAnTX register during transfer.

**Caution** When initializing transmissions during the execution of continuous transmissions, make sure that the UAnSTR.UAnTSF bit is 0, then perform the initialization. Transmit data that is initialized when the UAnTSF bit is 1 cannot be guaranteed.

Figure 15-11. Continuous Transmission Processing Flow

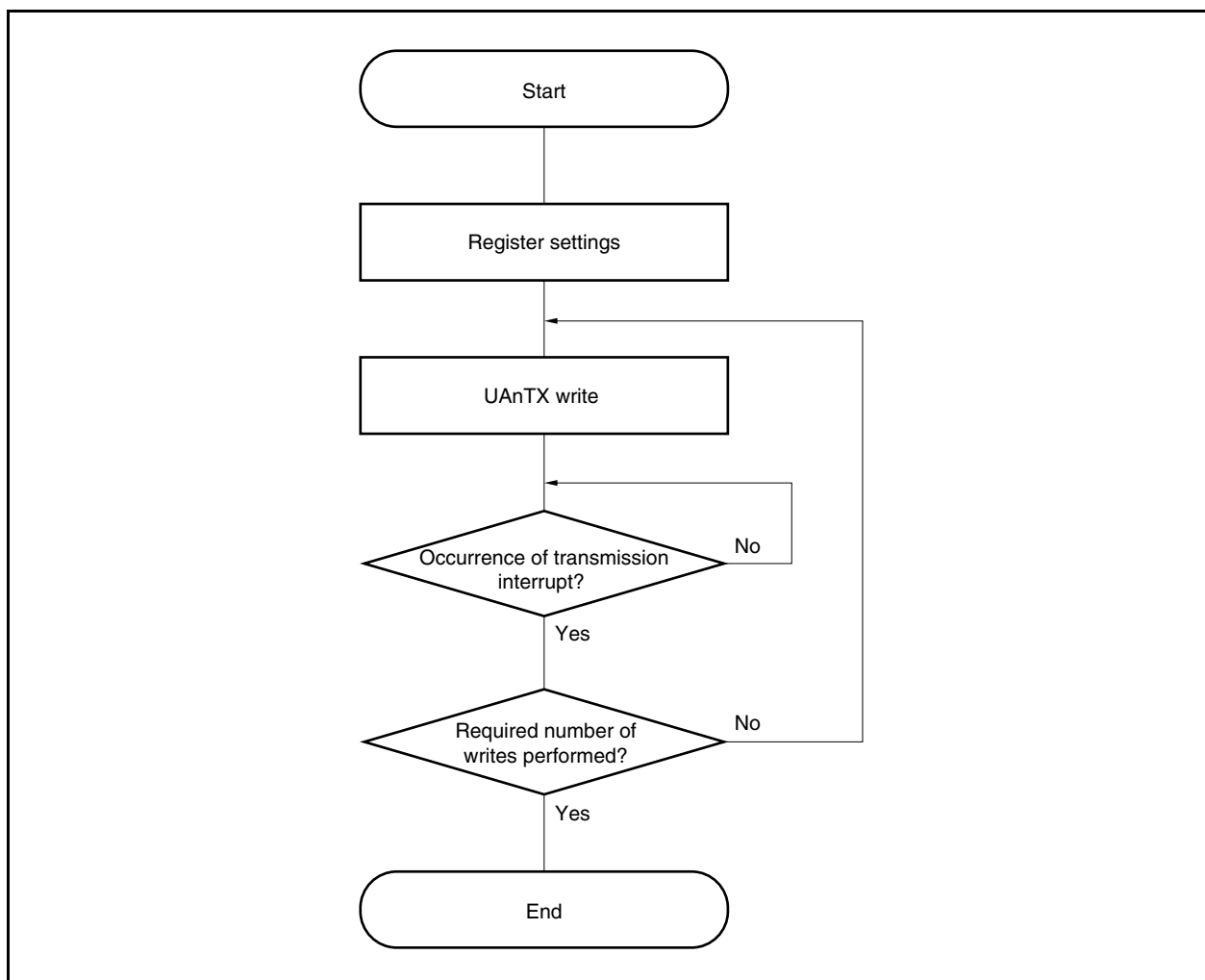
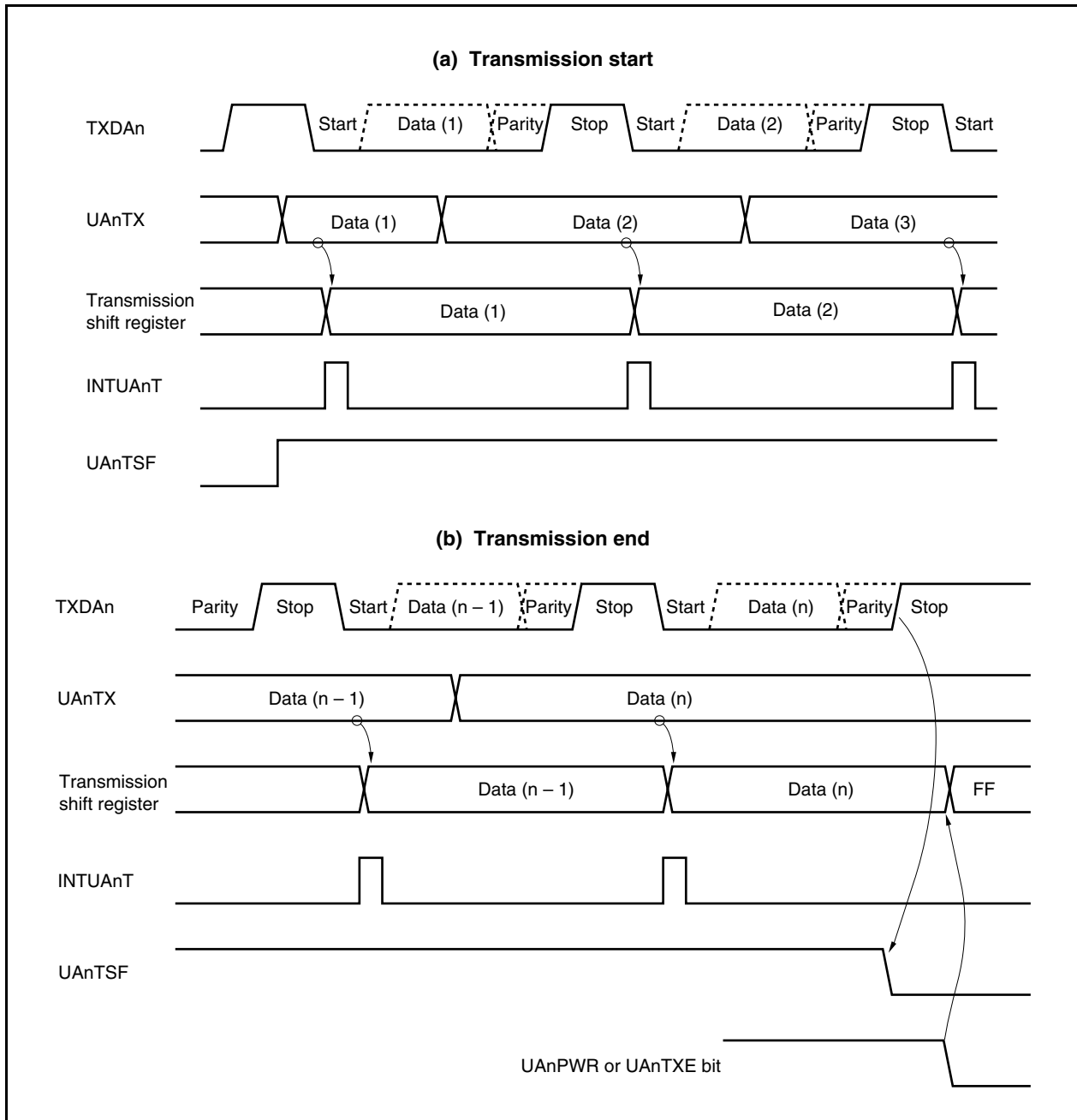


Figure 15-12. Continuous Transmission Operation Timing





### 15.6.7 UART reception

The reception wait status is set by setting the UAnCTL0.UAnPWR bit to 1 and then setting the UAnCTL0.UAnRXE bit to 1. In the reception wait status, the RXDAn pin is monitored and start bit detection is performed.

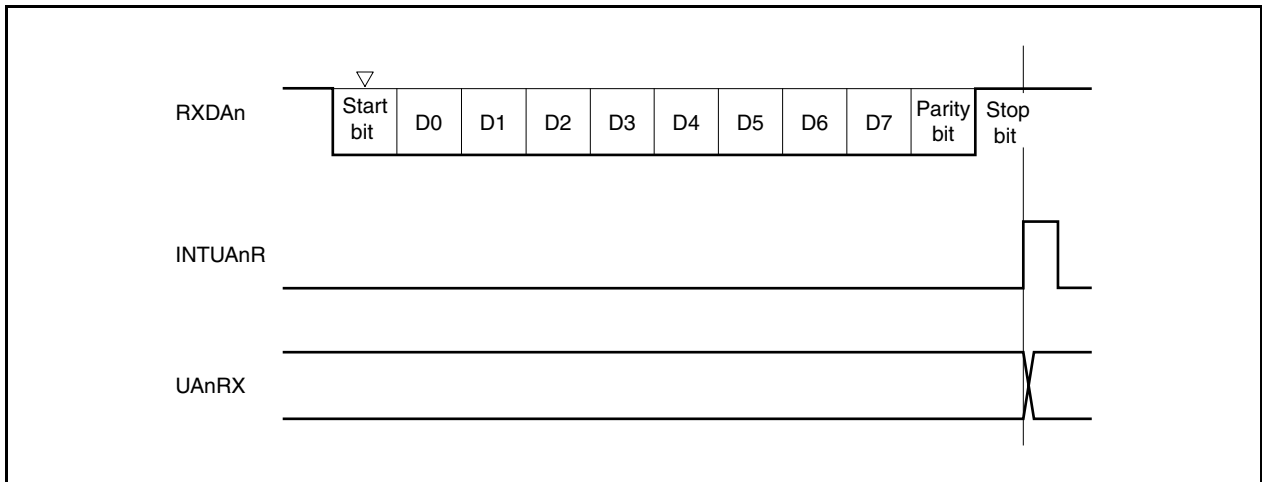
Start bit detection is performed using a two-step detection routine.

First the rising edge of the RXDAn pin is detected and sampling is started at the falling edge. The start bit is recognized if the RXDAn pin is low level at the start bit sampling point. After a start bit has been recognized, the receive operation starts, and serial data is saved to the UAnRX receive shift register according to the set baud rate.

When the reception complete interrupt request signal (INTUAnR) is output upon reception of the stop bit, the data of the UAnRX receive shift register is written to the UAnRX register. However, if an overrun error (UAnSTR.UAnOVE bit) occurs, the receive data at this time is not written to the UAnRX register and is discarded.

Even if a parity error (UAnSTR.UAnPE bit) or a framing error (UAnSTR.UAnFE bit) occurs during reception, reception continues until the reception position of the first stop bit, and INTUAnR is output following reception completion.

Figure 15-13. UART Reception



- Cautions**
1. Be sure to read the UAnRX register even when a reception error occurs. If the UAnRX register is not read, an overrun error occurs during reception of the next data, and reception errors continue occurring indefinitely.
  2. The operation during reception is performed assuming that there is only one stop bit. A second stop bit is ignored.
  3. When reception is completed, read the UAnRX register after the reception complete interrupt request signal (INTUAnR) has been generated, and clear the UAnPWR or UAnRXE bit to 0. If the UAnPWR or UAnRXE bit is cleared to 0 before the INTUAnR signal is generated, the read value of the UAnRX register cannot be guaranteed.
  4. If receive completion processing (INTUAnR signal generation) of UARTAn and the UAnPWR bit = 0 or UAnRXE bit = 0 conflict, the INTUAnR signal may be generated in spite of these being no data stored in the UAnRX register.

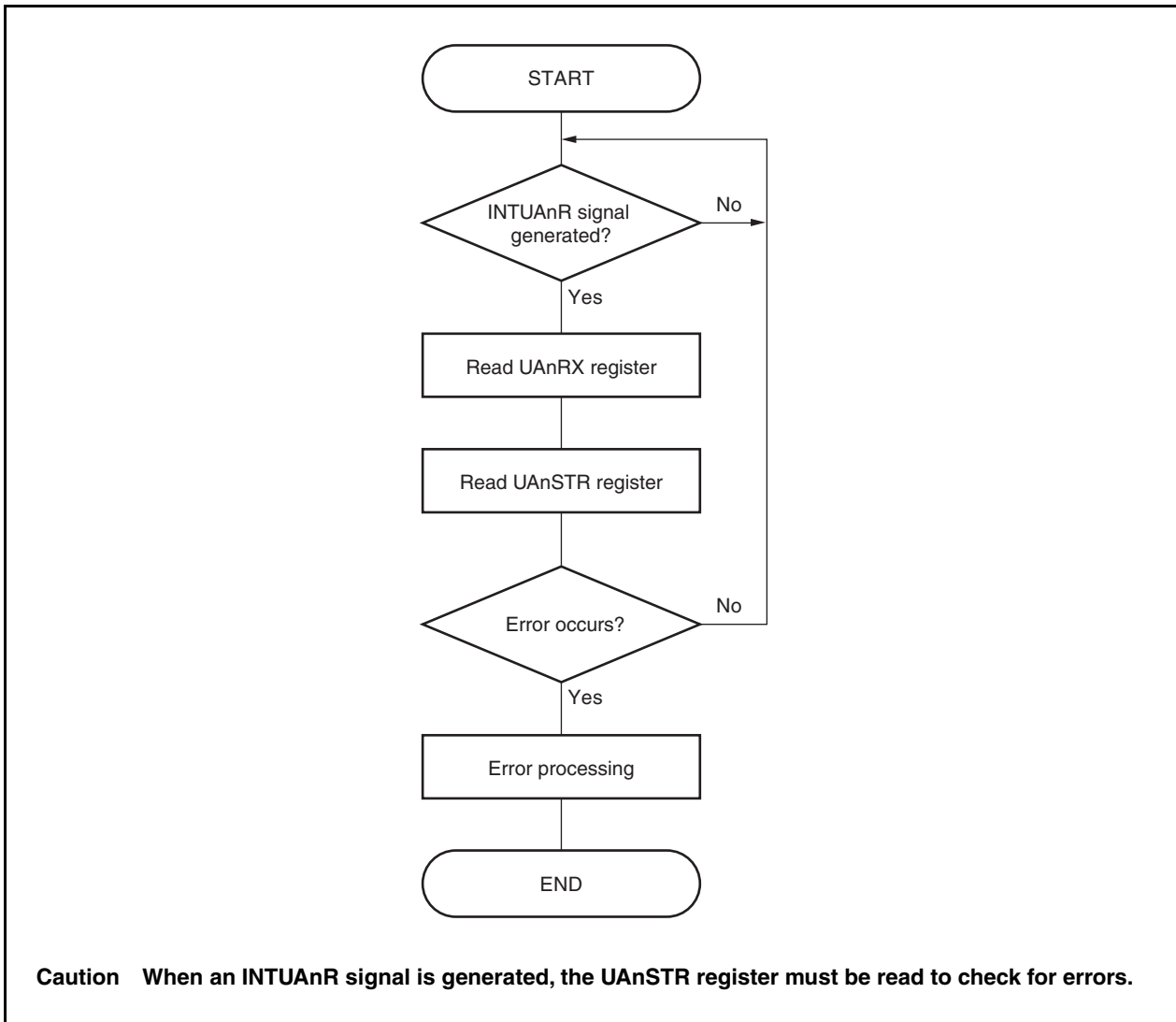
To complete reception without waiting INTUAnR signal generation, be sure to clear (0) the interrupt request flag (UAnRIF) of the UAnRIC register, after setting (1) the interrupt mask flag (UAnRMK) of the interrupt control register (UAnRIC) and then set (1) the UAnPWR bit = 0 or UAnRXE bit = 0.

**15.6.8 Reception errors**

Errors during a receive operation are of three types: parity errors, framing errors, and overrun errors. Data reception result error flags are set in the UAnSTR register and a reception complete interrupt request signal (INTUAnR) is output when an error occurs.

It is possible to ascertain which error occurred during reception by reading the contents of the UAnSTR register. Clear the reception error flag by writing 0 to it after reading it.

- Receive data read flow



- Reception error causes

| Error Flag | Reception Error | Cause   |
|------------|-----------------|---|
| UAnPE      | Parity error    | Received parity bit does not match the setting                            |
| UAnFE      | Framing error   | Stop bit not detected   |
| UAnOVE     | Overrun error   | Reception of next data completed before data was read from receive buffer |

When reception errors occur, perform the following procedures depending upon the kind of error.

- Parity error  
If false data is received due to problems such as noise in the reception line, discard the received data and retransmit.
- Framing error  
A baud rate error may have occurred between the reception side and transmission side or the start bit may have been erroneously detected. Since this is a fatal error for the communication format, check the operation stop in the transmission side, perform initialization processing each other, and then start the communication again.
- Overrun error  
Since the next reception is completed before reading receive data, 1 frame of data is discarded. If this data was needed, do a retransmission.

**Caution** If a receive error interrupt occurs during continuous reception, read the contents of the UAnSTR register must be read before the next reception is completed, then perform error processing.

### 15.6.9 Parity types and operations

**Caution** When using the LIN function, fix the UAnPS1 and UAnPS0 bits of the UAnCTL0 register to 00.

The parity bit is used to detect bit errors in the communication data. Normally the same parity is used on the transmission side and the reception side.

In the case of even parity and odd parity, it is possible to detect odd-count bit errors. In the case of 0 parity and no parity, errors cannot be detected.

#### (a) Even parity

##### (i) During transmission

The number of bits whose value is "1" among the transmit data, including the parity bit, is controlled so as to be an even number. The parity bit values are as follows.

- Odd number of bits whose value is "1" among transmit data: 1
- Even number of bits whose value is "1" among transmit data: 0

##### (ii) During reception

The number of bits whose value is "1" among the reception data, including the parity bit, is counted, and if it is an odd number, a parity error is output.

#### (b) Odd parity

##### (i) During transmission

Opposite to even parity, the number of bits whose value is "1" among the transmit data, including the parity bit, is controlled so that it is an odd number. The parity bit values are as follows.

- Odd number of bits whose value is "1" among transmit data: 0
- Even number of bits whose value is "1" among transmit data: 1

##### (ii) During reception

The number of bits whose value is "1" among the receive data, including the parity bit, is counted, and if it is an even number, a parity error is output.

#### (c) 0 parity

During transmission, the parity bit is always made 0, regardless of the transmit data.

During reception, parity bit check is not performed. Therefore, no parity error occurs, regardless of whether the parity bit is 0 or 1.

#### (d) No parity

No parity bit is added to the transmit data.

Reception is performed assuming that there is no parity bit. No parity error occurs since there is no parity bit.

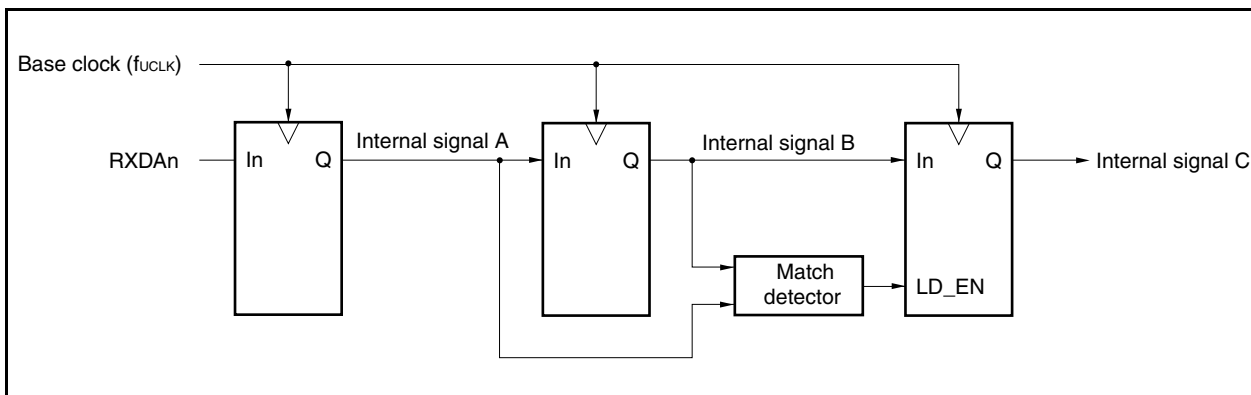
**15.6.10 Receive data noise filter**

This filter samples the RXDAn pin using the base clock of the prescaler output.

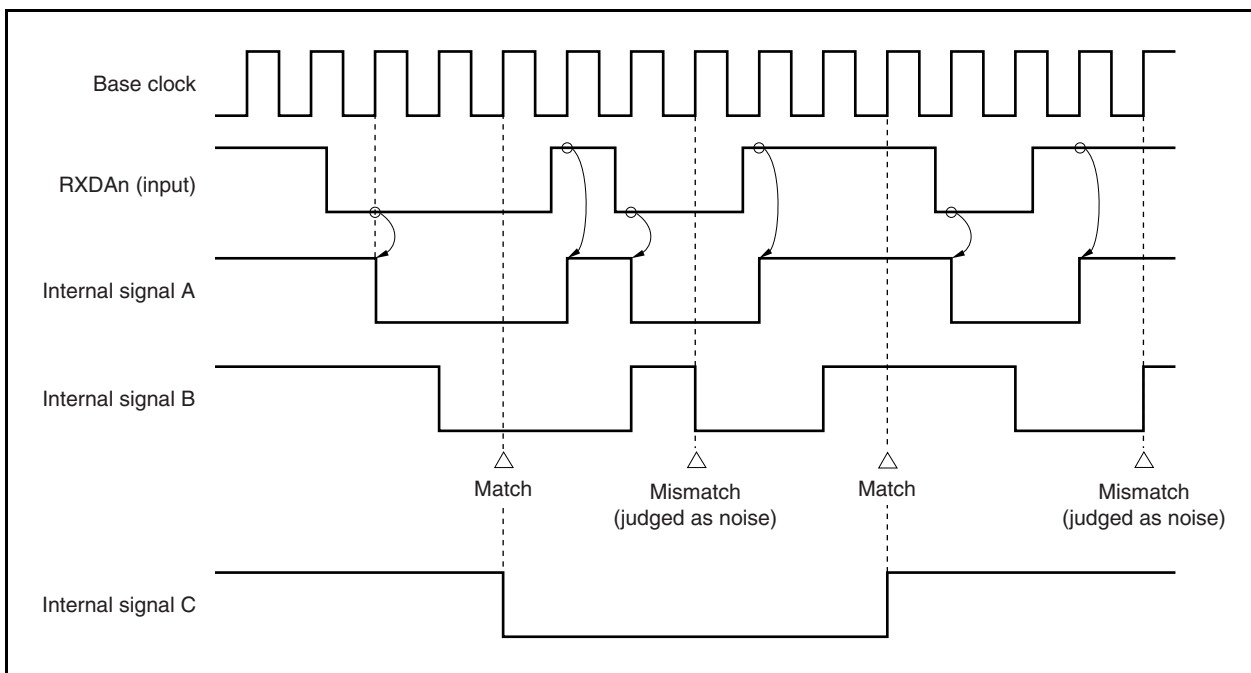
When the same sampling value is read twice, the match detector output changes and the RXDAn signal is sampled as the input data. Therefore, data not exceeding 2 clock width is judged to be noise and is not delivered to the internal circuit (see **Figure 15-15**). See **15.7 (1) (a) Base clock** regarding the base clock.

Moreover, since the circuit is as shown in Figure 15-14, the processing that goes on within the receive operation is delayed by 3 clocks in relation to the external signal status.

**Figure 15-14. Noise Filter Circuit**



**Figure 15-15. Timing of RXDAn Signal Judged as Noise**



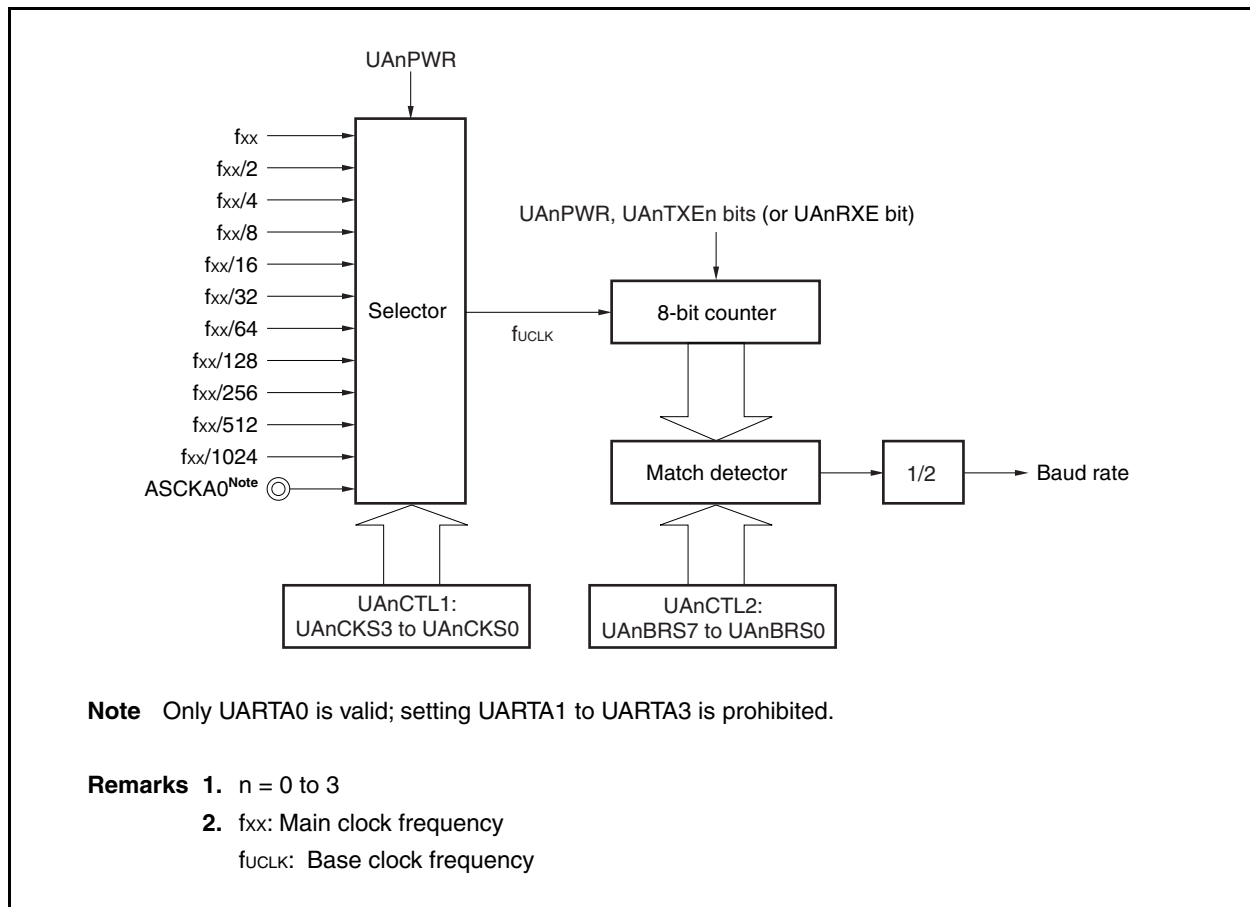
## 15.7 Dedicated Baud Rate Generator

The dedicated baud rate generator consists of a source clock selector block and an 8-bit programmable counter, and generates a serial clock during transmission and reception with UARTAn. Regarding the serial clock, a dedicated baud rate generator output can be selected for each channel.

There is an 8-bit counter for transmission and another one for reception.

### (1) Baud rate generator configuration

Figure 15-16. Configuration of Baud Rate Generator



#### (a) Base clock

When the UAnCTL0.UAnPWR bit is 1, the clock selected by the UAnCTL1.UAnCKS3 to UAnCTL1.UAnCKS0 bits is supplied to the 8-bit counter. This clock is called the base clock ( $f_{UCLK}$ ).

#### (b) Serial clock generation

A serial clock can be generated by setting the UAnCTL1 register and the UAnCTL2 register ( $n = 0$  to 3).

The base clock is selected by UAnCTL1.UAnCKS3 to UAnCTL1.UAnCKS0 bits.

The frequency division value for the 8-bit counter can be set using the UAnCTL2.UAnBRS7 to UAnCTL2.UAnBRS0 bits.

**(2) UARTAn control register 1 (UAnCTL1)**

The UAnCTL1 register is an 8-bit register that selects the UARTAn base clock.

This register can be read or written in 8-bit units.

Reset sets this register to 00H.

**Caution** Clear the UAnCTL0.UAnPWR bit to 0 before rewriting the UAnCTL1 register.

After reset: 00H    R/W    Address: UA0CTL1 FFFFFFFA01H, UA1CTL1 FFFFFFFA11H,  
UA2CTL1 FFFFFFFA21H, UA3CTL1 FFFFFFFA31H

|                         |   |   |   |   |         |         |         |         |
|-------------------------|---|---|---|---|---------|---------|---------|---------|
|                         | 7 | 6 | 5 | 4 | 3       | 2       | 1       | 0       |
| UAnCTL1<br>(n = 0 to 3) | 0 | 0 | 0 | 0 | UAnCKS3 | UAnCKS2 | UAnCKS1 | UAnCKS0 |

| UAnCKS3          | UAnCKS2 | UAnCKS1 | UAnCKS0 | Base clock (f <sub>CLK</sub> ) selection    |
|------------------|---------|---------|---------|---|
| 0                | 0       | 0       | 0       | fxx   |
| 0                | 0       | 0       | 1       | fxx/2                                       |
| 0                | 0       | 1       | 0       | fxx/4                                       |
| 0                | 0       | 1       | 1       | fxx/8                                       |
| 0                | 1       | 0       | 0       | fxx/16                                      |
| 0                | 1       | 0       | 1       | fxx/32                                      |
| 0                | 1       | 1       | 0       | fxx/64                                      |
| 0                | 1       | 1       | 1       | fxx/128                                     |
| 1                | 0       | 0       | 0       | fxx/256                                     |
| 1                | 0       | 0       | 1       | fxx/512                                     |
| 1                | 0       | 1       | 0       | fxx/1,024                                   |
| 1                | 0       | 1       | 1       | External clock <sup>Note</sup> (ASCKA0 pin) |
| Other than above |         |         |         | Setting prohibited                          |

**Note** Only UARTA0 is valid; setting UARTA1 to UARTA3 is prohibited.

**Remark** fxx: Main clock frequency

**(3) UARTAn control register 2 (UAnCTL2)**

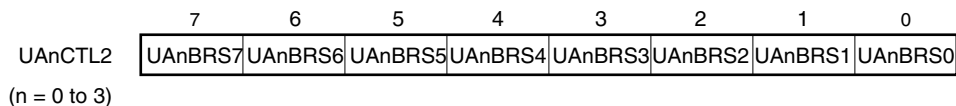
The UAnCTL2 register is an 8-bit register that selects the baud rate (serial transfer speed) clock of UARTAn.

This register can be read or written in 8-bit units.

Reset sets this register to FFH.

**Caution** Clear the UAnCTL0.UAnPWR bit to 0 or clear the UAnTXE and UAnRXE bits to 00 before rewriting the UAnCTL2 register.

After reset FFH R/W Address: UA0CTL2 FFFFA02H, UA1CTL2 FFFFA12H,  
UA2CTL2 FFFFA22H, UA3CTL2 FFFFA32H



| UAn BRS7 | UAn BRS6 | UAn BRS5 | UAn BRS4 | UAn BRS3 | UAn BRS2 | UAn BRS1 | UAn BRS0 | Default (k) | Serial clock           |
|----------|----------|----------|----------|----------|----------|----------|----------|-------------|------------------------|
| 0        | 0        | 0        | 0        | 0        | 0        | ×        | ×        | ×           | Setting prohibited     |
| 0        | 0        | 0        | 0        | 0        | 1        | 0        | 0        | 4           | f <sub>uclk</sub> /4   |
| 0        | 0        | 0        | 0        | 0        | 1        | 0        | 1        | 5           | f <sub>uclk</sub> /5   |
| 0        | 0        | 0        | 0        | 0        | 1        | 1        | 0        | 6           | f <sub>uclk</sub> /6   |
| :        | :        | :        | :        | :        | :        | :        | :        | :           | :                      |
| 1        | 1        | 1        | 1        | 1        | 1        | 0        | 0        | 252         | f <sub>uclk</sub> /252 |
| 1        | 1        | 1        | 1        | 1        | 1        | 0        | 1        | 253         | f <sub>uclk</sub> /253 |
| 1        | 1        | 1        | 1        | 1        | 1        | 1        | 0        | 254         | f <sub>uclk</sub> /254 |
| 1        | 1        | 1        | 1        | 1        | 1        | 1        | 1        | 255         | f <sub>uclk</sub> /255 |

**Remark** f<sub>uclk</sub>: Clock frequency selected by the UAnCTL1.UAnCKS3 to UAnCTL1.UAnCKS0 bits



**(4) Baud rate**

The baud rate is obtained by the following equation.

$$\text{Baud rate} = \frac{f_{\text{UCLK}}}{2 \times k} \text{ [bps]}$$

When using the internal clock, the equation will be as follows (when using the ASCKA0 pin as clock at UARTA0, calculate using the above equation).

$$\text{Baud rate} = \frac{f_{\text{XX}}}{2^{m+1} \times k} \text{ [bps]}$$

**Remark**  $f_{\text{UCLK}}$  = Frequency of base clock selected by the UAnCTL1.UAnCKS3 to UAnCTL1.UAnCKS0 bits  
 $f_{\text{XX}}$ : Main clock frequency  
 $m$  = Value set using the UAnCTL1.UAnCKS3 to UAnCTL1.UAnCKS0 bits ( $m = 0$  to  $10$ )  
 $k$  = Value set using the UAnCTL2.UAnBRS7 to UAnCTL2.UAnBRS0 bits ( $k = 4$  to  $255$ )

The baud rate error is obtained by the following equation.

$$\begin{aligned} \text{Error (\%)} &= \left( \frac{\text{Actual baud rate (baud rate with error)}}{\text{Target baud rate (correct baud rate)}} - 1 \right) \times 100 \text{ [\%]} \\ &= \left( \frac{f_{\text{UCLK}}}{2 \times k \times \text{Target baud rate}} - 1 \right) \times 100 \text{ [\%]} \end{aligned}$$

When using the internal clock, the equation will be as follows (when using the ASCKA0 pin as clock at UARTA0, calculate the baud rate error using the above equation).

$$\text{Error (\%)} = \left( \frac{f_{\text{XX}}}{2^{m+1} \times k \times \text{Target baud rate}} - 1 \right) \times 100 \text{ [\%]}$$

- Cautions**
1. The baud rate error during transmission must be within the error tolerance on the receiving side.
  2. The baud rate error during reception must satisfy the range indicated in (5) Allowable baud rate range during reception.

To set the baud rate, perform the following calculation for setting the UAnCTL1 and UAnCTL2 registers (when using internal clock).

- <1> Set k to  $f_{xx}/(2 \times \text{target baud rate})$  and m to 0.
- <2> If k is 256 or greater ( $k \geq 256$ ), reduce k to half ( $k/2$ ) and increment m by 1 ( $m + 1$ ).
- <3> Repeat Step <2> until k becomes less than 256 ( $k < 256$ ).
- <4> Round off the first decimal point of k to the nearest whole number.  
If k becomes 256 after round-off, perform Step <2> again to set k to 128.
- <5> Set the value of m to UAnCTL1 register and the value of k to the UAnCTL2 register.

**Example:** When  $f_{xx} = 32 \text{ MHz}$  and target baud rate = 153,600 bps

<1>  $k = 32,000,000/(2 \times 153,600) = 104.16\dots$ ,  $m = 0$

<2>, <3>  $k = 104.16\dots < 256$ ,  $m = 0$

<4> Set value of UAnCTL2 register:  $k = 104 = 68\text{H}$ , set value of UAnCTL1 register:  $m = 0$

Actual baud rate =  $32,000,000/(2 \times 104)$   
= 153,846 [bps]

Baud rate error =  $\{32,000,000/(2 \times 104 \times 153,600) - 1\} \times 100$   
= 0.160 [%]

The representative examples of baud rate settings are shown below.

**Table 15-3. Baud Rate Generator Setting Data**

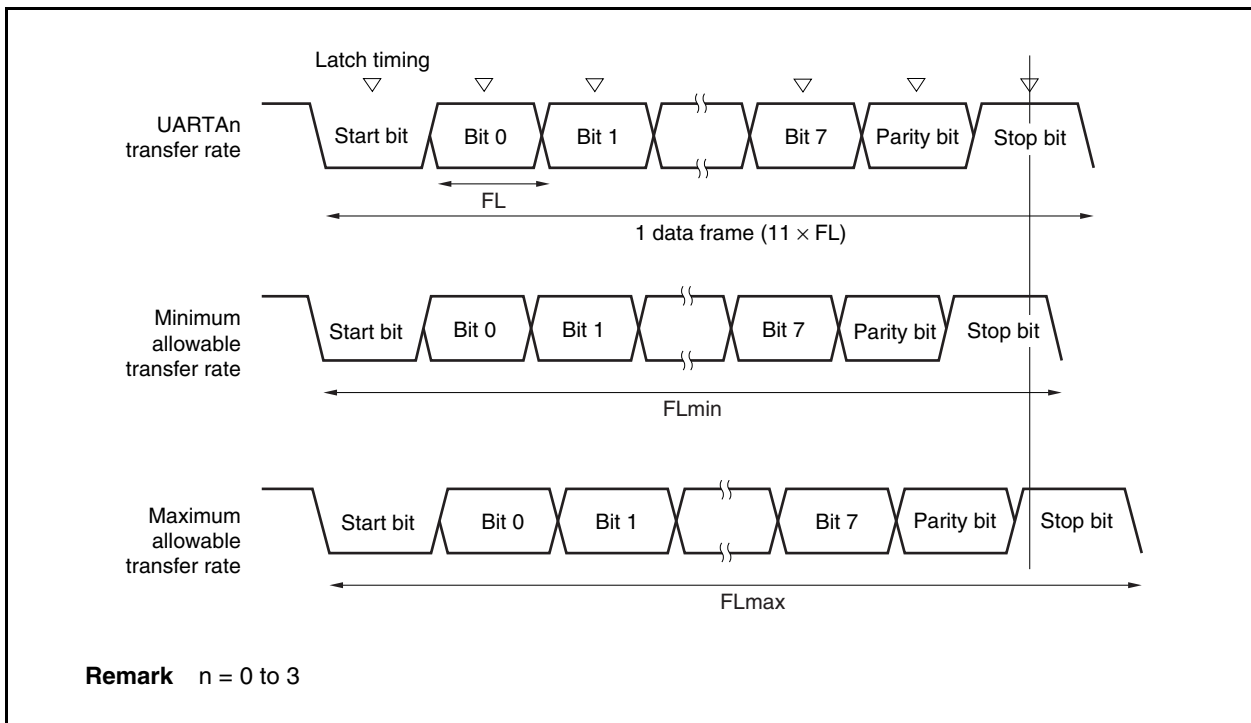
| Baud Rate<br>(bps) | $f_{xx} = 32 \text{ MHz}$ |         |         | $f_{xx} = 20 \text{ MHz}$ |         |         | $f_{xx} = 10 \text{ MHz}$ |         |         |
|--------------------|---------------------------|---------|---------|---------------------------|---------|---------|---------------------------|---------|---------|
|                    | UAnCTL1                   | UAnCTL2 | ERR (%) | UAnCTL1                   | UAnCTL2 | ERR (%) | UAnCTL1                   | UAnCTL2 | ERR (%) |
| 300                | 08H                       | D0H     | 0.16    | 08H                       | 82H     | 0.16    | 07H                       | 82H     | 0.16    |
| 600                | 07H                       | D0H     | 0.16    | 07H                       | 82H     | 0.16    | 06H                       | 82H     | 0.16    |
| 1,200              | 06H                       | D0H     | 0.16    | 06H                       | 82H     | 0.16    | 05H                       | 82H     | 0.16    |
| 2,400              | 05H                       | D0H     | 0.16    | 05H                       | 82H     | 0.16    | 04H                       | 82H     | 0.16    |
| 4,800              | 04H                       | D0H     | 0.16    | 04H                       | 82H     | 0.16    | 03H                       | 82H     | 0.16    |
| 9,600              | 03H                       | D0H     | 0.16    | 03H                       | 82H     | 0.16    | 02H                       | 82H     | 0.16    |
| 19,200             | 02H                       | D0H     | 0.16    | 02H                       | 82H     | 0.16    | 01H                       | 82H     | 0.16    |
| 31,250             | 02H                       | 80H     | 0.00    | 01H                       | A0H     | 0.00    | 00H                       | A0H     | 0.00    |
| 38,400             | 01H                       | D0H     | 0.16    | 01H                       | 82H     | 0.16    | 00H                       | 82H     | 0.16    |
| 76,800             | 00H                       | D0H     | 0.16    | 00H                       | 82H     | 0.16    | 00H                       | 41H     | 0.16    |
| 153,600            | 00H                       | 68H     | 0.16    | 00H                       | 41H     | 0.16    | 00H                       | 21H     | -1.36   |
| 312,500            | 00H                       | 33H     | 0.39    | 00H                       | 20H     | 0.00    | 00H                       | 10H     | 0.00    |
| 625,000            | 00H                       | 1AH     | 1.54    | 00H                       | 10H     | 0.00    | 00H                       | 08H     | 0.00    |

**Remark**  $f_{xx}$ : Main clock frequency  
ERR: Baud rate error (%)

**(5) Allowable baud rate range during reception**

The baud rate error range at the destination that is allowable during reception is shown below.

**Caution** The baud rate error during reception must be set within the allowable error range using the following equation.

**Figure 15-17. Allowable Baud Rate Range During Reception**


As shown in Figure 15-17, the receive data latch timing is determined by the counter set using the UAnCTL2 register following start bit detection. The transmit data can be normally received if up to the last data (stop bit) can be received in time for this latch timing.

When this is applied to 11-bit reception, the following is the theoretical result.

$$FL = (\text{Brate})^{-1}$$

Brate: UARTAn baud rate ( $n = 0$  to  $3$ )

k: Setting value of UAnCTL2.UAnBRS7 to UAnCTL2.UAnBRS0 bits ( $n = 0$  to  $3$ )

FL: 1-bit data length

Latch timing margin: 2 clocks

$$\text{Minimum allowable transfer rate: } FL_{\min} = 11 \times FL - \frac{k-2}{2k} \times FL = \frac{21k+2}{2k} FL$$

Therefore, the maximum baud rate that can be received by the destination is as follows.

$$BR_{max} = (FL_{min}/11)^{-1} = \frac{22k}{21k + 2} \text{ Brate}$$

Similarly, obtaining the following maximum allowable transfer rate yields the following.

$$\frac{10}{11} \times FL_{max} = 11 \times FL - \frac{k + 2}{2 \times k} \times FL = \frac{21k - 2}{2 \times k} FL$$

$$FL_{max} = \frac{21k - 2}{20k} FL \times 11$$

Therefore, the minimum baud rate that can be received by the destination is as follows.

$$BR_{min} = (FL_{max}/11)^{-1} = \frac{20k}{21k - 2} \text{ Brate}$$

Obtaining the allowable baud rate error for UARTA and the destination from the above-described equations for obtaining the minimum and maximum baud rate values yields the following.

**Table 15-4. Maximum/Minimum Allowable Baud Rate Error**

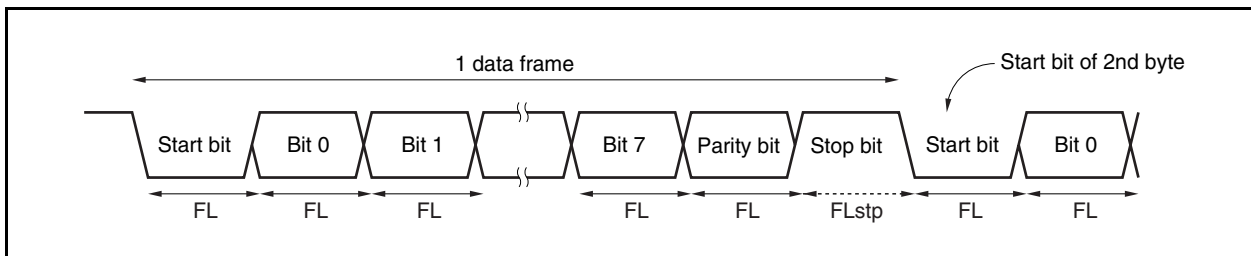
| Division Ratio (k) | Maximum Allowable Baud Rate Error | Minimum Allowable Baud Rate Error |
|--------------------|-----------------------------------|-----------------------------------|
| 4                  | +2.32%                            | -2.43%                            |
| 8                  | +3.52%                            | -3.61%                            |
| 20                 | +4.26%                            | -4.30%                            |
| 50                 | +4.56%                            | -4.58%                            |
| 100                | +4.66%                            | -4.67%                            |
| 255                | +4.72%                            | -4.72%                            |

- Remarks 1.** The reception accuracy depends on the bit count in 1 frame, the input clock frequency, and the division ratio (k). The higher the input clock frequency and the larger the division ratio (k), the higher the accuracy.
- 2.** k: Setting value of UAnCTL2.UAnBRS7 to UAnCTL2.UAnBRS0 bits (n = 0 to 3)

**(6) Baud rate during continuous transmission**

During continuous transmission, the transfer rate from the stop bit to the next start bit is usually 2 base clocks longer. However, timing initialization is performed via start bit detection by the receiving side, so this has no influence on the transfer result.

**Figure 15-18. Transfer Rate During Continuous Transfer**



Assuming 1 bit data length: FL; stop bit length: FLstp; and base clock frequency:  $f_{\text{UCLK}}$ , we obtain the following equation.

$$\text{FLstp} = \text{FL} + 2/f_{\text{UCLK}}$$

Therefore, the transfer rate during continuous transmission is as follows.

$$\text{Transfer rate} = 11 \times \text{FL} + (2/f_{\text{UCLK}})$$

## 15.8 Cautions

- (1) When the clock supply to UARTAn is stopped (for example, in IDLE1, IDLE2, or STOP mode), the operation stops with each register retaining the value it had immediately before the clock supply was stopped. The TXDAn pin output also holds and outputs the value it had immediately before the clock supply was stopped. However, the operation is not guaranteed after the clock supply is resumed. Therefore, after the clock supply is resumed, the circuits should be initialized by setting the UAnCTL0.UAnPWR, UAnCTL0.UAnRXEn, and UAnCTL0.UAnTXEn bits to 000.
- (2) The RXDA1 and KR7 pins must not be used at the same time. To use the RXDA1 pin, do not use the KR7 pin. To use the KR7 pin, do not use the RXDA1 pin (it is recommended to set the PFC91 bit to 1 and clear PFCE91 bit to 0).
- (3) In UARTAn, the interrupt caused by a communication error does not occur. When performing the transfer of transmit data and receive data using DMA transfer, error processing cannot be performed even if errors (parity, overrun, framing) occur during transfer. Either read the UAnSTR register after DMA transfer has been completed to make sure that there are no errors, or read the UAnSTR register during communication to check for errors.
- (4) Start up the UARTAn in the following sequence.
  - <1> Set the UAnCTL0.UAnPWR bit to 1.
  - <2> Set the ports.
  - <3> Set the UAnCTL0.UAnTXE bit to 1, UAnCTL0.UAnRXE bit to 1.
- (5) Stop the UARTAn in the following sequence.
  - <1> Set the UAnCTL0.UAnTXE bit to 0, UAnCTL0.UAnRXE bit to 0.
  - <2> Set the ports and set the UAnCTL0.UAnPWR bit to 0 (it is not a problem if port setting is not changed).
- (6) In transmit mode (UAnCTL0.UAnPWR bit = 1 and UAnCTL0.UAnTXE bit = 1), do not overwrite the same value to the UAnTX register by software because transmission starts by writing to this register. To transmit the same value continuously, overwrite the same value.
- (7) In continuous transmission, the communication rate from the stop bit to the next start bit is extended 2 base clocks more than usual. However, the reception side initializes the timing by detecting the start bit, so the reception result is not affected.

## CHAPTER 16 3-WIRE VARIABLE-LENGTH SERIAL I/O (CSIB)

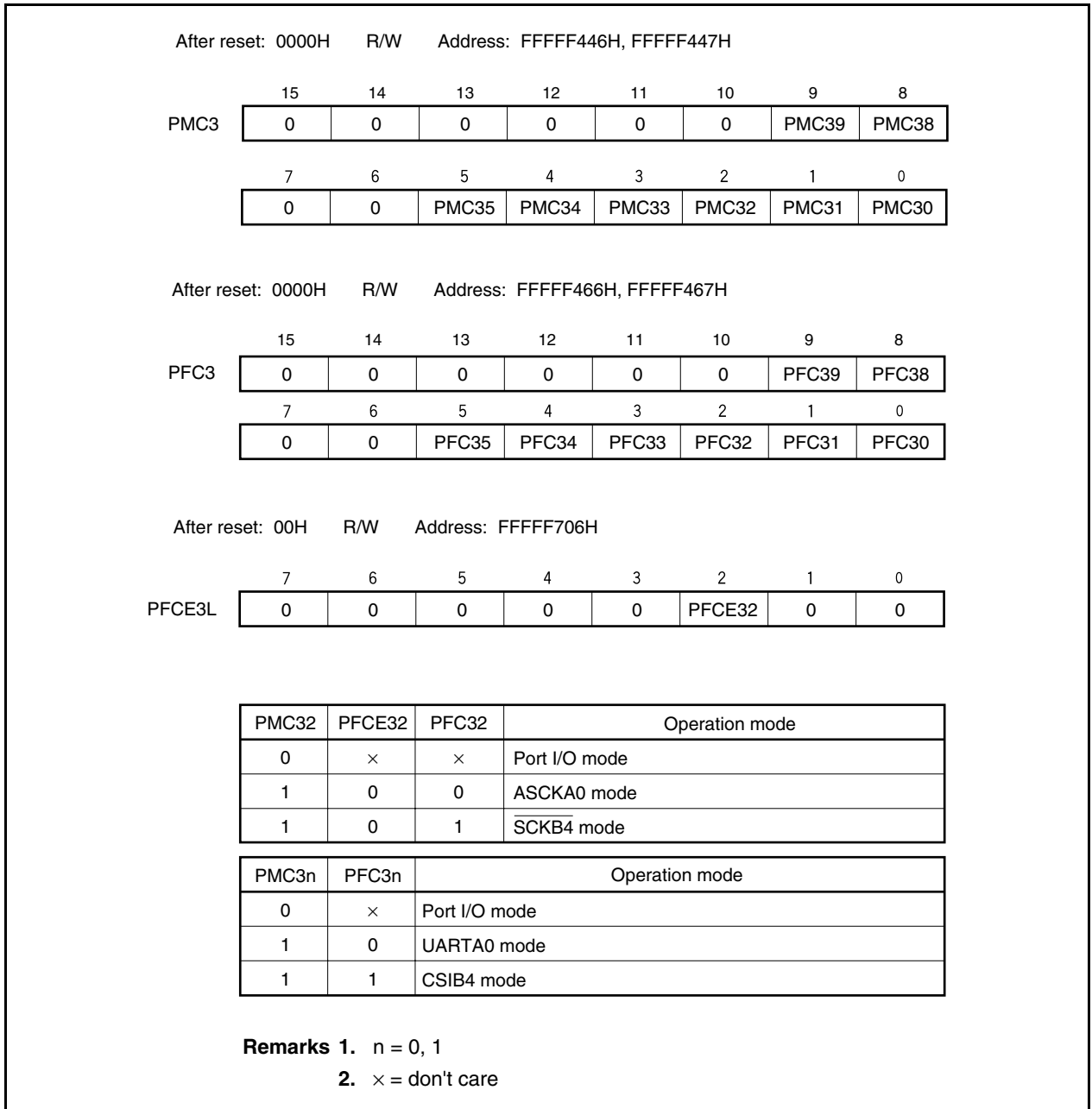
### 16.1 Mode Switching of CSIB and Other Serial Interfaces

#### 16.1.1 CSIB4 and UARTA0 mode switching

In the V850ES/JJ3, CSIB4 and UARTA0 are alternate functions of the same pin and therefore cannot be used simultaneously. Set CSIB4, in advance, using the PMC3 and PFC3 registers, before use.

**Caution** The transmit/receive operation of CSIB4 and UARTA0 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.

**Figure 16-1. CSIB4 and UARTA0 Mode Switch Settings**

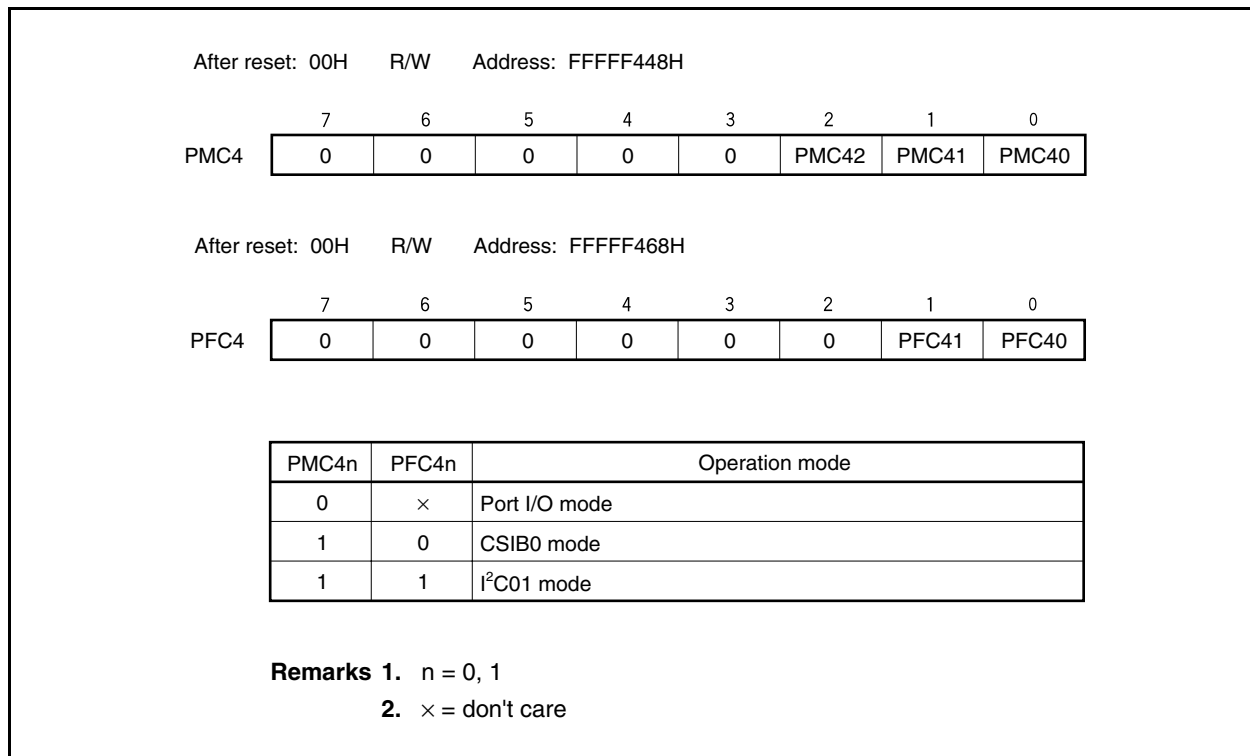


16.1.2 CSIB0 and I<sup>2</sup>C01 mode switching

In the V850ES/JJ3, CSIB0 and I<sup>2</sup>C01 are alternate functions of the same pin and therefore cannot be used simultaneously. Set CSIB0 in advance, using the PMC4 and PFC4 registers, before use.

**Caution** The transmit/receive operation of CSIB0 and I<sup>2</sup>C01 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.

Figure 16-2. CSIB0 and I<sup>2</sup>C01 Mode Switch Settings



16.2 Features

- Transfer rate: 8 Mbps (f<sub>xx</sub> = 32 MHz, using internal clock)
  - Master mode and slave mode selectable
  - 8-bit to 16-bit transfer, 3-wire serial interface
  - Interrupt request signals (INTCBnT, INTCBnR) × 2
  - Serial clock and data phase switchable
  - Transfer data length selectable in 1-bit units between 8 and 16 bits
  - Transfer data MSB-first/LSB-first switchable
  - 3-wire transfer
    - SOBn: Serial data output
    - SIBn: Serial data input
    - $\overline{SCKBn}$ : Serial clock I/O
- Transmission mode, reception mode, and transmission/reception mode specifiable

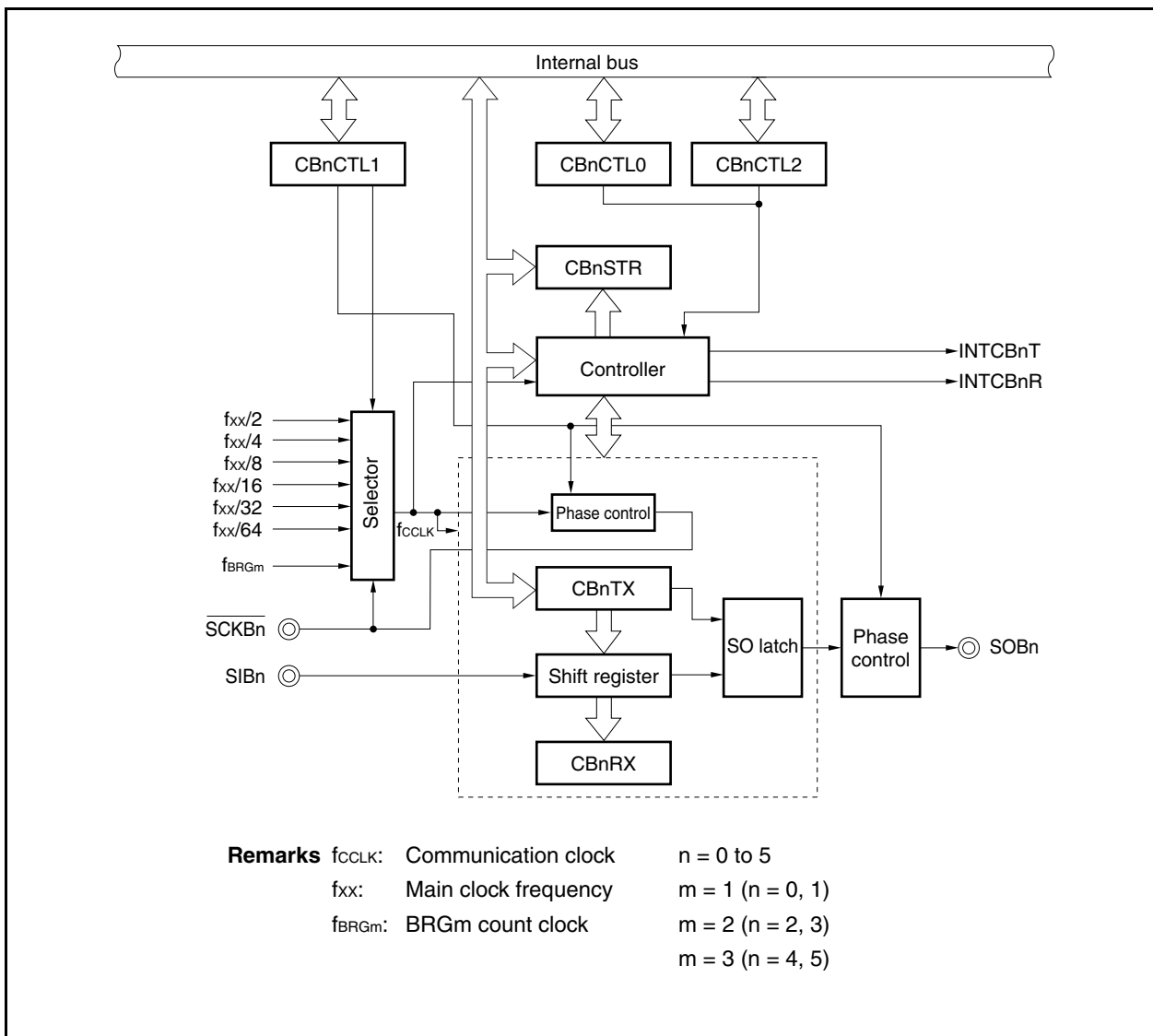
**Remark** n = 0 to 5



### 16.3 Configuration

The following shows the block diagram of CSIBn.

Figure 16-3. Block Diagram of CSIBn



CSIBn includes the following hardware.

Table 16-1. Configuration of CSIBn

| Item              | Configuration  |
|-------------------|--|
| Registers         | CSIBn receive data register (CBnRX)<br>CSIBn transmit data register (CBnTX)  |
| Control registers | CSIBn control register 0 (CBnCTL0)<br>CSIBn control register 1 (CBnCTL1)<br>CSIBn control register 2 (CBnCTL2)<br>CSIBn status register (CBnSTR) |

**(1) CSIBn receive data register (CBnRX)**

The CBnRX register is a 16-bit buffer register that holds receive data.

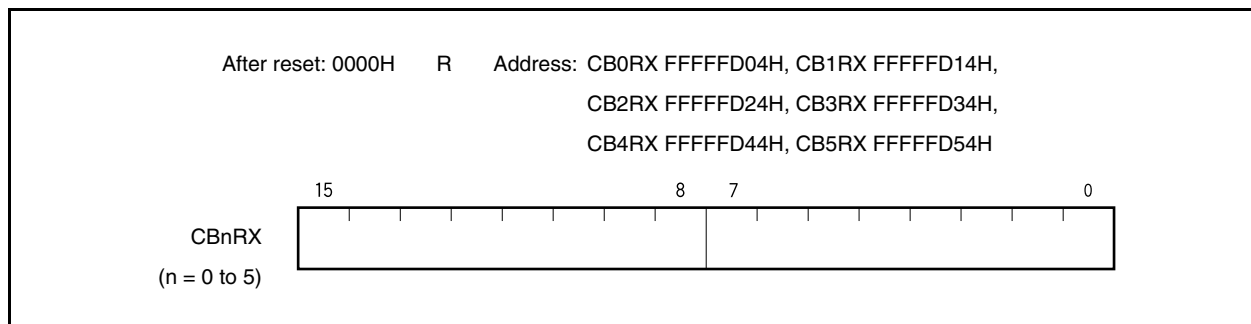
This register is read-only, in 16-bit units.

The receive operation is started by reading the CBnRX register in the reception enabled status.

If the transfer data length is 8 bits, the lower 8 bits of this register are read-only in 8-bit units as the CBnRXL register.

Reset sets this register to 0000H.

In addition to reset input, the CBnRX register can be initialized by clearing (to 0) the CBnPWR bit of the CBnCTL0 register.



**(2) CSIBn transmit data register (CBnTX)**

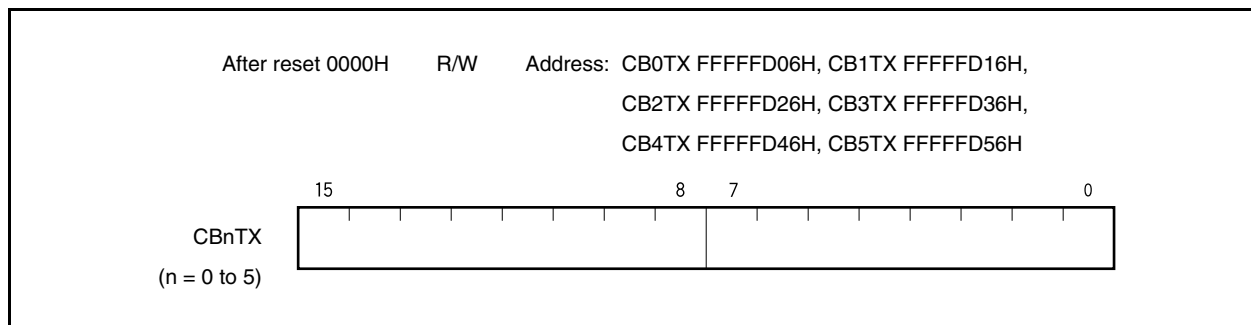
The CBnTX register is a 16-bit buffer register used to write the CSIBn transfer data.

This register can be read or written in 16-bit units.

The transmit operation is started by writing data to the CBnTX register in the transmission enabled status.

If the transfer data length is 8 bits, the lower 8 bits of this register are read-only in 8-bit units as the CBnTXL register.

Reset sets this register to 0000H.



**Remark** The communication start conditions are shown below.

- Transmission mode (CBnTXE bit = 1, CBnRXE bit = 0):                      Write to CBnTX register
- Transmission/reception mode (CBnTXE bit = 1, CBnRXE bit = 1): Write to CBnTX register
- Reception mode (CBnTXE bit = 0, CBnRXE bit = 1):                      Read from CBnRX register

## 16.4 Registers

The following registers are used to control CSIBn.

- CSIBn control register 0 (CBnCTL0)
- CSIBn control register 1 (CBnCTL1)
- CSIBn control register 2 (CBnCTL2)
- CSIBn status register (CBnSTR)

### (1) CSIBn control register 0 (CBnCTL0)

CBnCTL0 is a register that controls the CSIBn serial transfer operation.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 01H.

(1/3)

After reset: 01H    R/W    Address: CB0CTL0 FFFFFFFD00H, CB1CTL0 FFFFFFFD10H,  
CB2CTL0 FFFFFFFD20H, CB3CTL0 FFFFFFFD30H,  
CB4CTL0 FFFFFFFD40H, CB5CTL0 FFFFFFFD50H

|                         |        |                        |                        |                        |   |   |                        |        |
|-------------------------|--------|------------------------|------------------------|------------------------|---|---|------------------------|--------|
| CBnCTL0<br>(n = 0 to 5) | <7>    | <6>                    | <5>                    | <4>                    | 3 | 2 | 1                      | <0>    |
|                         | CBnPWR | CBnTXE <sup>Note</sup> | CBnRXE <sup>Note</sup> | CBnDIR <sup>Note</sup> | 0 | 0 | CBnTMS <sup>Note</sup> | CBnSCE |

|  |   |
|--|---|
| CBnPWR   | Specification of CSIBn operation disable/enable       |
| 0  | Disable CSIBn operation and reset the CBnSTR register |
| 1  | Enable CSIBn operation                                |
| • The CBnPWR bit controls the CSIBn operation and resets the internal circuit. |   |

|  |  |
|--|--|
| CBnTXE <sup>Note</sup>                                   | Specification of transmit operation disable/enable |
| 0  | Disable transmit operation                         |
| 1  | Enable transmit operation                          |
| • The SOBn output is low level when the CBnTXE bit is 0. |  |

|  |   |
|--|---|
| CBnRXE <sup>Note</sup>   | Specification of receive operation disable/enable |
| 0  | Disable receive operation                         |
| 1  | Enable receive operation                          |
| • When the CBnRXE bit is cleared to 0, no reception complete interrupt is output even when the prescribed data is transferred in order to disable the receive operation, and the receive data (CBnRX register) is not updated. |   |

**Note** These bits can only be rewritten when the CBnPWR bit = 0. However, CBnPWR bit = 1 can also be set at the same time as rewriting these bits.

**Caution** To forcibly suspend transmission/reception, clear the CBnPWR bit to 0 instead of the CBnRXE and CBnTXE bits. At this time, the clock output is stopped.

| CBnDIR <sup>Note</sup> | Specification of transfer direction mode (MSB/LSB) |
|------------------------|--|
| 0                      | MSB-first transfer                                 |
| 1                      | LSB-first transfer                                 |

| CBnTMS <sup>Note</sup> | Transfer mode specification |
|------------------------|-----------------------------|
| 0                      | Single transfer mode        |
| 1                      | Continuous transfer mode    |

[In single transfer mode]

The reception complete interrupt request signal (INTCBnR) is generated.

Even if transmission is enabled (CBnTXE bit = 1), the transmission enable interrupt request signal (INTCBnT) is not generated.

If the next transmit data is written during communication (CBnSTR.CBnTSF bit = 1), it is ignored and the next communication is not started. Also, if reception-only communication is set (CBnTXE bit = 0, CBnRXE bit = 1), the next communication is not started even if the receive data is read during communication (CBnSTR.CBbTSF bit = 1).

[In continuous transfer mode]

The continuous transmission is enabled by writing the next transmit data during communication (CBnSTR.CBnTSF bit = 1). Writing the next transmission data is enabled after a transmission enable interrupt (INTCBnT) occurrence.

If reception-only communication is set (CBnTXE bit = 0, CBnRXE bit = 1) in the continuous transfer mode, the next reception is started continuously after a reception complete interrupt (INTCBnR) regardless of the read operation of the CBnRX register.

Therefore, read immediately the receive data from the CBnRX register. If this read operation is delayed, an overrun error (CBnOVE bit = 1) occurs.

**Note** These bits can only be rewritten when the CBnPWR bit = 0.  
However, CBnPWR bit = 1 can also be set at the same time as rewriting these bits.

| CBnSCE | Specification of start transfer disable/enable |
|--------|--|
| 0      | Communication start trigger invalid            |
| 1      | Communication start trigger valid              |

- In master mode  
This bit enables or disables the communication start trigger.
  - (a) In single transmission or transmission/reception mode, or continuous transmission or continuous transmission/reception mode  
The setting of the CBnSCE bit has no influence on communication operation.
  - (b) In single reception mode  
Clear the CBnSCE bit to 0 before reading the last receive data because reception is started by reading the receive data (CBnRX register) to disable the reception startup<sup>Note 1</sup>.
  - (c) In continuous reception mode  
Clear the CBnSCE bit to 0 one communication clock before reception of the last data is completed to disable the reception startup after the last data is received<sup>Note 2</sup>.
- In slave mode  
This bit enables or disables the communication start trigger.  
Set the CBnSCE bit to 1.

[Usage of CBnSCE bit]

- In single reception mode
  - <1> When reception of the last data is completed by INTCBnR interrupt servicing, clear the CBnSCE bit to 0 before reading the CBnRX register.
  - <2> After confirming the CBnSTR.CBnTSF bit = 0, clear the CBnRXE bit to 0 to disable reception.  
To continue reception, set the CBnSCE bit to 1 to start up the next reception by dummy-reading the CBnRX register.
- In continuous reception mode
  - <1> Clear the CBnSCE bit to 0 during the reception of the last data by INTCBnR interrupt servicing.
  - <2> Read the CBnRX register.
  - <3> Read the last reception data by reading the CBnRX register after acknowledging the CBnTIR interrupt.
  - <4> After confirming the CBnSTR.CBnTSF bit = 0, clear the CBnRXE bit to 0 to disable reception.  
To continue reception, set the CBnSCE bit to 1 to wait for the next reception by dummy-reading the CBnRX register.

- Notes**
- If the CBnSCE bit is read while it is 1, the next communication operation is started.
  - The CBnSCE bit is not cleared to 0 one communication clock before the completion of the last data reception, the next communication operation is automatically started.

**Caution** Be sure to clear bits 3 and 2 to “0”.

**(2) CSIBn control register 1 (CBnCTL1)**

CBnCTL1 is an 8-bit register that controls the CSIBn serial transfer operation.

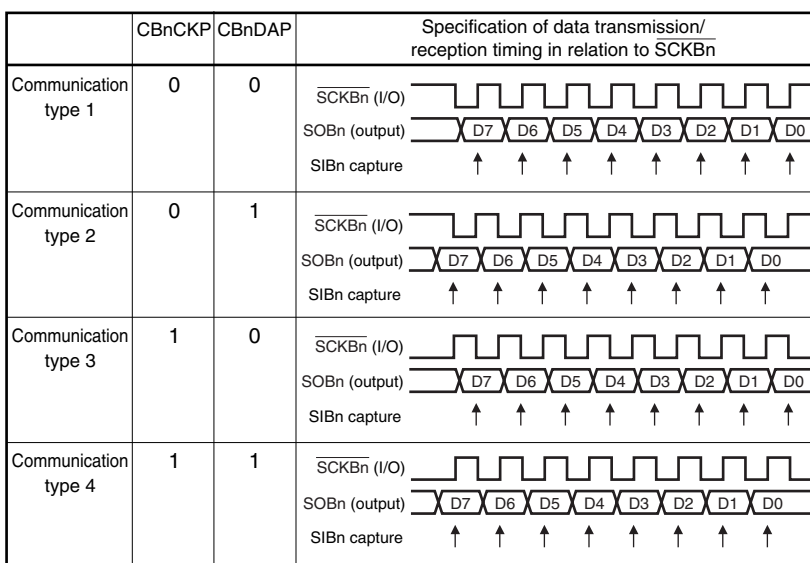
This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

**Caution** The CBnCTL1 register can be rewritten only when the CBnCTL0.CBnPWR bit = 0.

After reset 00H R/W Address: CB0CTL1 FFFFD01H, CB1CTL1 FFFFD11H,  
 CB2CTL1 FFFFD21H, CB3CTL1 FFFFD31H,  
 CB4CTL1 FFFFD41H, CB5CTL1 FFFFD51H

|                         |   |   |   |        |        |         |         |         |
|-------------------------|---|---|---|--------|--------|---------|---------|---------|
|                         | 7 | 6 | 5 | 4      | 3      | 2       | 1       | 0       |
| CBnCTL1<br>(n = 0 to 5) | 0 | 0 | 0 | CBnCKP | CBnDAP | CBnCKS2 | CBnCKS1 | CBnCKS0 |



| CBnCKS2 | CBnCKS1 | CBnCKS0 | Communication clock (f <sub>CCLK</sub> ) <sup>Note</sup> | Mode        |
|---------|---------|---------|--|-------------|
| 0       | 0       | 0       | f <sub>xx</sub> /2                                       | Master mode |
| 0       | 0       | 1       | f <sub>xx</sub> /4                                       | Master mode |
| 0       | 1       | 0       | f <sub>xx</sub> /8                                       | Master mode |
| 0       | 1       | 1       | f <sub>xx</sub> /16                                      | Master mode |
| 1       | 0       | 0       | f <sub>xx</sub> /32                                      | Master mode |
| 1       | 0       | 1       | f <sub>xx</sub> /64                                      | Master mode |
| 1       | 1       | 0       | f <sub>BRGm</sub>  | Master mode |
| 1       | 1       | 1       | External clock (SCKBn)                                   | Slave mode  |

**Note** Set the communication clock (f<sub>CCLK</sub>) to 8 MHz or lower.

**Remark** When n = 0, 1, m = 1  
 When n = 2, 3, m = 2  
 When n = 4, 5, m = 3  
 For details of f<sub>BRGm</sub>, see **16.8 Baud Rate Generator**.

**(3) CSIBn control register 2 (CBnCTL2)**

CBnCTL2 is an 8-bit register that controls the number of CSIBn serial transfer bits.

This register can be read or written in 8-bit units.

Reset sets this register to 00H.

**Caution** The CBnCTL2 register can be rewritten only when the CBnCTL0.CBnPWR bit = 0 or when both the CBnTXE and CBnRXE bits = 0.

After reset: 00H    R/W    Address: CB0CTL2 FFFFFFFD02H, CB1CTL2 FFFFFFFD12H,  
 CB2CTL2 FFFFFFFD22H, CB3CTL2 FFFFFFFD32H,  
 CB4CTL2 FFFFFFFD42H, CB5CTL2 FFFFFFFD52H

|                         |   |   |   |   |        |        |        |        |
|-------------------------|---|---|---|---|--------|--------|--------|--------|
|                         | 7 | 6 | 5 | 4 | 3      | 2      | 1      | 0      |
| CBnCTL2<br>(n = 0 to 5) | 0 | 0 | 0 | 0 | CBnCL3 | CBnCL2 | CBnCL1 | CBnCL0 |

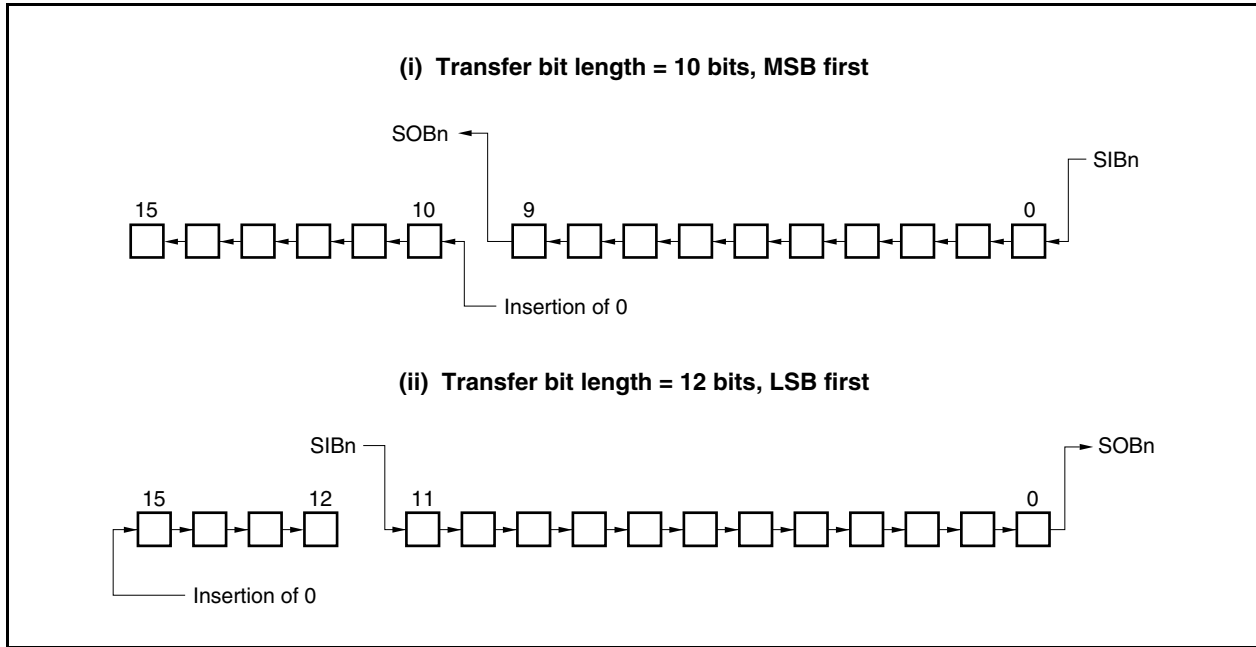
| CBnCL3 | CBnCL2 | CBnCL1 | CBnCL0 | Serial register bit length |
|--------|--------|--------|--------|----------------------------|
| 0      | 0      | 0      | 0      | 8 bits                     |
| 0      | 0      | 0      | 1      | 9 bits                     |
| 0      | 0      | 1      | 0      | 10 bits                    |
| 0      | 0      | 1      | 1      | 11 bits                    |
| 0      | 1      | 0      | 0      | 12 bits                    |
| 0      | 1      | 0      | 1      | 13 bits                    |
| 0      | 1      | 1      | 0      | 14 bits                    |
| 0      | 1      | 1      | 1      | 15 bits                    |
| 1      | ×      | ×      | ×      | 16 bits                    |

- Remarks**
1. If the number of transfer bits is other than 8 or 16, prepare and use data stuffed from the LSB of the CBnTX and CBnRX registers.
  2. ×: don't care

**(a) Transfer data length change function**

The CSIB<sub>n</sub> transfer data length can be set in 1-bit units between 8 and 16 bits using the CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits.

When the transfer bit length is set to a value other than 16 bits, set the data to the CBnTX or CBnRX register starting from the LSB, regardless of whether the transfer start bit is the MSB or LSB. Any data can be set for the higher bits that are not used, but the receive data becomes 0 following serial transfer.





**(4) CSIBn status register (CBnSTR)**

CBnSTR is an 8-bit register that displays the CSIBn status.

This register can be read or written in 8-bit or 1-bit units, but the CBnTSF flag is read-only.

Reset sets this register to 00H.

In addition to reset input, the CBnSTR register can be initialized by clearing (0) the CBnCTL0.CBnPWR bit.

After reset 00H R/W Address: CB0STR FFFFFFFD03H, CB1STR FFFFFFFD13H,  
CB2STR FFFFFFFD23H, CB3STR FFFFFFFD33H,  
CB4STR FFFFFFFD43H, CB5STR FFFFFFFD53H

|                        |        |   |   |   |   |   |   |        |
|------------------------|--------|---|---|---|---|---|---|--------|
|                        | <7>    | 6 | 5 | 4 | 3 | 2 | 1 | <0>    |
| CBnSTR<br>(n = 0 to 5) | CBnTSF | 0 | 0 | 0 | 0 | 0 | 0 | CBnOVE |

|  |                           |
|--|---------------------------|
| CBnTSF   | Communication status flag |
| 0  | Communication stopped     |
| 1  | Communicating             |
| <ul style="list-style-type: none"> <li>• During transmission, this register is set when data is prepared in the CBnTX register, and during reception, it is set when a dummy read of the CBnRX register is performed.</li> <li>• When transfer ends, this flag is cleared to 0 at the last edge of the clock.</li> </ul> |                           |

|  |                    |
|--|--------------------|
| CBnOVE   | Overrun error flag |
| 0  | No overrun         |
| 1  | Overrun            |
| <ul style="list-style-type: none"> <li>• An overrun error occurs when the next reception completes without reading the value of the receive buffer by CPU, upon completion of the receive operation. The CBnOVE flag displays the overrun error occurrence status in this case.</li> <li>• The CBnOVE bit is valid also in the single transfer mode. Therefore, when only using transmission, note the following. <ul style="list-style-type: none"> <li>• Do not check the CBnOVE flag.</li> <li>• Read this bit even if reading the reception data is not required.</li> </ul> </li> <li>• The CBnOVE flag is cleared by writing 0 to it. It cannot be set even by writing 1 to it.</li> </ul> |                    |

## 16.5 Interrupt Request Signals

CSIBn can generate the following two types of interrupt request signals.

- Reception complete interrupt request signal (INTCBnR)
- Transmission enable interrupt request signal (INTCBnT)

Of these two interrupt request signals, the reception complete interrupt request signal has the higher priority by default, and the priority of the transmission enable interrupt request signal is lower.

**Table 16-2. Interrupts and Their Default Priority**

| Interrupt           | Priority |
|---------------------|----------|
| Reception complete  | High     |
| Transmission enable | Low      |

### (1) Reception complete interrupt request signal (INTCBnR)

When receive data is transferred to the CBnRX register while reception is enabled, the reception complete interrupt request signal is generated.

This interrupt request signal can also be generated if an overrun error occurs.

When the reception complete interrupt request signal is acknowledged and the data is read, read the CBnSTR register to check that the result of reception is not an error.

In the single transfer mode, the INTCBnR interrupt request signal is generated upon completion of transmission, even when only transmission is executed.

### (2) Transmission enable interrupt request signal (INTCBnT)

In the continuous transmission or continuous transmission/reception mode, transmit data is transferred from the CBnTX register and, as soon as writing to CBnTX has been enabled, the transmission enable interrupt request signal is generated.

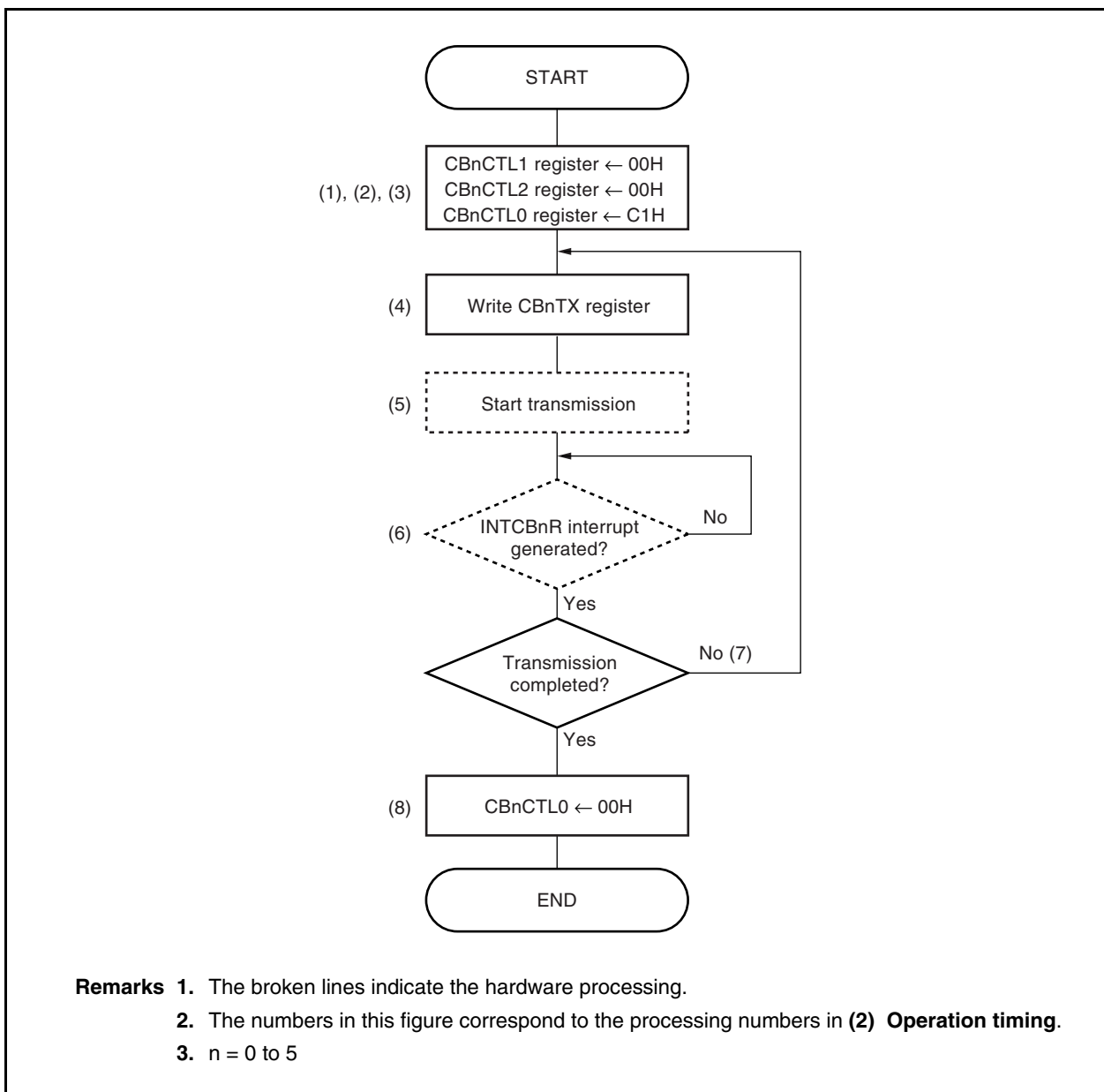
In the single transmission and single transmission/reception modes, the INTCBnT interrupt is not generated.

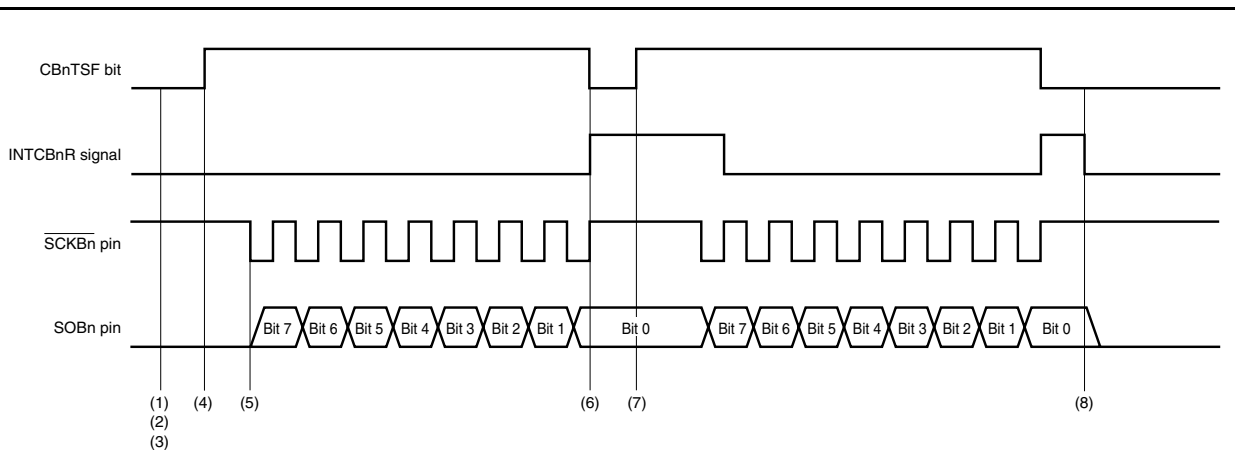
## 16.6 Operation

### 16.6.1 Single transfer mode (master mode, transmission mode)

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{\text{CCLK}} = f_{\text{xx}}/2$ ) (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

#### (1) Operation flow



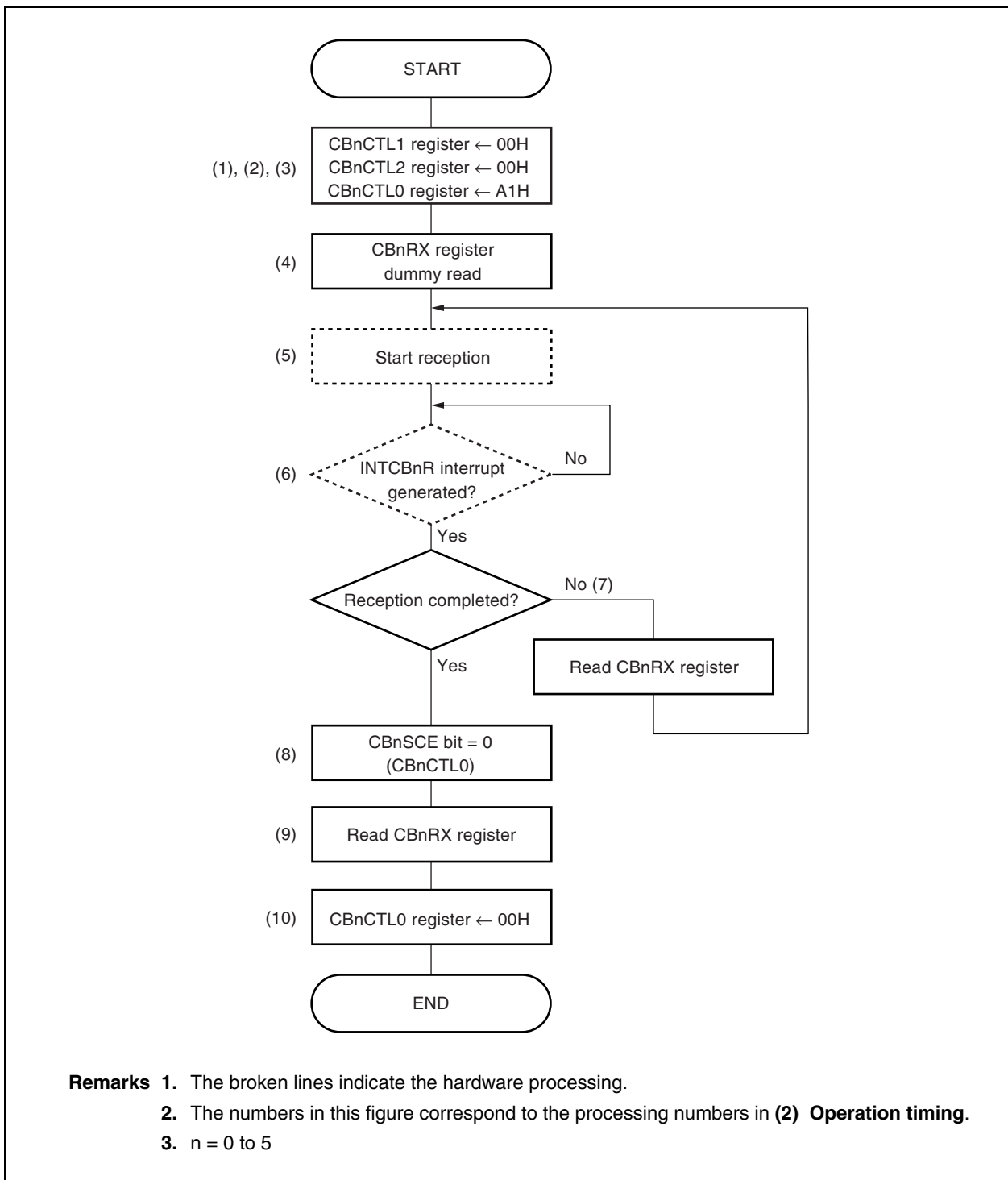
**(2) Operation timing**

- (1) Write 00H to the CBNCTL1 register, and select communication type 1, communication clock ( $f_{\text{CLK}}$ ) =  $f_{\text{xx}}/2$ , and master mode.
- (2) Write 00H to the CBNCTL2 register, and set the transfer data length to 8 bits.
- (3) Write C1H to the CBNCTL0 register, and select the transmission mode and MSB first at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The CBNSTR.CBN\_TSF bit is set to 1 by writing the transmit data to the CBN\_TX register, and transmission is started.
- (5) When transmission is started, output the serial clock to the  $\overline{\text{SCK}}_{\text{Bn}}$  pin, and output the transmit data from the SOB\_n pin in synchronization with the serial clock.
- (6) When transmission of the transfer data length set with the CBNCTL2 register is completed, stop the serial clock output and transmit data output, generate the reception completion interrupt request signal (INT\_CBN\_R) at the last edge of the serial clock, and clear the CBN\_TSF bit to 0.
- (7) To continue transmission, start the next transmission by writing the transmit data to the CBN\_TX register again after the INT\_CBN\_R signal is generated.
- (8) To end transmission, write the CBNCTL0.CBN\_PWR bit = 0 and the CBNCTL0.CBN\_TXE bit = 0.

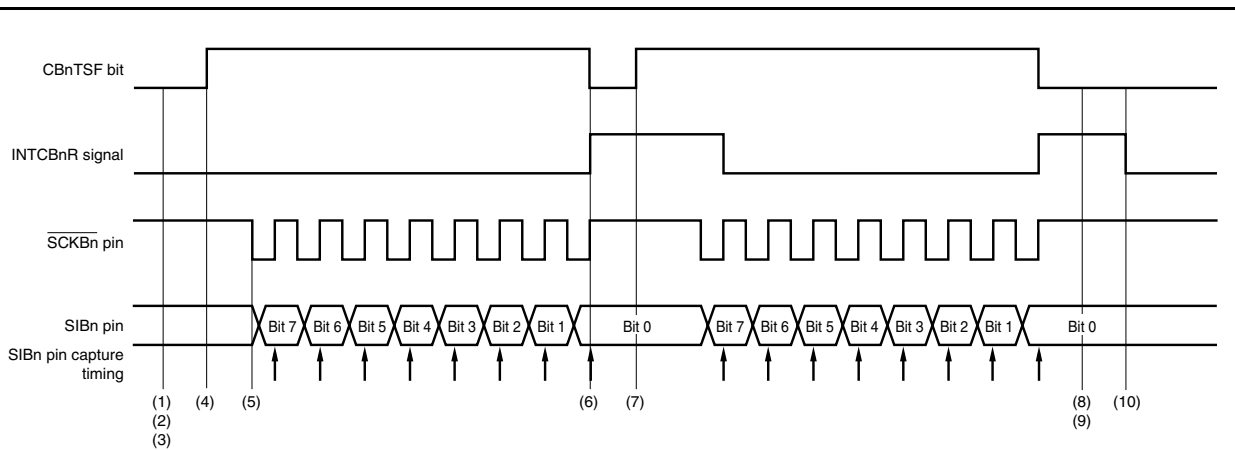
**Remark** n = 0 to 5

**16.6.2 Single transfer mode (master mode, reception mode)**

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{CLK}$ ) =  $f_{XX}/2$  (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

**(1) Operation flow**

## (2) Operation timing



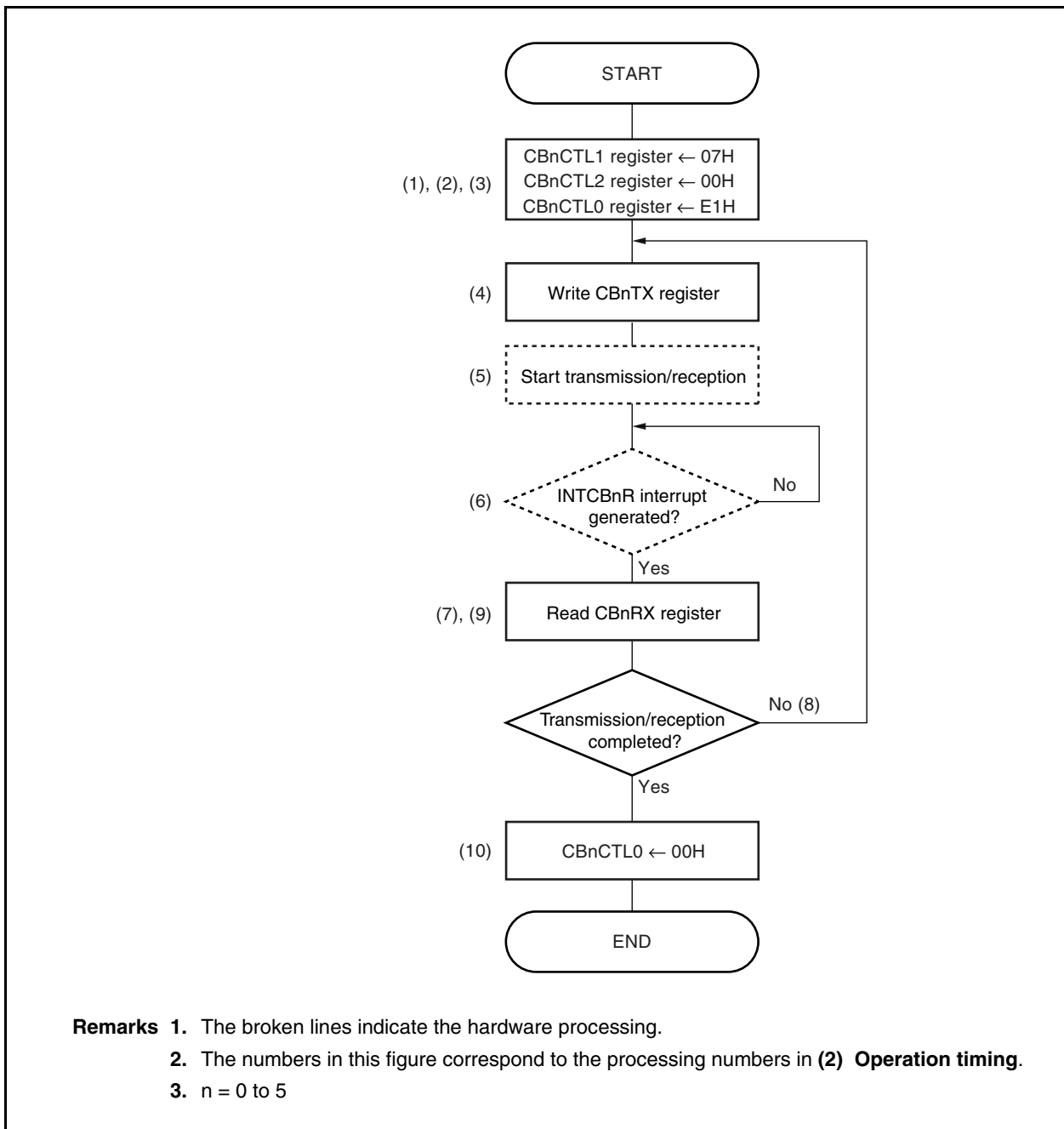
- (1) Write 00H to the CBnCTL1 register, and select communication type 1, communication clock ( $f_{\text{CLK}} = f_{\text{xx}}/2$ , and master mode.
- (2) Write 00H to the CBnCTL2 register, and set the transfer data length to 8 bits.
- (3) Write A1H to the CBnCTL0 register, and select the reception mode and MSB first at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The CBnSTR.CBnTSP bit is set to 1 by performing a dummy read of the CBnRX register, and reception is started.
- (5) When reception is started, output the serial clock to the  $\overline{\text{SCKBn}}$  pin, and capture the receive data of the SIBn pin in synchronization with the serial clock.
- (6) When reception of the transfer data length set with the CBnCTL2 register is completed, stop the serial clock output and data capturing, generate the reception completion interrupt request signal (INTCBnR) at the last edge of the serial clock, and clear the CBnTSP bit to 0.
- (7) To continue reception, read the CBnRX register with the CBnCTL0.CBnSCE bit = 1 remained after the INTCBnR signal is generated.
- (8) To read the CBnRX register without starting the next reception, write the CBnSCE bit = 0.
- (9) Read the CBnRX register.
- (10) To end reception, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnRXE bit = 0.

**Remark**  $n = 0$  to 5

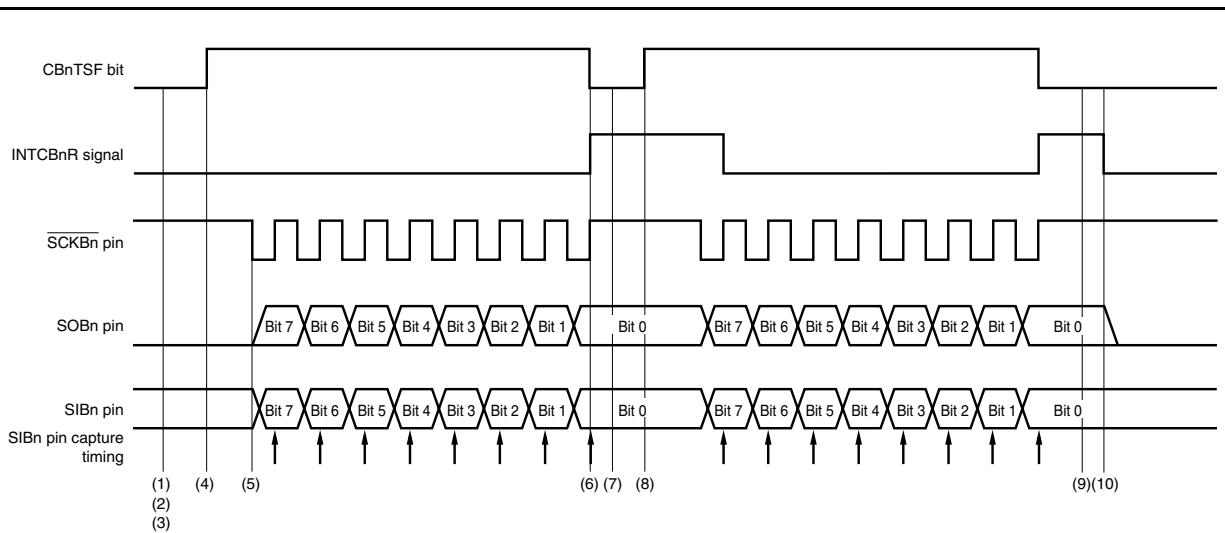
### 16.6.3 Single transfer mode (master mode, transmission/reception mode)

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{CLK}$ ) =  $f_{XX}/2$  (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

#### (1) Operation flow



## (2) Operation timing



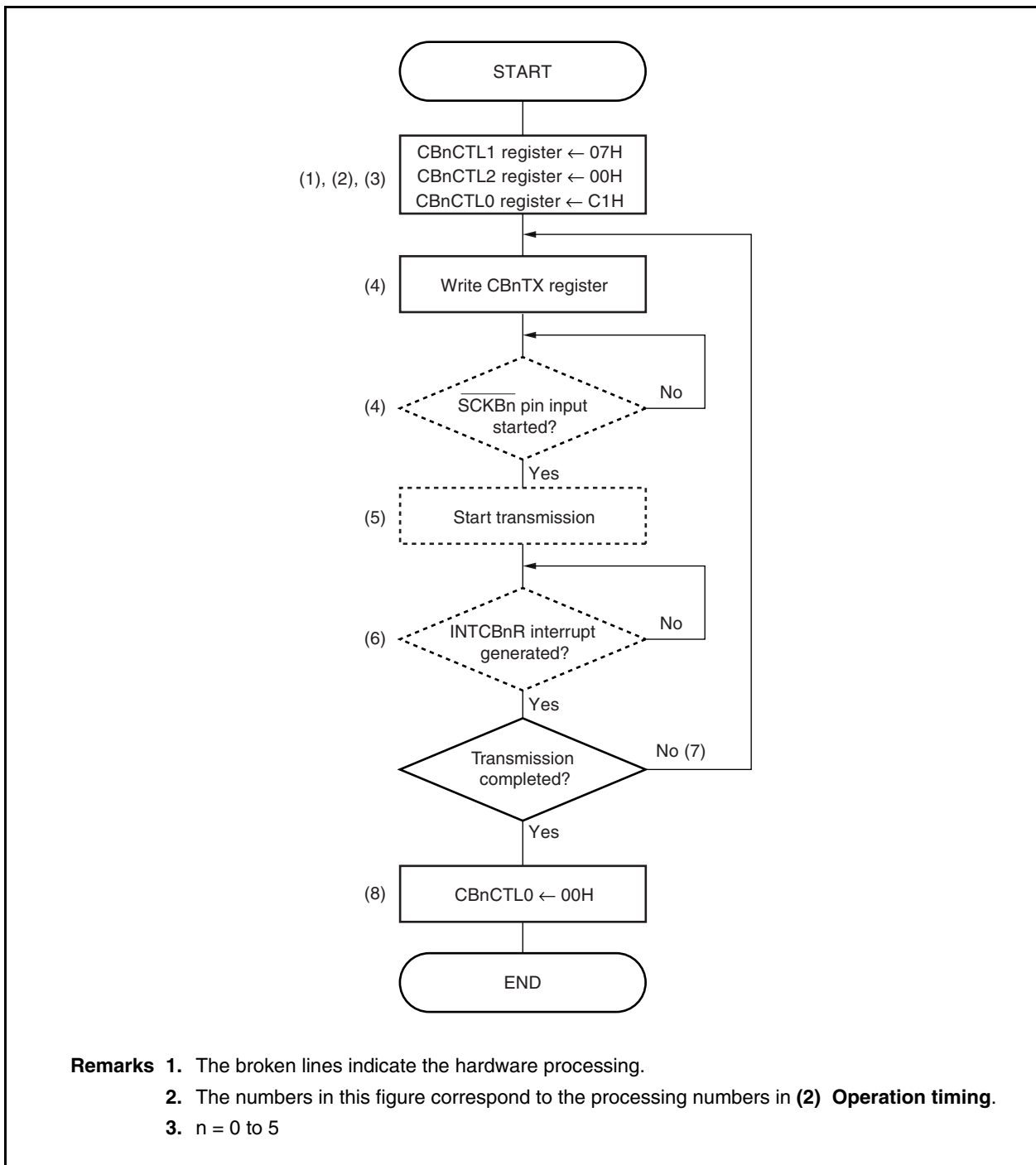
- (1) Write 00H to the CBnCTL1 register, and select communication type 1, communication clock ( $f_{\text{CLK}}$ ) =  $f_{\text{xx}}/2$ , and master mode.
- (2) Write 00H to the CBnCTL2 register, and set the transfer data length to 8 bits.
- (3) Write E1H to the CBnCTL0 register, and select the transmission/reception mode and MSB first at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and transmission/reception is started.
- (5) When transmission/reception is started, output the serial clock to the  $\overline{\text{SCKBn}}$  pin, output the transmit data to the SOBn pin in synchronization with the serial clock, and capture the receive data of the SIBn pin.
- (6) When transmission/reception of the transfer data length set with the CBnCTL2 register is completed, stop the serial clock output, transmit data output, and data capturing, generate the reception completion interrupt request signal (INTCBnR) at the last edge of the serial clock, and clear the CBnTSF bit to 0.
- (7) Read the CBnRX register.
- (8) To continue transmission/reception, write the transmit data to the CBnTX register again.
- (9) Read the CBnRX register.
- (10) To end transmission/reception, write the CBnCTL0.CBnPWR bit = 0, the CBnCTL0.CBnTXE bit = 0, and the CBnCTL0.CBnRXE bit = 0.

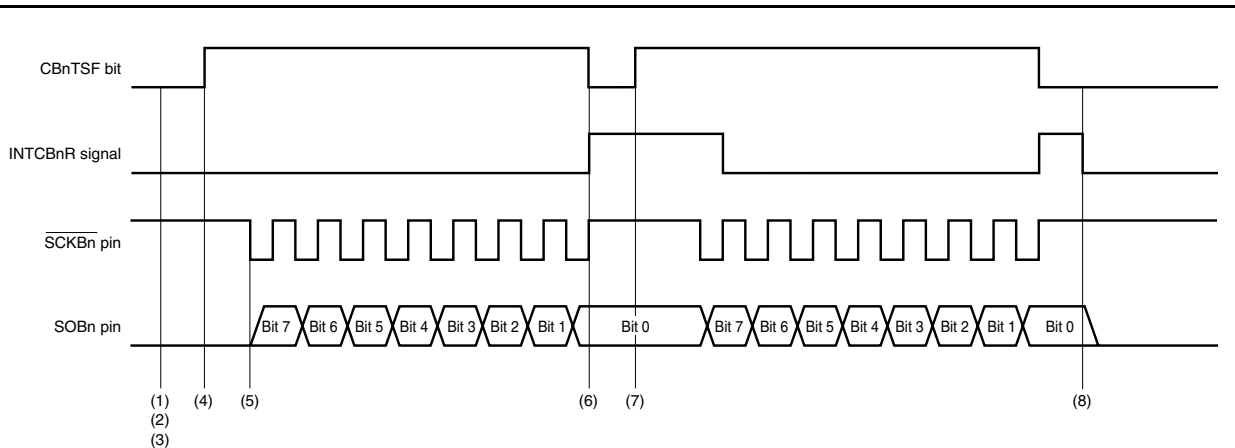
**Remark** n = 0 to 5



**16.6.4 Single transfer mode (slave mode, transmission mode)**

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{CLK}$ ) = external clock ( $\overline{SCKBn}$ ) (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 111), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

**(1) Operation flow**

**(2) Operation timing**

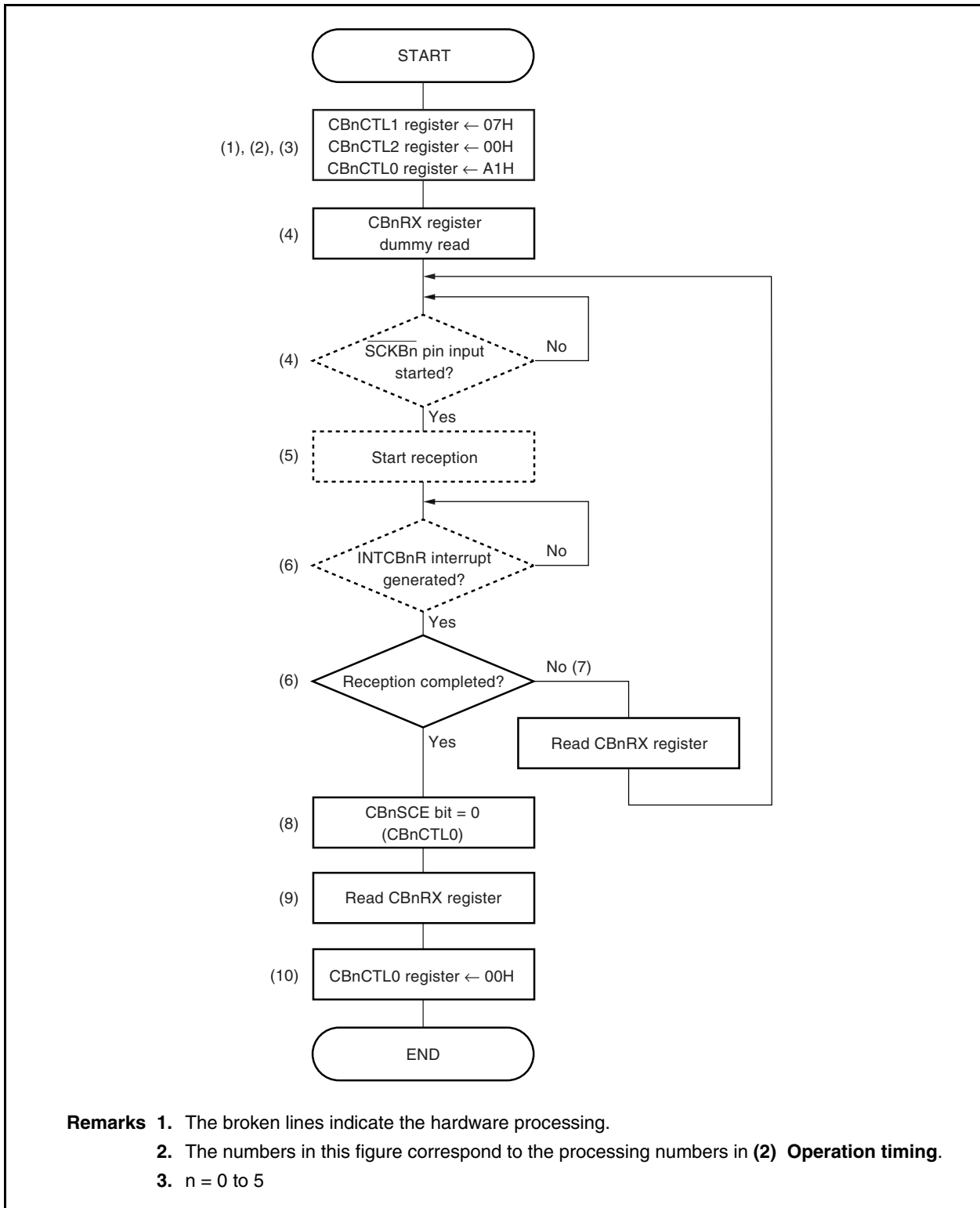
- (1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock ( $f_{\text{CLK}}$ ) = external clock (SCKBn), and slave mode.
- (2) Write 00H to the CBnCTL2 register, and set the transfer data length to 8 bits.
- (3) Write C1H to the CBnCTL0 register, and select the transmission mode and MSB first at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and the device waits for a serial clock input.
- (5) When a serial clock is input, output the transmit data from the SOBn pin in synchronization with the serial clock.
- (6) When transmission of the transfer data length set with the CBnCTL2 register is completed, stop the serial clock input and transmit data output, generate the reception completion interrupt request signal (INTCBnR) at the last edge of the serial clock, and clear the CBnTSF bit to 0.
- (7) To continue transmission, write the transmit data to the CBnTX register again after the INTCBnR signal is generated, and wait for a serial clock input.
- (8) To end transmission, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnTXE bit = 0.

**Remark** n = 0 to 5

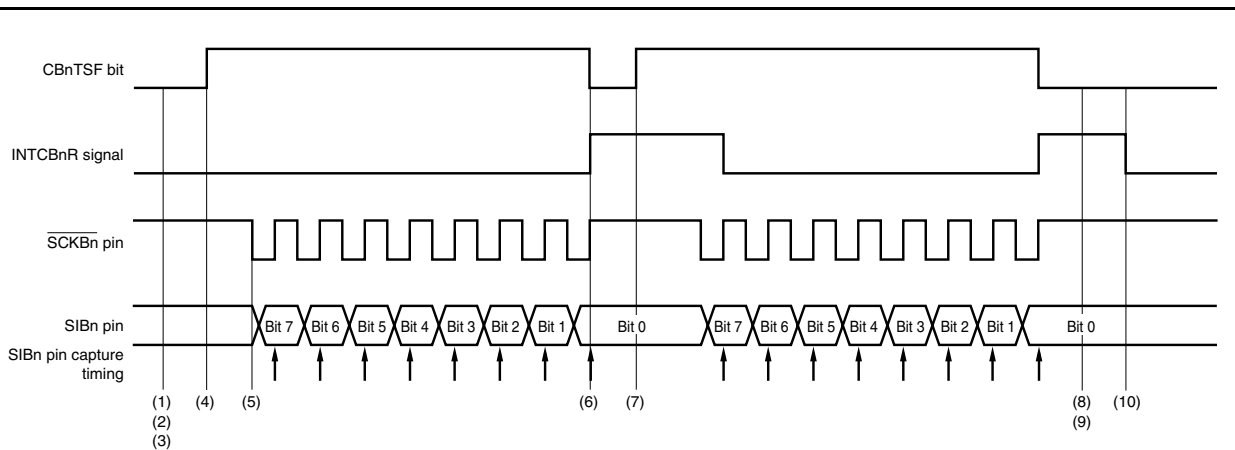
**16.6.5 Single transfer mode (slave mode, reception mode)**

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock (f<sub>CLK</sub>) = external clock (SCKBn) (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 111), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

**(1) Operation flow**



- Remarks**
1. The broken lines indicate the hardware processing.
  2. The numbers in this figure correspond to the processing numbers in (2) **Operation timing**.
  3. n = 0 to 5

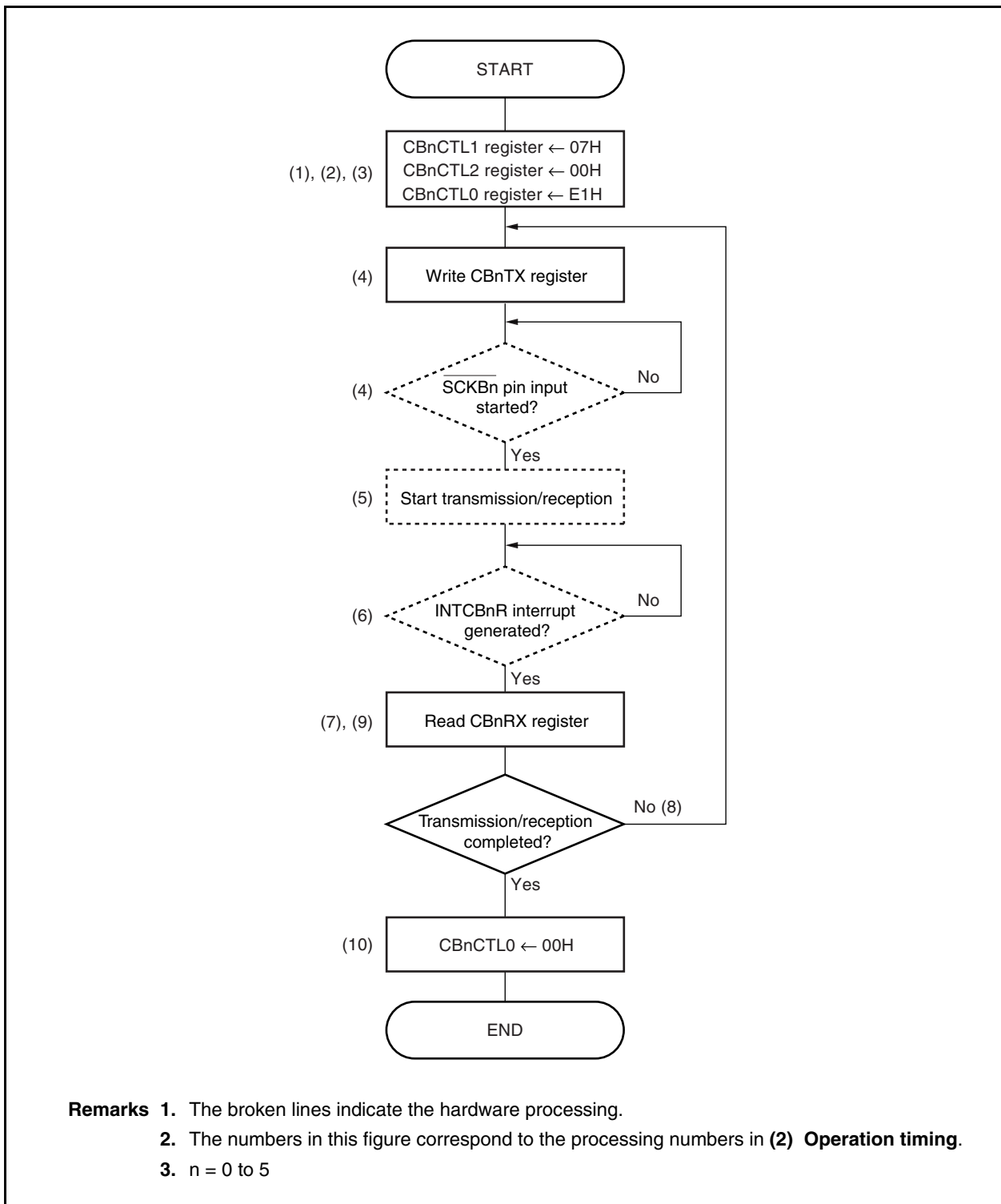
**(2) Operation timing**

- (1) Write 07H to the `CBnCTL1` register, and select communication type 1, communication clock ( $f_{\text{CLK}}$ ) = external clock (`SCKBn`), and slave mode.
- (2) Write 00H to the `CBnCTL2` register, and set the transfer data length to 8 bits.
- (3) Write A1H to the `CBnCTL0` register, and select the reception mode and MSB first at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The `CBnSTR.CBnTSF` bit is set to 1 by performing a dummy read of the `CBnRX` register, and the device waits for a serial clock input.
- (5) When a serial clock is input, capture the receive data of the `SIBn` pin in synchronization with the serial clock.
- (6) When reception of the transfer data length set with the `CBnCTL2` register is completed, stop the serial clock input and data capturing, generate the reception completion interrupt request signal (`INTCBnR`) at the last edge of the serial clock, and clear the `CBnTSF` bit to 0.
- (7) To continue reception, read the `CBnRX` register with the `CBnCTL0.CBnSCE` bit = 1 remained after the `INTCBnR` signal is generated, and wait for a serial clock input.
- (8) To end reception, write the `CBnSCE` bit = 0.
- (9) Read the `CBnRX` register.
- (10) To end reception, write the `CBnCTL0.CBnPWR` bit = 0 and the `CBnCTL0.CBnRXE` bit = 0.

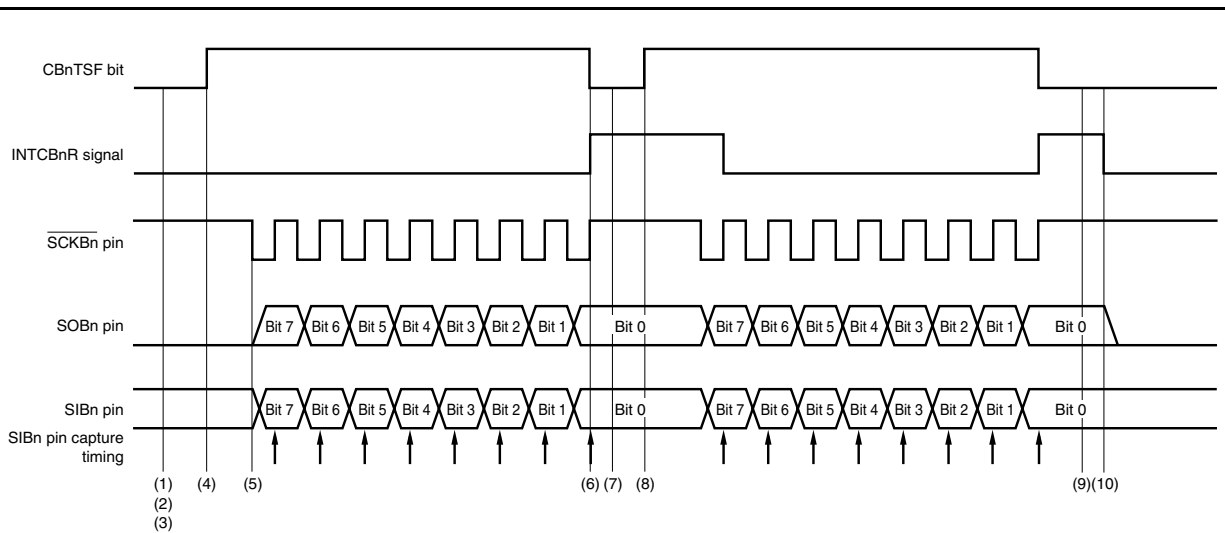
**Remark** n = 0 to 5

**16.6.6 Single transfer mode (slave mode, transmission/reception mode)**

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{CLK}$ ) = external clock ( $\overline{SCKBn}$ ) (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 111), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

**(1) Operation flow**

## (2) Operation timing

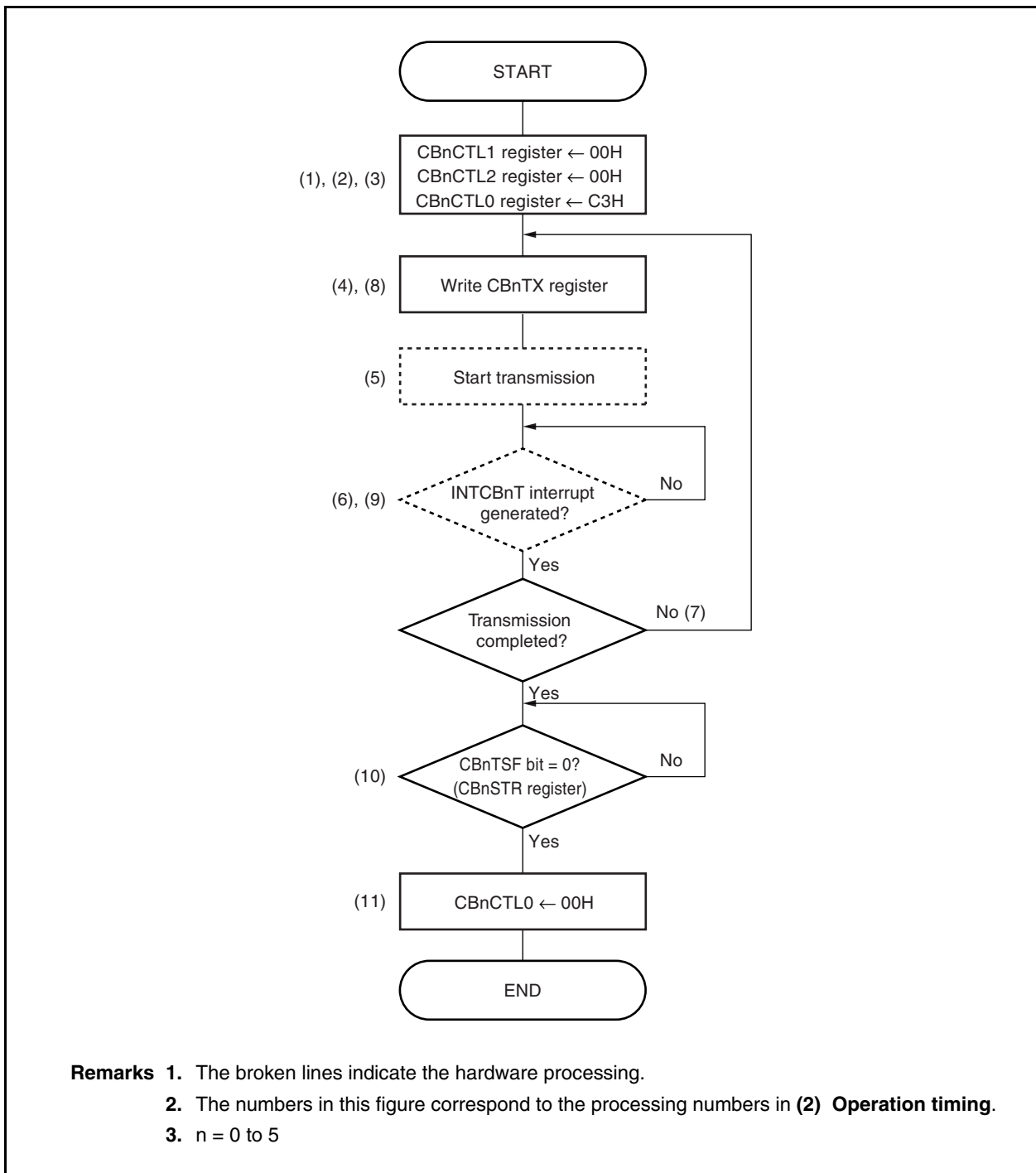


- (1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock ( $f_{\text{CCLK}}$ ) = external clock ( $\text{SCKBn}$ ), and slave mode.
- (2) Write 00H to the CBnCTL2 register, and set the transfer data length to 8 bits.
- (3) Write E1H to the CBnCTL0 register, and select the transmission/reception mode and MSB first at the same time as enabling the operation of the communication clock ( $f_{\text{CCLK}}$ ).
- (4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and the device waits for a serial clock input.
- (5) When a serial clock is input, output the transmit data to the SOBn pin in synchronization with the serial clock, and capture the receive data of the SIBn pin.
- (6) When transmission/reception of the transfer data length set with the CBnCTL2 register is completed, stop the serial clock input, transmit data output, and data capturing, generate the reception completion interrupt request signal (INTCBnR) at the last edge of the serial clock, and clear the CBnTSF bit to 0.
- (7) Read the CBnRX register.
- (8) To continue transmission/reception, write the transmit data to the CBnTX register again, and wait for a serial clock input.
- (9) Read the CBnRX register.
- (10) To end transmission/reception, write the CBnCTL0.CBnPWR bit = 0, the CBnCTL0.CBnTXE bit = 0, and the CBnCTL0.CBnRXE bit = 0.

**Remark** n = 0 to 5

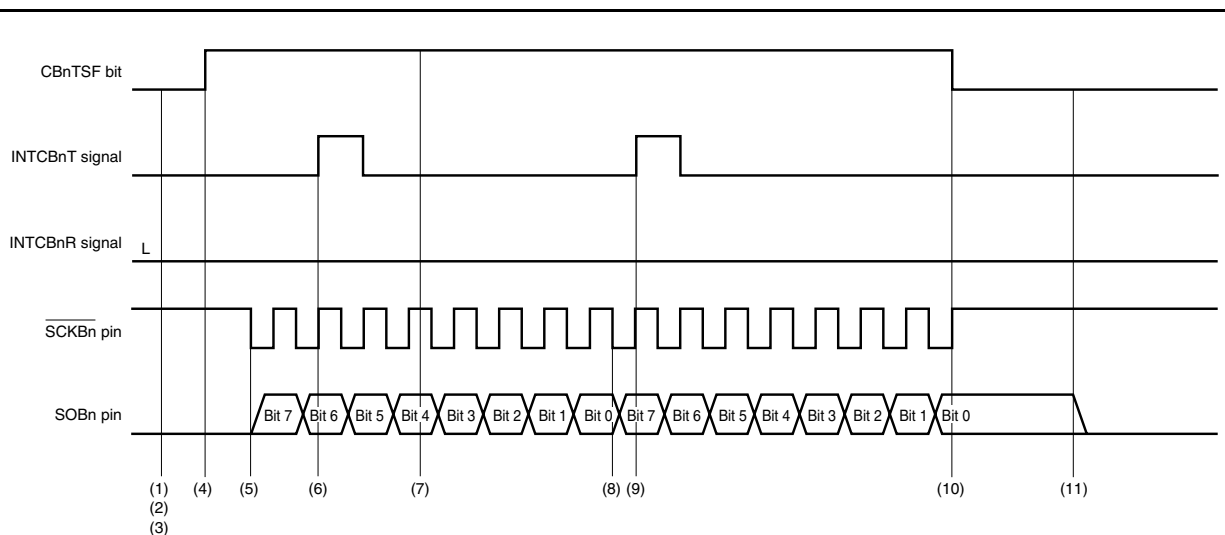
**16.6.7 Continuous transfer mode (master mode, transmission mode)**

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{CLK} = f_{XX}/2$ ) (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

**(1) Operation flow**

- Remarks**
1. The broken lines indicate the hardware processing.
  2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.
  3.  $n = 0$  to 5

## (2) Operation timing



- (1) Write 00H to the CBnCTL1 register, and select communication type 1, communication clock ( $f_{\text{CLK}}$ ) =  $f_{\text{xx}}/2$ , and master mode.
- (2) Write 00H to the CBnCTL2 register, and set the transfer data length to 8 bits.
- (3) Write C3H to the CBnCTL0 register, and select the transmission mode, MSB first, and continuous transfer mode at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The CBnSTR.CBnTnSF bit is set to 1 by writing the transmit data to the CBnTX register, and transmission is started.
- (5) When transmission is started, output the serial clock to the  $\overline{\text{SCKBn}}$  pin, and output the transmit data from the SOBn pin in synchronization with the serial clock.
- (6) When transfer of the transmit data from the CBnTX register to the shift register is completed and writing to the CBnTX register is enabled, the transmission enable interrupt request signal (INTCBnT) is generated.
- (7) To continue transmission, write the transmit data to the CBnTX register again after the INTCBnT signal is generated.
- (8) When a new transmit data is written to the CBnTX register before communication completion, the next communication is started following communication completion.
- (9) The transfer of the transmit data from the CBnTX register to the shift register is completed and the INTCBnT signal is generated. To end continuous transmission with the current transmission, do not write to the CBnTX register.
- (10) When the next transmit data is not written to the CBnTX register before transfer completion, stop the serial clock input to the  $\overline{\text{SCKBn}}$  pin after transfer completion, and clear the CBnTnSF bit to 0.
- (11) To release the transmission enable status, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnTXE bit = 0 after checking that the CBnTnSF bit = 0.

**Caution** In continuous transmission mode, the reception completion interrupt request signal (INTCBnR) is not generated.

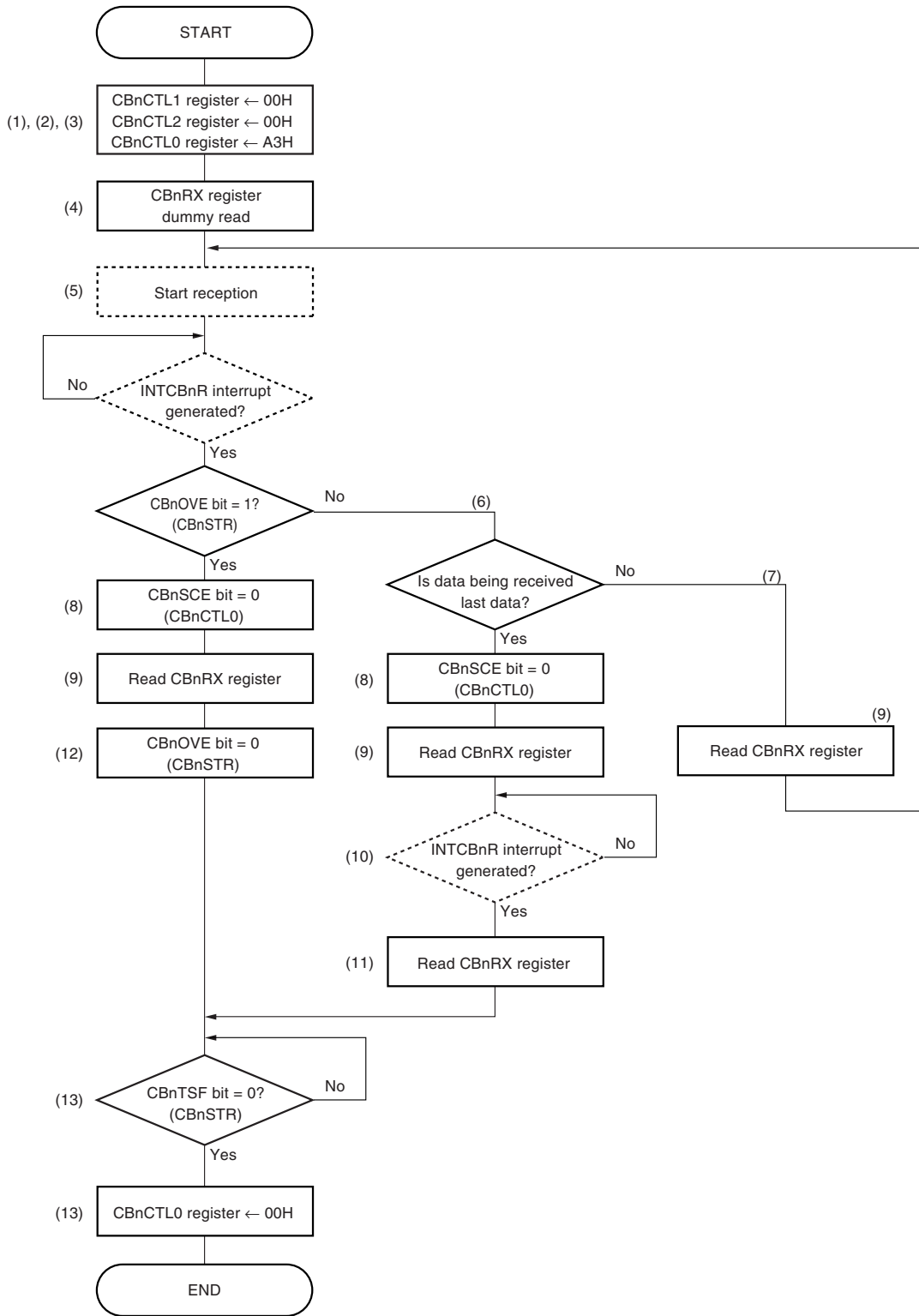
**Remark** n = 0 to 5



**16.6.8 Continuous transfer mode (master mode, reception mode)**

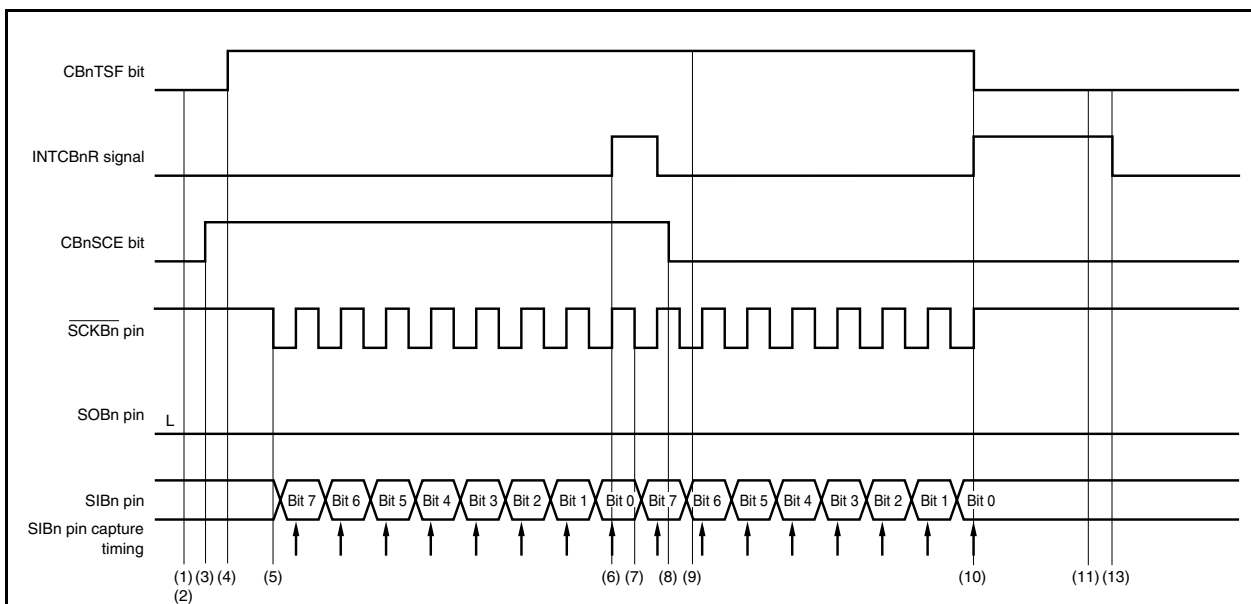
MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{\text{CLK}}$ ) =  $f_{\text{XX}}/2$  (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

(1) Operation flow



- Remarks**
1. The broken lines indicate the hardware processing.
  2. The numbers in this figure correspond to the processing numbers in (2) Operation timing.
  3. n = 0 to 5

## (2) Operation timing



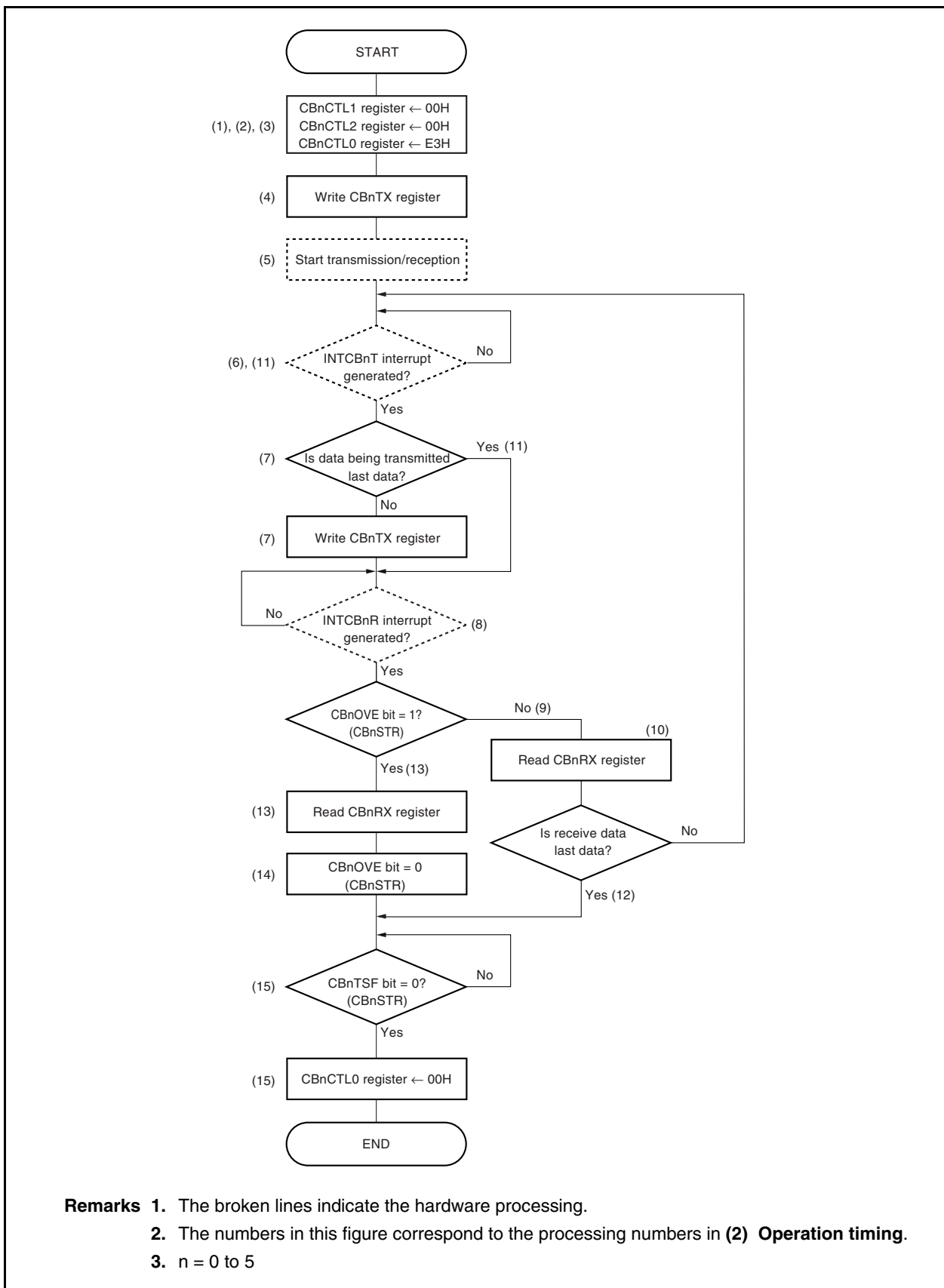
- (1) Write 00H to the CBnCTL1 register, and select communication type 1, communication clock ( $f_{CCLK}$ ) =  $f_{xx}/2$ , and master mode.
- (2) Write 00H to the CBnCTL2 register, and set the transfer data length to 8 bits.
- (3) Write A3H to the CBnCTL0 register, and select the reception mode, MSB first, and continuous transfer mode at the same time as enabling the operation of the communication clock ( $f_{CCLK}$ ).
- (4) The CBnSTR.CBnTSF bit is set to 1 by performing a dummy read of the CBnRX register, and reception is started.
- (5) When reception is started, output the serial clock to the SCKBn pin, and capture the receive data of the SIBn pin in synchronization with the serial clock.
- (6) When reception is completed, the reception completion interrupt request signal (INTCBnR) is generated, and reading of the CBnRX register is enabled.
- (7) When the CBnCTL0.CBnSCE bit = 1 upon communication completion, the next communication is started following communication completion.
- (8) To end continuous reception with the current reception, write the CBnSCE bit = 0.
- (9) Read the CBnRX register.
- (10) When reception is completed, the INTCBnR signal is generated, and reading of the CBnRX register is enabled. When the CBnSCE bit = 0 is set before communication completion, stop the serial clock output to the SCKBn pin, and clear the CBnTSF bit to 0, to end the receive operation.
- (11) Read the CBnRX register.
- (12) If an overrun error occurs, write the CBnSTR.CBnOVE bit = 0, and clear the error flag.
- (13) To release the reception enable status, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnRXE bit = 0 after checking that the CBnTSF bit = 0.

**Remark** n = 0 to 5

**16.6.9 Continuous transfer mode (master mode, transmission/reception mode)**

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{\text{CLK}}$ ) =  $f_{\text{XX}}/2$  (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

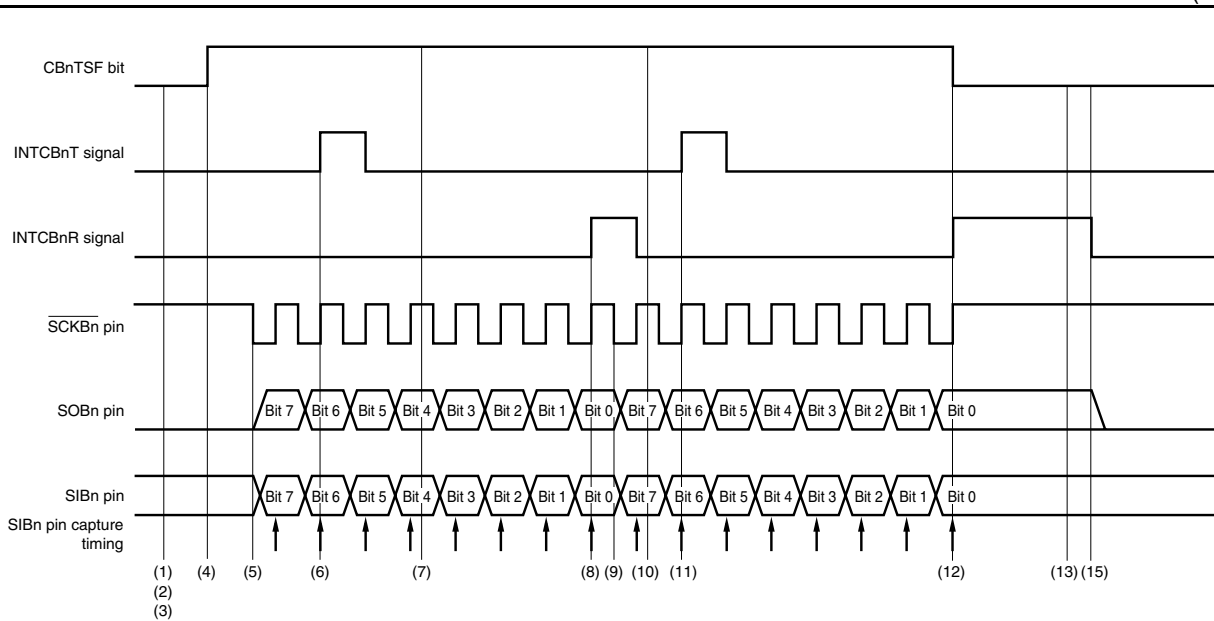
(1) Operation flow



- Remarks**
1. The broken lines indicate the hardware processing.
  2. The numbers in this figure correspond to the processing numbers in (2) Operation timing.
  3. n = 0 to 5

## (2) Operation timing

(1/2)



- (1) Write 00H to the CBnCTL1 register, and select communication type 1, communication clock ( $f_{\text{CLK}} = f_{\text{xx}}/2$ , and master mode.
- (2) Write 00H to the CBnCTL2 register, and set the transfer data length to 8 bits.
- (3) Write E3H to the CBnCTL0 register, and select the transmission/reception mode, MSB first, and continuous transfer mode at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and transmission/reception is started.
- (5) When transmission/reception is started, output the serial clock to the SCKBn pin, output the transmit data to the SOBn pin in synchronization with the serial clock, and capture the receive data of the SIBn pin.
- (6) When transfer of the transmit data from the CBnTX register to the shift register is completed and writing to the CBnTX register is enabled, the transmission enable interrupt request signal (INTCBnT) is generated.
- (7) To continue transmission/reception, write the transmit data to the CBnTX register again after the INTCBnT signal is generated.
- (8) When one transmission/reception is completed, the reception completion interrupt request signal (INTCBnR) is generated, and reading of the CBnRX register is enabled.
- (9) When a new transmit data is written to the CBnTX register before communication completion, the next communication is started following communication completion.
- (10) Read the CBnRX register.

**Remark**  $n = 0$  to 5

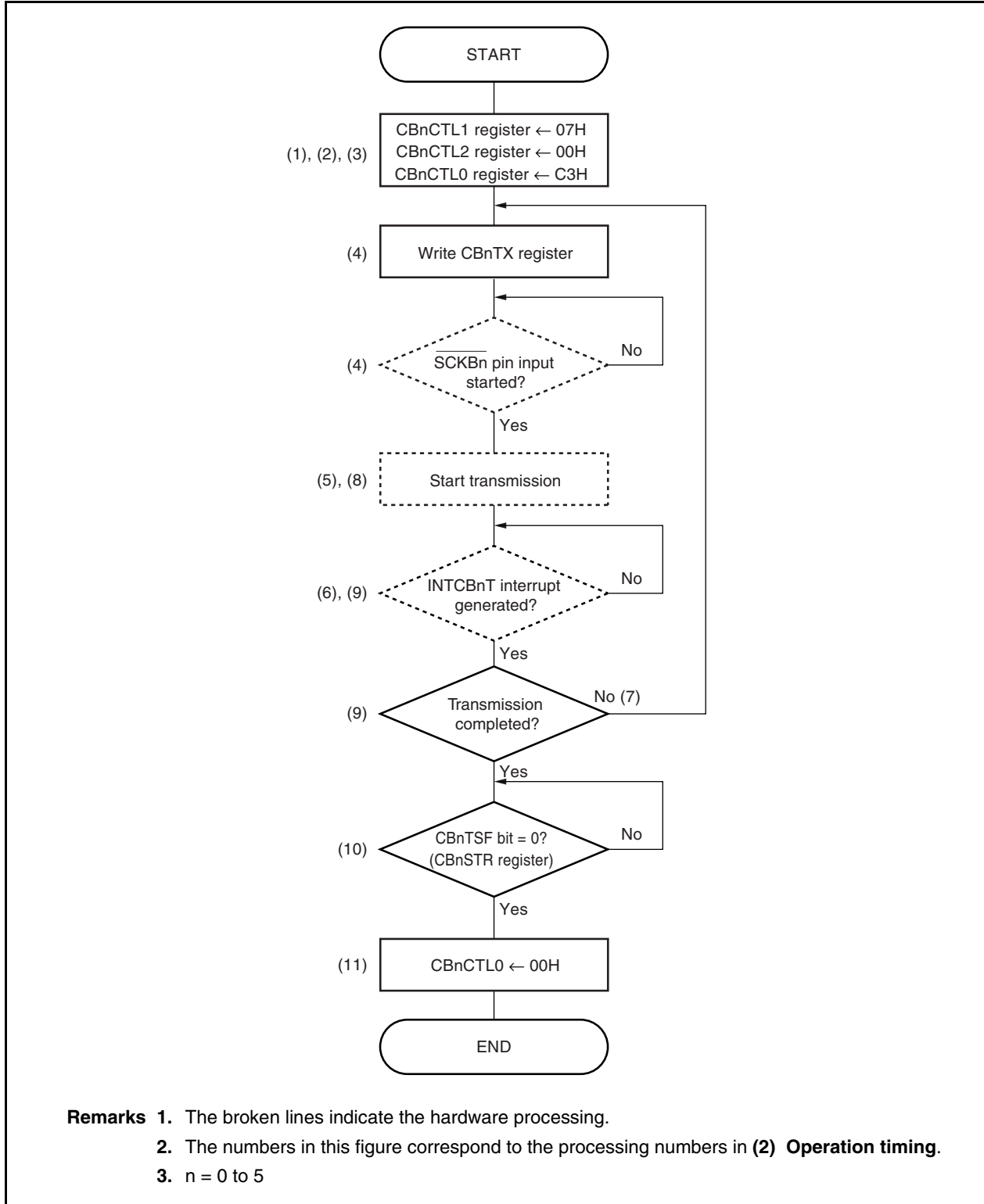
- (11) The transfer of the transmit data from the CBnTX register to the shift register is completed and the INTCBnT signal is generated. To end continuous transmission/reception with the current transmission/reception, do not write to the CBnTX register.
- (12) When the next transmit data is not written to the CBnTX register before transfer completion, stop the serial clock output to the  $\overline{\text{SCKBn}}$  pin after transfer completion, and clear the CBnTSF bit to 0.
- (13) When the reception error interrupt request signal (INTCBnR) is generated, read the CBnRX register.
- (14) If an overrun error occurs, write the CBnSTR.CBnOVE bit = 0, and clear the error flag.
- (15) To release the transmission/reception enable status, write the CBnCTL0.CBnPWR bit = 0, the CBnCTL0.CBnTXE bit = 0, and the CBnCTL0.CBnRXE bit = 0 after checking that the CBnTSF bit = 0.

**Remark** n = 0 to 5

**16.6.10 Continuous transfer mode (slave mode, transmission mode)**

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock (f<sub>CLK</sub>) = external clock ( $\overline{\text{SCKBn}}$ ) (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 111), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

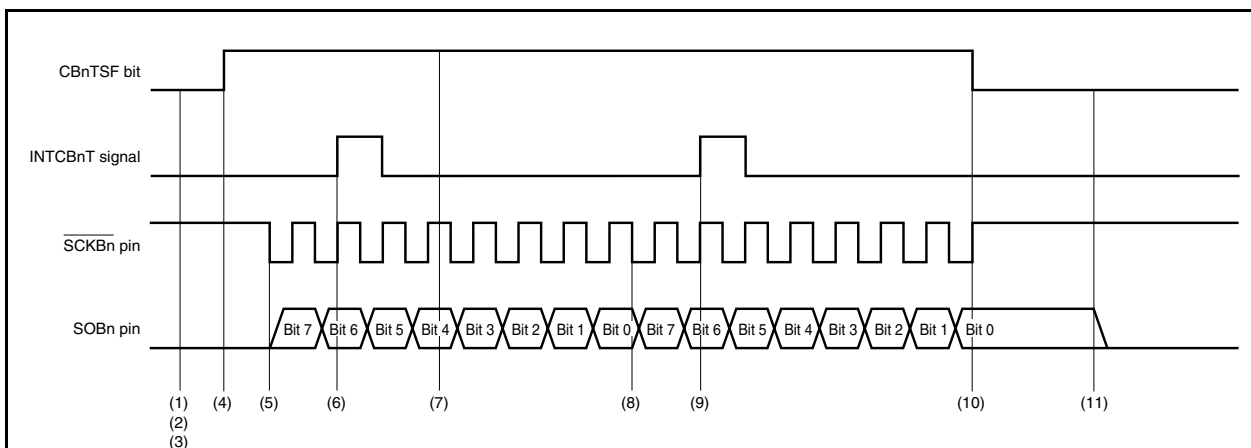
**(1) Operation flow**



- Remarks**
1. The broken lines indicate the hardware processing.
  2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.
  3. n = 0 to 5



## (2) Operation timing



- (1) Write 07H to the `CBnCTL1` register, and select communication type 1, communication clock ( $f_{\text{CLK}}$ ) = external clock (`SCKBn`), and slave mode.
- (2) Write 00H to the `CBnCTL2` register, and set the transfer data length to 8 bits.
- (3) Write C3H to the `CBnCTL0` register, and select the transmission mode, MSB first, and continuous transfer mode at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The `CBnSTR.CBnTSF` bit is set to 1 by writing the transmit data to the `CBnTX` register, and the device waits for a serial clock input.
- (5) When a serial clock is input, output the transmit data from the `SOBn` pin in synchronization with the serial clock.
- (6) When transfer of the transmit data from the `CBnTX` register to the shift register is completed and writing to the `CBnTX` register is enabled, the transmission enable interrupt request signal (`INTCBnT`) is generated.
- (7) To continue transmission, write the transmit data to the `CBnTX` register again after the `INTCBnT` signal is generated.
- (8) When a serial clock is input following completion of the transmission of the transfer data length set with the `CBnCTL2` register, continuous transmission is started.
- (9) When transfer of the transmit data from the `CBnTX` register to the shift register is completed and writing to the `CBnTX` register is enabled, the `INTCBnT` signal is generated. To end continuous transmission with the current transmission, do not write to the `CBnTX` register.
- (10) When the clock of the transfer data length set with the `CBnCTL2` register is input without writing to the `CBnTX` register, clear the `CBnTSF` bit to 0 to end transmission.
- (11) To release the transmission enable status, write the `CBnCTL0.CBnPWR` bit = 0 and the `CBnCTL0.CBnTXE` bit = 0 after checking that the `CBnTSF` bit = 0.

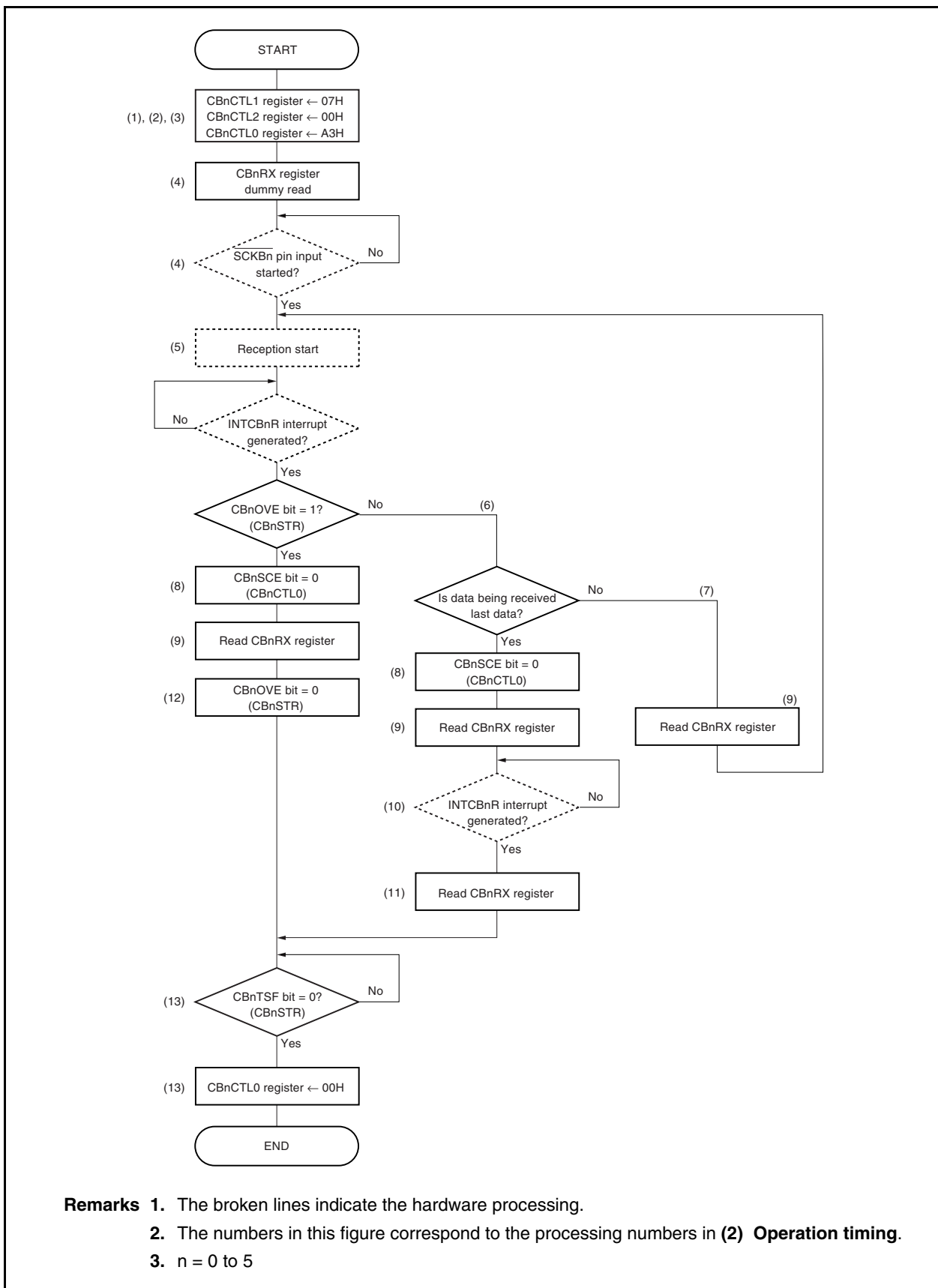
**Caution** In continuous transmission mode, the reception completion interrupt request signal (`INTCBnR`) is not generated.

**Remark**  $n = 0$  to 5

**16.6.11 Continuous transfer mode (slave mode, reception mode)**

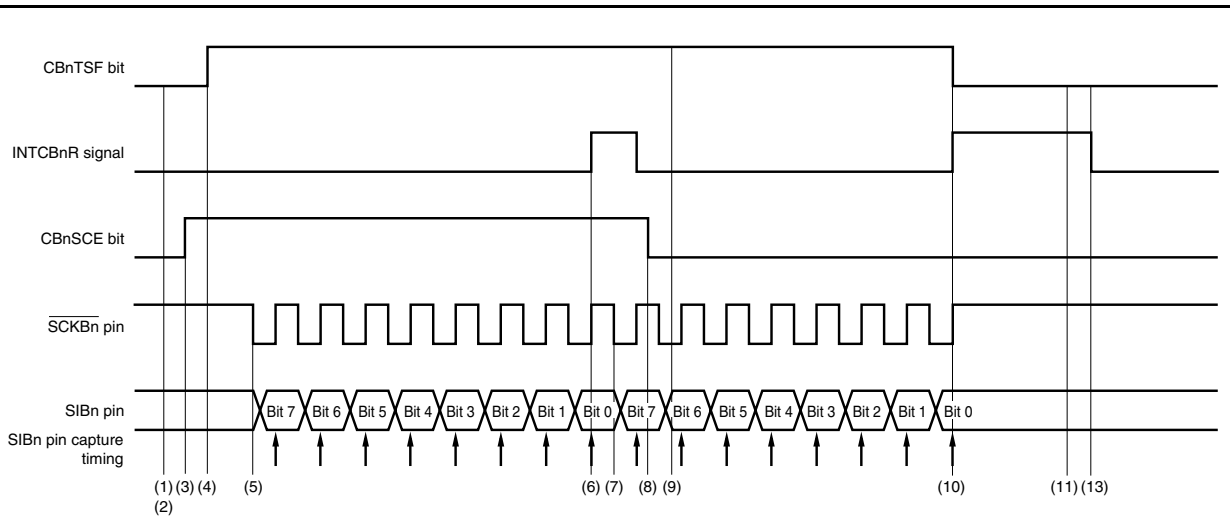
MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{\text{CCLK}}$ ) = external clock ( $\overline{\text{SCKBn}}$ ) (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 111), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

(1) Operation flow



- Remarks**
1. The broken lines indicate the hardware processing.
  2. The numbers in this figure correspond to the processing numbers in (2) **Operation timing**.
  3. n = 0 to 5

## (2) Operation timing



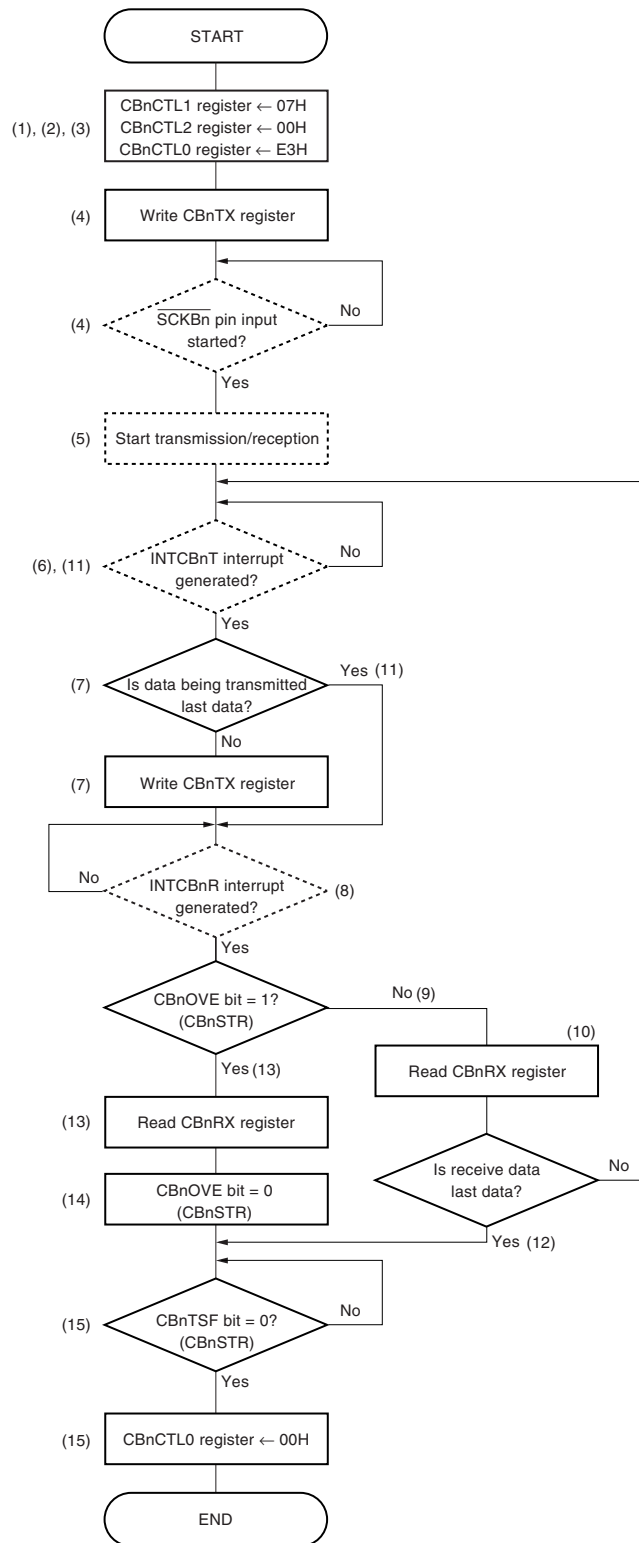
- (1) Write 07H to the `CBnCTL1` register, and select communication type 1, communication clock ( $f_{\text{CLK}}$ ) = external clock (`SCKBn`), and slave mode.
- (2) Write 00H to the `CBnCTL2` register, and set the transfer data length to 8 bits.
- (3) Write A3H to the `CBnCTL0` register, and select the reception mode, MSB first, and continuous transfer mode at the same time as enabling the operation of the communication clock ( $f_{\text{CLK}}$ ).
- (4) The `CBnSTR.CBnTSF` bit is set to 1 by performing a dummy read of the `CBnRX` register, and the device waits for a serial clock input.
- (5) When a serial clock is input, capture the receive data of the `SIBn` pin in synchronization with the serial clock.
- (6) When reception is completed, the reception completion interrupt request signal (`INTCBnR`) is generated, and reading of the `CBnRX` register is enabled.
- (7) When a serial clock is input in the `CBnCTL0.CBnSCE` bit = 1 status, continuous reception is started.
- (8) To end continuous reception with the current reception, write the `CBnSCE` bit = 0.
- (9) Read the `CBnRX` register.
- (10) When reception is completed, the `INTCBnR` signal is generated, and reading of the `CBnRX` register is enabled. When the `CBnSCE` bit = 0 is set before communication completion, clear the `CBnTSF` bit to 0 to end the receive operation.
- (11) Read the `CBnRX` register.
- (12) If an overrun error occurs, write the `CBnSTR.CBnOVE` bit = 0, and clear the error flag.
- (13) To release the reception enable status, write the `CBnCTL0.CBnPWR` bit = 0 and the `CBnCTL0.CBnRXE` bit = 0 after checking that the `CBnTSF` bit = 0.

**Remark**  $n = 0$  to 5

**16.6.12 Continuous transfer mode (slave mode, transmission/reception mode)**

MSB first (CBnCTL0.CBnDIR bit = 0), communication type 1 (CBnCTL1.CBnCKP and CBnCTL1.CBnDAP bits = 00), communication clock ( $f_{\text{CLK}}$ ) = external clock ( $\overline{\text{SCKBn}}$ ) (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 111), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

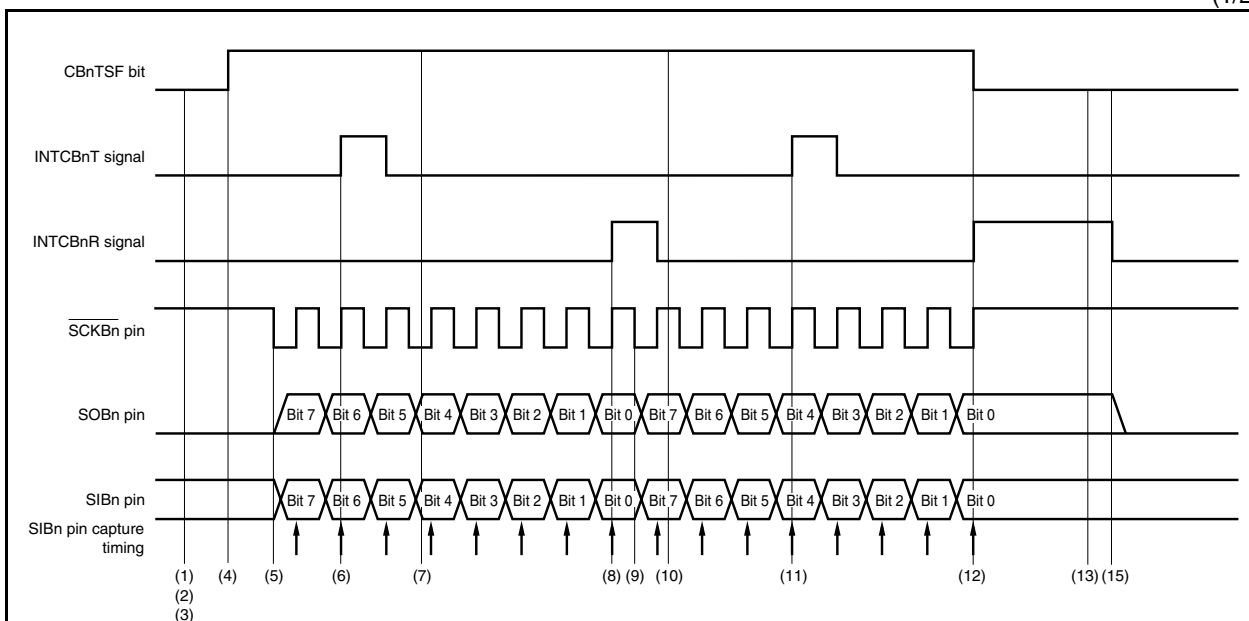
(1) Operation flow



- Remarks**
1. The broken lines indicate the hardware processing.
  2. The numbers in this figure correspond to the processing numbers in (2) Operation timing.
  3. n = 0 to 5

## (2) Operation timing

(1/2)



- (1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock ( $f_{\text{CCLK}}$ ) = external clock (SCKBn), and slave mode.
- (2) Write 00H to the CBnCTL2 register, and set the transfer data length to 8 bits.
- (3) Write E3H to the CBnCTL0 register, and select the transmission/reception mode, MSB first, and continuous transfer mode at the same time as enabling the operation of the communication clock ( $f_{\text{CCLK}}$ ).
- (4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and the device waits for a serial clock input.
- (5) When a serial clock is input, output the transmit data to the SOBn pin in synchronization with the serial clock, and capture the receive data of the SIBn pin.
- (6) When transfer of the transmit data from the CBnTX register to the shift register is completed and writing to the CBnTX register is enabled, the transmission enable interrupt request signal (INTCBnT) is generated.
- (7) To continue transmission, write the transmit data to the CBnTX register again after the INTCBnT signal is generated.
- (8) When reception of the transfer data length set with the CBnCTL2 register is completed, the reception completion interrupt request signal (INTCBnR) is generated, and reading of the CBnRX register is enabled.
- (9) When a serial clock is input continuously, continuous transmission/reception is started.
- (10) Read the CBnRX register.
- (11) When transfer of the transmit data from the CBnTX register to the shift register is completed and writing to the CBnTX register is enabled, the INTCBnT signal is generated. To end continuous transmission/reception with the current transmission/reception, do not write to the CBnTX register.

**Remark** n = 0 to 5

- (12) When the clock of the transfer data length set with the CBnCTL2 register is input without writing to the CBnTX register, the INTCBnR signal is generated. Clear the CBnTSF bit to 0 to end transmission/reception.
- (13) When the INTCBnR signal is generated, read the CBnRX register.
- (14) If an overrun error occurs, write the CBnSTR.CBnOVE bit = 0, and clear the error flag.
- (15) To release the transmission/reception enable status, write the CBnCTL0.CBnPWR bit = 0, the CBnCTL0.CBnTXE bit = 0, and the CBnCTL0.CBnRXE bit = 0 after checking that the CBnTSF bit = 0.

**Remark** n = 0 to 5



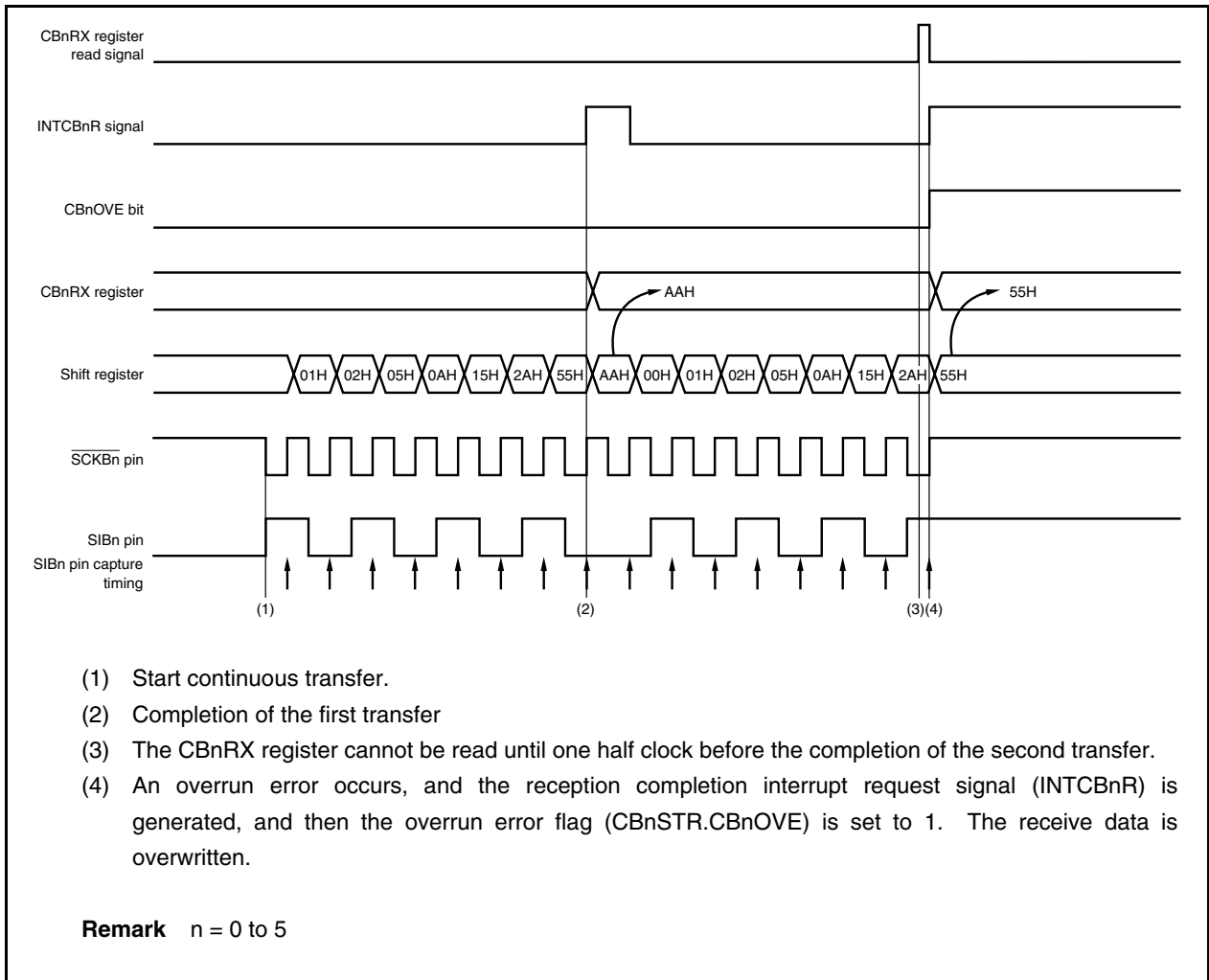
### 16.6.13 Reception error

When transfer is performed with reception enabled (CBnCTL0.CBnRXE bit = 1) in the continuous transfer mode, the reception completion interrupt request signal (INTCBnR) is generated again when the next receive operation is completed before the CBnRX register is read after the INTCBnR signal is generated, and the overrun error flag (CBnSTR.CBnOVE) is set to 1.

Even if an overrun error has occurred, the previous receive data is lost since the CBnRX register is updated. Even if a reception error has occurred, the INTCBnR signal is generated again upon the next reception completion if the CBnRX register is not read.

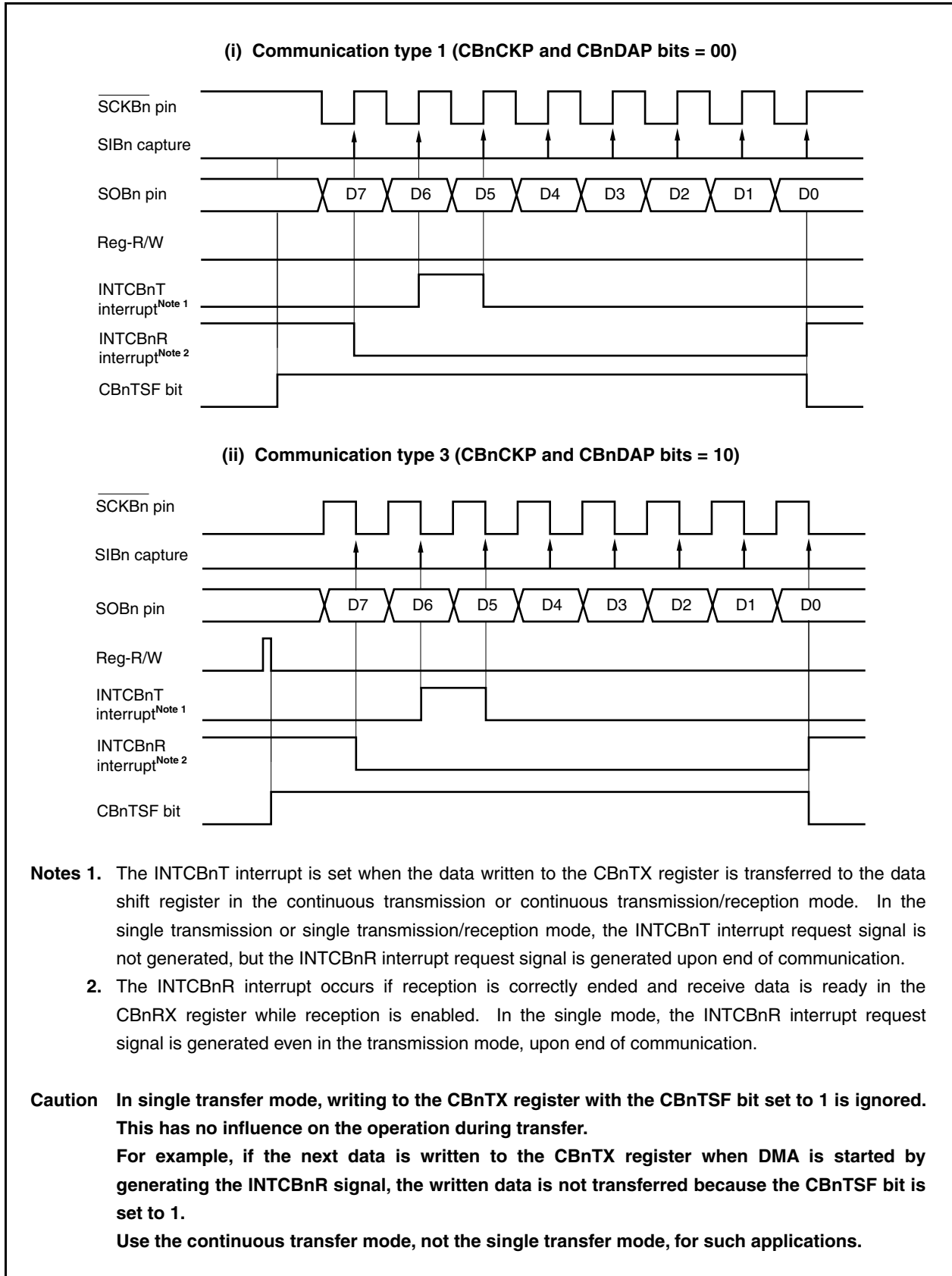
To avoid an overrun error, complete reading the CBnRX register until one half clock before sampling the last bit of the next receive data from the INTCBnR signal generation.

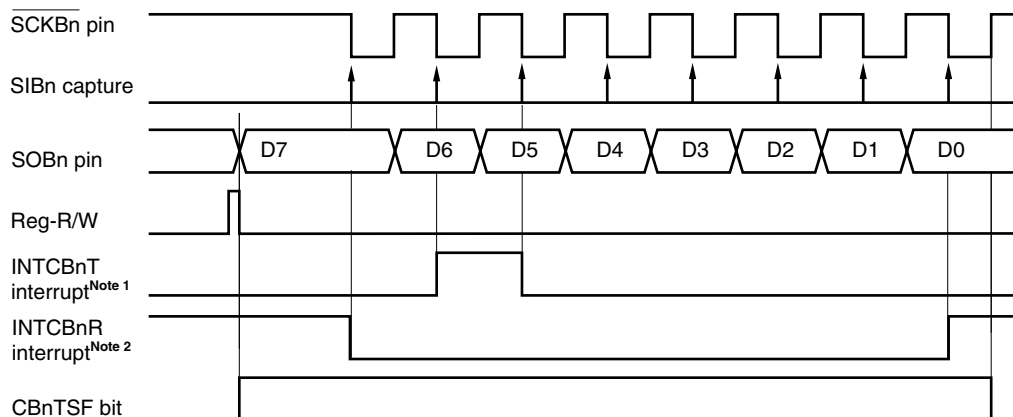
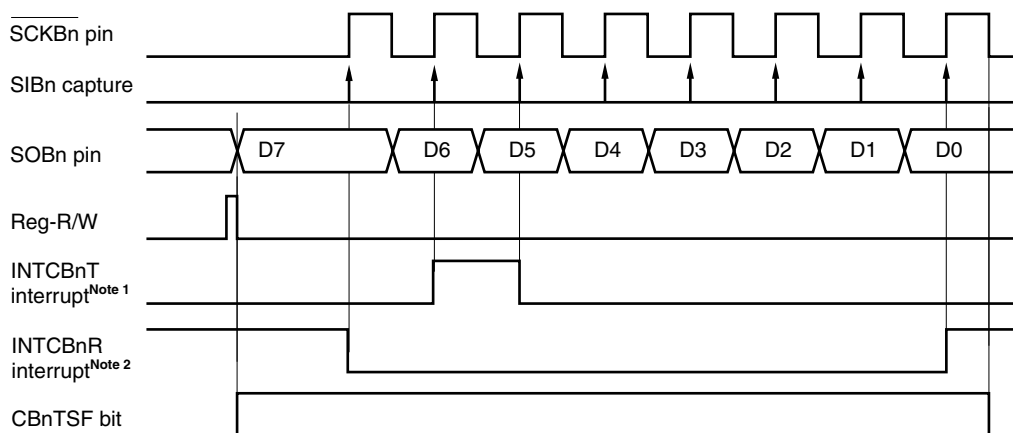
#### (1) Operation timing



## 16.6.14 Clock timing

(1/2)



**(iii) Communication type 2 (CBnCKP and CBnDAP bits = 01)****(iv) Communication type 4 (CBnCKP and CBnDAP bits = 11)**

**Notes 1.** The INTCBnT interrupt is set when the data written to the CBnTX register is transferred to the data shift register in the continuous transmission or continuous transmission/reception modes. In the single transmission or single transmission/reception modes, the INTCBnT interrupt request signal is not generated, but the INTCBnR interrupt request signal is generated upon end of communication.

**2.** The INTCBnR interrupt occurs if reception is correctly ended and receive data is ready in the CBnRX register while reception is enabled. In the single mode, the INTCBnR interrupt request signal is generated even in the transmission mode, upon end of communication.

**Caution** In single transfer mode, writing to the CBnTX register with the CBnTSM bit set to 1 is ignored. This has no influence on the operation during transfer.

For example, if the next data is written to the CBnTX register when DMA is started by generating the INTCBnR signal, the written data is not transferred because the CBnTSM bit is set to 1.

Use the continuous transfer mode, not the single transfer mode, for such applications.

## 16.7 Output Pins

### (1) $\overline{\text{SCKBn}}$ pin

When CSIBn operation is disabled (CBnCTL0.CBnPWR bit = 0), the  $\overline{\text{SCKBn}}$  pin output status is as follows.

| CBnCKP | CBnCKS2          | CBnCKS1 | CBnCKS0 | $\overline{\text{SCKBn}}$ Pin Output |
|--------|------------------|---------|---------|--------------------------------------|
| 0      | 1                | 1       | 1       | High impedance                       |
|        | Other than above |         |         | Fixed to high level                  |
| 1      | 1                | 1       | 1       | High impedance                       |
|        | Other than above |         |         | Fixed to low level                   |

**Remarks 1.** The output level of the  $\overline{\text{SCKBn}}$  pin changes if any of the CBnCTL1.CBnCKP and CBnCKS2 to CBnCKS0 bits is rewritten.

**2.** n = 0 to 5

### (2) SOBn pin

When CSIBn operation is disabled (CBnPWR bit = 0), the SOBn pin output status is as follows.

| CBnTXE | CBnDAP | CBnDIR | SOBn Pin Output              |
|--------|--------|--------|------------------------------|
| 0      | ×      | ×      | Fixed to low level           |
| 1      | 0      | ×      | SOBn latch value (low level) |
|        | 1      | 0      | CBnTX0 value (MSB)           |
|        |        | 1      | CBnTX0 value (LSB)           |

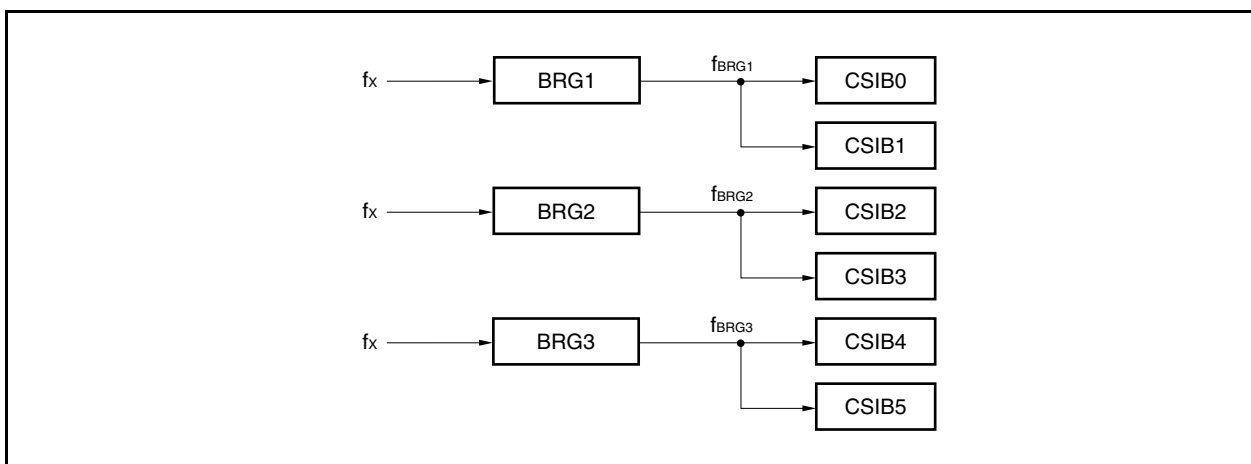
**Remarks 1.** The SOBn pin output changes when any one of the CBnCTL0.CBnTXE, CBnCTL0.CBnDIR bits, and CBnCTL1.CBnDAP bit is rewritten.

**2.** ×: Don't care

**3.** n = 0 to 5

### 16.8 Baud Rate Generator

The BRG1 to BRG3 and CSIB0 to CSIB5 baud rate generators are connected as shown in the following block diagram.



#### (1) Prescaler mode registers 1 to 3 (PRSM1 to PRSM3)

The PRSM1 to PRSM3 registers control generation of the baud rate signal for CSIB.

These registers can be read or written in 8-bit or 1-bit units.

Reset sets these registers to 00H.

After reset: 00H    R/W    Address: PRSM1 FFFFF320H, PRSM2 FFFFF324H, PRSM3 FFFFF328H

|                       |   |   |   |       |   |   |        |        |
|-----------------------|---|---|---|-------|---|---|--------|--------|
|                       | 7 | 6 | 5 | <4>   | 3 | 2 | 1      | 0      |
| PRSMm<br>(m = 1 to 3) | 0 | 0 | 0 | BGCEm | 0 | 0 | BGCSm1 | BGCSm0 |

|       |  |                  |
|-------|--|------------------|
| BGCEm |  | Baud rate output |
| 0     |  | Disabled         |
| 1     |  | Enabled          |

| BGCSm1 | BGCSm0 | Input clock selection ( $f_{BGCSm}$ ) | Setting value (k) |
|--------|--------|---------------------------------------|-------------------|
| 0      | 0      | $f_{xx}$                              | 0                 |
| 0      | 1      | $f_{xx}/2$                            | 1                 |
| 1      | 0      | $f_{xx}/4$                            | 2                 |
| 1      | 1      | $f_{xx}/8$                            | 3                 |

**Cautions**

1. Do not rewrite the PRSMm register during operation.
2. Set the PRSMm register before setting the BGCEm bit to 1.

**(2) Prescaler compare registers 1 to 3 (PRSCM1 to PRSCM3)**

The PRSCM1 to PRSCM3 registers are 8-bit compare registers.

These registers can be read or written in 8-bit units.

Reset sets these registers to 00H.

After reset: 00H    R/W    Address: PRSCM1 FFFF321H, PRSCM2 FFFF325H,  
PRSCM3 FFFF329H

|                        |         |         |         |         |         |         |         |         |
|------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| PRSCMm<br>(m = 1 to 3) | 7       | 6       | 5       | 4       | 3       | 2       | 1       | 0       |
|                        | PRSCMm7 | PRSCMm6 | PRSCMm5 | PRSCMm4 | PRSCMm3 | PRSCMm2 | PRSCMm1 | PRSCMm0 |

**Cautions**

1. Do not rewrite the PRSCMm register during operation.
2. Set the PRSCMm register before setting the PRSMm.BGCEm bit to 1.

**16.8.1 Baud rate generation**

The transmission/reception clock is generated by dividing the main clock. The baud rate generated from the main clock is obtained by the following equation.

$$f_{BRGm} = \frac{f_{xx}}{2^{k+1} \times N}$$

**Caution** Set  $f_{BRGm}$  to 8 MHz or lower.

**Remark**  $f_{BRGm}$ : BRGm count clock

$f_{xx}$ : Main clock oscillation frequency

k: PRSMm register setting value = 0 to 3

N: PRSCMm register setting value = 1 to 256

However, N = 256 only when PRSCMm register is set to 00H.

m = 1 to 3

## 16.9 Cautions

- (1) When transferring transmit data and receive data using DMA transfer, error processing cannot be performed even if an overrun error occurs during serial transfer. Check that the no overrun error has occurred by reading the CBnSTR.CBnOVE bit after DMA transfer has been completed.
- (2) In regards to registers that are forbidden from being rewritten during operations (CBnCTL0.CBnPWR bit is 1), if rewriting has been carried out by mistake during operations, set the CBnCTL0.CBnPWR bit to 0 once, then initialize CSIBn.

Registers to which rewriting during operation are prohibited are shown below.

- CBnCTL0 register: CBnTXE, CBnRXE, CBnDIR, CBnTMS bits
- CBnCTL1 register: CBnCKP, CBnDAP, CBnCKS2 to CBnCKS0 bits
- CBnCTL2 register: CBnCL3 to CBnCL0 bits

- (3) In communication type 2 and 4 (CBnCTL1.CBnDAP bit = 1), the CBnSTR.CBnTSF bit is cleared half a  $\overline{\text{SCKBn}}$  clock after occurrence of a reception complete interrupt (INTCBnR).

In the single transfer mode, writing the next transmit data is ignored during communication (CBnTSF bit = 1), and the next communication is not started. Also if reception-only communication (CBnCTL0.CBnTXE bit = 0, CBnCTL0.CBnRXE bit = 1) is set, the next communication is not started even if the receive data is read during communication (CBnTSF bit = 1).

Therefore, when using the single transfer mode with communication type 2 or 4 (CBnDAP bit = 1), pay particular attention to the following.

- To start the next transmission, confirm that CBnTSF bit = 0 and then write the transmit data to the CBnTX register.
- To perform the next reception continuously when reception-only communication (CBnTXE bit = 0, CBnRXE bit = 1) is set, confirm that CBnTSF bit = 0 and then read the CBnRX register.

Or, use the continuous transfer mode instead of the single transfer mode. Use of the continuous transfer mode is recommended especially for using DMA.

**Remark** n = 0 to 5

## CHAPTER 17 I<sup>2</sup>C BUS

To use the I<sup>2</sup>C bus function, use the P38/SDA00, P39/SCL00, P40/SDA01, P41/SCL01, P90/SDA02, and P91/SCL02 pins as the serial transmit/receive data I/O pins (SDA00 to SDA02) and serial clock I/O pins (SCL00 to SCL02), respectively, and set them to N-ch open-drain output.

### 17.1 Mode Switching of I<sup>2</sup>C Bus and Other Serial Interfaces

#### 17.1.1 UARTA2 and I<sup>2</sup>C00 mode switching

In the V850ES/JJ3, UARTA2 and I<sup>2</sup>C00 are alternate functions of the same pin and therefore cannot be used simultaneously. Set I<sup>2</sup>C00 in advance, using the PMC3 and PFC3 registers, before use.

**Caution** The transmit/receive operation of UARTA2 and I<sup>2</sup>C00 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.

**Figure 17-1. UARTA2 and I<sup>2</sup>C00 Mode Switch Settings**

After reset: 0000H    R/W    Address: FFFFF446H, FFFFF447H

|      |    |    |       |       |       |       |       |       |
|------|----|----|-------|-------|-------|-------|-------|-------|
|      | 15 | 14 | 13    | 12    | 11    | 10    | 9     | 8     |
| PMC3 | 0  | 0  | 0     | 0     | 0     | 0     | PMC39 | PMC38 |
|      | 7  | 6  | 5     | 4     | 3     | 2     | 1     | 0     |
|      | 0  | 0  | PMC35 | PMC34 | PMC33 | PMC32 | PMC31 | PMC30 |

After reset: 0000H    R/W    Address: FFFFF466H, FFFFF467H

|      |    |    |       |       |       |       |       |       |
|------|----|----|-------|-------|-------|-------|-------|-------|
|      | 15 | 14 | 13    | 12    | 11    | 10    | 9     | 8     |
| PFC3 | 0  | 0  | 0     | 0     | 0     | 0     | PFC39 | PFC38 |
|      | 7  | 6  | 5     | 4     | 3     | 2     | 1     | 0     |
|      | 0  | 0  | PFC35 | PFC34 | PFC33 | PFC32 | PFC31 | PFC30 |

| PMC3n | PFC3n | Operation mode          |
|-------|-------|-------------------------|
| 0     | ×     | Port I/O mode           |
| 1     | 0     | UARTA2 mode             |
| 1     | 1     | I <sup>2</sup> C00 mode |

**Remarks**

1. n = 8, 9
2. × = don't care

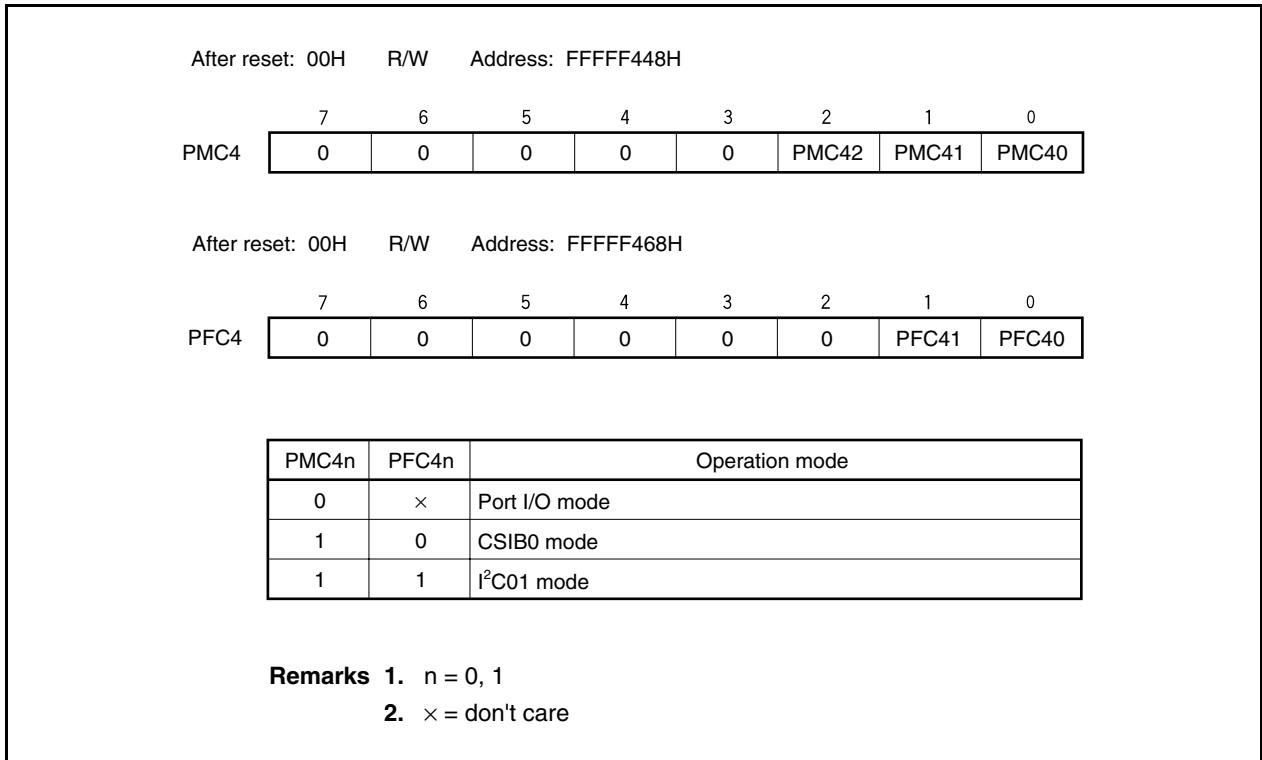


**17.1.2 CSIB0 and I<sup>2</sup>C01 mode switching**

In the V850ES/JJ3, CSIB0 and I<sup>2</sup>C01 are alternate functions of the same pin and therefore cannot be used simultaneously. Set I<sup>2</sup>C01 in advance, using the PMC4 and PFC4 registers, before use.

**Caution** The transmit/receive operation of CSIB0 and I<sup>2</sup>C01 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.

**Figure 17-2. CSIB0 and I<sup>2</sup>C01 Mode Switch Settings**

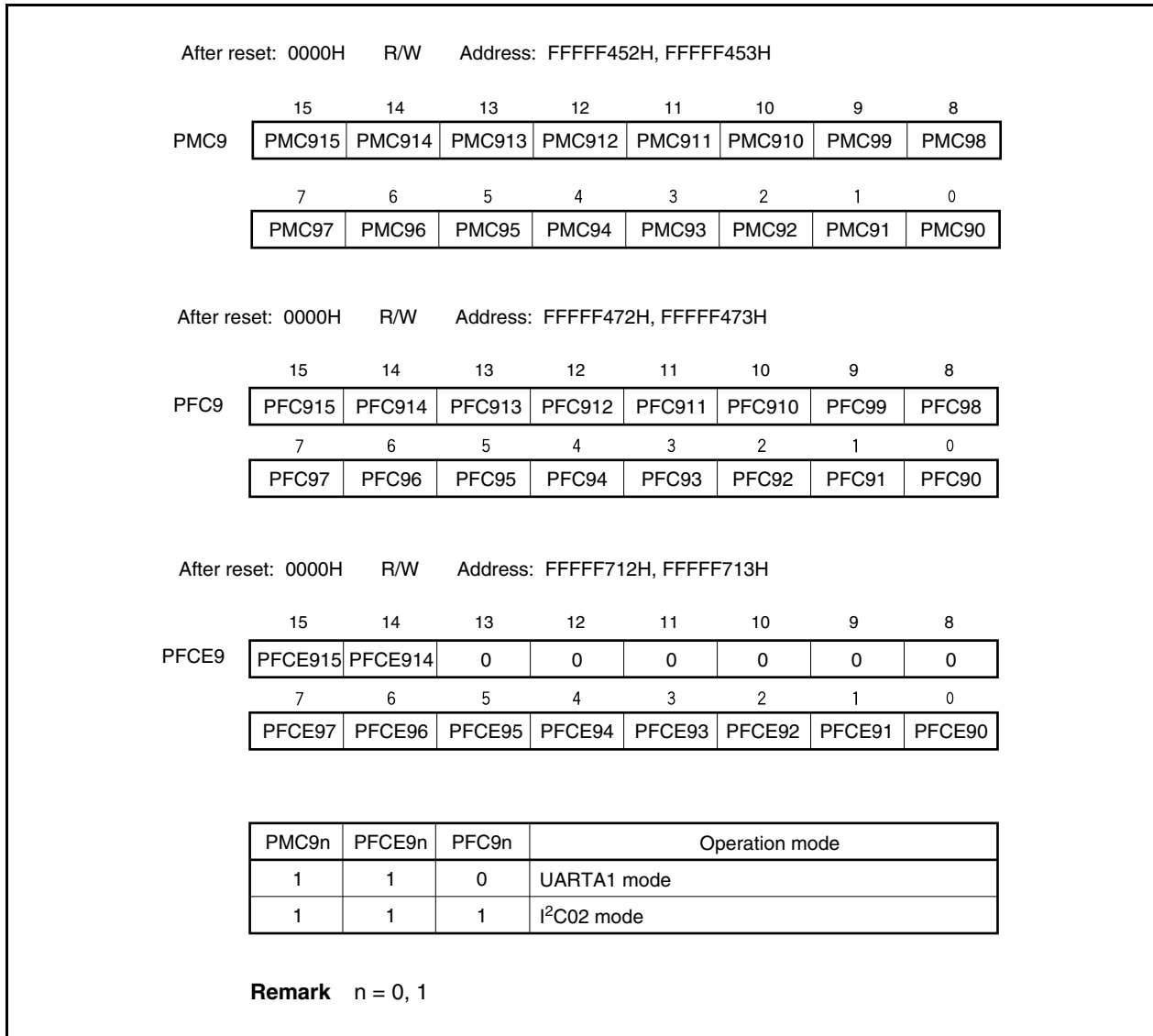


17.1.3 UARTA1 and I<sup>2</sup>C02 mode switching

In the V850ES/JJ3, UARTA1 and I<sup>2</sup>C02 are alternate functions of the same pin and therefore cannot be used simultaneously. Set I<sup>2</sup>C02 in advance, using the PMC9, PFC9, and PMCE9 registers, before use.

**Caution** The transmit/receive operation of UARTA1 and I<sup>2</sup>C02 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.

Figure 17-3. UARTA1 and I<sup>2</sup>C02 Mode Switch Settings



## 17.2 Features

I<sup>2</sup>C00 to I<sup>2</sup>C02 have the following two modes.

- Operation stopped mode
- I<sup>2</sup>C (Inter IC) bus mode (multimasters supported)

### (1) Operation stopped mode

In this mode, serial transfers are not performed, thus enabling a reduction in power consumption.

### (2) I<sup>2</sup>C bus mode (multimaster support)

This mode is used for 8-bit data transfers with several devices via two lines: a serial clock pin (SCL0n) and a serial data bus pin (SDA0n).

This mode complies with the I<sup>2</sup>C bus format and the master device can generate "start condition", "address", "transfer direction specification", "data", and "stop condition" data to the slave device via the serial data bus. The slave device automatically detects the received statuses and data by hardware. This function can simplify the part of an application program that controls the I<sup>2</sup>C bus.

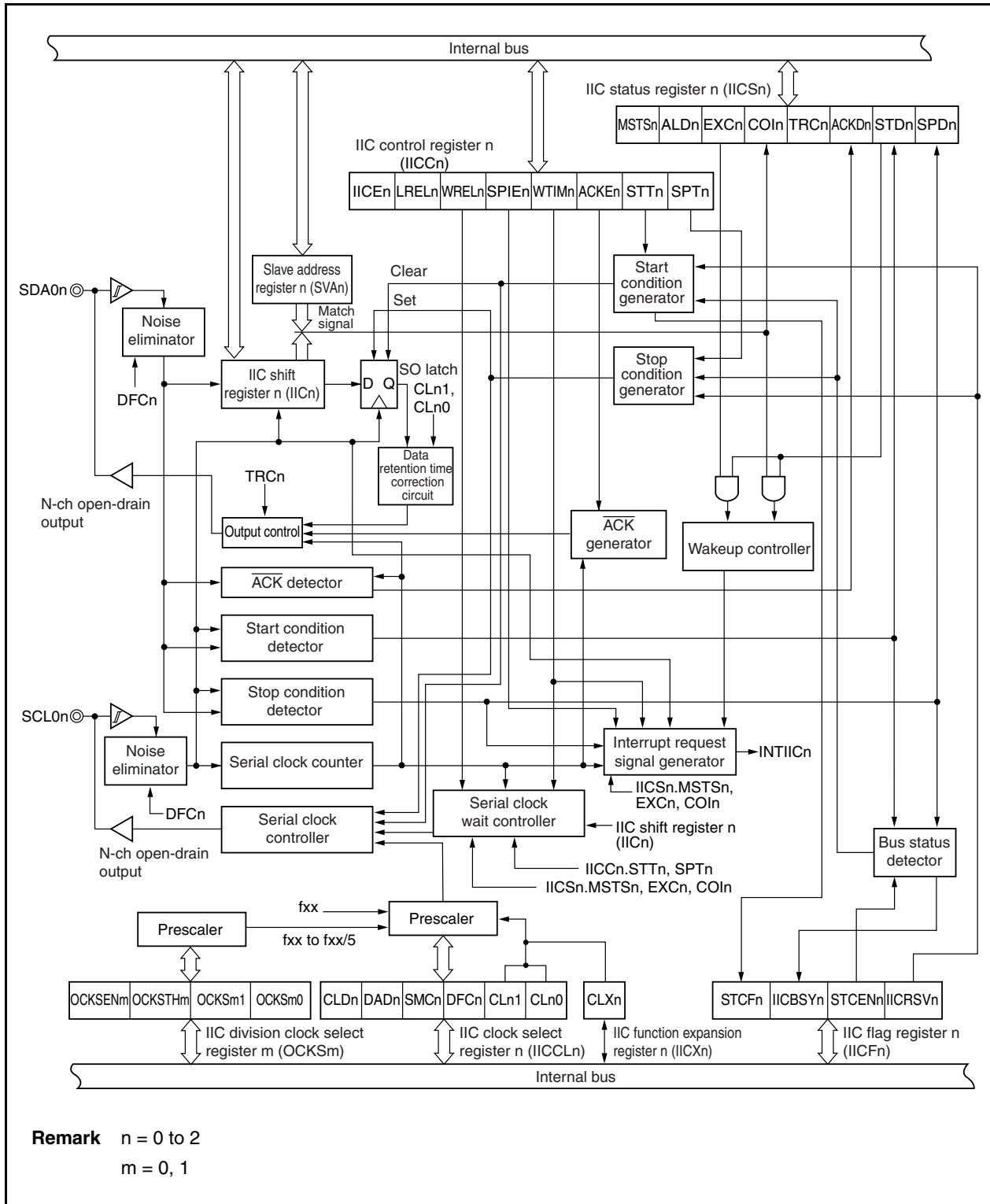
Since SCL0n and SDA0n pins are used for N-ch open-drain outputs, I<sup>2</sup>C0n requires pull-up resistors for the serial clock line and the serial data bus line.

**Remark** n = 0 to 2

### 17.3 Configuration

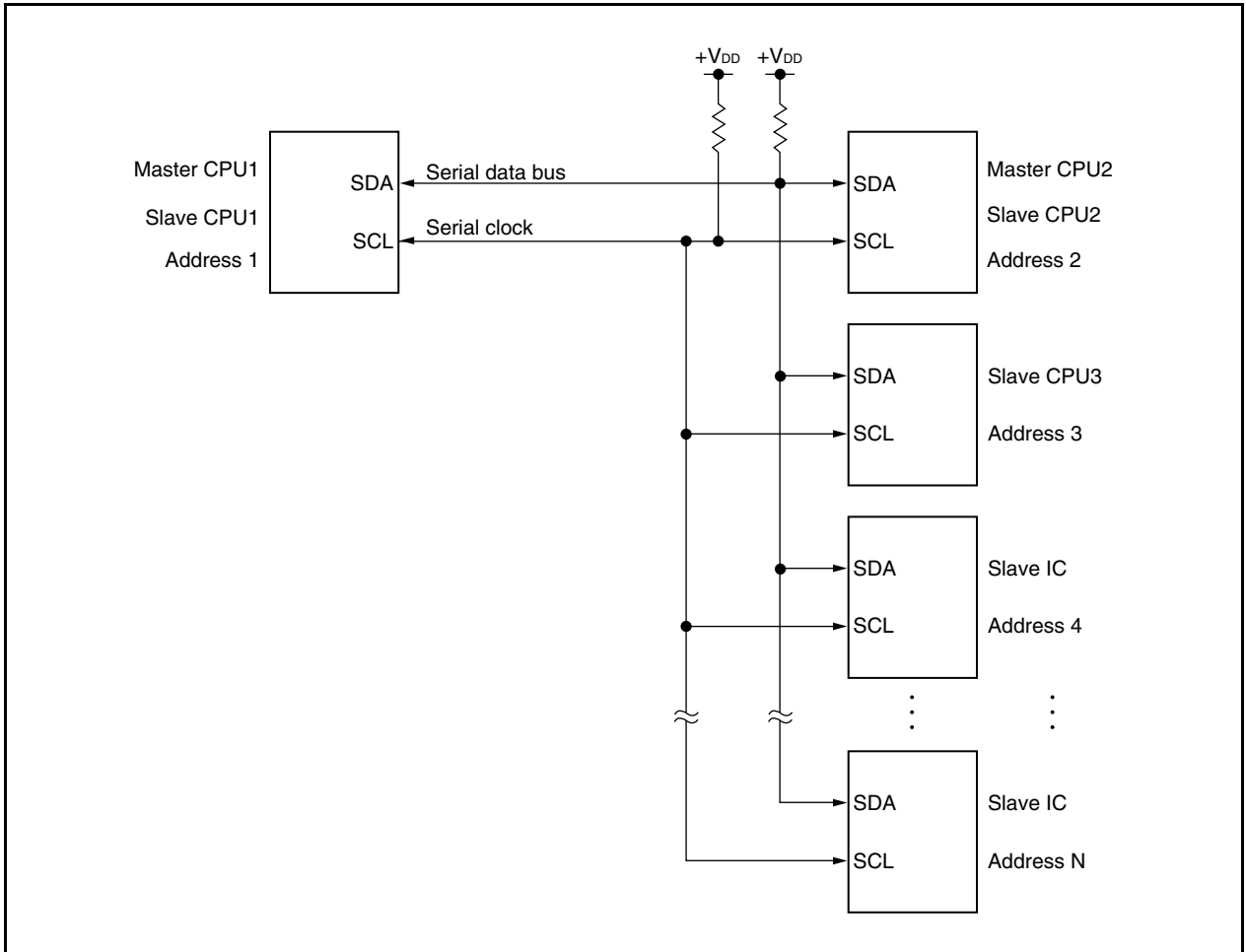
The block diagram of the I<sup>2</sup>C0n is shown below.

Figure 17-4. Block Diagram of I<sup>2</sup>C0n



A serial bus configuration example is shown below.

**Figure 17-5. Serial Bus Configuration Example Using I<sup>2</sup>C Bus**



I<sup>2</sup>C0n includes the following hardware (n = 0 to 2).

**Table 17-1. Configuration of I<sup>2</sup>C0n**

| Item              | Configuration  |
|-------------------|--|
| Registers         | IIC shift register n (IICn)<br>Slave address register n (SVAn)   |
| Control registers | IIC control register n (IICCn)<br>IIC status register n (IICSn)<br>IIC flag register n (IICFn)<br>IIC clock select register n (IICCLn)<br>IIC function expansion register n (IICXn)<br>IIC division clock select registers 0, 1 (OCKS0, OCKS1) |

**(1) IIC shift register n (IICn)**

The IICn register converts 8-bit serial data into 8-bit parallel data and vice versa, and can be used for both transmission and reception (n = 0 to 2).

Write and read operations to the IICn register are used to control the actual transmit and receive operations.

This register can be read or written in 8-bit units.

Reset sets this register to 00H.

**(2) Slave address register n (SVAn)**

The SVAn register sets local addresses when in slave mode (n = 0 to 2).

This register can be read or written in 8-bit units.

Reset sets this register to 00H.

**(3) SO latch**

The SO latch is used to retain the output level of the SDA0n pin (n = 0 to 2).

**(4) Wakeup controller**

This circuit generates an interrupt request signal (INTIICn) when the address received by this register matches the address value set to the SVAn register or when an extension code is received (n = 0 to 2).

**(5) Prescaler**

This selects the sampling clock to be used.

**(6) Serial clock counter**

This counter counts the serial clocks that are output and the serial clocks that are input during transmit/receive operations and is used to verify that 8-bit data was transmitted or received.

**(7) Interrupt request signal generator**

This circuit controls the generation of interrupt request signals (INTIICn).

An I<sup>2</sup>C interrupt is generated following either of two triggers.

- Falling edge of eighth or ninth clock of the serial clock (set by IICCN.WTIMn bit)
- Interrupt occurrence due to stop condition detection (set by IICCN.SPIEn bit)

**Remark** n = 0 to 2

**(8) Serial clock controller**

In master mode, this circuit generates the clock output via the SCL0n pin from the sampling clock (n = 0 to 2).

**(9) Serial clock wait controller**

This circuit controls the wait timing.

**(10)  $\overline{\text{ACK}}$  generator, stop condition detector, start condition detector, and  $\overline{\text{ACK}}$  detector**

These circuits are used to generate and detect various statuses.

**(11) Data hold time correction circuit**

This circuit generates the hold time for data corresponding to the falling edge of the SCL0n pin.

**(12) Start condition generator**

A start condition is generated when the IICCN.STTn bit is set.

However, in the communication reservation disabled status (IICFn.IICRSVn bit = 1), this request is ignored and the IICFn.STCFn bit is set to 1 if the bus is not released (IICFn.IICBSYn bit = 1).

**(13) Stop condition generator**

A stop condition is generated when the IICCN.SPTn bit is set.

**(14) Bus status detector**

Whether the bus is released or not is ascertained by detecting a start condition and stop condition.

However, the bus status cannot be detected immediately after operation, so set the bus status detector to the initial status by using the IICFn.STCENn bit.

## 17.4 Registers

I<sup>2</sup>C00 to I<sup>2</sup>C02 are controlled by the following registers.

- IIC control registers 0 to 2 (IICC0 to IICC2)
- IIC status registers 0 to 2 (IICS0 to IICS2)
- IIC flag registers 0 to 2 (IICF0 to IICF2)
- IIC clock select registers 0 to 2 (IICCL0 to IICCL2)
- IIC function expansion registers 0 to 2 (IICX0 to IICX2)
- IIC division clock select registers 0, 1 (OCKS0, OCKS1)

The following registers are also used.

- IIC shift registers 0 to 2 (IIC0 to IIC2)
- Slave address registers 0 to 2 (SVA0 to SVA2)

**Remark** For the alternate-function pin settings, see **Table 4-19 Using Port Pins as Alternate-Function Pins**.

### (1) IIC control registers 0 to 2 (IICC0 to IICC2)

The IICn register enables/stops I<sup>2</sup>C0n operations, sets the wait timing, and sets other I<sup>2</sup>C operations (n = 0 to 2).

This register can be read or written in 8-bit or 1-bit units. However, set the SPIEn, WTIMn, and ACKEn bits when the IICEn bit is 0 or during the wait period. When setting the IICEn bit from "0" to "1", these bits can also be set at the same time.

Reset sets this register to 00H.



After reset: 00H      R/W      Address: IICC0 FFFFFFFD82H, IICC1 FFFFFFFD92H, IICC2 FFFFFFFDA2H

|       |       |       |       |       |       |       |      |      |
|-------|-------|-------|-------|-------|-------|-------|------|------|
|       | <7>   | <6>   | <5>   | <4>   | <3>   | <2>   | <1>  | <0>  |
| IICcn | IICEn | LRELn | WRELn | SPIEn | WTIMn | ACKEn | STTn | SPTn |

(n = 0 to 2)

|   |   |
|---|---|
| IICEn   | Specification of I <sup>2</sup> Cn operation enable/disable                             |
| 0   | Operation stopped. IICSn register reset <sup>Note 1</sup> . Internal operation stopped. |
| 1   | Operation enabled.  |
| Be sure to set this bit to 1 when the SCL0n and SDA0n lines are high level.                       |   |
| Condition for clearing (IICEn bit = 0)  |   |
| <ul style="list-style-type: none"> <li>• Cleared by instruction</li> <li>• After reset</li> </ul> |   |
| Condition for setting (IICEn bit = 1)   |   |
| <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul>                            |   |

|   |  |
|---|--|
| LRELn <sup>Note 2</sup>   | Exit from communications   |
| 0   | Normal operation   |
| 1   | This exits from the current communication operation and sets standby mode. This setting is automatically cleared after being executed. Its uses include cases in which a locally irrelevant extension code has been received.<br>The SCL0n and SDA0n lines are set to high impedance.<br>The STTn and SPTn bits and the MSTSn, EXCn, COIn, TRCn, ACKDn, and STDn bits of the IICSn register are cleared. |
| The standby mode following exit from communications remains in effect until the following communication entry conditions are met.   |  |
| <ul style="list-style-type: none"> <li>• After a stop condition is detected, restart is in master mode.</li> <li>• An address match occurs or an extension code is received after the start condition.</li> </ul> |  |
| Condition for clearing (LRELn bit = 0)  |  |
| <ul style="list-style-type: none"> <li>• Automatically cleared after execution</li> <li>• After reset</li> </ul>  |  |
| Condition for setting (LRELn bit = 1)   |  |
| <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul>  |  |

|  |  |
|--|--|
| WRELn <sup>Note 2</sup>  | Wait state cancellation control  |
| 0  | Wait state not canceled  |
| 1  | Wait state canceled. This setting is automatically cleared after wait state is canceled. |
| Condition for clearing (WRELn bit = 0)   |  |
| <ul style="list-style-type: none"> <li>• Automatically cleared after execution</li> <li>• After reset</li> </ul> |  |
| Condition for setting (WRELn bit = 1)  |  |
| <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul>   |  |

- Notes**
1. The IICSn register, IICFn.STCFn and IICFn.IICBSYn bits, and IICCLn.CLDn and IICCLn.DADn bits are reset.
  2. This flag's signal is invalid when the IICEn bit = 0.

**Caution** If the I<sup>2</sup>Cn operation is enabled (IICEn bit = 1) when the SCL0n line is high level and the SDA0n line is low level, the start condition is detected immediately. To avoid this, after enabling the I<sup>2</sup>Cn operation, immediately set the LRELn bit to 1 with a bit manipulation instruction.

**Remark** The LRELn and WRELn bits are 0 when read after the data has been set.

|   |  |  |
|---|--|--|
| SPIEn <sup>Note</sup>   | Enable/disable generation of interrupt request when stop condition is detected |  |
| 0   | Disabled   |  |
| 1   | Enabled  |  |
| Condition for clearing (SPIEn bit = 0)  |  | Condition for setting (SPIEn bit = 1)                                  |
| <ul style="list-style-type: none"> <li>• Cleared by instruction</li> <li>• After reset</li> </ul> |  | <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul> |

|  |   |  |
|--|---|--|
| WTIMn <sup>Note</sup>  | Control of wait state and interrupt request generation  |  |
| 0  | Interrupt request is generated at the eighth clock's falling edge.<br>Master mode: After output of eight clocks, clock output is set to low level and the wait state is set.<br>Slave mode: After input of eight clocks, the clock is set to low level and the wait state is set for the master device. |  |
| 1  | Interrupt request is generated at the ninth clock's falling edge.<br>Master mode: After output of nine clocks, clock output is set to low level and the wait state is set.<br>Slave mode: After input of nine clocks, the clock is set to low level and the wait state is set for the master device.    |  |
| During address transfer, an interrupt occurs at the falling edge of the ninth clock regardless of this bit setting. This bit setting becomes valid when the address transfer is completed. In master mode, a wait state is inserted at the falling edge of the ninth clock during address transfer. For a slave device that has received a local address, a wait state is inserted at the falling edge of the ninth clock after ACK is generated. When the slave device has received an extension code, however, a wait state is inserted at the falling edge of the eighth clock. |   |  |
| Condition for clearing (WTIMn bit = 0)   |   | Condition for setting (WTIMn bit = 1)                                  |
| <ul style="list-style-type: none"> <li>• Cleared by instruction</li> <li>• After reset</li> </ul>  |   | <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul> |

|  |  |  |
|--|--|--|
| ACKEn <sup>Note</sup>  | Acknowledgment control   |  |
| 0  | Acknowledgment disabled.   |  |
| 1  | Acknowledgment enabled. During the ninth clock period, the SDA0n line is set to low level. |  |
| The ACKEn bit setting is invalid for address reception by the slave device. In this case, $\overline{\text{ACK}}$ is generated when the addresses match.<br>However, the ACKEn bit setting is valid for reception of the extension code. Set the ACKEn bit in the system that receives the extension code. |  |  |
| Condition for clearing (ACKEn bit = 0)   |  | Condition for setting (ACKEn bit = 1)                                  |
| <ul style="list-style-type: none"> <li>• Cleared by instruction</li> <li>• After reset</li> </ul>  |  | <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul> |

**Note** This flag's signal is invalid when the IICEn bit = 0.

**Remark** n = 0 to 2

| STTn  | Start condition trigger   |                                       |                                      |  |  |
|---|---|---------------------------------------|--------------------------------------|--|--|
| 0   | Start condition is not generated.   |                                       |                                      |  |  |
| 1   | <p>When bus is released (in STOP mode):<br/>                     A start condition is generated (for starting as master). The SDA0n line is changed from high level to low level while the SCL0n line is high level and then the start condition is generated. Next, after the rated amount of time has elapsed, the SCL0n line is changed to low level.</p> <p>During communication with a third party:<br/>                     If the communication reservation function is enabled (IICFn.IICRSVn bit = 0)<br/>                     • This trigger functions as a start condition reserve flag. When set to 1, it releases the bus and then automatically generates a start condition.</p> <p>If the communication reservation function is disabled (IICRSVn = 1)<br/>                     • The IICFn.STCFn bit is set to 1 to clear the information set (1) to the STTn bit. This trigger does not generate a start condition.</p> <p>In the wait state (when master device):<br/>                     A restart condition is generated after the wait state is released.</p> |                                       |                                      |  |  |
| <p>Cautions concerning set timing</p> <p>For master reception: Cannot be set to 1 during transfer. Can be set to 1 only when the ACKEn bit has been set to 0 and the slave has been notified of final reception.</p> <p>For master transmission: A start condition cannot be generated normally during the ACK period. Set to 1 during the wait period that follows output of the ninth clock.</p> <p>For slave: Even when the communication reservation function is disabled (IICRSVn bit = 1), the communication reservation status is entered.</p> <ul style="list-style-type: none"> <li>• Setting to 1 at the same time as the SPTn bit is prohibited.</li> <li>• When the STTn bit is set to 1, setting the STTn bit to 1 again is disabled until the setting is cleared to 0.</li> </ul> |   |                                       |                                      |  |  |
| <table border="1"> <thead> <tr> <th>Condition for clearing (STTn bit = 0)</th> <th>Condition for setting (STTn bit = 1)</th> </tr> </thead> <tbody> <tr> <td> <ul style="list-style-type: none"> <li>• When the STTn bit is set to 1 in the communication reservation disabled status</li> <li>• Cleared by loss in arbitration</li> <li>• Cleared after start condition is generated by master device</li> <li>• When the LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit = 0 (operation stop)</li> <li>• After reset</li> </ul> </td> <td> <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul> </td> </tr> </tbody> </table>  |   | Condition for clearing (STTn bit = 0) | Condition for setting (STTn bit = 1) | <ul style="list-style-type: none"> <li>• When the STTn bit is set to 1 in the communication reservation disabled status</li> <li>• Cleared by loss in arbitration</li> <li>• Cleared after start condition is generated by master device</li> <li>• When the LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit = 0 (operation stop)</li> <li>• After reset</li> </ul> | <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul> |
| Condition for clearing (STTn bit = 0)   | Condition for setting (STTn bit = 1)  |                                       |                                      |  |  |
| <ul style="list-style-type: none"> <li>• When the STTn bit is set to 1 in the communication reservation disabled status</li> <li>• Cleared by loss in arbitration</li> <li>• Cleared after start condition is generated by master device</li> <li>• When the LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit = 0 (operation stop)</li> <li>• After reset</li> </ul>  | <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul>  |                                       |                                      |  |  |

- Remarks**
1. The STTn bit is 0 if it is read immediately after data setting.
  2. n = 0 to 2

| SPTn  | Stop condition trigger  |                                       |                                      |   |  |
|---|---|---------------------------------------|--------------------------------------|---|--|
| 0   | Stop condition is not generated.  |                                       |                                      |   |  |
| 1   | Stop condition is generated (termination of master device's transfer).<br>After the SDA0n line goes to low level, either set the SCL0n line to high level or wait until the SCL0n pin goes to high level. Next, after the rated amount of time has elapsed, the SDA0n line is changed from low level to high level and a stop condition is generated. |                                       |                                      |   |  |
| <p>Cautions concerning set timing</p> <p>For master reception: Cannot be set to 1 during transfer.<br/>Can be set to 1 only when the ACKEn bit has been set to 0 and during the wait period after the slave has been notified of final reception.</p> <p>For master transmission: A stop condition cannot be generated normally during the <math>\overline{\text{ACK}}</math> reception period. Set to 1 during the wait period that follows output of the ninth clock.</p> <ul style="list-style-type: none"> <li>• Cannot be set to 1 at the same time as the STTn bit.</li> <li>• The SPTn bit can be set to 1 only when in master mode<sup>Note</sup>.</li> <li>• When the WTIMn bit has been set to 0, if the SPTn bit is set to 1 during the wait period that follows output of eight clocks, note that a stop condition will be generated during the high-level period of the ninth clock. The WTIMn bit should be changed from 0 to 1 during the wait period following output of eight clocks, and the SPTn bit should be set to 1 during the wait period that follows output of the ninth clock.</li> <li>• When the SPTn bit is set to 1, setting the SPTn bit to 1 again is disabled until the setting is cleared to 0.</li> </ul> |   |                                       |                                      |   |  |
| <table border="1"> <thead> <tr> <th>Condition for clearing (SPTn bit = 0)</th> <th>Condition for setting (SPTn bit = 1)</th> </tr> </thead> <tbody> <tr> <td> <ul style="list-style-type: none"> <li>• Cleared by loss in arbitration</li> <li>• Automatically cleared after stop condition is detected</li> <li>• When the LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit = 0 (operation stop)</li> <li>• After reset</li> </ul> </td> <td> <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul> </td> </tr> </tbody> </table>   |   | Condition for clearing (SPTn bit = 0) | Condition for setting (SPTn bit = 1) | <ul style="list-style-type: none"> <li>• Cleared by loss in arbitration</li> <li>• Automatically cleared after stop condition is detected</li> <li>• When the LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit = 0 (operation stop)</li> <li>• After reset</li> </ul> | <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul> |
| Condition for clearing (SPTn bit = 0)   | Condition for setting (SPTn bit = 1)  |                                       |                                      |   |  |
| <ul style="list-style-type: none"> <li>• Cleared by loss in arbitration</li> <li>• Automatically cleared after stop condition is detected</li> <li>• When the LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit = 0 (operation stop)</li> <li>• After reset</li> </ul>   | <ul style="list-style-type: none"> <li>• Set by instruction</li> </ul>  |                                       |                                      |   |  |

**Note** Set the SPTn bit to 1 only in master mode. However, when the IICRSVn bit is 0, the SPTn bit must be set to 1 and a stop condition generated before the first stop condition is detected following the switch to the operation enabled status. For details, see **17.15 Cautions**.

**Caution** When the TRCn bit = 1, the WRELn bit is set to 1 during the ninth clock and the wait state is canceled, after which the TRCn bit is cleared to 0 and the SDA0n line is set to high impedance.

**Remarks**

1. The SPTn bit is 0 if it is read immediately after data setting.
2. n = 0 to 2

**(2) IIC status registers 0 to 2 (IICS0 to IICS2)**

The IICS<sub>n</sub> register indicates the status of the I<sup>2</sup>C0<sub>n</sub> (n = 0 to 2).

This register is read-only, in 8-bit or 1-bit units. However, the IICS<sub>n</sub> register can only be read when the IIC<sub>n</sub>.STT<sub>n</sub> bit is 1 or during the wait period.

Reset sets this register to 00H.

**Caution Accessing the IICS<sub>n</sub> register is prohibited in the following statuses. For details, see 3.4.8 (2) Accessing specific on-chip peripheral I/O registers.**

- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock

(1/3)

|  |  |   |                  |  |                  |                   |                  |                  |
|--|--|---|------------------|--|------------------|-------------------|------------------|------------------|
| After reset: 00H   | R  | Address: IICS0 FFFFD86H, IICS1 FFFFD96H, IICS2 FFFFD66H |                  |  |                  |                   |                  |                  |
| IICS <sub>n</sub>  | <7>  | <6>   | <5>              | <4>  | <3>              | <2>               | <1>              | <0>              |
|  | MST <sub>n</sub>   | ALD <sub>n</sub>  | EXC <sub>n</sub> | COI <sub>n</sub>   | TRC <sub>n</sub> | ACKD <sub>n</sub> | STD <sub>n</sub> | SPD <sub>n</sub> |
| (n = 0 to 2)   |  |   |                  |  |                  |                   |                  |                  |
| MST <sub>n</sub>   | Master device status   |   |                  |  |                  |                   |                  |                  |
| 0  | Slave device status or communication standby status  |   |                  |  |                  |                   |                  |                  |
| 1  | Master device communication status   |   |                  |  |                  |                   |                  |                  |
| Condition for clearing (MST <sub>n</sub> bit = 0)  |  |   |                  | Condition for setting (MST <sub>n</sub> bit = 1)   |                  |                   |                  |                  |
| <ul style="list-style-type: none"> <li>• When a stop condition is detected</li> <li>• When the ALD<sub>n</sub> bit = 1 (arbitration loss)</li> <li>• Cleared by LREL<sub>n</sub> bit = 1 (communication save)</li> <li>• When the IICEn bit changes from 1 to 0 (operation stop)</li> <li>• After reset</li> </ul> |  |   |                  | <ul style="list-style-type: none"> <li>• When a start condition is generated</li> </ul>  |                  |                   |                  |                  |
| ALD <sub>n</sub>   | Arbitration loss detection   |   |                  |  |                  |                   |                  |                  |
| 0  | This status means either that there was no arbitration or that the arbitration result was a "win".   |   |                  |  |                  |                   |                  |                  |
| 1  | This status indicates the arbitration result was a "loss". The MST <sub>n</sub> bit is cleared to 0. |   |                  |  |                  |                   |                  |                  |
| Condition for clearing (ALD <sub>n</sub> bit = 0)  |  |   |                  | Condition for setting (ALD <sub>n</sub> bit = 1)   |                  |                   |                  |                  |
| <ul style="list-style-type: none"> <li>• Automatically cleared after the IICS<sub>n</sub> register is read<sup>Note</sup></li> <li>• When the IICEn bit changes from 1 to 0 (operation stop)</li> <li>• After reset</li> </ul>   |  |   |                  | <ul style="list-style-type: none"> <li>• When the arbitration result is a "loss".</li> </ul>   |                  |                   |                  |                  |
| EXC <sub>n</sub>   | Detection of extension code reception  |   |                  |  |                  |                   |                  |                  |
| 0  | Extension code was not received.   |   |                  |  |                  |                   |                  |                  |
| 1  | Extension code was received.   |   |                  |  |                  |                   |                  |                  |
| Condition for clearing (EXC <sub>n</sub> bit = 0)  |  |   |                  | Condition for setting (EXC <sub>n</sub> bit = 1)   |                  |                   |                  |                  |
| <ul style="list-style-type: none"> <li>• When a start condition is detected</li> <li>• When a stop condition is detected</li> <li>• Cleared by LREL<sub>n</sub> bit = 1 (communication save)</li> <li>• When the IICEn bit changes from 1 to 0 (operation stop)</li> <li>• After reset</li> </ul>                  |  |   |                  | <ul style="list-style-type: none"> <li>• When the higher four bits of the received address data are either "0000" or "1111" (set at the rising edge of the eighth clock).</li> </ul> |                  |                   |                  |                  |
| <p><b>Note</b> The ALD<sub>n</sub> bit is also cleared when a bit manipulation instruction is executed for another bit in the IICS<sub>n</sub> register.</p>   |  |   |                  |  |                  |                   |                  |                  |

| COIn   | Matching address detection |   |
|--|----------------------------|---|
| 0  | Addresses do not match.    |   |
| 1  | Addresses match.           |   |
| Condition for clearing (COIn bit = 0)  |                            | Condition for setting (COIn bit = 1)  |
| <ul style="list-style-type: none"> <li>• When a start condition is detected</li> <li>• When a stop condition is detected</li> <li>• Cleared by LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit changes from 1 to 0 (operation stop)</li> <li>• After reset</li> </ul> |                            | <ul style="list-style-type: none"> <li>• When the received address matches the local address (SVAn register) (set at the rising edge of the eighth clock).</li> </ul> |

| TRCn  | Transmit/receive status detection  |  |
|---|--|--|
| 0   | Receive status (other than transmit status). The SDA0n line is set to high impedance.  |  |
| 1   | Transmit status. The value in the SO latch is enabled for output to the SDA0n line (valid starting at the falling edge of the first byte's ninth clock). |  |
| Condition for clearing (TRCn bit = 0)   |  | Condition for setting (TRCn bit = 1)   |
| <ul style="list-style-type: none"> <li>• When a stop condition is detected</li> <li>• Cleared by LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit changes from 1 to 0 (operation stop)</li> <li>• Cleared by IICn.WRELn bit = 1<sup>Note</sup></li> <li>• When the ALDn bit changes from 0 to 1 (arbitration loss)</li> <li>• After reset</li> </ul> <p>Master</p> <ul style="list-style-type: none"> <li>• When "1" is output to the first byte's LSB (transfer direction specification bit)</li> </ul> <p>Slave</p> <ul style="list-style-type: none"> <li>• When a start condition is detected</li> </ul> <p>When not used for communication</p> |  | <p>Master</p> <ul style="list-style-type: none"> <li>• When a start condition is generated</li> <li>• When "0" is output to the first byte's LSB (transfer direction specification bit)</li> </ul> <p>Slave</p> <ul style="list-style-type: none"> <li>• When "1" is input by the first byte's LSB (transfer direction specification bit)</li> </ul> |

| ACKDn   | ACK detection                             |   |
|---|---|---|
| 0   | $\overline{\text{ACK}}$ was not detected. |   |
| 1   | $\overline{\text{ACK}}$ was detected.     |   |
| Condition for clearing (ACKDn bit = 0)  |   | Condition for setting (ACKDn bit = 1)   |
| <ul style="list-style-type: none"> <li>• When a stop condition is detected</li> <li>• At the rising edge of the next byte's first clock</li> <li>• Cleared by LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit changes from 1 to 0 (operation stop)</li> <li>• After reset</li> </ul> |   | <ul style="list-style-type: none"> <li>• After the SDA0n bit is set to low level at the rising edge of the SCL0n pin's ninth clock</li> </ul> |

**Note** The TRCn bit is cleared to 0 and SDA0n line becomes high impedance when the WRELn bit is set to 1 and the wait state is canceled to 0 at the ninth clock by TRCn bit = 1.

**Remark** n = 0 to 2

| STDn   | Start condition detection  |  |
|--|--|--|
| 0  | Start condition was not detected.  |  |
| 1  | Start condition was detected. This indicates that the address transfer period is in effect |  |
| Condition for clearing (STDn bit = 0)  |  | Condition for setting (STDn bit = 1)   |
| <ul style="list-style-type: none"> <li>• When a stop condition is detected</li> <li>• At the rising edge of the next byte's first clock following address transfer</li> <li>• Cleared by LRELn bit = 1 (communication save)</li> <li>• When the IICEn bit changes from 1 to 0 (operation stop)</li> <li>• After reset</li> </ul> |  | <ul style="list-style-type: none"> <li>• When a start condition is detected</li> </ul> |

| SPDn   | Stop condition detection  |   |
|--|---|---|
| 0  | Stop condition was not detected.  |   |
| 1  | Stop condition was detected. The master device's communication is terminated and the bus is released. |   |
| Condition for clearing (SPDn bit = 0)  |   | Condition for setting (SPDn bit = 1)  |
| <ul style="list-style-type: none"> <li>• At the rising edge of the address transfer byte's first clock following setting of this bit and detection of a start condition</li> <li>• When the IICEn bit changes from 1 to 0 (operation stop)</li> <li>• After reset</li> </ul> |   | <ul style="list-style-type: none"> <li>• When a stop condition is detected</li> </ul> |

**Remark** n = 0 to 2

**(3) IIC flag registers 0 to 2 (IICF0 to IICF2)**

The IICFn register sets the I<sup>2</sup>C0n operation mode and indicates the I<sup>2</sup>C bus status.

This register can be read or written in 8-bit or 1-bit units. However, the STCFn and IICBSYn bits are read-only.

IICRSVn enables/disables the communication reservation function (see **17.14 Communication Reservation**).

The initial value of the IICBSYn bit is set by using the STCENn bit (see **17.15 Cautions**).

The IICRSVn and STCENn bits can be written only when operation of I<sup>2</sup>C0n is disabled (IICn.IICEn bit = 0).

After operation is enabled, IICFn can be read (n = 0 to 2).

Reset sets this register to 00H.



After reset: 00H R/W<sup>Note</sup> Address: IICF0 FFFFFFFD8AH, IICF1 FFFFFFFD9AH, IICF2 FFFFFFFDAAH

|       |       |         |   |   |   |   |        |         |
|-------|-------|---------|---|---|---|---|--------|---------|
|       | <7>   | <6>     | 5 | 4 | 3 | 2 | <1>    | <0>     |
| IICFn | STCFn | IICBSYn | 0 | 0 | 0 | 0 | STCENn | IICRSVn |

(n = 0 to 2)

|  |  |
|--|--|
| STCFn  | STTn bit clear                                     |
| 0  | Start condition issued                             |
| 1  | Start condition cannot be issued, STTn bit cleared |
| Condition for clearing (STCFn bit = 0)   |  |
| <ul style="list-style-type: none"> <li>• Cleared by IICn.STTn bit = 1</li> <li>• When the IICn.IICEn bit = 0</li> <li>• After reset</li> </ul>                                       |  |
| Condition for setting (STCFn bit = 1)  |  |
| <ul style="list-style-type: none"> <li>• When start condition is not issued and STTn flag is cleared to 0 during communication reservation is disabled (IICRSVn bit = 1).</li> </ul> |  |

|  |   |
|--|---|
| IICBSYn  | I <sup>2</sup> C0n bus status   |
| 0  | Bus released status (default communication status when STCENn bit = 1)      |
| 1  | Bus communication status (default communication status when STCENn bit = 0) |
| Condition for clearing (IICBSYn bit = 0)   |   |
| <ul style="list-style-type: none"> <li>• When stop condition is detected</li> <li>• When the IICEn bit = 0</li> <li>• After reset</li> </ul>     |   |
| Condition for setting (IICBSYn bit = 1)  |   |
| <ul style="list-style-type: none"> <li>• When start condition is detected</li> <li>• By setting the IICEn bit when the STCENn bit = 0</li> </ul> |   |

|   |  |
|---|--|
| STCENn  | Initial start enable trigger   |
| 0   | Start conditions cannot be generated until a stop condition is detected following operation enable (IICEn bit = 1).    |
| 1   | Start conditions can be generated even if a stop condition is not detected following operation enable (IICEn bit = 1). |
| Condition for clearing (STCENn bit = 0)   |  |
| <ul style="list-style-type: none"> <li>• When start condition is detected</li> <li>• After reset</li> </ul> |  |
| Condition for setting (STCENn bit = 1)  |  |
| <ul style="list-style-type: none"> <li>• Setting by instruction</li> </ul>                                  |  |

|  |  |
|--|--|
| IICRSVn  | Communication reservation function disable bit |
| 0  | Communication reservation enabled              |
| 1  | Communication reservation disabled             |
| Condition for clearing (IICRSVn bit = 0)   |  |
| <ul style="list-style-type: none"> <li>• Clearing by instruction</li> <li>• After reset</li> </ul> |  |
| Condition for setting (IICRSVn bit = 1)  |  |
| <ul style="list-style-type: none"> <li>• Setting by instruction</li> </ul>                         |  |

**Note** Bits 6 and 7 are read-only bits.

- Cautions**
1. Write the STCENn bit only when operation is stopped (IICEn bit = 0).
  2. When the STCENn bit = 1, the bus released status (IICBSYn bit = 0) is recognized regardless of the actual bus status immediately after the I<sup>2</sup>Cn bus operation is enabled. Therefore, to issue the first start condition (STTn bit = 1), it is necessary to confirm that the bus has been released, so as to not disturb other communications.
  3. Write the IICRSVn bit only when operation is stopped (IICEn bit = 0).

**(4) IIC clock select registers 0 to 2 (IICCL0 to IICCL2)**

The IICCLn register sets the transfer clock for the I<sup>2</sup>C0n.

This register can be read or written in 8-bit or 1-bit units. However, the CLDn and DADn bits are read-only.

Set the IICCLn register when the IICn.IICEn bit = 0.

The SMCn, CLn1, and CLn0 bits are set by the combination of the IICXn.CLXn bit and the OCKSTHm, OCKSm1, and OCKSm0 bits of the OCKSm register (see 17.4 (6) I<sup>2</sup>C0n transfer clock setting method) (n = 0 to 2, m = 0, 1).

Reset sets this register to 00H.

|  |                     |   |   |      |   |      |      |      |      |
|--|---------------------|---|---|------|---|------|------|------|------|
| After reset: 00H   | R/W <sup>Note</sup> | Address: IICCL0 FFFFFFFD84H, IICCL1 FFFFFFFD94H, IICCL2 FFFFFFFDA4H |   |      |   |      |      |      |      |
|  |                     | 7   | 6 | <5>  | <4>   | 3    | 2    | 1    | 0    |
| IICCLn   |                     | 0   | 0 | CLDn | DADn  | SMCn | DFCn | CLn1 | CLn0 |
| (n = 0 to 2)   |                     |   |   |      |   |      |      |      |      |
| CLDn   |                     | Detection of SCL0n pin level (valid only when IICn.IICEn bit = 1)   |   |      |   |      |      |      |      |
| 0  |                     | The SCL0n pin was detected at low level.                            |   |      |   |      |      |      |      |
| 1  |                     | The SCL0n pin was detected at high level.                           |   |      |   |      |      |      |      |
| Condition for clearing (CLDn bit = 0)  |                     |   |   |      | Condition for setting (CLDn bit = 1)  |      |      |      |      |
| <ul style="list-style-type: none"> <li>• When the SCL0n pin is at low level</li> <li>• When the IICEn bit = 0 (operation stop)</li> <li>• After reset</li> </ul>   |                     |   |   |      | <ul style="list-style-type: none"> <li>• When the SCL0n pin is at high level</li> </ul> |      |      |      |      |
| DADn   |                     | Detection of SDA0n pin level (valid only when IICEn bit = 1)        |   |      |   |      |      |      |      |
| 0  |                     | The SDA0n pin was detected at low level.                            |   |      |   |      |      |      |      |
| 1  |                     | The SDA0n pin was detected at high level.                           |   |      |   |      |      |      |      |
| Condition for clearing (DADn bit = 0)  |                     |   |   |      | Condition for setting (DADn bit = 1)  |      |      |      |      |
| <ul style="list-style-type: none"> <li>• When the SDA0n pin is at low level</li> <li>• When the IICEn bit = 0 (operation stop)</li> <li>• After reset</li> </ul>   |                     |   |   |      | <ul style="list-style-type: none"> <li>• When the SDA0n pin is at high level</li> </ul> |      |      |      |      |
| SMCn   |                     | Operation mode switching  |   |      |   |      |      |      |      |
| 0  |                     | Operation in standard mode.   |   |      |   |      |      |      |      |
| 1  |                     | Operation in high-speed mode.                                       |   |      |   |      |      |      |      |
| DFCn   |                     | Digital filter operation control                                    |   |      |   |      |      |      |      |
| 0  |                     | Digital filter off.   |   |      |   |      |      |      |      |
| 1  |                     | Digital filter on.  |   |      |   |      |      |      |      |
| <p>The digital filter can be used only in high-speed mode.<br/>                 In high-speed mode, the transfer clock does not vary regardless of the DFCn bit setting (on/off).<br/>                 The digital filter is used to eliminate noise in high-speed mode.</p> |                     |   |   |      |   |      |      |      |      |
| <b>Note</b> Bits 4 and 5 are read-only bits.   |                     |   |   |      |   |      |      |      |      |
| <b>Caution</b> Be sure to clear bits 7 and 6 to “0”.   |                     |   |   |      |   |      |      |      |      |
| <b>Remark</b> When the IICn.IICEn bit = 0, 0 is read when reading the CLDn and DADn bits.  |                     |   |   |      |   |      |      |      |      |

**(5) IIC function expansion registers 0 to 2 (IICX0 to IICX2)**

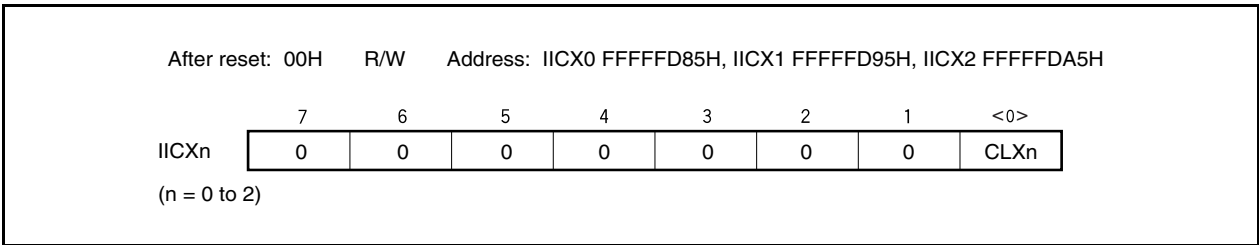
The IICXn register sets I<sup>2</sup>C0n function expansion (valid only in the high-speed mode).

This register can be read or written in 8-bit or 1-bit units.

Setting of the CLXn bit is performed in combination with the SMCn, CLn1, and CLn0 bits of the IICCLn register and the OCKSTHm, OCKSm1, and OCKSm0 bits of the OCKSm register (see 17.4 (6) I<sup>2</sup>C0n transfer clock setting method) (m = 0, 1).

Set the IICXn register when the IICCn.IICEn bit = 0.

Reset sets this register to 00H.



**(6) I<sup>2</sup>C0n transfer clock setting method**

The I<sup>2</sup>C0n transfer clock frequency (f<sub>SCL</sub>) is calculated using the following expression (n = 0 to 2).

$$f_{SCL} = 1/(m \times T + t_R + t_F)$$

m = 12, 18, 24, 36, 44, 48, 54, 60, 66, 72, 86, 88, 96, 132, 172, 176, 198, 220, 258, 344 (see **Table 17-2 Clock Settings**).

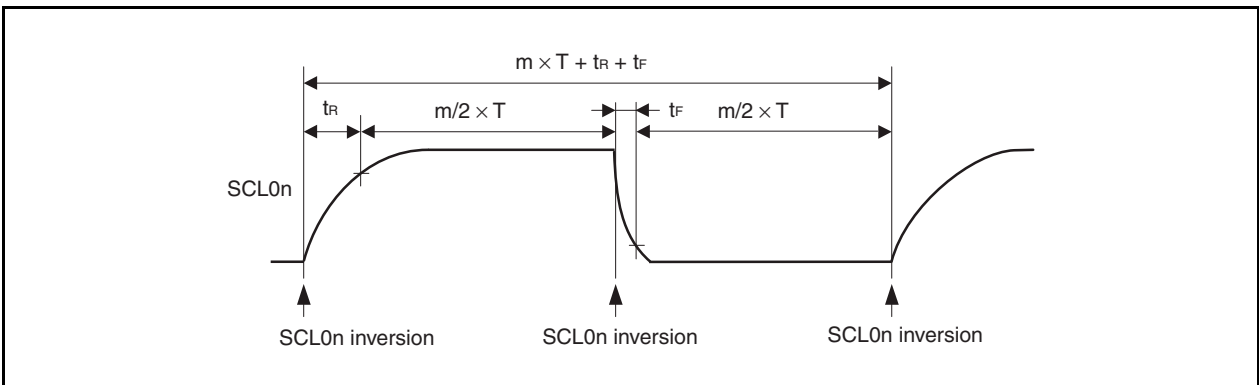
T: 1/f<sub>XX</sub>

t<sub>R</sub>: SCL0n pin rise time

t<sub>F</sub>: SCL0n pin fall time

For example, the I<sup>2</sup>C0n transfer clock frequency (f<sub>SCL</sub>) when f<sub>XX</sub> = 19.2 MHz, m = 198, t<sub>R</sub> = 200 ns, and t<sub>F</sub> = 50 ns is calculated using following expression.

$$f_{SCL} = 1/(198 \times 52 \text{ ns} + 200 \text{ ns} + 50 \text{ ns}) \cong 94.7 \text{ kHz}$$



The clock to be selected can be set by the combination of the SMCn, CLn1, and CLn0 bits of the IICCLn register, the CLXn bit of the IICXn register, and the OCKSTHm, OCKSm1, and OCKSm0 bits of the OCKSm register (n = 0 to 2, m = 0, 1).

Table 17-2. Clock Settings (1/2)

| IICX0            | IICCL0 |       |       | Selection Clock                           | Transfer Clock       | Settable Main Clock Frequency (f <sub>xx</sub> ) Range | Operating Mode                    |       |
|------------------|--------|-------|-------|---|----------------------|--|-----------------------------------|-------|
|                  | Bit 0  | Bit 3 | Bit 1 |   |                      |  |                                   | Bit 0 |
|                  | CLX0   | SMC0  | CL01  |   |                      |  |                                   | CL00  |
| 0                | 0      | 0     | 0     | f <sub>xx</sub> (when OCKS0 = 18H set)    | f <sub>xx</sub> /44  | 2.00 MHz ≤ f <sub>xx</sub> ≤ 4.19 MHz                  | Standard mode<br>(SMC0 bit = 0)   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS0 = 10H set) | f <sub>xx</sub> /88  | 4.00 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS0 = 11H set) | f <sub>xx</sub> /132 | 6.00 MHz ≤ f <sub>xx</sub> ≤ 12.57 MHz                 |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS0 = 12H set) | f <sub>xx</sub> /176 | 8.00 MHz ≤ f <sub>xx</sub> ≤ 16.76 MHz                 |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS0 = 13H set) | f <sub>xx</sub> /220 | 10.00 MHz ≤ f <sub>xx</sub> ≤ 20.95 MHz                |                                   |       |
| 0                | 0      | 0     | 1     | f <sub>xx</sub> (when OCKS0 = 18H set)    | f <sub>xx</sub> /86  | 4.19 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS0 = 10H set) | f <sub>xx</sub> /172 | 8.38 MHz ≤ f <sub>xx</sub> ≤ 16.76 MHz                 |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS0 = 11H set) | f <sub>xx</sub> /258 | 12.57 MHz ≤ f <sub>xx</sub> ≤ 25.14 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS0 = 12H set) | f <sub>xx</sub> /344 | 16.76 MHz ≤ f <sub>xx</sub> ≤ 32.00 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS0 = 13H set) | f <sub>xx</sub> /430 | 20.95 MHz ≤ f <sub>xx</sub> ≤ 32.00 MHz                |                                   |       |
| 0                | 0      | 1     | 0     | f <sub>xx</sub> <sup>Note</sup>           | f <sub>xx</sub> /86  | 4.19 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
| 0                | 0      | 1     | 1     | f <sub>xx</sub> (when OCKS0 = 18H set)    | f <sub>xx</sub> /66  | 6.40 MHz   |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS0 = 10H set) | f <sub>xx</sub> /132 | 12.80 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS0 = 11H set) | f <sub>xx</sub> /198 | 19.20 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS0 = 12H set) | f <sub>xx</sub> /264 | 25.60 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS0 = 13H set) | f <sub>xx</sub> /330 | 32.00 MHz  |                                   |       |
| 0                | 1      | 0     | ×     | f <sub>xx</sub> (when OCKS0 = 18H set)    | f <sub>xx</sub> /24  | 4.19 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  | High-speed mode<br>(SMC0 bit = 1) |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS0 = 10H set) | f <sub>xx</sub> /48  | 8.00 MHz ≤ f <sub>xx</sub> ≤ 16.76 MHz                 |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS0 = 11H set) | f <sub>xx</sub> /72  | 12.00 MHz ≤ f <sub>xx</sub> ≤ 25.14 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS0 = 12H set) | f <sub>xx</sub> /96  | 16.00 MHz ≤ f <sub>xx</sub> ≤ 32.00 MHz                |                                   |       |
| 0                | 1      | 1     | 0     | f <sub>xx</sub> <sup>Note</sup>           | f <sub>xx</sub> /24  | 4.00 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
| 0                | 1      | 1     | 1     | f <sub>xx</sub> (when OCKS0 = 18H set)    | f <sub>xx</sub> /18  | 6.40 MHz   |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS0 = 10H set) | f <sub>xx</sub> /36  | 12.80 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS0 = 11H set) | f <sub>xx</sub> /54  | 19.20 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS0 = 12H set) | f <sub>xx</sub> /72  | 25.60 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS0 = 13H set) | f <sub>xx</sub> /90  | 32.00 MHz  |                                   |       |
| 1                | 1      | 0     | ×     | f <sub>xx</sub> (when OCKS0 = 18H set)    | f <sub>xx</sub> /12  | 4.00 MHz ≤ f <sub>xx</sub> ≤ 4.19 MHz                  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS0 = 10H set) | f <sub>xx</sub> /24  | 8.00 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS0 = 11H set) | f <sub>xx</sub> /36  | 12.00 MHz ≤ f <sub>xx</sub> ≤ 12.57 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS0 = 12H set) | f <sub>xx</sub> /48  | 16.00 MHz ≤ f <sub>xx</sub> ≤ 16.67 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS0 = 13H set) | f <sub>xx</sub> /60  | 20.00 MHz ≤ f <sub>xx</sub> ≤ 20.95 MHz                |                                   |       |
| 1                | 1      | 1     | 0     | f <sub>xx</sub> <sup>Note</sup>           | f <sub>xx</sub> /12  | 4.00 MHz ≤ f <sub>xx</sub> ≤ 4.19 MHz                  |                                   |       |
| Other than above |        |       |       | Setting prohibited                        | –                    | –  | –                                 |       |

**Note** Since the selection clock is f<sub>xx</sub> regardless of the value set to the OCKS0 register, clear the OCKS0 register to 00H (I<sup>2</sup>C division clock stopped status).

**Remark** ×: don't care

Table 17-2. Clock Settings (2/2)

| IICXm            | IICCLm |       |       | Selection Clock                           | Transfer Clock       | Settable Main Clock Frequency (f <sub>xx</sub> ) Range | Operating Mode                    |       |
|------------------|--------|-------|-------|---|----------------------|--|-----------------------------------|-------|
|                  | Bit 0  | Bit 3 | Bit 1 |   |                      |  |                                   | Bit 0 |
|                  | CLXm   | SMCm  | CLm1  |   |                      |  |                                   | CLm0  |
| 0                | 0      | 0     | 0     | f <sub>xx</sub> (when OCKS1 = 18H set)    | f <sub>xx</sub> /44  | 2.00 MHz ≤ f <sub>xx</sub> ≤ 4.19 MHz                  | Standard mode<br>(SMCm bit = 0)   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS1 = 10H set) | f <sub>xx</sub> /88  | 4.00 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS1 = 11H set) | f <sub>xx</sub> /132 | 6.00 MHz ≤ f <sub>xx</sub> ≤ 12.57 MHz                 |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS1 = 12H set) | f <sub>xx</sub> /176 | 8.00 MHz ≤ f <sub>xx</sub> ≤ 16.76 MHz                 |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS1 = 13H set) | f <sub>xx</sub> /220 | 10.00 MHz ≤ f <sub>xx</sub> ≤ 20.95 MHz                |                                   |       |
| 0                | 0      | 0     | 1     | f <sub>xx</sub> (when OCKS1 = 18H set)    | f <sub>xx</sub> /86  | 4.19 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS1 = 10H set) | f <sub>xx</sub> /172 | 8.38 MHz ≤ f <sub>xx</sub> ≤ 16.76 MHz                 |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS1 = 11H set) | f <sub>xx</sub> /258 | 12.57 MHz ≤ f <sub>xx</sub> ≤ 25.14 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS1 = 12H set) | f <sub>xx</sub> /344 | 16.76 MHz ≤ f <sub>xx</sub> ≤ 32.00 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS1 = 13H set) | f <sub>xx</sub> /430 | 20.95 MHz ≤ f <sub>xx</sub> ≤ 32.00 MHz                |                                   |       |
| 0                | 0      | 1     | 0     | f <sub>xx</sub> <sup>Note</sup>           | f <sub>xx</sub> /86  | 4.19 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
| 0                | 0      | 1     | 1     | f <sub>xx</sub> (when OCKS1 = 18H set)    | f <sub>xx</sub> /66  | 6.40 MHz   |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS1 = 10H set) | f <sub>xx</sub> /132 | 12.80 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS1 = 11H set) | f <sub>xx</sub> /198 | 19.20 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS1 = 12H set) | f <sub>xx</sub> /264 | 25.60 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS1 = 13H set) | f <sub>xx</sub> /330 | 32.00 MHz  |                                   |       |
| 0                | 1      | 0     | ×     | f <sub>xx</sub> (when OCKS1 = 18H set)    | f <sub>xx</sub> /24  | 4.19 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  | High-speed mode<br>(SMCm bit = 1) |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS1 = 10H set) | f <sub>xx</sub> /48  | 8.00 MHz ≤ f <sub>xx</sub> ≤ 16.76 MHz                 |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS1 = 11H set) | f <sub>xx</sub> /72  | 12.00 MHz ≤ f <sub>xx</sub> ≤ 25.14 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS1 = 12H set) | f <sub>xx</sub> /96  | 16.00 MHz ≤ f <sub>xx</sub> ≤ 32.00 MHz                |                                   |       |
| 0                | 1      | 1     | 0     | f <sub>xx</sub> <sup>Note</sup>           | f <sub>xx</sub> /24  | 4.00 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
| 0                | 1      | 1     | 1     | f <sub>xx</sub> (when OCKS1 = 18H set)    | f <sub>xx</sub> /18  | 6.40 MHz   |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS1 = 10H set) | f <sub>xx</sub> /36  | 12.80 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS1 = 11H set) | f <sub>xx</sub> /54  | 19.20 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS1 = 12H set) | f <sub>xx</sub> /72  | 25.60 MHz  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS1 = 13H set) | f <sub>xx</sub> /90  | 32.00 MHz  |                                   |       |
| 1                | 1      | 0     | ×     | f <sub>xx</sub> (when OCKS1 = 18H set)    | f <sub>xx</sub> /12  | 4.00 MHz ≤ f <sub>xx</sub> ≤ 4.19 MHz                  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /2 (when OCKS1 = 10H set) | f <sub>xx</sub> /24  | 8.00 MHz ≤ f <sub>xx</sub> ≤ 8.38 MHz                  |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /3 (when OCKS1 = 11H set) | f <sub>xx</sub> /36  | 12.00 MHz ≤ f <sub>xx</sub> ≤ 12.57 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /4 (when OCKS1 = 12H set) | f <sub>xx</sub> /48  | 16.00 MHz ≤ f <sub>xx</sub> ≤ 16.67 MHz                |                                   |       |
|                  |        |       |       | f <sub>xx</sub> /5 (when OCKS1 = 13H set) | f <sub>xx</sub> /60  | 20.00 MHz ≤ f <sub>xx</sub> ≤ 20.95 MHz                |                                   |       |
| 1                | 1      | 1     | 0     | f <sub>xx</sub> <sup>Note</sup>           | f <sub>xx</sub> /12  | 4.00 MHz ≤ f <sub>xx</sub> ≤ 4.19 MHz                  |                                   |       |
| Other than above |        |       |       | Setting prohibited                        | –                    | –  | –                                 |       |

**Note** Since the selection clock is f<sub>xx</sub> regardless of the value set to the OCKS1 register, clear the OCKS1 register to 00H (I<sup>2</sup>C division clock stopped status).

- Remarks**
- m = 1, 2
  - ×: don't care

**(7) IIC division clock select registers 0, 1 (OCKS0, OCKS1)**

The OCKSm register controls the I<sup>2</sup>C0n division clock (n = 0 to 2, m = 0, 1).

This register controls the I<sup>2</sup>C00 division clock via the OCKS0 register and the I<sup>2</sup>C01 and I<sup>2</sup>C02 division clocks via the OCKS1 register.

This register can be read or written in 8-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: OCKS0 FFFFF340H, OCKS1 FFFFF344H

|       |   |   |   |         |         |   |        |        |
|-------|---|---|---|---------|---------|---|--------|--------|
|       | 7 | 6 | 5 | 4       | 3       | 2 | 1      | 0      |
| OCKSm | 0 | 0 | 0 | OCKSENm | OCKSTHm | 0 | OCKSm1 | OCKSm0 |

(m = 0, 1)

|         |  |
|---------|--|
| OCKSENm | Operation setting of I <sup>2</sup> C division clock |
| 0       | Disable I <sup>2</sup> C division clock operation    |
| 1       | Enable I <sup>2</sup> C division clock operation     |

|                  |        |        |  |
|------------------|--------|--------|--|
| OCKSTHm          | OCKSm1 | OCKSm0 | Selection of I <sup>2</sup> C division clock |
| 0                | 0      | 0      | f <sub>xx</sub> /2                           |
| 0                | 0      | 1      | f <sub>xx</sub> /3                           |
| 0                | 1      | 0      | f <sub>xx</sub> /4                           |
| 0                | 1      | 1      | f <sub>xx</sub> /5                           |
| 1                | 0      | 0      | f <sub>xx</sub>                              |
| Other than above |        |        | Setting prohibited                           |

**(8) IIC shift registers 0 to 2 (IIC0 to IIC2)**

The IICn register is used for serial transmission/reception (shift operations) synchronized with the serial clock.

This register can be read or written in 8-bit units, but data should not be written to the IICn register during a data transfer.

Access (read/write) the IICn register only during the wait period. Accessing this register in communication states other than the wait period is prohibited. However, for the master device, the IICn register can be written once only after the transmission trigger bit (IICn.STTn bit) has been set to 1.

A wait state is released by writing the IICn register during the wait period, and data transfer is started (n = 0 to 2).

Reset sets this register to 00H.

After reset: 00H    R/W    Address: IIC0 FFFFFD80H, IIC1 FFFFFD90H, IIC2 FFFFFDA0H

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

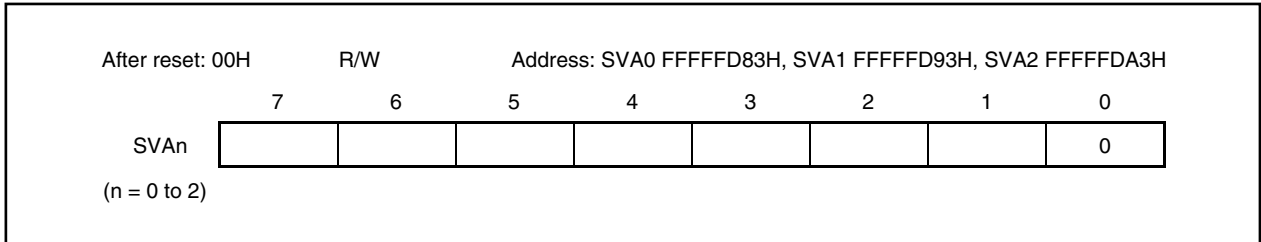
(n = 0 to 2)

**(9) Slave address registers 0 to 2 (SVA0 to SVA2)**

The SVAn register holds the I<sup>2</sup>C bus's slave addresses (n = 0 to 2).

This register can be read or written in 8-bit units, but bit 0 should be fixed to 0. However, rewriting this register is prohibited when the IICSn.STDn bit = 1 (start condition detection).

Reset sets this register to 00H.



## 17.5 I<sup>2</sup>C Bus Mode Functions

### 17.5.1 Pin configuration

The serial clock pin (SCL0n) and serial data bus pin (SDA0n) are configured as follows (n = 0 to 2).

SCL0n .....This pin is used for serial clock input and output.

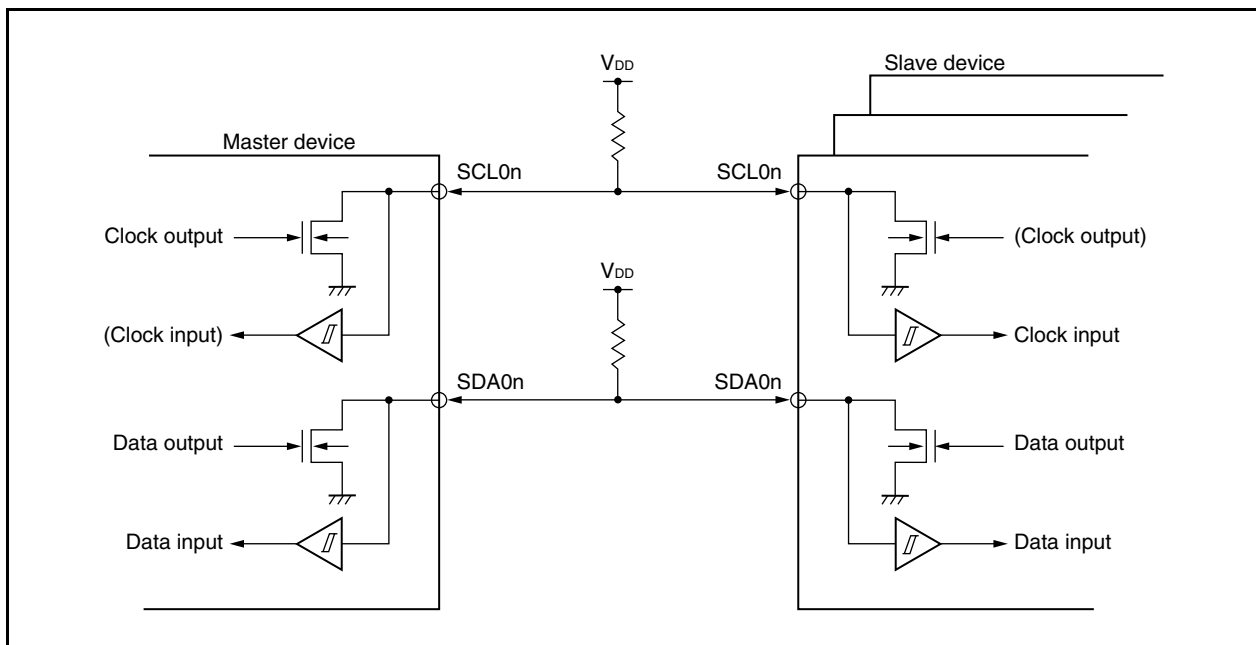
This pin is an N-ch open-drain output for both master and slave devices. Input is Schmitt input.

SDA0n .....This pin is used for serial data input and output.

This pin is an N-ch open-drain output for both master and slave devices. Input is Schmitt input.

Since outputs from the serial clock line and the serial data bus line are N-ch open-drain outputs, an external pull-up resistor is required.

**Figure 17-6. Pin Configuration Diagram**

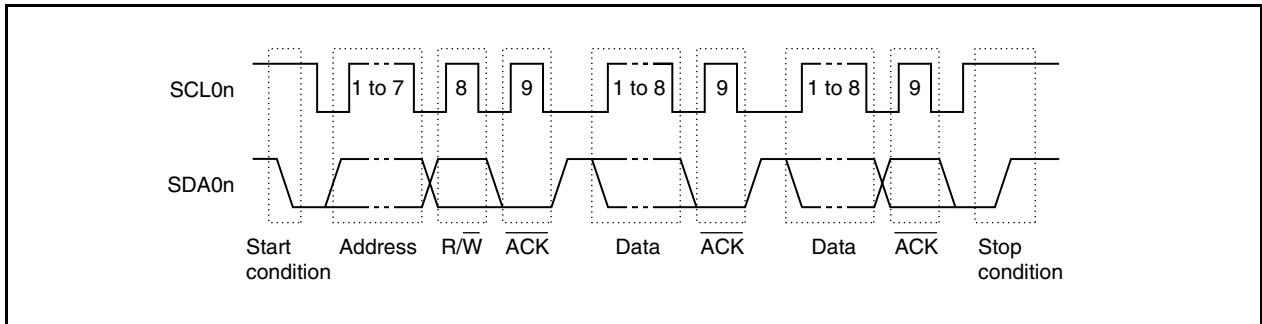




## 17.6 I<sup>2</sup>C Bus Definitions and Control Methods

The following section describes the I<sup>2</sup>C bus's serial data communication format and the signals used by the I<sup>2</sup>C bus. The transfer timing for the "start condition", "address", "transfer direction specification", "data", and "stop condition" generated on the I<sup>2</sup>C bus's serial data bus is shown below.

Figure 17-7. I<sup>2</sup>C Bus Serial Data Transfer Timing



The master device generates the start condition, slave address, and stop condition.

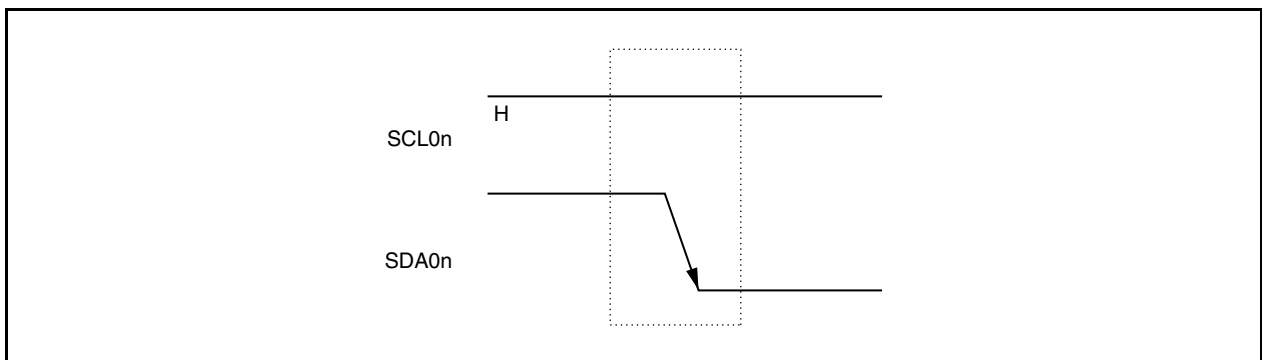
$\overline{\text{ACK}}$  can be generated by either the master or slave device (normally, it is generated by the device that receives 8-bit data).

The serial clock (SCL0n) is continuously output by the master device. However, in the slave device, the SCL0n pin's low-level period can be extended and a wait state can be inserted ( $n = 0$  to 2).

### 17.6.1 Start condition

A start condition is met when the SCL0n pin is high level and the SDA0n pin changes from high level to low level. The start condition for the SCL0n and SDA0n pins is a signal that the master device outputs to the slave device when starting a serial transfer. The slave device can detect the start condition ( $n = 0$  to 2).

Figure 17-8. Start Condition



A start condition is output when the IICn.STTn bit is set (1) after a stop condition has been detected (IICn.SPdn bit = 1). When a start condition is detected, the IICn.STDn bit is set (1) ( $n = 0$  to 2).

**Caution** When the IICn.IICEn bit of the V850ES/JJ3 is set to 1 while communications with other devices are in progress, the start condition may be detected depending on the status of the communication line. Be sure to set the IICn.IICEn bit to 1 when the SCL0n and SDA0n lines are high level.

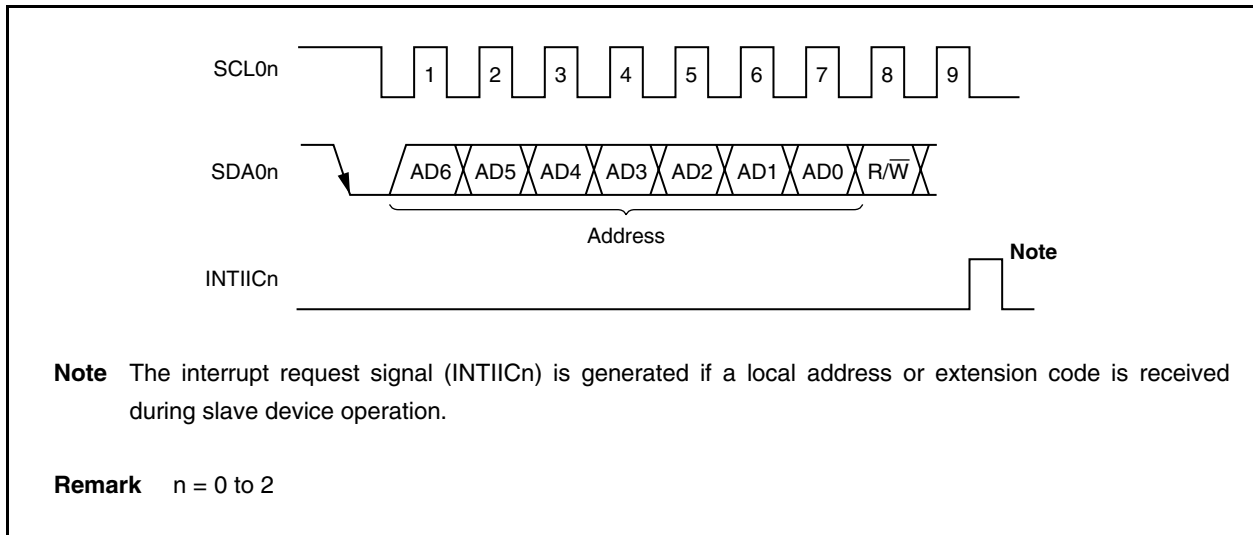
**17.6.2 Addresses**

The 7 bits of data that follow the start condition are defined as an address.

An address is a 7-bit data segment that is output in order to select one of the slave devices that are connected to the master device via the bus lines. Therefore, each slave device connected via the bus lines must have a unique address.

The slave devices include hardware that detects the start condition and checks whether or not the 7-bit address data matches the data values stored in the SVAn register. If the address data matches the values of the SVAn register, the slave device is selected and communicates with the master device until the master device generates a start condition or stop condition (n = 0 to 2).

**Figure 17-9. Address**



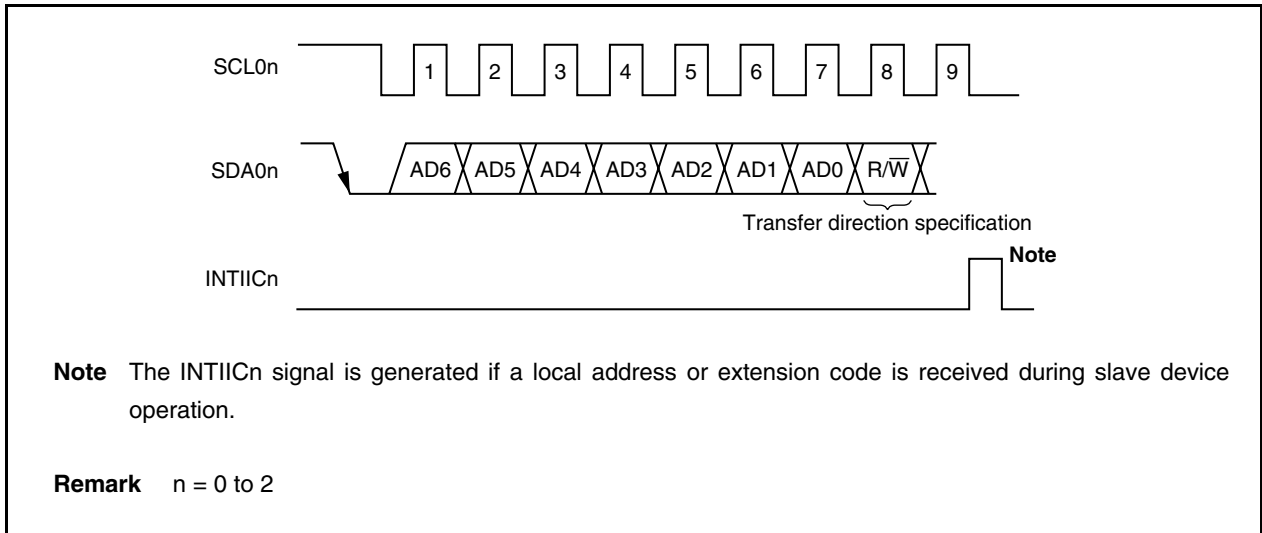
The slave address and the eighth bit, which specifies the transfer direction as described in **17.6.3 Transfer direction specification** below, are written together to IIC shift register n (IICn) and then output. Received addresses are written to the IICn register (n = 0 to 2).

The slave address is assigned to the higher 7 bits of the IICn register.

### 17.6.3 Transfer direction specification

In addition to the 7-bit address data, the master device sends 1 bit that specifies the transfer direction. When this transfer direction specification bit has a value of 0, it indicates that the master device is transmitting data to a slave device. When the transfer direction specification bit has a value of 1, it indicates that the master device is receiving data from a slave device.

Figure 17-10. Transfer Direction Specification



### 17.6.4 $\overline{\text{ACK}}$

$\overline{\text{ACK}}$  is used to confirm the serial data status of the transmitting and receiving devices.

The receiving device returns  $\overline{\text{ACK}}$  for every 8 bits of data it receives.

The transmitting device normally receives  $\overline{\text{ACK}}$  after transmitting 8 bits of data. When  $\overline{\text{ACK}}$  is returned from the receiving device, the reception is judged as normal and processing continues. The detection of  $\overline{\text{ACK}}$  is confirmed with the IICSn.ACKDn bit.

When the master device is the receiving device, after receiving the final data, it does not return  $\overline{\text{ACK}}$  and generates the stop condition. When the slave device is the receiving device and does not return  $\overline{\text{ACK}}$ , the master device generates either a stop condition or a restart condition, and then stops the current transmission. Failure to return  $\overline{\text{ACK}}$  may be caused by the following factors.

- (a) Reception was not performed normally.
- (b) The final data was received.
- (c) The receiving device (slave) does not exist for the specified address.

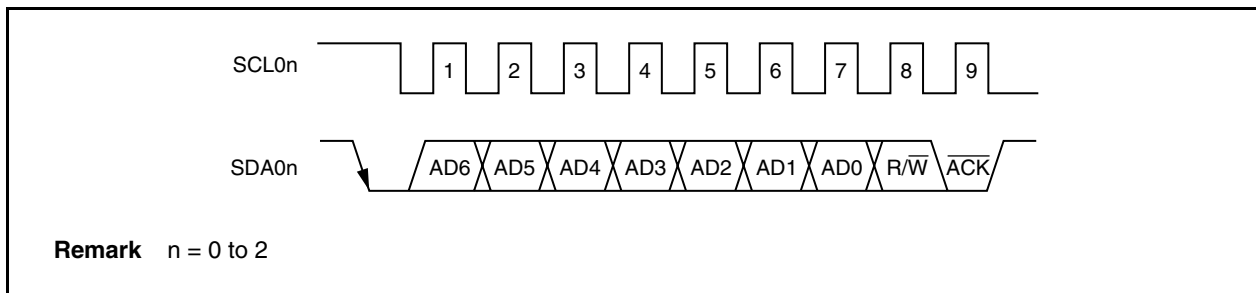
When the receiving device sets the SDA0n line to low level during the ninth clock,  $\overline{\text{ACK}}$  is generated (normal reception).

When the IICcn.ACKEn bit is set to 1, automatic  $\overline{\text{ACK}}$  generation is enabled. Transmission of the eighth bit following the 7 address data bits causes the IICsn.TRCn bit to be set. Normally, set the ACKEn bit to 1 for reception (TRCn bit = 0).

When the slave device is receiving (when TRCn bit = 0), if the slave device cannot receive data or does not need to receive any more data, clear the ACKEn bit to 0 to indicate to the master that no more data can be received.

Similarly, when the master device is receiving (when TRCn bit = 0) and the subsequent data is not needed, clear the ACKEn bit to 0 to prevent  $\overline{\text{ACK}}$  from being generated. This notifies the slave device (transmitting device) of the end of the data transmission (transmission stopped).

Figure 17-11.  $\overline{\text{ACK}}$



When the local address is received,  $\overline{\text{ACK}}$  is automatically generated regardless of the value of the ACKEn bit. No  $\overline{\text{ACK}}$  is generated if the received address is not a local address (NACK).

When receiving the extension code, set the ACKEn bit to 1 in advance to generate  $\overline{\text{ACK}}$ .

The  $\overline{\text{ACK}}$  generation method during data reception is based on the wait timing setting, as described by the following.

- When 8-clock wait is selected (IICcn.WTIMn bit = 0):  
 $\overline{\text{ACK}}$  is generated at the falling edge of the SCL0n pin's eighth clock if the ACKEn bit is set to 1 before the wait state cancellation.
- When 9-clock wait is selected (IICcn.WTIMn bit = 1):  
 $\overline{\text{ACK}}$  is generated if the ACKEn bit is set to 1 in advance.

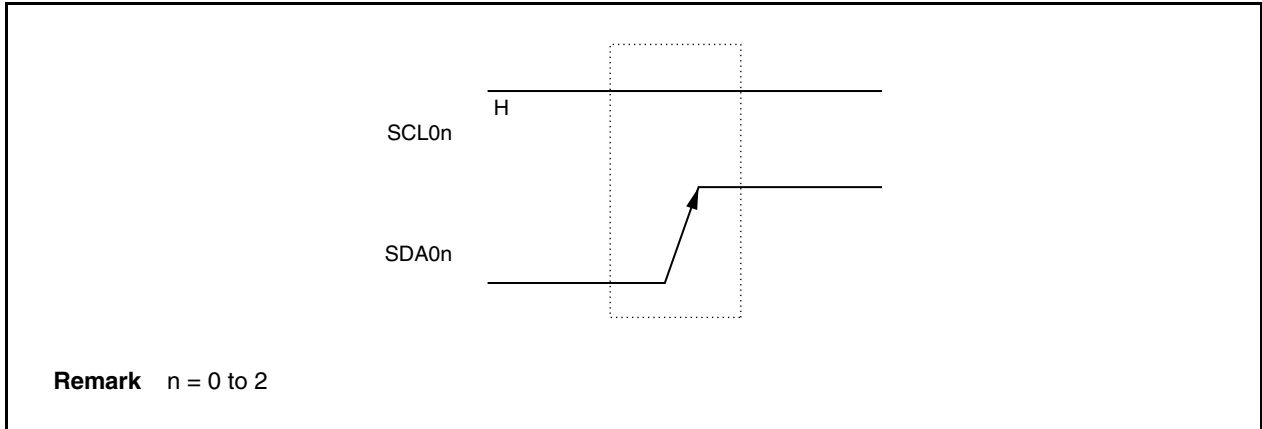
**Remark** n = 0 to 2

### 17.6.5 Stop condition

When the SCL0n pin is high level, changing the SDA0n pin from low level to high level generates a stop condition (n = 0 to 2).

A stop condition is generated when serial transfer from the master device to the slave device has been completed. When used as the slave device, the start condition can be detected.

**Figure 17-12. Stop Condition**



A stop condition is generated when the IICCn.SPTn bit is set to 1. When the stop condition is detected, the IICSn.SPDn bit is set to 1 and the interrupt request signal (INTIICn) is generated when the IICCn.SPIEn bit is set to 1 (n = 0 to 2).

**17.6.6 Wait state**

A wait state is used to notify the communication partner that a device (master or slave) is preparing to transmit or receive data (i.e., is in a wait state).

Setting the SCL0n pin to low level notifies the communication partner of the wait state. When the wait state has been canceled for both the master and slave devices, the next data transfer can begin (n = 0 to 2).

**Figure 17-13. Wait State (1/2)**

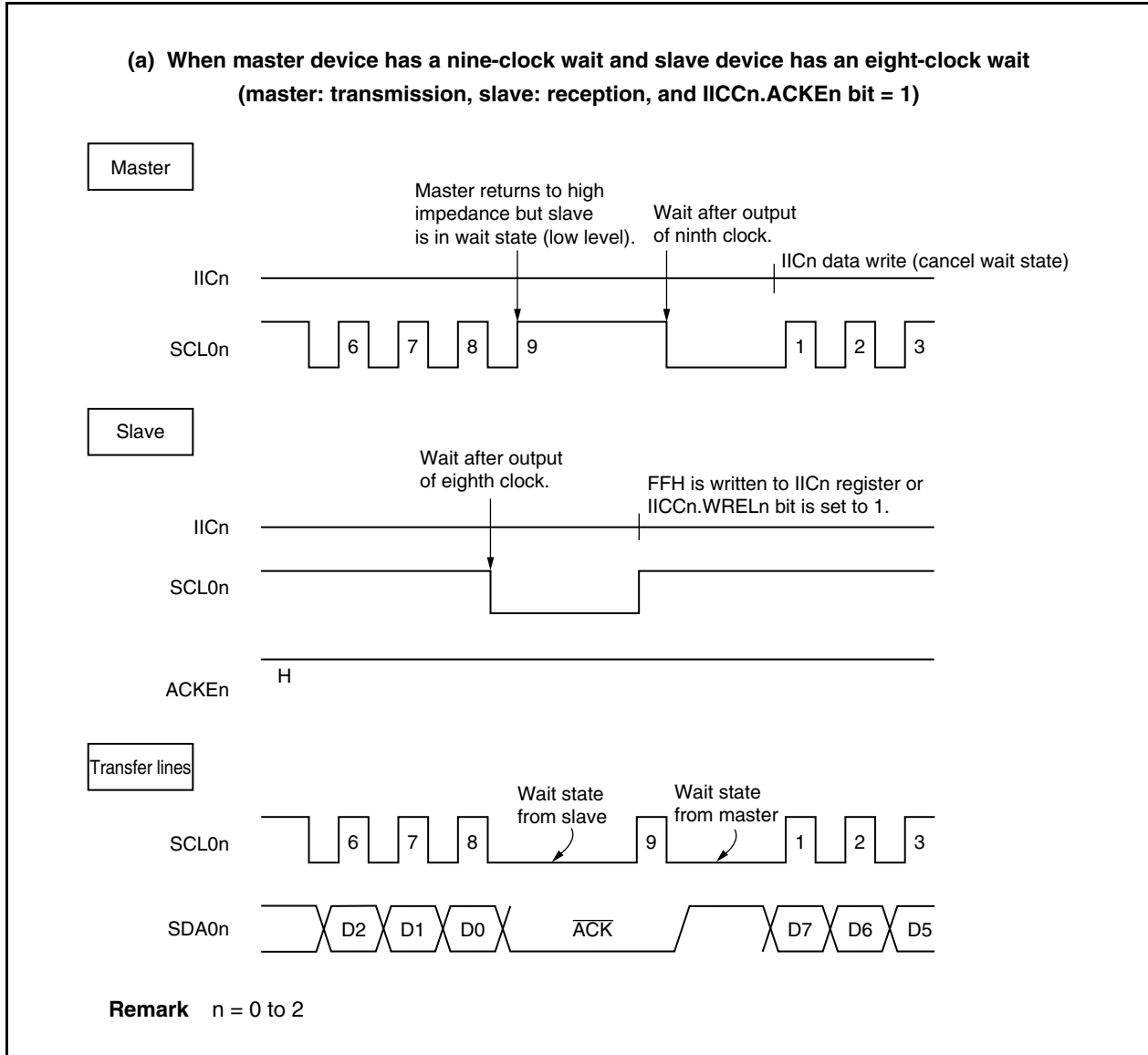
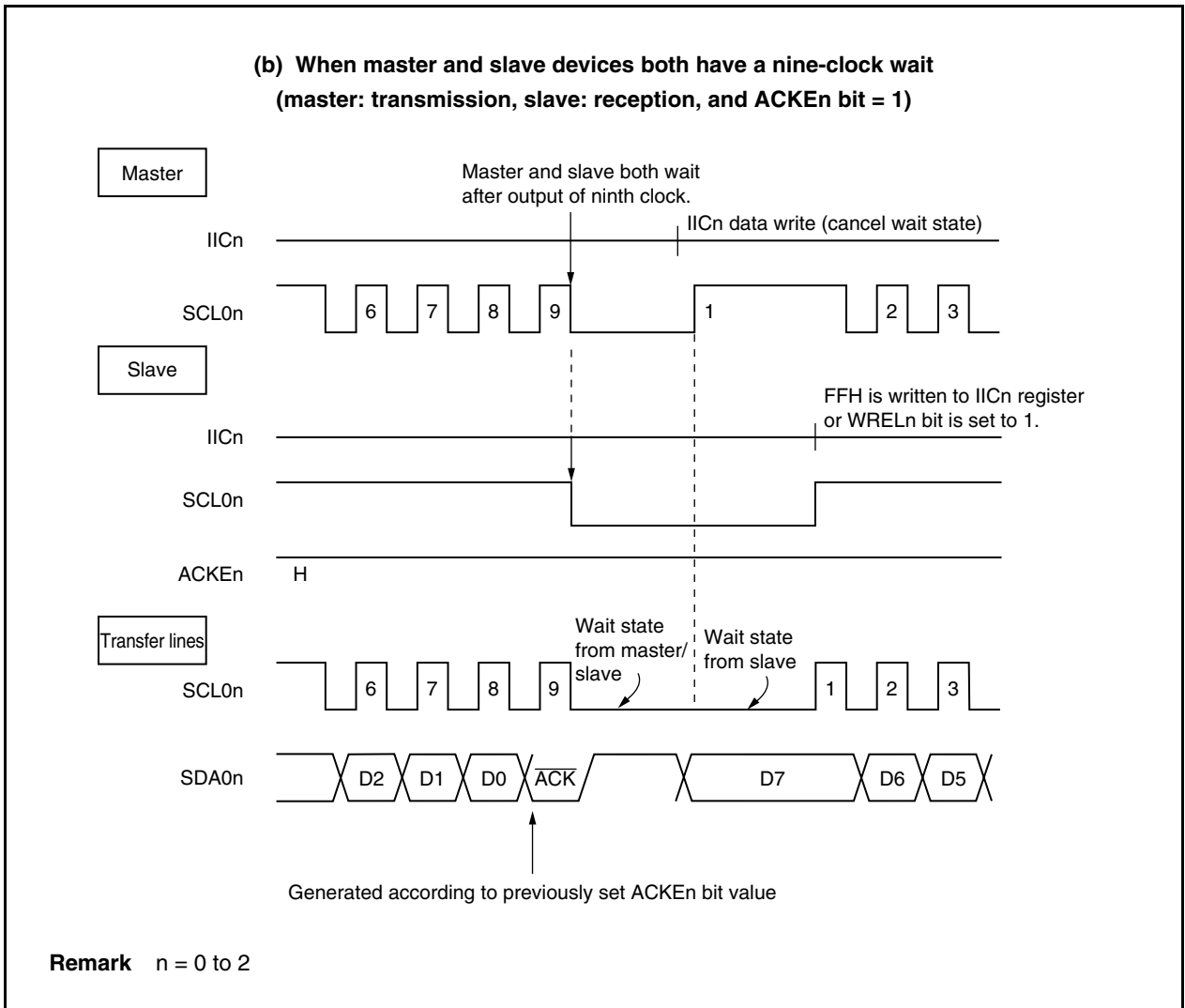


Figure 17-13. Wait State (2/2)



A wait state may be automatically generated depending on the setting of the IICn.WTIMn bit (n = 0 to 2). Normally, when the IICn.WRELn bit is set to 1 or when FFH is written to the IICn register on the receiving side, the wait state is canceled and the transmitting side writes data to the IICn register to cancel the wait state. The master device can also cancel the wait state via either of the following methods.

- By setting the IICn.STTn bit to 1
- By setting the IICn.SPTn bit to 1

### 17.6.7 Wait state cancellation method

In the case of I<sup>2</sup>C0n, wait state can be canceled normally in the following ways (n = 0 to 2).

- By writing data to the IICn register
- By setting the IICn.WRELn bit to 1 (wait state cancellation)
- By setting the IICn.STTn bit to 1 (start condition generation)
- By setting the IICn.SPTn bit to 1 (stop condition generation)

If any of these wait state cancellation actions is performed, I<sup>2</sup>C0n will cancel wait state and restart communication.

When canceling wait state and sending data (including address), write data to the IICn register.

To receive data after canceling wait state, or to complete data transmission, set the WRELn bit to 1.

To generate a restart condition after canceling wait state, set the STTn bit to 1.

To generate a stop condition after canceling wait state, set the SPTn bit to 1.

Execute cancellation only once for each wait state.

For example, if data is written to the IICn register following wait state cancellation by setting the WRELn bit to 1, conflict between the SDA0n line change timing and IICn register write timing may result in the data output to the SDA0n line may be incorrect.

Even in other operations, if communication is stopped halfway, clearing the IICn.IICEn bit to 0 will stop communication, enabling wait state to be cancelled.

If the I<sup>2</sup>C bus dead-locks due to noise, etc., setting the IICn.LRELn bit to 1 causes the communication operation to be exited, enabling wait state to be cancelled.



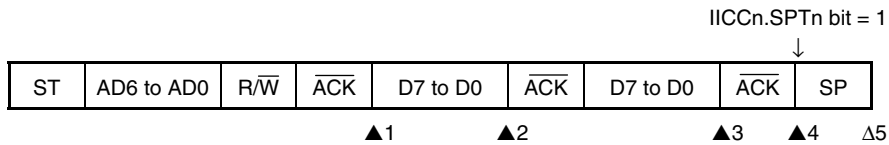
### 17.7 I<sup>2</sup>C Interrupt Request Signals (INTIICn)

The following shows the value of the IICSn register at the INTIICn interrupt request signal generation timing and at the INTIICn signal timing (n = 0 to 2).

#### 17.7.1 Master device operation

##### (1) Start ~ Address ~ Data ~ Data ~ Stop (normal transmission/reception)

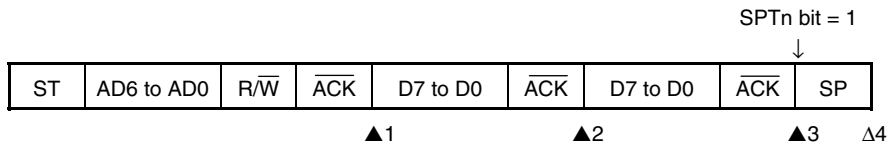
###### <1> When IICn.WTIMn bit = 0



- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000X000B
- ▲3: IICSn register = 1000X000B (WTIMn bit = 1)
- ▲4: IICSn register = 1000XX00B
- Δ 5: IICSn register = 00000001B

- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

###### <2> When WTIMn bit = 1

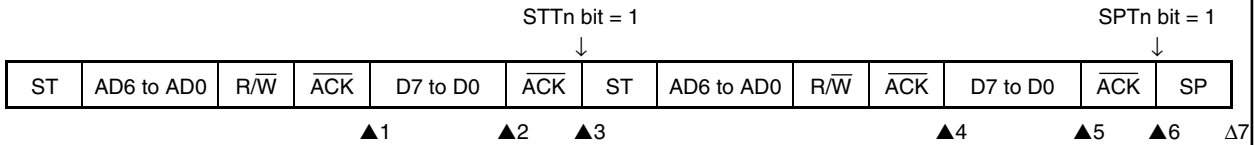


- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000X100B
- ▲3: IICSn register = 1000XX00B
- Δ 4: IICSn register = 00000001B

- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

(2) Start ~ Address ~ Data ~ Start ~ Address ~ Data ~ Stop (restart)

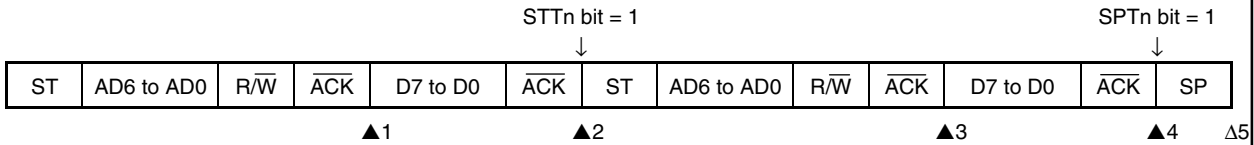
<1> When WTIMn bit = 0



- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000X000B (WTIMn bit = 1)
- ▲3: IICSn register = 1000XX00B (WTIMn bit = 0)
- ▲4: IICSn register = 1000X110B (WTIMn bit = 0)
- ▲5: IICSn register = 1000X000B (WTIMn bit = 1)
- ▲6: IICSn register = 1000XX00B
- Δ 7: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

<2> When WTIMn bit = 1

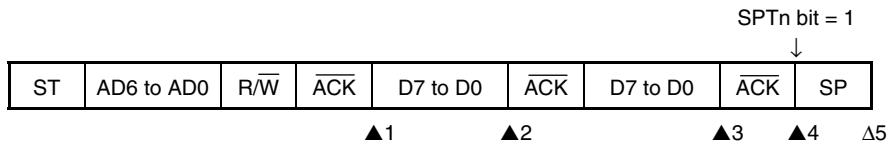


- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000XX00B
- ▲3: IICSn register = 1000X110B
- ▲4: IICSn register = 1000XX00B
- Δ 5: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

## (3) Start ~ Code ~ Data ~ Data ~ Stop (extension code transmission)

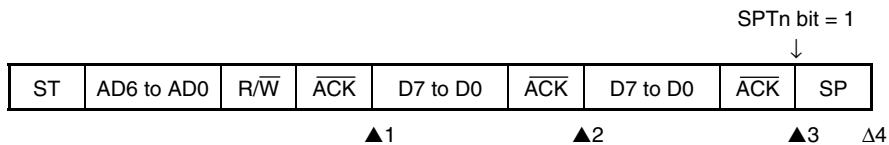
## &lt;1&gt; When WTIMn bit = 0



- ▲1: IICSn register = 1010X110B
- ▲2: IICSn register = 1010X000B
- ▲3: IICSn register = 1010X000B (WTIMn bit = 1)
- ▲4: IICSn register = 1010XX00B
- Δ5: IICSn register = 00000001B

- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care
- 2.** n = 0 to 2

## &lt;2&gt; When WTIMn bit = 1



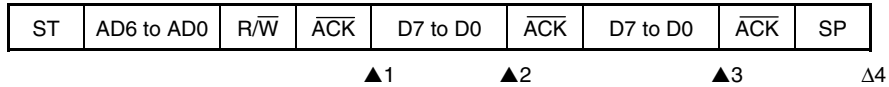
- ▲1: IICSn register = 1010X110B
- ▲2: IICSn register = 1010X100B
- ▲3: IICSn register = 1010XX00B
- Δ4: IICSn register = 00000001B

- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care
- 2.** n = 0 to 2

## 17.7.2 Slave device operation (when receiving slave address data (address match))

## (1) Start ~ Address ~ Data ~ Data ~ Stop

## &lt;1&gt; When IICn.WTIMn bit = 0



▲1: IICSn register = 0001X110B

▲2: IICSn register = 0001X000B

▲3: IICSn register = 0001X000B

Δ 4: IICSn register = 00000001B

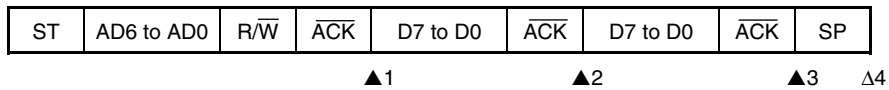
**Remarks 1.** ▲: Always generated

Δ: Generated only when IICn.SPIEn bit = 1

X: don't care

2. n = 0 to 2

## &lt;2&gt; When WTIMn bit = 1



▲1: IICSn register = 0001X110B

▲2: IICSn register = 0001X100B

▲3: IICSn register = 0001XX00B

Δ 4: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated

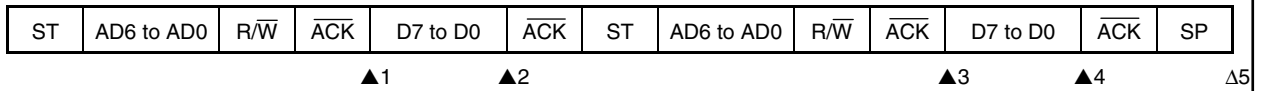
Δ: Generated only when SPIEn bit = 1

X: don't care

2. n = 0 to 2

(2) Start ~ Address ~ Data ~ Start ~ Address ~ Data ~ Stop

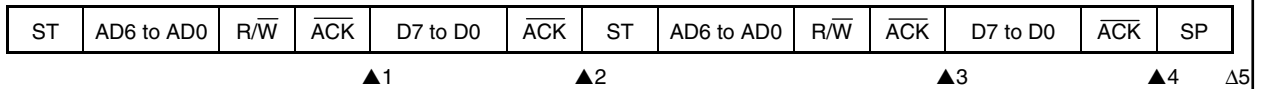
<1> When WTIMn bit = 0 (after restart, address match)



- ▲1: IICSn register = 0001X110B
- ▲2: IICSn register = 0001X000B
- ▲3: IICSn register = 0001X110B
- ▲4: IICSn register = 0001X000B
- Δ 5: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

<2> When WTIMn bit = 1 (after restart, address match)

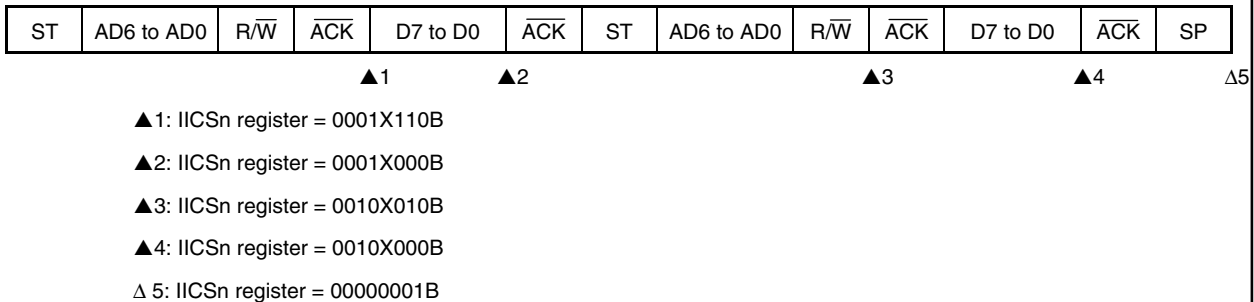


- ▲1: IICSn register = 0001X110B
- ▲2: IICSn register = 0001XX00B
- ▲3: IICSn register = 0001X110B
- ▲4: IICSn register = 0001XX00B
- Δ 5: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

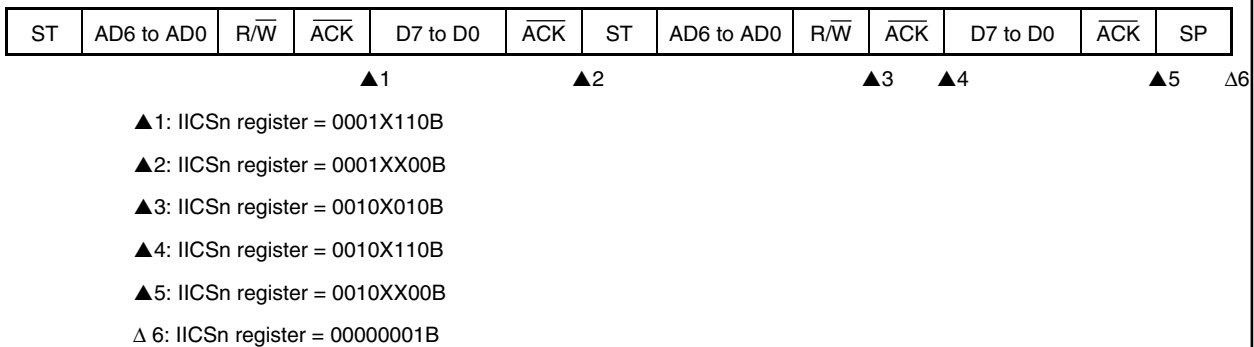
## (3) Start ~ Address ~ Data ~ Start ~ Code ~ Data ~ Stop

## &lt;1&gt; When WTIMn bit = 0 (after restart, extension code reception)



- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

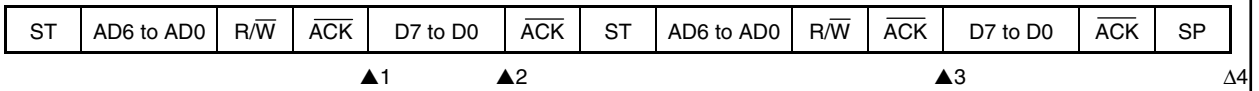
## &lt;2&gt; When WTIMn bit = 1 (after restart, extension code reception)



- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

(4) Start ~ Address ~ Data ~ Start ~ Address ~ Data ~ Stop

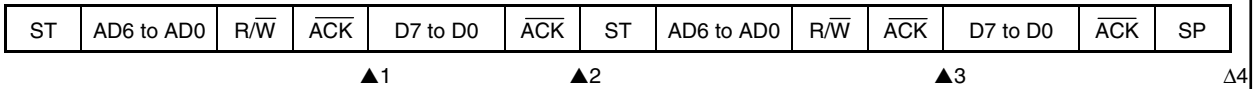
<1> When WTIMn bit = 0 (after restart, address mismatch (= not extension code))



- ▲1: IICSn register = 0001X110B
- ▲2: IICSn register = 0001X000B
- ▲3: IICSn register = 00000X10B
- Δ 4: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

<2> When WTIMn bit = 1 (after restart, address mismatch (= not extension code))



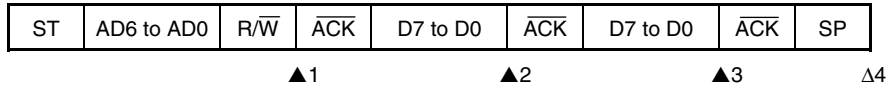
- ▲1: IICSn register = 0001X110B
- ▲2: IICSn register = 0001XX00B
- ▲3: IICSn register = 00000X10B
- Δ 4: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

## 17.7.3 Slave device operation (when receiving extension code)

## (1) Start ~ Code ~ Data ~ Data ~ Stop

## &lt;1&gt; When IICn.WTIMn bit = 0



▲1: IICSn register = 0010X010B

▲2: IICSn register = 0010X000B

▲3: IICSn register = 0010X000B

Δ4: IICSn register = 00000001B

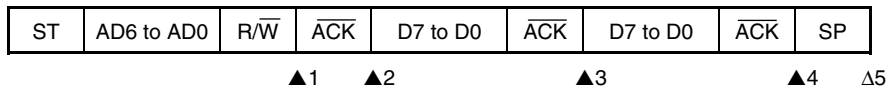
**Remarks 1.** ▲: Always generated

Δ: Generated only when IICn.SPIEn bit = 1

X: don't care

2. n = 0 to 2

## &lt;2&gt; When WTIMn bit = 1



▲1: IICSn register = 0010X010B

▲2: IICSn register = 0010X110B

▲3: IICSn register = 0010X100B

▲4: IICSn register = 0010XX00B

Δ5: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated

Δ: Generated only when SPIEn bit = 1

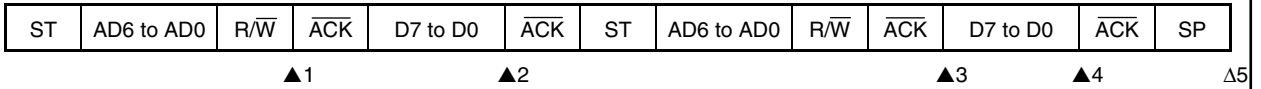
X: don't care

2. n = 0 to 2



(2) Start ~ Code ~ Data ~ Start ~ Address ~ Data ~ Stop

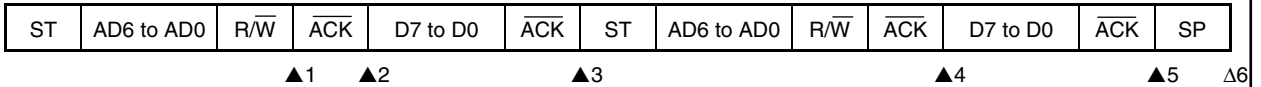
<1> When WTIMn bit = 0 (after restart, address match)



- ▲1: IICSn register = 0010X010B
- ▲2: IICSn register = 0010X000B
- ▲3: IICSn register = 0001X110B
- ▲4: IICSn register = 0001X000B
- Δ 5: IICSn register = 00000001B

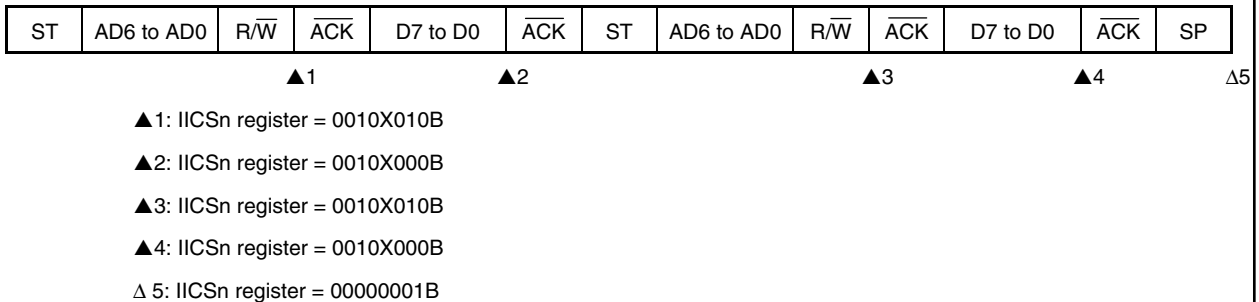
**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

<2> When WTIMn bit = 1 (after restart, address match)

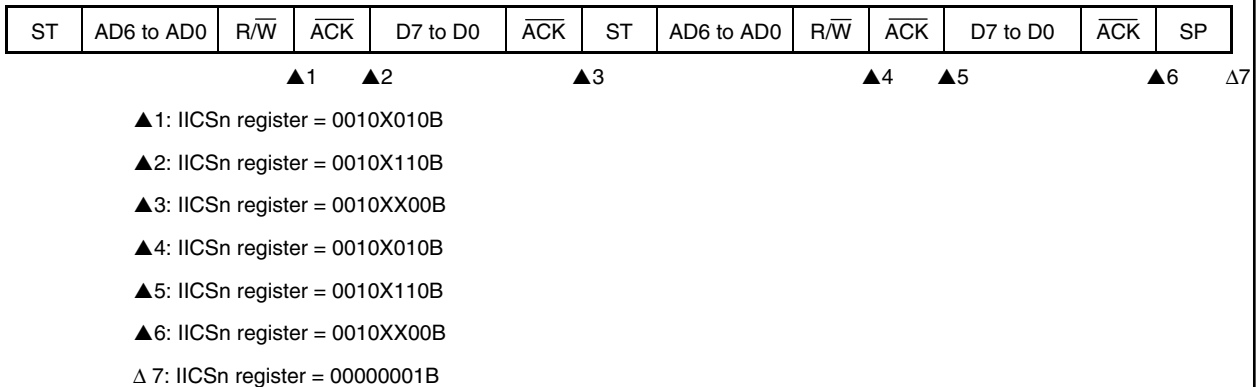


- ▲1: IICSn register = 0010X010B
- ▲2: IICSn register = 0010X110B
- ▲3: IICSn register = 0010XX00B
- ▲4: IICSn register = 0001X110B
- ▲5: IICSn register = 0001XX00B
- Δ 6: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

**(3) Start ~ Code ~ Data ~ Start ~ Code ~ Data ~ Stop****<1> When WTIMn bit = 0 (after restart, extension code reception)**

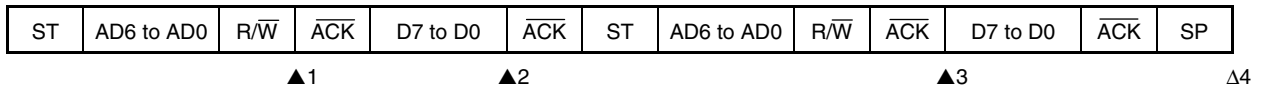
- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

**<2> When WTIMn bit = 1 (after restart, extension code reception)**

- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

(4) Start ~ Code ~ Data ~ Start ~ Address ~ Data ~ Stop

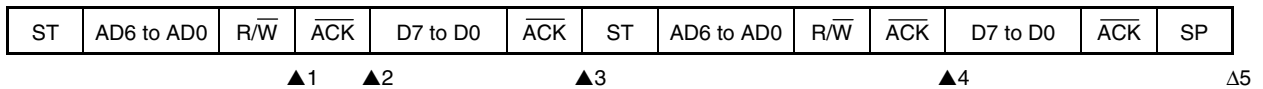
<1> When WTIMn bit = 0 (after restart, address mismatch (= not extension code))



- ▲1: IICSn register = 0010X010B
- ▲2: IICSn register = 0010X000B
- ▲3: IICSn register = 00000X10B
- Δ 4: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

<2> When WTIMn bit = 1 (after restart, address mismatch (= not extension code))

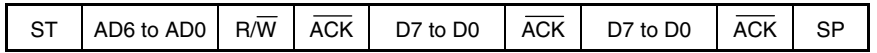


- ▲1: IICSn register = 0010X010B
- ▲2: IICSn register = 0010X110B
- ▲3: IICSn register = 0010XX00B
- ▲4: IICSn register = 00000X10B
- Δ 5: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

17.7.4 Operation without communication

(1) Start ~ Code ~ Data ~ Data ~ Stop



Δ1

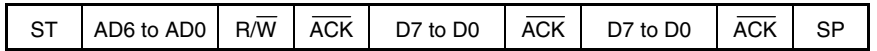
Δ 1: IICSn register = 00000001B

- Remarks 1.** Δ: Generated only when SPIEn bit = 1  
 2. n = 0 to 2

17.7.5 Arbitration loss operation (operation as slave after arbitration loss)

(1) When arbitration loss occurs during transmission of slave address data

<1> When IICn.WTIMn bit = 0



▲1

▲2

▲3

Δ4

▲1: IICSn register = 0101X110B (Example: When IICSn.ALDn bit is read during interrupt servicing)

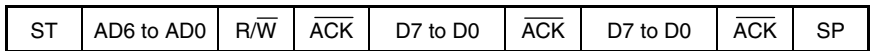
▲2: IICSn register = 0001X000B

▲3: IICSn register = 0001X000B

Δ 4: IICSn register = 00000001B

- Remarks 1.** ▲: Always generated  
 Δ: Generated only when IICn.SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

<2> When WTIMn bit = 1



▲1

▲2

▲3

Δ4

▲1: IICSn register = 0101X110B (Example: When ALDn bit is read during interrupt servicing)

▲2: IICSn register = 0001X100B

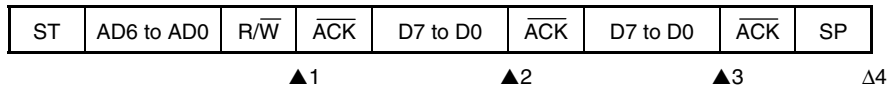
▲3: IICSn register = 0001XX00B

Δ 4: IICSn register = 00000001B

- Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

## (2) When arbitration loss occurs during transmission of extension code

## &lt;1&gt; When WTIMn bit = 0



▲1: IICSn register = 0110X010B (Example: When ALDn bit is read during interrupt servicing)

▲2: IICSn register = 0010X000B

▲3: IICSn register = 0010X000B

Δ 4: IICSn register = 00000001B

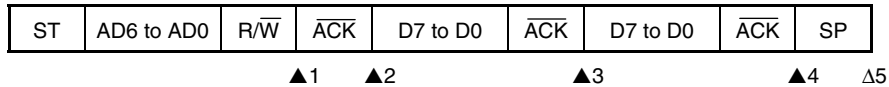
**Remarks 1.** ▲: Always generated

Δ: Generated only when SPIEn bit = 1

X: don't care

2. n = 0 to 2

## &lt;2&gt; When WTIMn bit = 1



▲1: IICSn register = 0110X010B (Example: When ALDn bit is read during interrupt servicing)

▲2: IICSn register = 0010X110B

▲3: IICSn register = 0010X100B

▲4: IICSn register = 0010XX00B

Δ 5: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated

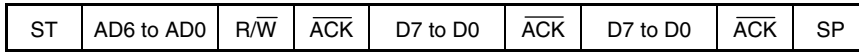
Δ: Generated only when SPIEn bit = 1

X: don't care

2. n = 0 to 2

17.7.6 Operation when arbitration loss occurs (no communication after arbitration loss)

(1) When arbitration loss occurs during transmission of slave address data



▲1

Δ2

▲1: IICSn register = 01000110B (Example: When IICSn.ALDn bit is read during interrupt servicing)

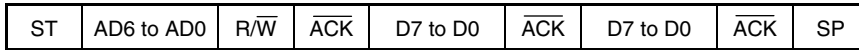
Δ 2: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated

Δ: Generated only when IICcn.SPIEn bit = 1

2. n = 0 to 2

(2) When arbitration loss occurs during transmission of extension code



▲1

Δ2

▲1: IICSn register = 0110X010B (Example: When ALDn bit is read during interrupt servicing)

IICcn.LRELn bit is set to 1 by software

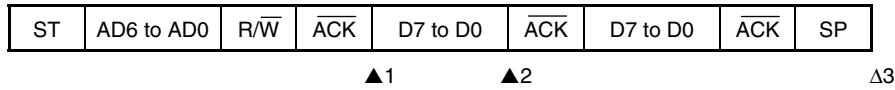
Δ 2: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated

Δ: Generated only when SPIEn bit = 1

X: don't care

2. n = 0 to 2

**(3) When arbitration loss occurs during data transfer****<1> When IICn.WTIMn bit = 0**

▲1: IICSn register = 10001110B

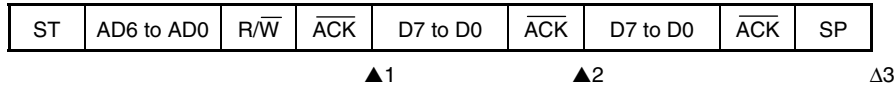
▲2: IICSn register = 01000000B (Example: When ALDn bit is read during interrupt servicing)

Δ3: IICSn register = 00000001B

**Remarks 1. ▲:** Always generated

Δ: Generated only when SPIEn bit = 1

2. n = 0 to 2

**<2> When WTIMn bit = 1**

▲1: IICSn register = 10001110B

▲2: IICSn register = 01000100B (Example: When ALDn bit is read during interrupt servicing)

Δ3: IICSn register = 00000001B

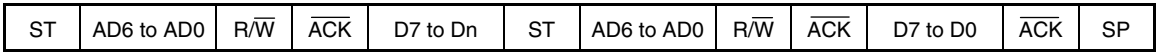
**Remarks 1. ▲:** Always generated

Δ: Generated only when SPIEn bit = 1

2. n = 0 to 2

(4) When arbitration loss occurs due to restart condition during data transfer

<1> Not extension code (Example: Address mismatch)



▲1

▲2

Δ3

▲1: IICSn register = 1000X110B

▲2: IICSn register = 01000110B (Example: When ALDn bit is read during interrupt servicing)

Δ 3: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated

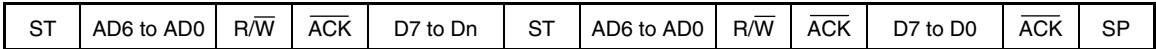
Δ: Generated only when SPIEn bit = 1

X: don't care

2. Dn = D6 to D0

n = 0 to 2

<2> Extension code



▲1

▲2

Δ3

▲1: IICSn register = 1000X110B

▲2: IICSn register = 0110X010B (Example: When ALDn bit is read during interrupt servicing)

IICcn.LRELn bit is set to 1 by software

Δ 3: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated

Δ: Generated only when SPIEn bit = 1

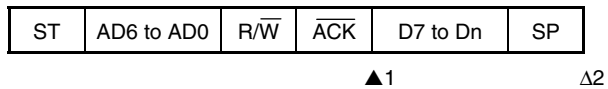
X: don't care

2. Dn = D6 to D0

n = 0 to 2



## (5) When arbitration loss occurs due to stop condition during data transfer



▲1: IICSn register = 1000X110B

Δ 2: IICSn register = 01000001B

**Remarks 1.** ▲: Always generated

Δ: Generated only when SPIEn bit = 1

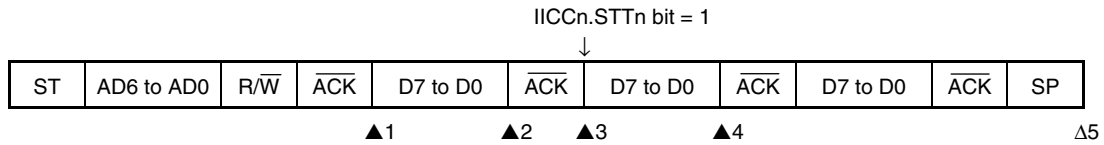
X: don't care

**2.** Dn = D6 to D0

n = 0 to 2

(6) When arbitration loss occurs due to low level of SDA0n pin when attempting to generate a restart condition

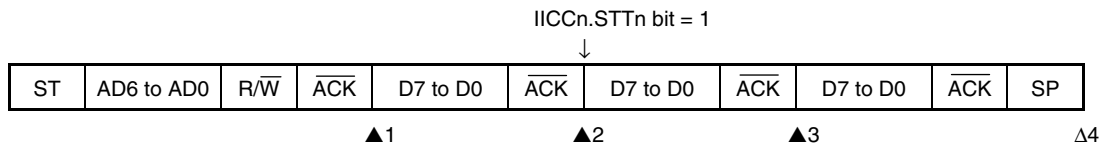
<1> When WTIMn bit = 0



- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000X000B (WTIMn bit = 1)
- ▲3: IICSn register = 1000XX00B (WTIMn bit = 0)
- ▲4: IICSn register = 01000000B (Example: When ALDn bit is read during interrupt servicing)
- Δ 5: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

<2> When WTIMn bit = 1

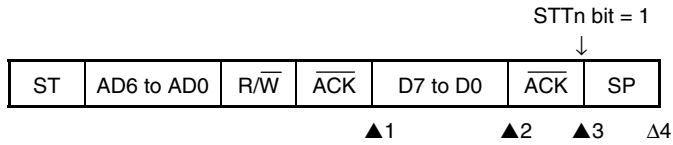


- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000XX00B
- ▲3: IICSn register = 01000100B (Example: When ALDn bit is read during interrupt servicing)
- Δ 4: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

(7) When arbitration loss occurs due to a stop condition when attempting to generate a restart condition

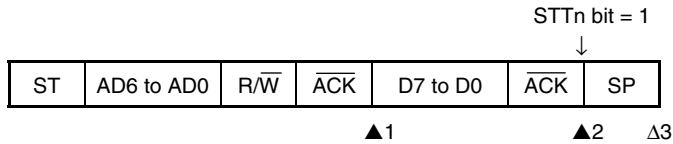
<1> When WTIMn bit = 0



- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000X000B (WTIMn bit = 1)
- ▲3: IICSn register = 1000XX00B
- Δ 4: IICSn register = 01000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
**2.** n = 0 to 2

<2> When WTIMn bit = 1

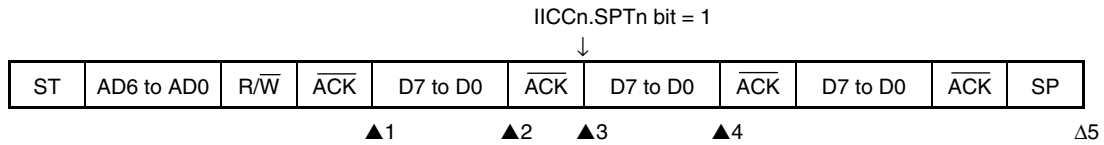


- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000XX00B
- Δ 3: IICSn register = 01000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
**2.** n = 0 to 2

(8) When arbitration loss occurs due to low level of SDA0n pin when attempting to generate a stop condition

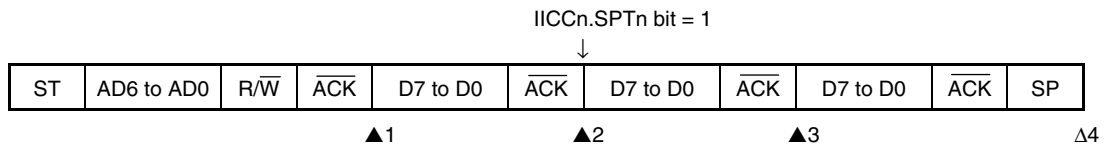
<1> When WTIMn bit = 0



- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000X000B (WTIMn bit = 1)
- ▲3: IICSn register = 1000XX00B (WTIMn bit = 0)
- ▲4: IICSn register = 01000000B (Example: When ALDn bit is read during interrupt servicing)
- Δ 5: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

<2> When WTIMn bit = 1



- ▲1: IICSn register = 1000X110B
- ▲2: IICSn register = 1000XX00B
- ▲3: IICSn register = 01000000B (Example: When ALDn bit is read during interrupt servicing)
- Δ 4: IICSn register = 00000001B

**Remarks 1.** ▲: Always generated  
 Δ: Generated only when SPIEn bit = 1  
 X: don't care  
 2. n = 0 to 2

## 17.8 Interrupt Request Signal (INTIICn) Generation Timing and Wait Control

The setting of the IICn.WTIMn bit determines the timing by which the INTIICn register is generated and the corresponding wait control, as shown below (n = 0 to 2).

**Table 17-3. INTIICn Generation Timing and Wait Control**

| WTIMn Bit | During Slave Device Operation |                     |                     | During Master Device Operation |                |                   |
|-----------|-------------------------------|---------------------|---------------------|--------------------------------|----------------|-------------------|
|           | Address                       | Data Reception      | Data Transmission   | Address                        | Data Reception | Data Transmission |
| 0         | g <sup>Notes 1, 2</sup>       | g <sup>Note 2</sup> | g <sup>Note 2</sup> | 9                              | 8              | 8                 |
| 1         | g <sup>Notes 1, 2</sup>       | g <sup>Note 2</sup> | g <sup>Note 2</sup> | 9                              | 9              | 9                 |

**Notes 1.** The slave device's INTIICn signal and wait period occur at the falling edge of the ninth clock only when there is a match with the address set to the SVAn register.

At this point,  $\overline{ACK}$  is generated regardless of the value set to the IICn.ACKEn bit. For a slave device that has received an extension code, the INTIICn signal occurs at the falling edge of the eighth clock.

When the address does not match after restart, the INTIICn signal is generated at the falling edge of the ninth clock, but no wait occurs.

- 2.** If the received address does not match the contents of the SVAn register and an extension code is not received, neither the INTIICn signal nor a wait state is generated.

**Remarks 1.** The numbers in the table indicate the number of the serial clock's clock signals. Interrupt requests and wait control are both synchronized with the falling edge of these clock signals.

- 2.** n = 0 to 2

### (1) During address transmission/reception

- Slave device operation: Interrupt and wait timing are determined regardless of the WTIMn bit.
- Master device operation: Interrupt and wait timing occur at the falling edge of the ninth clock regardless of the WTIMn bit.

### (2) During data reception

- Master/slave device operation: Interrupt and wait timing is determined according to the WTIMn bit.

### (3) During data transmission

- Master/slave device operation: Interrupt and wait timing is determined according to the WTIMn bit.

**(4) Wait state cancellation method**

The four wait state cancellation methods are as follows.

- By setting the IICn.WRELn bit to 1
- By writing to the IICn register
- By start condition setting (IICn.STTn bit = 1)<sup>Note</sup>
- By stop condition setting (IICn.SPTn bit = 1)<sup>Note</sup>

**Note** Master only

When an 8-clock wait has been selected (WTIMn bit = 0), whether or not  $\overline{\text{ACK}}$  has been generated must be determined prior to wait cancellation.

**Remark** n = 0 to 2

**(5) Stop condition detection**

The INTIICn signal is generated when a stop condition is detected.

**Remark** n = 0 to 2

## 17.9 Address Match Detection Method

In I<sup>2</sup>C bus mode, the master device can select a particular slave device by transmitting the corresponding slave address.

Address match detection is performed automatically by hardware. The INTIICn signal occurs when a local address has been set to the SVAn register and when the address set to the SVAn register matches the slave address sent by the master device, or when an extension code has been received (n = 0 to 2).

## 17.10 Error Detection

In I<sup>2</sup>C bus mode, the status of the serial data bus pin (SDA0n) during data transmission is captured by the IICn register of the transmitting device, so the data of the IICn register prior to transmission can be compared with the transmitted IICn data to enable detection of transmission errors. A transmission error is judged as having occurred when the compared data values do not match (n = 0 to 2).

## 17.11 Extension Code

- (1) When the higher 4 bits of the receive address are either 0000 or 1111, the extension code flag (IICSn.EXCn bit) is set for extension code reception and an interrupt request signal (INTIICn) is issued at the falling edge of the eighth clock (n = 0 to 2).

The local address stored in the SVAn register is not affected.

- (2) If 11110xx0 is set to the SVAn register by a 10-bit address transfer and 11110xx0 is transferred from the master device, the results are as follows. Note that the INTIICn signal occurs at the falling edge of the eighth clock (n = 0 to 2).

- Higher four bits of data match: EXCn bit = 1
- Seven bits of data match: IICSn.COIn bit = 1

- (3) Since the processing after the interrupt request signal occurs differs according to the data that follows the extension code, such processing is performed by software.

For example, when operation as a slave is not desired after the extension code is received, set the IICn.LRELn bit to 1 and the CPU will enter the next communication wait state.

**Table 17-4. Extension Code Bit Definitions**

| Slave Address | R/W Bit | Description                                       |
|---------------|---------|---|
| 0000 000      | 0       | General call address                              |
| 0000 000      | 1       | Start byte  |
| 0000 001      | X       | CBUS address                                      |
| 0000 010      | X       | Address that is reserved for different bus format |
| 1111 0xx      | X       | 10-bit slave address specification                |

## 17.12 Arbitration

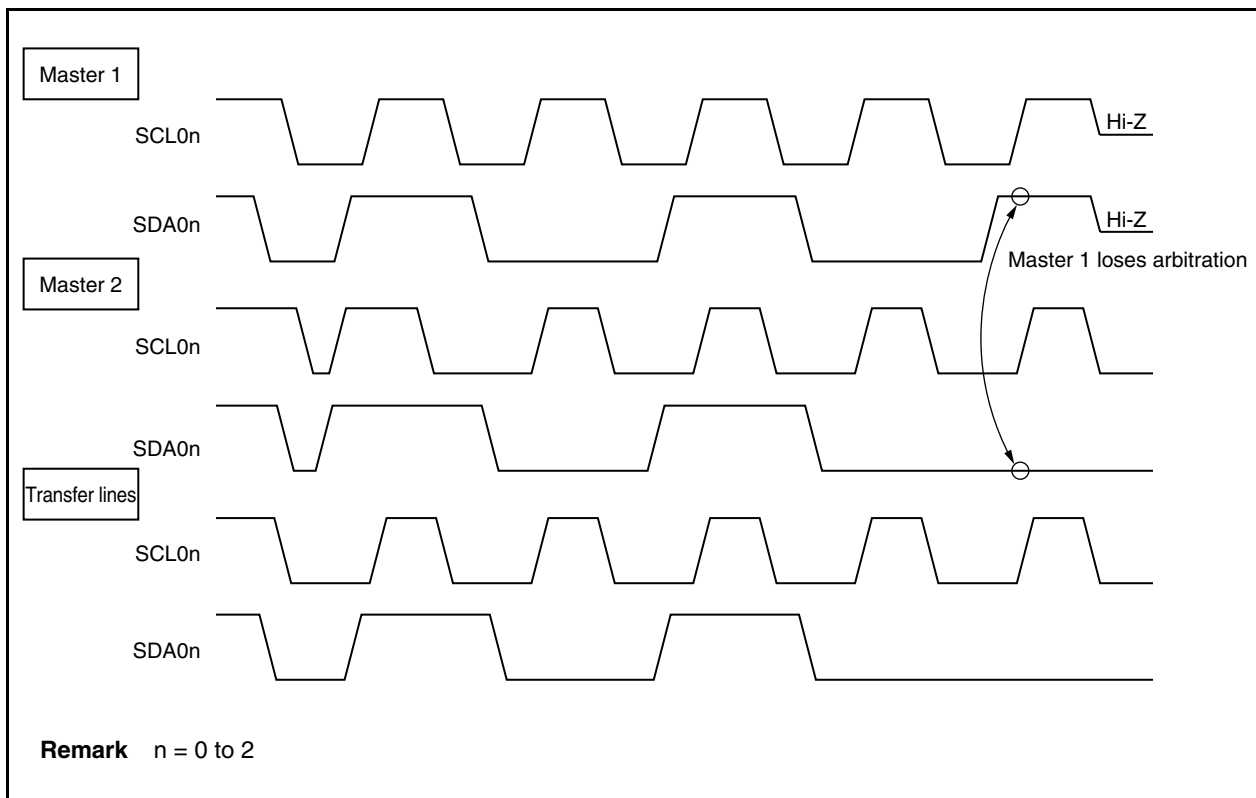
When several master devices simultaneously generate a start condition (when the IICn.STTn bit is set to 1 before the IICSn.STDn bit is set to 1), communication between the master devices is performed while the number of clocks is adjusted until the data differs. This kind of operation is called arbitration ( $n = 0$  to 2).

When one of the master devices loses in arbitration, an arbitration loss flag (IICSn.ALDn bit) is set to 1 via the timing by which the arbitration loss occurred, and the SCL0n and SDA0n lines are both set to high impedance, which releases the bus ( $n = 0$  to 2).

Arbitration loss is detected based on the timing of the next interrupt request signal (INTIICn) (the eighth or ninth clock, when a stop condition is detected, etc.) and the setting of the ALDn bit to 1, which is made by software ( $n = 0$  to 2).

For details of interrupt request timing, see 17.7 I<sup>2</sup>C Interrupt Request Signals (INTIICn).

**Figure 17-14. Arbitration Timing Example**





**Table 17-5. Status During Arbitration and Interrupt Request Signal Generation Timing**

| Status During Arbitration  | Interrupt Request Generation Timing  |
|--|--|
| Transmitting address transmission  | At falling edge of eighth or ninth clock following byte transfer <sup>Note 1</sup> |
| Read/write data after address transmission                                     |  |
| Transmitting extension code  |  |
| Read/write data after extension code transmission                              |  |
| Transmitting data  |  |
| ACK transfer period after data reception                                       |  |
| When restart condition is detected during data transfer                        |  |
| When stop condition is detected during data transfer                           | When stop condition is generated (when IICCn.SPIEn bit = 1) <sup>Note 2</sup>      |
| When SDA0n pin is low level while attempting to generate restart condition     | At falling edge of eighth or ninth clock following byte transfer <sup>Note 1</sup> |
| When stop condition is detected while attempting to generate restart condition | When stop condition is generated (when IICCn.SPIEn bit = 1) <sup>Note 2</sup>      |
| When DSA0n pin is low level while attempting to generate stop condition        | At falling edge of eighth or ninth clock following byte transfer <sup>Note 1</sup> |
| When SCL0n pin is low level while attempting to generate restart condition     |  |

**Notes 1.** When the IICCn.WTIMn bit = 1, an INTIICn signal occurs at the falling edge of the ninth clock. When the WTIMn bit = 0 and the extension code's slave address is received, an INTIICn signal occurs at the falling edge of the eighth clock (n = 0 to 2).

- 2.** When there is a possibility that arbitration will occur, set the SPIEn bit to 1 for master device operation (n = 0 to 2).

### 17.13 Wakeup Function

The I<sup>2</sup>C bus slave function is a function that generates an interrupt request signal (INTIICn) when a local address and extension code have been received.

This function makes processing more efficient by preventing unnecessary the INTIICn signal from occurring when addresses do not match.

When a start condition is detected, wakeup standby mode is set. This wakeup standby mode is in effect while addresses are transmitted due to the possibility that an arbitration loss may change the master device (which has generated a start condition) to a slave device.

However, when a stop condition is detected, the IICCn.SPIEn bit is set regardless of the wakeup function, and this determines whether INTIICn signal is enabled or disabled (n = 0 to 2).

## 17.14 Communication Reservation

### 17.14.1 When communication reservation function is enabled (IICFn.IICRSVn bit = 0)

To start master device communications when not currently using the bus, a communication reservation can be made to enable transmission of a start condition when the bus is released. There are two modes in which the bus is not used.

- When arbitration results in neither master nor slave operation
- When an extension code is received and slave operation is disabled ( $\overline{\text{ACK}}$  is not returned and the bus was released when the IICFn.LRELn bit was set to 1) (n = 0 to 2).

If the IICFn.STTn bit is set to 1 while the bus is not used, a start condition is automatically generated and a wait state is set after the bus is released (after a stop condition is detected).

When the bus release is detected (when a stop condition is detected), writing to the IICFn register causes master address transfer to start. At this point, the IICFn.SPIEn bit should be set to 1 (n = 0 to 2).

When STTn has been set to 1, the operation mode (as start condition or as communication reservation) is determined according to the bus status (n = 0 to 2).

If the bus has been released .....A start condition is generated

If the bus has not been released (standby mode).....Communication reservation

To detect which operation mode has been determined for the STTn bit, set the STTn bit to 1, wait for the wait period, then check the IICFn.MSTS bit (n = 0 to 2).

The wait periods, which should be set via software, are listed in Table 17-6. These wait periods can be set by the SMCn, CLn1, and CLn0 bits of the IICCLn register and the IICFn.CLXn bit (n = 0 to 2).

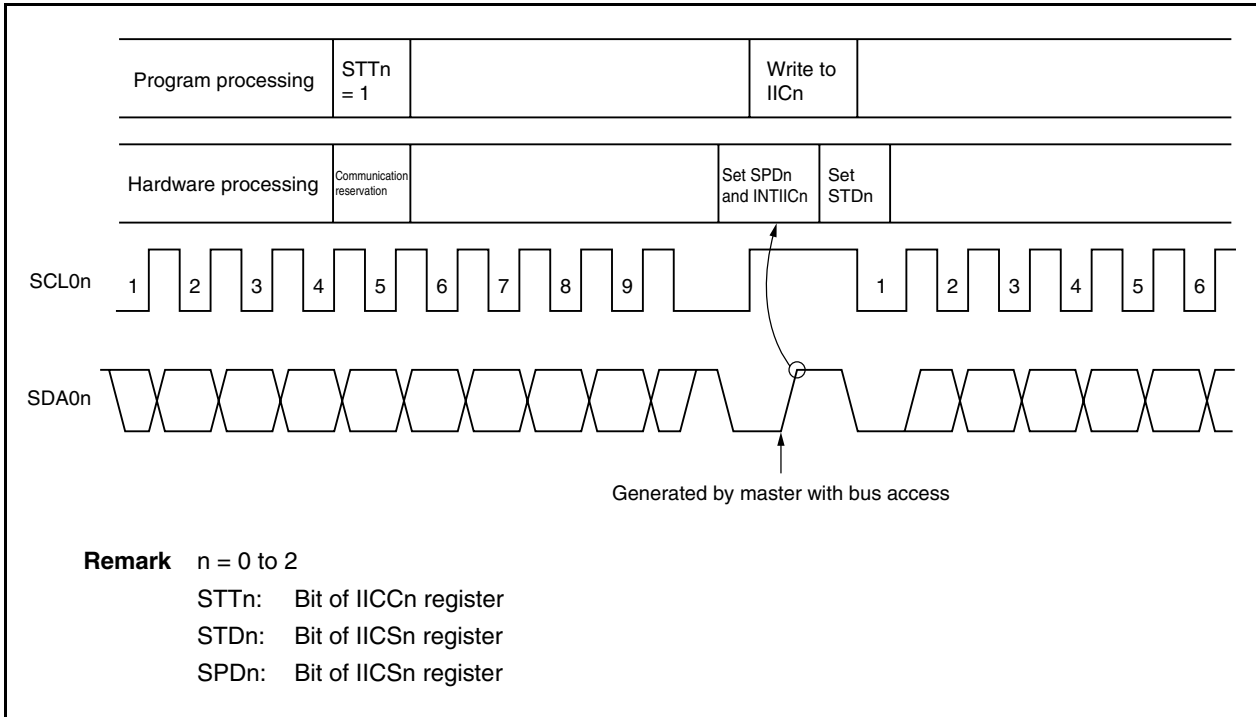
Table 17-6. Wait Periods

| Clock Selection              | CLXn | SMCn | CLn1 | CLn0 | Wait Period |
|------------------------------|------|------|------|------|-------------|
| fxx (when OCKSm = 18H set)   | 0    | 0    | 0    | 0    | 26 clocks   |
| fxx/2 (when OCKSm = 10H set) | 0    | 0    | 0    | 0    | 52 clocks   |
| fxx/3 (when OCKSm = 11H set) | 0    | 0    | 0    | 0    | 78 clocks   |
| fxx/4 (when OCKSm = 12H set) | 0    | 0    | 0    | 0    | 104 clocks  |
| fxx/5 (when OCKSm = 13H set) | 0    | 0    | 0    | 0    | 130 clocks  |
| fxx (when OCKSm = 18H set)   | 0    | 0    | 0    | 1    | 47 clocks   |
| fxx/2 (when OCKSm = 10H set) | 0    | 0    | 0    | 1    | 94 clocks   |
| fxx/3 (when OCKSm = 11H set) | 0    | 0    | 0    | 1    | 141 clocks  |
| fxx/4 (when OCKSm = 12H set) | 0    | 0    | 0    | 1    | 188 clocks  |
| fxx/5 (when OCKSm = 13H set) | 0    | 0    | 0    | 1    | 235 clocks  |
| fxx                          | 0    | 0    | 1    | 0    | 47 clocks   |
| fxx (when OCKSm = 18H set)   | 0    | 0    | 1    | 1    | 37 clocks   |
| fxx/2 (when OCKSm = 10H set) | 0    | 0    | 1    | 1    | 74 clocks   |
| fxx/3 (when OCKSm = 11H set) | 0    | 0    | 1    | 1    | 111 clocks  |
| fxx/4 (when OCKSm = 12H set) | 0    | 0    | 1    | 1    | 148 clocks  |
| fxx/5 (when OCKSm = 13H set) | 0    | 0    | 1    | 1    | 185 clocks  |
| fxx (when OCKSm = 18H set)   | 0    | 1    | 0    | ×    | 16 clocks   |
| fxx/2 (when OCKSm = 10H set) | 0    | 1    | 0    | ×    | 32 clocks   |
| fxx/3 (when OCKSm = 11H set) | 0    | 1    | 0    | ×    | 48 clocks   |
| fxx/4 (when OCKSm = 12H set) | 0    | 1    | 0    | ×    | 64 clocks   |
| fxx/5 (when OCKSm = 13H set) | 0    | 1    | 0    | ×    | 80 clocks   |
| fxx                          | 0    | 1    | 1    | 0    | 16 clocks   |
| fxx (when OCKSm = 18H set)   | 0    | 1    | 1    | 1    | 13 clocks   |
| fxx/2 (when OCKSm = 10H set) | 0    | 1    | 1    | 1    | 26 clocks   |
| fxx/3 (when OCKSm = 11H set) | 0    | 1    | 1    | 1    | 39 clocks   |
| fxx/4 (when OCKSm = 12H set) | 0    | 1    | 1    | 1    | 52 clocks   |
| fxx/5 (when OCKSm = 13H set) | 0    | 1    | 1    | 1    | 65 clocks   |
| fxx (when OCKSm = 18H set)   | 1    | 1    | 0    | ×    | 10 clocks   |
| fxx/2 (when OCKSm = 10H set) | 1    | 1    | 0    | ×    | 20 clocks   |
| fxx/3 (when OCKSm = 11H set) | 1    | 1    | 0    | ×    | 30 clocks   |
| fxx/4 (when OCKSm = 12H set) | 1    | 1    | 0    | ×    | 40 clocks   |
| fxx/5 (when OCKSm = 13H set) | 1    | 1    | 0    | ×    | 50 clocks   |
| fxx                          | 1    | 1    | 1    | 0    | 10 clocks   |

- Remarks 1.** n = 0 to 2  
m = 0, 1  
**2.** × = don't care

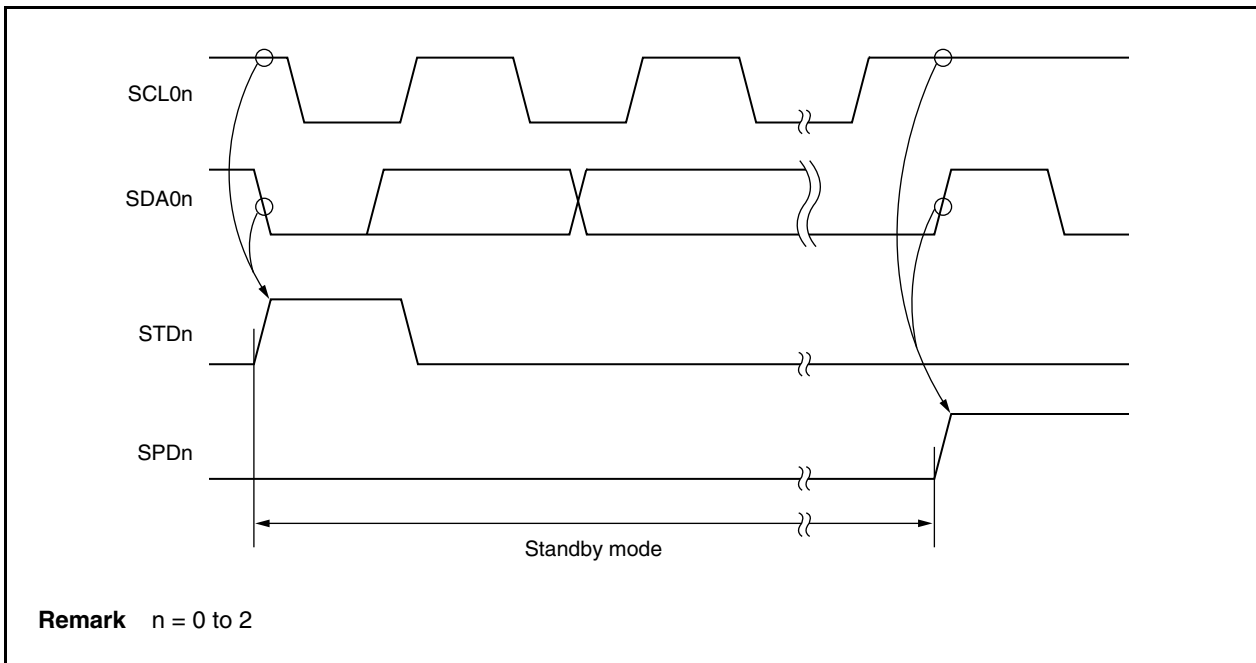
The communication reservation timing is shown below.

Figure 17-15. Communication Reservation Timing



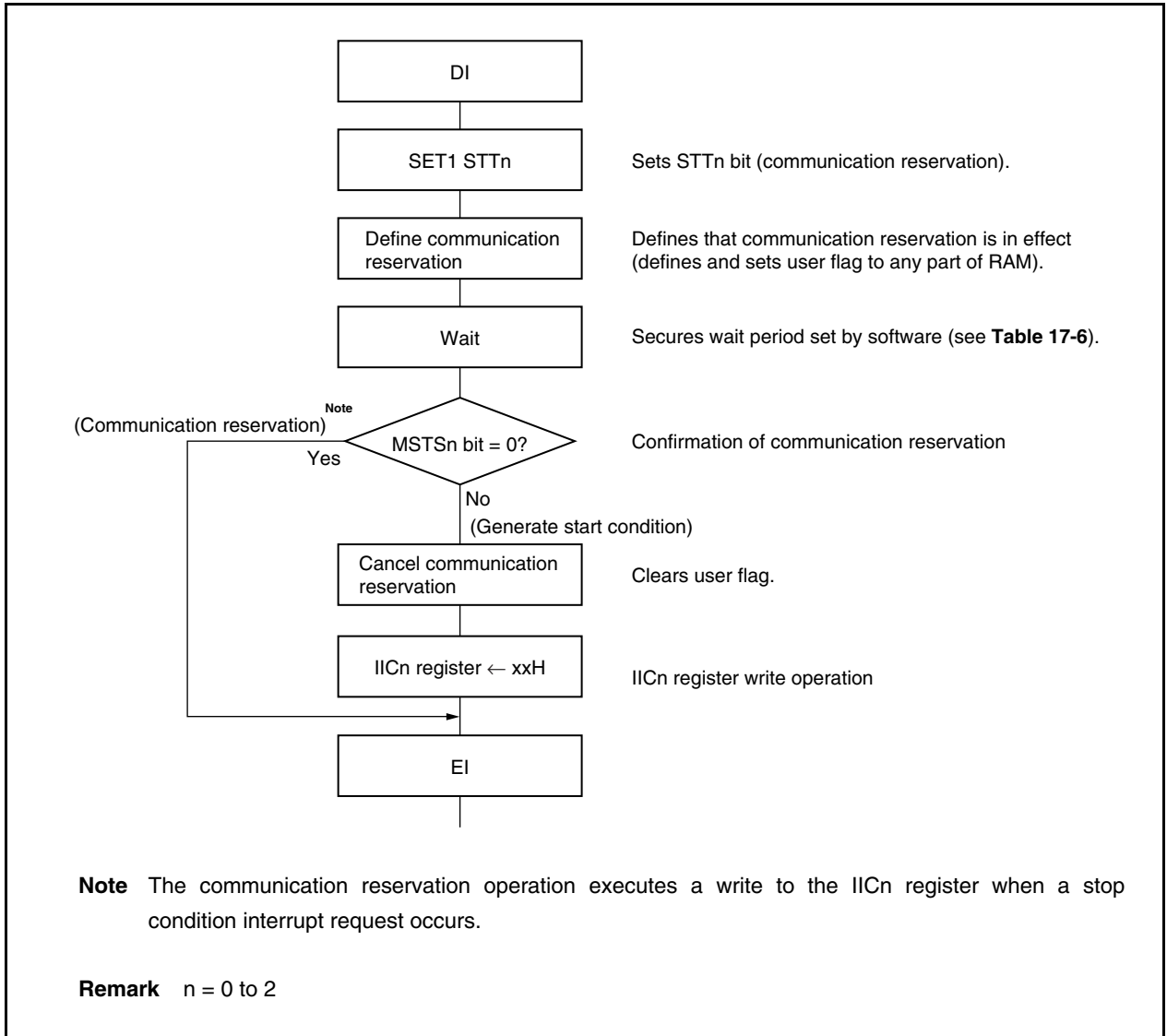
Communication reservations are accepted via the following timing. After the IICSn.STDn bit is set to 1, a communication reservation can be made by setting the IICn.STTn bit to 1 before a stop condition is detected (n = 0 to 2).

Figure 17-16. Timing for Accepting Communication Reservations



The communication reservation flowchart is illustrated below.

**Figure 17-17. Communication Reservation Flowchart**



**17.14.2 When communication reservation function is disabled (IICFn.IICRSVn bit = 1)**

When the IICCN.STTn bit is set when the bus is not used in a communication during bus communication, this request is rejected and a start condition is not generated. There are two modes in which the bus is not used.

- When arbitration results in neither master nor slave operation
- When an extension code is received and slave operation is disabled ( $\overline{\text{ACK}}$  is not returned and the bus was released when the IICCN.LRELn bit was set to 1) (n = 0 to 2).

To confirm whether the start condition was generated or request was rejected, check the IICFn.STCFn flag. The time shown in Table 17-7 is required until the STCFn flag is set after setting the STTn bit to 1. Therefore, secure the time by software.

**Table 17-7. Wait Periods**

| OCKSENm | OCKSm1 | OCKSm0 | CLn1 | CLn0 | Wait Period |
|---------|--------|--------|------|------|-------------|
| 1       | 0      | 0      | 0    | ×    | 10 clocks   |
| 1       | 0      | 1      | 0    | ×    | 15 clocks   |
| 1       | 1      | 0      | 0    | ×    | 20 clocks   |
| 1       | 1      | 1      | 0    | ×    | 25 clocks   |
| 0       | 0      | 0      | 1    | 0    | 5 clocks    |

- Remarks**
1. ×: don't care
  2. n = 0 to 2  
m = 0, 1

### 17.15 Cautions

- (1) When IICFn.STCENn bit = 0  
 Immediately after the I<sup>2</sup>C0n operation is enabled, the bus communication status (IICFn.IICBSYn bit = 1) is recognized regardless of the actual bus status. To execute master communication in the status where a stop condition has not been detected, generate a stop condition and then release the bus before starting the master communication.  
 Use the following sequence for generating a stop condition.  
  
 <1> Set the IICCLn register.  
 <2> Set the IICCN.IICEn bit.  
 <3> Set the IICCN.SPTn bit.
- (2) When IICFn.STCENn bit = 1  
 Immediately after I<sup>2</sup>C0n operation is enabled, the bus released status (IICBSYn bit = 0) is recognized regardless of the actual bus status. To generate the first start condition (IICCN.STTn bit = 1), it is necessary to confirm that the bus has been released, so as to not disturb other communications.
- (3) When the IICCN.IICEn bit of the V850ES/JJ3 is set to 1 while communications among other devices are in progress, the start condition may be detected depending on the status of the communication line. Be sure to set the IICCN.IICEn bit to 1 when the SCL0n and SDA0n lines are high level.
- (4) Determine the operation clock frequency by the IICCLn, IICXn, and OCKSm registers before enabling the operation (IICCN.IICEn bit = 1). To change the operation clock frequency, clear the IICCN.IICEn bit to 0 once.
- (5) After the IICCN.STTn and IICCN.SPTn bits have been set to 1, they must not be re-set without being cleared to 0 first.
- (6) If transmission has been reserved, set the IICCN.SPIEn bit to 1 so that an interrupt request is generated by the detection of a stop condition. After an interrupt request has been generated, the wait state will be released by writing communication data to I<sup>2</sup>Cn, then transferring will begin. If an interrupt is not generated by the detection of a stop condition, transmission will halt in the wait state because an interrupt request was not generated. However, it is not necessary to set the SPIEn bit to 1 for the software to detect the IICSn.MSTS n bit.

**Remark** n = 0 to 2  
 m = 0, 1

## 17.16 Communication Operations

The following shows three operation procedures with the flowchart.

### (1) Master operation in single master system

The flowchart when using the V850ES/JJ3 as the master in a single master system is shown below.

This flowchart is broadly divided into the initial settings and communication processing. Execute the initial settings at startup. If communication with the slave is required, prepare the communication and then execute communication processing.

### (2) Master operation in multimaster system

In the I<sup>2</sup>C0n bus multimaster system, whether the bus is released or used cannot be judged by the I<sup>2</sup>C bus specifications when the bus takes part in a communication. Here, when data and clock are at a high level for a certain period (1 frame), the V850ES/JJ3 takes part in a communication with bus released state.

This flowchart is broadly divided into the initial settings, communication waiting, and communication processing. The processing when the V850ES/JJ3 loses in arbitration and is specified as the slave is omitted here, and only the processing as the master is shown. Execute the initial settings at startup to take part in a communication. Then, wait for the communication request as the master or wait for the specification as the slave. The actual communication is performed in the communication processing, and it supports the transmission/reception with the slave and the arbitration with other masters.

### (3) Slave operation

An example of when the V850ES/JJ3 is used as the slave of the I<sup>2</sup>C0n bus is shown below.

When used as the slave, operation is started by an interrupt. Execute the initial settings at startup, then wait for the INTIICn interrupt occurrence (communication waiting). When the INTIICn interrupt occurs, the communication status is judged and its result is passed as a flag over to the main processing.

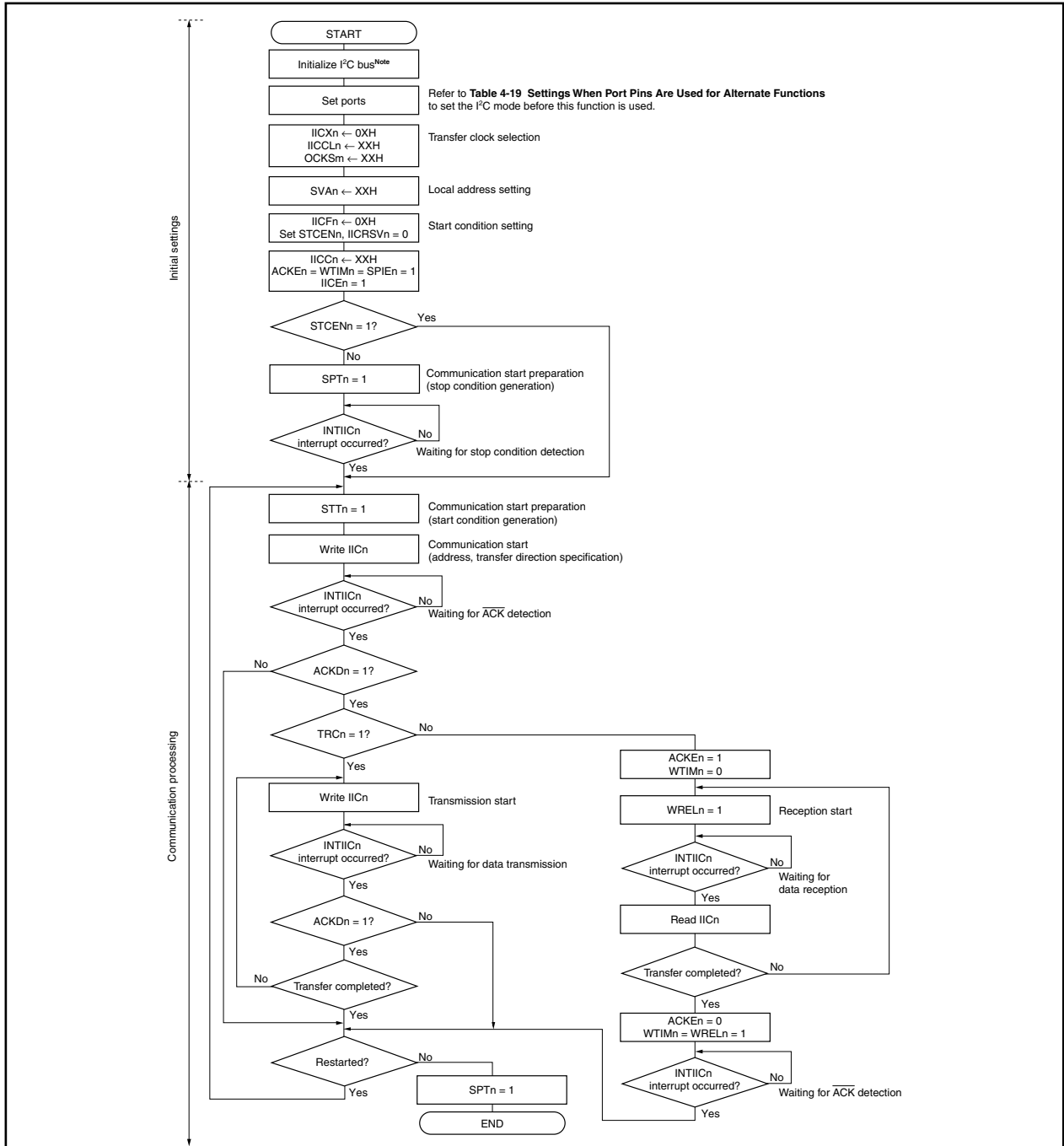
By checking the flags, necessary communication processing is performed.

**Remark** n = 0 to 2



17.16.1 Master operation in single master system

Figure 17-18. Master Operation in Single Master System



**Note** Release the I<sup>2</sup>C<sub>0n</sub> bus (SCL<sub>0n</sub>, SDA<sub>0n</sub> pins = high level) in conformity with the specifications of the product in communication.

For example, when the EEPROM™ outputs a low level to the SDA<sub>0n</sub> pin, set the SCL<sub>0n</sub> pin to the output port and output clock pulses from that output port until when the SDA<sub>0n</sub> pin is constantly high level.

**Remarks 1.** For the transmission and reception formats, conform to the specifications of the product in communication.

**2.** n = 0 to 2, m = 0, 1

17.16.2 Master operation in multimaster system

Figure 17-19. Master Operation in Multimaster System (1/3)

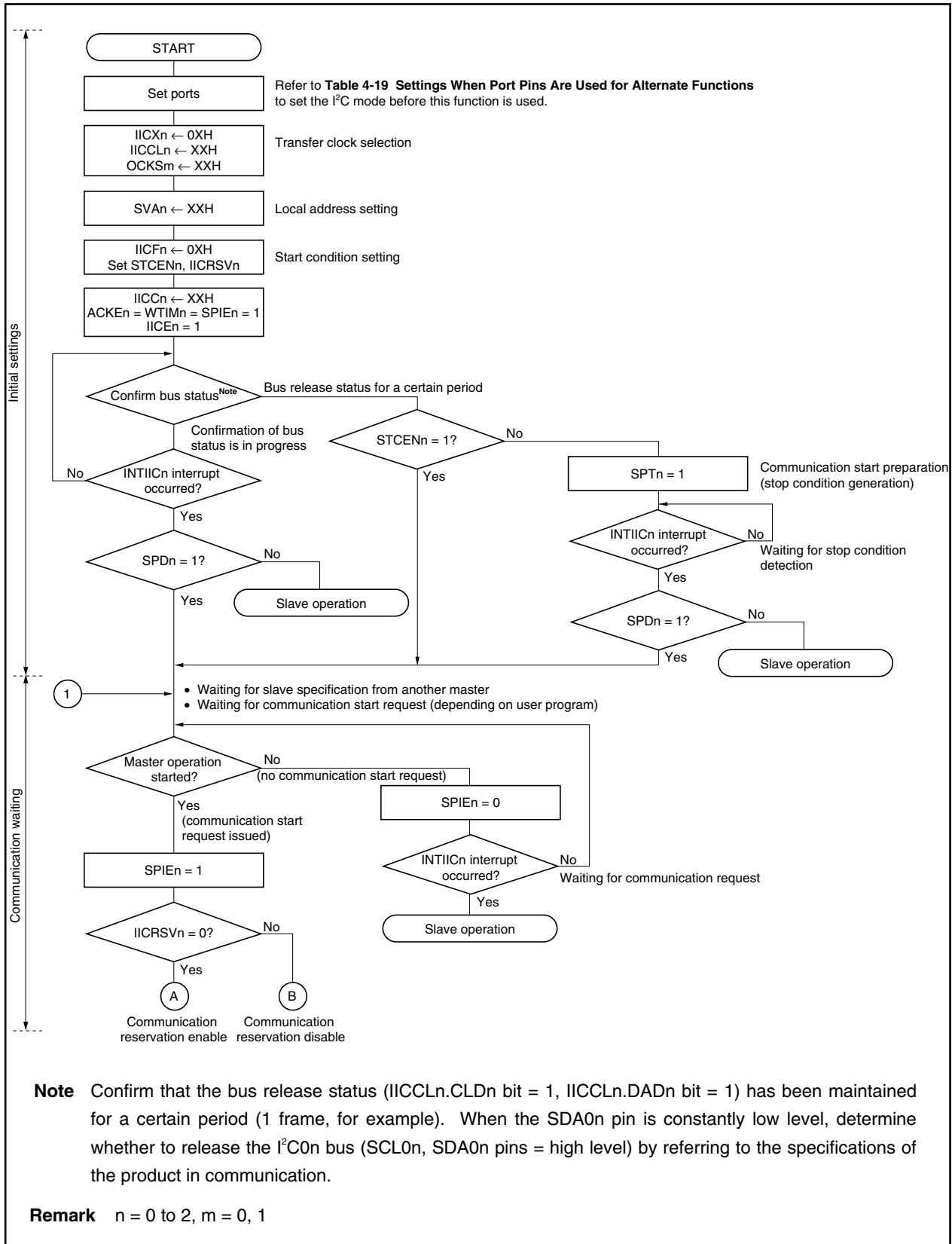


Figure 17-19. Master Operation in Multimaster System (2/3)

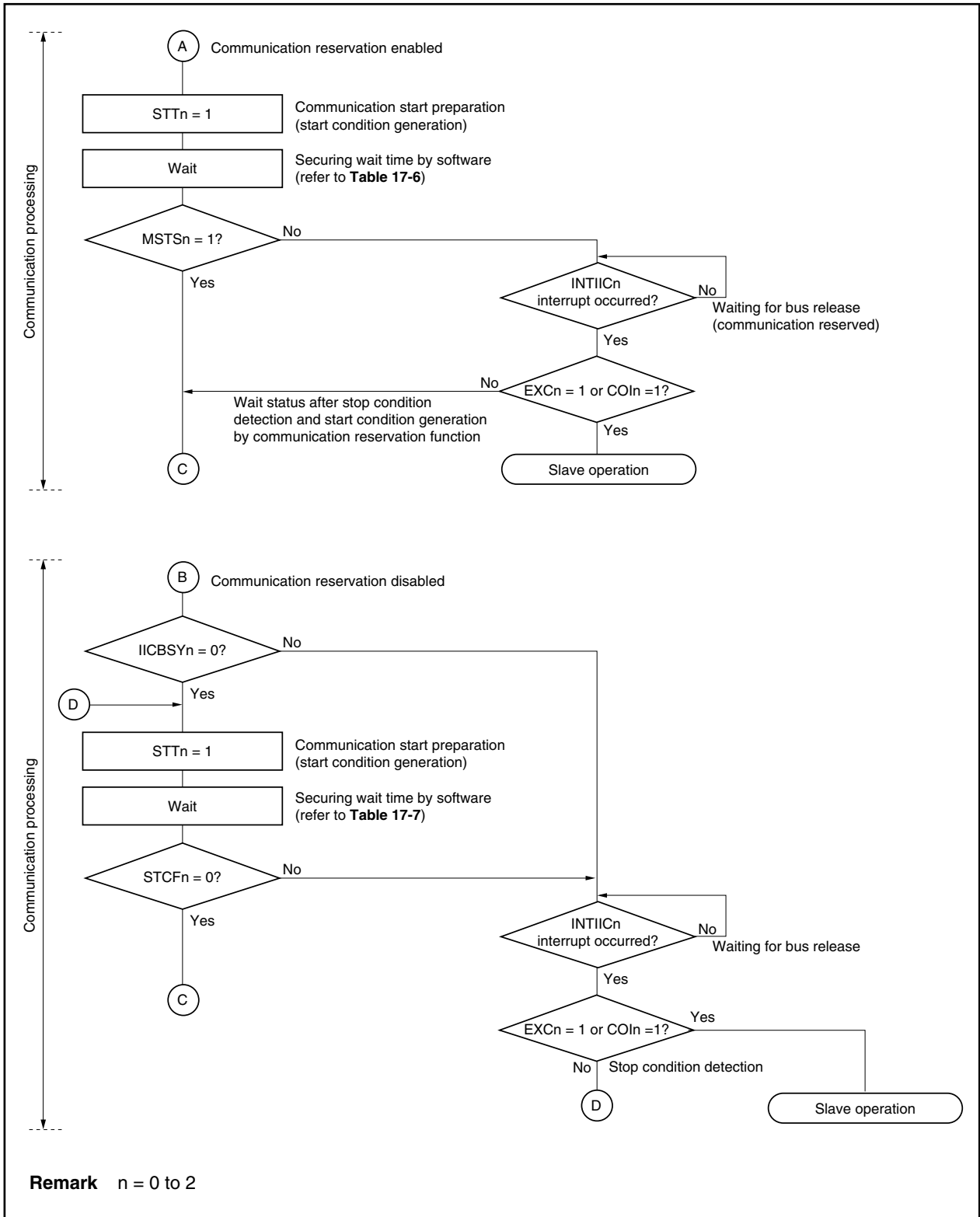
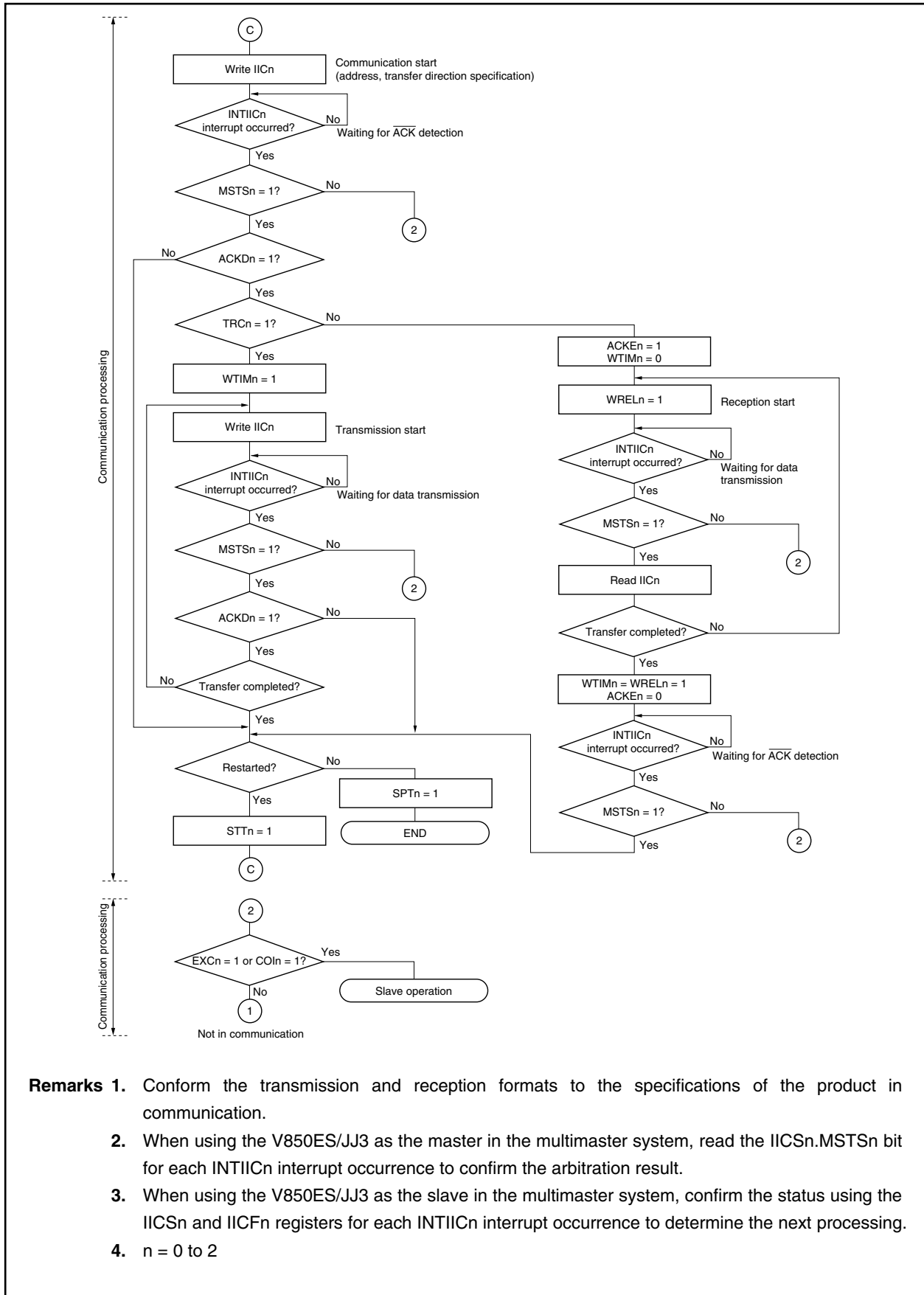


Figure 17-19. Master Operation in Multimaster System (3/3)



- Remarks**
1. Conform the transmission and reception formats to the specifications of the product in communication.
  2. When using the V850ES/JJ3 as the master in the multimaster system, read the IICSn.MSTSn bit for each INTIICn interrupt occurrence to confirm the arbitration result.
  3. When using the V850ES/JJ3 as the slave in the multimaster system, confirm the status using the IICSn and IICFn registers for each INTIICn interrupt occurrence to determine the next processing.
  4. n = 0 to 2

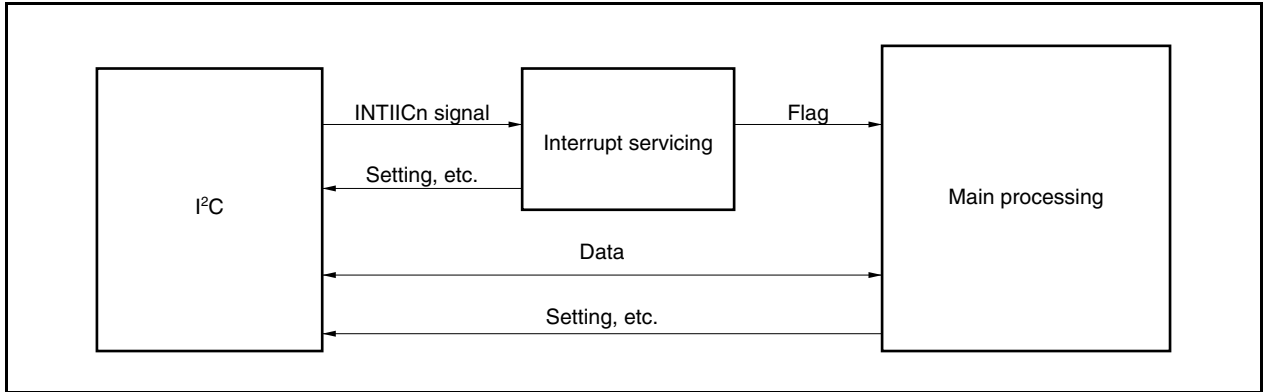
### 17.16.3 Slave operation

The following shows the processing procedure of the slave operation.

Basically, the operation of the slave device is event-driven. Therefore, processing by an INTIICn interrupt (processing requiring a significant change of the operation status, such as stop condition detection during communication) is necessary.

The following description assumes that data communication does not support extension codes. Also, it is assumed that the INTIICn interrupt servicing performs only status change processing and that the actual data communication is performed during the main processing.

**Figure 17-20. Software Outline During Slave Operation**



Therefore, the following three flags are prepared so that the data transfer processing can be performed by transmitting these flags to the main processing instead of INTIICn signal.

#### (1) Communication mode flag

This flag indicates the following communication statuses.

Clear mode: Data communication not in progress

Communication mode: Data communication in progress (valid address detection stop condition detection,  $\overline{\text{ACK}}$  from master not detected, address mismatch)

#### (2) Ready flag

This flag indicates that data communication is enabled. This is the same status as an INTIICn interrupt during normal data transfer. This flag is set in the interrupt processing block and cleared in the main processing block. The ready flag for the first data for transmission is not set in the interrupt processing block, so the first data is transmitted without clear processing (the address match is regarded as a request for the next data).

#### (3) Communication direction flag

This flag indicates the direction of communication and is the same as the value of IICSn.TRCn bit.

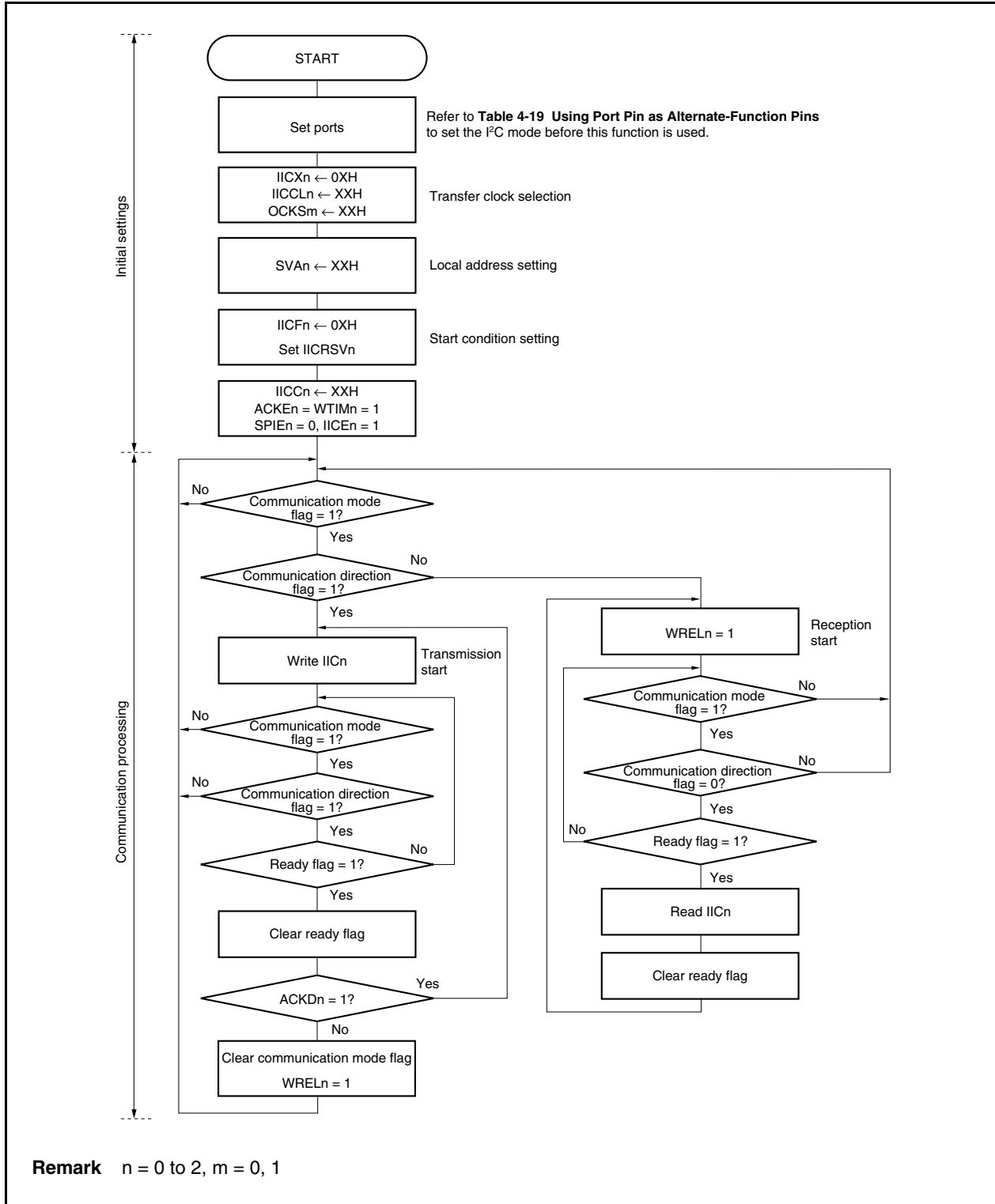
The following shows the operation of the main processing block during slave operation.

Start I<sup>2</sup>C0n and wait for the communication enabled status. When communication is enabled, perform transfer using the communication mode flag and ready flag (the processing of the stop condition and start condition is performed by interrupts, conditions are confirmed by flags).

For transmission, repeat the transmission operation until the master device stops returning  $\overline{\text{ACK}}$ . When the master device stops returning  $\overline{\text{ACK}}$ , transfer is complete.

For reception, receive the required number of data and do not return  $\overline{\text{ACK}}$  for the next data immediately after transfer is complete. After that, the master device generates the stop condition or restart condition. This causes exit from communications.

Figure 17-21. Slave Operation Flowchart (1)

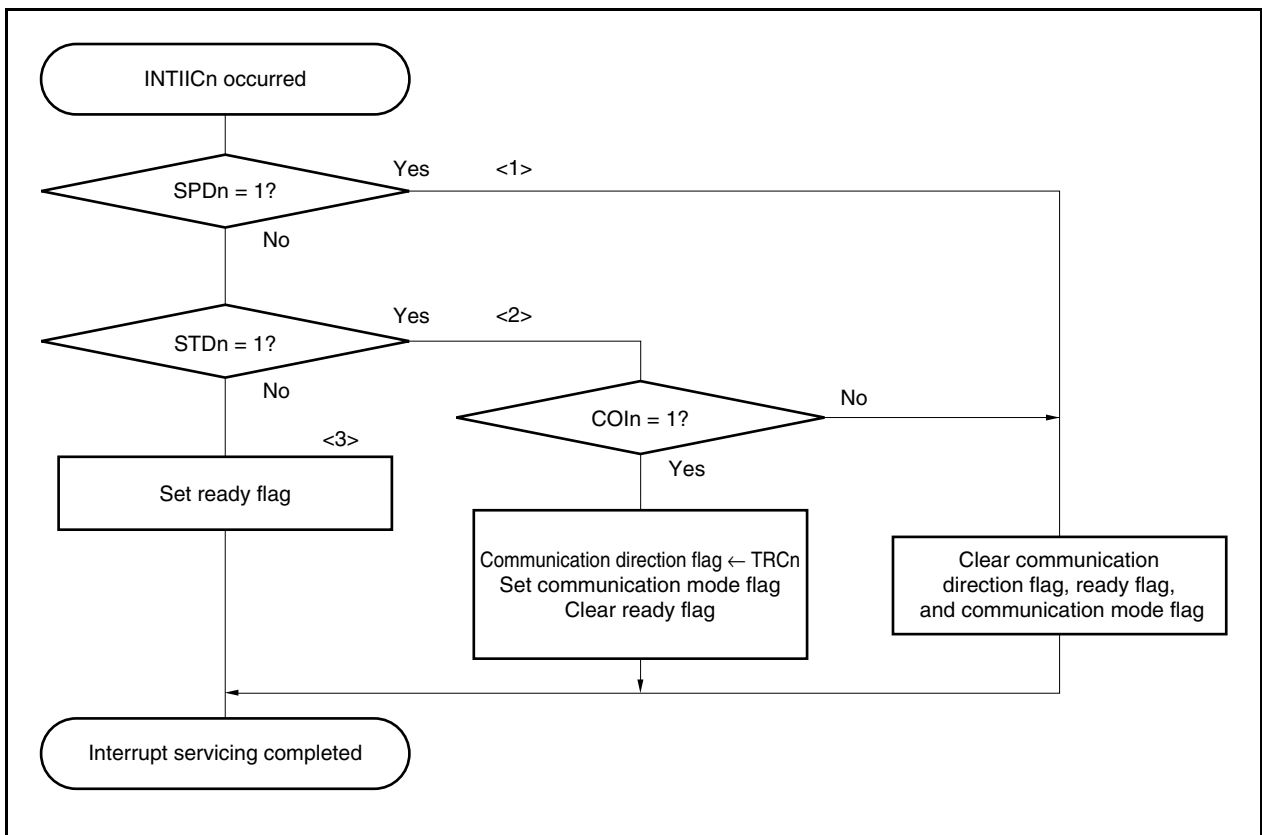


The following shows an example of the processing of the slave device by an INTIICn interrupt (it is assumed that no extension codes are used here). During an INTIICn interrupt, the status is confirmed and the following steps are executed.

- <1> When a stop condition is detected, communication is terminated.
- <2> When a start condition is detected, the address is confirmed. If the address does not match, communication is terminated. If the address matches, the communication mode is set and wait state is released, and operation returns from the interrupt (the ready flag is cleared).
- <3> For data transmission/reception, when the ready flag is set, operation returns from the interrupt while the I<sup>2</sup>C0n bus remains in the wait state.

**Remark** <1> to <3> in the above correspond to <1> to <3> in **Figure 17-22 Slave Operation Flowchart (2)**.

**Figure 17-22. Slave Operation Flowchart (2)**



### 17.17 Timing of Data Communication

When using I<sup>2</sup>C bus mode, the master device outputs an address via the serial bus to select one of several slave devices as its communication partner.

After outputting the slave address, the master device transmits the IICSn.TRCn bit, which specifies the data transfer direction, and then starts serial communication with the slave device.

The shift operation of the IICn register is synchronized with the falling edge of the serial clock pin (SCL0n). The transmit data is transferred to the SO latch and is output (MSB first) via the SDA0n pin.

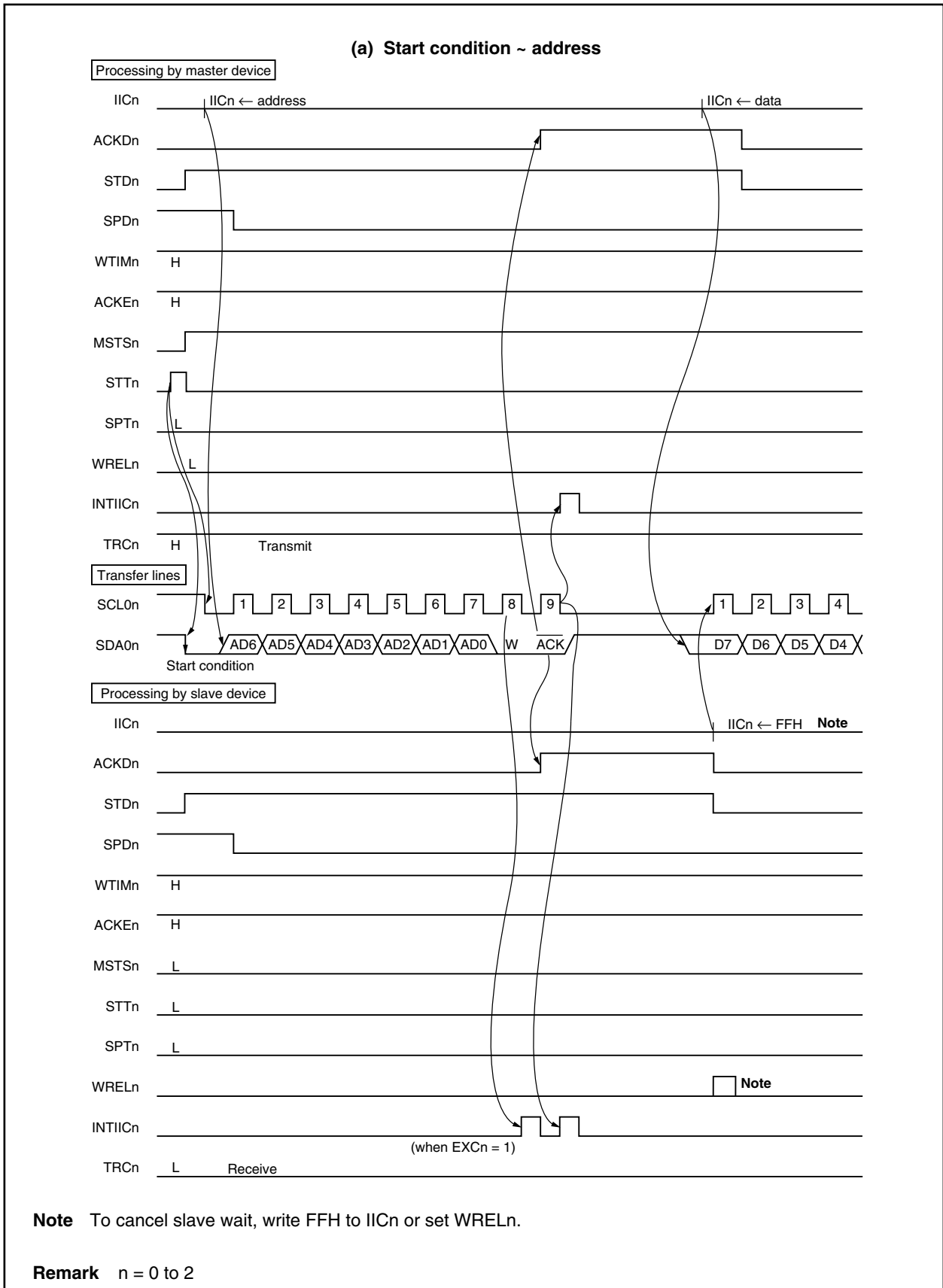
Data input via the SDA0n pin is captured by the IICn register at the rising edge of the SCL0n pin.

The data communication timing is shown below.

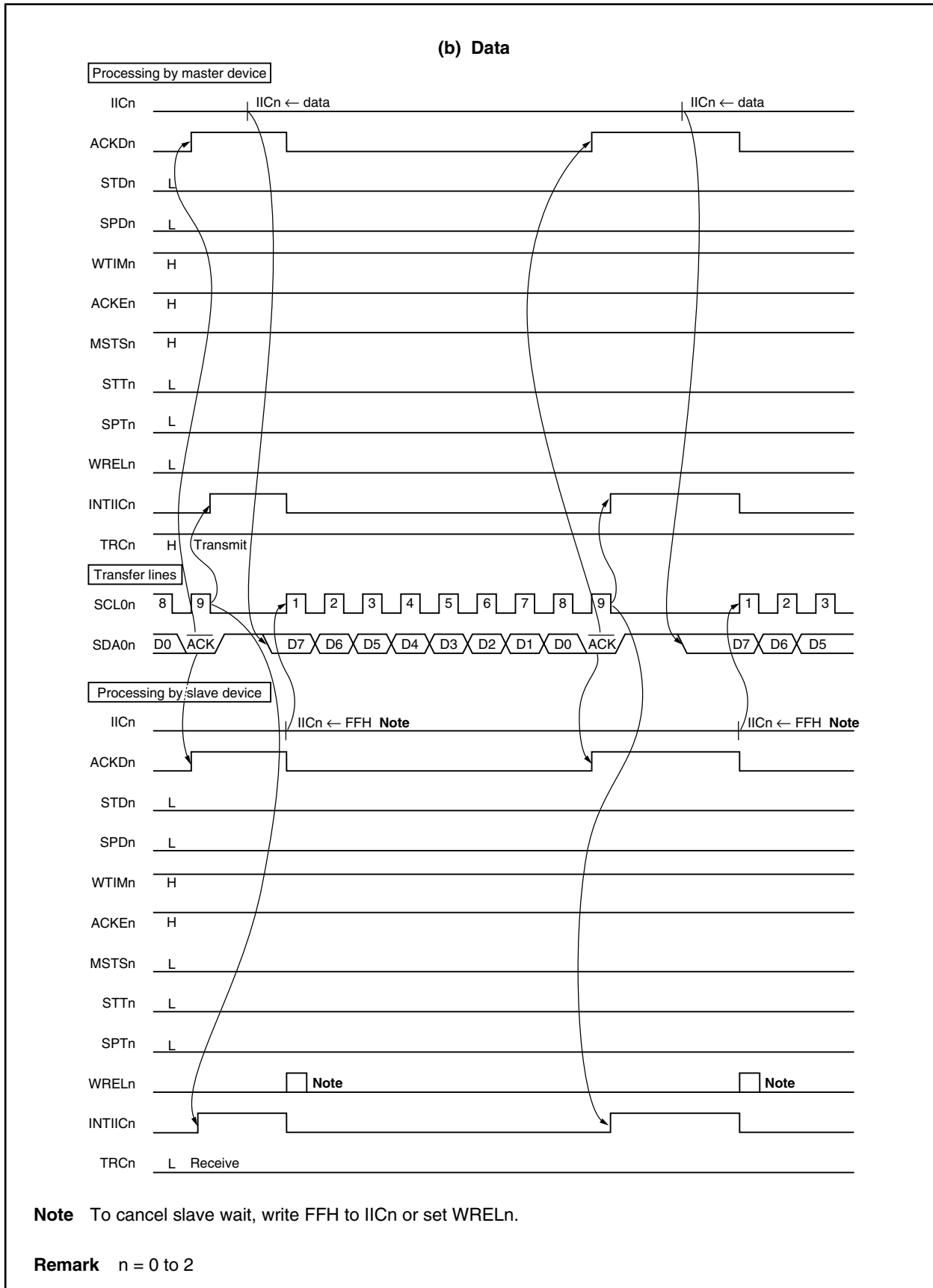
**Remark** n = 0 to 2



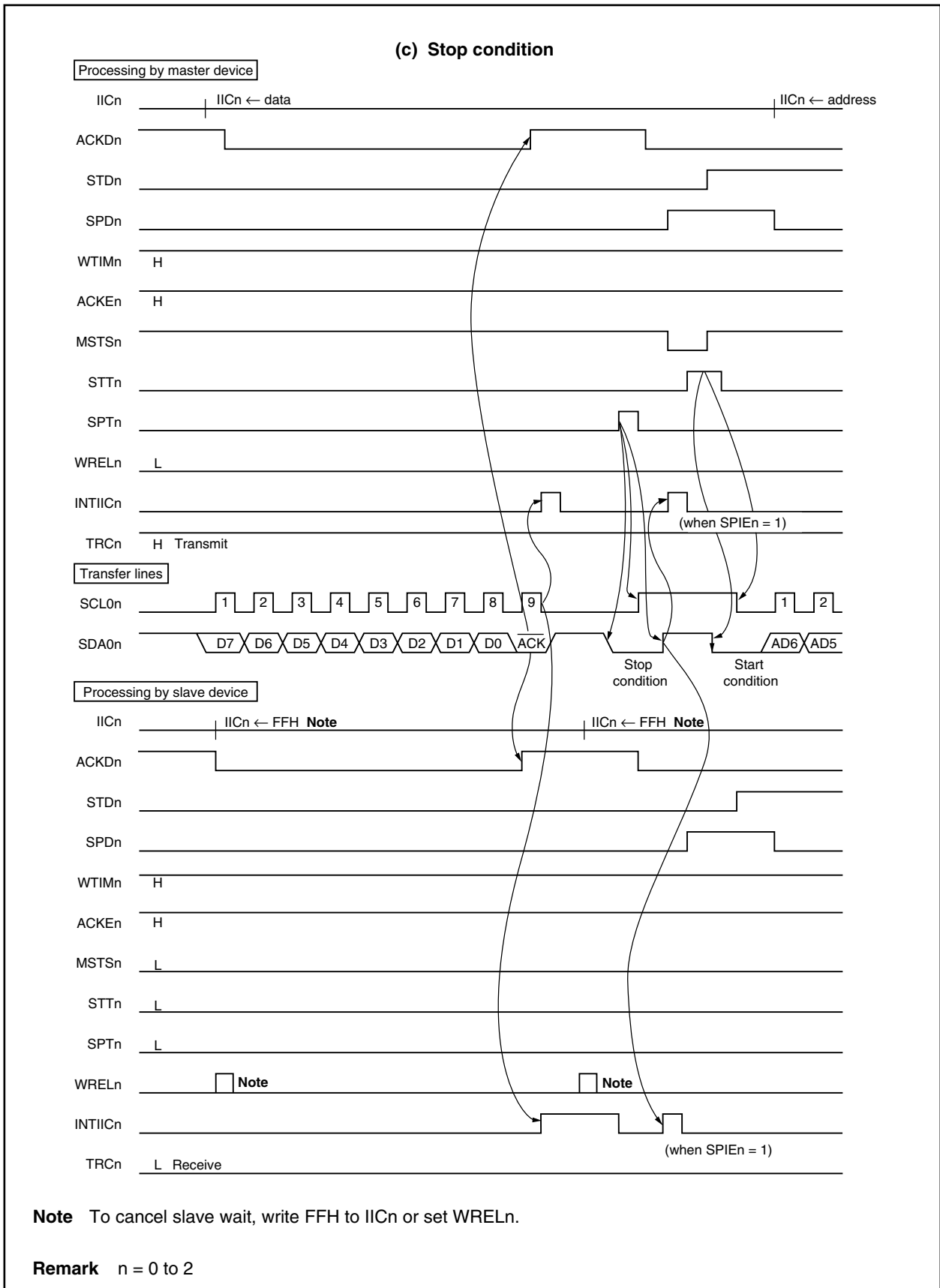
**Figure 17-23. Example of Master to Slave Communication  
(When 9-Clock Wait Is Selected for Both Master and Slave) (1/3)**



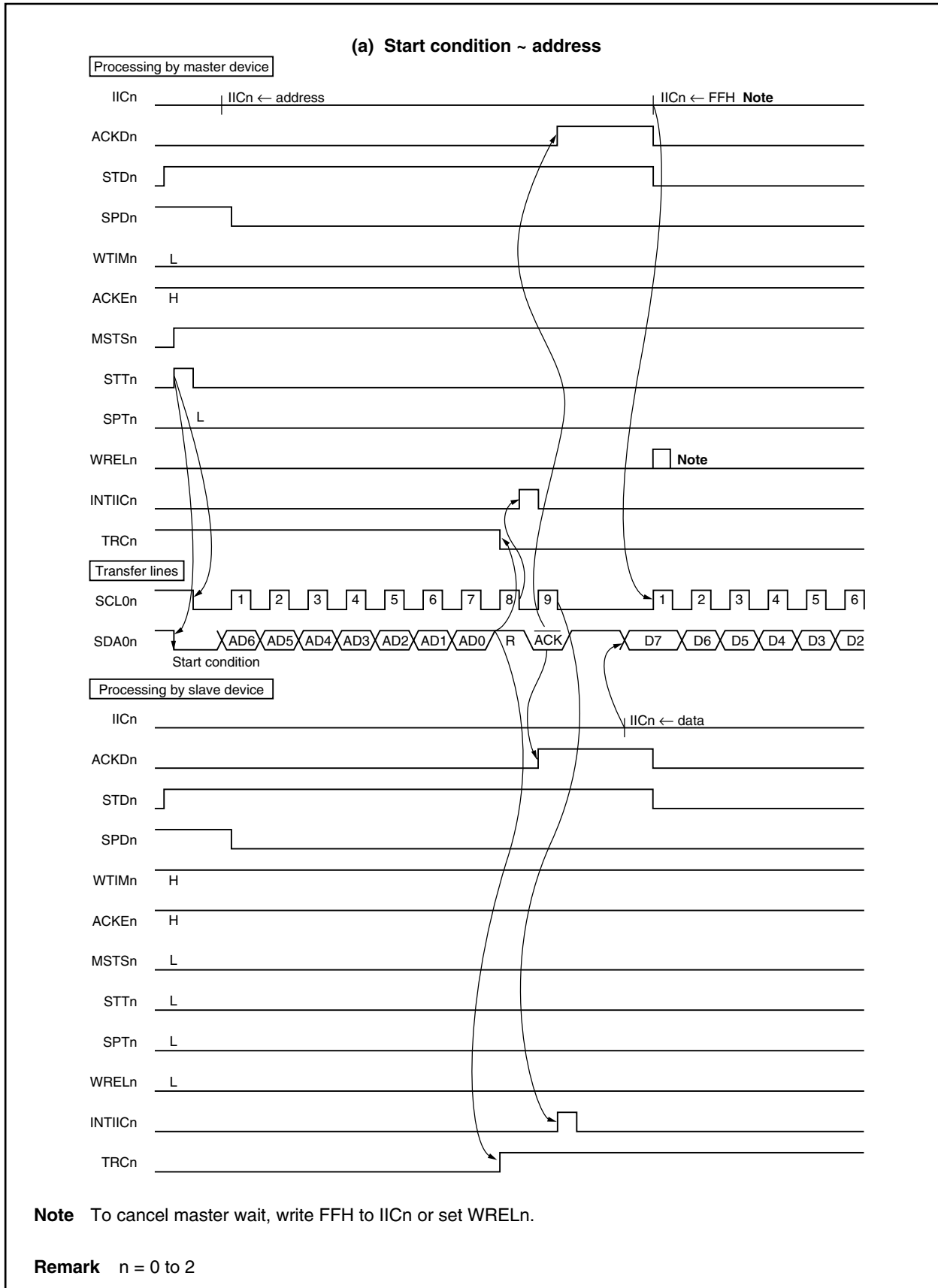
**Figure 17-23. Example of Master to Slave Communication  
(When 9-Clock Wait Is Selected for Both Master and Slave) (2/3)**



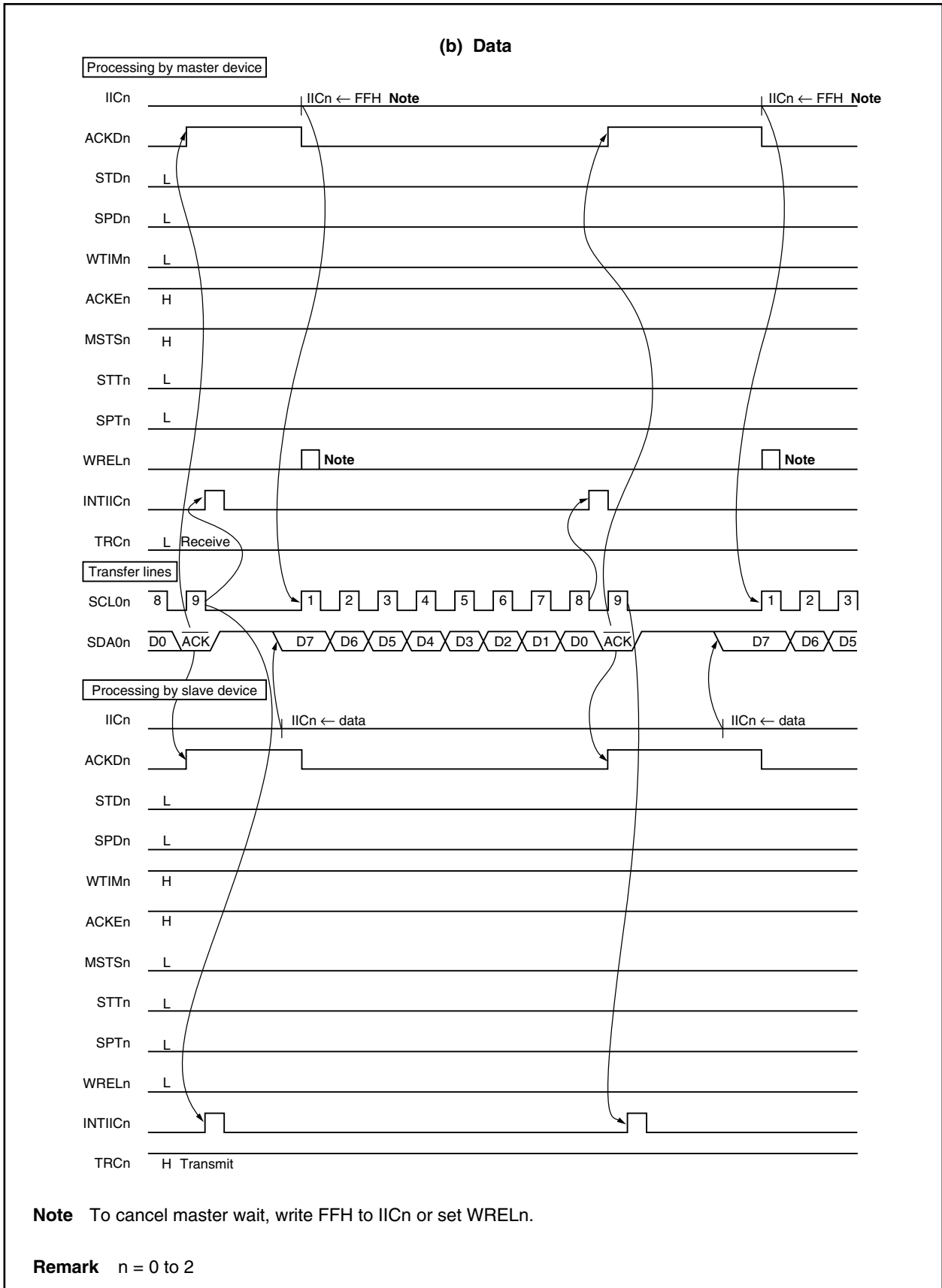
**Figure 17-23. Example of Master to Slave Communication  
(When 9-Clock Wait Is Selected for Both Master and Slave) (3/3)**



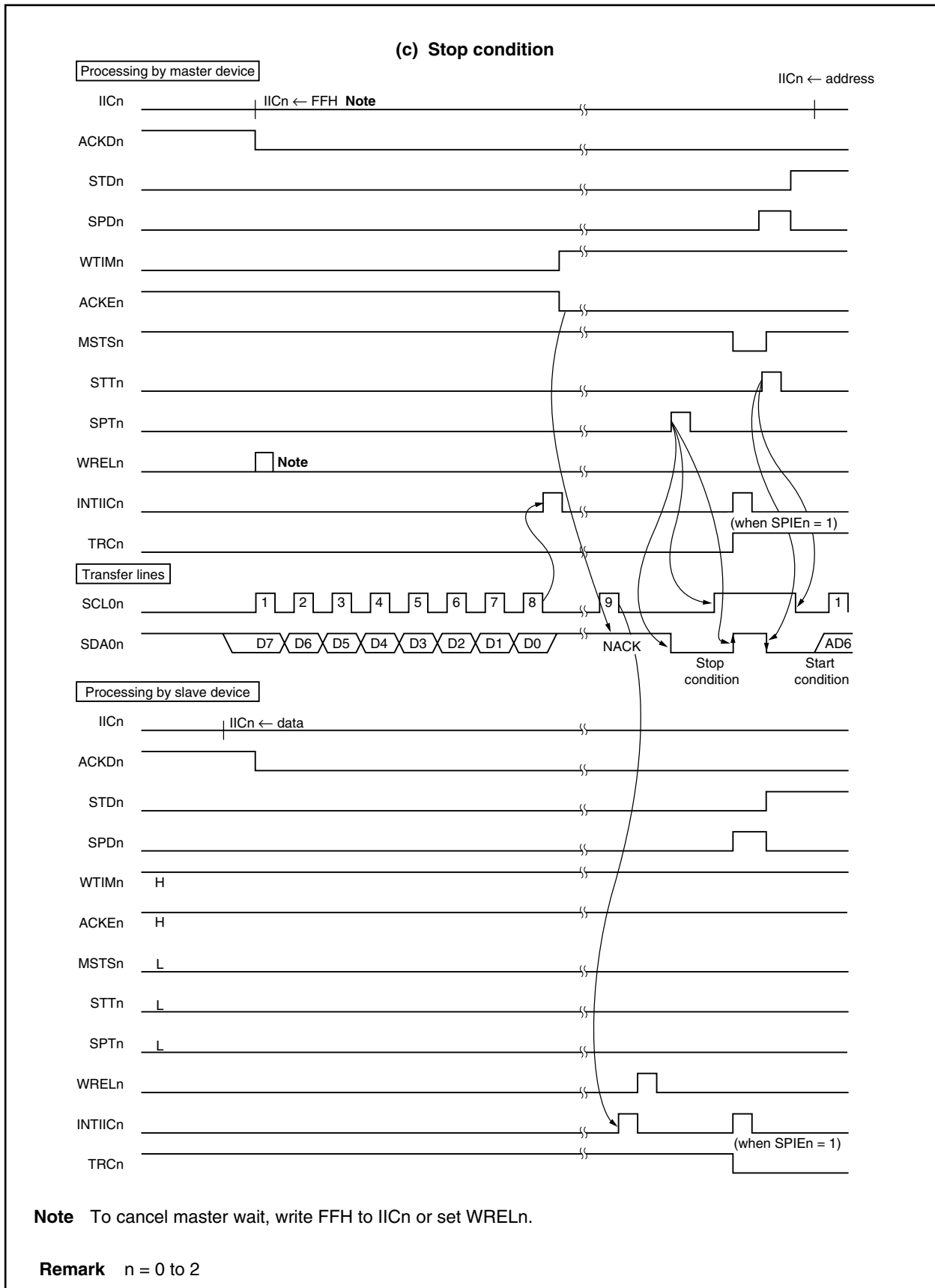
**Figure 17-24. Example of Slave to Master Communication  
(When 8-Clock Wait for Master and 9-Clock Wait for Slave Are Selected) (1/3)**



**Figure 17-24. Example of Slave to Master Communication**  
**(When 8-Clock Wait for Master and 9-Clock Wait for Slave Are Selected) (2/3)**



**Figure 17-24. Example of Slave to Master Communication  
(When 8-Clock Wait for Master and 9-Clock Wait for Slave Are Selected) (3/3)**



## CHAPTER 18 DMA FUNCTION (DMA CONTROLLER)

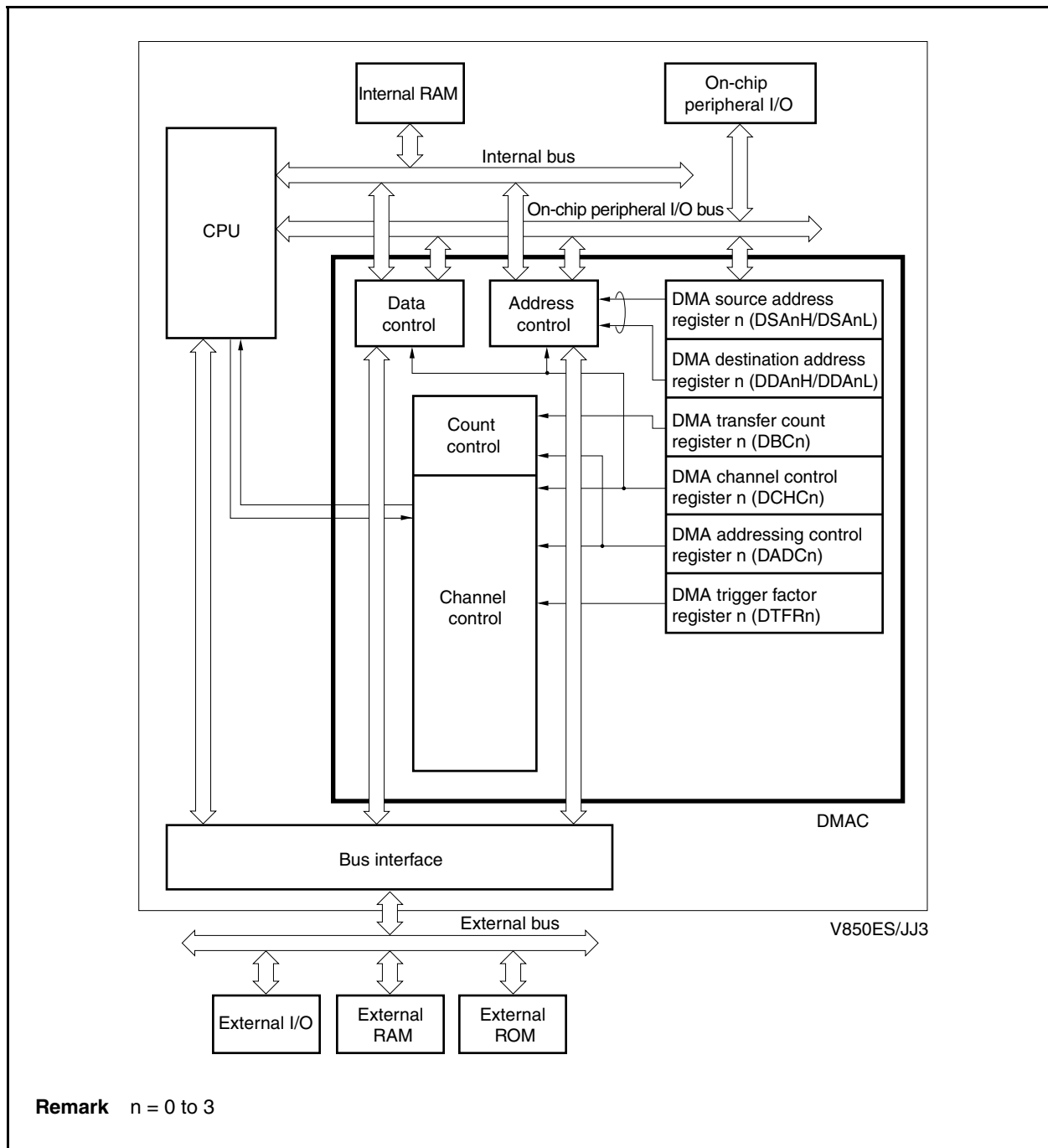
The V850ES/JJ3 includes a direct memory access (DMA) controller (DMAC) that executes and controls DMA transfer.

The DMAC controls data transfer between memory and I/O, between memories, or between I/Os based on DMA requests issued by the on-chip peripheral I/O (serial interface, timer/counter, and A/D converter), interrupts from external input pins, or software triggers (memory refers to internal RAM or external memory).

### 18.1 Features

- 4 independent DMA channels
- Transfer unit: 8/16 bits
- Maximum transfer count: 65,536 ( $2^{16}$ )
- Transfer type: Two-cycle transfer
- Transfer mode: Single transfer mode
- Transfer requests
  - Request by interrupts from on-chip peripheral I/O (serial interface, timer/counter, A/D converter) or interrupts from external input pin
  - Requests by software trigger
- Transfer targets
  - Internal RAM ↔ Peripheral I/O
  - Peripheral I/O ↔ Peripheral I/O
  - Internal RAM ↔ External memory
  - External memory ↔ Peripheral I/O
  - External memory ↔ External memory

18.2 Configuration





### 18.3 Registers

#### (1) DMA source address registers 0 to 3 (DSA0 to DSA3)

The DSA0 to DSA3 registers set the DMA source addresses (26 bits each) for DMA channel n (n = 0 to 3).

These registers are divided into two 16-bit registers, DSA<sub>n</sub>H and DSA<sub>n</sub>L.

These registers can be read or written in 16-bit units.

After reset: Undefined R/W Address: DSA0H FFFFF082H, DSA1H FFFFF08AH,  
 DSA2H FFFFF092H, DSA3H FFFFF09AH,  
 DSA0L FFFFF080H, DSA1L FFFFF088H,  
 DSA2L FFFFF090H, DSA3L FFFFF098H

|                                    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
|------------------------------------|----|----|----|----|----|----|------|------|------|------|------|------|------|------|------|------|
|                                    | 15 | 14 | 13 | 12 | 11 | 10 | 9    | 8    | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| DSA <sub>n</sub> H<br>(n = 0 to 3) | IR | 0  | 0  | 0  | 0  | 0  | SA25 | SA24 | SA23 | SA22 | SA21 | SA20 | SA19 | SA18 | SA17 | SA16 |

|                                    |      |      |      |      |      |      |     |     |     |     |     |     |     |     |     |     |
|------------------------------------|------|------|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                                    | 15   | 14   | 13   | 12   | 11   | 10   | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
| DSA <sub>n</sub> L<br>(n = 0 to 3) | SA15 | SA14 | SA13 | SA12 | SA11 | SA10 | SA9 | SA8 | SA7 | SA6 | SA5 | SA4 | SA3 | SA2 | SA1 | SA0 |

|    |   |
|----|---|
| IR | Specification of DMA transfer source      |
| 0  | External memory or on-chip peripheral I/O |
| 1  | Internal RAM                              |

|              |   |
|--------------|---|
| SA25 to SA16 | Set the address (A25 to A16) of the DMA transfer source (default value is undefined).<br>During DMA transfer, the next DMA transfer source address is held.<br>When DMA transfer is completed, the DMA address set first is held. |
|--------------|---|

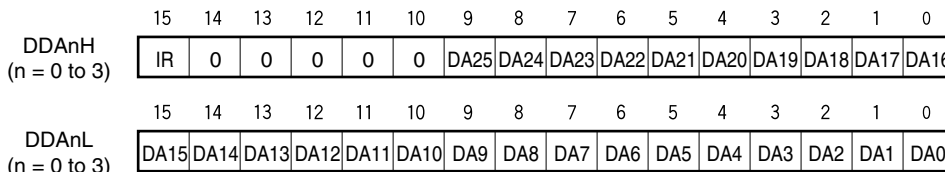
|             |  |
|-------------|--|
| SA15 to SA0 | Set the address (A15 to A0) of the DMA transfer source (default value is undefined).<br>During DMA transfer, the next DMA transfer source address is held.<br>When DMA transfer is completed, the DMA address set first is held. |
|-------------|--|

- Cautions**
- Be sure to clear bits 14 to 10 of the DSA<sub>n</sub>H register to 0.
  - Set the DSA<sub>n</sub>H and DSA<sub>n</sub>L registers at the following timing when DMA transfer is disabled (DCHC<sub>n</sub>.Enn bit = 0).
    - Period from after reset to start of first DMA transfer
    - Period from after channel initialization by DCHC<sub>n</sub>.INIT<sub>n</sub> bit to start of DMA transfer
    - Period from after completion of DMA transfer (DCHC<sub>n</sub>.TC<sub>n</sub> bit = 1) to start of the next DMA transfer
  - When the value of the DSA<sub>n</sub> register is read, two 16-bit registers, DSA<sub>n</sub>H and DSA<sub>n</sub>L, are read. If reading and updating conflict, the value being updated may be read (see 18.13 Cautions).
  - Following reset, set the DSA<sub>n</sub>H, DSA<sub>n</sub>L, DDAnH, DDAnL, and DBC<sub>n</sub> registers before starting DMA transfer. If these registers are not set, the operation when DMA transfer is started is not guaranteed.

**(2) DMA destination address registers 0 to 3 (DDA0 to DDA3)**

The DDA0 to DDA3 registers set the DMA destination address (26 bits each) for DMA channel n (n = 0 to 3). These registers are divided into two 16-bit registers, DDAnH and DDAnL. These registers can be read or written in 16-bit units.

After reset: Undefined    R/W    Address: DDA0H FFFFF086H, DDA1H FFFFF08EH,  
 DDA2H FFFFF096H, DDA3H FFFFF09EH,  
 DDA0L FFFFF084H, DDA1L FFFFF08CH,  
 DDA2L FFFFF094H, DDA3L FFFFF09CH



|    |   |
|----|---|
| IR | Specification of DMA transfer destination |
| 0  | External memory or on-chip peripheral I/O |
| 1  | Internal RAM                              |

|              |   |
|--------------|---|
| DA25 to DA16 | Set an address (A25 to A16) of DMA transfer destination (default value is undefined).<br>During DMA transfer, the next DMA transfer destination address is held. When DMA transfer is completed, the DMA transfer source address set first is held. |
|--------------|---|

|             |  |
|-------------|--|
| DA15 to DA0 | Set an address (A15 to A0) of DMA transfer destination (default value is undefined).<br>During DMA transfer, the next DMA transfer destination address is held. When DMA transfer is completed, the DMA transfer source address set first is held. |
|-------------|--|

- Cautions**
- Be sure to clear bits 14 to 10 of the DDAnH register to 0.
  - Set the DDAnH and DDAnL registers at the following timing when DMA transfer is disabled (DCHCn.Enn bit = 0).
    - Period from after reset to start of first DMA transfer
    - Period from after channel initialization by DCHCn.INITn bit to start of DMA transfer
    - Period from after completion of DMA transfer (DCHCn.TCn bit = 1) to start of the next DMA transfer
  - When the value of the DDAn register is read, two 16-bit registers, DDAnH and DDAnL, are read. If reading and updating conflict, a value being updated may be read (see 18.13 Cautions).
  - Following reset, set the DSAnH, DSAnL, DDAnH, DDAnL, and DBCn registers before starting DMA transfer. If these registers are not set, the operation when DMA transfer is started is not guaranteed.

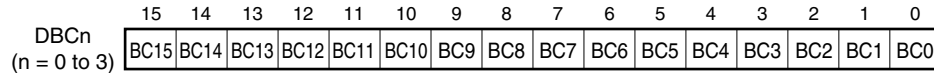
**(3) DMA byte count registers 0 to 3 (DBC0 to DBC3)**

The DBC0 to DBC3 registers are 16-bit registers that set the byte transfer count for DMA channel n (n = 0 to 3). These registers hold the remaining transfer count during DMA transfer.

These registers are decremented by 1 per one transfer regardless of the transfer data unit (8/16 bits), and the transfer is terminated if a borrow occurs.

These registers can be read or written in 16-bit units.

After reset: Undefined    R/W    Address: DBC0 FFFFF0C0H, DBC1 FFFFF0C2H,  
 DBC2 FFFFF0C4H, DBC3 FFFFF0C6H



|  |  |
|--|--|
| BC15 to BC0  | Byte transfer count setting or remaining byte transfer count during DMA transfer |
| 0000H  | Byte transfer count 1 or remaining byte transfer count                           |
| 0001H  | Byte transfer count 2 or remaining byte transfer count                           |
| :  | :  |
| FFFFH  | Byte transfer count 65,536 (2 <sup>16</sup> ) or remaining byte transfer count   |
| The number of transfer data set first is held when DMA transfer is complete. |  |

- Cautions**
1. Set the DBCn register at the following timing when DMA transfer is disabled (DCHCn.Enn bit = 0).
    - Period from after reset to start of first DMA transfer
    - Period from after channel initialization by DCHCn.INITn bit to start of DMA transfer
    - Period from after completion of DMA transfer (DCHCn.TCn bit = 1) to start of the next DMA transfer
  2. Following reset, set the DSAnH, DSAnL, DDAnH, DDAnL, and DBCn registers before starting DMA transfer. If these registers are not set, the operation when DMA transfer is started is not guaranteed.

**(4) DMA addressing control registers 0 to 3 (DADC0 to DADC3)**

The DADC0 to DADC3 registers are 16-bit registers that control the DMA transfer mode for DMA channel n (n = 0 to 3).

These registers can be read or written in 16-bit units.

Reset sets these registers to 0000H.

After reset: 0000H    R/W    Address: DADC0 FFFF0D0H, DADC1 FFFF0D2H,  
DADC2 FFFF0D4H, DADC3 FFFF0D6H

|              |      |      |      |      |    |    |   |   |
|--------------|------|------|------|------|----|----|---|---|
|              | 15   | 14   | 13   | 12   | 11 | 10 | 9 | 8 |
| DADCn        | 0    | DS0  | 0    | 0    | 0  | 0  | 0 | 0 |
| (n = 0 to 3) |      |      |      |      |    |    |   |   |
|              | 7    | 6    | 5    | 4    | 3  | 2  | 1 | 0 |
|              | SAD1 | SAD0 | DAD1 | DAD0 | 0  | 0  | 0 | 0 |

|     |                               |  |
|-----|-------------------------------|--|
| DS0 | Setting of transfer data size |  |
| 0   | 8 bits                        |  |
| 1   | 16 bits                       |  |

|      |      |   |
|------|------|---|
| SAD1 | SAD0 | Setting of count direction of the transfer source address |
| 0    | 0    | Increment   |
| 0    | 1    | Decrement   |
| 1    | 0    | Fixed   |
| 1    | 1    | Setting prohibited  |

|      |      |   |
|------|------|---|
| DAD1 | DAD0 | Setting of count direction of the destination address |
| 0    | 0    | Increment   |
| 0    | 1    | Decrement   |
| 1    | 0    | Fixed   |
| 1    | 1    | Setting prohibited                                    |

- Cautions**
1. Be sure to clear bits 15, 13 to 8, and 3 to 0 of the DADCn register to “0”.
  2. Set the DADCn register at the following timing when DMA transfer is disabled (DCHCn.Enn bit = 0).
    - Period from after reset to start of first DMA transfer
    - Period from after channel initialization by DCHCn.INITn bit to start of DMA transfer
    - Period from after completion of DMA transfer (DCHCn.TCn bit = 1) to start of the next DMA transfer
  3. The DS0 bit specifies the size of the transfer data, and does not control bus sizing. If 8-bit data (DS0 bit = 0) is set, therefore, the lower data bus is not always used.
  4. If the transfer data size is set to 16 bits (DS0 bit = 1), transfer cannot be started from an odd address. Transfer is always started from an address with the first bit of the lower address aligned to 0.
  5. If DMA transfer is executed on an on-chip peripheral I/O register (as the transfer source or destination), be sure to specify the same transfer size as the register size. For example, to execute DMA transfer on an 8-bit register, be sure to specify 8-bit transfer.

**(5) DMA channel control registers 0 to 3 (DCHC0 to DCHC3)**

The DCHC0 to DCHC3 registers are 8-bit registers that control the DMA transfer operating mode for DMA channel n.

These registers can be read or written in 8-bit or 1-bit units. (However, bit 7 is read-only and bits 1 and 2 are write-only. If bit 1 or 2 is read, the read value is always 0.)

Reset sets these registers to 00H.

|                       |                       |  |   |   |   |                         |                        |     |
|-----------------------|-----------------------|--|---|---|---|-------------------------|------------------------|-----|
| After reset: 00H      | R/W                   | Address: DCHC0 FFFFF0E0H, DCHC1 FFFFF0E2H,<br>DCHC2 FFFFF0E4H, DCHC3 FFFFF0E6H |   |   |   |                         |                        |     |
| DCHCn<br>(n = 0 to 3) | <7>                   | 6  | 5 | 4 | 3 | <2>                     | <1>                    | <0> |
|                       | TCn <sup>Note 1</sup> | 0  | 0 | 0 | 0 | INITn <sup>Note 2</sup> | STGn <sup>Note 2</sup> | Enn |

|   |   |
|---|---|
| TCn <sup>Note 1</sup>   | Status flag indicates whether DMA transfer through DMA channel n has completed or not |
| 0   | DMA transfer had not completed.   |
| 1   | DMA transfer had completed.   |
| It is set to 1 on the last DMA transfer and cleared to 0 when it is read. |   |

|                         |  |
|-------------------------|--|
| INITn <sup>Note 2</sup> | If the INITn bit is set to 1 with DMA transfer disabled (Enn bit = 0), the DMA transfer status can be initialized.<br>When re-setting the DMA transfer status (re-setting the DDAnH, DDAnL, DSAnH, DSAnL, DBCn, and DADCn registers) before DMA transfer is completed (before the TCn bit is set to 1), be sure to initialize the DMA channel.<br>When initializing the DMA controller, however, be sure to observe the procedure described in <b>18.13 Cautions</b> . |
|-------------------------|--|

|                        |  |
|------------------------|--|
| STGn <sup>Note 2</sup> | This is a software startup trigger of DMA transfer.<br>If this bit is set to 1 in the DMA transfer enable state (TCn bit = 0, Enn bit = 1), DMA transfer is started. |
|------------------------|--|

|  |  |
|--|--|
| Enn  | Setting of whether DMA transfer through DMA channel n is to be enabled or disabled |
| 0  | DMA transfer disabled  |
| 1  | DMA transfer enabled   |
| DMA transfer is enabled when the Enn bit is set to 1.<br>When DMA transfer is completed (when a terminal count is generated), this bit is automatically cleared to 0.<br>To abort DMA transfer, clear the Enn bit to 0 by software. To resume, set the Enn bit to 1 again.<br>When aborting or resuming DMA transfer, however, be sure to observe the procedure described in <b>18.13 Cautions</b> . |  |

**Notes 1.** The TCn bit is read-only.

**2.** The INITn and STGn bits are write-only.

**Cautions 1.** Be sure to clear bits 6 to 3 of the DCHCn register to 0.

**2.** When DMA transfer is completed (when a terminal count is generated), the Enn bit is cleared to 0 and then the TCn bit is set to 1. If the DCHCn register is read while its bits are being updated, a value indicating "transfer not completed and transfer is disabled" (TCn bit = 0 and Enn bit = 0) may be read.

**(6) DMA trigger factor registers 0 to 3 (DTFR0 to DTFR3)**

The DTFR0 to DTFR3 registers are 8-bit registers that control the DMA transfer start trigger via interrupt request signals from on-chip peripheral I/O.

The interrupt request signals set by these registers serve as DMA transfer start factors.

These registers can be read or written in 8-bit units. However, DF<sub>n</sub> bit can be read or written in 1-bit units.

Reset sets these registers to 00H.

After reset: 00H    R/W    Address: DTFR0 FFFFF810H, DTFR1 FFFFF812H,  
DTFR2 FFFFF814H, DTFR3 FFFFF816H

|                   |                 |   |                   |                   |                   |                   |                   |                   |
|-------------------|-----------------|---|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|                   | <7>             | 6 | 5                 | 4                 | 3                 | 2                 | 1                 | 0                 |
| DTFR <sub>n</sub> | DF <sub>n</sub> | 0 | IFC <sub>n5</sub> | IFC <sub>n4</sub> | IFC <sub>n3</sub> | IFC <sub>n2</sub> | IFC <sub>n1</sub> | IFC <sub>n0</sub> |

(n = 0 to 3)

|                                 |                                  |
|---------------------------------|----------------------------------|
| DF <sub>n</sub> <sup>Note</sup> | DMA transfer request status flag |
| 0                               | No DMA transfer request          |
| 1                               | DMA transfer request             |

**Note** Do not set the DF<sub>n</sub> bit to 1 by software. Write 0 to this bit to clear a DMA transfer request if an interrupt that is specified as the cause of starting DMA transfer occurs while DMA transfer is disabled.

**Cautions 1.** Set the IFC<sub>n5</sub> to IFC<sub>n0</sub> bits at the following timing when DMA transfer is disabled (DCHC<sub>n</sub>.Enn bit = 0).

- Period from after reset to start of first DMA transfer
  - Period from after channel initialization by DCHC<sub>n</sub>.INIT<sub>n</sub> bit to start of DMA transfer
  - Period from after completion of DMA transfer (DCHC<sub>n</sub>.TC<sub>n</sub> bit = 1) to start of the next DMA transfer
2. An interrupt request that is generated in the standby mode (IDEL1, IDLE2, STOP, or sub-IDLE mode) does not start the DMA transfer cycle (nor is the DF<sub>n</sub> bit set to 1).
  3. If a DMA start factor is selected by the IFC<sub>n5</sub> to IFC<sub>n0</sub> bits, the DF<sub>n</sub> bit is set to 1 when an interrupt occurs from the selected on-chip peripheral I/O, regardless of whether the DMA transfer is enabled or disabled. If DMA is enabled in this status, DMA transfer is immediately started.

**Remark** For the IFC<sub>n5</sub> to IFC<sub>n0</sub> bits, see **Table 18-1 DMA Start Factors**.

Table 18-1. DMA Start Factors (1/2)

| IFCn5 | IFCn4 | IFCn3 | IFCn2 | IFCn1 | IFCn0 | Interrupt Source                  |
|-------|-------|-------|-------|-------|-------|-----------------------------------|
| 0     | 0     | 0     | 0     | 0     | 0     | DMA request by interrupt disabled |
| 0     | 0     | 0     | 0     | 0     | 1     | INTP0                             |
| 0     | 0     | 0     | 0     | 1     | 0     | INTP1                             |
| 0     | 0     | 0     | 0     | 1     | 1     | INTP2                             |
| 0     | 0     | 0     | 1     | 0     | 0     | INTP3                             |
| 0     | 0     | 0     | 1     | 0     | 1     | INTP4                             |
| 0     | 0     | 0     | 1     | 1     | 0     | INTP5                             |
| 0     | 0     | 0     | 1     | 1     | 1     | INTP6                             |
| 0     | 0     | 1     | 0     | 0     | 0     | INTP7                             |
| 0     | 0     | 1     | 0     | 0     | 1     | INTTQ0OV                          |
| 0     | 0     | 1     | 0     | 1     | 0     | INTTQ0CC0                         |
| 0     | 0     | 1     | 0     | 1     | 1     | INTTQ0CC1                         |
| 0     | 0     | 1     | 1     | 0     | 0     | INTTQ0CC2                         |
| 0     | 0     | 1     | 1     | 0     | 1     | INTTQ0CC3                         |
| 0     | 0     | 1     | 1     | 1     | 0     | INTTP0OV                          |
| 0     | 0     | 1     | 1     | 1     | 1     | INTTP0CC0                         |
| 0     | 1     | 0     | 0     | 0     | 0     | INTTP0CC1                         |
| 0     | 1     | 0     | 0     | 0     | 1     | INTTP1OV                          |
| 0     | 1     | 0     | 0     | 1     | 0     | INTTP1CC0                         |
| 0     | 1     | 0     | 0     | 1     | 1     | INTTP1CC1                         |
| 0     | 1     | 0     | 1     | 0     | 0     | INTTP2OV                          |
| 0     | 1     | 0     | 1     | 0     | 1     | INTTP2CC0                         |
| 0     | 1     | 0     | 1     | 1     | 0     | INTTP2CC1                         |
| 0     | 1     | 0     | 1     | 1     | 1     | INTTP3CC0                         |
| 0     | 1     | 1     | 0     | 0     | 0     | INTTP3CC1                         |
| 0     | 1     | 1     | 0     | 0     | 1     | INTTP4CC0                         |
| 0     | 1     | 1     | 0     | 1     | 0     | INTTP4CC1                         |
| 0     | 1     | 1     | 0     | 1     | 1     | INTTP5CC0                         |
| 0     | 1     | 1     | 1     | 0     | 0     | INTTP5CC1                         |
| 0     | 1     | 1     | 1     | 0     | 1     | INTTM0EQ0                         |
| 0     | 1     | 1     | 1     | 1     | 0     | INTCB0R/INTIIC1                   |
| 0     | 1     | 1     | 1     | 1     | 1     | INTCB0T                           |
| 1     | 0     | 0     | 0     | 0     | 0     | INTCB1R                           |
| 1     | 0     | 0     | 0     | 0     | 1     | INTCB1T                           |
| 1     | 0     | 0     | 0     | 1     | 0     | INTCB2R                           |
| 1     | 0     | 0     | 0     | 1     | 1     | INTCB2T                           |
| 1     | 0     | 0     | 1     | 0     | 0     | INTCB3R                           |
| 1     | 0     | 0     | 1     | 0     | 1     | INTCB3T                           |
| 1     | 0     | 0     | 1     | 1     | 0     | INTUA0R/INTCB4R                   |
| 1     | 0     | 0     | 1     | 1     | 1     | INTUA0T/INTCB4T                   |
| 1     | 0     | 1     | 0     | 0     | 0     | INTUA1R/INTIIC2                   |
| 1     | 0     | 1     | 0     | 0     | 1     | INTUA1T                           |
| 1     | 0     | 1     | 0     | 1     | 0     | INTUA2R/INTIIC0                   |

**Remark** n = 0 to 3

Table 18-1. DMA Start Factors (2/2)

| IFCn5            | IFCn4 | IFCn3 | IFCn2 | IFCn1 | IFCn0 | Interrupt Source   |
|------------------|-------|-------|-------|-------|-------|--------------------|
| 1                | 0     | 1     | 0     | 1     | 1     | INTUA2T            |
| 1                | 0     | 1     | 1     | 0     | 0     | INTAD              |
| 1                | 0     | 1     | 1     | 0     | 1     | INTKR              |
| 1                | 1     | 0     | 0     | 0     | 1     | INTP8              |
| 1                | 1     | 0     | 0     | 1     | 0     | INTTP6CC0          |
| 1                | 1     | 0     | 0     | 1     | 1     | INTTP6CC1          |
| 1                | 1     | 0     | 1     | 0     | 0     | INTTP7CC0          |
| 1                | 1     | 0     | 1     | 0     | 1     | INTTP7CC1          |
| 1                | 1     | 0     | 1     | 1     | 0     | INTTP8CC0          |
| 1                | 1     | 0     | 1     | 1     | 1     | INTTP8CC1          |
| 1                | 1     | 1     | 0     | 0     | 0     | INTCB5R            |
| 1                | 1     | 1     | 0     | 0     | 1     | INTCB5T            |
| 1                | 1     | 1     | 0     | 1     | 0     | INTUA3R            |
| 1                | 1     | 1     | 0     | 1     | 1     | INTUA3T            |
| Other than above |       |       |       |       |       | Setting prohibited |

**Remark** n = 0 to 3

### 18.4 Transfer Targets

Table 18-2 shows the relationship between the transfer targets (√: Transfer enabled, ×: Transfer disabled).

Table 18-2. Relationship Between Transfer Targets

|        |                        | Transfer Destination |                        |              |                 |
|--------|------------------------|----------------------|------------------------|--------------|-----------------|
|        |                        | Internal ROM         | On-Chip Peripheral I/O | Internal RAM | External Memory |
| Source | On-chip peripheral I/O | ×                    | √                      | √            | √               |
|        | Internal RAM           | ×                    | √                      | ×            | √               |
|        | External memory        | ×                    | √                      | √            | √               |
|        | Internal ROM           | ×                    | ×                      | ×            | ×               |

**Caution** The operation is not guaranteed for combinations of transfer destination and source marked with "x" in Table 18-2.



## 18.5 Transfer Modes

Single transfer is supported as the transfer mode.

In single transfer mode, the bus is released at each byte/halfword transfer. If there is a subsequent DMA transfer request, transfer is performed again once. This operation continues until a terminal count occurs.

When the DMAC has released the bus, if another higher priority DMA transfer request is issued, the higher priority DMA request always takes precedence.

If a new transfer request of the same channel and a transfer request of another channel with a lower priority are generated in a transfer cycle, DMA transfer of the channel with the lower priority is executed after the bus is released to the CPU (the new transfer request of the same channel is ignored in the transfer cycle).

## 18.6 Transfer Types

As a transfer type, the 2-cycle transfer is supported.

In two-cycle transfer, data transfer is performed in two cycles, a read cycle and a write cycle.

In the read cycle, the transfer source address is output and reading is performed from the source to the DMAC. In the write cycle, the transfer destination address is output and writing is performed from the DMAC to the destination.

An idle cycle of one clock is always inserted between a read cycle and a write cycle. If the data bus width differs between the transfer source and destination for DMA transfer of two cycles, the operation is performed as follows.

<16-bit data transfer>

<1> Transfer from 32-bit bus → 16-bit bus

A read cycle (the higher 16 bits are in a high-impedance state) is generated, followed by generation of a write cycle (16 bits).

<2> Transfer from 16-/32-bit bus to 8-bit bus

A 16-bit read cycle is generated once, and then an 8-bit write cycle is generated twice.

<3> Transfer from 8-bit bus to 16-/32-bit bus

An 8-bit read cycle is generated twice, and then a 16-bit write cycle is generated once.

<4> Transfer between 16-bit bus and 32-bit bus

A 16-bit read cycle is generated once, and then a 16-bit write cycle is generated once.

For DMA transfer executed to an on-chip peripheral I/O register (transfer source/destination), be sure to specify the same transfer size as the register size. For example, for DMA transfer to an 8-bit register, be sure to specify byte (8-bit) transfer.

**Remark** The bus width of each transfer target (transfer source/destination) is as follows.

- On-chip peripheral I/O: 16-bit bus width
- Internal RAM: 32-bit bus width
- External memory: 8-bit or 16-bit bus width

## 18.7 DMA Channel Priorities

The DMA channel priorities are fixed as follows.

DMA channel 0 > DMA channel 1 > DMA channel 2 > DMA channel 3

The priorities are checked for every transfer cycle.

## 18.8 Time Related to DMA Transfer

The time required to respond to a DMA request, and the minimum number of clocks required for DMA transfer are shown below.

Single transfer: DMA response time (<1>) + Transfer source memory access (<2>) + 1<sup>Note 1</sup> + Transfer destination memory access (<2>)

| DMA Cycle                     |                                | Minimum Number of Execution Clocks  |
|-------------------------------|--------------------------------|---|
| <1> DMA request response time |                                | 4 clocks (MIN.) + Noise elimination time <sup>Note 2</sup>                    |
| <2> Memory access             | External memory access         | Depends on connected memory.  |
|                               | Internal RAM access            | 2 clocks <sup>Note 3</sup>  |
|                               | Peripheral I/O register access | 3 clocks + Number of wait cycles specified by VSWC register <sup>Note 4</sup> |

- Notes**
1. One clock is always inserted between a read cycle and a write cycle in DMA transfer.
  2. If an external interrupt (INTPn) is specified as the trigger to start DMA transfer, noise elimination time is added (n = 0 to 8).
  3. Two clocks are required for a DMA cycle.
  4. More wait cycles are necessary for accessing a specific peripheral I/O register (for details, see **3.4.8 (2)**).

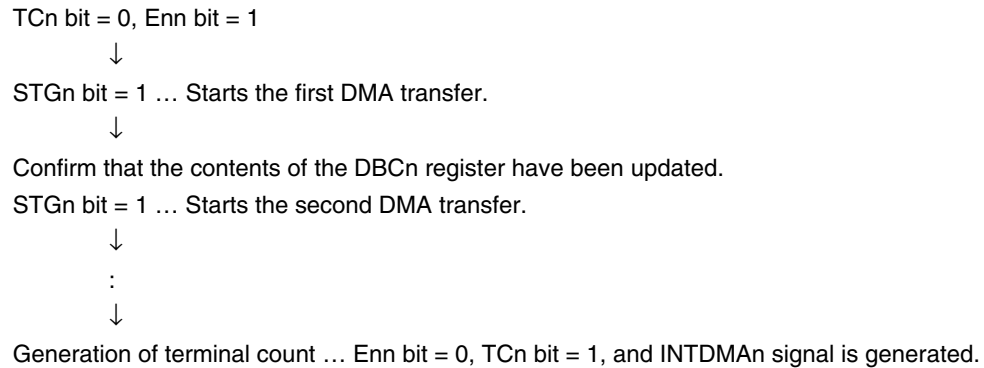
## 18.9 DMA Transfer Start Factors

There are two types of DMA transfer start factors, as shown below.

### (1) Request by software

If the STGn bit is set to 1 while the DCHCn.TCn bit = 1 and Enn bit = 1 (DMA transfer enabled), DMA transfer is started.

To request the next DMA transfer cycle immediately after that, confirm, by using the DBCn register, that the preceding DMA transfer cycle has been completed, and set the STGn bit to 1 again (n = 0 to 3).



### (2) Request by on-chip peripheral I/O

If an interrupt request is generated from the on-chip peripheral I/O set by the DTFRn register when the DCHCn.TCn bit = 0 and Enn bit = 1 (DMA transfer enabled), DMA transfer is started.

- Cautions**
- Two start factors (software trigger and hardware trigger) cannot be used for one DMA channel. If two start factors are simultaneously generated for one DMA channel, only one of them is valid. The start factor that is valid cannot be identified.**
  - A new transfer request that is generated after the preceding DMA transfer request was generated or in the preceding DMA transfer cycle is ignored (cleared).**
  - The transfer request interval of the same DMA channel varies depending on the setting of bus wait in the DMA transfer cycle, the start status of the other channels, or the external bus hold request. In particular, as described in Caution 2, a new transfer request that is generated for the same channel before the DMA transfer cycle or during the DMA transfer cycle is ignored. Therefore, the transfer request intervals for the same DMA channel must be sufficiently separated by the system. When the software trigger is used, completion of the DMA transfer cycle that was generated before can be checked by updating the DBCn register.**

### 18.10 DMA Abort Factors

DMA transfer is aborted if a bus hold occurs.

The same applies if transfer is executed between the internal memory/on-chip peripheral I/O and internal memory/on-chip peripheral I/O.

When the bus hold is cleared, DMA transfer is resumed.

### 18.11 End of DMA Transfer

When DMA transfer has been completed the number of times set to the DBCn register and when the DHCn.Enn bit is cleared to 0 and TCn bit is set to 1, a DMA transfer end interrupt request signal (INTDMAn) is generated for the interrupt controller (INTC) (n = 0 to 3).

The V850ES/JJ3 does not output a terminal count signal to an external device. Therefore, confirm completion of DMA transfer by using the DMA transfer end interrupt or polling the TCn bit.

### 18.12 Operation Timing

Figures 18-1 to 18-4 show DMA operation timing.

Figure 18-1. Priority of DMA (1)

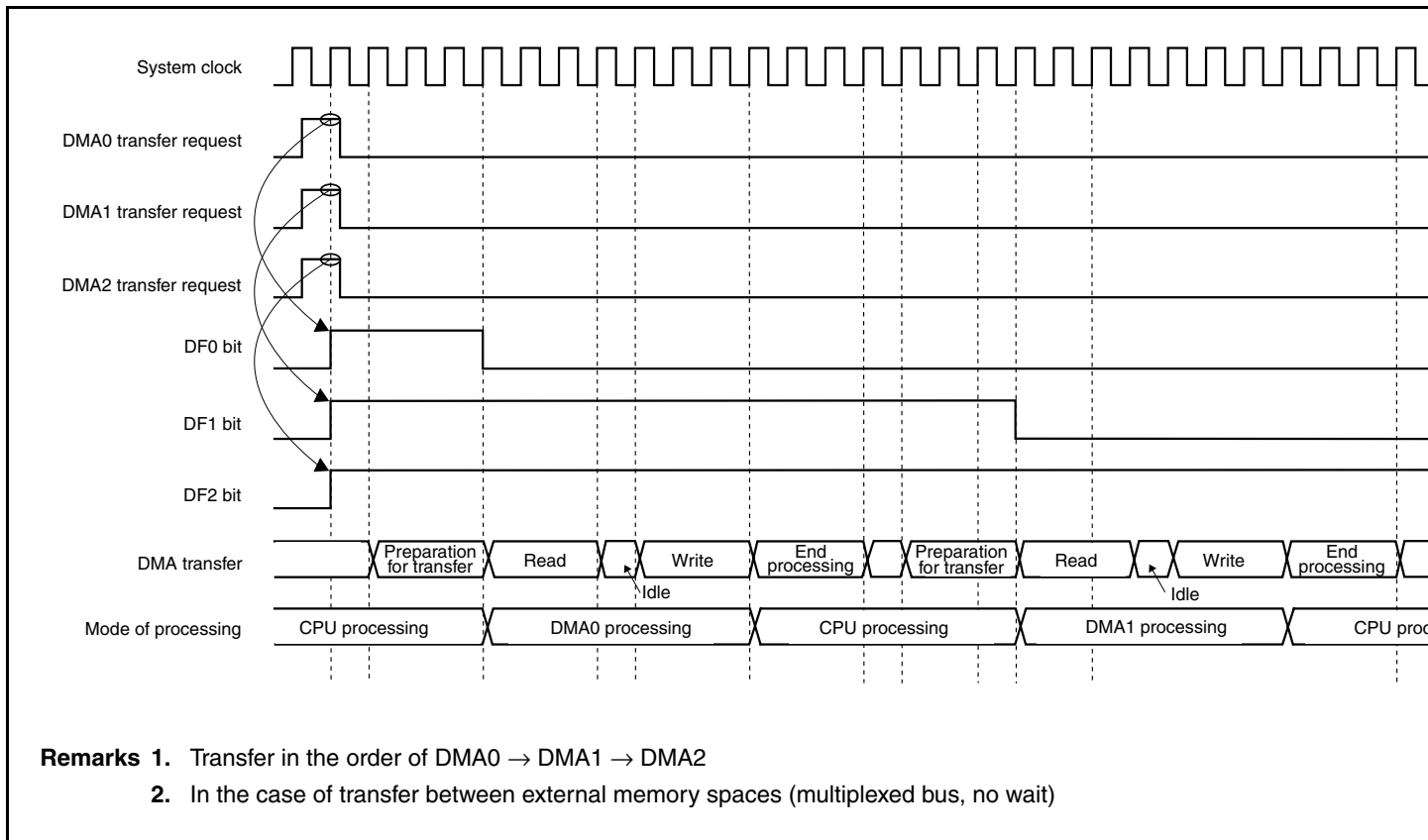


Figure 18-2. Priority of DMA (2)

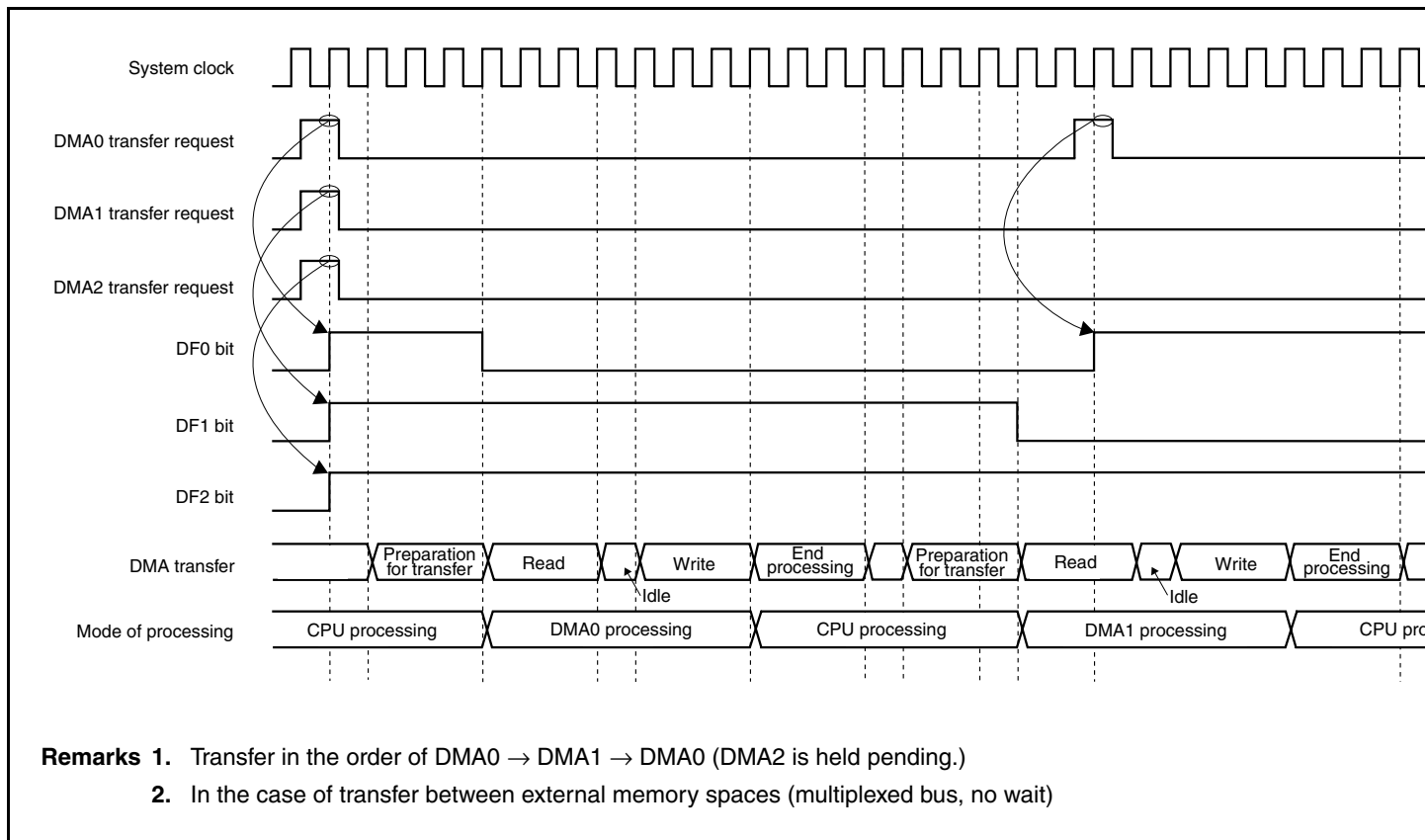


Figure 18-3. Period in Which DMA Transfer Request Is Ignored (1)

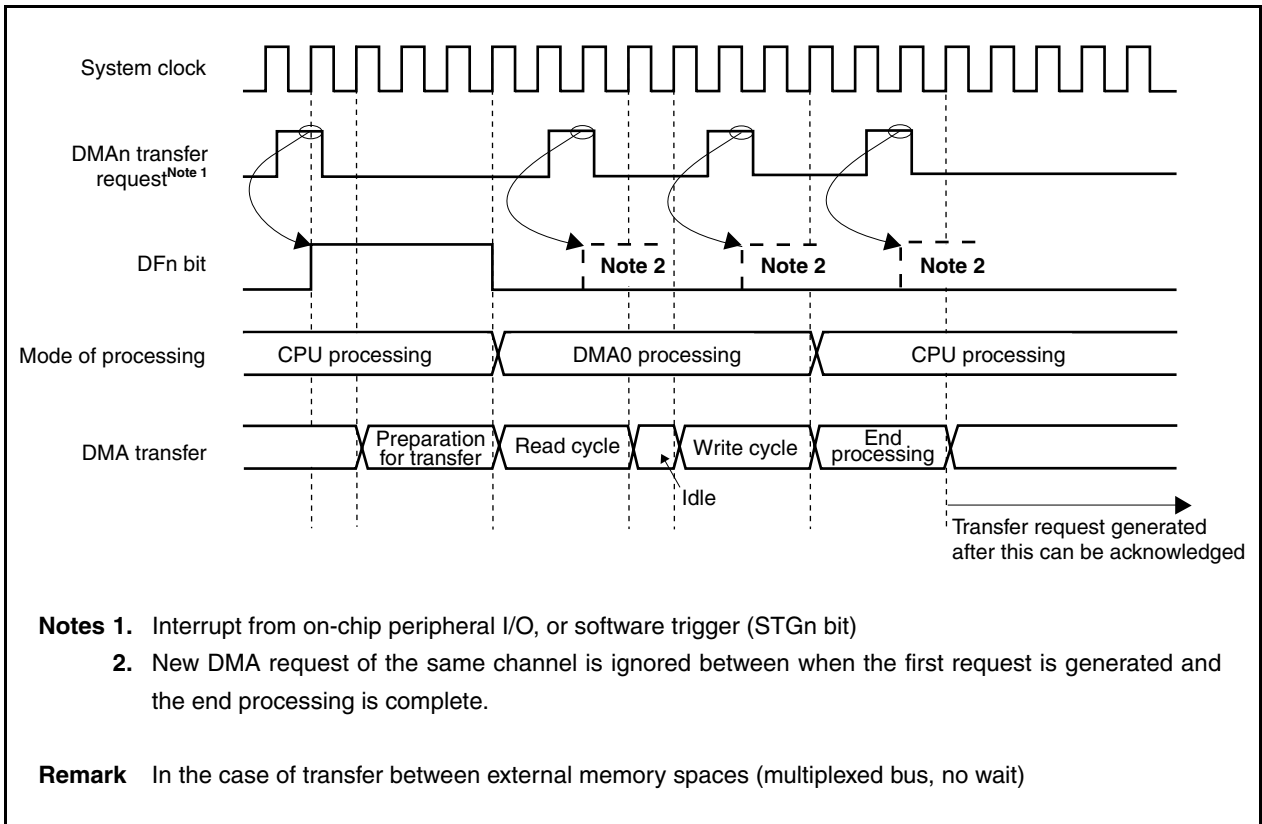
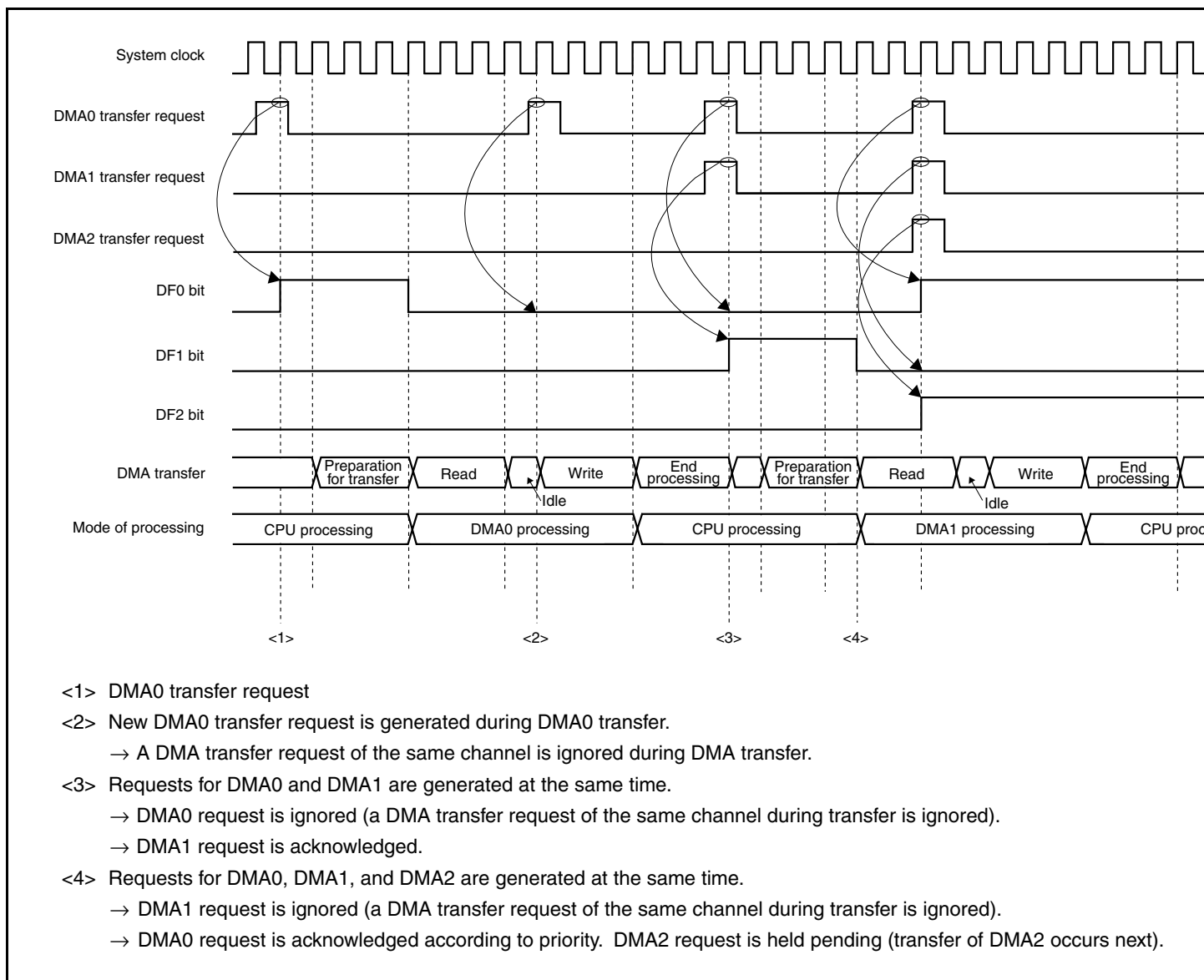


Figure 18-4. Period in Which DMA Transfer Request Is Ignored (2)





## 18.13 Cautions

### (1) Caution for VSWC register

When using the DMAC, be sure to set an appropriate value, in accordance with the operating frequency, to the VSWC register.

When the default value (77H) of the VSWC register is used, or if an inappropriate value is set to the VSWC register, the operation is not correctly performed (for details of the VSWC register, see **3.4.8 (1) (a) System wait control register (VSWC)**).

### (2) Caution for DMA transfer executed on internal RAM

When executing the following instructions located in the internal RAM, do not execute a DMA transfer that transfers data to/from the internal RAM (transfer source/destination), because the CPU may not operate correctly afterward.

- Bit manipulation instruction located in internal RAM (SET1, CLR1, or NOT1)
- Data access instruction to misaligned address located in internal RAM

Conversely, when executing a DMA transfer to transfer data to/from the internal RAM (transfer source/destination), do not execute the above two instructions.

### (3) Caution for reading DCHCn.TCn bit (n = 0 to 3)

The TCn bit is cleared to 0 when it is read, but it is not automatically cleared even if it is read at a specific timing. To accurately clear the TCn bit, add the following processing.

#### (a) When waiting for completion of DMA transfer by polling TCn bit

Confirm that the TCn bit has been set to 1 (after TCn bit = 1 is read), and then read the TCn bit three more times.

#### (b) When reading TCn bit in interrupt servicing routine

Execute reading the TCn bit three times.

**(4) DMA transfer initialization procedure (setting DHCn.INITn bit to 1)**

Even if the INITn bit is set to 1 when the channel executing DMA transfer is to be initialized, the channel may not be initialized. To accurately initialize the channel, execute either of the following two procedures.

**(a) Temporarily stop transfer of all DMA channels**

Initialize the channel executing DMA transfer using the procedure in <1> to <7> below.

Note, however, that TCn bit is cleared to 0 when step <5> is executed. Make sure that the other processing programs do not expect that the TCn bit is 1.

- <1> Disable interrupts (DI).
- <2> Read the DHCn.Enn bit of DMA channels other than the one to be forcibly terminated, and transfer the value to a general-purpose register.
- <3> Clear the Enn bit of the DMA channels used (including the channel to be forcibly terminated) to 0. To clear the Enn bit of the last DMA channel, execute the clear instruction twice. If the target of DMA transfer (transfer source/destination) is the internal RAM, execute the instruction three times.

Example: Execute instructions in the following order if channels 0, 1, and 2 are used (if the target of transfer is not the internal RAM).

- Clear DHC0.E00 bit to 0.
- Clear DHC1.E11 bit to 0.
- Clear DHC2.E22 bit to 0.
- Clear DHC2.E22 bit to 0 again.

- <4> Set the INITn bit of the channel to be forcibly terminated to 1.
- <5> Read the TCn bit of each channel not to be forcibly terminated. If both the TCn bit and the Enn bit read in <2> are 1 (logical product (AND) is 1), clear the saved Enn bit to 0.
- <6> After the operation in <5>, write the Enn bit value to the DHCn register.
- <7> Enable interrupts (EI).

**Caution** Be sure to execute step <5> above to prevent illegal setting of the Enn bit of the channels whose DMA transfer has been normally completed between <2> and <3>.

**(b) Repeatedly execute setting INITn bit until transfer is forcibly terminated correctly**

- <1> Suppress a request from the DMA request source of the channel to be forcibly terminated (stop operation of the on-chip peripheral I/O).
- <2> Check that the DMA transfer request of the channel to be forcibly terminated is not held pending, by using the DTFRn.DFn bit. If a DMA transfer request is held pending, wait until execution of the pending request is completed.
- <3> When it has been confirmed that the DMA request of the channel to be forcibly terminated is not held pending, clear the Enn bit to 0.
- <4> Again, clear the Enn bit of the channel to be forcibly terminated.  
If the target of transfer for the channel to be forcibly terminated (transfer source/destination) is the internal RAM, execute this operation once more.
- <5> Copy the initial number of transfers of the channel to be forcibly terminated to a general-purpose register.
- <6> Set the INITn bit of the channel to be forcibly terminated to 1.
- <7> Read the value of the DBCn register of the channel to be forcibly terminated, and compare it with the value copied in <5>. If the two values do not match, repeat operations <6> and <7>.

- Remarks**
1. When the value of the DBCn register is read in <7>, the initial number of transfers is read if forced termination has been correctly completed. If not, the remaining number of transfers is read.
  2. Note that method (b) may take a long time if the application frequently uses DMA transfer for a channel other than the DMA channel to be forcibly terminated.

**(5) Procedure of temporarily stopping DMA transfer (clearing Enn bit)**

Stop and resume the DMA transfer under execution using the following procedure.

- <1> Suppress a transfer request from the DMA request source (stop the operation of the on-chip peripheral I/O).
- <2> Check the DMA transfer request is not held pending, by using the DFn bit (check if the DFn bit = 0).  
If a request is pending, wait until execution of the pending DMA transfer request is completed.
- <3> If it has been confirmed that no DMA transfer request is held pending, clear the Enn bit to 0 (this operation stops DMA transfer).
- <4> Set the Enn bit to 1 to resume DMA transfer.
- <5> Resume the operation of the DMA request source that has been stopped (start the operation of the on-chip peripheral I/O).

**(6) Memory boundary**

The operation is not guaranteed if the address of the transfer source or destination exceeds the area of the DMA target (external memory, internal RAM, or on-chip peripheral I/O) during DMA transfer.

**(7) Transferring misaligned data**

DMA transfer of misaligned data with a 16-bit bus width is not supported.

If an odd address is specified as the transfer source or destination, the least significant bit of the address is forcibly assumed to be 0.

**(8) Bus arbitration for CPU**

Because the DMA controller has a higher priority bus mastership than the CPU, a CPU access that takes place during DMA transfer is held pending until the DMA transfer cycle is completed and the bus is released to the CPU.

However, the CPU can access the external memory, on-chip peripheral I/O, and internal RAM to/from which DMA transfer is not being executed.

- The CPU can access the internal RAM when DMA transfer is being executed between the external memory and on-chip peripheral I/O.
- The CPU can access the internal RAM and on-chip peripheral I/O when DMA transfer is being executed between the external memory and external memory.

**(9) Registers/bits that must not be rewritten during DMA operation**

Set the following registers at the following timing when a DMA operation is not under execution.

[Registers]

- DSAnH, DSAnL, DDAnH, DDAnL, DBCn, and DADCn registers
- DTFRn.IFCn5 to DTFRn.IFCn0 bits

[Timing of setting]

- Period from after reset to start of the first DMA transfer
- Time after channel initialization to start of DMA transfer
- Period from after completion of DMA transfer (TCn bit = 1) to start of the next DMA transfer

**(10) Be sure to set the following register bits to 0.**

- Bits 14 to 10 of DSAnH register
- Bits 14 to 10 of DDAnH register
- Bits 15, 13 to 8, and 3 to 0 of DADCn register
- Bits 6 to 3 of DCHCn register

**(11) DMA start factor**

Do not start two or more DMA channels with the same start factor. If two or more channels are started with the same factor, DMA for which a channel has already been set may be started or a DMA channel with a lower priority may be acknowledged earlier than a DMA channel with a higher priority. The operation cannot be guaranteed.

**(12) Read values of DSAn and DDAn registers**

Values in the middle of updating may be read from the DSAn and DDAn registers during DMA transfer (n = 0 to 3).

For example, if the DSAnH register and then the DSAnL register are read when the DMA transfer source address (DSAn register) is 0000FFFFH and the count direction is incremental (DADCn.SAD1 and DADCn.SAD0 bits = 00), the value of the DSAn register differs as follows, depending on whether DMA transfer is executed immediately after the DSAnH register is read.

**(a) If DMA transfer does not occur while DSAn register is read**

- <1> Read value of DSAnH register: DSAnH = 0000H
- <2> Read value of DSAnL register: DSAnL = FFFFH

**(b) If DMA transfer occurs while DSAn register is read**

- <1> Read value of DSAnH register: DSAnH = 0000H
- <2> Occurrence of DMA transfer
- <3> Incrementing DSAn register: DSAn = 00100000H
- <4> Read value of DSAnL register: DSAnL = 0000H

## CHAPTER 19 INTERRUPT/EXCEPTION PROCESSING FUNCTION

The V850ES/JJ3 is provided with a dedicated interrupt controller (INTC) for interrupt servicing and can process a total of 71 interrupt requests.

An interrupt is an event that occurs independently of program execution, and an exception is an event whose occurrence is dependent on program execution.

The V850ES/JJ3 can process interrupt request signals from the on-chip peripheral hardware and external sources. Moreover, exception processing can be started by the TRAP instruction (software exception) or by generation of an exception event (i.e. fetching of an illegal opcode) (exception trap).

### 19.1 Features

- Interrupts
  - Non-maskable interrupts: 2 sources
  - Maskable interrupts: External: 9, Internal: 60 sources
  - 8 levels of programmable priorities (maskable interrupts)
  - Multiple interrupt control according to priority
  - Masks can be specified for each maskable interrupt request.
  - Noise elimination, edge detection, and valid edge specification for external interrupt request signals.
- Exceptions
  - Software exceptions: 32 sources
  - Exception trap: 2 sources (illegal opcode exception, debug trap)

Interrupt/exception sources are listed in Table 19-1.

Table 19-1. Interrupt Source List (1/3)

| Type               | Classification | Default Priority               | Name                     | Trigger   | Generating Unit | Exception Code          | Handler Address | Restored PC   | Interrupt Control Register |
|--------------------|----------------|--------------------------------|--------------------------|---|-----------------|-------------------------|-----------------|---------------|----------------------------|
| Reset              | Interrupt      | –                              | RESET                    | RESET pin input<br>Reset by internal source         | RESET           | 0000H                   | 00000000H       | Undefined     | –                          |
| Non-maskable       | Interrupt      | –                              | NMI                      | NMI pin valid edge input                            | Pin             | 0010H                   | 00000010H       | nextPC        | –                          |
|                    |                | –                              | INTWDT2                  | WDT2 overflow                                       | WDT2            | 0020H                   | 00000020H       | <b>Note 1</b> | –                          |
| Software exception | Exception      | –                              | TRAP0 <sup>Note 2</sup>  | TRAP instruction                                    | –               | 004nH <sup>Note 2</sup> | 00000040H       | nextPC        | –                          |
|                    |                | –                              | TRAP1n <sup>Note 2</sup> | TRAP instruction                                    | –               | 005nH <sup>Note 2</sup> | 00000050H       | nextPC        | –                          |
| Exception trap     | Exception      | –                              | ILGOP/<br>DBG0           | Illegal opcode/DBTRAP instruction                   | –               | 0060H                   | 00000060H       | nextPC        | –                          |
| Maskable           | Interrupt      | 0                              | INTLVI                   | Low-voltage detection                               | POCLVI          | 0080H                   | 00000080H       | nextPC        | LVIC                       |
|                    |                | 1                              | INTP0                    | External interrupt pin input edge detection (INTP0) | Pin             | 0090H                   | 00000090H       | nextPC        | PIC0                       |
|                    |                | 2                              | INTP1                    | External interrupt pin input edge detection (INTP1) | Pin             | 00A0H                   | 000000A0H       | nextPC        | PIC1                       |
|                    |                | 3                              | INTP2                    | External interrupt pin input edge detection (INTP2) | Pin             | 00B0H                   | 000000B0H       | nextPC        | PIC2                       |
|                    |                | 4                              | INTP3                    | External interrupt pin input edge detection (INTP3) | Pin             | 00C0H                   | 000000C0H       | nextPC        | PIC3                       |
|                    |                | 5                              | INTP4                    | External interrupt pin input edge detection (INTP4) | Pin             | 00D0H                   | 000000D0H       | nextPC        | PIC4                       |
|                    |                | 6                              | INTP5                    | External interrupt pin input edge detection (INTP5) | Pin             | 00E0H                   | 000000E0H       | nextPC        | PIC5                       |
|                    |                | 7                              | INTP6                    | External interrupt pin input edge detection (INTP6) | Pin             | 00F0H                   | 000000F0H       | nextPC        | PIC6                       |
|                    |                | 8                              | INTP7                    | External interrupt pin input edge detection (INTP7) | Pin             | 0100H                   | 00000100H       | nextPC        | PIC7                       |
|                    |                | 9                              | INTTQ0OV                 | TMQ0 overflow                                       | TMQ0            | 0110H                   | 00000110H       | nextPC        | TQ0OVIC                    |
|                    |                | 10                             | INTTQ0CC0                | TMQ0 capture 0/compare 0 match                      | TMQ0            | 0120H                   | 00000120H       | nextPC        | TQ0CCIC0                   |
|                    |                | 11                             | INTTQ0CC1                | TMQ0 capture 1/compare 1 match                      | TMQ0            | 0130H                   | 00000130H       | nextPC        | TQ0CCIC1                   |
|                    |                | 12                             | INTTQ0CC2                | TMQ0 capture 2/compare 2 match                      | TMQ0            | 0140H                   | 00000140H       | nextPC        | TQ0CCIC2                   |
|                    |                | 13                             | INTTQ0CC3                | TMQ0 capture 3/compare 3 match                      | TMQ0            | 0150H                   | 00000150H       | nextPC        | TQ0CCIC3                   |
|                    |                | 14                             | INTTP0OV                 | TMP0 overflow                                       | TMP0            | 0160H                   | 00000160H       | nextPC        | TP0OVIC                    |
|                    |                | 15                             | INTTP0CC0                | TMP0 capture 0/compare 0 match                      | TMP0            | 0170H                   | 00000170H       | nextPC        | TP0CCIC0                   |
|                    |                | 16                             | INTTP0CC1                | TMP0 capture 1/compare 1 match                      | TMP0            | 0180H                   | 00000180H       | nextPC        | TP0CCIC1                   |
|                    |                | 17                             | INTTP1OV                 | TMP1 overflow                                       | TMP1            | 0190H                   | 00000190H       | nextPC        | TP1OVIC                    |
|                    |                | 18                             | INTTP1CC0                | TMP1 capture 0/compare 0 match                      | TMP1            | 01A0H                   | 000001A0H       | nextPC        | TP1CCIC0                   |
|                    |                | 19                             | INTTP1CC1                | TMP1 capture 1/compare 1 match                      | TMP1            | 01B0H                   | 000001B0H       | nextPC        | TP1CCIC1                   |
|                    |                | 20                             | INTTP2OV                 | TMP2 overflow                                       | TMP2            | 01C0H                   | 000001C0H       | nextPC        | TP2OVIC                    |
|                    |                | 21                             | INTTP2CC0                | TMP2 capture 0/compare 0 match                      | TMP2            | 01D0H                   | 000001D0H       | nextPC        | TP2CCIC0                   |
|                    |                | 22                             | INTTP2CC1                | TMP2 capture 1/compare 1 match                      | TMP2            | 01E0H                   | 000001E0H       | nextPC        | TP2CCIC1                   |
|                    |                | 23                             | INTTP3OV                 | TMP3 overflow                                       | TMP3            | 01F0H                   | 000001F0H       | nextPC        | TP3OVIC                    |
|                    |                | 24                             | INTTP3CC0                | TMP3 capture 0/compare 0 match                      | TMP3            | 0200H                   | 00000200H       | nextPC        | TP3CCIC0                   |
| 25                 | INTTP3CC1      | TMP3 capture 1/compare 1 match | TMP3                     | 0210H   | 00000210H       | nextPC                  | TP3CCIC1        |               |                            |

**Notes 1.** For the restoring in the case of INTWDT2, see 19.2.2 (2) From INTWDT2 signal.

**2.** n = 0 to FH

Table 19-1. Interrupt Source List (2/3)

| Type     | Classification | Default Priority           | Name                | Trigger  | Generating Unit  | Exception Code | Handler Address | Restored PC | Interrupt Control Register |
|----------|----------------|----------------------------|---------------------|--|------------------|----------------|-----------------|-------------|----------------------------|
| Maskable | Interrupt      | 26                         | INTTP4OV            | TMP4 overflow  | TMP4             | 0220H          | 00000220H       | nextPC      | TP4OVIC                    |
|          |                | 27                         | INTTP4CC0           | TMP4 capture 0/compare 0 match   | TMP4             | 0230H          | 00000230H       | nextPC      | TP4CCIC0                   |
|          |                | 28                         | INTTP4CC1           | TMP4 capture 1/compare 1 match   | TMP4             | 0240H          | 00000240H       | nextPC      | TP4CCIC1                   |
|          |                | 29                         | INTTP5OV            | TMP5 overflow  | TMP5             | 0250H          | 00000250H       | nextPC      | TP5OVIC                    |
|          |                | 30                         | INTTP5CC0           | TMP5 capture 0/compare 0 match   | TMP5             | 0260H          | 00000260H       | nextPC      | TP5CCIC0                   |
|          |                | 31                         | INTTP5CC1           | TMP5 capture 1/compare 1 match   | TMP5             | 0270H          | 00000270H       | nextPC      | TP5CCIC1                   |
|          |                | 32                         | INTTM0EQ0           | TMM0 compare match   | TMM0             | 0280H          | 00000280H       | nextPC      | TM0EQIC0                   |
|          |                | 33                         | INTCB0R/<br>INTIIC1 | CSIB0 reception completion/<br>CSIB0 reception error/<br>IIC1 transfer completion            | CSIB0/<br>IIC1   | 0290H          | 00000290H       | nextPC      | CB0RIC/<br>IIC1C1          |
|          |                | 34                         | INTCB0T             | CSIB0 consecutive transmission<br>write enable   | CSIB0            | 02A0H          | 000002A0H       | nextPC      | CB0TIC                     |
|          |                | 35                         | INTCB1R             | CSIB1 reception completion/<br>CSIB1 reception error   | CSIB1            | 02B0H          | 000002B0H       | nextPC      | CB1RIC                     |
|          |                | 36                         | INTCB1T             | CSIB1 consecutive transmission<br>write enable   | CSIB1            | 02C0H          | 000002C0H       | nextPC      | CB1TIC                     |
|          |                | 37                         | INTCB2R             | CSIB2 reception completion/<br>CSIB2 reception error   | CSIB2            | 02D0H          | 000002D0H       | nextPC      | CB2RIC                     |
|          |                | 38                         | INTCB2T             | CSIB2 consecutive transmission<br>write enable   | CSIB2            | 02E0H          | 000002E0H       | nextPC      | CB2TIC                     |
|          |                | 39                         | INTCB3R             | CSIB3 reception completion/<br>CSIB3 reception error   | CSIB3            | 02F0H          | 000002F0H       | nextPC      | CB3RIC                     |
|          |                | 40                         | INTCB3T             | CSIB3 consecutive transmission<br>write enable   | CSIB3            | 0300H          | 00000300H       | nextPC      | CB3TIC                     |
|          |                | 41                         | INTUA0R/<br>INTCB4R | UARTA0 reception completion/<br>CSIB4 reception completion/<br>CSIB4 reception error         | UARTA0/<br>CSIB4 | 0310H          | 00000310H       | nextPC      | UA0RIC/<br>CB4RIC          |
|          |                | 42                         | INTUA0T/<br>INTCB4T | UARTA0 consecutive transmission<br>enable/<br>CSIB4 consecutive transmission<br>write enable | UARTA0/<br>CSIB4 | 0320H          | 00000320H       | nextPC      | UA0TIC/<br>CB4TIC          |
|          |                | 43                         | INTUA1R/<br>INTIIC2 | UARTA1 reception completion/<br>UARTA1 reception error/<br>IIC2 transfer completion          | UARTA1/<br>IIC2  | 0330H          | 00000330H       | nextPC      | UA1RIC/<br>IIC2C2          |
|          |                | 44                         | INTUA1T             | UARTA1 consecutive transmission<br>enable  | UARTA1           | 0340H          | 00000340H       | nextPC      | UA1TIC                     |
|          |                | 45                         | INTUA2R/<br>INTIIC0 | UARTA2 reception completion/<br>IIC0 transfer completion                                     | UARTA/<br>IIC0   | 0350H          | 00000350H       | nextPC      | UA2RIC/<br>IIC0C0          |
|          |                | 46                         | INTUA2T             | UARTA2 consecutive transmission<br>enable  | UARTA2           | 0360H          | 00000360H       | nextPC      | UA2TIC                     |
|          |                | 47                         | INTAD               | A/D conversion completion  | A/D              | 0370H          | 00000370H       | nextPC      | ADIC                       |
|          |                | 48                         | INTDMA0             | DMA0 transfer completion   | DMA              | 0380H          | 00000380H       | nextPC      | DMAIC0                     |
|          |                | 49                         | INTDMA1             | DMA1 transfer completion   | DMA              | 0390H          | 00000390H       | nextPC      | DMAIC1                     |
|          |                | 50                         | INTDMA2             | DMA2 transfer completion   | DMA              | 03A0H          | 000003A0H       | nextPC      | DMAIC2                     |
|          |                | 51                         | INTDMA3             | DMA3 transfer completion   | DMA              | 03B0H          | 000003B0H       | nextPC      | DMAIC3                     |
|          |                | 52                         | INTKR               | Key return interrupt   | KR               | 03C0H          | 000003C0H       | nextPC      | KRIC                       |
|          |                | 53                         | INTWTI              | Watch timer interval   | WT               | 03D0H          | 000003D0H       | nextPC      | WTIIC                      |
| 54       | INTWT          | Watch timer reference time | WT                  | 03E0H  | 000003E0H        | nextPC         | WTIC            |             |                            |



Table 19-1. Interrupt Source List (3/3)

| Type     | Classification | Default Priority | Name      | Trigger   | Generating Unit | Exception Code | Handler Address | Restored PC | Interrupt Control Register |
|----------|----------------|------------------|-----------|---|-----------------|----------------|-----------------|-------------|----------------------------|
| Maskable | Interrupt      | 55               | INTP8     | External interrupt pin input edge detection (INTP8) | Pin             | 0470H          | 00000470H       | nextPC      | PIC8                       |
|          |                | 56               | INTTP6OV  | TMP6 overflow                                       | TMP6            | 0480H          | 00000480H       | nextPC      | TP6OVIC                    |
|          |                | 57               | INTTP6CC0 | TMP6 capture 0/compare 0 match                      | TMP6            | 0490H          | 00000490H       | nextPC      | TP6CCIC0                   |
|          |                | 58               | INTTP6CC1 | TMP6 capture 1/compare 1 match                      | TMP6            | 04A0H          | 000004A0H       | nextPC      | TP6CCIC1                   |
|          |                | 59               | INTTP7OV  | TMP7 overflow                                       | TMP7            | 04B0H          | 000004B0H       | nextPC      | TP7OVIC                    |
|          |                | 60               | INTTP7CC0 | TMP7 capture 1/compare 0 match                      | TMP7            | 04C0H          | 000004C0H       | nextPC      | TP7CCIC0                   |
|          |                | 61               | INTTP7CC1 | TMP7 capture 1/compare 1 match                      | TMP7            | 04D0H          | 000004D0H       | nextPC      | TP7CCIC1                   |
|          |                | 62               | INTTP8OV  | TMP8 overflow                                       | TMP8            | 04E0H          | 000004E0H       | nextPC      | TP8OVIC                    |
|          |                | 63               | INTTP8CC0 | TMP8 capture 0/compare 0 match                      | TMP8            | 04F0H          | 000004F0H       | nextPC      | TP8CCIC0                   |
|          |                | 64               | INTTP8CC1 | TMP8 capture 1/compare 1 match                      | TMP8            | 0500H          | 00000500H       | nextPC      | TP8CCIC1                   |
|          |                | 65               | INTCB5R   | CSIB5 reception completion                          | CSIB5           | 0510H          | 00000510H       | nextPC      | CB5RIC                     |
|          |                | 66               | INTCB5T   | CSIB5 consecutive transmission write enable         | CSIB5           | 0520H          | 00000520H       | nextPC      | CB5TIC                     |
|          |                | 67               | INTUA3R   | UART3 consecutive reception completion              | UARTA3          | 0530H          | 00000530H       | nextPC      | UA3RIC                     |
|          |                | 68               | INTUA3T   | UARTA3 consecutive transmission enable              | UARTA3          | 0540H          | 00000540H       | nextPC      | UA3TIC                     |

**Remarks 1.** Default Priority: The priority order when two or more maskable interrupt requests occur at the same time. The highest priority is 0.

The priority order of non-maskable interrupt is INTWDT2 > NMI.

Restored PC: The value of the program counter (PC) saved to EIPC, FEPC, or DBPC when interrupt servicing is started. Note, however, that the restored PC when a non-maskable or maskable interrupt is acknowledged while one of the following instructions is being executed does not become the nextPC (if an interrupt is acknowledged during interrupt execution, execution stops, and then resumes after the interrupt servicing has finished).

- Load instructions (SLD.B, SLD.BU, SLD.H, SLD.HU, SLD.W)
- Division instructions (DIV, DIVH, DIVU, DIVHU)
- PREPARE, DISPOSE instructions (only if an interrupt is generated before the stack pointer is updated)

nextPC: The PC value that starts the processing following interrupt/exception processing.

2. The execution address of the illegal instruction when an illegal opcode exception occurs is calculated by (Restored PC – 4).

## 19.2 Non-Maskable Interrupts

A non-maskable interrupt request signal is acknowledged unconditionally, even when interrupts are in the interrupt disabled (DI) status. An NMI is not subject to priority control and takes precedence over all the other interrupt request signals.

This product has the following two non-maskable interrupt request signals.

- NMI pin input (NMI)
- Non-maskable interrupt request signal generated by overflow of watchdog timer (INTWDT2)

The valid edge of the NMI pin can be selected from four types: "rising edge", "falling edge", "both edges", and "no edge detection".

The non-maskable interrupt request signal generated by overflow of watchdog timer 2 (INTWDT2) functions when the WDTM2.WDM21 and WDTM2.WDM20 bits are set to "01".

If two or more non-maskable interrupt request signals occur at the same time, the interrupt with the higher priority is serviced, as follows (the interrupt request signal with the lower priority is ignored).

INTWDT2 > NMI

If a new NMI or INTWDT2 request signal is issued while an NMI is being serviced, it is serviced as follows.

### (1) If new NMI request signal is issued while NMI is being serviced

The new NMI request signal is held pending, regardless of the value of the PSW.NP bit. The pending NMI request signal is acknowledged after the NMI currently under execution has been serviced (after the RETI instruction has been executed).

### (2) If INTWDT2 request signal is issued while NMI is being serviced

The INTWDT2 request signal is held pending if the NP bit remains set (1) while the NMI is being serviced. The pending INTWDT2 request signal is acknowledged after the NMI currently under execution has been serviced (after the RETI instruction has been executed).

If the NP bit is cleared (0) while the NMI is being serviced, the newly generated INTWDT2 request signal is executed (the NMI servicing is stopped).

**Caution** For the non-maskable interrupt servicing executed by the non-maskable interrupt request signal (INTWDT2), see 19.2.2 (2) From INTWDT2 signal.

Figure 19-1. Non-Maskable Interrupt Request Signal Acknowledgment Operation (1/2)

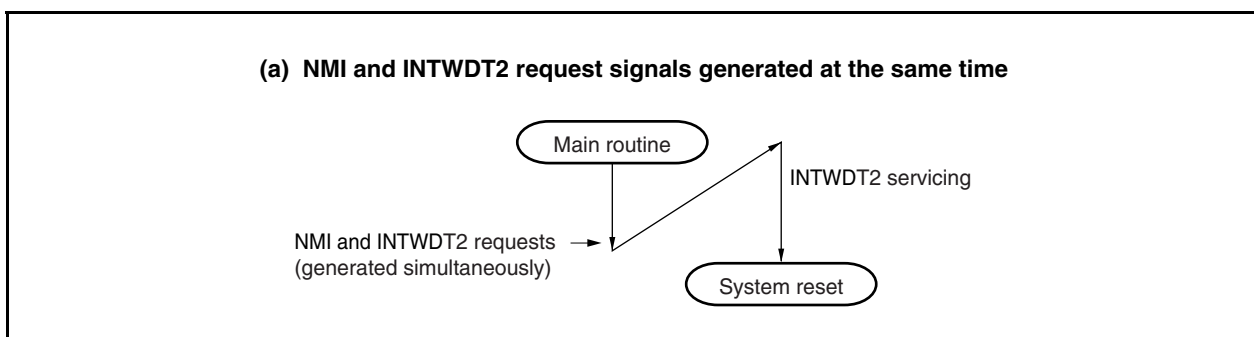
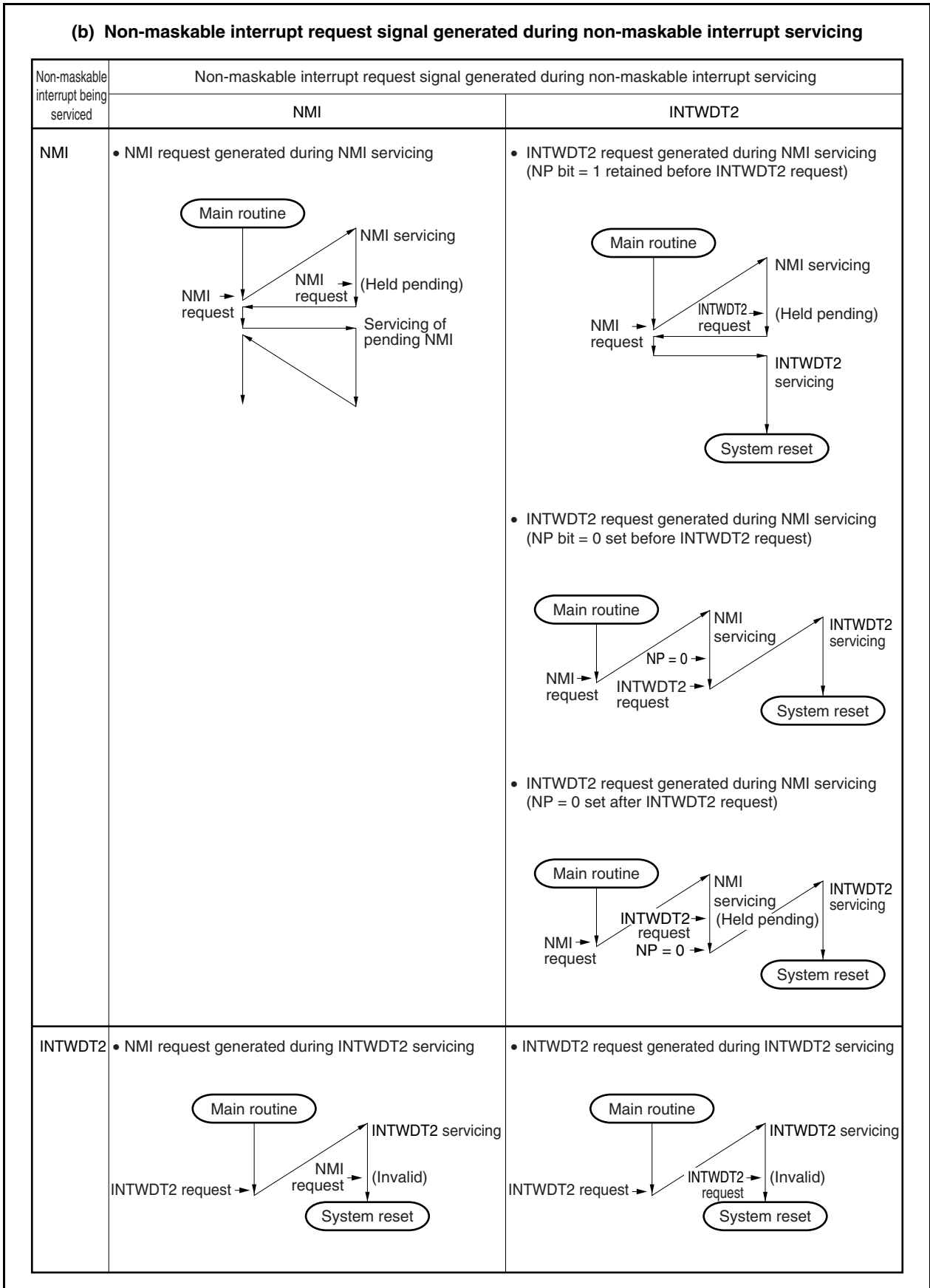


Figure 19-1. Non-Maskable Interrupt Request Signal Acknowledgment Operation (2/2)



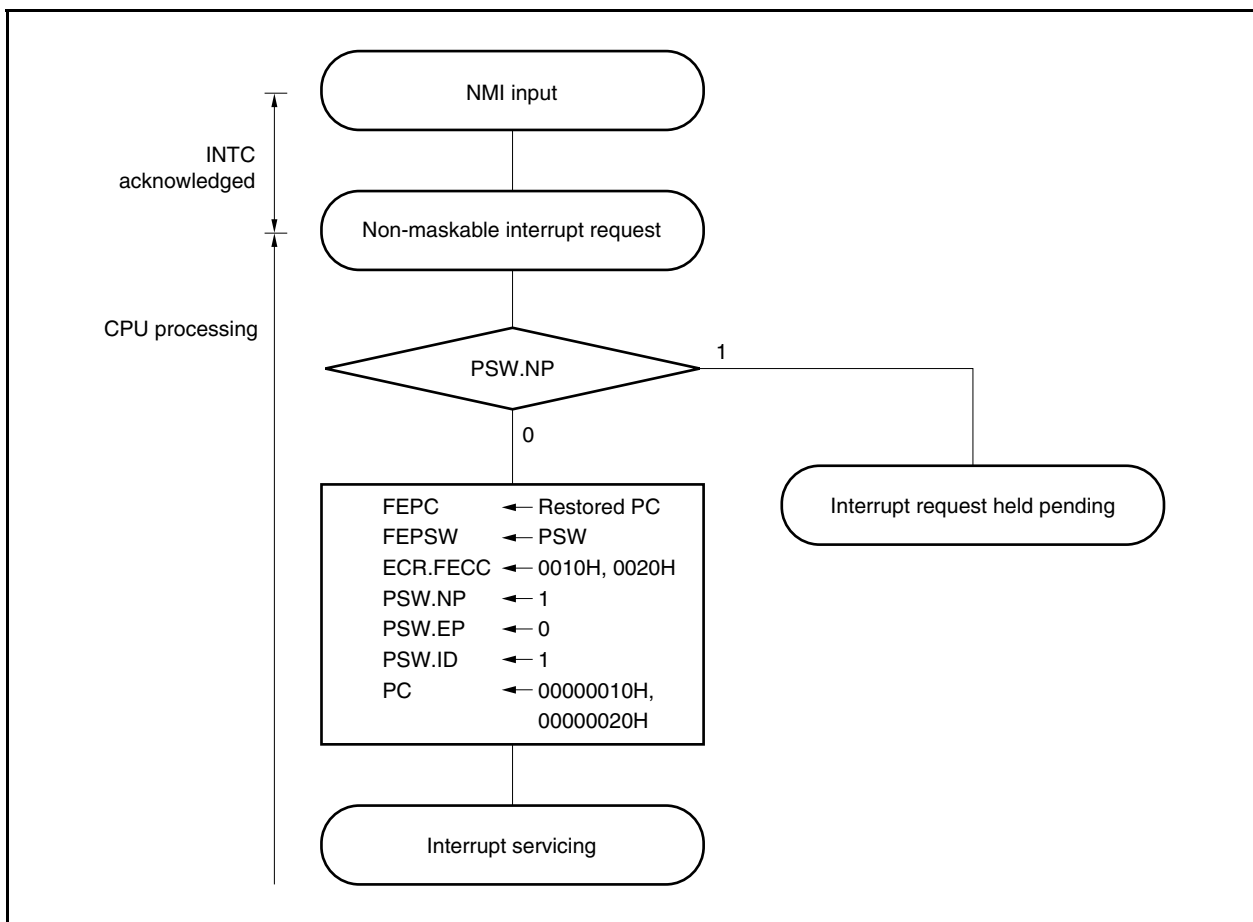
**19.2.1 Operation**

If a non-maskable interrupt request signal is generated, the CPU performs the following processing, and transfers control to the handler routine.

- <1> Saves the restored PC to FEPC.
- <2> Saves the current PSW to FEPSW.
- <3> Writes exception code (0010H, 0020H) to the higher halfword (FECC) of ECR.
- <4> Sets the PSW.NP and PSW.ID bits to 1 and clears the PSW.EP bit to 0.
- <5> Sets the handler address (00000010H, 00000020H) corresponding to the non-maskable interrupt to the PC, and transfers control.

The servicing configuration of a non-maskable interrupt is shown below.

**Figure 19-2. Servicing Configuration of Non-Maskable Interrupt**



## 19.2.2 Restore

## (1) From NMI pin input

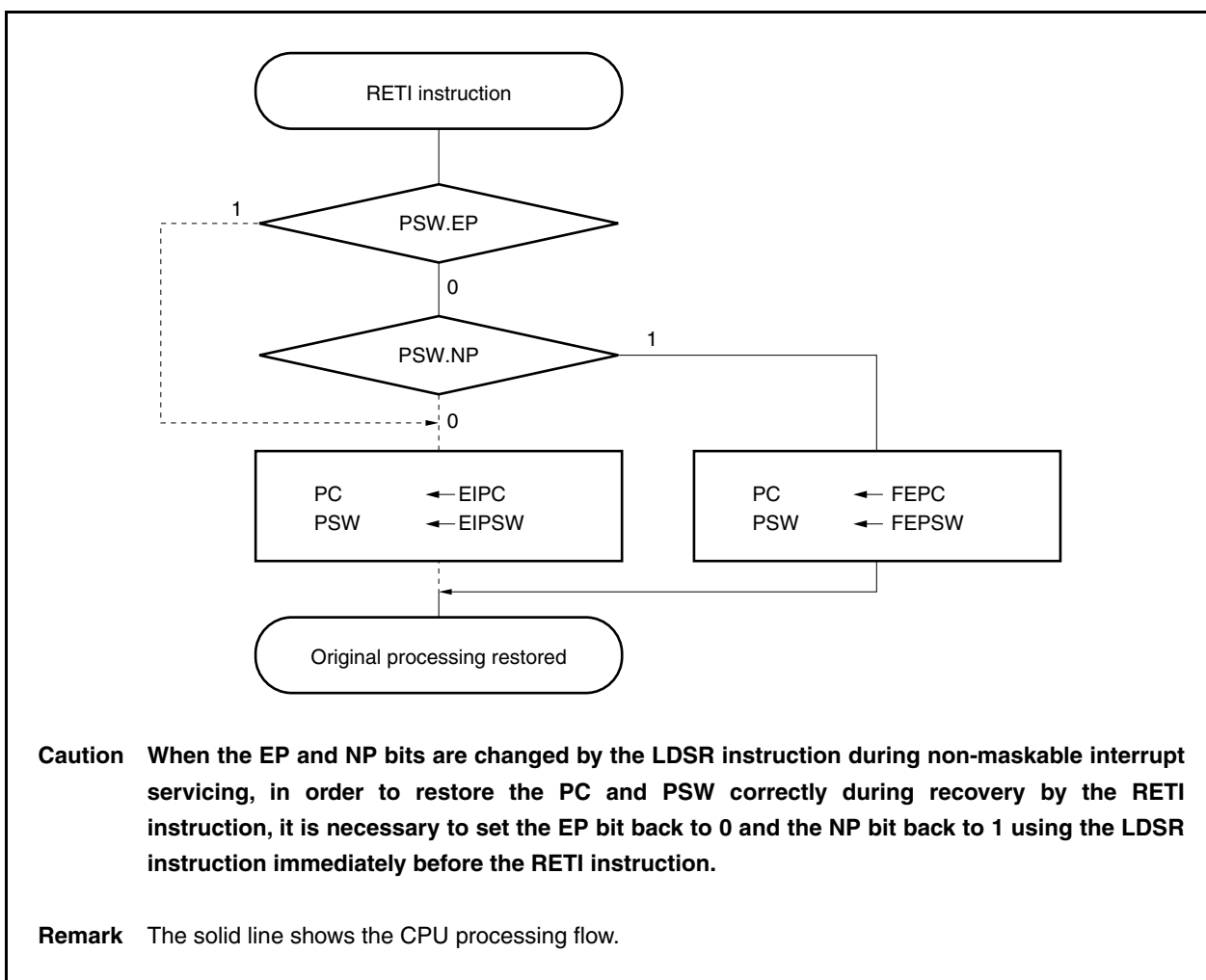
Execution is restored from the NMI servicing by the RETI instruction.

When the RETI instruction is executed, the CPU performs the following processing, and transfers control to the address of the restored PC.

- <1> Loads the restored PC and PSW from FEPC and FEPSW, respectively, because the PSW.EP bit is 0 and the PSW.NP bit is 1.
- <2> Transfers control back to the address of the restored PC and PSW.

The processing of the RETI instruction is shown below.

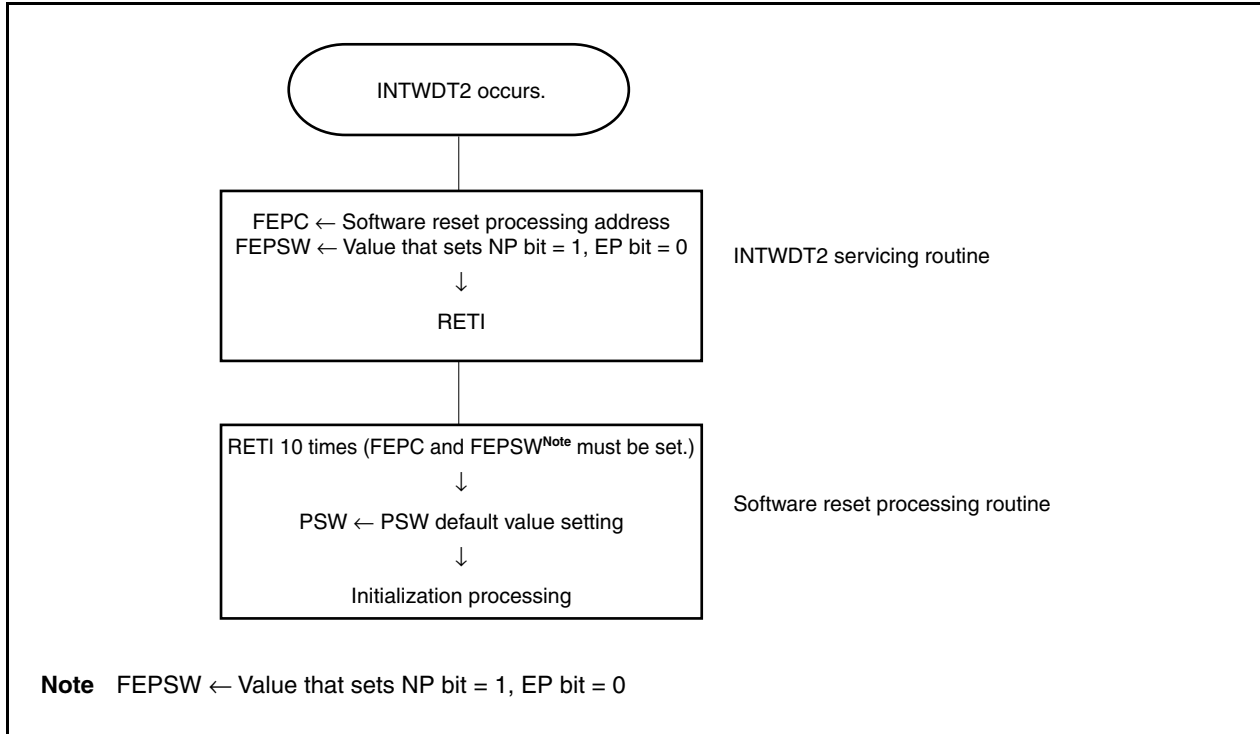
Figure 19-3. RETI Instruction Processing



(2) From INTWDT2 signal

Restoring from non-maskable interrupt servicing executed by the non-maskable interrupt request (INTWDT2) by using the RETI instruction is disabled. Execute the following software reset processing.

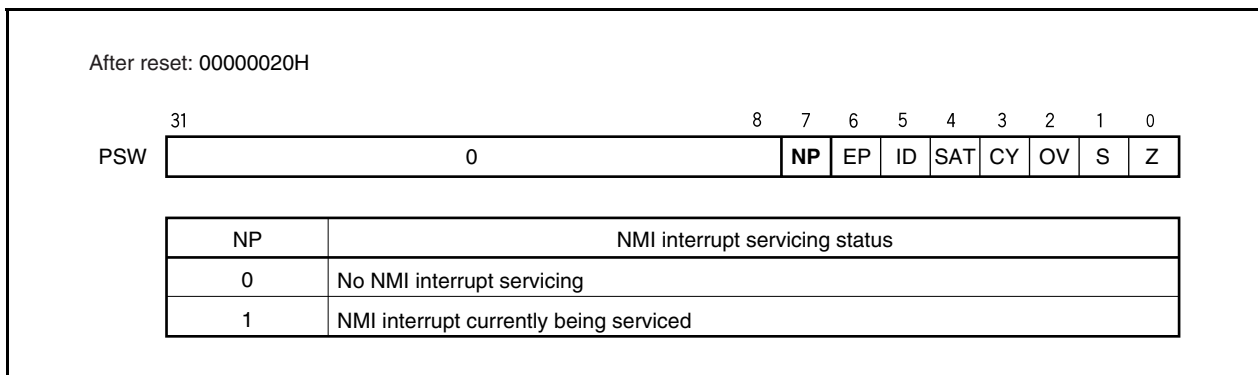
Figure 19-4. Software Reset Processing



19.2.3 NP flag

The NP flag is a status flag that indicates that non-maskable interrupt servicing is under execution.

This flag is set when a non-maskable interrupt request signal has been acknowledged, and masks non-maskable interrupt requests to prohibit multiple interrupts from being acknowledged.



### 19.3 Maskable Interrupts

Maskable interrupt request signals can be masked by interrupt control registers. The V850ES/JJ3 has 69 maskable interrupt sources.

If two or more maskable interrupt request signals are generated at the same time, they are acknowledged according to the default priority. In addition to the default priority, eight levels of priorities can be specified by using the interrupt control registers (programmable priority control).

When an interrupt request signal has been acknowledged, the acknowledgment of other maskable interrupt request signals is disabled and the interrupt disabled (DI) status is set.

When the EI instruction is executed in an interrupt service routine, the interrupt enabled (EI) status is set, which enables servicing of interrupts having a higher priority than the interrupt request signal in progress (specified by the interrupt control register). Note that only interrupts with a higher priority will have this capability; interrupts with the same priority level cannot be nested.

To enable multiple interrupts, however, save EIPC and EIPSW to memory or general-purpose registers before executing the EI instruction, and execute the DI instruction before the RETI instruction to restore the original values of EIPC and EIPSW.

#### 19.3.1 Operation

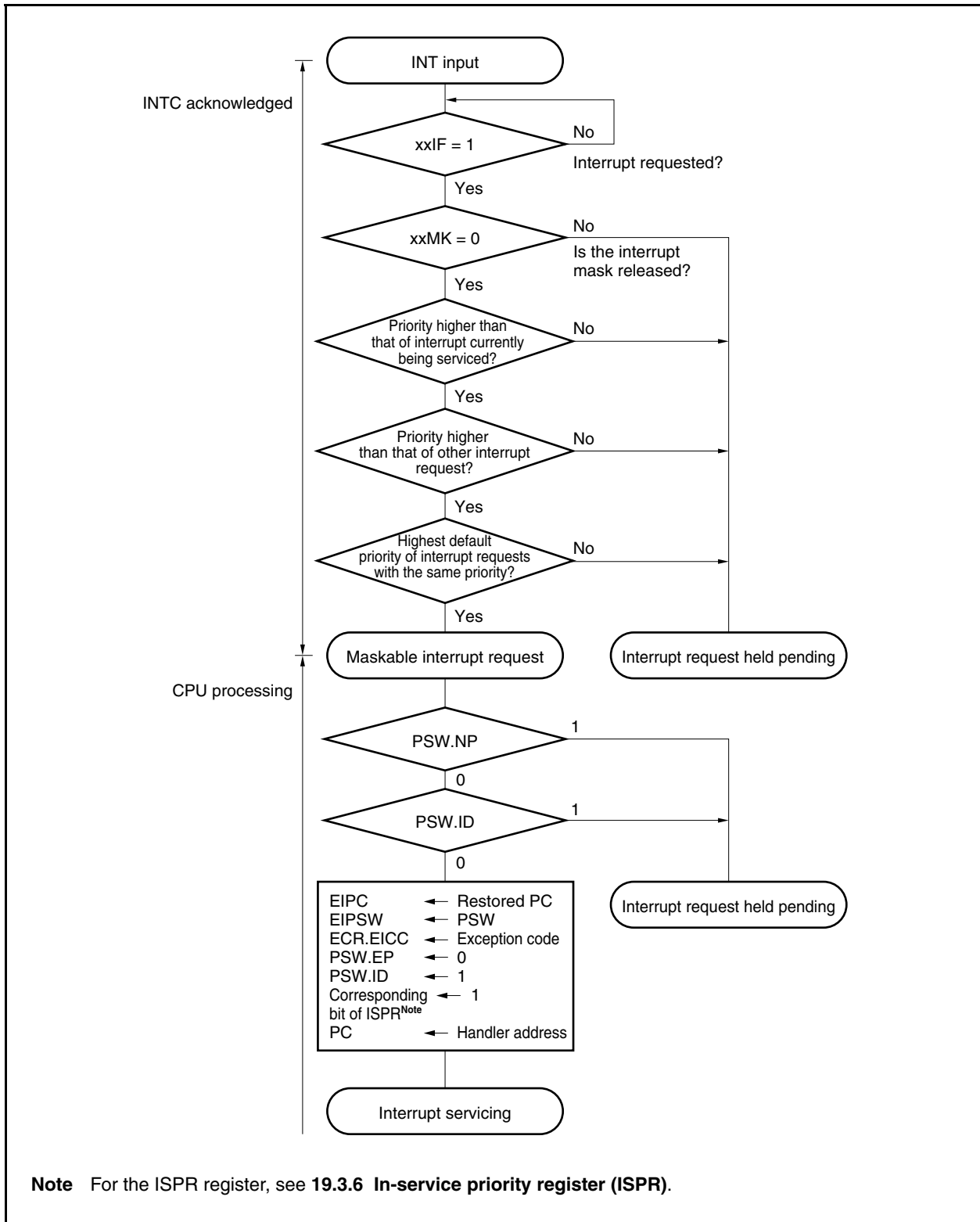
If a maskable interrupt occurs, the CPU performs the following processing, and transfers control to a handler routine.

- <1> Saves the restored PC to EIPC.
- <2> Saves the current PSW to EIPSW.
- <3> Writes an exception code to the lower halfword of ECR (EICC).
- <4> Sets the PSW.ID bit to 1 and clears the PSW.EP bit to 0.
- <5> Sets the handler address corresponding to each interrupt to the PC, and transfers control.

The maskable interrupt request signal masked by INTC and the maskable interrupt request signal generated while another interrupt is being serviced (while the PSW.NP bit = 1 or the PSW.ID bit = 1) are held pending inside INTC. In this case, servicing a new maskable interrupt is started in accordance with the priority of the pending maskable interrupt request signal if either the maskable interrupt is unmasked or the NP and ID bits are cleared to 0 by using the RETI or LDSR instruction.

How maskable interrupts are serviced is illustrated below.

Figure 19-5. Maskable Interrupt Servicing





### 19.3.2 Restore

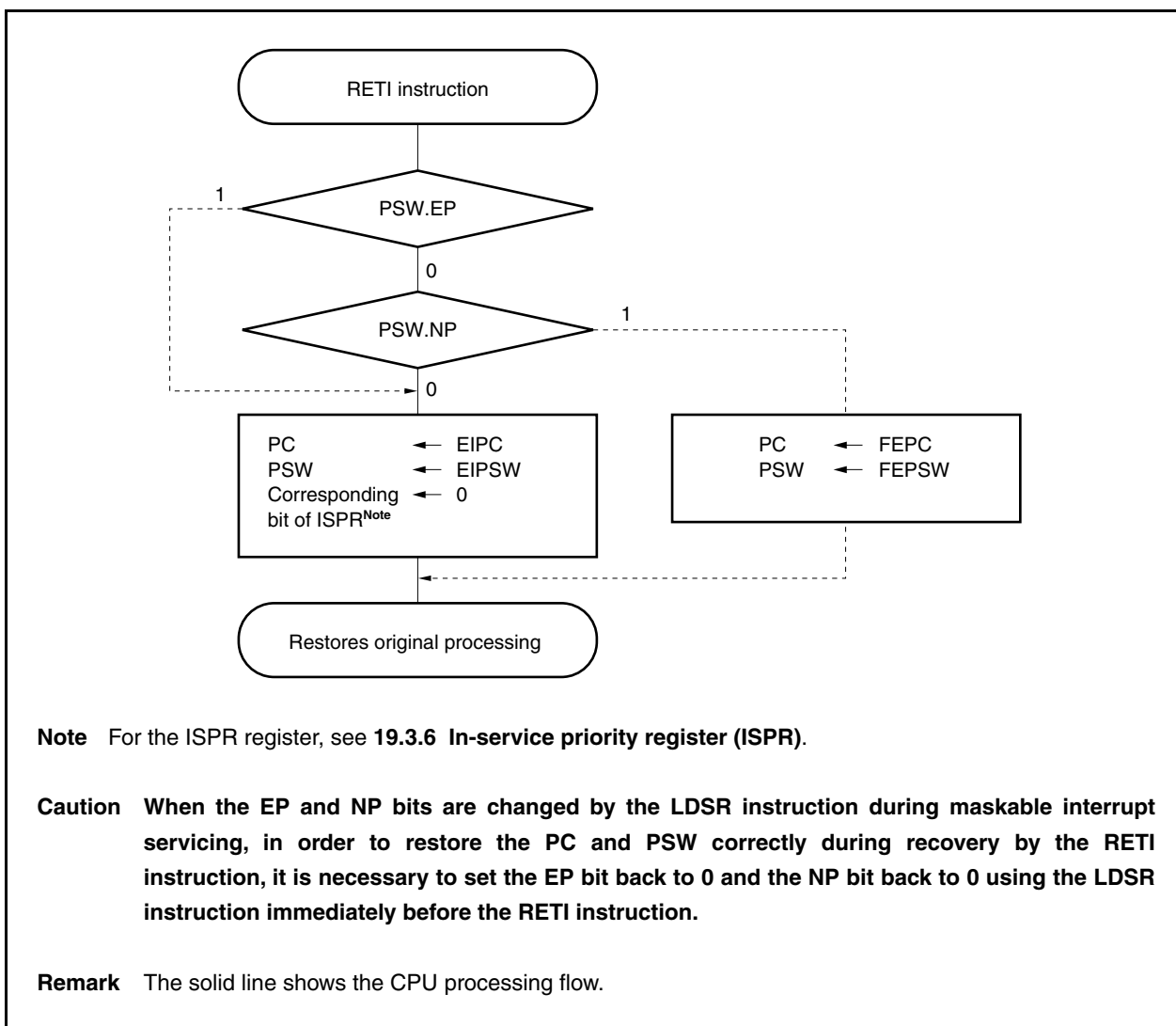
Recovery from maskable interrupt servicing is carried out by the RETI instruction.

When the RETI instruction is executed, the CPU performs the following processing, and transfers control to the address of the restored PC.

- <1> Loads the restored PC and PSW from EIPC and EIPSW, respectively, because the PSW.EP bit is 0 and the PSW.NP bit is 0.
- <2> Transfers control back to the address of the restored PC and PSW.

The processing of the RETI instruction is shown below.

**Figure 19-6. RETI Instruction Processing**



### 19.3.3 Priorities of maskable interrupts

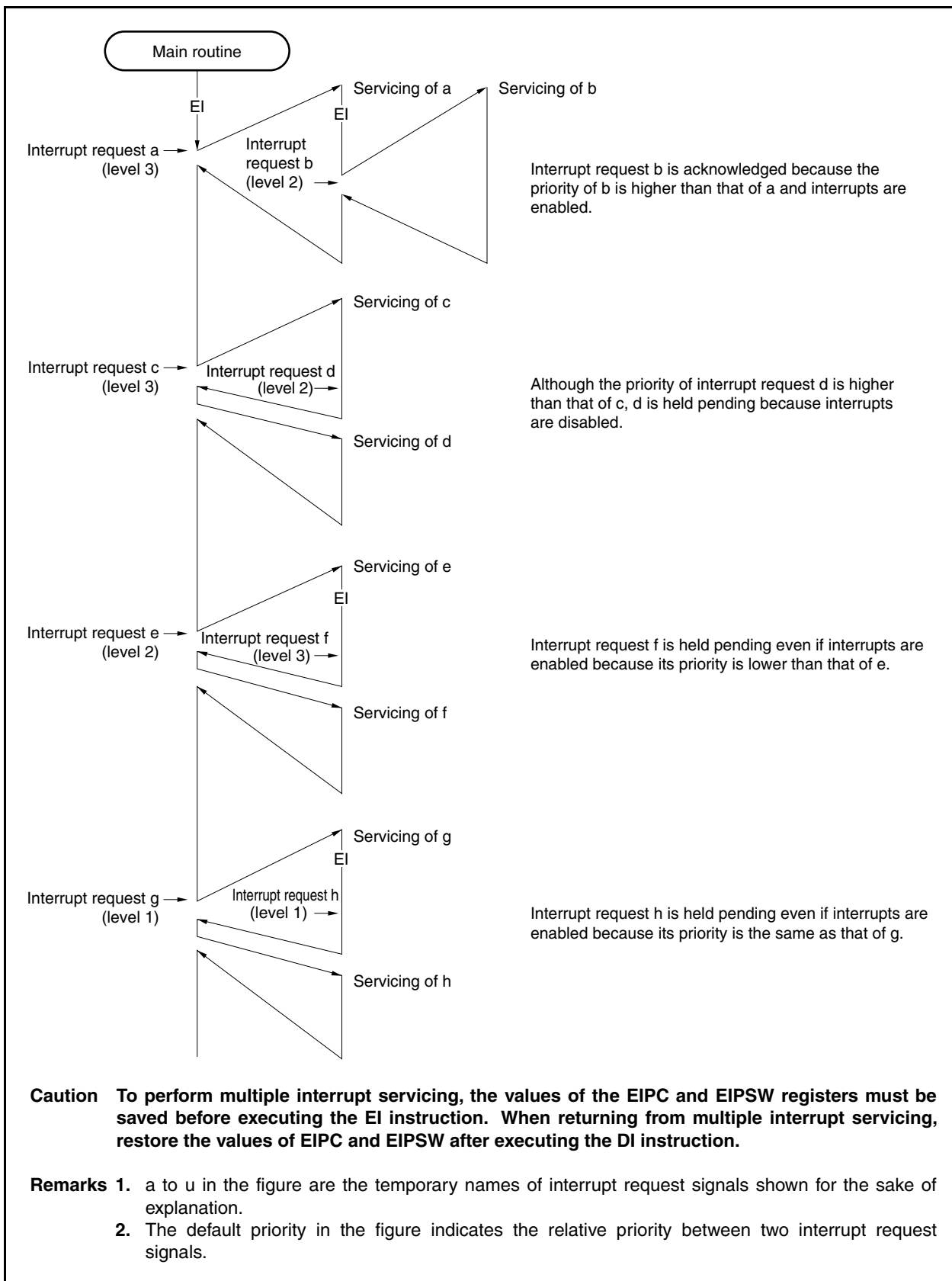
The INTC performs multiple interrupt servicing in which an interrupt is acknowledged while another interrupt is being serviced. Multiple interrupts can be controlled by priority levels.

There are two types of priority level control: control based on the default priority levels, and control based on the programmable priority levels that are specified by the interrupt priority level specification bit (xxPRn) of the interrupt control register (xxICn). When two or more interrupts having the same priority level specified by the xxPRn bit are generated at the same time, interrupt request signals are serviced in order depending on the priority level allocated to each interrupt request type (default priority level) beforehand. For more information, see **Table 19-1 Interrupt Source List**. The programmable priority control customizes interrupt request signals into eight levels by setting the priority level specification flag.

Note that when an interrupt request signal is acknowledged, the PSW.ID flag is automatically set to 1. Therefore, when multiple interrupts are to be used, clear the ID flag to 0 beforehand (for example, by placing the EI instruction in the interrupt service program) to set the interrupt enable mode.

**Remark** xx: Identification name of each peripheral unit (see **Table 19-2 Interrupt Control Register (xxICn)**)  
n: Peripheral unit number (see **Table 19-2 Interrupt Control Register (xxICn)**).

**Figure 19-7. Example of Processing in Which Another Interrupt Request Signal Is Issued While an Interrupt Is Being Serviced (1/2)**



**Figure 19-7. Example of Processing in Which Another Interrupt Request Signal Is Issued While an Interrupt Is Being Serviced (2/2)**

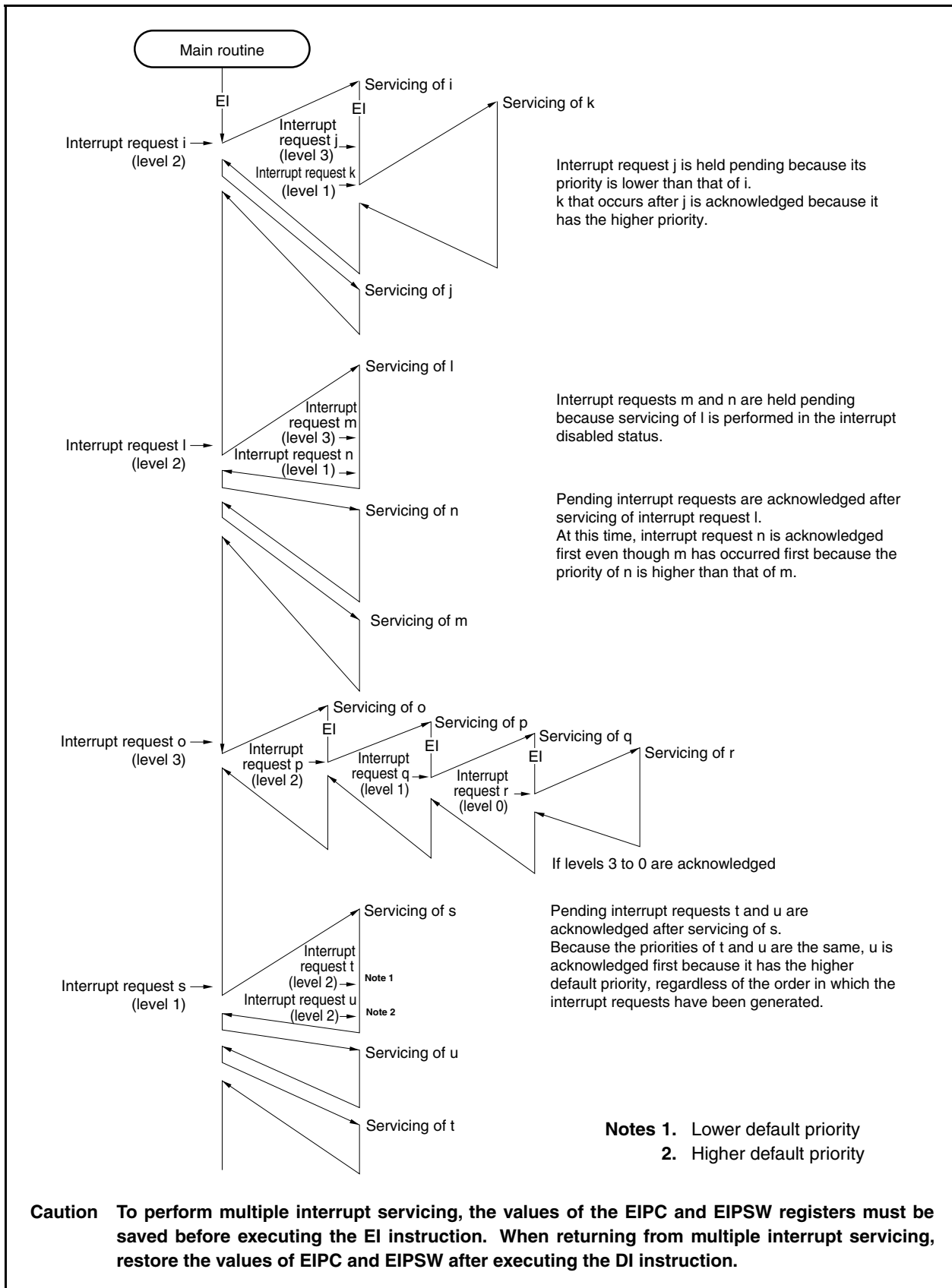
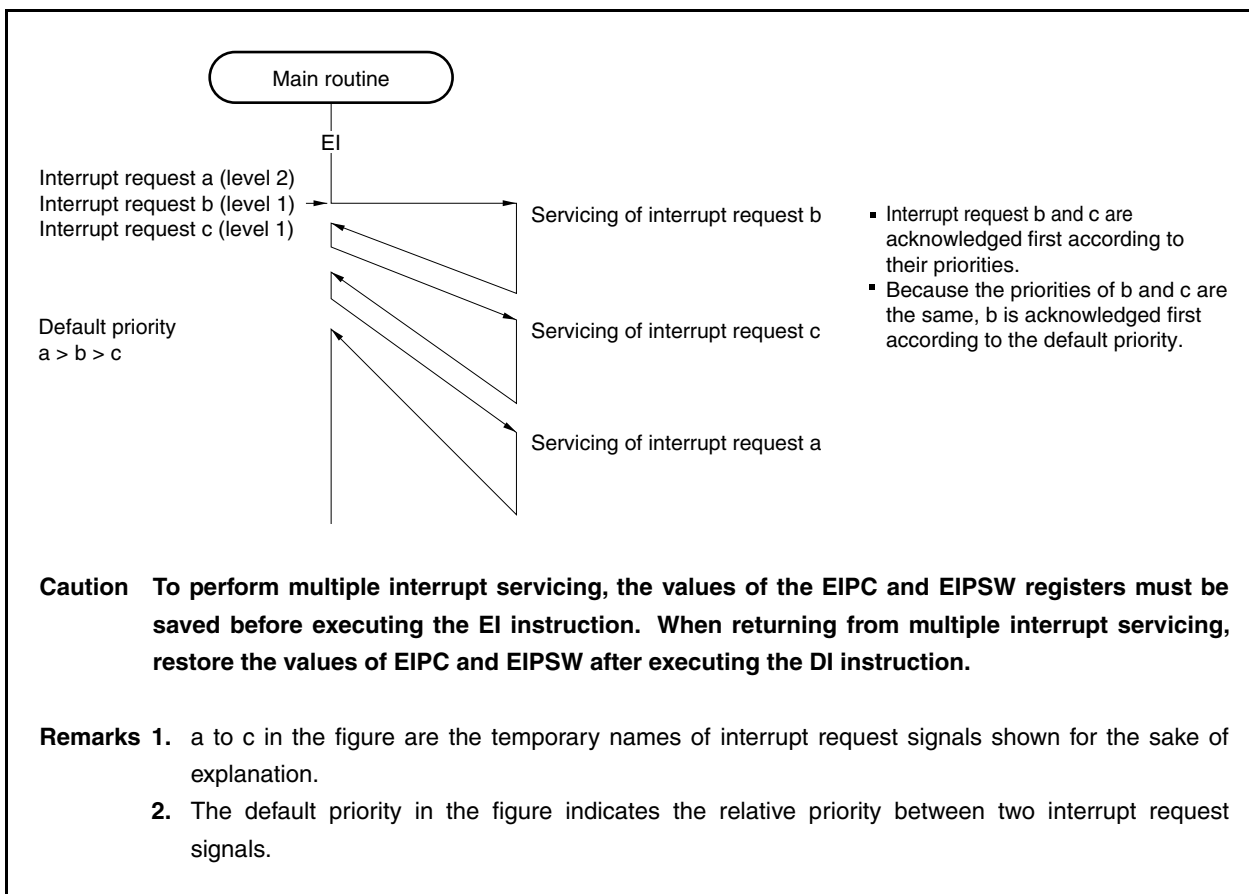


Figure 19-8. Example of Servicing Interrupt Request Signals Simultaneously Generated



**19.3.4 Interrupt control register (xxlCn)**

The xxlCn register is assigned to each interrupt request signal (maskable interrupt) and sets the control conditions for each maskable interrupt request.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 47H.

**Caution** Disable interrupts (DI) or mask the interrupt to read the xxlCn.xxIFn bit. If the xxIFn bit is read while interrupts are enabled (EI) or while the interrupt is unmasked, the correct value may not be read when acknowledging an interrupt and reading the bit conflict.

After reset: 47H    R/W    Address: FFFFF112H to FFFFF1A8H

|       |       |       |   |   |   |        |        |        |
|-------|-------|-------|---|---|---|--------|--------|--------|
| xxlCn | <7>   | <6>   | 5 | 4 | 3 | 2      | 1      | 0      |
|       | xxIFn | xxMKn | 0 | 0 | 0 | xxPRn2 | xxPRn1 | xxPRn0 |

|       |  |
|-------|--|
| xxIFn | Interrupt request flag <sup>Note</sup> |
| 0     | Interrupt request not issued           |
| 1     | Interrupt request issued               |

|       |  |
|-------|--|
| xxMKn | Interrupt mask flag                    |
| 0     | Interrupt servicing enabled            |
| 1     | Interrupt servicing disabled (pending) |

|        |        |        |                                      |
|--------|--------|--------|--------------------------------------|
| xxPRn2 | xxPRn1 | xxPRn0 | Interrupt priority specification bit |
| 0      | 0      | 0      | Specifies level 0 (highest).         |
| 0      | 0      | 1      | Specifies level 1.                   |
| 0      | 1      | 0      | Specifies level 2.                   |
| 0      | 1      | 1      | Specifies level 3.                   |
| 1      | 0      | 0      | Specifies level 4.                   |
| 1      | 0      | 1      | Specifies level 5.                   |
| 1      | 1      | 0      | Specifies level 6.                   |
| 1      | 1      | 1      | Specifies level 7 (lowest).          |

**Note** The flag xxIFn is reset automatically by the hardware if an interrupt request signal is acknowledged.

**Remark** xx: Identification name of each peripheral unit (see **Table 19-2 Interrupt Control Register (xxlCn)**)  
n: Peripheral unit number (see **Table 19-2 Interrupt Control Register (xxlCn)**).

The addresses and bits of the interrupt control registers are as follows.

Table 19-2. Interrupt Control Register (xxICn) (1/2)

| Address   | Register          | Bit               |                   |   |   |   |                     |                     |                     |
|-----------|-------------------|-------------------|-------------------|---|---|---|---------------------|---------------------|---------------------|
|           |                   | <7>               | <6>               | 5 | 4 | 3 | 2                   | 1                   | 0                   |
| FFFFF110H | LVIIIC            | LVIIIF            | LVIMK             | 0 | 0 | 0 | LVIPR2              | LVIPR1              | LVIPR0              |
| FFFFF112H | PIC0              | PIF0              | PMK0              | 0 | 0 | 0 | PPR02               | PPR01               | PPR00               |
| FFFFF114H | PIC1              | PIF1              | PMK1              | 0 | 0 | 0 | PPR12               | PPR11               | PPR10               |
| FFFFF116H | PIC2              | PIF2              | PMK2              | 0 | 0 | 0 | PPR22               | PPR21               | PPR20               |
| FFFFF118H | PIC3              | PIF3              | PMK3              | 0 | 0 | 0 | PPR32               | PPR31               | PPR30               |
| FFFFF11AH | PIC4              | PIF4              | PMK4              | 0 | 0 | 0 | PPR42               | PPR41               | PPR40               |
| FFFFF11CH | PIC5              | PIF5              | PMK5              | 0 | 0 | 0 | PPR52               | PPR51               | PPR50               |
| FFFFF11EH | PIC6              | PIF6              | PMK6              | 0 | 0 | 0 | PPR62               | PPR61               | PPR60               |
| FFFFF120H | PIC7              | PIF7              | PMK7              | 0 | 0 | 0 | PPR72               | PPR71               | PPR70               |
| FFFFF122H | TQ0OVIC           | TQ0OVIF           | TQ0OVMK           | 0 | 0 | 0 | TQ0OVPR2            | TQ0OVPR1            | TQ0OVPR0            |
| FFFFF124H | TQ0CCIC0          | TQ0CCIF0          | TQ0CCMK0          | 0 | 0 | 0 | TQ0CCPR02           | TQ0CCPR01           | TQ0CCPR00           |
| FFFFF126H | TQ0CCIC1          | TQ0CCIF1          | TQ0CCMK1          | 0 | 0 | 0 | TQ0CCPR12           | TQ0CCPR11           | TQ0CCPR10           |
| FFFFF128H | TQ0CCIC2          | TQ0CCIF2          | TQ0CCMK2          | 0 | 0 | 0 | TQ0CCPR22           | TQ0CCPR21           | TQ0CCPR20           |
| FFFFF12AH | TQ0CCIC3          | TQ0CCIF3          | TQ0CCMK3          | 0 | 0 | 0 | TQ0CCPR32           | TQ0CCPR31           | TQ0CCPR30           |
| FFFFF12CH | TP0OVIC           | TP0OVIF           | TP0OVMK           | 0 | 0 | 0 | TP0OVPR2            | TP0OVPR1            | TP0OVPR0            |
| FFFFF12EH | TP0CCIC0          | TP0CCIF0          | TP0CCMK0          | 0 | 0 | 0 | TP0CCPR02           | TP0CCPR01           | TP0CCPR00           |
| FFFFF130H | TP0CCIC1          | TP0CCIF1          | TP0CCMK1          | 0 | 0 | 0 | TP0CCPR12           | TP0CCPR11           | TP0CCPR10           |
| FFFFF132H | TP1OVIC           | TP1OVIF           | TP1OVMK           | 0 | 0 | 0 | TP1OVPR2            | TP1OVPR1            | TP1OVPR0            |
| FFFFF134H | TP1CCIC0          | TP1CCIF0          | TP1CCMK0          | 0 | 0 | 0 | TP1CCPR02           | TP1CCPR01           | TP1CCPR00           |
| FFFFF136H | TP1CCIC1          | TP1CCIF1          | TP1CCMK1          | 0 | 0 | 0 | TP1CCPR12           | TP1CCPR11           | TP1CCPR10           |
| FFFFF138H | TP2OVIC           | TP2OVIF           | TP2OVMK           | 0 | 0 | 0 | TP2OVPR2            | TP2OVPR1            | TP2OVPR0            |
| FFFFF13AH | TP2CCIC0          | TP2CCIF0          | TP2CCMK0          | 0 | 0 | 0 | TP2CCPR02           | TP2CCPR01           | TP2CCPR00           |
| FFFFF13CH | TP2CCIC1          | TP2CCIF1          | TP2CCMK1          | 0 | 0 | 0 | TP2CCPR12           | TP2CCPR11           | TP2CCPR10           |
| FFFFF13EH | TP3OVIC           | TP3OVIF           | TP3OVMK           | 0 | 0 | 0 | TP3OVPR2            | TP3OVPR1            | TP3OVPR0            |
| FFFFF140H | TP3CCIC0          | TP3CCIF0          | TP3CCMK0          | 0 | 0 | 0 | TP3CCPR02           | TP3CCPR01           | TP3CCPR00           |
| FFFFF142H | TP3CCIC1          | TP3CCIF1          | TP3CCMK1          | 0 | 0 | 0 | TP3CCPR12           | TP3CCPR11           | TP3CCPR10           |
| FFFFF144H | TP4OVIC           | TP4OVIF           | TP4OVMK           | 0 | 0 | 0 | TP4OVPR2            | TP4OVPR1            | TP4OVPR0            |
| FFFFF146H | TP4CCIC0          | TP4CCIF0          | TP4CCMK0          | 0 | 0 | 0 | TP4CCPR02           | TP4CCPR01           | TP4CCPR00           |
| FFFFF148H | TP4CCIC1          | TP4CCIF1          | TP4CCMK1          | 0 | 0 | 0 | TP4CCPR12           | TP4CCPR11           | TP4CCPR10           |
| FFFFF14AH | TP5OVIC           | TP5OVIF           | TP5OVMK           | 0 | 0 | 0 | TP5OVPR2            | TP5OVPR1            | TP5OVPR0            |
| FFFFF14CH | TP5CCIC0          | TP5CCIF0          | TP5CCMK0          | 0 | 0 | 0 | TP5CCPR02           | TP5CCPR01           | TP5CCPR00           |
| FFFFF14EH | TP5CCIC1          | TP5CCIF1          | TP5CCMK1          | 0 | 0 | 0 | TP5CCPR12           | TP5CCPR11           | TP5CCPR10           |
| FFFFF150H | TM0EQIC0          | TM0EQIF0          | TM0EQMK0          | 0 | 0 | 0 | TM0EQPR02           | TM0EQPR01           | TM0EQPR00           |
| FFFFF152H | CB0RIC/<br>IICIC1 | CB0RIF/<br>IICIF1 | CB0RMK/<br>IICMK1 | 0 | 0 | 0 | CB0RPR2/<br>IICPR12 | CB0RPR1/<br>IICPR11 | CB0RPR0/<br>IICPR10 |
| FFFFF154H | CB0TIC            | CB0TIF            | CB0TMK            | 0 | 0 | 0 | CB0TPR2             | CB0TPR1             | CB0TPR0             |
| FFFFF156H | CB1RIC            | CB1RIF            | CB1RMK            | 0 | 0 | 0 | CB1RPR2             | CB1RPR1             | CB1RPR0             |
| FFFFF158H | CB1TIC            | CB1TIF            | CB1TMK            | 0 | 0 | 0 | CB1TPR2             | CB1TPR1             | CB1TPR0             |
| FFFFF15AH | CB2RIC            | CB2RIF            | CB2RMK            | 0 | 0 | 0 | CB2RPR2             | CB2RPR1             | CB2RPR0             |
| FFFFF15CH | CB2TIC            | CB2TIF            | CB2TMK            | 0 | 0 | 0 | CB2TPR2             | CB2TPR1             | CB2TPR0             |
| FFFFF15EH | CB3RIC            | CB3RIF            | CB3RMK            | 0 | 0 | 0 | CB3RPR2             | CB3RPR1             | CB3RPR0             |
| FFFFF160H | CB3TIC            | CB3TIF            | CB3TMK            | 0 | 0 | 0 | CB3TPR2             | CB3TPR1             | CB3TPR0             |

Table 19-2. Interrupt Control Register (xxICn) (2/2)

| Address   | Register          | Bit               |                   |   |   |   |                     |                     |                     |
|-----------|-------------------|-------------------|-------------------|---|---|---|---------------------|---------------------|---------------------|
|           |                   | <7>               | <6>               | 5 | 4 | 3 | 2                   | 1                   | 0                   |
| FFFFF162H | UA0RIC/<br>CB4RIC | UA0RIF/<br>CB4RIF | UA0RMK/<br>CB4RMK | 0 | 0 | 0 | UA0RPR2/<br>CB4RPR2 | UA0RPR1/<br>CB4RPR1 | UA0RPR0/<br>CB4RPR0 |
| FFFFF164H | UA0TIC/<br>CB4TIC | UA0TIF/<br>CB4TIF | UA0TMK/<br>CB4TMK | 0 | 0 | 0 | UA0TPR2/<br>CB4TPR2 | UA0TPR1/<br>CB4TPR1 | UA0TPR0/<br>CB4TPR0 |
| FFFFF166H | UA1RIC/<br>IICIC2 | UA1RIF/<br>IICIF2 | UA1RMK/<br>IICMK2 | 0 | 0 | 0 | UA1RPR2/<br>IICPR22 | UA1RPR1/<br>IICPR21 | UA1RPR0/<br>IICPR20 |
| FFFFF168H | UA1TIC            | UA1TIF            | UA1TMK            | 0 | 0 | 0 | UA1TPR2             | UA1TPR1             | UA1TPR0             |
| FFFFF16AH | UA2RIC/<br>IICIC0 | UA2RIF/<br>IICIF0 | UA2RMK/<br>IICMK0 | 0 | 0 | 0 | UA2RPR2/<br>IICPR02 | UA2RPR1/<br>IICPR01 | UA2RPR0/<br>IICPR00 |
| FFFFF16CH | UA2TIC            | UA2TIF            | UA2TMK            | 0 | 0 | 0 | UA2TPR2             | UA2TPR1             | UA2TPR0             |
| FFFFF16EH | ADIC              | ADIF              | ADMK              | 0 | 0 | 0 | ADPR2               | ADPR1               | ADPR0               |
| FFFFF170H | DMAIC0            | DMAIF0            | DMAMK0            | 0 | 0 | 0 | DMAPR02             | DMAPR01             | DMAPR00             |
| FFFFF172H | DMAIC1            | DMAIF1            | DMAMK1            | 0 | 0 | 0 | DMAPR12             | DMAPR11             | DMAPR10             |
| FFFFF174H | DMAIC2            | DMAIF2            | DMAMK2            | 0 | 0 | 0 | DMAPR22             | DMAPR21             | DMAPR20             |
| FFFFF176H | DMAIC3            | DMAIF3            | DMAMK3            | 0 | 0 | 0 | DMAPR32             | DMAPR31             | DMAPR30             |
| FFFFF178H | KRIC              | KRIF              | KRMK              | 0 | 0 | 0 | KRPR2               | KRPR1               | KRPR0               |
| FFFFF17AH | WTIIC             | WTIIF             | WTIMK             | 0 | 0 | 0 | WTIPR2              | WTIPR1              | WTIPR0              |
| FFFFF17CH | WTIC              | WTIF              | WTMK              | 0 | 0 | 0 | WTPR2               | WTPR1               | WTPR0               |
| FFFFF18EH | PIC8              | PIF8              | PMK8              | 0 | 0 | 0 | PPR82               | PPR81               | PPR80               |
| FFFFF190H | TP6OVIC           | TP6OVIF           | TP6OVMK           | 0 | 0 | 0 | TP6OVPR2            | TP6OVPR1            | TP6OVPR0            |
| FFFFF192H | TP6CCIC0          | TP6CCIF0          | TP6CCMK0          | 0 | 0 | 0 | TP6CCPR02           | TP6CCPR01           | TP6CCPR00           |
| FFFFF194H | TP6CCIC1          | TP6CCIF1          | TP6CCMK1          | 0 | 0 | 0 | TP6CCPR12           | TP6CCPR11           | TP6CCPR10           |
| FFFFF196H | TP7OVIC           | TP7OVIF           | TP7OVMK           | 0 | 0 | 0 | TP7OVPR2            | TP7OVPR1            | TP7OVPR0            |
| FFFFF198H | TP7CCIC0          | TP7CCIF0          | TP7CCMK0          | 0 | 0 | 0 | TP7CCPR02           | TP7CCPR01           | TP7CCPR00           |
| FFFFF19AH | TP7CCIC1          | TP7CCIF1          | TP7CCMK1          | 0 | 0 | 0 | TP7CCPR12           | TP7CCPR11           | TP7CCPR10           |
| FFFFF19CH | TP8OVIC           | TP8OVIF           | TP8OVMK           | 0 | 0 | 0 | TP8OVPR2            | TP8OVPR1            | TP8OVPR0            |
| FFFFF19EH | TP8CCIC0          | TP8CCIF0          | TP8CCMK0          | 0 | 0 | 0 | TP8CCPR02           | TP8CCPR01           | TP8CCPR00           |
| FFFFF1A0H | TP8CCIC1          | TP8CCIF1          | TP8CCMK1          | 0 | 0 | 0 | TP8CCPR12           | TP8CCPR11           | TP8CCPR10           |
| FFFFF1A2H | CB5RIC            | CB5RIF            | CB5RMK            | 0 | 0 | 0 | CB5RPR2             | CB5RPR1             | CB5RPR0             |
| FFFFF1A4H | CB5TIC            | CB5TIF            | CB5TMK            | 0 | 0 | 0 | CB5TPR2             | CB5TPR1             | CB5TPR0             |
| FFFFF1A6H | UA3RIC            | UA3RIF            | UA3RMK            | 0 | 0 | 0 | UA3RPR2             | UA3RPR1             | UA3RPR0             |
| FFFFF1A8H | UA3TIC            | UA3TIF            | UA3TMK            | 0 | 0 | 0 | UA3TPR2             | UA3TPR1             | UA3TPR0             |

### 19.3.5 Interrupt mask registers 0 to 4 (IMR0 to IMR4)

The IMR0 to IMR4 registers set the interrupt mask state for the maskable interrupts. The xxMKn bit of the IMR0 to IMR4 registers is equivalent to the xxICn.xxMKn bit.

The IMRm register can be read or written in 16-bit units (m = 0 to 4).

If the higher 8 bits of the IMRm register are used as an IMRmH register and the lower 8 bits as an IMRmL register, these registers can be read or written in 8-bit or 1-bit units (m = 0 to 4).

Reset sets these registers to FFFFH.

**Caution** The device file defines the xxICn.xxMKn bit as a reserved word. If a bit is manipulated using the name of xxMKn, the contents of the xxICn register, instead of the IMRm register, are rewritten (as a result, the contents of the IMRm register are also rewritten).



After reset: FFFFH R/W Address: IMR4 FFFFF108H,  
IMR4L FFFFF108H, IMR4H FFFFF109H

|                               |          |         |          |          |         |          |          |          |
|-------------------------------|----------|---------|----------|----------|---------|----------|----------|----------|
|                               | 15       | 14      | 13       | 12       | 11      | 10       | 9        | 8        |
| IMR4 (IMR4H <sup>Note</sup> ) | 1        | 1       | 1        | UA3TMK   | UA3RMK  | CB5TMK   | CB5RMK   | TP8CCMK1 |
|                               | 7        | 6       | 5        | 4        | 3       | 2        | 1        | 0        |
| IMR4L                         | TP8CCMK0 | TP8OVMK | TP7CCMK1 | TP7CCMK0 | TP7OVMK | TP6CCMK1 | TP6CCMK0 | TP6OVMK  |

After reset: FFFFH R/W Address: IMR3 FFFFF106H,  
IMR3L FFFFF106H, IMR3H FFFFF107H

|                               |      |      |       |      |        |        |        |        |
|-------------------------------|------|------|-------|------|--------|--------|--------|--------|
|                               | 15   | 14   | 13    | 12   | 11     | 10     | 9      | 8      |
| IMR3 (IMR3H <sup>Note</sup> ) | PMK8 | 1    | 1     | 1    | 1      | 1      | 1      | 1      |
|                               | 7    | 6    | 5     | 4    | 3      | 2      | 1      | 0      |
| IMR3L                         | 1    | WTMK | WTIMK | KRMK | DMAMK3 | DMAMK2 | DMAMK1 | DMAMK0 |

After reset: FFFFH R/W Address: IMR2 FFFFF104H,  
IMR2L FFFFF104H, IMR2H FFFFF105H

|                               |        |        |                   |        |                   |                   |                   |          |
|-------------------------------|--------|--------|-------------------|--------|-------------------|-------------------|-------------------|----------|
|                               | 15     | 14     | 13                | 12     | 11                | 10                | 9                 | 8        |
| IMR2 (IMR2H <sup>Note</sup> ) | ADMK   | UA2TMK | UA2RMK/<br>IICMK0 | UA1TMK | UA1RMK/<br>IIC2MK | UA0TMK/<br>CB4TMK | UA0RMK/<br>CB4RMK | CB3TMK   |
|                               | 7      | 6      | 5                 | 4      | 3                 | 2                 | 1                 | 0        |
| IMR2L                         | CB3RMK | CB2TMK | CB2RMK            | CB1TMK | CB1RMK            | CB0TMK            | CB0RMK/<br>IICMK1 | TM0EQMK0 |

After reset: FFFFH R/W Address: IMR1 FFFFF102H,  
IMR1L FFFFF102H, IMR1H FFFFF103H

|                               |          |          |          |          |          |          |          |          |
|-------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|
|                               | 15       | 14       | 13       | 12       | 11       | 10       | 9        | 8        |
| IMR1 (IMR1H <sup>Note</sup> ) | TP5CCMK1 | TP5CCMK0 | TP5OVMK  | TP4CCMK1 | TP4CCMK0 | TP4OVMK  | TP3CCMK1 | TP3CCMK0 |
|                               | 7        | 6        | 5        | 4        | 3        | 2        | 1        | 0        |
| IMR1L                         | TP3OVMK  | TP2CCMK1 | TP2CCMK0 | TP2OVMK  | TP1CCMK1 | TP1CCMK0 | TP1OVMK  | TP0CCMK1 |

After reset: FFFFH R/W Address: IMR0 FFFFF100H,  
IMR0L FFFFF100H, IMR0H FFFFF101H

|                               |          |         |          |          |          |          |         |       |
|-------------------------------|----------|---------|----------|----------|----------|----------|---------|-------|
|                               | 15       | 14      | 13       | 12       | 11       | 10       | 9       | 8     |
| IMR0 (IMR0H <sup>Note</sup> ) | TP0CCMK0 | TP0OVMK | TQ0CCMK3 | TQ0CCMK2 | TQ0CCMK1 | TQ0CCMK0 | TQ0OVMK | PMK7  |
|                               | 7        | 6       | 5        | 4        | 3        | 2        | 1       | 0     |
| IMR0L                         | PMK6     | PMK5    | PMK4     | PMK3     | PMK2     | PMK1     | PMK0    | LVIMK |

|       |                                |
|-------|--------------------------------|
| xxMKn | Setting of interrupt mask flag |
| 0     | Interrupt servicing enabled    |
| 1     | Interrupt servicing disabled   |

**Note** To read bits 8 to 15 of the IMR0 to IMR4 registers in 8-bit or 1-bit units, specify them as bits 0 to 7 of IMR0H to IMR4H registers.

**Caution** Set bits 13 to 15 of the IMR4 register and bits 7 to 14 of the IMR3 register to 1. If the setting of these bits is changed, the operation is not guaranteed.

**Remark** xx: Identification name of each peripheral unit (see Table 19-2 Interrupt Control Register (xxICn)).

n: Peripheral unit number (see Table 19-2 Interrupt Control Register (xxICn))

### 19.3.6 In-service priority register (ISPR)

The ISPR register holds the priority level of the maskable interrupt currently acknowledged. When an interrupt request signal is acknowledged, the bit of this register corresponding to the priority level of that interrupt request signal is set to 1 and remains set while the interrupt is serviced.

When the RETI instruction is executed, the bit corresponding to the interrupt request signal having the highest priority is automatically reset to 0 by hardware. However, it is not reset to 0 when execution is returned from non-maskable interrupt servicing or exception processing.

This register is read-only, in 8-bit or 1-bit units.

Reset sets this register to 00H.

**Caution** If an interrupt is acknowledged while the ISPR register is being read in the interrupt enabled (EI) status, the value of the ISPR register after the bits of the register have been set by acknowledging the interrupt may be read. To accurately read the value of the ISPR register before an interrupt is acknowledged, read the register while interrupts are disabled (DI).

|                  |   |       |                    |       |       |       |       |       |
|------------------|---|-------|--------------------|-------|-------|-------|-------|-------|
| After reset: 00H |   | R     | Address: FFFFF1FAH |       |       |       |       |       |
|                  | <7>   | <6>   | <5>                | <4>   | <3>   | <2>   | <1>   | <0>   |
| ISPR             | ISPR7   | ISPR6 | ISPR5              | ISPR4 | ISPR3 | ISPR2 | ISPR1 | ISPR0 |
| ISPRn            | Priority of interrupt currently acknowledged              |       |                    |       |       |       |       |       |
| 0                | Interrupt request signal with priority n not acknowledged |       |                    |       |       |       |       |       |
| 1                | Interrupt request signal with priority n acknowledged     |       |                    |       |       |       |       |       |

**Remark** n = 0 to 7 (priority level)

### 19.3.7 ID flag

This flag controls the maskable interrupt's operating state, and stores control information regarding enabling or disabling of interrupt request signals. An interrupt disable flag (ID) is assigned to the PSW.

Reset sets this flag to 00000020H.

After reset: 00000020H

|     |    |  |   |   |    |    |           |     |    |    |   |   |
|-----|----|--|---|---|----|----|-----------|-----|----|----|---|---|
|     | 31 |  | 8 | 7 | 6  | 5  | 4         | 3   | 2  | 1  | 0 |   |
| PSW | 0  |  |   |   | NP | EP | <b>ID</b> | SAT | CY | OV | S | Z |

| ID | Specification of maskable interrupt servicing <sup>Note</sup>       |
|----|---|
| 0  | Maskable interrupt request signal acknowledgment enabled            |
| 1  | Maskable interrupt request signal acknowledgment disabled (pending) |

**Note** Interrupt disable flag (ID) function  
 This bit is set to 1 by the DI instruction and cleared to 0 by the EI instruction. Its value is also modified by the RETI instruction or LDSR instruction when referencing the PSW.  
 Non-maskable interrupt request signals and exceptions are acknowledged regardless of this flag. When a maskable interrupt request signal is acknowledged, the ID flag is automatically set to 1 by hardware.  
 The interrupt request signal generated during the acknowledgment disabled period (ID flag = 1) is acknowledged when the xxICn.xxIFn bit is set to 1, and the ID flag is cleared to 0.

### 19.3.8 Watchdog timer mode register 2 (WDTM2)

This register can be read or written in 8-bit units (for details, see **CHAPTER 11 FUNCTIONS OF WATCHDOG TIMER 2**).

Reset sets this register to 67H.

After reset: 67H    R/W    Address: FFFFF6D0H

|       |   |       |       |   |   |   |   |   |
|-------|---|-------|-------|---|---|---|---|---|
|       | 7 | 6     | 5     | 4 | 3 | 2 | 1 | 0 |
| WDTM2 | 0 | WDM21 | WDM20 | 0 | 0 | 0 | 0 | 0 |

| WDM21 | WDM20 | Selection of watchdog timer operation mode |
|-------|-------|--|
| 0     | 0     | Stops operation                            |
| 0     | 1     | Non-maskable interrupt request mode        |
| 1     | ×     | Reset mode (initial-value)                 |

## 19.4 Software Exception

A software exception is generated when the CPU executes the TRAP instruction, and can always be acknowledged.

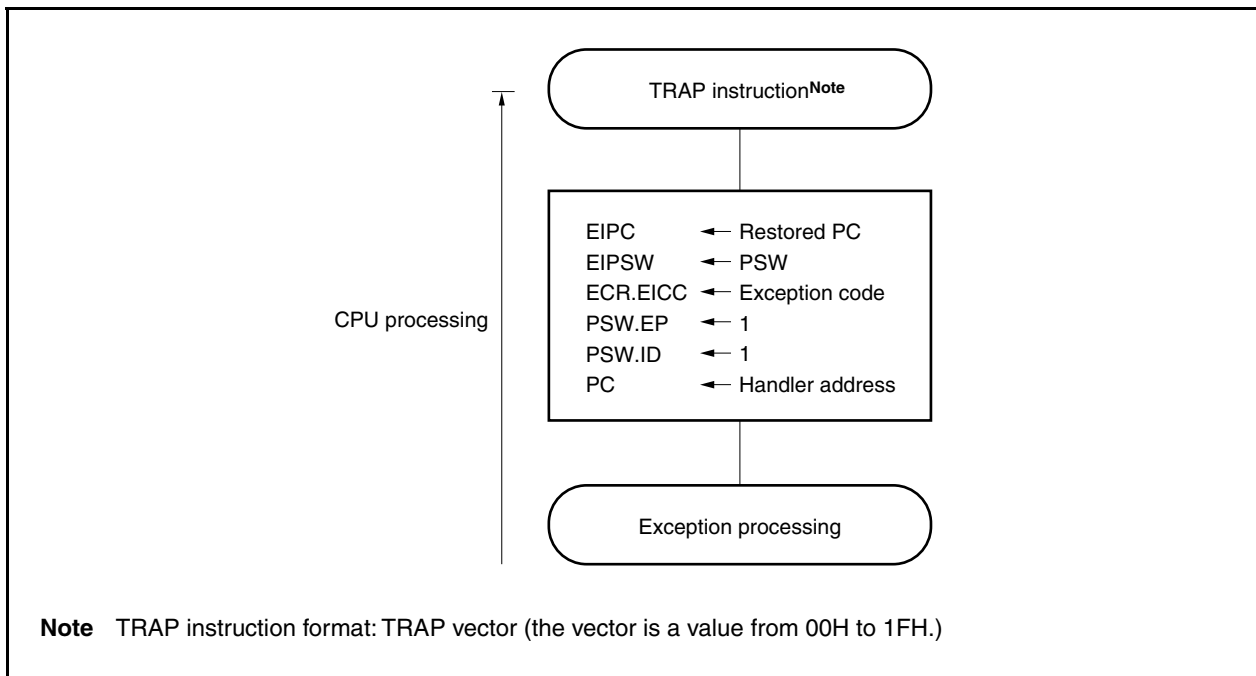
### 19.4.1 Operation

If a software exception occurs, the CPU performs the following processing, and transfers control to the handler routine.

- <1> Saves the restored PC to EIPC.
- <2> Saves the current PSW to EIPSW.
- <3> Writes an exception code to the lower 16 bits (EICC) of ECR (interrupt source).
- <4> Sets the PSW.EP and PSW.ID bits to 1.
- <5> Sets the handler address (00000040H or 00000050H) corresponding to the software exception to the PC, and transfers control.

The processing of a software exception is shown below.

**Figure 19-9. Software Exception Processing**



The handler address is determined by the TRAP instruction's operand (vector). If the vector is 00H to 0FH, it becomes 00000040H, and if the vector is 10H to 1FH, it becomes 00000050H.

### 19.4.2 Restore

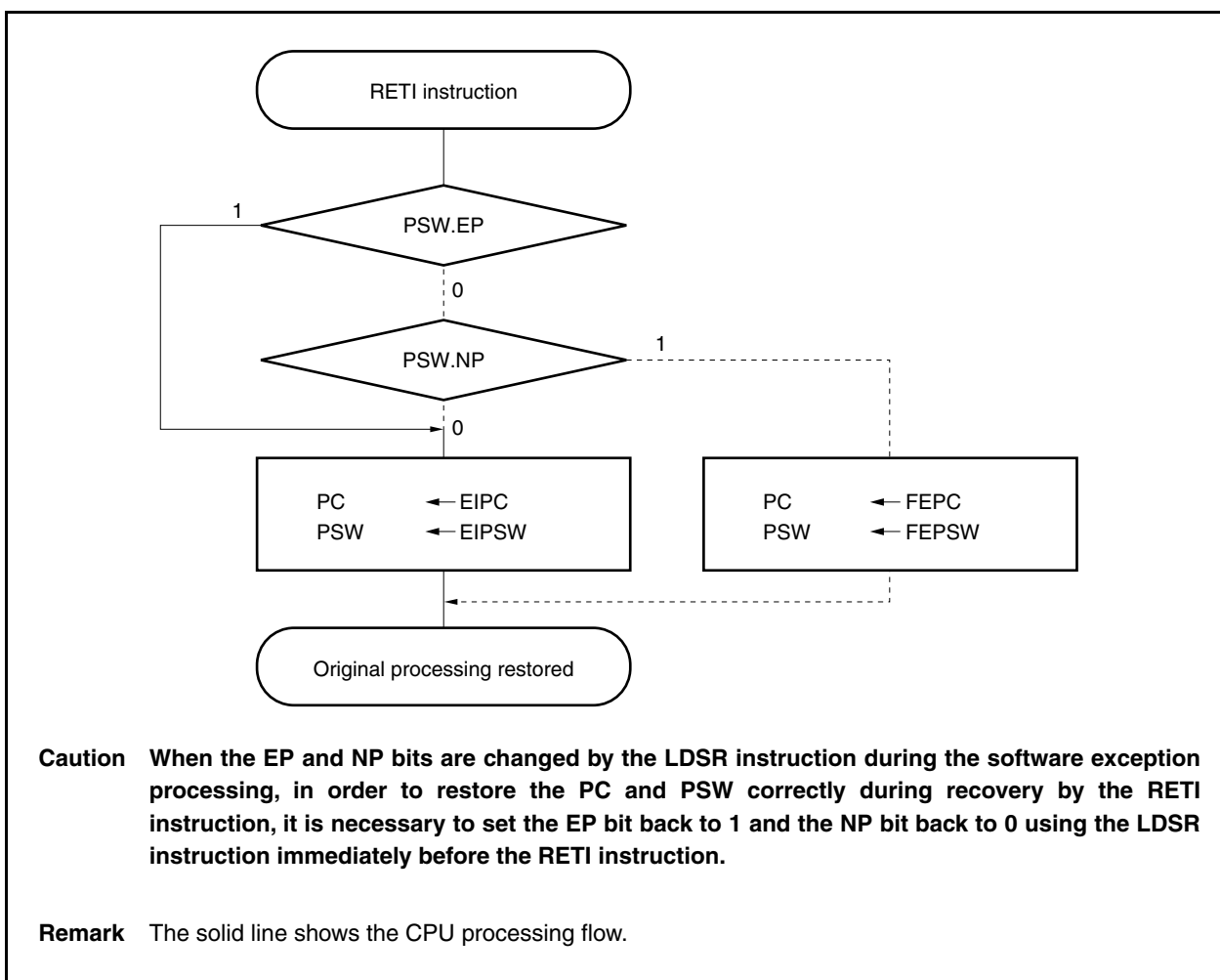
Restoration from software exception processing is carried out by the RETI instruction.

By executing the RETI instruction, the CPU carries out the following processing and shifts control to the restored PC's address.

- <1> Loads the restored PC and PSW from EIPC and EIPSW because the PSW.EP bit is 1.
- <2> Transfers control to the address of the restored PC and PSW.

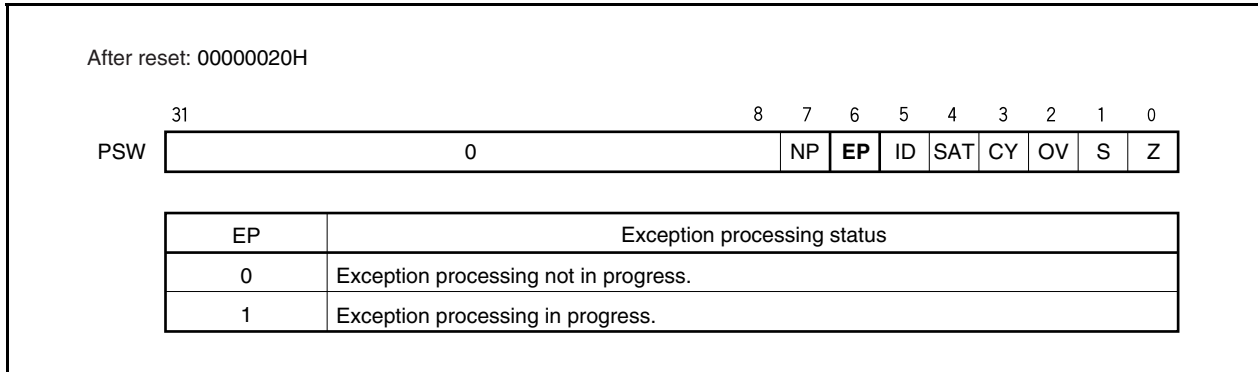
The processing of the RETI instruction is shown below.

**Figure 19-10. RETI Instruction Processing**



**19.4.3 EP flag**

The EP flag is a status flag used to indicate that exception processing is in progress. It is set when an exception occurs.

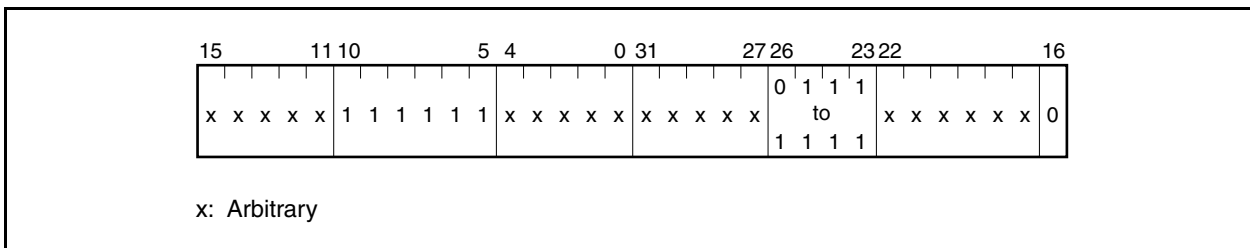


### 19.5 Exception Trap

An exception trap is an interrupt that is requested when the illegal execution of an instruction takes place. In the V850ES/JJ3, an illegal opcode exception (ILGOP: Illegal Opcode Trap) is considered as an exception trap.

#### 19.5.1 Illegal opcode definition

The illegal instruction has an opcode (bits 10 to 5) of 111111B, a sub-opcode (bits 26 to 23) of 0111B to 1111B, and a sub-opcode (bit 16) of 0B. An exception trap is generated when an instruction applicable to this illegal instruction is executed.



**Caution** Since it is possible to assign this instruction to an illegal opcode in the future, it is recommended that it not be used.

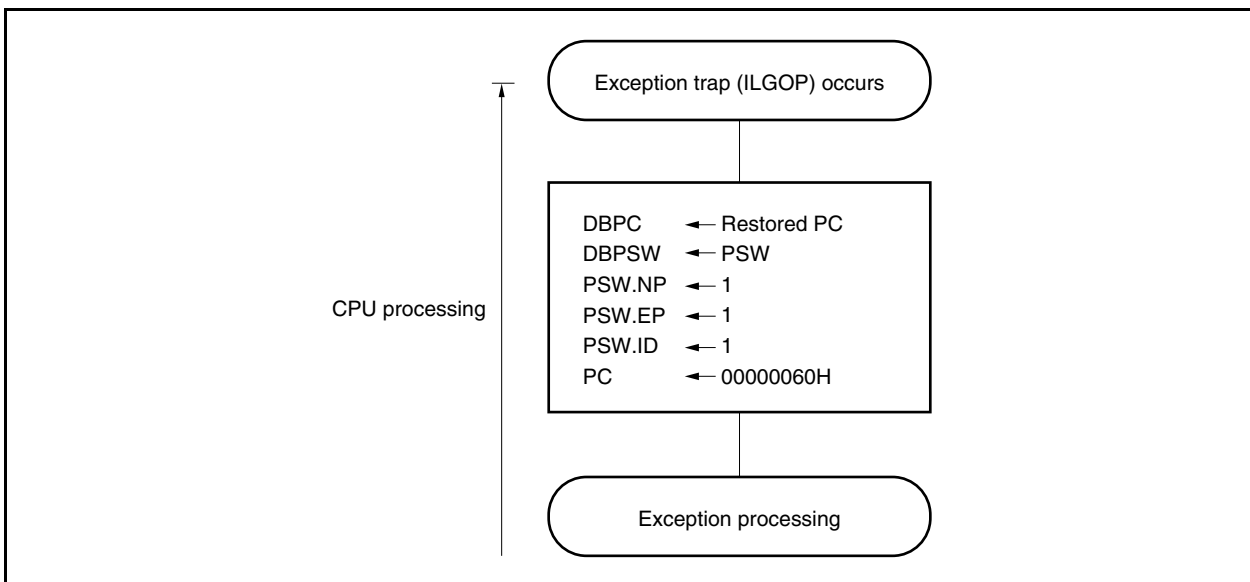
#### (1) Operation

If an exception trap occurs, the CPU performs the following processing, and transfers control to the handler routine.

- <1> Saves the restored PC to DBPC.
- <2> Saves the current PSW to DBPSW.
- <3> Sets the PSW.NP, PSW.EP, and PSW.ID bits to 1.
- <4> Sets the handler address (00000060H) corresponding to the exception trap to the PC, and transfers control.

The processing of the exception trap is shown below.

**Figure 19-11. Exception Trap Processing**



**(2) Restoration**

Restoration from an exception trap is carried out by the DBRET instruction. By executing the DBRET instruction, the CPU carries out the following processing and controls the address of the restored PC.

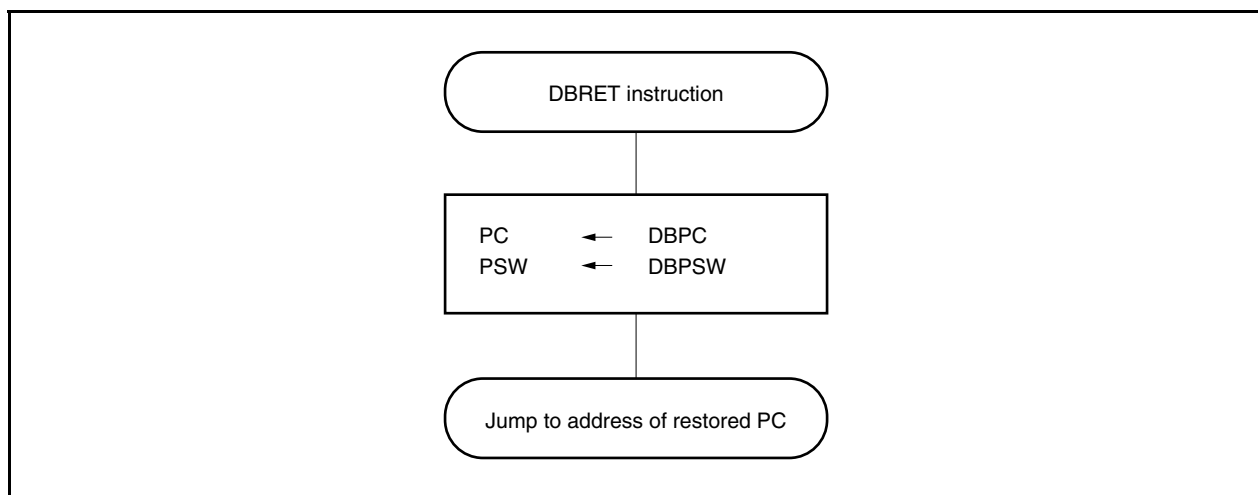
<1> Loads the restored PC and PSW from DBPC and DBPSW.

<2> Transfers control to the address indicated by the restored PC and PSW.

**Caution** DBPC and DBPSW can be accessed only during the interval between the execution of an illegal opcode and the DBRET instruction.

The restore processing from an exception trap is shown below.

**Figure 19-12. Restore Processing from Exception Trap**





### 19.5.2 Debug trap

A debug trap is an exception that is generated when the DBTRAP instruction is executed and is always acknowledged.

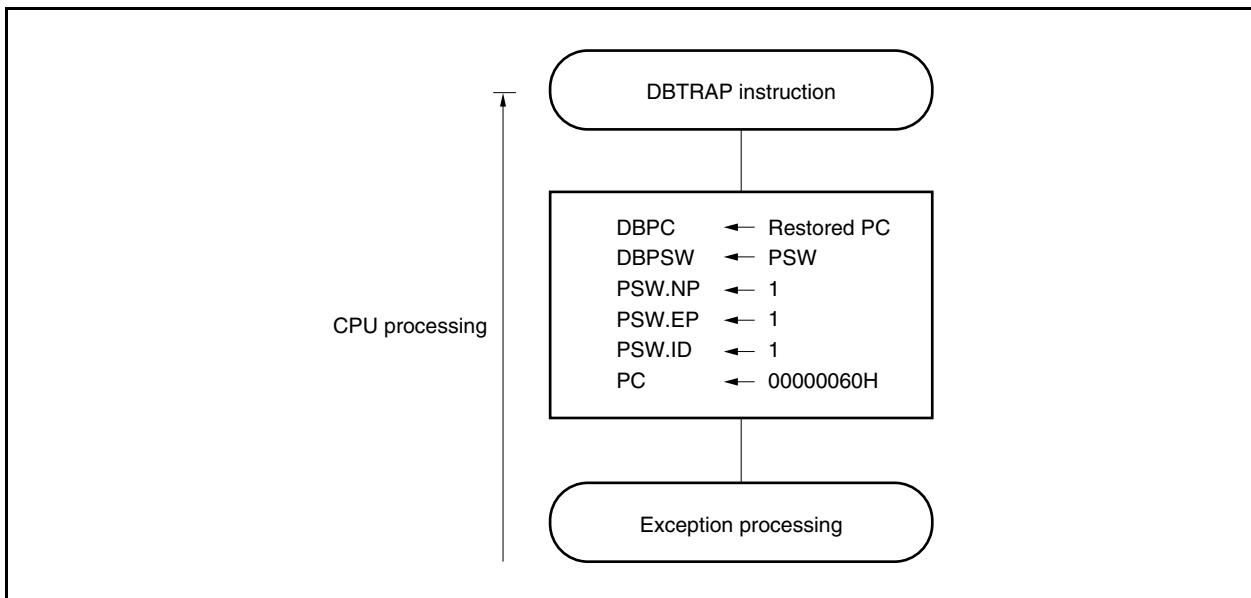
#### (1) Operation

Upon occurrence of a debug trap, the CPU performs the following processing.

- <1> Saves restored PC to DBPC.
- <2> Saves current PSW to DBPSW.
- <3> Sets the PSW.NP, PSW.EP, and PSW.ID bits to 1.
- <4> Sets handler address (00000060H) for debug trap to PC and transfers control.

The debug trap processing format is shown below.

**Figure 19-13. Debug Trap Processing Format**



**(2) Restoration**

Restoration from a debug trap is executed with the DBRET instruction.

With the DBRET instruction, the CPU performs the following steps and transfers control to the address of the restored PC.

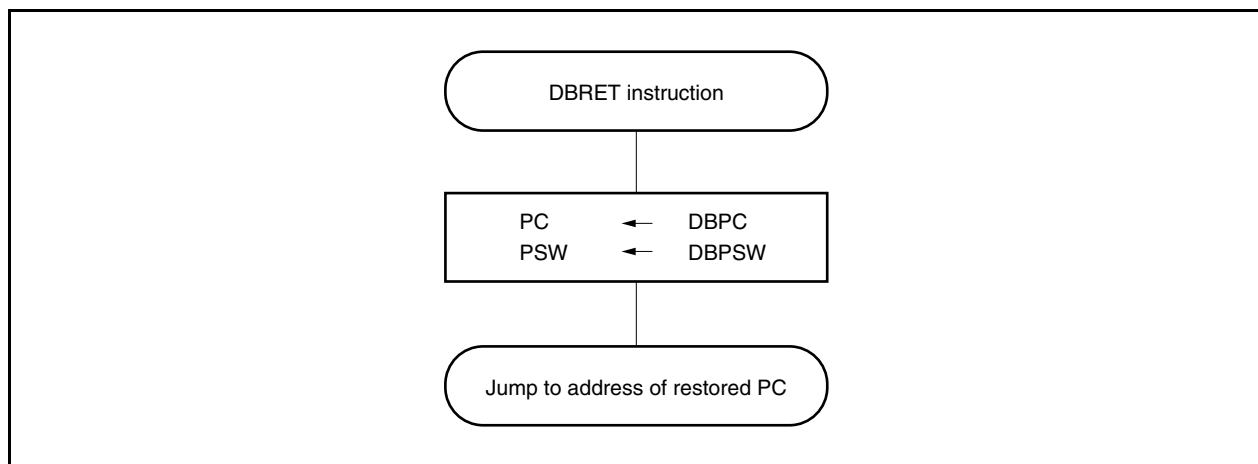
<1> The restored PC and PSW are read from DBPC and DBPSW.

<2> Control is transferred to the fetched address of the restored PC and PSW.

**Caution** DBPC and DBPSW can be accessed only during the interval between the execution of the DBTRAP instruction and the DBRET instruction.

The processing format for restoration from a debug trap is shown below.

**Figure 19-14. Processing Format of Restoration from Debug Trap**



## 19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP8)

### 19.6.1 Noise elimination

#### (1) Eliminating noise on NMI pin

The NMI pin has an internal noise elimination circuit that uses analog delay. Therefore, the input level of the NMI pin is not detected as an edge unless it is maintained for a specific time or longer. Therefore, an edge is detected after specific time.

The NMI pin can be used to release the STOP mode. In the STOP mode, noise is not eliminated by using the system clock because the internal system clock is stopped.

#### (2) Eliminating noise on INTP0 to INTP8 pins

The INTP0 to INTP8 pins have an internal noise elimination circuit that uses analog delay. Therefore, the input level of the NMI pin is not detected as an edge unless it is maintained for a specific time or longer. Therefore, an edge is detected after specific time.

### 19.6.2 Edge detection

The valid edge of each of the NMI and INTP0 to INTP8 pins can be selected from the following four.

- Rising edge
- Falling edge
- Both rising and falling edges
- No edge detected

The edge of the NMI pin is not detected after reset. Therefore, the interrupt request signal is not acknowledged unless a valid edge is enabled by using the INTF0 and INTR0 register (the NMI pin functions as a normal port pin).

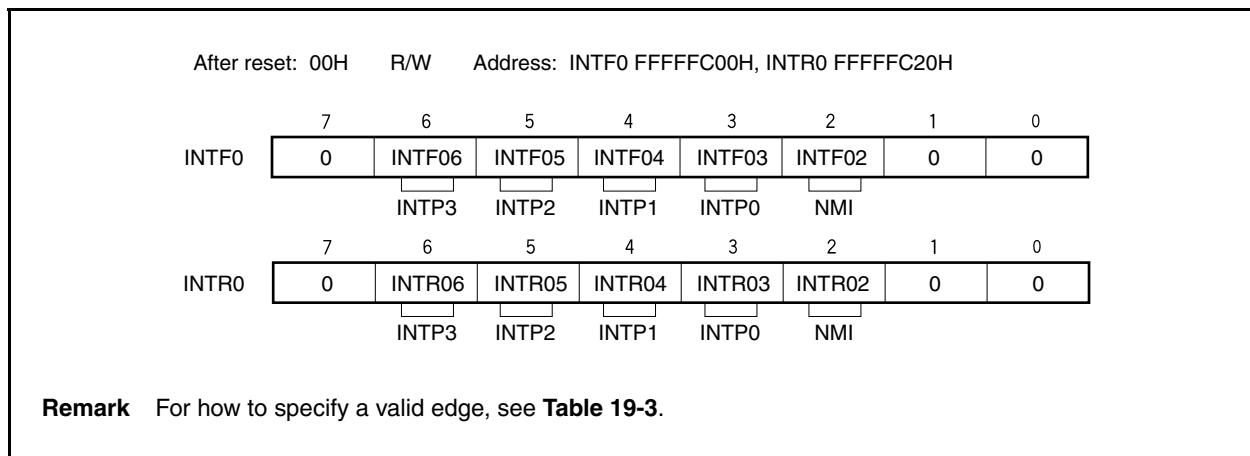
**(1) External interrupt falling, rising edge specification register 0 (INTF0, INTR0)**

The INTF0 and INTR0 registers are 8-bit registers that specify detection of the falling and rising edges of the NMI pin via bit 2 and the external interrupt pins (INTP0 to INTP3) via bits 3 to 6.

These registers can be read or written in 8-bit or 1-bit units.

Reset sets these registers to 00H.

**Caution** When the function is changed from the external interrupt function (alternate function) to the port function, an edge may be detected. Therefore, clear the INTF0n and INTR0n bits to 00, and then set the port mode.



**Table 19-3. Valid Edge Specification**

| INTF0n | INTR0n | Valid Edge Specification (n = 2 to 6) |
|--------|--------|---------------------------------------|
| 0      | 0      | No edge detected                      |
| 0      | 1      | Rising edge                           |
| 1      | 0      | Falling edge                          |
| 1      | 1      | Both rising and falling edges         |

**Caution** Be sure to clear the INTF0n and INTR0n bits to 00 when these registers are not used as the NMI or INTP0 to INTP3 pins.

**Remark** n = 2: Control of NMI pin  
 n = 3 to 6: Control of INTP0 to INTP3 pins

**(2) External interrupt falling, rising edge specification register 3 (INTF3, INTR3)**

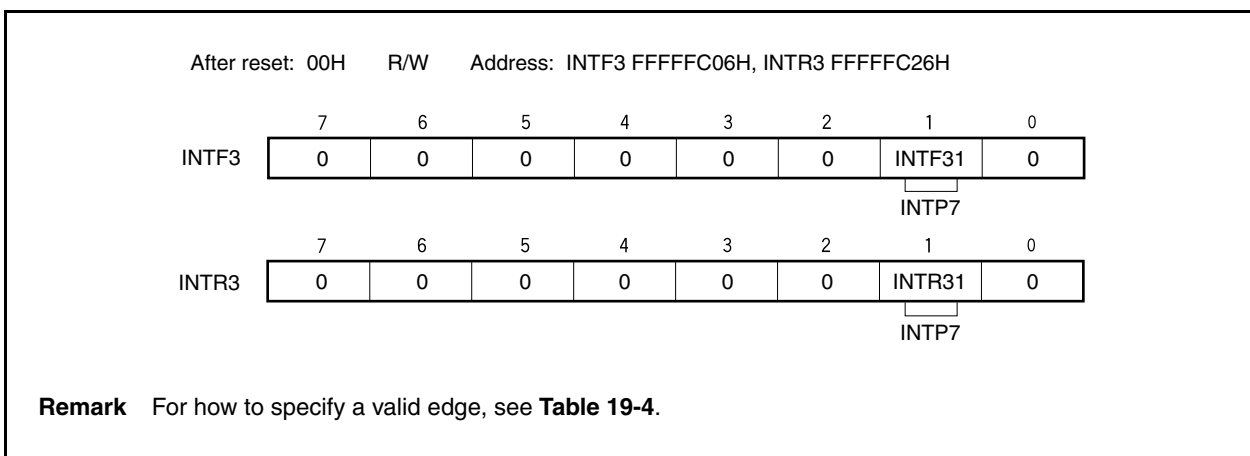
The INTF3 and INTR3 registers are 8-bit registers that specify detection of the falling and rising edges of the external interrupt pin (INTP7).

These registers can be read or written in 8-bit or 1-bit units.

Reset sets these registers to 00H.

**Cautions 1.** When the function is changed from the external interrupt function (alternate function) to the port function, an edge may be detected. Therefore, clear the INTF31 and INTR31 bits to 00, and then set the port mode.

**2.** The INTP7 pin and RXDA0 pin are alternate-function pins. When using the pin as the RXDA0 pin, disable edge detection for the INTP7 alternate-function pin (clear the INTF3.INTF31 bit and the INTR3.INTR31 bit to 0). When using the pin as the INTP7 pin, stop UARTA0 reception (clear the UA0CTL0.UA0RXE bit to 0).



**Table 19-4. Valid Edge Specification**

| INTF31 | INTR31 | Valid Edge Specification      |
|--------|--------|-------------------------------|
| 0      | 0      | No edge detected              |
| 0      | 1      | Rising edge                   |
| 1      | 0      | Falling edge                  |
| 1      | 1      | Both rising and falling edges |

**Caution** Be sure to clear the INTF31 and INTR31 bits to 00 when these registers are not used as INTP7 pin.

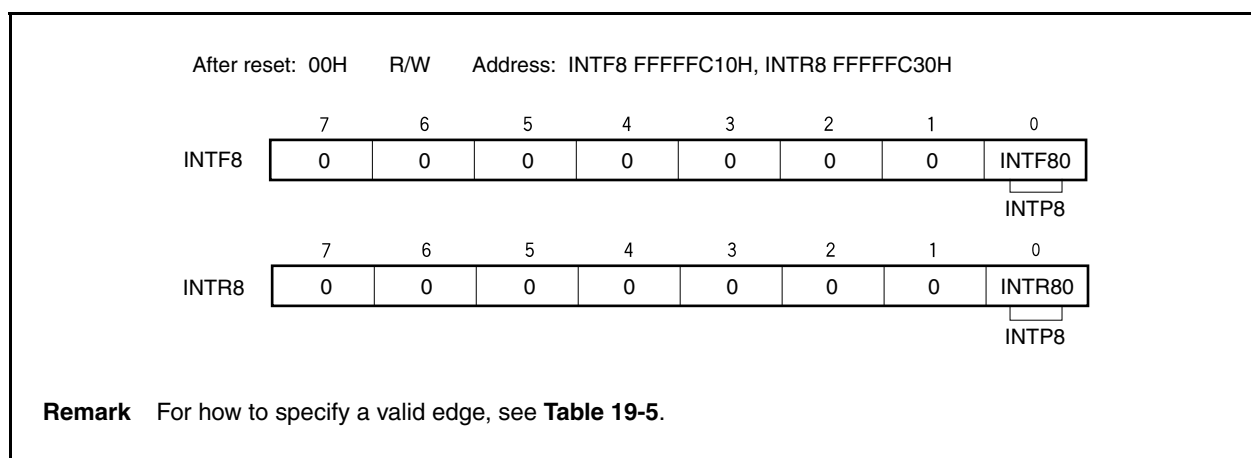
**(3) External interrupt falling, rising edge specification register 8 (INTF8, INTR8)**

The INTF8 and INTR8 registers are 8-bit registers that specify detection of the falling and rising edges of the external interrupt pin (INTP8).

These registers can be read or written in 8-bit or 1-bit units.

Reset sets these registers to 00H.

- Cautions**
1. When the function is changed from the external interrupt function (alternate function) to the port function, an edge may be detected. Therefore, clear the INTF80 and INTR80 bits to 00, and then set the port mode.
  2. The INTP8 pin and RXDA3 pin are alternate-function pins. When using the pin as the RXDA3 pin, disable edge detection for the INTP8 alternate-function pin (clear the INTF8.INTF80 bit and the INTR8.INTR80 bit to 0). When using the pin as the INTP8 pin, stop UARTA3 reception (clear the UA3CTL0.UA3RXE bit to 0).



**Table 19-5. Valid Edge Specification**

| INTF80 | INTR80 | Valid Edge Specification      |
|--------|--------|-------------------------------|
| 0      | 0      | No edge detected              |
| 0      | 1      | Rising edge                   |
| 1      | 0      | Falling edge                  |
| 1      | 1      | Both rising and falling edges |

**Caution** Be sure to clear the INTF80 and INTR80 bits to 00 when these registers are not used as INTP8 pin.

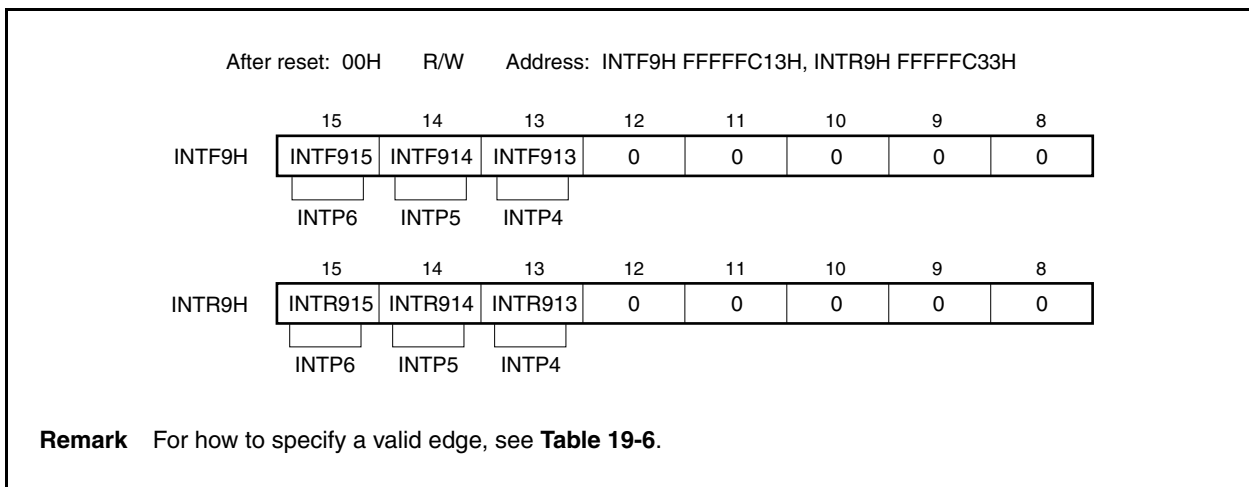
**(4) External interrupt falling, rising edge specification register 9H (INTF9H, INTR9H)**

The INTF9H and INTR9H registers are 8-bit registers that specify detection of the falling and rising edges of the external interrupt pins (INTP4 to INTP6).

These registers can be read or written in 8-bit or 1-bit units.

Reset sets these registers to 00H.

**Caution** When the function is changed from the external interrupt function (alternate function) to the port function, an edge may be detected. Therefore, clear the INTF9n and INTR9n bits to 0, and then set the port mode.



**Table 19-6. Valid Edge Specification**

| INTF9n | INTR9n | Valid Edge Specification (n = 13 to 15) |
|--------|--------|---|
| 0      | 0      | No edge detected                        |
| 0      | 1      | Rising edge                             |
| 1      | 0      | Falling edge                            |
| 1      | 1      | Both rising and falling edges           |

**Caution** Be sure to clear the INTF9n and INTR9n bits to 00 when these registers are not used as INTP4 to INTP6 pins.

**Remark** n = 13 to 15: Control of INTP4 to INTP6 pins

**(5) Noise elimination control register (NFC)**

Digital noise elimination can be selected for the INTP3 pin. The noise elimination settings are performed using the NFC register.

When digital noise elimination is selected, the sampling clock for digital sampling can be selected from among  $f_{xx}/64$ ,  $f_{xx}/128$ ,  $f_{xx}/256$ ,  $f_{xx}/512$ ,  $f_{xx}/1,024$ , and  $f_{XT}$ . Sampling is performed three times.

When digital noise elimination is selected, if the clock that performs sampling in the standby mode is stopped, then the INTP3 interrupt request signal cannot be used for releasing the standby mode. When  $f_{XT}$  is used as the sampling clock, the INTP3 interrupt request signal can be used for releasing either the subclock operating mode or the IDLE1/IDLE2/STOP/sub-IDLE mode.

This register can be read or written in 8-bit units.

Reset sets this register to 00H.

**Caution** After the sampling clock has been changed, it takes 3 sampling clocks to initialize the digital noise eliminator. Therefore, if an INTP3 valid edge is input within these 3 sampling clocks after the sampling clock has been changed, an interrupt request signal may be generated. Therefore, be careful about the following points when using the interrupt and DMA functions.

- When using the interrupt function, after the 3 sampling clocks have elapsed, enable interrupts after the interrupt request flag (PIC3.PIF3 bit) has been cleared.
- When using the DMA function (started by INTP3), enable DMA after 3 sampling clocks have elapsed.

After reset: 00H R/W Address: FFFFF318H

|     |      |   |   |   |   |      |      |      |
|-----|------|---|---|---|---|------|------|------|
|     | 7    | 6 | 5 | 4 | 3 | 2    | 1    | 0    |
| NFC | NFEN | 0 | 0 | 0 | 0 | NFC2 | NFC1 | NFC0 |

|      |   |
|------|---|
| NFEN | Settings of INTP3 pin noise elimination |
| 0    | Analog noise elimination (60 ns (TYP.)) |
| 1    | Digital noise elimination               |

|                  |      |      |                        |
|------------------|------|------|------------------------|
| NFC2             | NFC1 | NFC0 | Digital sampling clock |
| 0                | 0    | 0    | $f_{xx}/64$            |
| 0                | 0    | 1    | $f_{xx}/128$           |
| 0                | 1    | 0    | $f_{xx}/256$           |
| 0                | 1    | 1    | $f_{xx}/512$           |
| 1                | 0    | 0    | $f_{xx}/1,024$         |
| 1                | 0    | 1    | $f_{XT}$ (subclock)    |
| Other than above |      |      | Setting prohibited     |

- Remarks**
1. Since sampling is performed three times, the reliably eliminated noise width is 2 sampling clocks.
  2. In the case of noise with a width smaller than 2 sampling clocks, an interrupt request signal is generated if noise synchronized with the sampling clock is input.

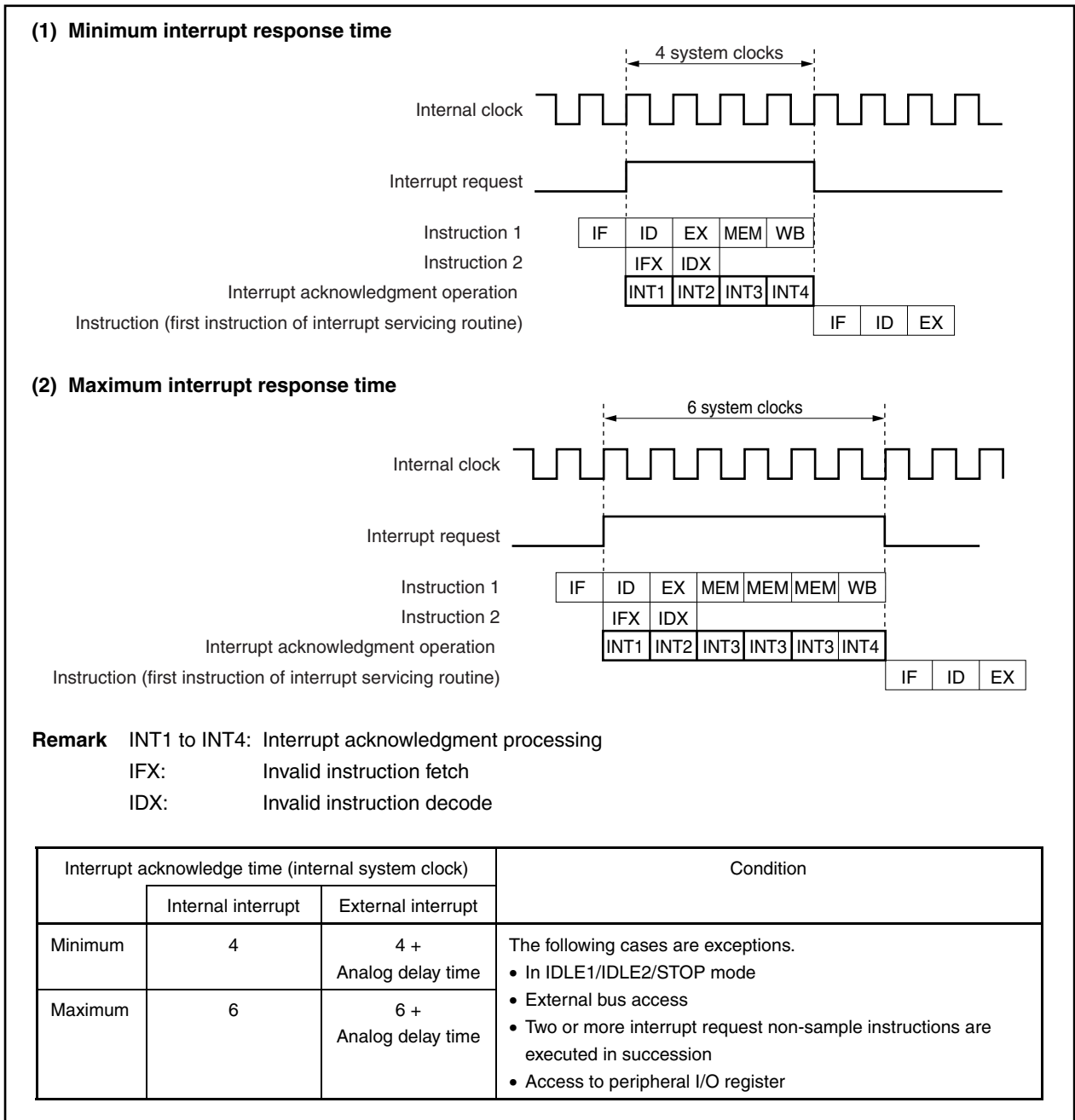


19.7 Interrupt Acknowledge Time of CPU

Except the following cases, the interrupt acknowledge time of the CPU is 4 clocks minimum. To input interrupt request signals successively, input the next interrupt request signal at least 5 clocks after the preceding interrupt.

- In IDLE1/IDLE2/STOP mode
- When the external bus is accessed
- When interrupt request non-sampling instructions are successively executed (see 19.8 Periods in Which Interrupts Are Not Acknowledged by CPU.)
- When the interrupt control register is accessed

Figure 19-15. Pipeline Operation at Interrupt Request Signal Acknowledgment (Outline)



## 19.8 Periods in Which Interrupts Are Not Acknowledged by CPU

An interrupt is acknowledged by the CPU while an instruction is being executed. However, no interrupt will be acknowledged between an interrupt request non-sample instruction and the next instruction (interrupt is held pending).

The interrupt request non-sample instructions are as follows.

- EI instruction
- DI instruction
- LDSR reg2, 0x5 instruction (for PSW)
- The store instruction for the PRCMD register
- The store, SET1, NOT1, or CLR1 instructions for the following registers.
  - Interrupt-related registers:
    - Interrupt control register (xxICn), interrupt mask registers 0 to 4 (IMR0 to IMR4)
  - Power save control register (PSC)
  - On-chip debug mode register (OCDM)

**Remark** xx: Identification name of each peripheral unit (see **Table 19-2 Interrupt Control Register (xxICn)**)

n: Peripheral unit number (see **Table 19-2 Interrupt Control Register (xxICn)**).

## 19.9 Cautions

The NMI pin and P02 pin are an alternate-function pin, and function as a normal port pin after being reset. To enable the NMI pin, validate the NMI pin with the PMC0 register. The initial setting of the NMI pin is "No edge detected". Select the NMI pin valid edge using the INTF0 and INTR0 registers.

## CHAPTER 20 KEY INTERRUPT FUNCTION

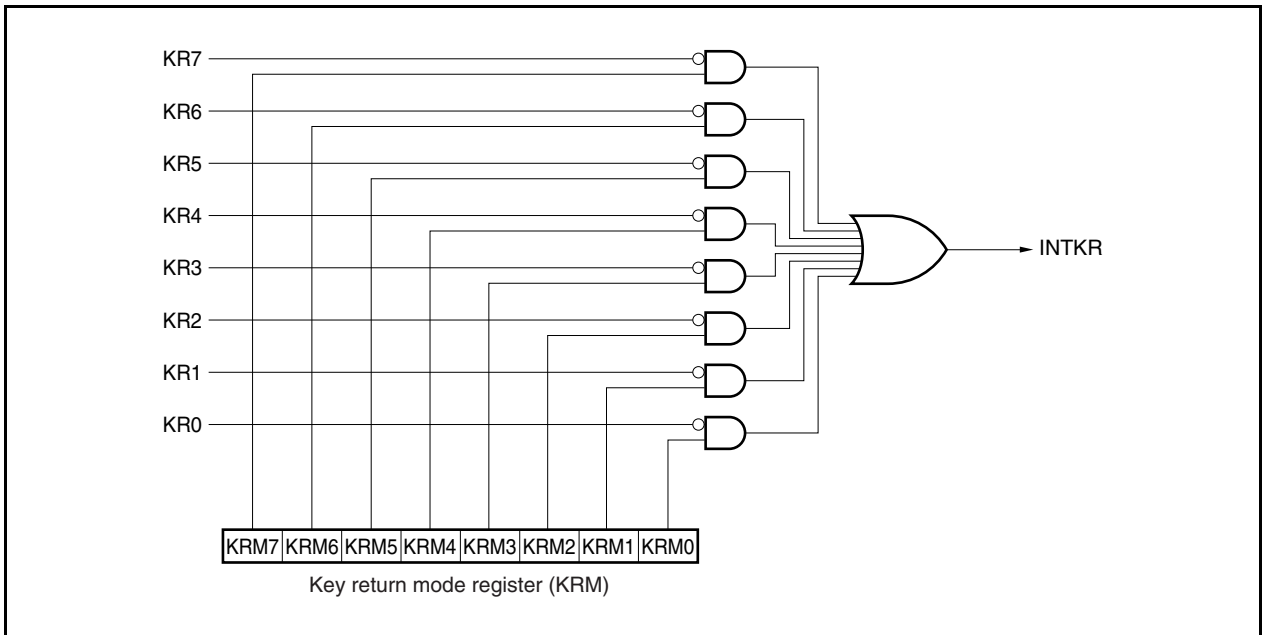
### 20.1 Function

A key interrupt request signal (INTKR) can be generated by inputting a falling edge to the eight key input pins (KR0 to KR7) by setting the KRM register.

**Table 20-1. Assignment of Key Return Detection Pins**

| Flag | Pin Description                    |
|------|------------------------------------|
| KRM0 | Controls KR0 signal in 1-bit units |
| KRM1 | Controls KR1 signal in 1-bit units |
| KRM2 | Controls KR2 signal in 1-bit units |
| KRM3 | Controls KR3 signal in 1-bit units |
| KRM4 | Controls KR4 signal in 1-bit units |
| KRM5 | Controls KR5 signal in 1-bit units |
| KRM6 | Controls KR6 signal in 1-bit units |
| KRM7 | Controls KR7 signal in 1-bit units |

**Figure 20-1. Key Return Block Diagram**



## 20.2 Register

### (1) Key return mode register (KRM)

The KRM register controls the KRM0 to KRM7 bits using the KR0 to KR7 signals.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

|                  |                                   |      |                    |      |      |      |      |      |
|------------------|-----------------------------------|------|--------------------|------|------|------|------|------|
| After reset: 00H |                                   | R/W  | Address: FFFFF300H |      |      |      |      |      |
|                  | 7                                 | 6    | 5                  | 4    | 3    | 2    | 1    | 0    |
| KRM              | KRM7                              | KRM6 | KRM5               | KRM4 | KRM3 | KRM2 | KRM1 | KRM0 |
| KRMn             | Control of key return mode        |      |                    |      |      |      |      |      |
| 0                | Does not detect key return signal |      |                    |      |      |      |      |      |
| 1                | Detects key return signal         |      |                    |      |      |      |      |      |

**Caution** Rewrite the KRM register after once clearing the KRM register to 00H.

**Remark** For the alternate-function pin settings, see **Table 4-19 Using Port Pins as Alternate-Function Pins**.

## 20.3 Cautions

- (1) If a low level is input to any of the KR0 to KR7 pins, the INTKR signal is not generated even if the falling edge of another pin is input.
- (2) The RXDA1 and KR7 pins must not be used at the same time. To use the RXDA1 pin, do not use the KR7 pin. To use the KR7 pin, do not use the RXDA1 pin (it is recommended to set the PFC91 bit to 1 and clear PFCE91 bit to 0).
- (3) If the KRM register is changed, an interrupt request signal (INTKR) may be generated. To prevent this, change the KRM register after disabling interrupts (DI) or masking, then clear the interrupt request flag (KRIC.KRIF bit) to 0, and enable interrupts (EI) or clear the mask.
- (4) To use the key interrupt function, be sure to set the port pin to the key return pin and then enable the operation with the KRM register. To switch from the key return pin to the port pin, disable the operation with the KRM register and then set the port pin.

## CHAPTER 21 STANDBY FUNCTION

### 21.1 Overview

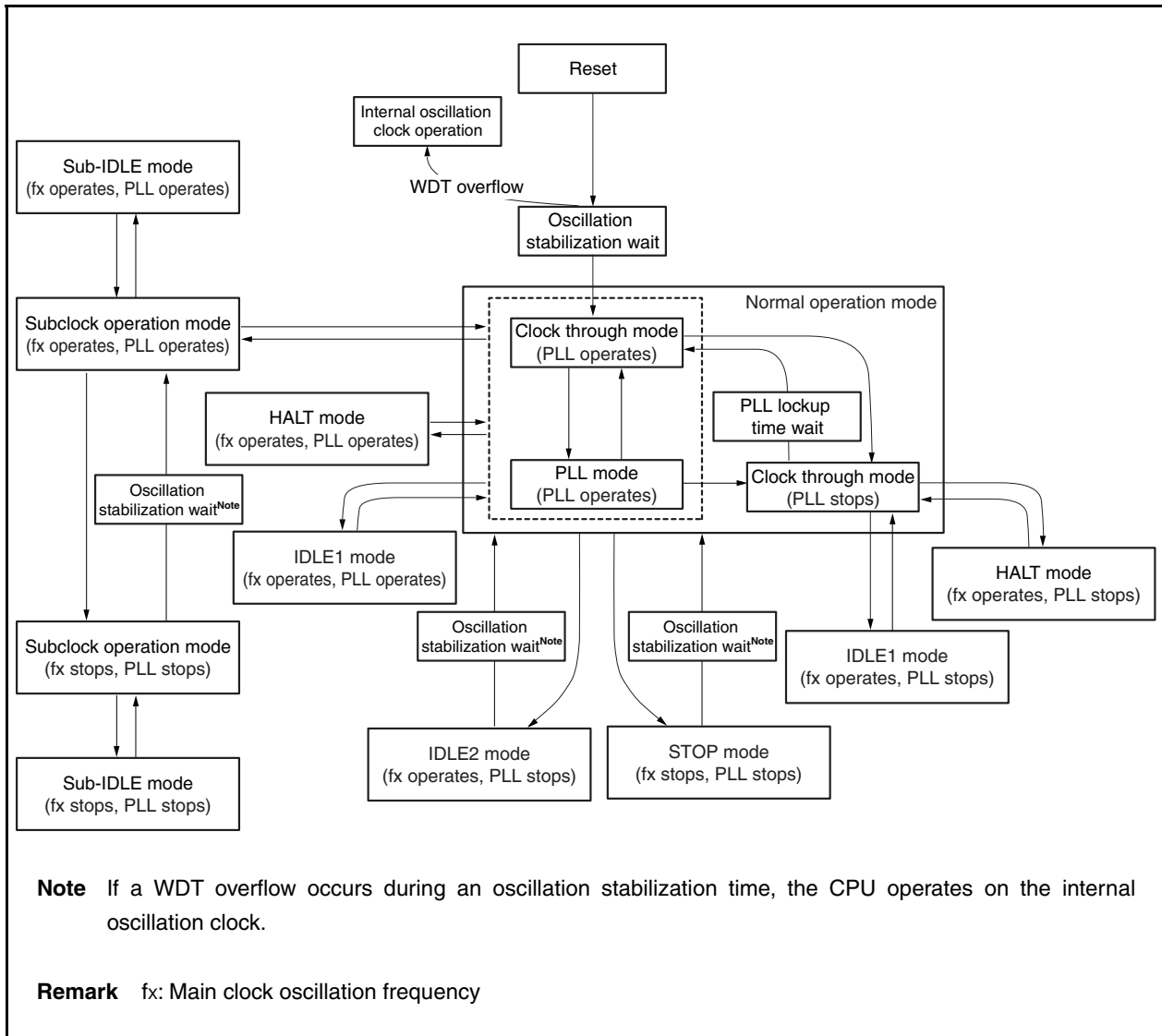
The power consumption of the system can be effectively reduced by using the standby modes in combination and selecting the appropriate mode for the application. The available standby modes are listed in Table 21-1.

**Table 21-1. Standby Modes**

| Mode                    | Functional Outline  |
|-------------------------|---|
| HALT mode               | Mode in which only the operating clock of the CPU is stopped  |
| IDLE1 mode              | Mode in which all the operations of the internal circuits except the oscillator, PLL <sup>Note</sup> , and flash memory are stopped |
| IDLE2 mode              | Mode in which all the operations of internal circuits except the oscillator are stopped   |
| STOP mode               | Mode in which all the operations of internal circuits except the subclock oscillator are stopped                                    |
| Subclock operation mode | Mode in which the subclock is used as the internal system clock   |
| Sub-IDLE mode           | Mode in which all the operations of internal circuits except the oscillator are stopped, in the subclock operation mode             |

**Note** The PLL holds the previous operating status.

Figure 21-1. Status Transition



## 21.2 Registers

### (1) Power save control register (PSC)

The PSC register is an 8-bit register that controls the standby function. The STP bit of this register is used to specify the STOP mode. This register is a special register that can be written only by the special sequence combinations (see 3.4.7 **Special registers**).

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF1FEH

|     |   |       |       |      |   |   |     |   |
|-----|---|-------|-------|------|---|---|-----|---|
|     | 7 | <6>   | <5>   | <4>  | 3 | 2 | <1> | 0 |
| PSC | 0 | NMI1M | NMI0M | INTM | 0 | 0 | STP | 0 |

|       |   |
|-------|---|
| NMI1M | Control of releasing standby mode by INTWDT2 signal |
| 0     | Releasing standby mode by INTWDT2 signal enabled    |
| 1     | Releasing standby mode by INTWDT2 signal disabled   |

|       |  |
|-------|--|
| NMI0M | Control of releasing standby mode by NMI pin input |
| 0     | Releasing standby mode by NMI pin input enabled    |
| 1     | Releasing standby mode by NMI pin input disabled   |

|      |   |
|------|---|
| INTM | Control of releasing standby mode by maskable interrupt request signals |
| 0    | Releasing standby mode by maskable interrupt request signals enabled    |
| 1    | Releasing standby mode by maskable interrupt request signals disabled   |

|     |                      |
|-----|----------------------|
| STP | Standby mode setting |
| 0   | Normal mode          |
| 1   | Standby mode         |

**Note** Standby mode set by STP bit: IDLE1, IDLE2, STOP, or sub-IDLE mode

- Cautions**
1. Before setting the IDLE1, IDLE2, STOP, or sub-IDLE mode, set the PSMR.PSM1 and PSMR.PSM0 bits and then set the STP bit.
  2. Settings of the NMI1M, NMI0M, and INTM bits are invalid when HALT mode is released.
  3. If the NMI1M, NMI0M, or INTM bit is set to 1 at the same time the STP bit is set to 1, the setting of NMI1M, NMI0M, or INTM bit becomes invalid. If there is an unmasked interrupt request signal being held pending when the IDLE1/IDLE2/STOP mode is set, set the bit corresponding to the interrupt request signal (NMI1M, NMI0M, or INTM) to 1, and then set the STP bit to 1.

**(2) Power save mode register (PSMR)**

The PSMR register is an 8-bit register that controls the operation status in the power save mode and the clock operation.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

After reset: 00H    R/W    Address: FFFFF820H

|      |   |   |   |   |   |   |      |      |
|------|---|---|---|---|---|---|------|------|
|      | 7 | 6 | 5 | 4 | 3 | 2 | <1>  | <0>  |
| PSMR | 0 | 0 | 0 | 0 | 0 | 0 | PSM1 | PSM0 |

| PSM1 | PSM0 | Specification of operation in software standby mode |
|------|------|---|
| 0    | 0    | IDLE1, sub-IDLE modes                               |
| 0    | 1    | STOP, sub-IDLE modes                                |
| 1    | 0    | IDLE2, sub-IDLE modes                               |
| 1    | 1    | STOP mode   |

- Cautions**
1. Be sure to clear bits 2 to 7 to “0”.
  2. The PSM0 and PSM1 bits are valid only when the PSC.STP bit is 1.

**Remark**

**IDLE1:** In this mode, all operations except the oscillator operation and some other circuits (flash memory and PLL) are stopped. After the IDLE1 mode is released, the normal operation mode is restored without needing to secure the oscillation stabilization time, like the HALT mode.

**IDLE2:** In this mode, all operations except the oscillator operation are stopped. After the IDLE2 mode is released, the normal operation mode is restored following the lapse of the setup time specified by the OSTS register (flash memory and PLL).

**STOP:** In this mode, all operations except the subclock oscillator operation are stopped. After the STOP mode is released, the normal operation mode is restored following the lapse of the oscillation stabilization time specified by the OSTS register.

**Sub-IDLE:** In this mode, all other operations are halted except for the oscillator. After the IDLE mode has been released by the interrupt request signal, the subclock operation mode will be restored after 12 cycles of the subclock have been secured.



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

The wait time until the oscillation stabilizes after the STOP mode is released or the wait time until the on-chip flash memory stabilizes after the IDLE2 mode is released is controlled by the OSTS register.

The OSTS register can be read or written 8-bit units.

Reset sets this register to 06H.

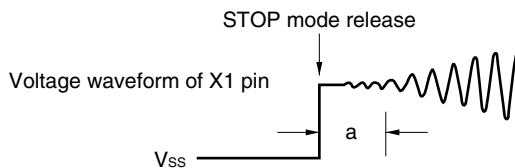
After reset: 06H R/W Address: FFFF6C0H

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

| OSTS2 | OSTS1 | OSTS0 | Selection of oscillation stabilization time/setup time <sup>Note</sup> | fx       |           |
|-------|-------|-------|--|----------|-----------|
|       |       |       |  | 4 MHz    | 5 MHz     |
|       |       |       |  | 0        | 0         |
| 0     | 0     | 1     | $2^{11}/f_x$   | 0.512 ms | 0.410 ms  |
| 0     | 1     | 0     | $2^{12}/f_x$   | 1.024 ms | 0.819 ms  |
| 0     | 1     | 1     | $2^{13}/f_x$   | 2.048 ms | 1.638 ms  |
| 1     | 0     | 0     | $2^{14}/f_x$   | 4.096 ms | 3.277 ms  |
| 1     | 0     | 1     | $2^{15}/f_x$   | 8.192 ms | 6.554 ms  |
| 1     | 1     | 0     | $2^{16}/f_x$   | 16.38 ms | 13.107 ms |
| 1     | 1     | 1     | Setting prohibited   |          |           |

**Note** The oscillation stabilization time and setup time are required when the STOP mode and IDLE2 mode are released, respectively.

**Cautions** 1. The wait time following release of the STOP mode does not include the time until the clock oscillation starts ("a" in the figure below) following release of the STOP mode, regardless of whether the STOP mode is released by reset or the occurrence of an interrupt request signal.



- 2. Be sure to clear bits 3 to 7 to "0".
- 3. The oscillation stabilization time following reset release is  $2^{16}/f_x$  (because the initial value of the OSTS register = 06H).

**Remark**  $f_x$  = Main clock oscillation frequency

## 21.3 HALT Mode

### 21.3.1 Setting and operation status

The HALT mode is set when a dedicated instruction (HALT) is executed in the normal operation mode.

In the HALT mode, the clock oscillator continues operating. Only clock supply to the CPU is stopped; clock supply to the other on-chip peripheral functions continues.

As a result, program execution is stopped, and the internal RAM retains the contents before the HALT mode was set. The on-chip peripheral functions that are independent of instruction processing by the CPU continue operating.

Table 21-3 shows the operating status in the HALT mode.

The average current consumption of the system can be reduced by using the HALT mode in combination with the normal operation mode for intermittent operation.

**Cautions 1. Insert five or more NOP instructions after the HALT instruction.**

- 2. If the HALT instruction is executed while an unmasked interrupt request signal is being held pending, the status shifts to HALT mode, but the HALT mode is then released immediately by the pending interrupt request.**

### 21.3.2 Releasing HALT mode

The HALT mode is released by a non-maskable interrupt request signal (NMI pin input, INTWDT2 signal), unmasked external interrupt request signal (INTP0 to INTP8 pin input), unmasked internal interrupt request signal from a peripheral function operable in the HALT mode, or reset signal (reset by  $\overline{\text{RESET}}$  pin input, WDT2RES signal, low-voltage detector (LVI), or clock monitor (CLM)).

After the HALT mode has been released, the normal operation mode is restored.

#### (1) Releasing HALT mode by non-maskable interrupt request signal or unmasked maskable interrupt request signal

The HALT mode is released by a non-maskable interrupt request signal or an unmasked maskable interrupt request signal, regardless of the priority of the interrupt request signal. If the HALT mode is set in an interrupt servicing routine, however, an interrupt request signal that is issued later is serviced as follows.

- (a) If an interrupt request signal with a priority lower than that of the interrupt request currently being serviced is issued, the HALT mode is released, but that interrupt request signal is not acknowledged. The interrupt request signal itself is retained.
- (b) If an interrupt request signal with a priority higher than that of the interrupt request currently being serviced is issued (including a non-maskable interrupt request signal), the HALT mode is released and that interrupt request signal is acknowledged.

**Table 21-2. Operation After Releasing HALT Mode by Interrupt Request Signal**

| Release Source                        | Interrupt Enabled (EI) Status  | Interrupt Disabled (DI) Status    |
|---------------------------------------|--|-----------------------------------|
| Non-maskable interrupt request signal | Execution branches to the handler address.                                     |                                   |
| Maskable interrupt request signal     | Execution branches to the handler address or the next instruction is executed. | The next instruction is executed. |

**(2) Releasing HALT mode by reset**

The same operation as the normal reset operation is performed.

**Table 21-3. Operating Status in HALT Mode**

| Setting of HALT Mode            |  | Operating Status  |                       |
|---------------------------------|--|---|-----------------------|
|                                 |  | When Subclock Is Not Used   | When Subclock Is Used |
| Main clock oscillator           |  | Oscillation enabled   |                       |
| Subclock oscillator             |  | –   | Oscillation enabled   |
| Internal oscillator             |  | Oscillation enabled   |                       |
| PLL                             |  | Operable  |                       |
| CPU                             |  | Stops operation   |                       |
| DMA                             |  | Operable  |                       |
| Interrupt controller            |  | Operable  |                       |
| Timer P (TMP0 to TMP8)          |  | Operable  |                       |
| Timer Q (TMQ0)                  |  | Operable  |                       |
| Timer M (TMM0)                  |  | Operable when a clock other than $f_{XT}$ is selected as the count clock  | Operable              |
| Watch timer                     |  | Operable when $f_x$ (divided BRG) is selected as the count clock  | Operable              |
| Watchdog timer 2                |  | Operable when a clock other than $f_{XT}$ is selected as the count clock  | Operable              |
| Serial interface                | CSIB0 to CSIB5                           | Operable  |                       |
|                                 | I <sup>2</sup> C00 to I <sup>2</sup> C02 | Operable  |                       |
|                                 | UARTA0 to UARTA3                         | Operable  |                       |
| A/D converter                   |  | Operable  |                       |
| D/A converter                   |  | Operable  |                       |
| Real-time output function (RTO) |  | Operable  |                       |
| Key interrupt function (KR)     |  | Operable  |                       |
| CRC operation circuit           |  | Operable (No data input to the CRCIN register because the CPU is stopped)   |                       |
| External bus interface          |  | See <b>2.2 Pin States</b> .   |                       |
| Port function                   |  | Retains status before HALT mode was set   |                       |
| Internal data                   |  | The CPU registers, statuses, data, and all other internal data such as the contents of the internal RAM are retained as they were before the HALT mode was set. |                       |

## 21.4 IDLE1 Mode

### 21.4.1 Setting and operation status

The IDLE1 mode is set by clearing the PSMR.PSM1 and PSMR.PSM0 bits to 00 and setting the PSC.STP bit to 1 in the normal operation mode.

In the IDLE1 mode, the clock oscillator, PLL, and flash memory continue operating but clock supply to the CPU and other on-chip peripheral functions stops.

As a result, program execution stops and the contents of the internal RAM before the IDLE1 mode was set are retained. The CPU and other on-chip peripheral functions stop operating. However, the on-chip peripheral functions that can operate with the subclock or an external clock continue operating.

Table 21-5 shows the operating status in the IDLE1 mode.

The IDLE1 mode can reduce the power consumption more than the HALT mode because it stops the operation of the on-chip peripheral functions. The main clock oscillator does not stop, so the normal operation mode can be restored without waiting for the oscillation stabilization time after the IDLE1 mode has been released, in the same manner as when the HALT mode is released.

- Cautions**
1. Insert five or more NOP instructions after the instruction that stores data in the PSC register to set the IDLE1 mode.
  2. If the IDLE1 mode is set while an unmasked interrupt request signal is being held pending, the IDLE1 mode is released immediately by the pending interrupt request.

### 21.4.2 Releasing IDLE1 mode

The IDLE1 mode is released by a non-maskable interrupt request signal (NMI pin input, INTWDT2 signal), unmasked external interrupt request signal (INTP0 to INTP8 pin input), unmasked internal interrupt request signal from a peripheral function operable in the IDLE1 mode, or reset signal (reset by RESET pin input, WDT2RES signal, low-voltage detector (LVI), or clock monitor (CLM)).

After the IDLE1 mode has been released, the normal operation mode is restored.

#### (1) Releasing IDLE1 mode by non-maskable interrupt request signal or unmasked maskable interrupt request signal

The IDLE1 mode is released by a non-maskable interrupt request signal or an unmasked maskable interrupt request signal, regardless of the priority of the interrupt request signal. If the IDLE1 mode is set in an interrupt servicing routine, however, an interrupt request signal that is issued later is processed as follows.

- (a) If an interrupt request signal with a priority lower than that of the interrupt request currently being serviced is issued, the IDLE1 mode is released, but that interrupt request signal is not acknowledged. The interrupt request signal itself is retained.
- (b) If an interrupt request signal with a priority higher than that of the interrupt request currently being serviced is issued (including a non-maskable interrupt request signal), the IDLE1 mode is released and that interrupt request signal is acknowledged.

**Caution** An interrupt request signal that is disabled by setting the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits to 1 becomes invalid and IDLE1 mode is not released.

**Table 21-4. Operation After Releasing IDLE1 Mode by Interrupt Request Signal**

| Release Source                        | Interrupt Enabled (EI) Status  | Interrupt Disabled (DI) Status    |
|---------------------------------------|--|-----------------------------------|
| Non-maskable interrupt request signal | Execution branches to the handler address.                                     |                                   |
| Maskable interrupt request signal     | Execution branches to the handler address or the next instruction is executed. | The next instruction is executed. |

**(2) Releasing IDLE1 mode by reset**

The same operation as the normal reset operation is performed.

**Table 21-5. Operating Status in IDLE1 Mode**

| Setting of IDLE1 Mode           |  | Operating Status   |  |
|---------------------------------|--|--|--|
|                                 |  | When Subclock Is Not Used  | When Subclock Is Used  |
| Main clock oscillator           |  | Oscillation enabled  |  |
| Subclock oscillator             |  | –  | Oscillation enabled  |
| Internal oscillator             |  | Oscillation enabled  |  |
| PLL                             |  | Operable   |  |
| CPU                             |  | Stops operation  |  |
| DMA                             |  | Stops operation  |  |
| Interrupt controller            |  | Stops operation (but standby mode release is possible)   |  |
| Timer P (TMP0 to TMP8)          |  | Stops operation  |  |
| Timer Q (TMQ0)                  |  | Stops operation  |  |
| Timer M (TMM0)                  |  | Operable when $f_{R/8}$ is selected as the count clock   | Operable when $f_{R/8}$ or $f_{XT}$ is selected as the count clock |
| Watch timer                     |  | Operable when $f_x$ (divided BRG) is selected as the count clock   | Operable   |
| Watchdog timer 2                |  | Operable when $f_R$ is selected as the count clock   | Operable when $f_R$ or $f_{XT}$ is selected as the count clock     |
| Serial interface                | CSIB0 to CSIB5                           | Operable when the $\overline{SCKBn}$ input clock is selected as the count clock ( $n = 0$ to $5$ )   |  |
|                                 | I <sup>2</sup> C00 to I <sup>2</sup> C02 | Stops operation  |  |
|                                 | UARTA0 to UARTA3                         | Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)   |  |
| A/D converter                   |  | Holds operation (conversion result held) <sup>Note</sup>   |  |
| D/A converter                   |  | Holds operation (output held) <sup>Note</sup>  |  |
| Real-time output function (RTO) |  | Stops operation (output held)  |  |
| Key interrupt function (KR)     |  | Operable   |  |
| CRC operation circuit           |  | Stops operation  |  |
| External bus interface          |  | See <b>2.2 Pin States</b> .  |  |
| Port function                   |  | Retains status before IDLE1 mode was set   |  |
| Internal data                   |  | The CPU registers, statuses, data, and all other internal data such as the contents of the internal RAM are retained as they were before the IDLE1 mode was set. |  |

**Note** To realize low power consumption, stop the A/D converter and D/A converter before shifting to the IDLE1 mode.

## 21.5 IDLE2 Mode

### 21.5.1 Setting and operation status

The IDLE2 mode is set by setting the PSMR.PSM1 and PSMR.PSM0 bits to 10 and setting the PSC.STP bit to 1 in the normal operation mode.

In the IDLE2 mode, the clock oscillator continues operation but clock supply to the CPU, PLL, flash memory, and other on-chip peripheral functions stops.

As a result, program execution stops and the contents of the internal RAM before the IDLE2 mode was set are retained. The CPU, PLL, and other on-chip peripheral functions stop operating. However, the on-chip peripheral functions that can operate with the subclock or an external clock continue operating.

Table 21-7 shows the operating status in the IDLE2 mode.

The IDLE2 mode can reduce the power consumption more than the IDLE1 mode because it stops the operations of the on-chip peripheral functions, PLL, and flash memory. However, because the PLL and flash memory are stopped, a setup time for the PLL and flash memory is required when IDLE2 mode is released.

- Cautions 1. Insert five or more NOP instructions after the instruction that stores data in the PSC register to set the IDLE2 mode.**
- 2. If the IDLE2 mode is set while an unmasked interrupt request signal is being held pending, the IDLE2 mode is released immediately by the pending interrupt request.**

### 21.5.2 Releasing IDLE2 mode

The IDLE2 mode is released by a non-maskable interrupt request signal (NMI pin input, INTWDT2 signal), unmasked external interrupt request signal (INTP0 to INTP8 pin input), unmasked internal interrupt request signal from the peripheral functions operable in the IDLE2 mode, or reset signal (reset by  $\overline{\text{RESET}}$  pin input, WDT2RES signal, low-voltage detector (LVI), or clock monitor (CLM)). The PLL returns to the operating status it was in before the IDLE2 mode was set.

After the IDLE2 mode has been released, the normal operation mode is restored.

#### (1) Releasing IDLE2 mode by non-maskable interrupt request signal or unmasked maskable interrupt request signal

The IDLE2 mode is released by a non-maskable interrupt request signal or an unmasked maskable interrupt request signal, regardless of the priority of the interrupt request signal. If the IDLE2 mode is set in an interrupt servicing routine, however, an interrupt request signal that is issued later is processed as follows.

- (a) If an interrupt request signal with a priority lower than that of the interrupt request currently being serviced is issued, the IDLE2 mode is released, but that interrupt request signal is not acknowledged. The interrupt request signal itself is retained.
- (b) If an interrupt request signal with a priority higher than that of the interrupt request currently being serviced is issued (including a non-maskable interrupt request signal), the IDLE2 mode is released and that interrupt request signal is acknowledged.

**Caution** The interrupt request signal that is disabled by setting the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits to 1 becomes invalid and IDLE2 mode is not released.

Table 21-6. Operation After Releasing IDLE2 Mode by Interrupt Request Signal

| Release Source                        | Interrupt Enabled (EI) Status   | Interrupt Disabled (DI) Status   |
|---------------------------------------|---|--|
| Non-maskable interrupt request signal | Execution branches to the handler address after securing the prescribed setup time.                                     |  |
| Maskable interrupt request signal     | Execution branches to the handler address or the next instruction is executed after securing the prescribed setup time. | The next instruction is executed after securing the prescribed setup time. |

**(2) Releasing IDLE2 mode by reset**

The same operation as the normal reset operation is performed.

Table 21-7. Operating Status in IDLE2 Mode

| Setting of IDLE2 Mode           |  | Operating Status   |  |
|---------------------------------|--|--|--|
|                                 |  | When Subclock Is Not Used  | When Subclock Is Used  |
| Main clock oscillator           |  | Oscillation enabled  |  |
| Subclock oscillator             |  | –  | Oscillation enabled  |
| Internal oscillator             |  | Oscillation enabled  |  |
| PLL                             |  | Stops operation  |  |
| CPU                             |  | Stops operation  |  |
| DMA                             |  | Stops operation  |  |
| Interrupt controller            |  | Stops operation (but standby mode release is possible)   |  |
| Timer P (TMP0 to TMP8)          |  | Stops operation  |  |
| Timer Q (TMQ0)                  |  | Stops operation  |  |
| Timer M (TMM0)                  |  | Operable when $f_{R/8}$ is selected as the count clock   | Operable when $f_{R/8}$ or $f_{XT}$ is selected as the count clock |
| Watch timer                     |  | Operable when $f_x$ (divided BRG) is selected as the count clock   | Operable   |
| Watchdog timer 2                |  | Operable when $f_R$ is selected as the count clock   | Operable when $f_R$ or $f_{XT}$ is selected as the count clock     |
| Serial interface                | CSIB0 to CSIB5                           | Operable when the $\overline{SCKBn}$ input clock is selected as the count clock ( $n = 0$ to $5$ )   |  |
|                                 | I <sup>2</sup> C00 to I <sup>2</sup> C02 | Stops operation  |  |
|                                 | UARTA0 to UARTA3                         | Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)   |  |
| A/D converter                   |  | Holds operation (conversion result held) <sup>Note</sup>   |  |
| D/A converter                   |  | Holds operation (output held) <sup>Note</sup>  |  |
| Real-time output function (RTO) |  | Stops operation (output held)  |  |
| Key interrupt function (KR)     |  | Operable   |  |
| CRC operation circuit           |  | Stops operation  |  |
| External bus interface          |  | See 2.2 Pin States.  |  |
| Port function                   |  | Retains status before IDLE2 mode was set   |  |
| Internal data                   |  | The CPU registers, statuses, data, and all other internal data such as the contents of the internal RAM are retained as they were before the IDLE2 mode was set. |  |

**Note** To realize low power consumption, stop the A/D converter and D/A converter before shifting to the IDLE2 mode.

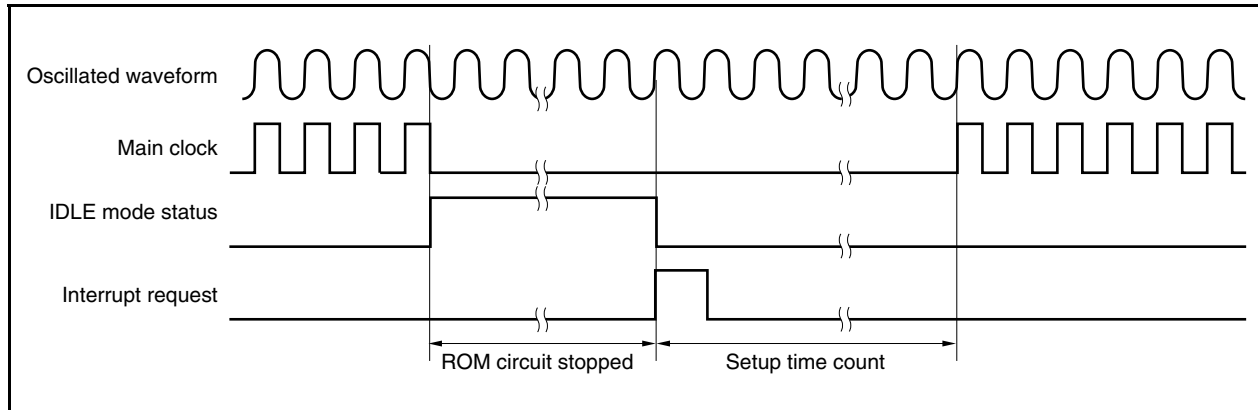
### 21.5.3 Securing setup time when releasing IDLE2 mode

Secure the setup time for the flash memory after releasing the IDLE2 mode because the operation of the blocks other than the main clock oscillator stops after the IDLE2 mode is set.

#### (1) Releasing IDLE2 mode by non-maskable interrupt request signal or unmasked maskable interrupt request signal

Secure the specified setup time by setting the OSTS register.

When the releasing source is generated, the dedicated internal timer starts counting according to the OSTS register setting. When it overflows, the normal operation mode is restored.



#### (2) Release by reset ( $\overline{\text{RESET}}$ pin input, WDT2RES generation)

This operation is the same as that of a normal reset.

The oscillation stabilization time is the initial value of the OSTS register,  $2^{16}/f_x$ .



## 21.6 STOP Mode

### 21.6.1 Setting and operation status

The STOP mode is set by setting the PSMR.PSM1 and PSMR.PSM0 bits to 01 or 11 and setting the PSC.STP bit to 1 in the normal operation mode.

In the STOP mode, the subclock oscillator continues operating but the main clock oscillator stops. Clock supply to the CPU and the on-chip peripheral functions is stopped.

As a result, program execution stops, and the contents of the internal RAM before the STOP mode was set are retained. The on-chip peripheral functions that operate with the clock oscillated by the subclock oscillator or an external clock continue operating.

Table 21-9 shows the operating status in the STOP mode.

Because the STOP mode stops operation of the main clock oscillator, it reduces the power consumption to a level lower than the IDLE2 mode. If the subclock oscillator, internal oscillator, and external clock are not used, the power consumption can be minimized with only leakage current flowing.

- Cautions**
1. Insert five or more NOP instructions after the instruction that stores data in the PSC register to set the STOP mode.
  2. If the STOP mode is set while an unmasked interrupt request signal is being held pending, the STOP mode is released immediately by the pending interrupt request.

### 21.6.2 Releasing STOP mode

The STOP mode is released by a non-maskable interrupt request signal (NMI pin input, INTWDT2 signal), unmasked external interrupt request signal (INTP0 to INTP8 pin input), unmasked internal interrupt request signal from the peripheral functions operable in the STOP mode, or reset signal (reset by  $\overline{\text{RESET}}$  pin input, WDT2RES signal, or low-voltage detector (LVI)).

After the STOP mode has been released, the normal operation mode is restored after the oscillation stabilization time has been secured.

#### (1) Releasing STOP mode by non-maskable interrupt request signal or unmasked maskable interrupt request signal

The STOP mode is released by a non-maskable interrupt request signal or an unmasked maskable interrupt request signal, regardless of the priority of the interrupt request signal. If the STOP mode is set in an interrupt servicing routine, however, an interrupt request signal that is issued later is serviced as follows.

- (a) If an interrupt request signal with a priority lower than that of the interrupt request currently being serviced is issued, the STOP mode is released, but that interrupt request signal is not acknowledged. The interrupt request signal itself is retained.
- (b) If an interrupt request signal with a priority higher than that of the interrupt request currently being serviced is issued (including a non-maskable interrupt request signal), the STOP mode is released and that interrupt request signal is acknowledged.

**Caution** The interrupt request that is disabled by setting the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits to 1 becomes invalid and STOP mode is not released.

**Table 21-8. Operation After Releasing STOP Mode by Interrupt Request Signal**

| Release Source                        | Interrupt Enabled (EI) Status  | Interrupt Disabled (DI) Status  |
|---------------------------------------|--|---|
| Non-maskable interrupt request signal | Execution branches to the handler address after securing the oscillation stabilization time.                                     |   |
| Maskable interrupt request signal     | Execution branches to the handler address or the next instruction is executed after securing the oscillation stabilization time. | The next instruction is executed after securing the oscillation stabilization time. |

**(2) Releasing STOP mode by reset**

The same operation as the normal reset operation is performed.

**Table 21-9. Operating Status in STOP Mode**

| Setting of STOP Mode            |  | Operating Status  |  |
|---------------------------------|--|---|--|
|                                 |  | When Subclock Is Not Used   | When Subclock Is Used  |
| Main clock oscillator           |  | Stops oscillation   |  |
| Subclock oscillator             |  | –   | Oscillation enabled  |
| Internal oscillator             |  | Oscillation enabled   |  |
| PLL                             |  | Stops operation   |  |
| CPU                             |  | Stops operation   |  |
| DMA                             |  | Stops operation   |  |
| Interrupt controller            |  | Stops operation (but standby mode release is possible)  |  |
| Timer P (TMP0 to TMP8)          |  | Stops operation   |  |
| Timer Q (TMQ0)                  |  | Stops operation   |  |
| Timer M (TMM0)                  |  | Operable when $f_{R/8}$ is selected as the count clock  | Operable when $f_{R/8}$ or $f_{XT}$ is selected as the count clock |
| Watch timer                     |  | Stops operation   | Operable when $f_{XT}$ is selected as the count clock              |
| Watchdog timer 2                |  | Operable when $f_R$ is selected as the count clock  | Operable when $f_R$ or $f_{XT}$ is selected as the count clock     |
| Serial interface                | CSIB0 to CSIB5                           | Operable when the $\overline{SCKBn}$ input clock is selected as the count clock ( $n = 0$ to $5$ )  |  |
|                                 | I <sup>2</sup> C00 to I <sup>2</sup> C02 | Stops operation   |  |
|                                 | UARTA0 to UARTA3                         | Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)  |  |
| A/D converter                   |  | Stops operation (conversion result undefined) <sup>Notes 1, 2</sup>   |  |
| D/A converter                   |  | Stops operation <sup>Notes 3, 4</sup> (high impedance is output)  |  |
| Real-time output function (RTO) |  | Stops operation (output held)   |  |
| Key interrupt function (KR)     |  | Operable  |  |
| CRC operation circuit           |  | Stops operation   |  |
| External bus interface          |  | See <b>2.2 Pin States</b> .   |  |
| Port function                   |  | Retains status before STOP mode was set   |  |
| Internal data                   |  | The CPU registers, statuses, data, and all other internal data such as the contents of the internal RAM are retained as they were before the STOP mode was set. |  |

**Notes 1.** If the STOP mode is set while the A/D converter is operating, the A/D converter is automatically stopped and starts operating again after the STOP mode is released. However, in that case, the A/D conversion results after the STOP mode is released are invalid. All the A/D conversion results before the STOP mode is set are invalid.

- 2.** Even if the STOP mode is set while the A/D converter is operating, the power consumption is reduced equivalently to when the A/D converter is stopped before the STOP mode is set.
- 3.** If the STOP mode is set while the D/A converter is operating, the D/A converter is automatically stopped and the pin status becomes high impedance. After the STOP mode is released, D/A conversion resumes, the setting time elapses, and the status returns to the output level before the STOP mode was set.
- 4.** Even if the STOP mode is set while the D/A converter is operating, the power consumption is reduced equivalently to when the D/A converter is stopped before the STOP mode is set.

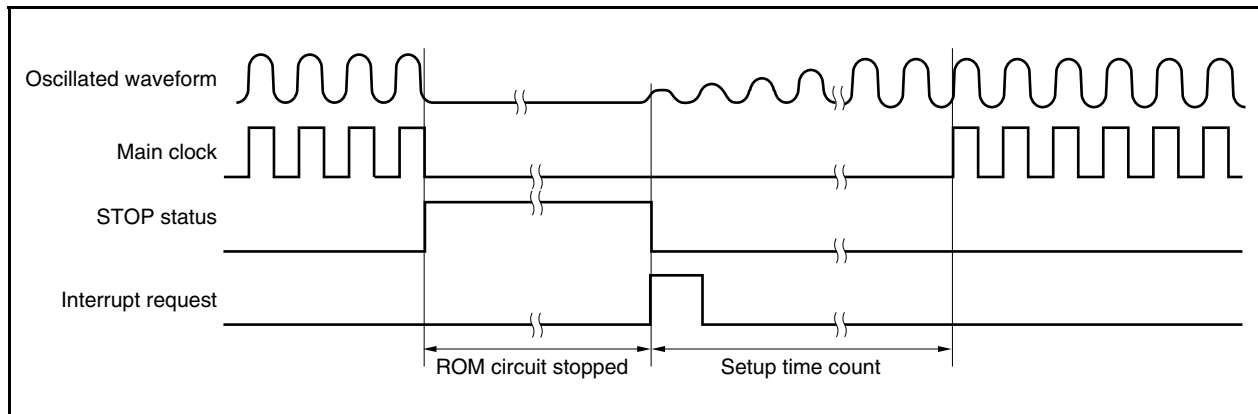
### 21.6.3 Securing oscillation stabilization time when releasing STOP mode

Secure the oscillation stabilization time for the main clock oscillator after releasing the STOP mode because the operation of the main clock oscillator stops after STOP mode is set.

#### (1) Releasing STOP mode by non-maskable interrupt request signal or unmasked maskable interrupt request signal

Secure the oscillation stabilization time by setting the OSTS register.

When the releasing source is generated, the dedicated internal timer starts counting according to the OSTS register setting. When it overflows, the normal operation mode is restored.



#### (2) Release by reset

This operation is the same as that of a normal reset.

The oscillation stabilization time is the initial value of the OSTS register,  $2^{16}/f_x$ .

## 21.7 Subclock Operation Mode

### 21.7.1 Setting and operation status

The subclock operation mode is set by setting the PCC.CK3 bit to 1 in the normal operation mode.

When the subclock operation mode is set, the internal system clock is changed from the main clock to the subclock. Check whether the clock has been switched by using the PCC.CLS bit.

When the PCC.MCK bit is set to 1, the operation of the main clock oscillator is stopped. As a result, the system operates only on the subclock.

In the subclock operation mode, the power consumption can be reduced to a level lower than in the normal operation mode because the subclock is used as the internal system clock. In addition, the power consumption can be further reduced to the level of the STOP mode by stopping the operation of the main clock oscillator.

Table 21-10 shows the operating status in subclock operation mode.

**Cautions** 1. When manipulating the CK3 bit, do not change the set values of the PCC.CK2 to PCC.CK0 bits (using a bit manipulation instruction to manipulate the bit is recommended). For details of the PCC register, see 6.3 (1) Processor clock control register (PCC).

2. If the following conditions are not satisfied, change the CK2 to CK0 bits so that the conditions are satisfied and set the subclock operation mode.

$$\text{Internal system clock (f}_{\text{CLK}}) > \text{Subclock (f}_{\text{XT}} = 32.768 \text{ kHz}) \times 4$$

**Remark** Internal system clock (f<sub>CLK</sub>): Clock generated from main clock (f<sub>XX</sub>) in accordance with the settings of the CK2 to CK0 bits

### 21.7.2 Releasing subclock operation mode

The subclock operation mode is released by a reset signal (reset by  $\overline{\text{RESET}}$  pin input, WDT2RES signal, low-voltage detector (LVI), or clock monitor (CLM)) when the CK3 bit is cleared to 0.

If the main clock is stopped (MCK bit = 1), set the MCK bit to 1, secure the oscillation stabilization time of the main clock by software, and clear the CK3 bit to 0.

The normal operation mode is restored when the subclock operation mode is released.

**Caution** When manipulating the CK3 bit, do not change the set values of the CK2 to CK0 bits (using a bit manipulation instruction to manipulate the bit is recommended).

For details of the PCC register, see 6.3 (1) Processor clock control register (PCC).

Table 21-10. Operating Status in Subclock Operation Mode

| Setting of Subclock Operation Mode<br>Item |  | Operating Status               |   |
|--|--|--------------------------------|---|
|  |  | When Main Clock Is Oscillating | When Main Clock Is Stopped  |
| Subclock oscillator                        |  | Oscillation enabled            |   |
| Internal oscillator                        |  | Oscillation enabled            |   |
| PLL  |  | Operable                       | Stops operation <sup>Note</sup>   |
| CPU  |  | Operable                       |   |
| DMA  |  | Operable                       |   |
| Interrupt controller                       |  | Operable                       |   |
| Timer P (TMP0 to TMP8)                     |  | Operable                       | Stops operation   |
| Timer Q (TMQ0)                             |  | Operable                       | Stops operation   |
| Timer M (TMM0)                             |  | Operable                       | Operable when $f_{R/8}$ or $f_{XT}$ is selected as the count clock                              |
| Watch timer                                |  | Operable                       | Operable when $f_{XT}$ is selected as the count clock   |
| Watchdog timer 2                           |  | Operable                       | Operable when $f_{R}$ or $f_{XT}$ is selected as the count clock                                |
| Serial interface                           | CSIB0 to CSIB5                           | Operable                       | Operable when the $\overline{SCKBn}$ input clock is selected as the count clock ( $n = 0$ to 5) |
|  | I <sup>2</sup> C00 to I <sup>2</sup> C02 | Operable                       | Stops operation   |
|  | UARTA0 to UARTA3                         | Operable                       | Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)                |
| A/D converter                              |  | Operable                       | Stops operation   |
| D/A converter                              |  | Operable                       |   |
| Real-time output function (RTO)            |  | Operable                       | Stops operation (output held)   |
| Key interrupt function (KR)                |  | Operable                       |   |
| CRC operation circuit                      |  | Operable                       |   |
| External bus interface                     |  | See 2.2 Pin States.            |   |
| Port function                              |  | Settable                       |   |
| Internal data                              |  | Settable                       |   |

**Note** Be sure to stop the PLL (PLLCTL.PLLON bit = 0) before stopping the main clock.

**Caution** When the CPU is operating on the subclock and main clock oscillation is stopped, accessing a register in which a wait occurs is disabled. If a wait is generated, it can be released only by reset (see 3.4.8 (2)).

## 21.8 Sub-IDLE Mode

### 21.8.1 Setting and operation status

The sub-IDLE mode is set by setting the PSMR.PSM1 and PSMR.PSM0 bits to 00 or 10 and setting the PSC.STP bit to 1 in the subclock operation mode.

In this mode, the clock oscillator continues operating but clock supply to the CPU, flash memory, and the other on-chip peripheral functions is stopped.

As a result, program execution stops and the contents of the internal RAM before the sub-IDLE mode was set are retained. The CPU and the other on-chip peripheral functions are stopped. However, the on-chip peripheral functions that can operate with the subclock or an external clock continue operating.

Because the sub-IDLE mode stops operation of the CPU, flash memory, and other on-chip peripheral functions, it can reduce the power consumption more than the subclock operation mode. If the sub-IDLE mode is set after the main clock has been stopped, the current consumption can be reduced to a level as low as that in the STOP mode.

Table 21-12 shows the operating status in the sub-IDLE mode.

- Cautions**
1. **Following the store instruction to the PSC register for setting the sub-IDLE mode, insert the five or more NOP instructions.**
  2. **If the sub-IDLE mode is set while an unmasked interrupt request signal is being held pending, the sub-IDLE mode is then released immediately by the pending interrupt request.**

### 21.8.2 Releasing sub-IDLE mode

The sub-IDLE mode is released by a non-maskable interrupt request signal (NMI pin input, INTWDT2 signal), unmasked external interrupt request signal (INTP0 to INTP8 pin input), unmasked internal interrupt request signal from the peripheral functions operable in the sub-IDLE mode, or reset signal (reset by  $\overline{\text{RESET}}$  pin input, WDT2RES signal, low-voltage detector (LVI), or clock monitor (CLM)). The PLL returns to the operating status it was in before the sub-IDLE mode was set.

When the sub-IDLE mode is released by an interrupt request signal, the subclock operation mode is set.

#### (1) Releasing sub-IDLE mode by non-maskable interrupt request signal or unmasked maskable interrupt request signal

The sub-IDLE mode is released by a non-maskable interrupt request signal or an unmasked maskable interrupt request signal, regardless of the priority of the interrupt request signal.

If the sub-IDLE mode is set in an interrupt servicing routine, however, an interrupt request signal that is issued later is serviced as follows.

- (a) If an interrupt request signal with a priority lower than that of the interrupt request currently being serviced is issued, the sub-IDLE mode is released, but that interrupt request signal is not acknowledged. The interrupt request signal itself is retained.
- (b) If an interrupt request signal with a priority higher than that of the interrupt request currently being serviced is issued (including a non-maskable interrupt request signal), the sub-IDLE mode is released and that interrupt request signal is acknowledged.

- Cautions**
1. **The interrupt request signal that is disabled by setting the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits to 1 becomes invalid and sub-IDLE mode is not released.**
  2. **When the sub-IDLE mode is released, 12 cycles of the subclock (about 366  $\mu\text{s}$ ) elapse from when the interrupt request signal that releases the sub-IDLE mode is generated to when the mode is released.**

**Table 21-11. Operation After Releasing Sub-IDLE Mode by Interrupt Request Signal**

| Release Source                        | Interrupt Enabled (EI) Status  | Interrupt Disabled (DI) Status    |
|---------------------------------------|--|-----------------------------------|
| Non-maskable interrupt request signal | Execution branches to the handler address.                                     |                                   |
| Maskable interrupt request signal     | Execution branches to the handler address or the next instruction is executed. | The next instruction is executed. |

**(2) Releasing sub-IDLE mode by reset**

The same operation as the normal reset operation is performed.

**Table 21-12. Operating Status in Sub-IDLE Mode**

| Setting of Sub-IDLE Mode<br>Item | Operating Status  |  |
|----------------------------------|---|--|
|                                  | When Main Clock Is Oscillating  | When Main Clock Is Stopped   |
| Subclock oscillator              | Oscillation enabled   |  |
| Internal oscillator              | Oscillation enabled   |  |
| PLL                              | Operable  | Stops operation <sup>Note 1</sup>  |
| CPU                              | Stops operation   |  |
| DMA                              | Stops operation   |  |
| Interrupt controller             | Stops operation (but standby mode release is possible)  |  |
| Timer P (TMP0 to TMP8)           | Stops operation   |  |
| Timer Q (TMQ0)                   | Stops operation   |  |
| Timer M (TMM0)                   | Operable when $f_{R/8}$ or $f_{XT}$ is selected as the count clock  |  |
| Watch timer                      | Stops operation   | Operable when $f_{XT}$ is selected as the count clock  |
| Watchdog timer 2                 | Operable when $f_R$ or $f_{XT}$ is selected as the count clock  |  |
| Serial interface                 | CSIB0 to CSIB5  | Operable when the $\overline{SCKBn}$ input clock is selected as the count clock (n = 0 to 5) |
|                                  | I <sup>2</sup> C00 to I <sup>2</sup> C02  | Stops operation  |
|                                  | UARTA0 to UARTA3  | Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)             |
| A/D converter                    | Holds operation (conversion result held) <sup>Note 2</sup>  |  |
| D/A converter                    | Holds operation (output held) <sup>Note 2</sup>   |  |
| Real-time output function (RTO)  | Stops operation (output held)   |  |
| Key interrupt function (KR)      | Operable  |  |
| CRC operation circuit            | Stops operation   |  |
| External bus interface           | See <b>2.2 Pin States</b> (same operation status as IDLE1, IDLE2 mode).   |  |
| Port function                    | Retains status before sub-IDLE mode was set   |  |
| Internal data                    | The CPU registers, statuses, data, and all other internal data such as the contents of the internal RAM are retained as they were before the sub-IDLE mode was set. |  |

**Notes 1.** Be sure to stop the PLL (PLLCTL.PLLON bit = 0) before stopping the main clock.

**2.** To realize low power consumption, stop the A/D and D/A converters before shifting to the sub-IDLE mode.





## 22.2 Registers to Check Reset Source

The V850ES/JJ3 has four kinds of reset sources. After a reset has been released, the source of the reset that occurred can be checked with the reset source flag register (RESF).

### (1) Reset source flag register (RESF)

The RESF register is a special register that can be written only by a combination of specific sequences (see **3.4.7 Special registers**).

The RESF register indicates the source from which a reset signal is generated.

This register is read or written in 8-bit or 1-bit units.

$\overline{\text{RESET}}$  pin input clears this register to 00H. The default value differs if the source of reset is other than the  $\overline{\text{RESET}}$  pin signal.

After reset: 00H<sup>Note</sup> R/W Address: FFFF888H

|      |   |   |   |        |   |   |       |       |
|------|---|---|---|--------|---|---|-------|-------|
|      | 7 | 6 | 5 | 4      | 3 | 2 | 1     | 0     |
| RESF | 0 | 0 | 0 | WDT2RF | 0 | 0 | CLMRF | LVIRF |

|        |                        |
|--------|------------------------|
| WDT2RF | Reset signal from WDT2 |
| 0      | Not generated          |
| 1      | Generated              |

|       |                       |
|-------|-----------------------|
| CLMRF | Reset signal from CLM |
| 0     | Not generated         |
| 1     | Generated             |

|       |                       |
|-------|-----------------------|
| LVIRF | Reset signal from LVI |
| 0     | Not generated         |
| 1     | Generated             |

**Note** The value of the RESF register is cleared to 00H when a reset is executed via the  $\overline{\text{RESET}}$  pin. When a reset is executed by the watchdog timer 2 (WDT2), low-voltage detector (LVI), or clock monitor (CLM), the reset flags of this register (WDT2RF bit, CLMRF bit, and LVIRF bit) are set. However, other sources are retained.

**Caution** Only "0" can be written to each bit of this register. If writing "0" conflicts with setting the flag (occurrence of reset), setting the flag takes precedence.

## 22.3 Operation

### 22.3.1 Reset operation via $\overline{\text{RESET}}$ pin

When a low level is input to the  $\overline{\text{RESET}}$  pin, the system is reset, and each hardware unit is initialized.

When the level of the  $\overline{\text{RESET}}$  pin is changed from low to high, the reset status is released.

**Table 22-1. Hardware Status on  $\overline{\text{RESET}}$  Pin Input**

| Item  | During Reset  | After Reset   |
|---|---|---|
| Main clock oscillator ( $f_x$ )                                 | Oscillation stops   | Oscillation starts  |
| Subclock oscillator ( $f_{XT}$ )                                | Oscillation continues   |   |
| Internal oscillator   | Oscillation stops   | Oscillation starts  |
| Peripheral clock ( $f_x$ to $f_x/1,024$ )                       | Operation stops   | Operation starts after securing oscillation stabilization time                              |
| Internal system clock ( $f_{CLK}$ ),<br>CPU clock ( $f_{CPU}$ ) | Operation stops   | Operation starts after securing oscillation stabilization time (initialized to $f_{XX}/8$ ) |
| CPU   | Initialized   | Program execution starts after securing oscillation stabilization time                      |
| Watchdog timer 2  | Operation stops (initialized to 0)  | Counts up from 0 with internal oscillation clock as source clock.                           |
| Internal RAM  | Undefined if power-on reset or CPU access and reset input conflict (data is damaged).<br>Otherwise value immediately after reset input is retained. |   |
| I/O lines (ports/alternate-function pins)                       | High impedance <sup>Note</sup>  |   |
| On-chip peripheral I/O registers                                | Initialized to specified status, OCDM register is set (01H).  |   |
| Other on-chip peripheral functions                              | Operation stops   | Operation can be started after securing oscillation stabilization time                      |

**Note** When the power is turned on, the following pin may output an undefined level temporarily, even during reset.

- P53/SIB2/KR3/TIQ00/TOQ00/RTP03/DDO pin

**Caution** The OCDM register is initialized by the  $\overline{\text{RESET}}$  pin input. Therefore, note with caution that, if a high level is input to the P05/ $\overline{\text{DRST}}$  pin after a reset release before the OCDM.OCDM0 bit is cleared, the on-chip debug mode is entered. For details, see CHAPTER 4 PORT FUNCTIONS.

Figure 22-2. Timing of Reset Operation by  $\overline{\text{RESET}}$  Pin Input

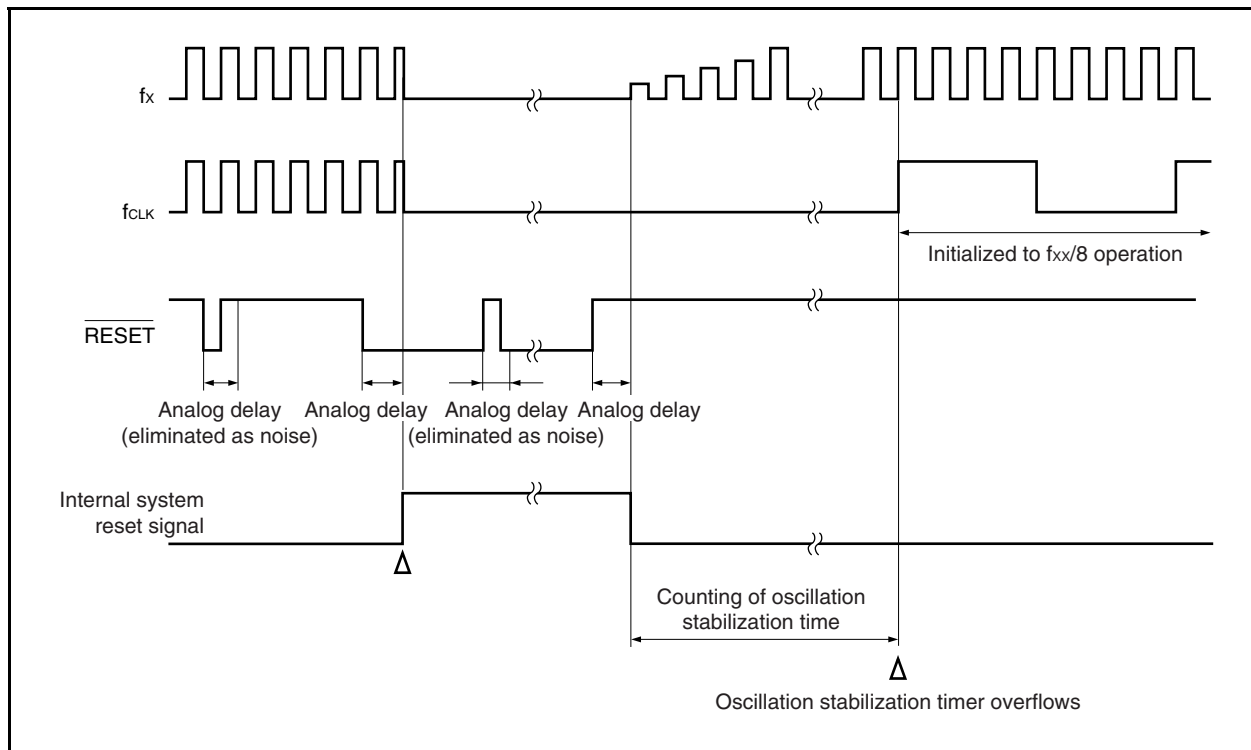
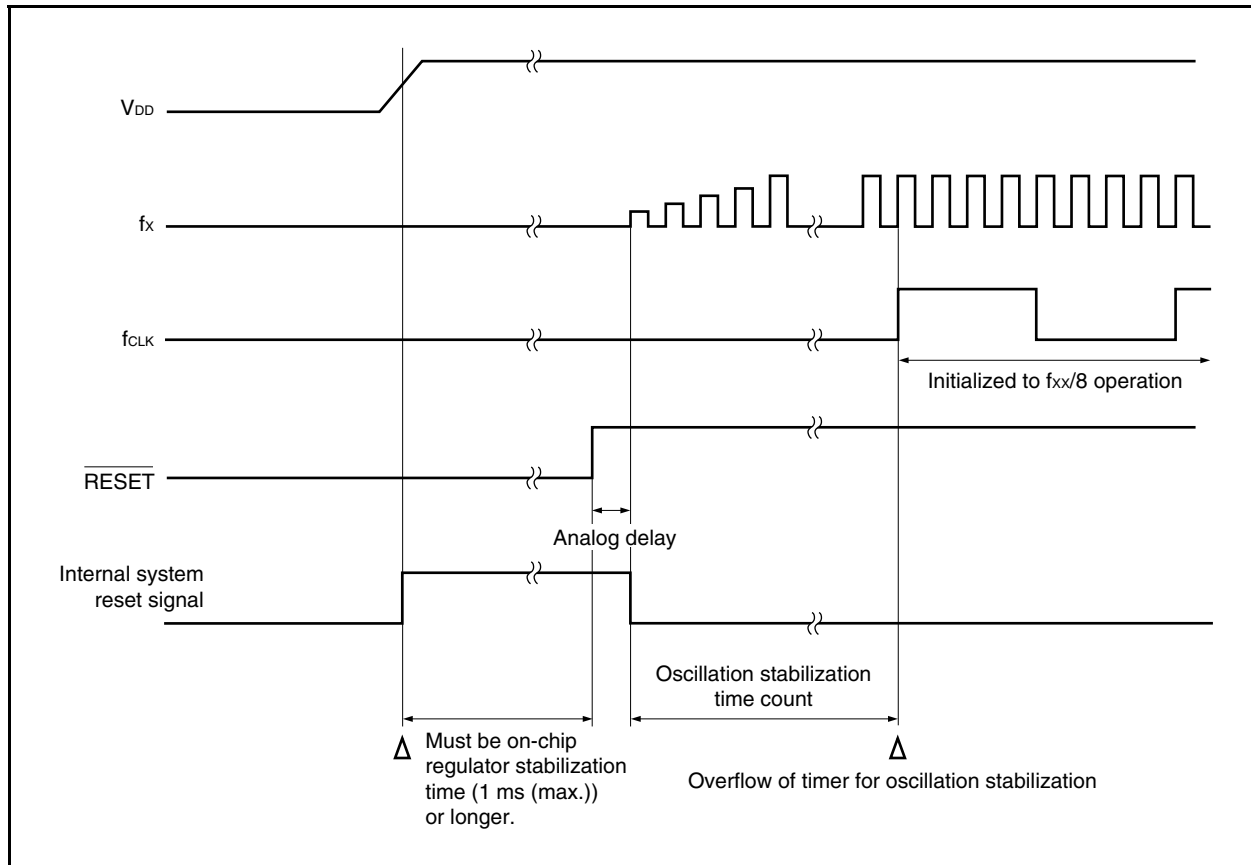


Figure 22-3. Timing of Power-on Reset Operation



### 22.3.2 Reset operation by watchdog timer 2

When watchdog timer 2 is set to the reset operation mode due to overflow, upon watchdog timer 2 overflow (WDT2RES signal generation), a system reset is executed and the hardware is initialized to the initial status.

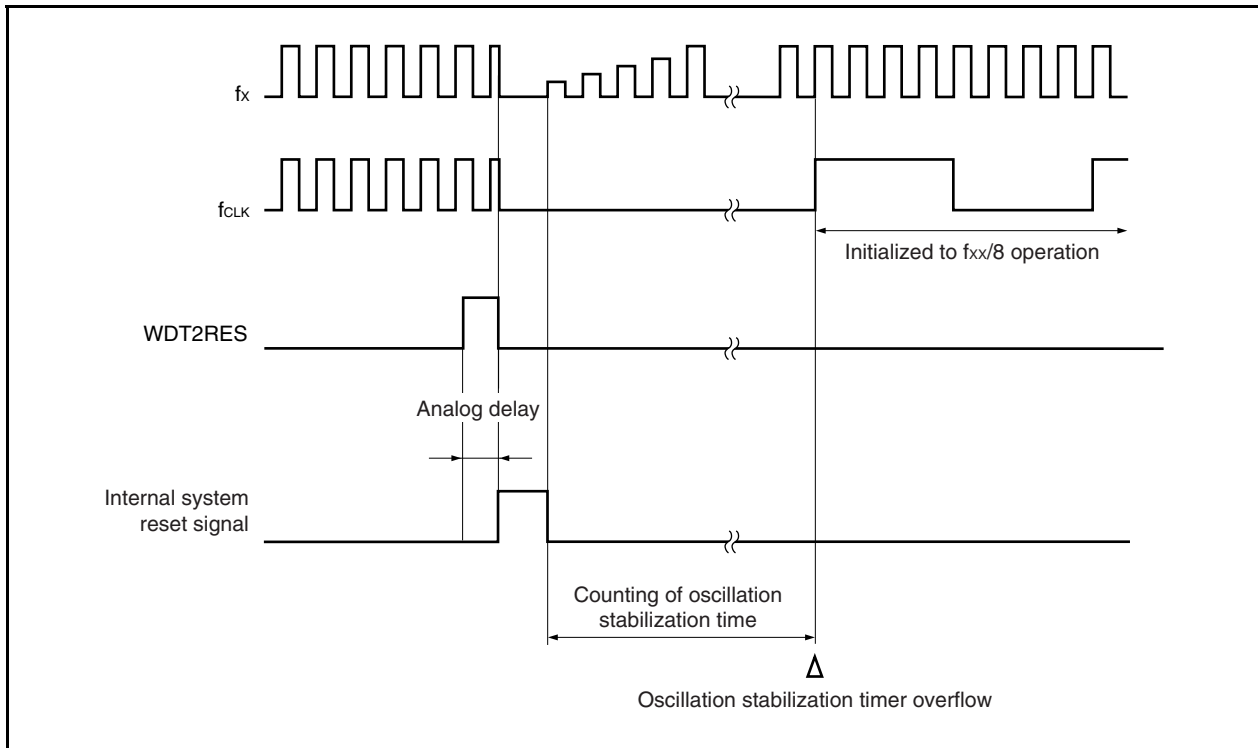
Following watchdog timer 2 overflow, the reset status is entered and lasts the predetermined time (analog delay), and the reset status is then automatically released.

The main clock oscillator is stopped during the reset period.

**Table 22-2. Hardware Status During Watchdog Timer 2 Reset Operation**

| Item   | During Reset   | After Reset   |
|--|--|---|
| Main clock oscillator (fx)                       | Oscillation stops  | Oscillation starts  |
| Subclock oscillator (fxT)                        | Oscillation continues  |   |
| Internal oscillator                              | Oscillation stops  | Oscillation starts  |
| Peripheral clock (fxx to fxx/1,024)              | Operation stops  | Operation starts after securing oscillation stabilization time                        |
| Internal system clock (fxx),<br>CPU clock (fCPU) | Operation stops  | Operation starts after securing oscillation stabilization time (initialized to fXX/8) |
| CPU  | Initialized  | Program execution after securing oscillation stabilization time                       |
| Watchdog timer 2                                 | Operation stops (initialized to 0)   | Counts up from 0 with internal oscillation clock as source clock.                     |
| Internal RAM                                     | Undefined if power-on reset or CPU access and reset input conflict (data is damaged). Otherwise value immediately after reset input is retained. |   |
| I/O lines (ports/alternate-function pins)        | High impedance   |   |
| On-chip peripheral I/O register                  | Initialized to specified status, OCDM register retains its value.  |   |
| On-chip peripheral functions other than above    | Operation stops  | Operation can be started after securing oscillation stabilization time.               |

Figure 22-4. Timing of Reset Operation by WDT2RES Signal Generation



### 22.3.3 Reset operation by low-voltage detector

If the supply voltage falls below the voltage detected by the low-voltage detector when LVI operation is enabled, a system reset is executed (when the LVIM.LVIMD bit is set to 1), and the hardware is initialized to the initial status.

The reset status lasts from when a supply voltage drop has been detected until the supply voltage rises above the LVI detection voltage.

The main clock oscillator is stopped during the reset period.

When the LVIMD bit = 0, an interrupt request signal (INTLVI) is generated if a low voltage is detected.

**Table 22-3. Hardware Status During Reset Operation by Low-Voltage Detector**

| Item   | During Reset   | After Reset   |
|--|--|---|
| Main clock oscillator ( $f_x$ )                                | Oscillation stops  | Oscillation starts  |
| Subclock oscillator ( $f_{XT}$ )                               | Oscillation continues  |   |
| Internal oscillator  | Oscillation stops  | Oscillation starts  |
| Peripheral clock ( $f_x$ to $f_x/1,024$ )                      | Operation stops  | Operation starts after securing oscillation stabilization time                              |
| Internal system clock ( $f_{XX}$ ),<br>CPU clock ( $f_{CPU}$ ) | Operation stops  | Operation starts after securing oscillation stabilization time (initialized to $f_{XX}/8$ ) |
| CPU  | Initialized  | Program execution starts after securing oscillation stabilization time                      |
| WDT2   | Operation stops (initialized to 0)   | Counts up from 0 with internal oscillation clock as source clock.                           |
| Internal RAM   | Undefined if power-on reset or CPU access and reset input conflict (data is damaged). Otherwise value immediately after reset input is retained. |   |
| I/O lines (ports/alternate-function pins)                      | High impedance   |   |
| On-chip peripheral I/O register                                | Initialized to specified status, OCDM register retains its value.  |   |
| LVI  | Operation continues  |   |
| On-chip peripheral functions other than above                  | Operation stops  | Operation can be started after securing oscillation stabilization time.                     |

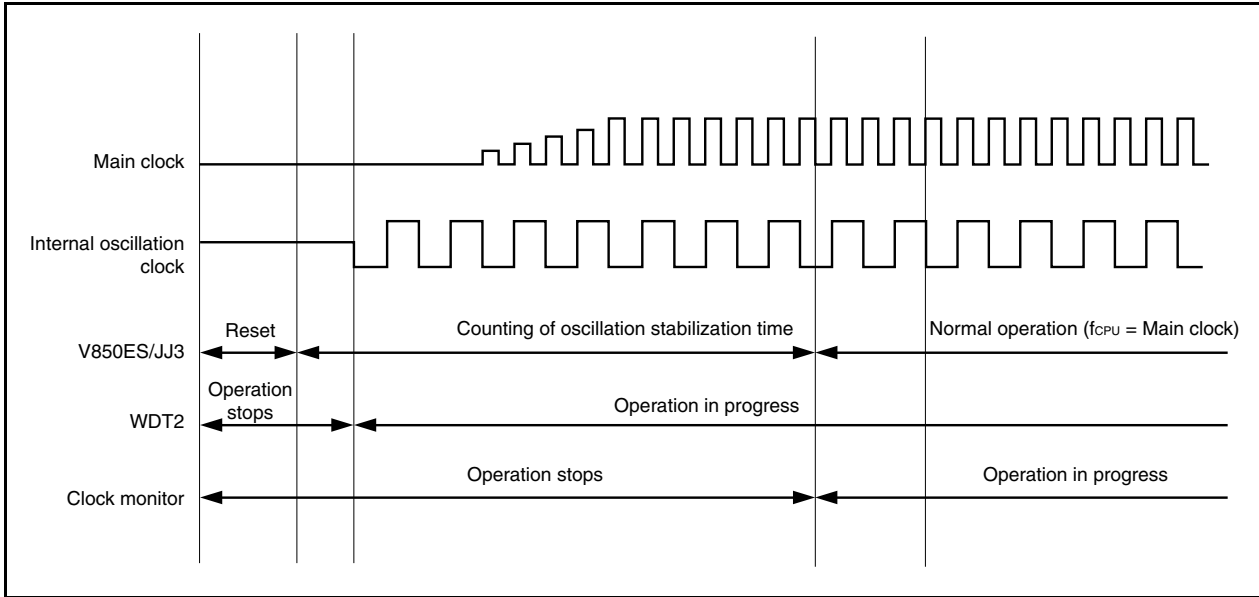
**Remark** For the reset timing of the low-voltage detector, see **CHAPTER 24 LOW-VOLTAGE DETECTOR (LVI)**.

**22.3.4 Operation after reset release**

After the reset is released, the main clock starts oscillation and oscillation stabilization time (OSTS register initial value:  $2^{16}/f_x$ ) is secured, and the CPU starts program execution.

WDT2 immediately begins to operate after a reset has been released using the internal oscillation clock as a source clock.

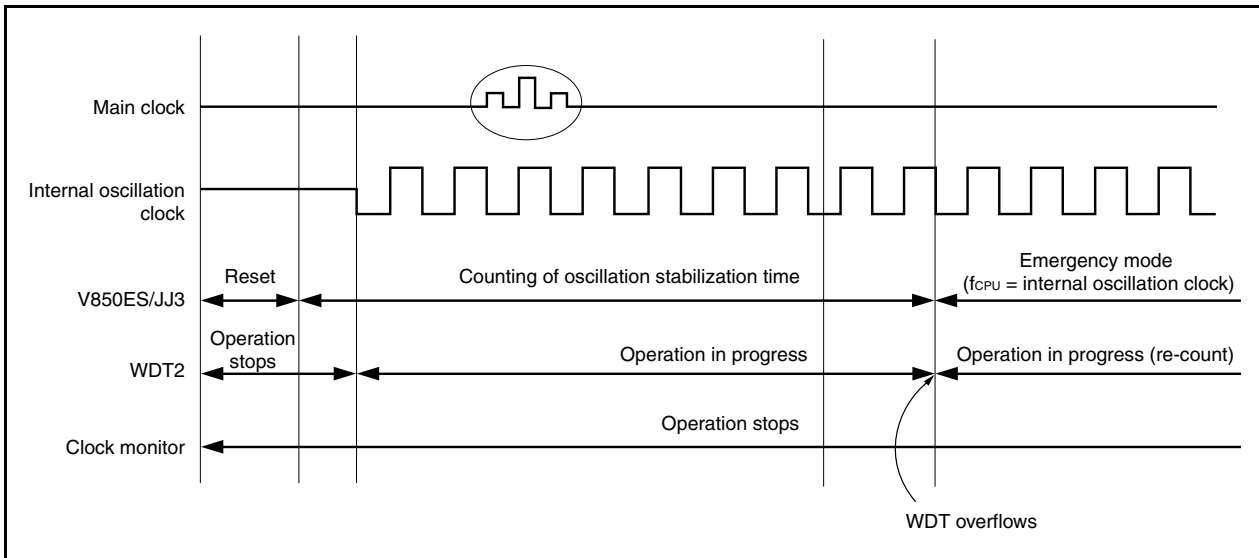
**Figure 22-5. Operation After Reset Release**



**(1) Emergent operation mode**

If an anomaly occurs in the main clock before oscillation stabilization time is secured, WDT2 overflows before executing the CPU program. At this time, the CPU starts program execution by using the internal oscillation clock as the source clock.

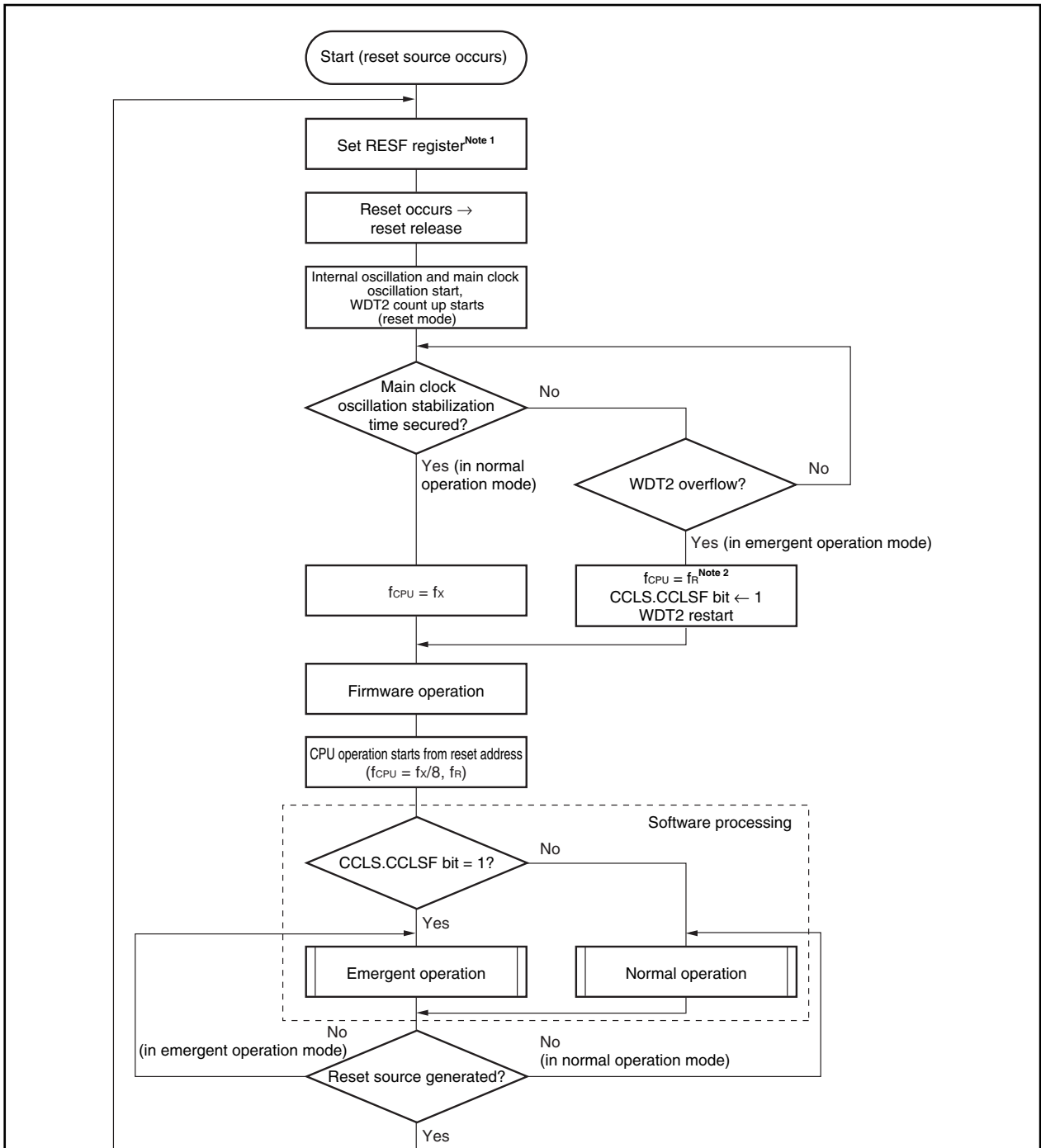
**Figure 22-6. Operation After Reset Release**



The CPU operation clock states can be checked with the CPU operation clock status register (CCLS).



22.3.5 Reset function operation flow



**Notes 1.** Bit to be set differs depending on the reset source.

| Reset Source | WDT2RF Bit                      | CRMRF Bit                       | LVIRF Bit                       |
|--------------|---------------------------------|---------------------------------|---------------------------------|
| RESET pin    | 0                               | 0                               | 0                               |
| WDT2         | 1                               | Value before reset is retained. | Value before reset is retained. |
| CLM          | Value before reset is retained. | 1                               | Value before reset is retained. |
| LVI          | Value before reset is retained. | Value before reset is retained. | 1                               |

**2.** The internal oscillator cannot be stopped.

## CHAPTER 23 CLOCK MONITOR

### 23.1 Functions

The clock monitor samples the main clock by using the internal oscillation clock and generates a reset request signal when oscillation of the main clock is stopped.

Once the operation of the clock monitor has been enabled by an operation enable flag, it cannot be cleared to 0 by any means other than reset.

When a reset by the clock monitor occurs, the RESF.CLMRF bit is set. For details on the RESF register, see **22.2 Registers to Check Reset Source**.

The clock monitor automatically stops under the following conditions.

- During oscillation stabilization time after STOP mode is released
- When the main clock is stopped (from when the PCC.MCK bit = 1 during subclock operation, until the PCC.CLS bit = 0 during main clock operation)
- When the sampling clock (internal oscillation clock) is stopped
- When the CPU operates with the internal oscillation clock

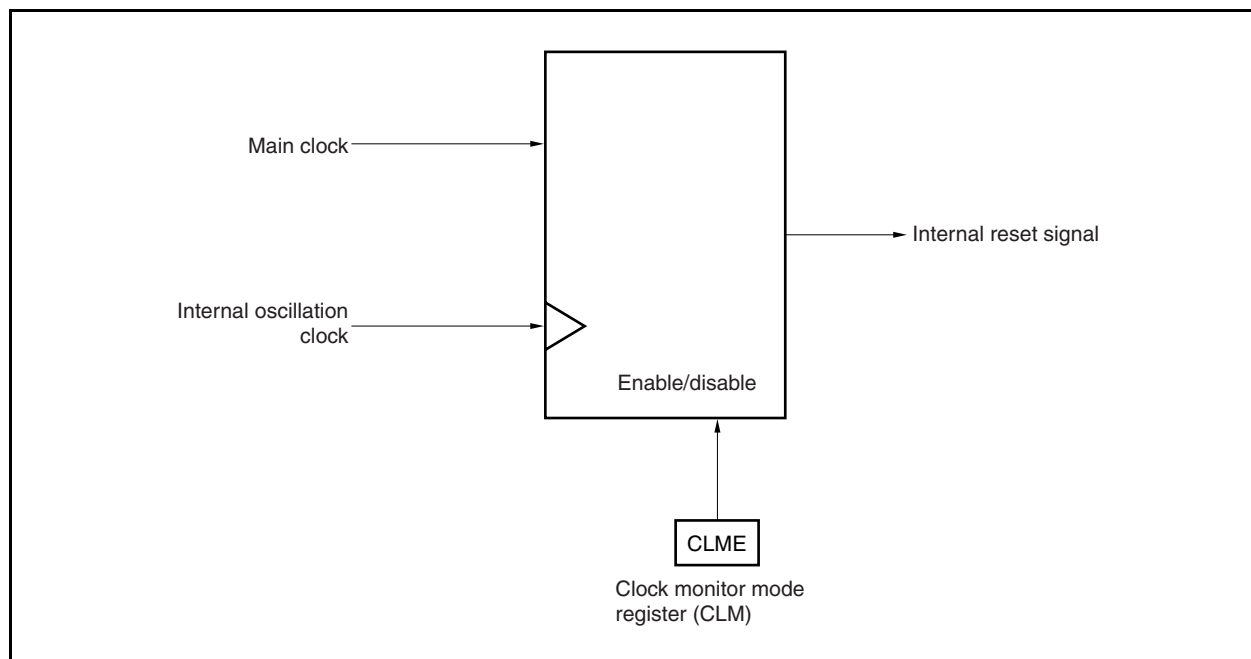
### 23.2 Configuration

The clock monitor includes the following hardware.

**Table 23-1. Configuration of Clock Monitor**

| Item             | Configuration                     |
|------------------|-----------------------------------|
| Control register | Clock monitor mode register (CLM) |

**Figure 23-1. Timing of Reset via the  $\overline{\text{RESET}}$  Pin Input**



## 23.3 Register

The clock monitor is controlled by the clock monitor mode register (CLM).

### (1) Clock monitor mode register (CLM)

The CLM register is a special register. This can be written only in a special combination of sequences (see **3.4.7 Special registers**).

This register is used to set the operation mode of the clock monitor.

This register can be read or written in 8-bit or 1-bit units.

Reset sets this register to 00H.

|     |                  |   |                    |   |   |   |   |      |
|-----|------------------|---|--------------------|---|---|---|---|------|
|     | After reset: 00H | R/W                                       | Address: FFFFF870H |   |   |   |   |      |
|     | 7                | 6   | 5                  | 4 | 3 | 2 | 1 | <0>  |
| CLM | 0                | 0   | 0                  | 0 | 0 | 0 | 0 | CLME |
|     | CLME             | Clock monitor operation enable or disable |                    |   |   |   |   |      |
|     | 0                | Disable clock monitor operation.          |                    |   |   |   |   |      |
|     | 1                | Enable clock monitor operation.           |                    |   |   |   |   |      |

- Cautions**
1. Once the CLME bit has been set to 1, it cannot be cleared to 0 by any means other than reset.
  2. When a reset by the clock monitor occurs, the CLME bit is cleared to 0 and the RESF.CLMRF bit is set to 1.

## 23.4 Operation

This section explains the functions of the clock monitor. The start and stop conditions are as follows.

### <Start condition>

Enabling operation by setting the CLM.CLME bit to 1

### <Stop conditions>

- While oscillation stabilization time is being counted after STOP mode is released
- When the main clock is stopped (from when PCC.MCK bit = 1 during subclock operation to when PCC.CLS bit = 0 during main clock operation)
- When the sampling clock (internal oscillation clock) is stopped
- When the CPU operates using the internal oscillation clock

**Table 23-2. Operation Status of Clock Monitor  
(When CLM.CLME Bit = 1, During Internal Oscillation Clock Operation)**

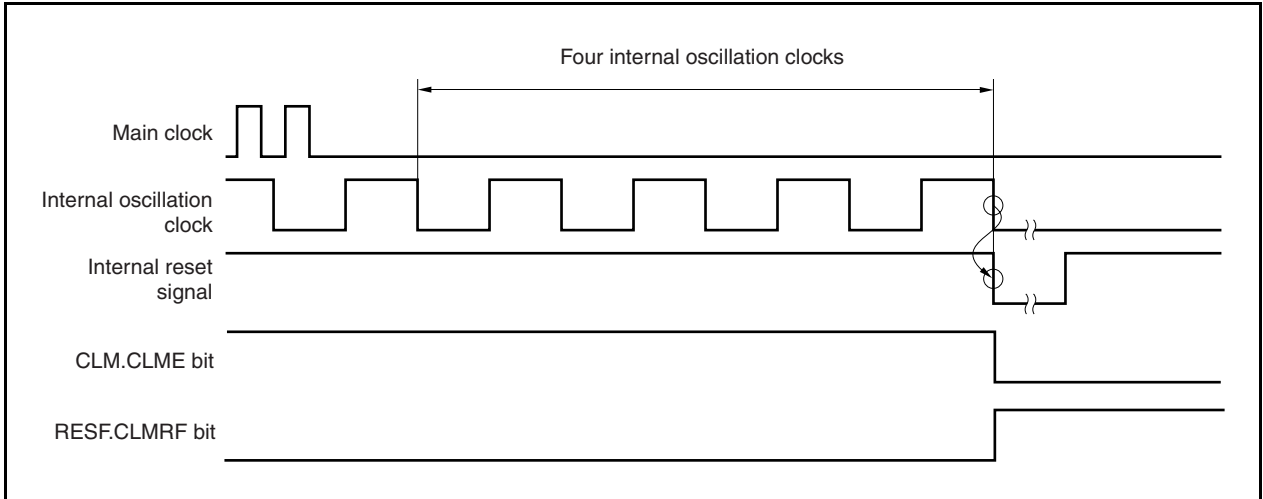
| CPU Operating Clock                    | Operation Mode     | Status of Main Clock | Status of Internal Oscillation Clock | Status of Clock Monitor    |
|--|--------------------|----------------------|--------------------------------------|----------------------------|
| Main clock                             | HALT mode          | Oscillates           | Oscillates <sup>Note 1</sup>         | Operates <sup>Note 2</sup> |
|  | IDLE1, IDLE2 modes | Oscillates           | Oscillates <sup>Note 1</sup>         | Operates <sup>Note 2</sup> |
|  | STOP mode          | Stops                | Oscillates <sup>Note 1</sup>         | Stops                      |
| Subclock (MCK bit of PCC register = 0) | Sub-IDLE mode      | Oscillates           | Oscillates <sup>Note 1</sup>         | Operates <sup>Note 2</sup> |
| Subclock (MCK bit of PCC register = 1) | Sub-IDLE mode      | Stops                | Oscillates <sup>Note 1</sup>         | Stops                      |
| Internal oscillation clock             | –                  | Stops                | Oscillates <sup>Note 3</sup>         | Stops                      |
| During reset                           | –                  | Stops                | Stops                                | Stops                      |

- Notes**
1. The internal oscillator can be stopped by setting the RCM.RSTOP bit to 1.
  2. The clock monitor is stopped while the internal oscillator is stopped.
  3. The internal oscillator cannot be stopped by software.

**(1) Operation when main clock oscillation is stopped (CLME bit = 1)**

If oscillation of the main clock is stopped when the CLME bit = 1, an internal reset signal is generated as shown in Figure 23-2.

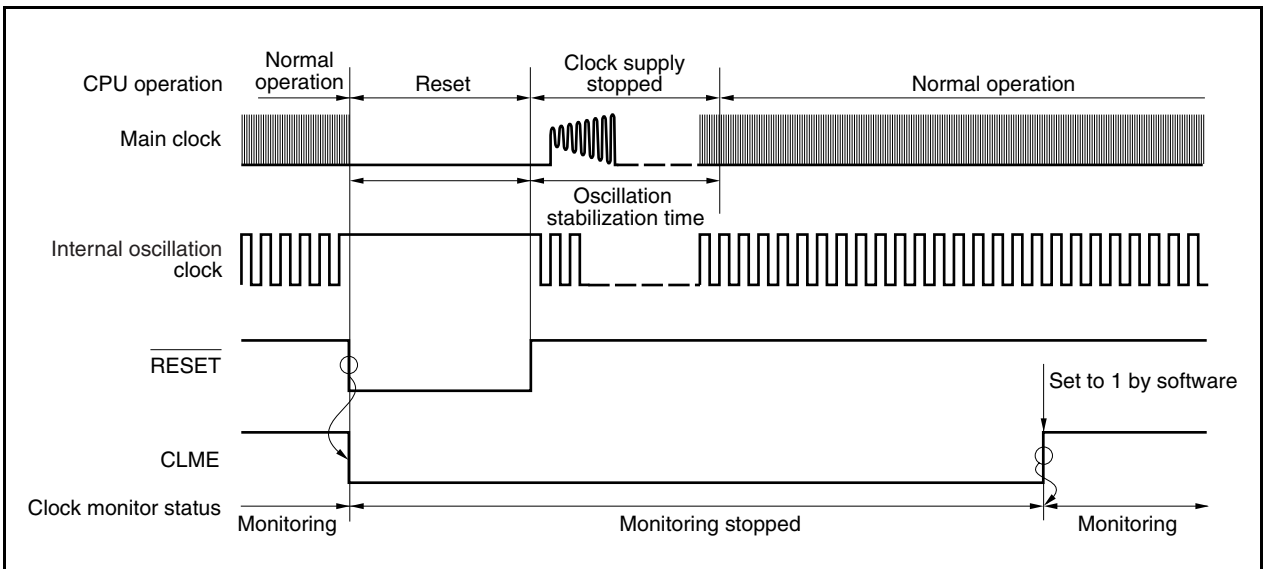
**Figure 23-2. Reset Period Due to That Oscillation of Main Clock Is Stopped**



**(2) Clock monitor status after  $\overline{\text{RESET}}$  input**

$\overline{\text{RESET}}$  input clears the CLM.CLME bit to 0 and stops the clock monitor operation. When CLME bit is set to 1 by software at the end of the oscillation stabilization time of the main clock, monitoring is started.

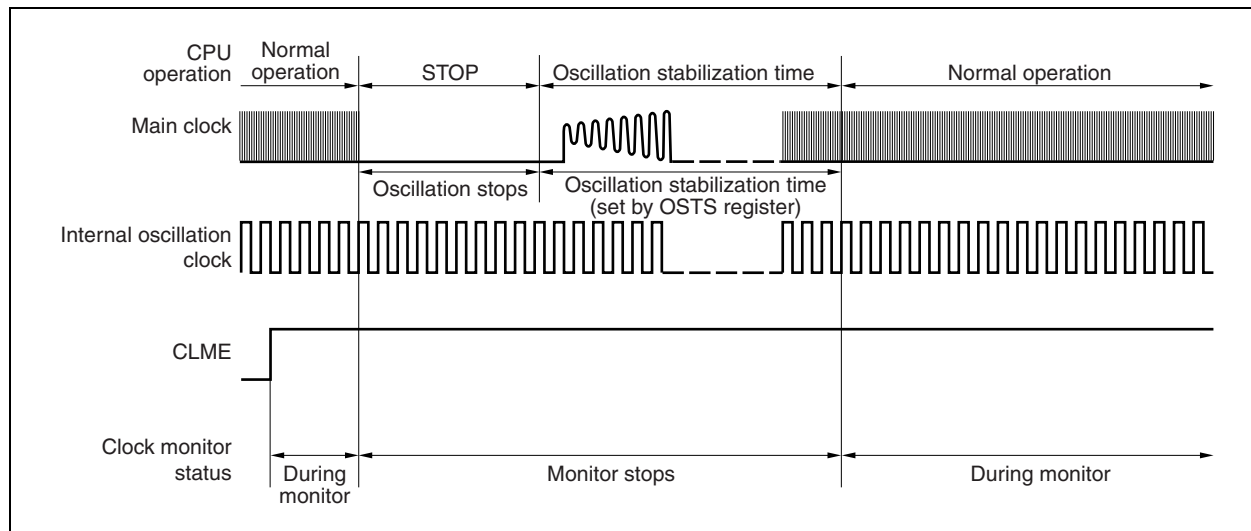
**Figure 23-3. Clock Monitor Status After  $\overline{\text{RESET}}$  Input  
(CLM.CLME bit = 1 is set after  $\overline{\text{RESET}}$  input and at the end of main clock oscillation stabilization time)**



**(3) Operation in STOP mode or after STOP mode is released**

If the STOP mode is set with the CLM.CLME bit = 1, the monitor operation is stopped in the STOP mode and while the oscillation stabilization time is being counted. After the oscillation stabilization time, the monitor operation is automatically started.

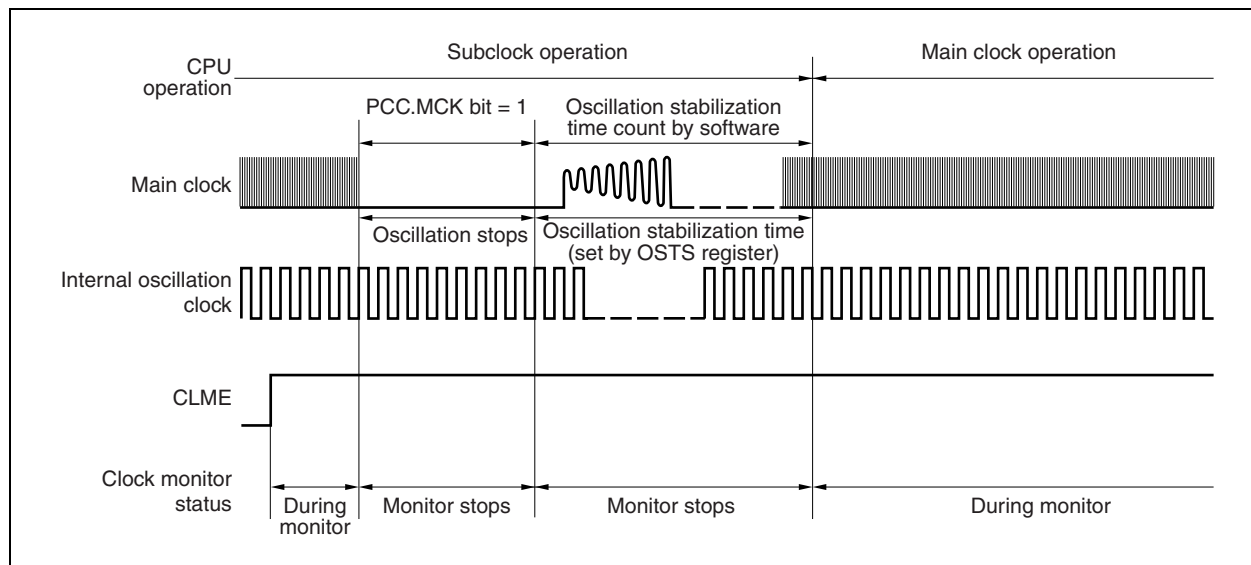
**Figure 23-4. Operation in STOP Mode or After STOP Mode Is Released**



**(4) Operation when main clock is stopped (arbitrary)**

During subclock operation (PCC.CLS bit = 1) or when the main clock is stopped by setting the PCC.MCK bit to 1, the monitor operation is stopped until the main clock operation is started (PCC.CLS bit = 0). The monitor operation is automatically started when the main clock operation is started.

**Figure 23-5. Operation When Main Clock Is Stopped (Arbitrary)**



**(5) Operation while CPU is operating on internal oscillation clock (CCLS.CCLS bit = 1)**

The monitor operation is not stopped when the CCLS bit is 1, even if the CLME bit is set to 1.

## CHAPTER 24 LOW-VOLTAGE DETECTOR (LVI)

### 24.1 Functions

The low-voltage detector (LVI) has the following functions.

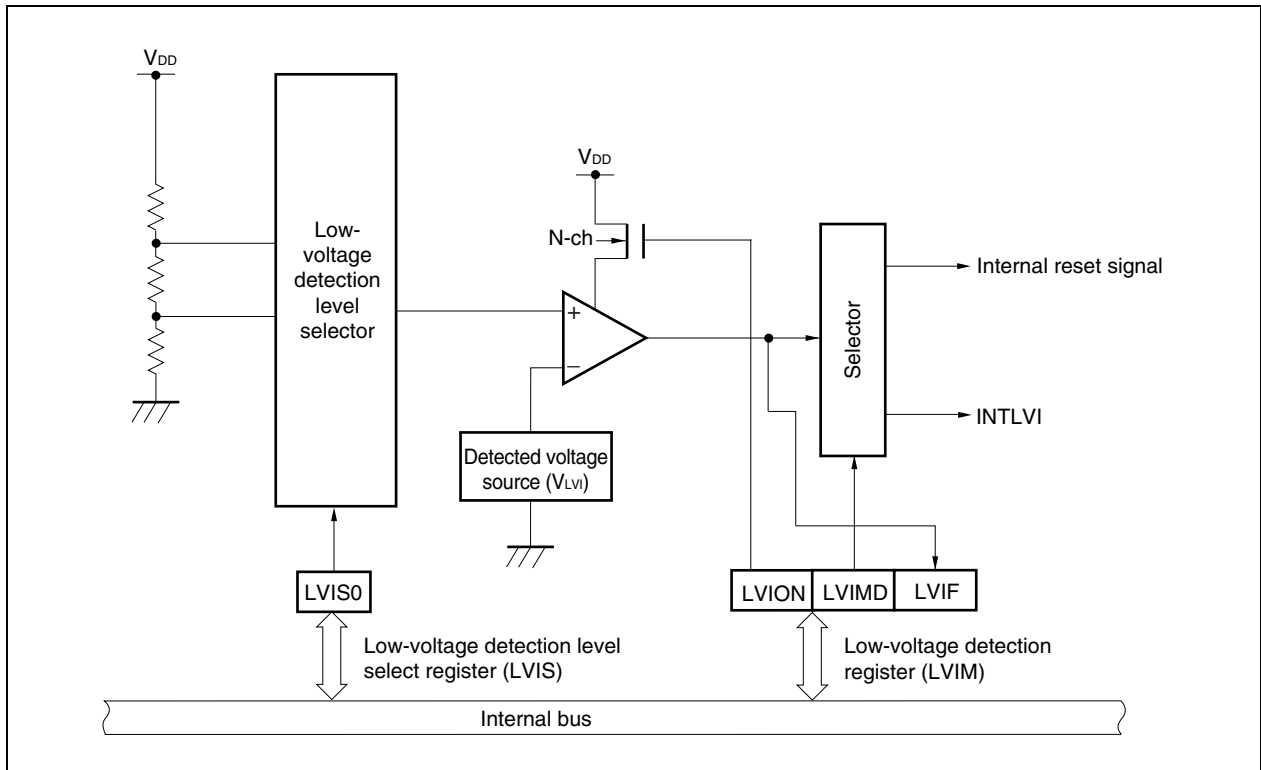
- If the interrupt occurrence at low voltage detection is selected, the low-voltage detector continuously compares the supply voltage ( $V_{DD}$ ) and the detected voltage ( $V_{LVI}$ ), and generates an internal interrupt signal when the supply voltage drops or rises across the detected voltage.
- If the reset occurrence at low voltage detection is selected, the low-voltage detector generates an interrupt reset signal when the supply voltage ( $V_{DD}$ ) drops across the detected voltage ( $V_{LVI}$ ).
- Interrupt or reset signal can be selected by software.
- Can operate in STOP mode.

If the low-voltage detector is used to generate a reset signal, the RESF.LVIRF bit is set to 1 when the reset signal is generated. For details of RESF register, see **22.2 Registers to Check Reset Source**.

### 24.2 Configuration

The block diagram of the low-voltage detector is shown below.

**Figure 24-1. Block Diagram of Low-Voltage Detector**



## 24.3 Registers

The low-voltage detector is controlled by the following registers.

- Low-voltage detection register (LVIM)
- Low-voltage detection level select register (LVIS)

### (1) Low-voltage detection register (LVIM)

The LVIM register is a special register. This can be written only in the special combination of the sequences (see 3.4.7 **Special registers**).

The LVIM register is used to enable or disable low-voltage detection, and to set the operation mode of the low-voltage detector.

This register can be read or written in 8-bit or 1-bit units. However, the LVIF bit is read-only.

| After reset: <b>Note 1</b> |                        | R/W  | Address: FFFFF890H |   |   |   |   |   |       |      |
|----------------------------|------------------------|--|--------------------|---|---|---|---|---|-------|------|
|                            |                        |  | <7>                | 6 | 5 | 4 | 3 | 2 | <1>   | <0>  |
| LVIM                       | LVION                  | 0  | 0                  | 0 | 0 | 0 | 0 | 0 | LVIMD | LVIF |
|                            | LVION                  | Low-voltage detection operation enable or disable  |                    |   |   |   |   |   |       |      |
|                            | 0                      | Disable operation.   |                    |   |   |   |   |   |       |      |
|                            | 1                      | Enable operation.  |                    |   |   |   |   |   |       |      |
|                            | LVIMD                  | Selection of operation mode of low-voltage detection   |                    |   |   |   |   |   |       |      |
|                            | 0                      | Generates interrupt request signal INTLVI when the supply voltage drops or rises across the detection voltage value. |                    |   |   |   |   |   |       |      |
|                            | 1                      | Generate internal reset signal LVIRES when the supply voltage drops across the detected voltage value.               |                    |   |   |   |   |   |       |      |
|                            | LVIF <sup>Note 2</sup> | Low-voltage detection flag   |                    |   |   |   |   |   |       |      |
|                            | 0                      | When supply voltage > detected voltage, or when operation is disabled  |                    |   |   |   |   |   |       |      |
|                            | 1                      | Supply voltage of connected power supply < detected voltage  |                    |   |   |   |   |   |       |      |

**Notes 1.** Reset by low-voltage detection: 82H

Reset due to other source: 00H

- 2.** After the LVI operation has started (LVION bit = 1) or when INTLVI has occurred, confirm the supply voltage state using the LVIF bit.

**Cautions 1.** When the LVION and LVIMD bits to 1, the low-voltage detector cannot be stopped until the reset request due to other than the low-voltage detection is generated.

- 2.** When the LVION bit is set to 1, the comparator in the LVI circuit starts operating. Wait 0.2 ms or longer by software before checking the voltage at the LVIF bit after the LVION bit is set.

- 3.** Be sure to clear bits 6 to 2 to “0”.



**(2) Low-voltage detection level select register (LVIS)**

The LVIS register is used to select the level of low voltage to be detected.

This register can be read or written in 8-bit or 1-bit units.

|      |                          |     |                    |   |   |   |   |       |
|------|--------------------------|-----|--------------------|---|---|---|---|-------|
|      | After reset: <b>Note</b> | R/W | Address: FFFFF891H |   |   |   |   |       |
|      | 7                        | 6   | 5                  | 4 | 3 | 2 | 1 | 0     |
| LVIS | 0                        | 0   | 0                  | 0 | 0 | 0 | 0 | LVIS0 |

|       |                               |
|-------|-------------------------------|
| LVIS0 | Detection level               |
| 0     | 2.95 V (TYP.) ±0.10 V         |
| 1     | Reserved (setting prohibited) |

**Note** Reset by low-voltage detection: Retained  
Reset due to other source: 00H

**Cautions** 1. This register cannot be written until a reset request due to something other than low-voltage detection is generated after the LVIM.LVION and LVIM.LVIMD bits are set to 1.  
2. Be sure to clear bits 7 to 1 to “0”.

**(3) Internal RAM data status register (RAMS)**

The RAMS register is a special register. This can be written only in a special combination of sequences (see 3.4.7 Special registers).

This register is a flag register that indicates whether the internal RAM is valid or not.

This register can be read or written in 8-bit or 1-bit units.

The set/clear conditions for the RAMF bit are shown below.

- Setting conditions: Detection of voltage lower than specified level  
Set by instruction
- Clearing condition: Writing of 0 in specific sequence

|      |                                  |     |                    |   |   |   |   |      |
|------|----------------------------------|-----|--------------------|---|---|---|---|------|
|      | After reset: 01H <sup>Note</sup> | R/W | Address: FFFFF892H |   |   |   |   |      |
|      | 7                                | 6   | 5                  | 4 | 3 | 2 | 1 | <0>  |
| RAMS | 0                                | 0   | 0                  | 0 | 0 | 0 | 0 | RAMF |

|      |   |
|------|---|
| RAMF | Internal RAM voltage detection                            |
| 0    | Voltage lower than RAM retention voltage is not detected. |
| 1    | Voltage lower than RAM retention voltage is detected.     |

**Note** This register is reset only when a voltage drop below the RAM retention voltage is detected.

## 24.4 Operation

Depending on the setting of the LVIM.VIMD bit, an interrupt signal (INTLVI) or an internal reset signal is generated. How to specify each operation is described below, together with timing charts.

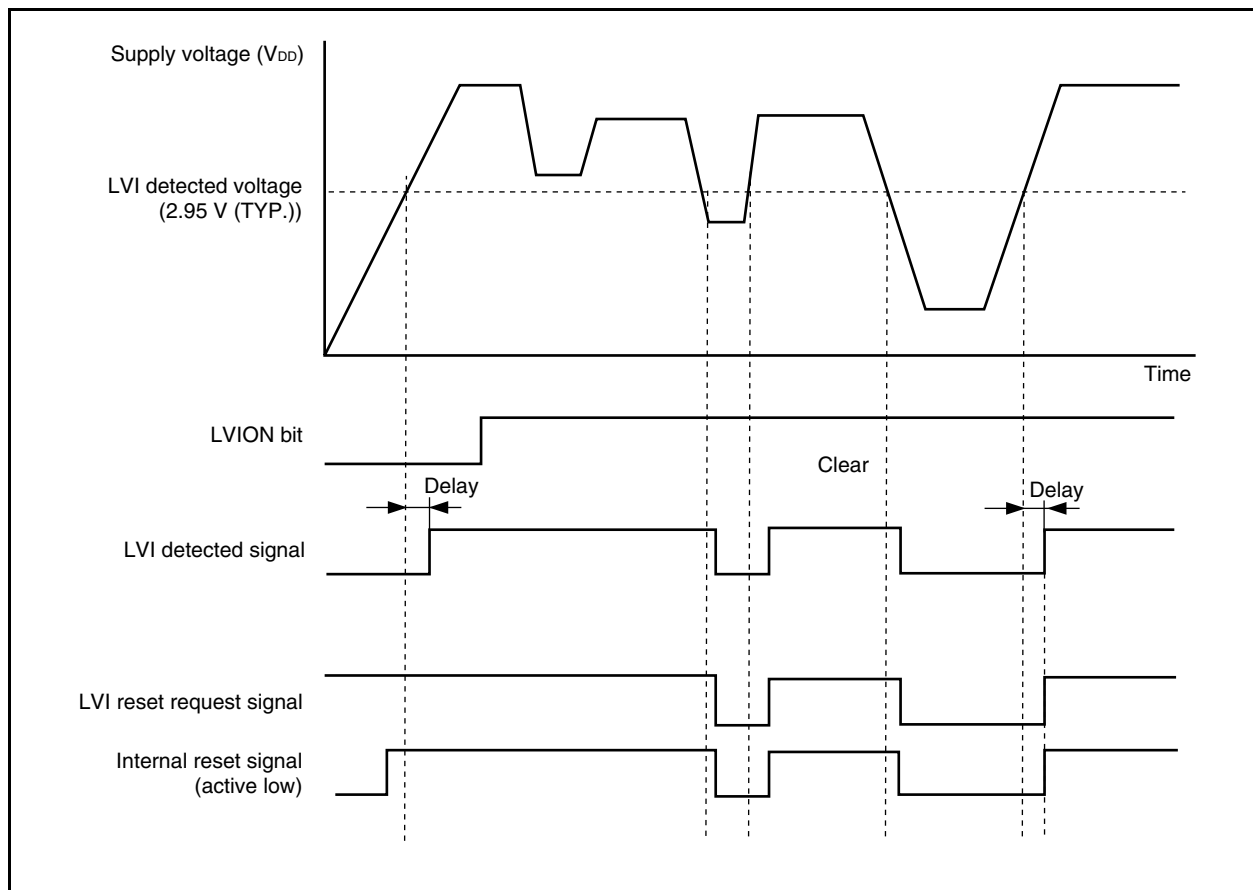
### 24.4.1 To use for internal reset signal

<To start operation>

- <1> Mask the interrupt of LVI.
- <2> Select the voltage to be detected by using the LVIS.LVIS0 bit.
- <3> Set the LVIM.LVION bit to 1 (to enable operation).
- <4> Insert a wait cycle of 0.2 ms (max.) or more by software.
- <5> By using the LVIM.LVIF bit, check if the supply voltage > detected voltage.
- <6> Set the LVIMD bit to 1 (to generate an internal reset signal).

**Caution** If the LVIMD bit is set to 1, the contents of the LVIM and LVIS registers cannot be changed until a reset request other than LVI is generated.

Figure 24-2. Operation Timing of Low-Voltage Detector (LVIMD Bit = 1)



## 24.4.2 To use for interrupt

<To start operation>

<1> Mask the interrupt of LVI.

<2> Select the voltage to be detected by using the LVIS.LVIS0 bit.

<3> Set the LVIM.LVION bit to 1 (to enable operation).

<4> Insert a wait cycle of 0.2 ms (max.) or more by software.

<5> By using the LVIM.LVIF bit, check if the supply voltage > detected voltage.

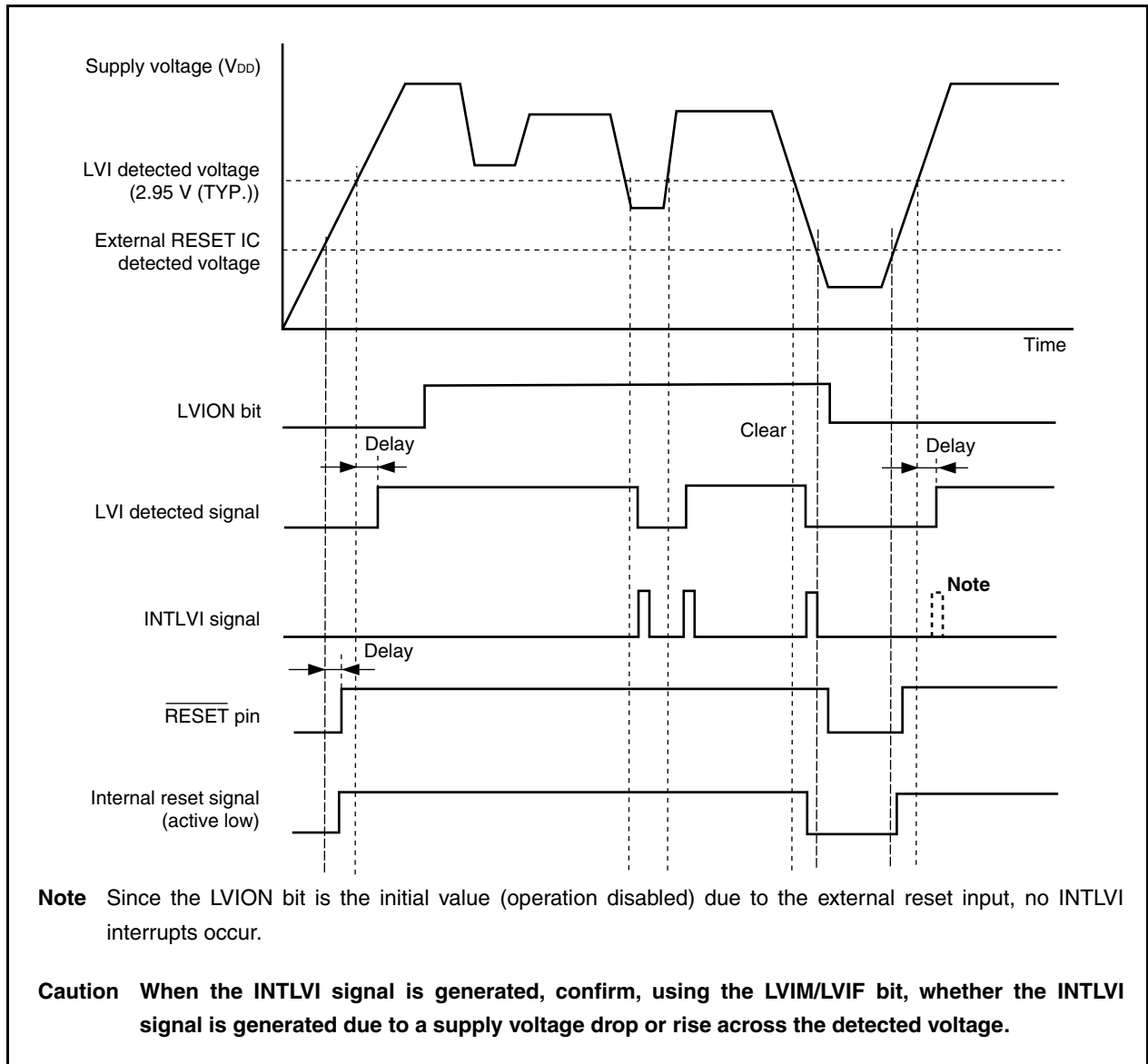
<6> Clear the interrupt request flag of LVI.

<7> Unmask the interrupt of LVI.

<To stop operation>

Clear the LVION bit to 0.

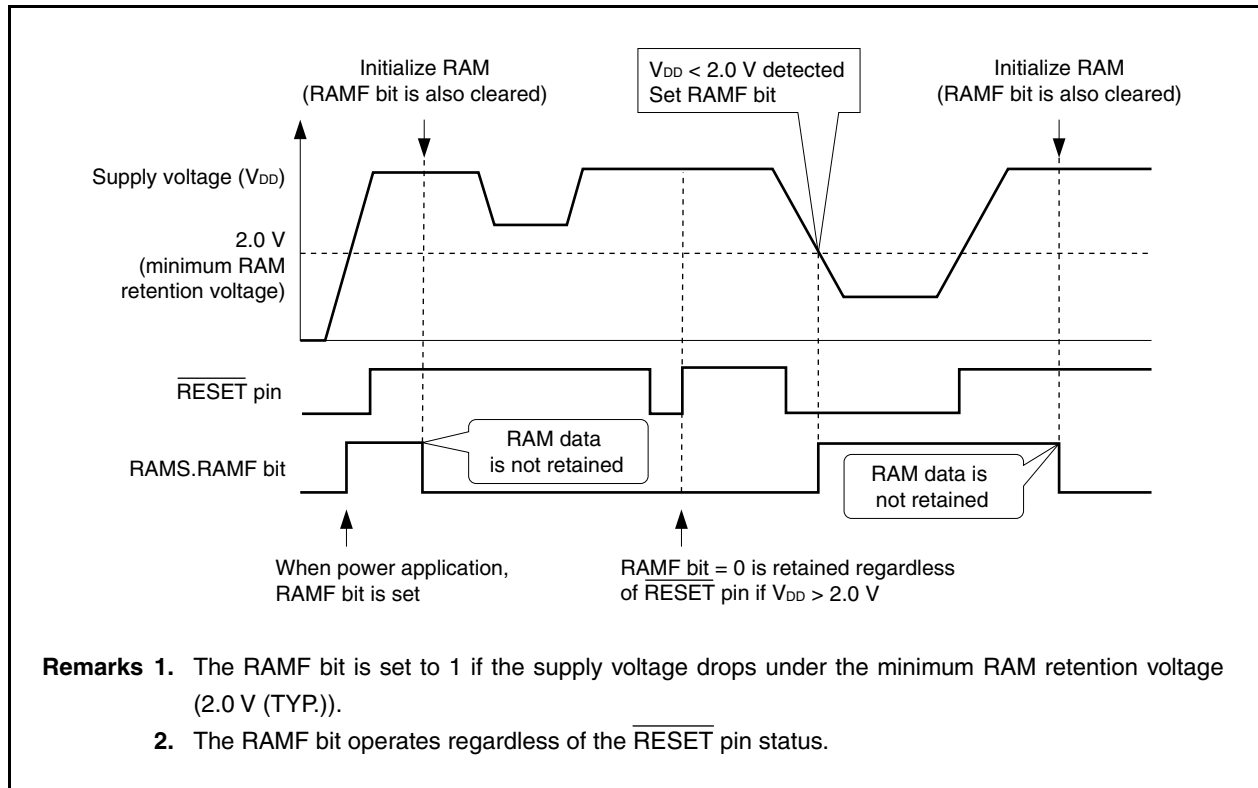
Figure 24-3. Operation Timing of Low-Voltage Detector (LVIMD Bit = 0)



## 24.5 RAM Retention Voltage Detection Operation

The supply voltage and detected voltage are compared. When the supply voltage drops below the detected voltage (including on power application), the RAMS.RAMF bit is set to 1.

**Figure 24-4. Operation Timing of RAM Retention Voltage Detection Function**



## 24.6 Emulation Function

When an in-circuit emulator is used, the operation of the RAM retention flag (RAMS.RAMF bit) can be pseudo-controlled and emulated by manipulating the PEMU1 register on the debugger.

This register is valid only in the emulation mode. It is invalid in the normal mode.

### (1) Peripheral emulation register 1 (PEMU1)

|                  |          |  |   |   |   |   |          |   |   |
|------------------|----------|--|---|---|---|---|----------|---|---|
| After reset: 00H | R/W      | Address: FFFFF9FEH   |   |   |   |   |          |   |   |
|                  |          | 7  | 6 | 5 | 4 | 3 | 2        | 1 | 0 |
| PEMU1            |          | 0  | 0 | 0 | 0 | 0 | EVARAMIN | 0 | 0 |
|                  | EVARAMIN | Pseudo specification of RAM retention voltage detection signal   |   |   |   |   |          |   |   |
|                  | 0        | Do not detect voltage lower than RAM retention voltage.          |   |   |   |   |          |   |   |
|                  | 1        | Detect voltage lower than RAM retention voltage (set RAMF flag). |   |   |   |   |          |   |   |

**Caution** This bit is not automatically cleared.

#### [Usage]

When an in-circuit emulator is used, pseudo emulation of RAMF is realized by rewriting this register on the debugger.

- <1> CPU break (CPU operation stops.)
- <2> Set the EVARAMIN bit to 1 by using a register write command.  
By setting the EVARAMIN bit to 1, the RAMF bit is set to 1 on hardware (the internal RAM data is invalid).
- <3> Clear the EVARAMIN bit to 0 by using a register write command again.  
Unless this operation is performed (clearing the EVARAMIN bit to 0), the RAMF bit cannot be cleared to 0 by a CPU operation instruction.
- <4> Run the CPU and resume emulation.

## CHAPTER 25 CRC FUNCTION

### 25.1 Functions

- CRC operation circuit for detection of data block errors
- Generation of 16-bit CRC code using a CRC-CCITT ( $X^{16} + X^{12} + X^5 + 1$ ) generation polynomial for blocks of data of any length in 8-bit units
- CRC code is set to the CRC data register each time 1-byte data is transferred to the CRCIN register, after the initial value is set to the CRCD register.

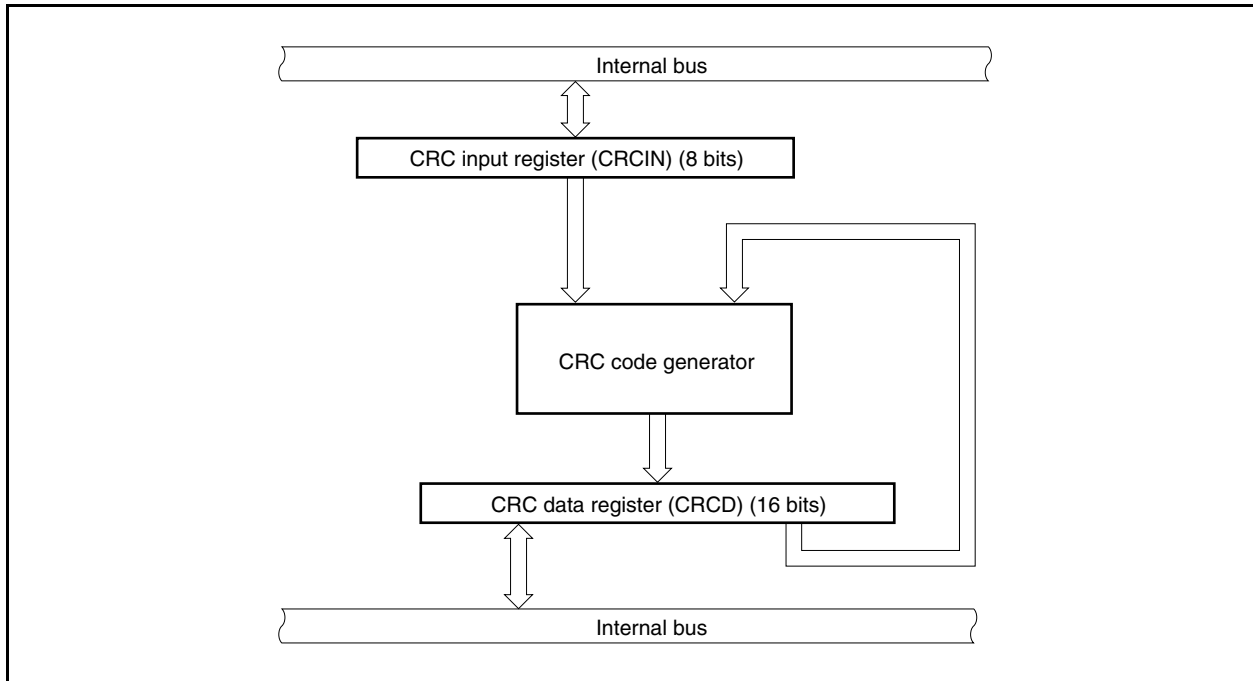
### 25.2 Configuration

The CRC function includes the following hardware.

**Table 25-1. CRC Configuration**

| Item              | Configuration  |
|-------------------|--|
| Control registers | CRC input register (CRCIN)<br>CRC data register (CRCD) |

**Figure 25-1. Block Diagram of CRC Register**



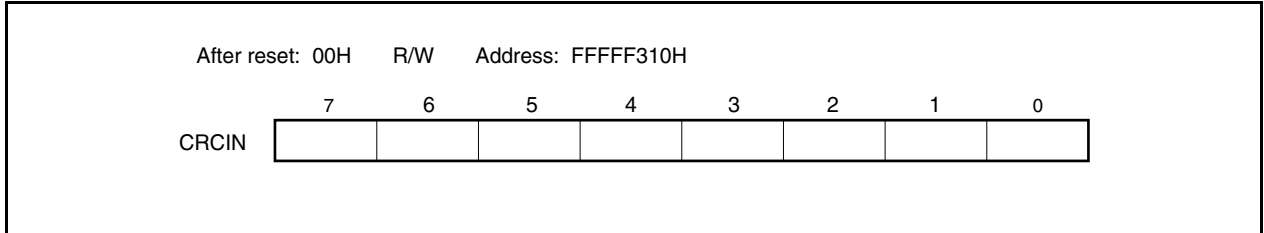
## 25.3 Registers

### (1) CRC input register (CRCIN)

The CRCIN register is an 8-bit register for setting data.

This register can be read or written in 8-bit units.

Reset sets this register to 00H.



### (2) CRC data register (CRCD)

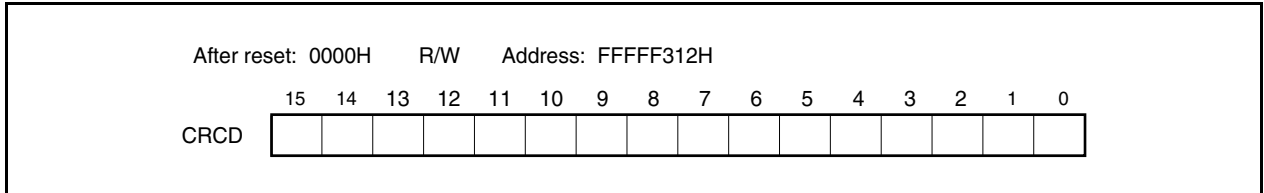
The CRCD register is a 16-bit register that stores the CRC-CCITT operation results.

This register can be read or written in 16-bit units.

Reset sets this register to 0000H.

**Caution** Accessing the CRCD register is prohibited in the following statuses. For details, refer to 3.4.9 (2) Accessing specific on-chip peripheral I/O registers.

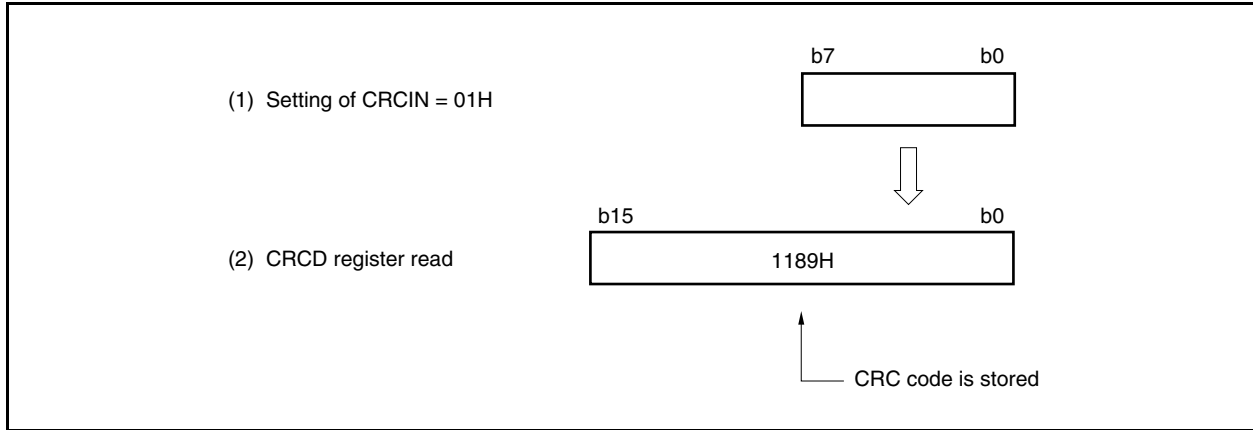
- When the CPU operates with the subclock and the main clock oscillation is stopped
- When the CPU operates with the internal oscillation clock



### 25.4 Operation

An example of the CRC operation circuit is shown below.

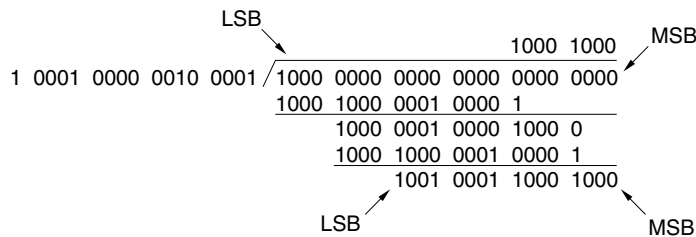
**Figure 25-2. CRC Operation Circuit Operation Example (LSB First)**



The code when 01H is sent LSB first is (1000 0000). Therefore, the CRC code from generation polynomial  $X^{16} + X^{12} + X^5 + 1$  becomes the remainder when  $(1000\ 0000) X^{16}$  is divided by  $(1\ 0001\ 0000\ 0010\ 0001)$  using the modulo-2 operation formula.

The modulo-2 operation is performed based on the following formula.

- 0 + 0 = 0
- 0 + 1 = 1
- 1 + 0 = 1
- 1 + 1 = 0
- 1 = 1



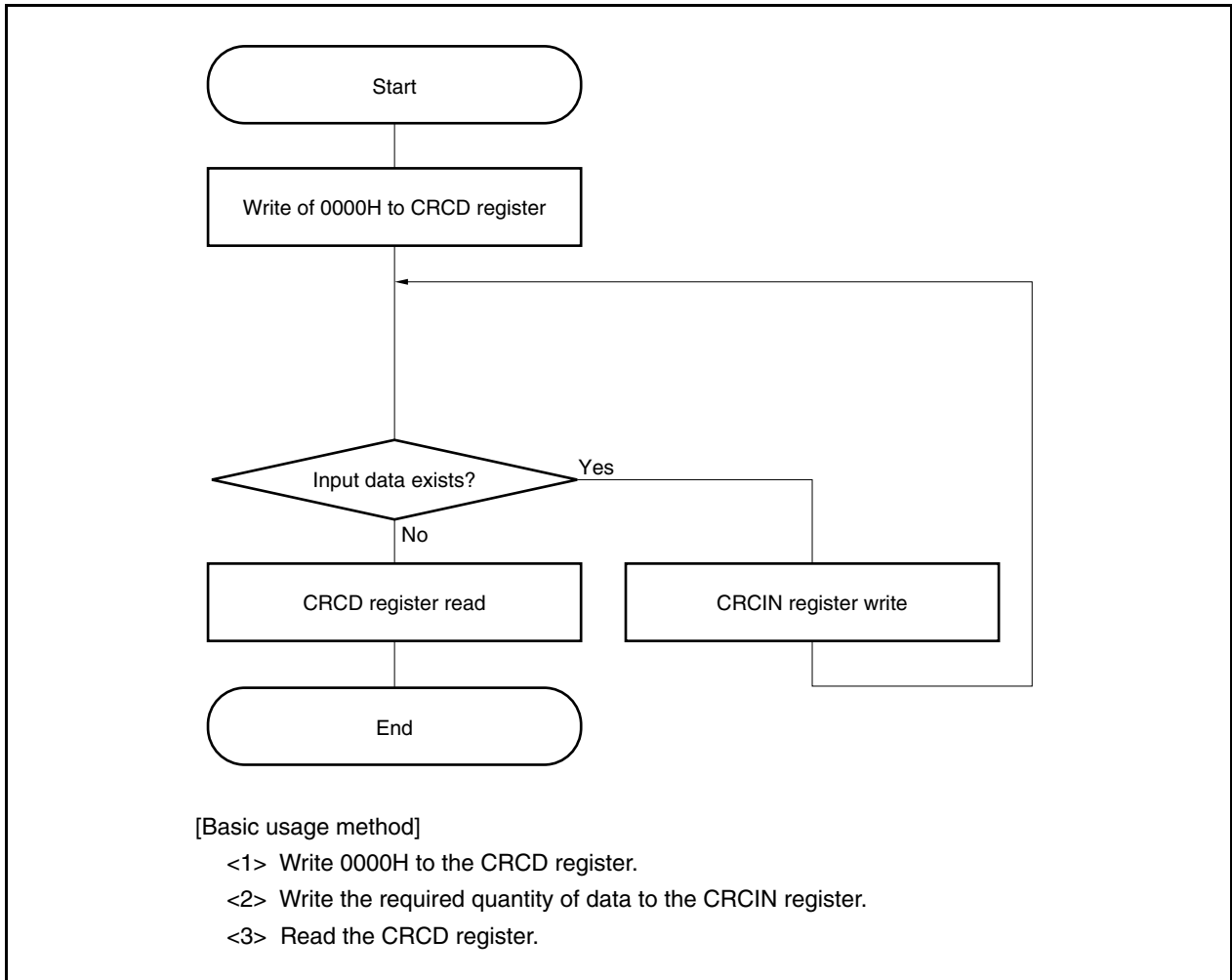
Therefore, the CRC code becomes  $\overbrace{1001}^9 \overbrace{0001}^8 \overbrace{1000}^1 \overbrace{1000}^1$ . Since LSB first is used, this corresponds to 1189H in hexadecimal notation.



## 25.5 Usage Method

How to use the CRC logic circuit is described below.

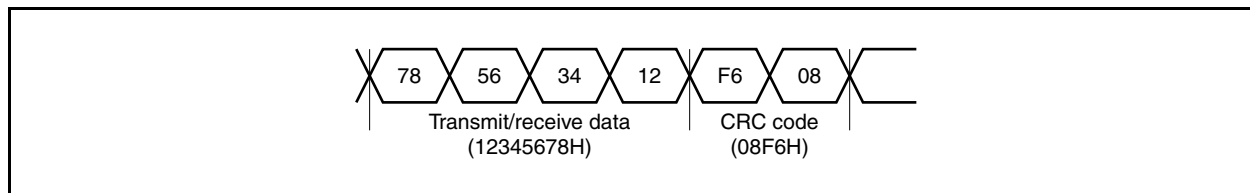
Figure 25-3. CRC Operation Flow



Communication errors can easily be detected if the CRC code is transmitted/received along with transmit/receive data when transmitting/receiving data consisting of several bytes.

The following is an illustration using the transmission of 12345678H (0001 0010 0011 0100 0101 0110 0111 1000B) LSB-first as an example.

**Figure 25-4. CRC Transmission Example**



#### Setting procedure on transmitting side

- <1> Write the initial value 0000H to the CRCD register.
- <2> Write the 1 byte of data to be transmitted first to the transmit buffer register. (At this time, also write the same data to the CRCIN register.)
- <3> When transmitting several bytes of data, write the same data to the CRCIN register each time transmit data is written to the transmit buffer register.
- <4> After all the data has been transmitted, write the contents of the CRCD register (CRC code) to the transmit buffer register and transmit them. (Since this is LSB first, transmit the data starting from the lower bytes, then the higher bytes.)

#### Setting procedure on receiving side

- <1> Write the initial value 0000H to the CRCD register.
- <2> When reception of the first 1 byte of data is complete, write that receive data to the CRCIN register.
- <3> If receiving several bytes of data, write the receive data to the CRCIN register upon every reception completion. (In the case of normal reception, when all the receive data has been written to the CRCIN register, the contents of the CRCD register on the receiving side and the contents of the CRCD register on the transmitting side are the same.)
- <4> Next, the CRC code is transmitted from the transmitting side, so write this data to the CRCIN register similarly to receive data.
- <5> When reception of all the data, including the CRC code, has been completed, reception was normal if the contents of the CRCD register are 0000H. If the contents of the CRCD register are other than 0000H, this indicates a communication error, so transmit a resend request to the transmitting side.

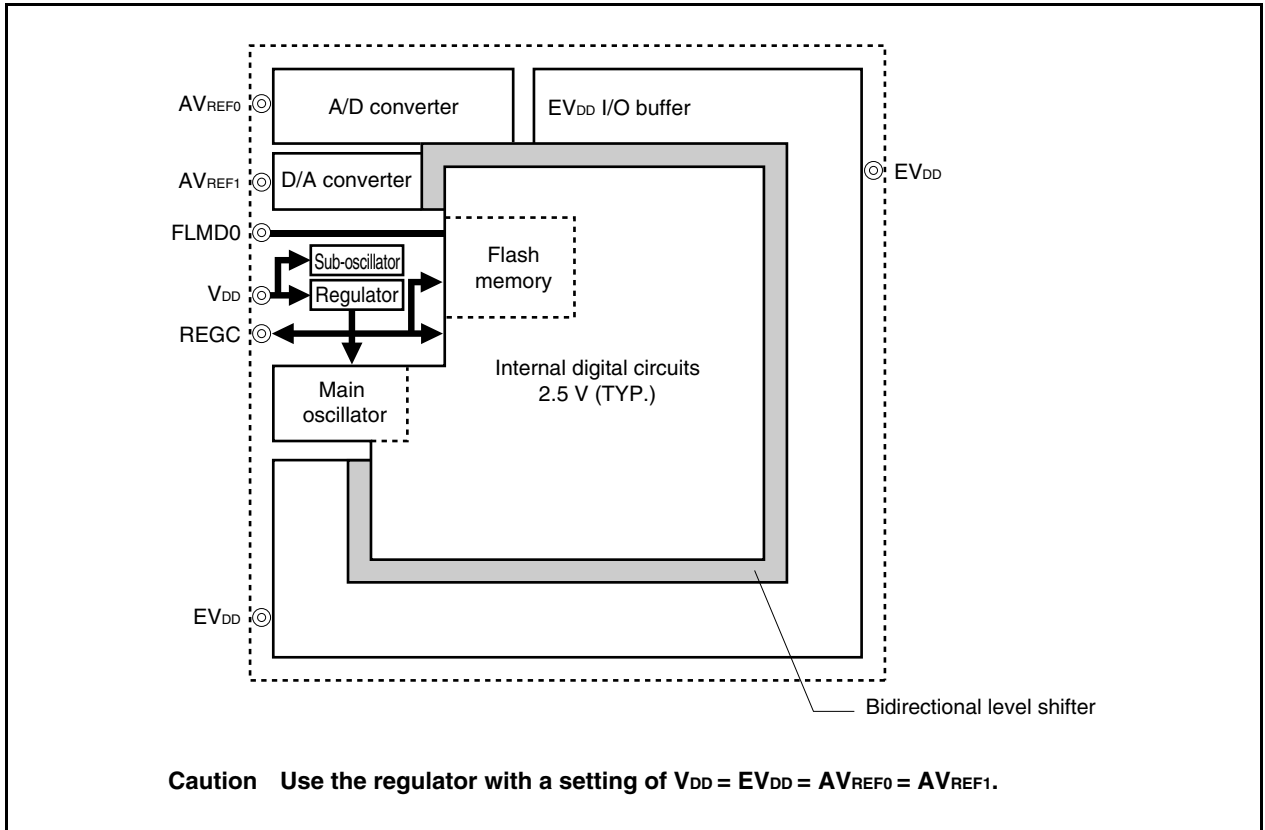
## CHAPTER 26 REGULATOR

### 26.1 Overview

The V850ES/JJ3 includes a regulator to reduce power consumption and noise.

This regulator supplies a stepped-down  $V_{DD}$  power supply voltage to the oscillator block and internal logic circuits (except the A/D converter, D/A converter, and output buffers). The regulator output voltage is set to 2.5 V (TYP.).

Figure 26-1. Regulator



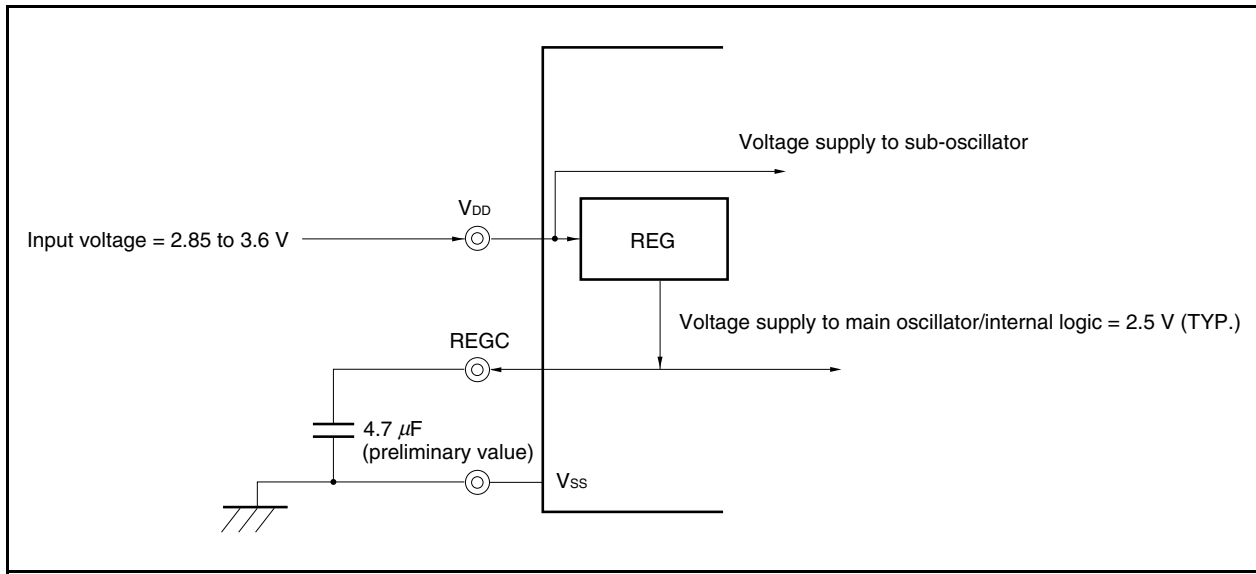
## 26.2 Operation

The regulator of this product always operates in any mode (normal operation mode, HALT mode, IDLE1 mode, IDLE2 mode, STOP mode, or during reset).

Be sure to connect a capacitor (4.7  $\mu\text{F}$  (preliminary value)) to the REGC pin to stabilize the regulator output.

A diagram of the regulator pin connection method is shown below.

**Figure 26-2. REGC Pin Connection**



## CHAPTER 27 FLASH MEMORY

The V850ES/JJ3 incorporates a flash memory.

- <R>                   •  $\mu$ PD70F3743: 384 KB flash memory
- <R>                   •  $\mu$ PD70F3744: 512 KB flash memory
- $\mu$ PD70F3745: 768 KB flash memory
- $\mu$ PD70F3746: 1024 KB flash memory

Flash memory versions offer the following advantages for development environments and mass production applications.

- For altering software after the V850ES/JJ3 is soldered onto the target system.
- For data adjustment when starting mass production.
- For differentiating software according to the specification in small scale production of various models.
- For facilitating inventory management.
- For updating software after shipment.

### 27.1 Features

- <R>                    4-byte/1-clock access (when instruction is fetched)
- <R>                    Capacity: 1024 KB/768 KB/512 KB/384 KB
- <R>                    Write voltage: Erase/write with a single power supply
- <R>                    Rewriting method
  - Rewriting by communication with dedicated flash programmer via serial interface (on-board/off-board programming)
  - Rewriting flash memory by user program (self programming)
- <R>                    Flash memory write prohibit function supported (security function)
- <R>                    Safe rewriting of entire flash memory area by self programming using boot swap function
- <R>                    Interrupts can be acknowledged during self programming.

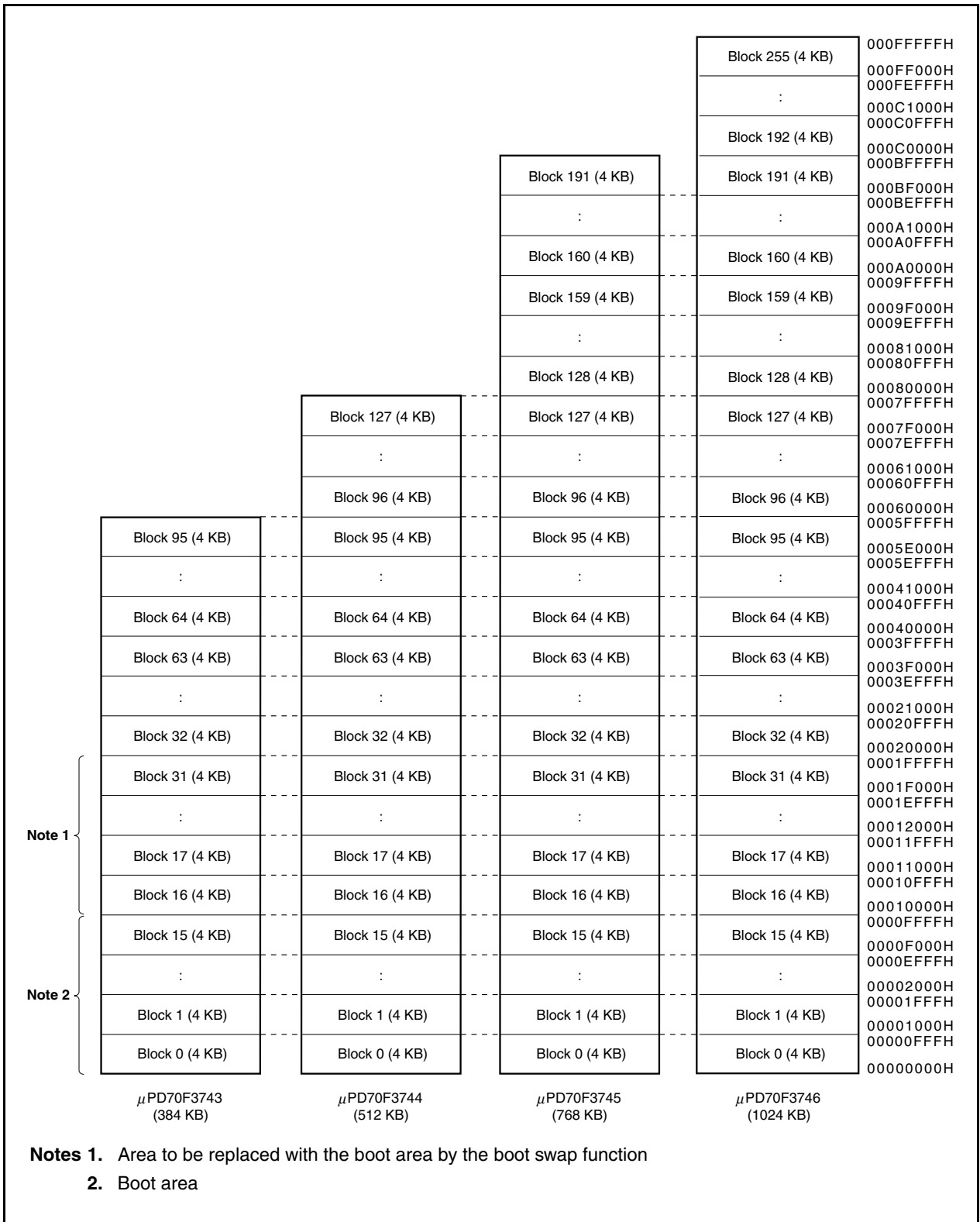
## 27.2 Memory Configuration

The V850ES/JJ3 internal flash memory area is divided into 4 KB blocks and can be programmed/erased in block units. All or some of the blocks can also be erased at once.

When the boot swap function is used, the physical memory allocated at the addresses of blocks 0 to 15 is replaced by the physical memory allocated at the addresses of blocks 16 to 31. For details of the boot swap function, see **27.5 Rewriting by Self Programming**.

<R>

Figure 27-1. Flash Memory Mapping



### 27.3 Functional Outline

The internal flash memory of the V850ES/JJ3 can be rewritten by using the rewrite function of the dedicated flash programmer, regardless of whether the V850ES/JJ3 has already been mounted on the target system or not (off-board/on-board programming).

In addition, a security function that prohibits rewriting the user program written to the internal flash memory is also supported, so that the program cannot be changed by an unauthorized person.

The rewrite function using the user program (self programming) is ideal for an application where it is assumed that the program is changed after production/shipment of the target system. A boot swap function that rewrites the entire flash memory area safely is also supported. In addition, interrupt servicing is supported during self programming, so that the flash memory can be rewritten under various conditions, such as while communicating with an external device.

**Table 27-1. Rewrite Method**

| Rewrite Method        | Functional Outline   | Operation Mode                |
|-----------------------|--|-------------------------------|
| On-board programming  | Flash memory can be rewritten after the device is mounted on the target system, by using a dedicated flash programmer.   | Flash memory programming mode |
| Off-board programming | Flash memory can be rewritten before the device is mounted on the target system, by using a dedicated flash programmer and a dedicated program adapter board (FA series).  |                               |
| Self programming      | Flash memory can be rewritten by executing a user program that has been written to the flash memory in advance by means of off-board/on-board programming. (During self-programming, instructions cannot be fetched from or data access cannot be made to the internal flash memory area. Therefore, the rewrite program must be transferred to the internal RAM or external memory in advance.) | Normal operation mode         |

**Remark** The FA series is a product of Naito Densai Machida Mfg. Co., Ltd.



Table 27-2. Basic Functions

| Function         | Functional Outline   | Support (√: Supported, ×: Not supported) |  |
|------------------|--|--|--|
|                  |  | On-Board/Off-Board Programming           | Self Programming   |
| Block erasure    | The contents of specified memory blocks are erased.  | √  | √  |
| Chip erasure     | The contents of the entire memory area are erased all at once.   | √  | ×  |
| Write            | Writing to specified addresses, and a verify check to see if write level is secured are performed.   | √  | √  |
| Verify/checksum  | Data read from the flash memory is compared with data transferred from the flash programmer.   | √  | ×<br>(Can be read by user program)                                   |
| Blank check      | The erasure status of the entire memory is checked.  | √  | √  |
| Security setting | Use of the block erase command, chip erase command, program command, and read command can be prohibited, and rewriting of the boot area can be prohibited. | √  | ×<br>(Supported only when setting is changed from enable to disable) |

The following table lists the security functions. The block erase command prohibit, chip erase command prohibit, and program command prohibit functions are enabled by default after shipment, and security can be set by rewriting via on-board/off-board programming. Each security function can be used in combination with the others at the same time.

Table 27-3. Security Functions

| Function                     | Function Outline   |
|------------------------------|--|
| Block erase command prohibit | Execution of a block erase command on all blocks is prohibited. Setting of prohibition can be initialized by execution of a chip erase command.  |
| Chip erase command prohibit  | Execution of block erase and chip erase commands on all the blocks is prohibited. Once prohibition is set, setting of prohibition cannot be initialized because the chip erase command cannot be executed.                   |
| Program command prohibit     | Execution of program and block erase commands on all the blocks is prohibited. Setting of prohibition can be initialized by execution of the chip erase command.   |
| Read command prohibit        | Execution of a read command on all of the blocks is prohibited. Setting of the prohibition can be initialized by execution of the chip erase command.  |
| Boot area rewrite prohibit   | Boot areas from block 0 to the specified last block can be protected. The protected boot area cannot be rewritten (erased and written). Setting of prohibition cannot be initialized by execution of the chip erase command. |

Table 27-4. Security Setting

| Function                     | Erase, Write, Read Operations When Each Security Is Set<br>(√: Executable, ×: Not Executable, -: Not Supported)              |   | Notes on Security Setting  |  |
|------------------------------|--|---|--|--|
|                              | On-Board/<br>Off-Board Programming   | Self Programming  | On-Board/<br>Off-Board<br>Programming                            | Self<br>Programming  |
| Block erase command prohibit | Block erase command: ×<br>Chip erase command: √<br>Program command: √<br>Read command: √                                     | Block erasure (FlashBlockErase): √<br>Chip erasure: -<br>Write (FlashWordWrite): √<br>Read (FlashWordRead): √                                     | Setting of prohibition can be initialized by chip erase command. | Supported only when setting is changed from enable to prohibit |
| Chip erase command prohibit  | Block erase command: ×<br>Chip erase command: ×<br>Program command: √ <sup>Note 1</sup><br>Read command: √                   | Block erasure (FlashBlockErase): √<br>Chip erasure: -<br>Write (FlashWordWrite): √<br>Read (FlashWordRead): √                                     | Setting of prohibition cannot be initialized.                    |  |
| Program command prohibit     | Block erase command: ×<br>Chip erase command: √<br>Program command: ×<br>Read command: √                                     | Block erasure (FlashBlockErase): √<br>Chip erasure: -<br>Write (FlashWordWrite): √<br>Read (FlashWordRead): √                                     | Setting of prohibition can be initialized by chip erase command. |  |
| Read command prohibit        | Block erase command: √<br>Chip erase command: √<br>Program command: √<br>Read command: ×                                     | Block erasure (FlashBlockErase): √<br>Chip erasure: -<br>Write (FlashWordWrite): √<br>Read (FlashWordRead): √                                     | Setting of prohibition can be initialized by chip erase command. |  |
| Boot area rewrite prohibit   | Block erase command: × <sup>Note 2</sup><br>Chip erase command: ×<br>Program command: × <sup>Note 2</sup><br>Read command: √ | Block erasure (FlashBlockErase): × <sup>Note 2</sup><br>Chip erasure: -<br>Write (FlashWordWrite): × <sup>Note 2</sup><br>Read (FlashWordRead): √ | Setting of prohibition cannot be initialized.                    |  |

**Notes 1.** In this case, since the erase command is invalid, data different from the data already written in the flash memory cannot be written.

**2.** Executable except in boot area.

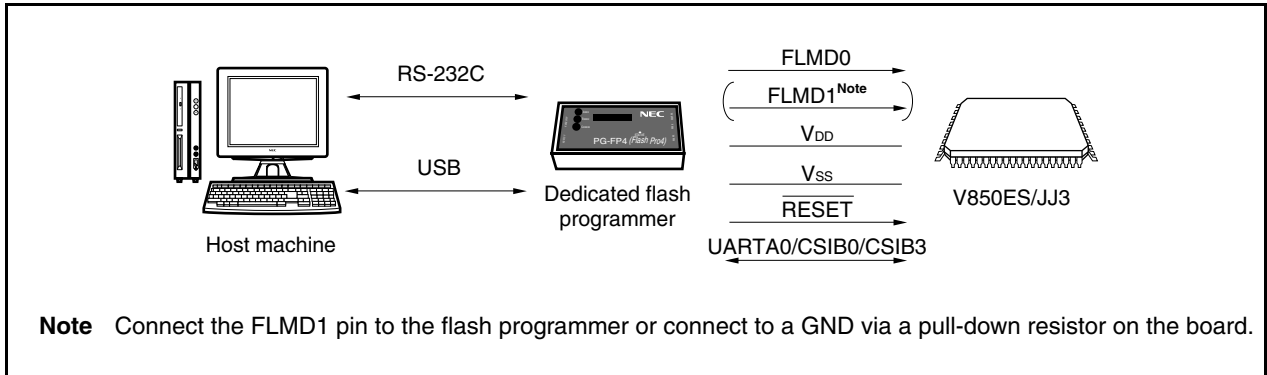
## 27.4 Rewriting by Dedicated Flash Programmer

The flash memory can be rewritten by using a dedicated flash programmer after the V850ES/JJ3 is mounted on the target system (on-board programming). The flash memory can also be rewritten before the device is mounted on the target system (off-board programming) by using a dedicated program adapter (FA series).

### 27.4.1 Programming environment

The following shows the environment required for writing programs to the flash memory of the V850ES/JJ3.

**Figure 27-2. Environment Required for Writing Programs to Flash Memory**



A host machine is required for controlling the dedicated flash programmer.

UARTA0, CSIB0, or CSIB3 is used for the interface between the dedicated flash programmer and the V850ES/JJ3 to perform writing, erasing, etc. A dedicated program adapter (FA series) required for off-board writing.

**Remark** The FA series is a product of Naito Densai Machida Mfg. Co., Ltd.

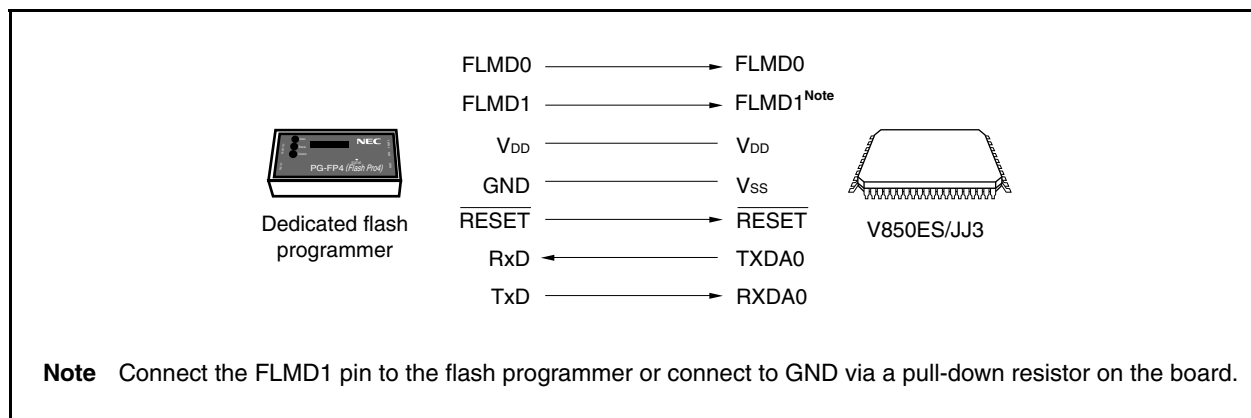
### 27.4.2 Communication mode

Communication between the dedicated flash programmer and the V850ES/JJ3 is performed by serial communication using the UARTA0, CSIB0, or CSIB3 interfaces of the V850ES/JJ3.

#### (1) UARTA0

Transfer rate: 9,600 to 153,600 bps

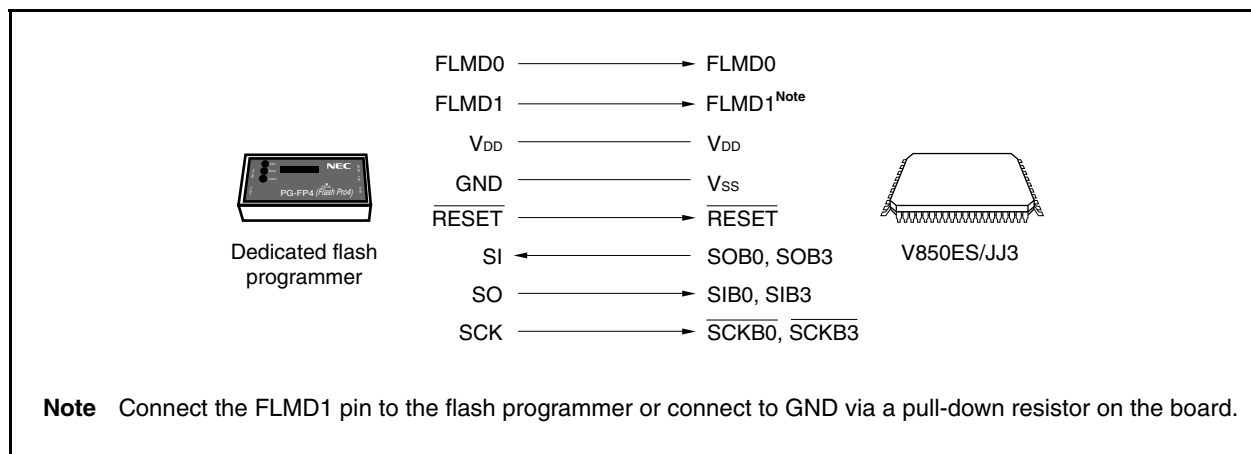
Figure 27-3. Communication with Dedicated Flash Programmer (UARTA0)



#### (2) CSIB0, CSIB3

Serial clock: 2.4 kHz to 2.5 MHz (MSB first)

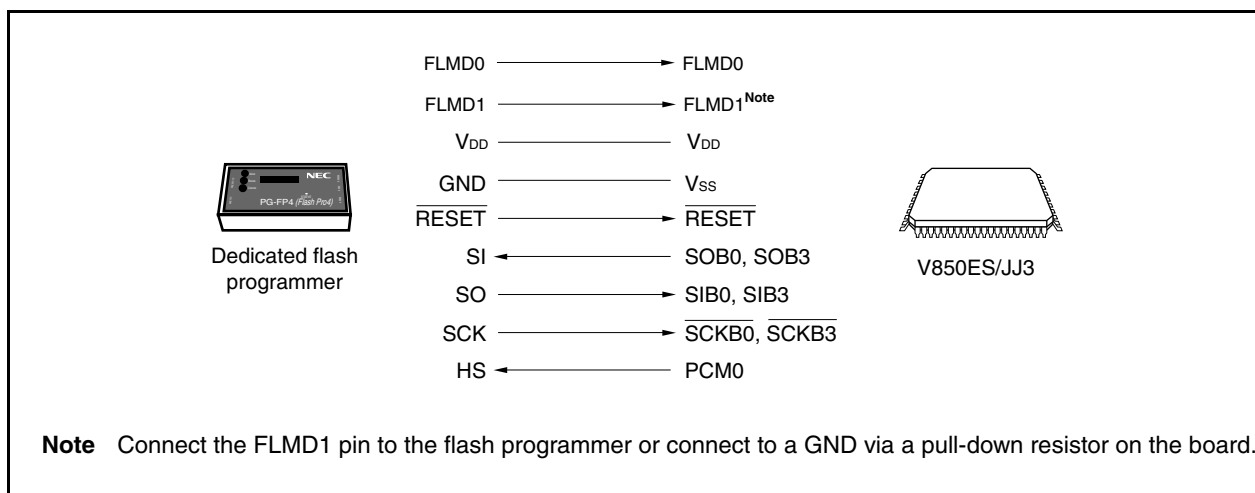
Figure 27-4. Communication with Dedicated Flash Programmer (CSIB0, CSIB3)



(3) CSIB0 + HS, CSIB3 + HS

Serial clock: 2.4 kHz to 2.5 MHz (MSB first)

Figure 27-5. Communication with Dedicated Flash Programmer (CSIB0 + HS, CSIB3 + HS)



The dedicated flash programmer outputs the transfer clock, and the V850ES/JJ3 operates as a slave.

When the PG-FP4 is used as the dedicated flash programmer, it generates the following signals to the V850ES/JJ3. For details, refer to the **PG-FP4 User's Manual (U15260E)**.

Table 27-5. Signal Connections of Dedicated Flash Programmer (PG-FP4)

| PG-FP4      |        |   | V850ES/JJ3           | Processing for Connection |                     |                        |
|-------------|--------|---|----------------------|---------------------------|---------------------|------------------------|
| Signal Name | I/O    | Pin Function  | Pin Name             | UARTA0                    | CSIB0, CSIB3        | CSIB0 + HS, CSIB3 + HS |
| FLMD0       | Output | Write enable/disable                                      | FLMD0                | ○                         | ○                   | ○                      |
| FLMD1       | Output | Write enable/disable                                      | FLMD1                | ○ <sup>Note 1</sup>       | ○ <sup>Note 1</sup> | ○ <sup>Note 1</sup>    |
| VDD         | –      | V <sub>DD</sub> voltage generation/voltage monitor        | V <sub>DD</sub>      | ○                         | ○                   | ○                      |
| GND         | –      | Ground  | V <sub>SS</sub>      | ○                         | ○                   | ○                      |
| CLK         | Output | Clock output to V850ES/JJ3                                | X1, X2               | × <sup>Note 2</sup>       | × <sup>Note 2</sup> | × <sup>Note 2</sup>    |
| RESET       | Output | Reset signal  | RESET                | ○                         | ○                   | ○                      |
| SI/RxD      | Input  | Receive signal  | SOB0, SOB3/<br>TXDA0 | ○                         | ○                   | ○                      |
| SO/TxD      | Output | Transmit signal   | SIB0, SIB3/<br>RXDA0 | ○                         | ○                   | ○                      |
| SCK         | Output | Transfer clock  | SCKB0, SCKB3         | ×                         | ○                   | ○                      |
| HS          | Input  | Handshake signal for CSIB0 + HS, CSIB3 + HS communication | PCM0                 | ×                         | ×                   | ○                      |

**Notes 1.** Wire these pins as shown in Figure 27-6, or connect them to GND via pull-down resistor on board.

**2.** Clock cannot be supplied via the CLK pin of the flash programmer. Create an oscillator on board and supply the clock.

**Remark** ○: Must be connected.

×: Does not have to be connected.

Table 27-6. Wiring of Flash Writing Adapter for V850ES/JJ3 (FA-144GJ-UEN-A) (1/2)

| Flash Programmer (PG-FP4)<br>Connection Pins |        |  | Pin Name<br>on FA<br>Board | When CSIB0 + HS Is<br>Used     |            | When CSIB0 Is Used             |            | When UARTA0 Is Used       |            |
|--|--------|--|----------------------------|--------------------------------|------------|--------------------------------|------------|---------------------------|------------|
| Signal<br>Name                               | I/O    | Pin Function   |                            | Pin Name                       | Pin<br>No. | Pin Name                       | Pin<br>No. | Pin Name                  | Pin<br>No. |
| SI/RxD                                       | Input  | Receive signal                                       | SI                         | P41/SOB0/SCL01                 | 23         | P41/SOB0/SCL01                 | 23         | P30/TXDA0/SOB4            | 25         |
| SO/TxD                                       | Output | Transmit signal                                      | SO                         | P40/SIB0/SDA01                 | 22         | P40/SIB0/SDA01                 | 22         | P31/RXDA0/INTP7/<br>SIB4  | 26         |
| SCK  | Output | Transfer clock                                       | SCK                        | P42/ $\overline{\text{SCKB0}}$ | 24         | P42/ $\overline{\text{SCKB0}}$ | 24         | Not necessary             | –          |
| CLK  | Output | Clock to<br>V850ES/JJ3                               | X1                         | Not necessary                  | –          | Not necessary                  | –          | Not necessary             | –          |
|  |        |  | X2                         | Not necessary                  | –          | Not necessary                  | –          | Not necessary             | –          |
| /RESET                                       | Output | Reset signal   | /RESET                     | $\overline{\text{RESET}}$      | 14         | $\overline{\text{RESET}}$      | 14         | $\overline{\text{RESET}}$ | 14         |
| FLMD0  | Output | Write voltage  | FLMD0                      | FLMD0                          | 8          | FLMD0                          | 8          | FLMD0                     | 8          |
| FLMD1  | Output | Write voltage  | FLMD1                      | PDL5/AD5/FLMD1                 | 110        | PDL5/AD5/FLMD1                 | 110        | PDL5/AD5/FLMD1            | 110        |
| HS   | Input  | Handshake<br>signal of CSIO<br>+ HS<br>communication | RESERVE/<br>HS             | PCMO/ $\overline{\text{WAIT}}$ | 85         | Not necessary                  | –          | Not necessary             | –          |
| VDD  | –      | VDD voltage<br>generation/<br>voltage monitor        | VDD                        | V <sub>DD</sub>                | 9          | V <sub>DD</sub>                | 9          | V <sub>DD</sub>           | 9          |
|  |        |  |                            | EV <sub>DD</sub>               | 34,<br>104 | EV <sub>DD</sub>               | 34,<br>104 | EV <sub>DD</sub>          | 34,<br>104 |
|  |        |  |                            | AV <sub>REF0</sub>             | 1          | AV <sub>REF0</sub>             | 1          | AV <sub>REF0</sub>        | 1          |
|  |        |  |                            | AV <sub>REF1</sub>             | 5          | AV <sub>REF1</sub>             | 5          | AV <sub>REF1</sub>        | 5          |
| GND  | –      | Ground   | GND                        | V <sub>SS</sub>                | 11         | V <sub>SS</sub>                | 11         | V <sub>SS</sub>           | 11         |
|  |        |  |                            | AV <sub>SS</sub>               | 2          | AV <sub>SS</sub>               | 2          | AV <sub>SS</sub>          | 2          |
|  |        |  |                            | EV <sub>SS</sub>               | 33,<br>103 | EV <sub>SS</sub>               | 33,<br>103 | EV <sub>SS</sub>          | 33,<br>103 |

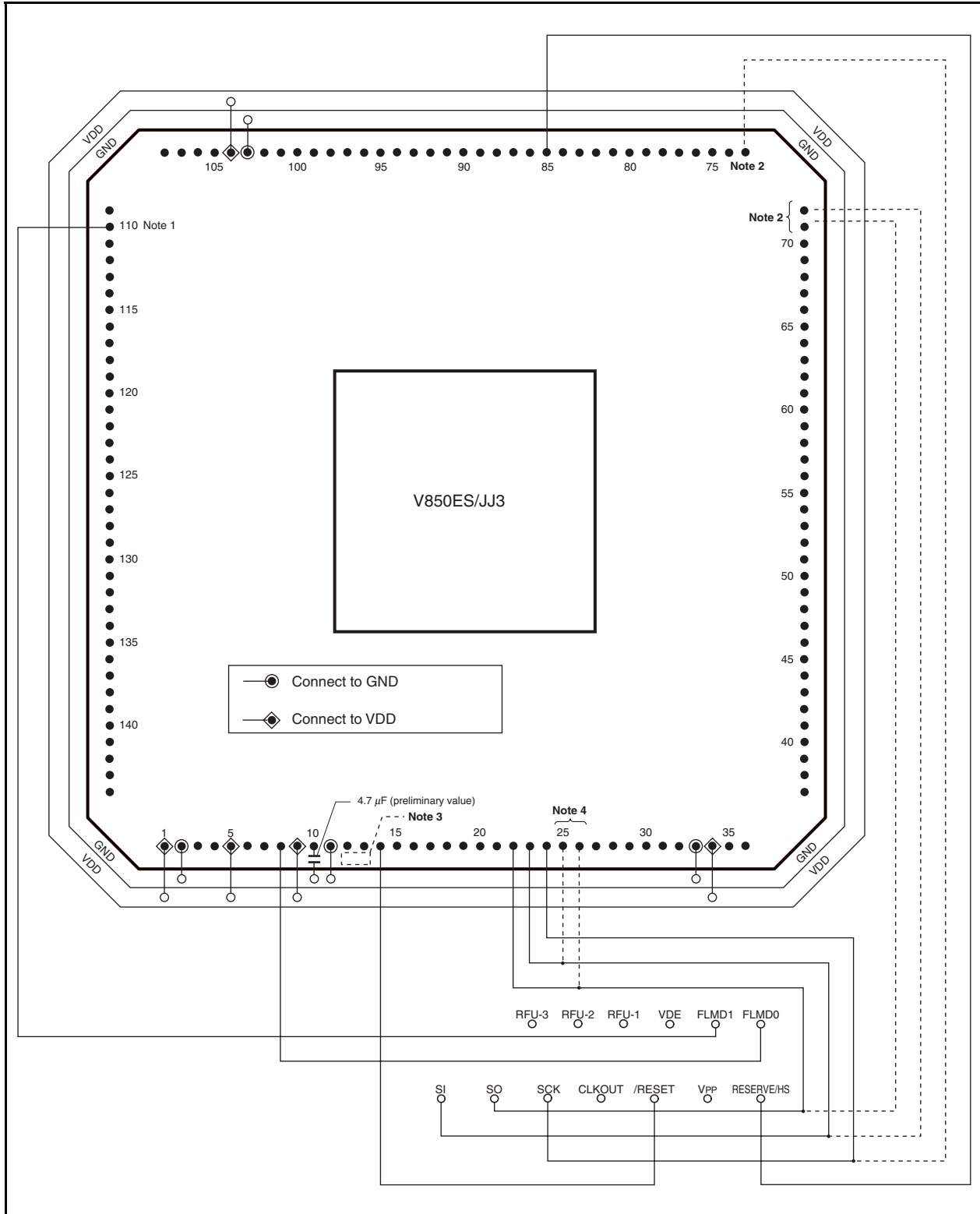
- Cautions**
1. Be sure to connect the REGC pin to GND via a 4.7  $\mu\text{F}$  (preliminary value) capacitor.
  2. A clock cannot be supplied from the CLK pin of the flash programmer. Create an oscillator on the board and supply the clock from that oscillator.

Table 27-6. Wiring of Flash Writing Adapter for V850ES/JJ3 (FA-144GJ-UEN-A) (2/2)

| Flash Programmer (PG-FP4)<br>Connection Pins |        |   | Pin Name on<br>FA Board | When CSIB3 + HS Is Used             |            | When CSIB3 Is Used                  |            |
|--|--------|---|-------------------------|-------------------------------------|------------|-------------------------------------|------------|
| Signal<br>Name                               | I/O    | Pin Function                                      |                         | Pin Name                            | Pin<br>No. | Pin Name                            | Pin<br>No. |
| SI/RxD                                       | Input  | Receive signal                                    | SI                      | P911/A11/SOB3                       | 72         | P911/A11/SOB3                       | 72         |
| SO/TxD                                       | Output | Transmit signal                                   | SO                      | P910/A10/SIB3                       | 71         | P910/A10/SIB3                       | 71         |
| SCK  | Output | Transfer clock                                    | SCK                     | P912/A12/ $\overline{\text{SCKB3}}$ | 73         | P912/A12/ $\overline{\text{SCKB3}}$ | 73         |
| CLK  | Output | Clock to<br>V850ES/JJ3                            | X1                      | Not necessary                       | –          | Not necessary                       | –          |
|  |        |   | X2                      | Not necessary                       | –          | Not necessary                       | –          |
| /RESET                                       | Output | Reset signal                                      | /RESET                  | $\overline{\text{RESET}}$           | 14         | $\overline{\text{RESET}}$           | 14         |
| FLMD0  | Output | Write voltage                                     | FLMD0                   | FLMD0                               | 8          | FLMD0                               | 8          |
| FLMD1  | Output | Write voltage                                     | FLMD1                   | PDL5/AD5/FLMD1                      | 110        | PDL5/AD5/FLMD1                      | 110        |
| HS   | Input  | Handshake signal<br>of CSIO + HS<br>communication | RESERVE/HS              | PCM0/ $\overline{\text{WAIT}}$      | 85         | Not necessary                       | –          |
| VDD  | –      | VDD voltage<br>generation/<br>voltage monitor     | VDD                     | VDD                                 | 9          | V <sub>DD</sub>                     | 9          |
|  |        |   |                         | EV <sub>DD</sub>                    | 34,<br>104 | EV <sub>DD</sub>                    | 34,<br>104 |
|  |        |   |                         | AV <sub>REF0</sub>                  | 1          | AV <sub>REF0</sub>                  | 1          |
|  |        |   |                         | AV <sub>REF1</sub>                  | 5          | AV <sub>REF1</sub>                  | 5          |
| GND  | –      | Ground  | GND                     | V <sub>SS</sub>                     | 11         | V <sub>SS</sub>                     | 11         |
|  |        |   |                         | AV <sub>SS</sub>                    | 2          | AV <sub>SS</sub>                    | 2          |
|  |        |   |                         | EV <sub>SS</sub>                    | 33,<br>103 | EV <sub>SS</sub>                    | 33,<br>103 |

- Cautions**
1. Be sure to connect the REGC pin to GND via a 4.7  $\mu\text{F}$  (preliminary value) capacitor.
  2. A clock cannot be supplied from the CLK pin of the flash programmer. Create an oscillator on the board and supply the clock from that oscillator.

Figure 27-6. Example of Wiring of V850ES/JJ3 Flash Writing Adapter (FA-144GJ-UEN-A)  
(in CSIB0 + HS Mode) (1/2)

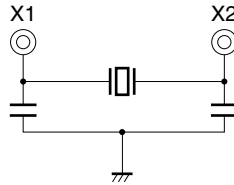




**Figure 27-6. Example of Wiring of V850ES/JJ3 Flash Writing Adapter (FA-144GJ-UEN-A)  
(in CSIB0 + HS Mode) (2/2)**

- Notes**
1. Wire the FLMD1 pin as shown below, or connect it to GND on board via a pull-down resistor.
  2. Pins used when CSIB3 is used
  3. Supply a clock by creating an oscillator on the flash writing adapter (enclosed by the broken lines). Here is an example of the oscillator.

**Example**



4. Pins used when UARTA0 is used.

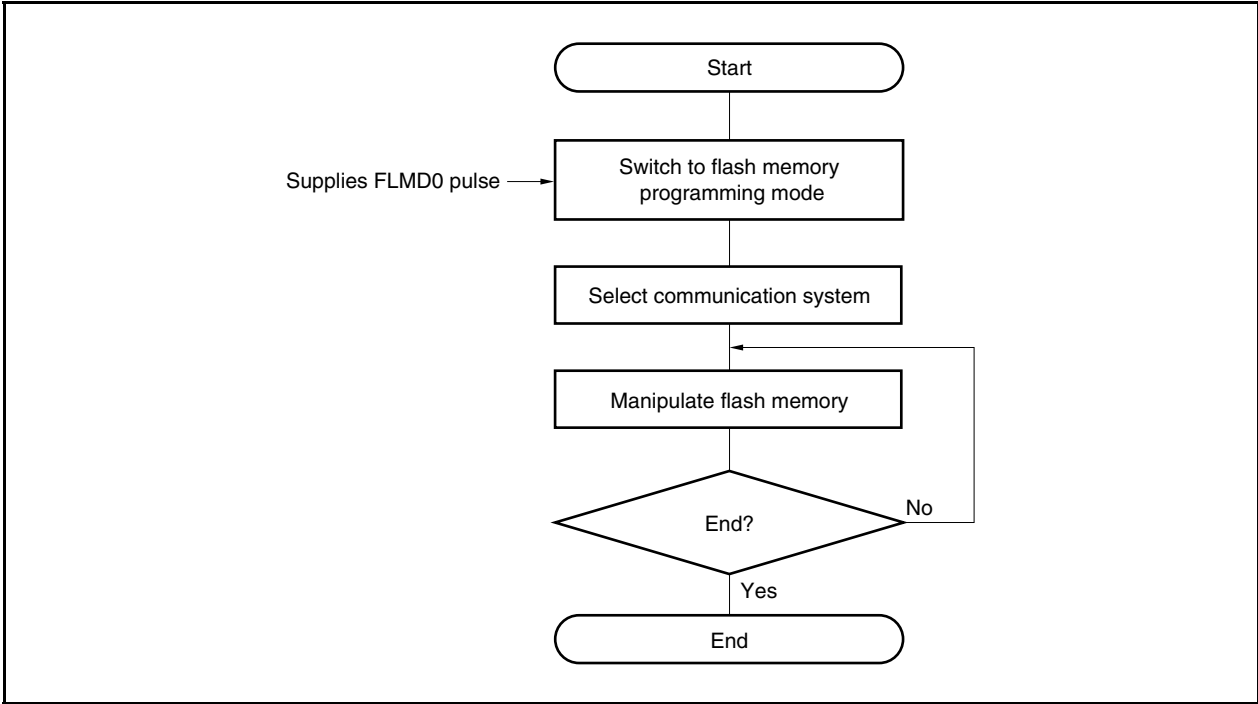
**Caution** Do not input a high level to the  $\overline{\text{DRST}}$  pin.

- Remarks**
1. Process the pins not shown in accordance with processing of unused pins (see 2.3 Pin I/O Circuit Types, I/O Buffer Power Supplies and Handling of Unused Pins).
  2. This adapter is for the 144-pin plastic LQFP package.

27.4.3 Flash memory control

The following shows the procedure for manipulating the flash memory.

Figure 27-7. Procedure for Manipulating Flash Memory

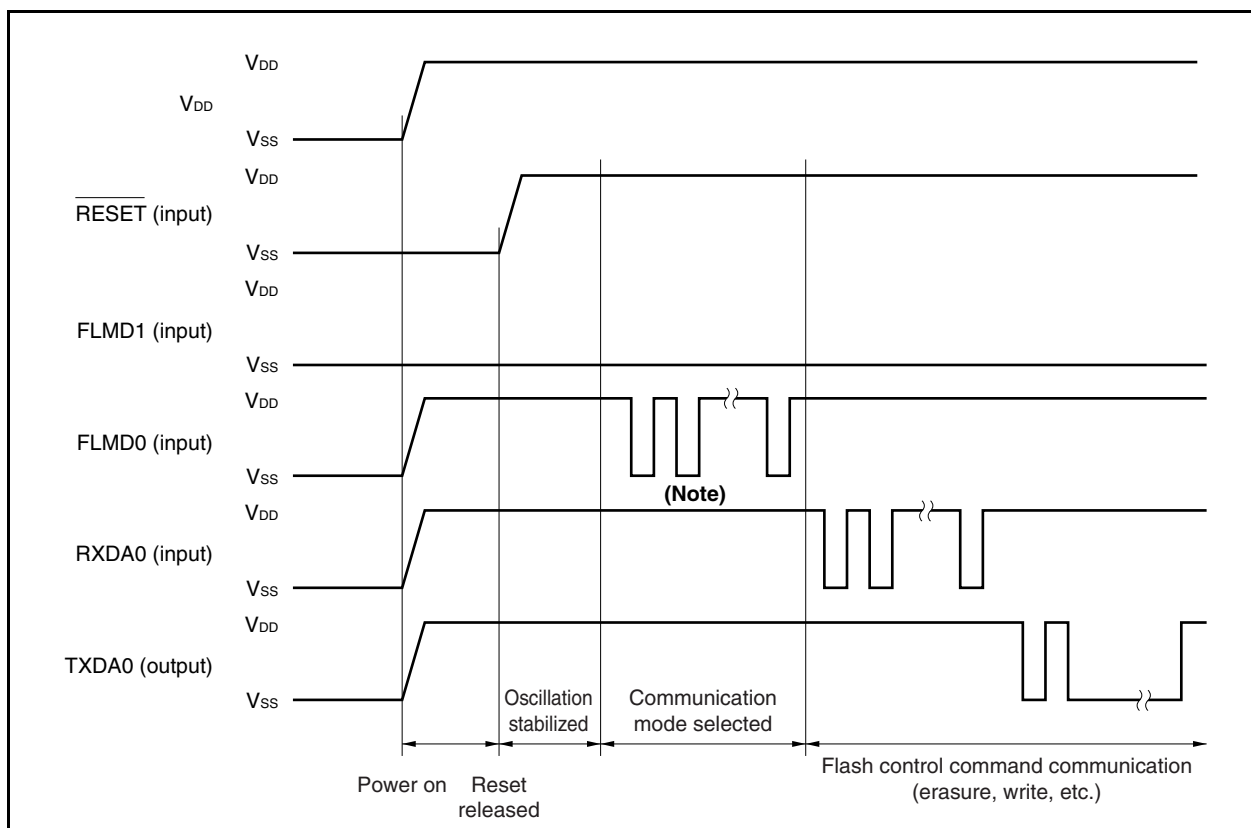


### 27.4.4 Selection of communication mode

In the V850ES/JJ3, the communication mode is selected by inputting pulses (12 pulses max.) to the FLMD0 pin after switching to the flash memory programming mode. The FLMD0 pulse is generated by the dedicated flash programmer.

The following shows the relationship between the number of pulses and the communication mode.

Figure 27-8. Selection of Communication Mode



**Note** The number of clocks is as follows depending on the communication mode.

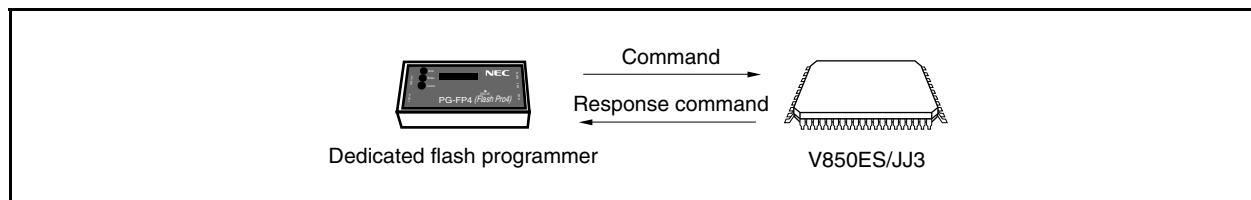
| FLMD0 Pulse | Communication Mode | Remarks  |
|-------------|--------------------|--|
| 0           | UARTA0             | Communication rate: 9,600 bps (after reset), LSB first |
| 8           | CSIB0              | V850ES/JJ3 performs slave operation, MSB first         |
| 9           | CSIB3              | V850ES/JJ3 performs slave operation, MSB first         |
| 11          | CSIB0 + HS         | V850ES/JJ3 performs slave operation, MSB first         |
| 12          | CSIB3 + HS         | V850ES/JJ3 performs slave operation, MSB first         |
| Other       | RFU                | Setting prohibited                                     |

**Caution** When UARTA0 is selected, the receive clock is calculated based on the reset command sent from the dedicated flash programmer after receiving the FLMD0 pulse.

### 27.4.5 Communication commands

The V850ES/JJ3 communicates with the dedicated flash programmer by means of commands. The signals sent from the dedicated flash programmer to the V850ES/JJ3 are called "commands". The response signals sent from the V850ES/JJ3 to the dedicated flash programmer are called "response commands".

Figure 27-9. Communication Commands



The following shows the commands for flash memory control in the V850ES/JJ3. All of these commands are issued from the dedicated flash programmer, and the V850ES/JJ3 performs the processing corresponding to the commands.

Table 27-7. Flash Memory Control Commands

| Classification          | Command Name              | Support      |                        |        | Function  |
|-------------------------|---------------------------|--------------|------------------------|--------|---|
|                         |                           | CSIB0, CSIB3 | CSIB0 + HS, CSIB3 + HS | UARTA0 |   |
| Blank check             | Block blank check command | √            | √                      | √      | Checks if the contents of the memory in the specified block have been correctly erased.                         |
| Erase                   | Chip erase command        | √            | √                      | √      | Erases the contents of the entire memory.   |
|                         | Block erase command       | √            | √                      | √      | Erases the contents of the memory of the specified block.   |
| Write                   | Program command           | √            | √                      | √      | Writes the specified address range, and executes a contents verify check.                                       |
| Verify                  | Verify command            | √            | √                      | √      | Compares the contents of memory in the specified address range with data transferred from the flash programmer. |
|                         | Checksum command          | √            | √                      | √      | Reads the checksum in the specified address range.  |
| System setting, control | Silicon signature command | √            | √                      | √      | Reads silicon signature information.  |
|                         | Security setting command  | √            | √                      | √      | Disables the chip erase command, block erase command, program command, read command, and boot area rewrite.     |

### 27.4.6 Pin connection

When performing on-board writing, mount a connector on the target system to connect to the dedicated flash programmer. Also, incorporate a function on-board to switch from the normal operation mode to the flash memory programming mode.

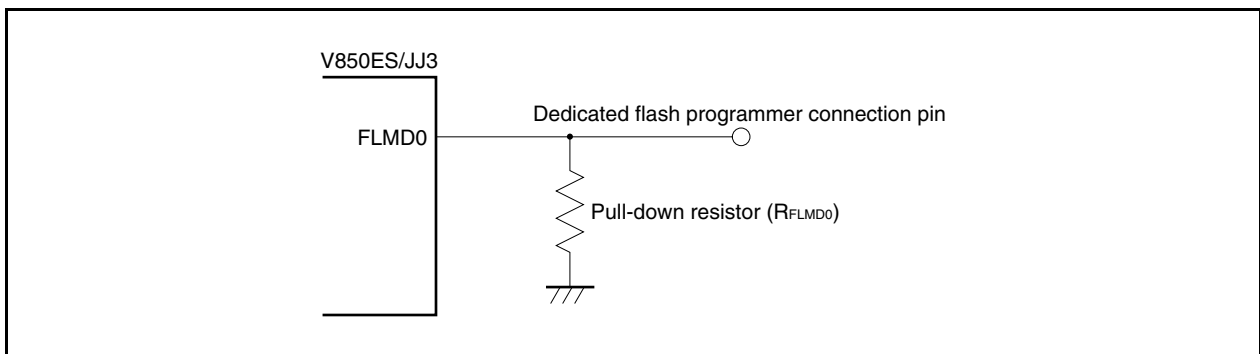
In the flash memory programming mode, all the pins not used for flash memory programming become the same status as that immediately after reset. Therefore, pin handling is required when the external device does not acknowledge the status immediately after a reset.

#### (1) FLMD0 pin

In the normal operation mode, input a voltage of  $V_{SS}$  level to the FLMD0 pin. In the flash memory programming mode, supply a write voltage of  $V_{DD}$  level to the FLMD0 pin.

Because the FLMD0 pin serves as a write protection pin in the self programming mode, a voltage of  $V_{DD}$  level must be supplied to the FLMD0 pin via port control, etc., before writing to the flash memory. For details, see 27.5.5 (1) FLMD0 pin.

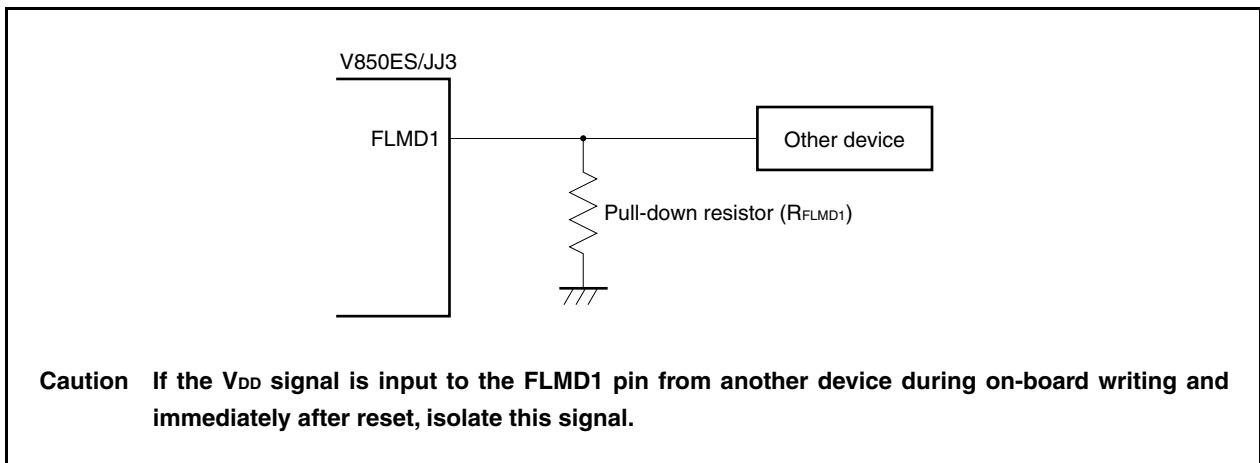
Figure 27-10. FLMD0 Pin Connection Example



#### (2) FLMD1 pin

When 0 V is input to the FLMD0 pin, the FLMD1 pin does not function. When  $V_{DD}$  is supplied to the FLMD0 pin, the flash memory programming mode is entered, so 0 V must be input to the FLMD1 pin. The following shows an example of the connection of the FLMD1 pin.

Figure 27-11. FLMD1 Pin Connection Example



**Table 27-8. Relationship Between FLMD0 and FLMD1 Pins and Operation Mode When Reset Is Released**

| FLMD0           | FLMD1           | Operation Mode                |
|-----------------|-----------------|-------------------------------|
| 0               | Don't care      | Normal operation mode         |
| V <sub>DD</sub> | 0               | Flash memory programming mode |
| V <sub>DD</sub> | V <sub>DD</sub> | Setting prohibited            |

**(3) Serial interface pin**

The following shows the pins used by each serial interface.

**Table 27-9. Pins Used by Serial Interfaces**

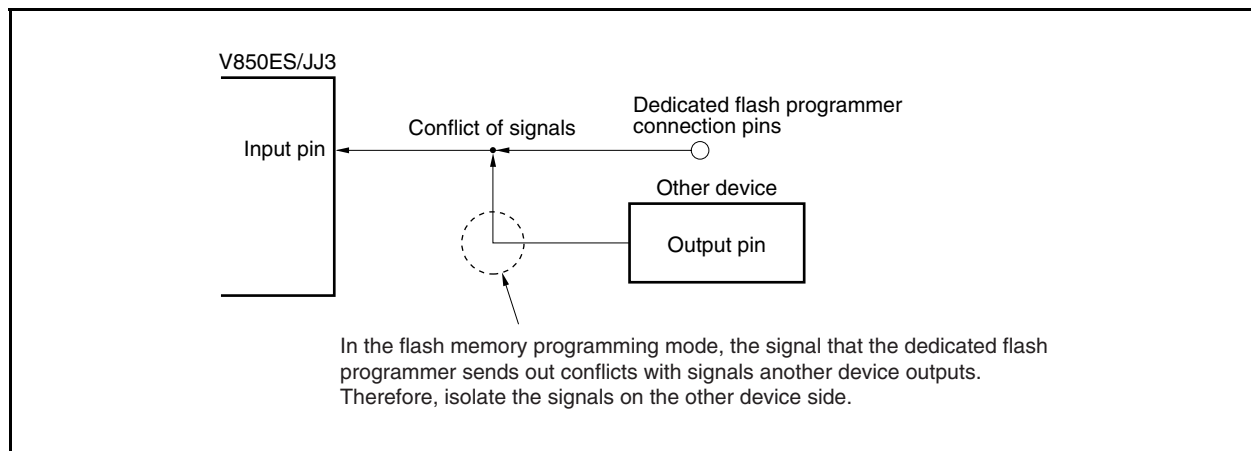
| Serial Interface | Pins Used                                    |
|------------------|--|
| UARTA0           | TXDA0, RXDA0                                 |
| CSIB0            | SOB0, SIB0, $\overline{\text{SCKB0}}$        |
| CSIB3            | SOB3, SIB3, $\overline{\text{SCKB3}}$        |
| CSIB0 + HS       | SOB0, SIB0, $\overline{\text{SCKB0}}$ , PCMO |
| CSIB3 + HS       | SOB3, SIB3, $\overline{\text{SCKB3}}$ , PCMO |

When connecting a dedicated flash programmer to a serial interface pin that is connected to another device on-board, care should be taken to avoid conflict of signals and malfunction of the other device.

**(a) Conflict of signals**

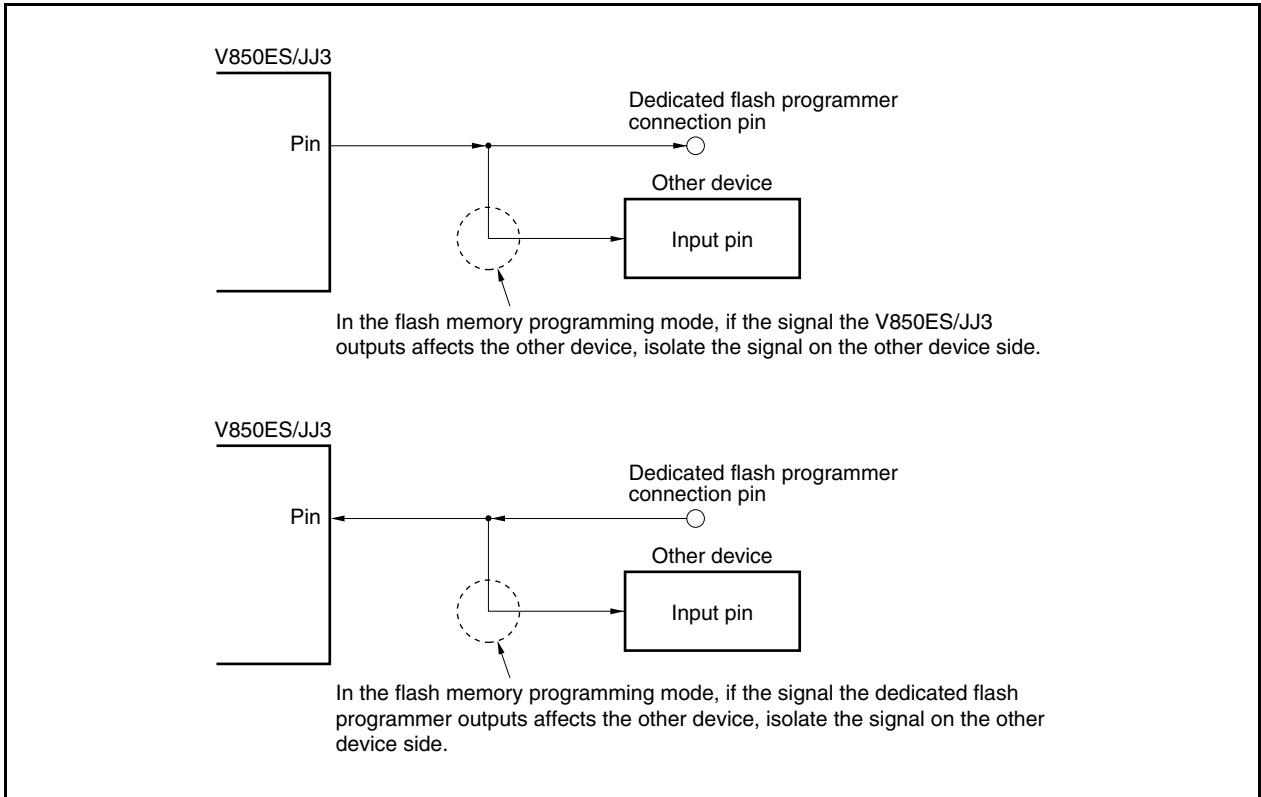
When the dedicated flash programmer (output) is connected to a serial interface pin (input) that is connected to another device (output), a conflict of signals occurs. To avoid the conflict of signals, isolate the connection to the other device or set the other device to the output high-impedance status.

**Figure 27-12. Conflict of Signals (Serial Interface Input Pin)**



**(b) Malfunction of other device**

When the dedicated flash programmer (output or input) is connected to a serial interface pin (input or output) that is connected to another device (input), the signal is output to the other device, causing the device to malfunction. To avoid this, isolate the connection to the other device.

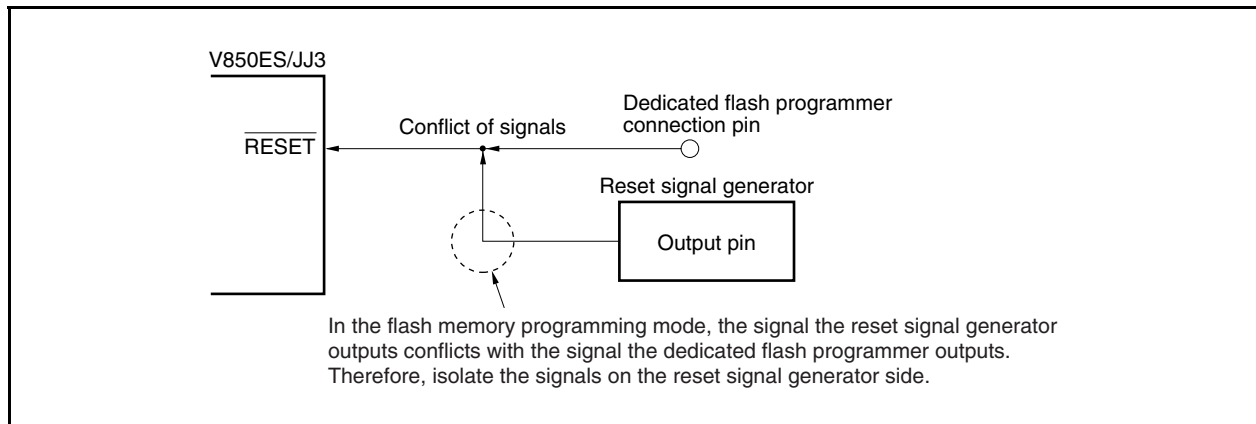
**Figure 27-13. Malfunction of Other Device**

**(4) RESET pin**

When the reset signals of the dedicated flash programmer are connected to the  $\overline{\text{RESET}}$  pin that is connected to the reset signal generator on-board, a conflict of signals occurs. To avoid the conflict of signals, isolate the connection to the reset signal generator.

When a reset signal is input from the user system in the flash memory programming mode, the programming operation will not be performed correctly. Therefore, do not input signals other than the reset signals from the dedicated flash programmer.

**Figure 27-14. Conflict of Signals ( $\overline{\text{RESET}}$  Pin)**

**(5) Port pins (including NMI)**

When the system shifts to the flash memory programming mode, all the pins that are not used for flash memory programming are in the same status as that immediately after reset. If the external device connected to each port does not recognize the status of the port immediately after reset, pins require appropriate processing, such as connecting to  $V_{DD}$  via a resistor or connecting to  $V_{SS}$  via a resistor.

**(6) Other signal pins**

Connect X1, X2, XT1, XT2, and REGC in the same status as that in the normal operation mode.

During flash memory programming, input a low level to the  $\overline{\text{DRST}}$  pin or leave it open. Do not input a high level.

**(7) Power supply**

Supply the same power ( $V_{DD}$ ,  $V_{SS}$ ,  $EV_{DD}$ ,  $EV_{SS}$ ,  $AV_{REF0}$ ,  $AV_{REF1}$ ,  $AV_{SS}$ ) as in normal operation mode.

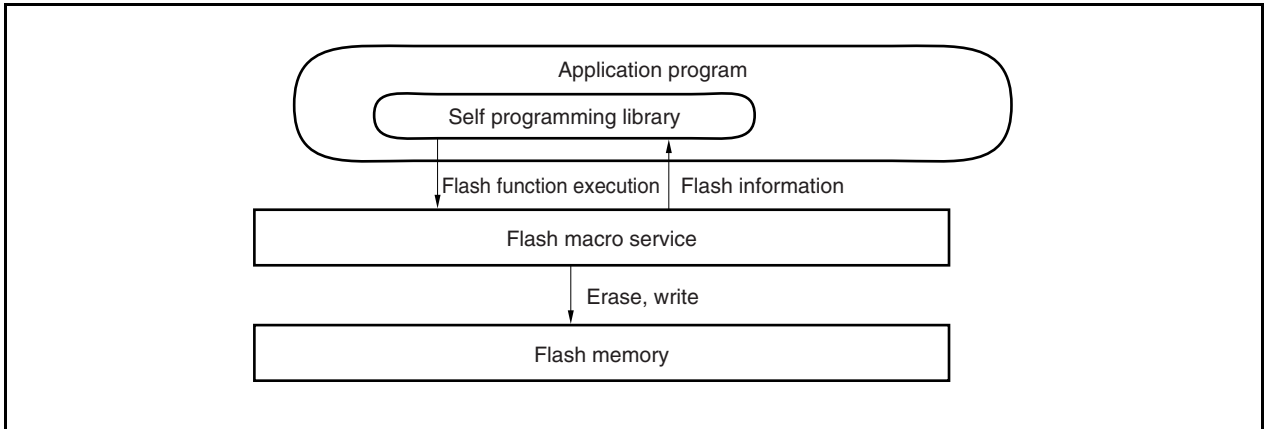


## 27.5 Rewriting by Self Programming

### 27.5.1 Overview

The V850ES/JJ3 supports a flash macro service that allows the user program to rewrite the internal flash memory by itself. By using this interface and a self programming library that is used to rewrite the flash memory with a user application program, the flash memory can be rewritten by a user application transferred in advance to the internal RAM or external memory. Consequently, the user program can be upgraded and constant data can be rewritten in the field.

**Figure 27-15. Concept of Self Programming**

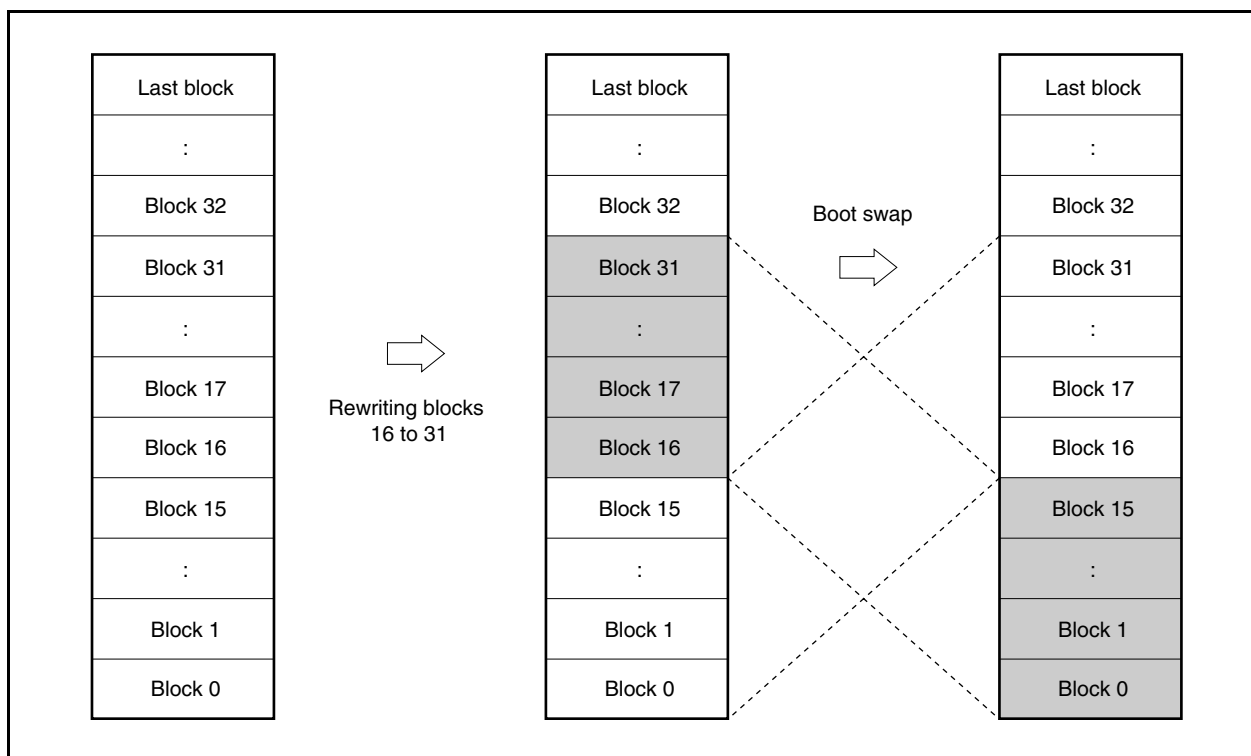


## 27.5.2 Features

## (1) Secure self programming (boot swap function)

The V850ES/JJ3 supports a boot swap function that can exchange the physical memory of blocks 0 to 15 with the physical memory of blocks 16 to 31. By writing the start program to be rewritten to blocks 16 to 31 in advance and then swapping the physical memory, the entire area can be safely rewritten even if a power failure occurs during rewriting because the correct user program always exists in blocks 0 to 15.

Figure 27-16. Rewriting Entire Memory Area (Boot Swap)



## (2) Interrupt support

Instructions cannot be fetched from the flash memory during self programming. Conventionally, a user handler written to the flash memory could not be used even if an interrupt occurred.

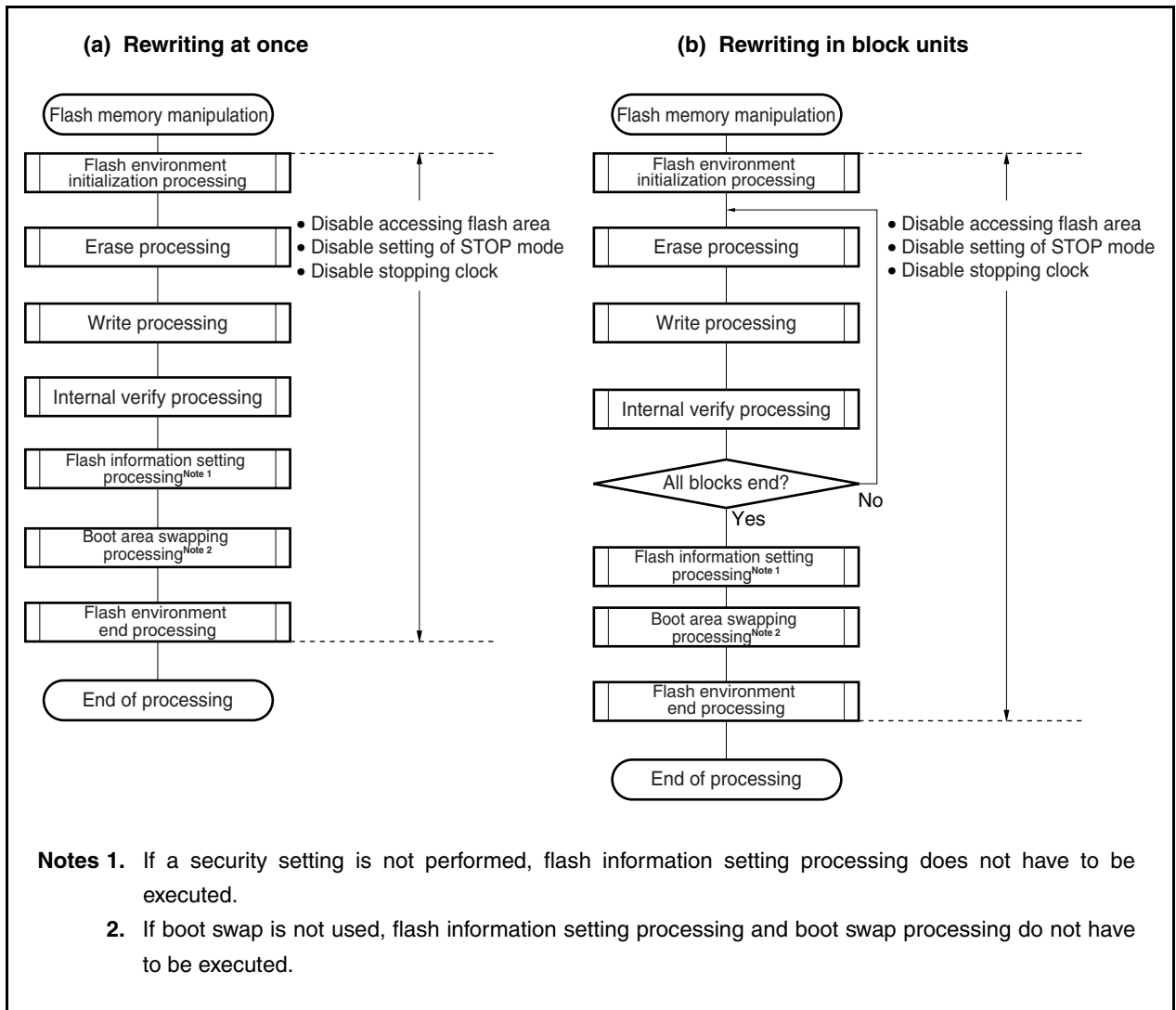
Therefore, in the V850ES/JJ3, to use an interrupt during self programming, processing transits to the specific address<sup>Note</sup> in the internal RAM. Allocate the jump instruction that transits processing to the user interrupt servicing at the specific address<sup>Note</sup> in the internal RAM.

**Note** NMI interrupt: Start address of internal RAM  
 Maskable interrupt: Start address of internal RAM + 4 addresses

27.5.3 Standard self programming flow

The entire processing to rewrite the flash memory by flash self programming is illustrated below.

Figure 27-17. Standard Self Programming Flow



## 27.5.4 Flash functions

Table 27-10. Flash Function List

| Function Name        | Outline  | Support |
|----------------------|--|---------|
| FlashEnv             | Initialization of flash control macro                  | √       |
| FlashBlockErase      | Erasure of only specified one block                    | √       |
| FlashWordWrite       | Writing from specified address                         | √       |
| FlashBlockVerify     | Internal verification of specified one block           | √       |
| FlashBlockBlankCheck | Blank check of specified one block                     | √       |
| FlashFLMDCheck       | Check of FLMD pin                                      | √       |
| FlashStatusCheck     | Status check of operation specified immediately before | √       |
| FlashGetInfo         | Reading of flash information                           | √       |
| FlashSetInfo         | Setting of flash information                           | √       |
| FlashBootSwap        | Swapping of boot area                                  | √       |
| FlashSetUserHandler  | User interrupt handler registration function           | √       |

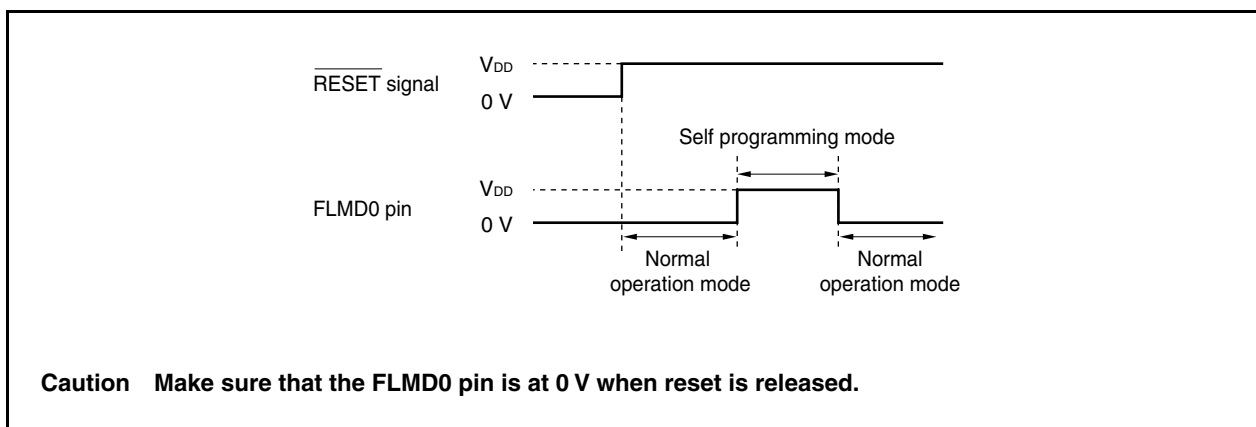
## 27.5.5 Pin processing

## (1) FLMD0 pin

The FLMD0 pin is used to set the operation mode when reset is released and to protect the flash memory from being written during self rewriting. It is therefore necessary to keep the voltage applied to the FLMD0 pin at 0 V when reset is released and a normal operation is executed. It is also necessary to apply a voltage of  $V_{DD}$  level to the FLMD0 pin during the self programming mode period via port control before the memory is rewritten.

When self programming has been completed, the voltage on the FLMD0 pin must be returned to 0 V.

Figure 27-18. Mode Change Timing



### 27.5.6 Internal resources used

The following table lists the internal resources used for self programming. These internal resources can also be used freely for purposes other than self programming.

**Table 27-11. Internal Resources Used**

| Resource Name                         | Description   |
|---------------------------------------|---|
| Stack area (user stack + (TBD) bytes) | An extension of the stack used by the user is used by the library (can be used in both the internal RAM and external RAM).  |
| Library code ((TBD) bytes)            | Program entity of library (can be used anywhere other than the flash memory block to be manipulated).   |
| Application program                   | Executed as user application.<br>Calls flash functions.   |
| Maskable interrupt                    | Can be used in the user application execution status or self programming status. To use this interrupt in the self programming status, the interrupt servicing start address must be registered in advance by a registration function.  |
| NMI interrupt                         | Can be used in user application execution status or self programming status. To use this interrupt in the self-programming status, since the processing transits to the address of the internal RAM start address, allocate the jump instruction that transits the processing to the user interrupt servicing at the internal RAM start address in advance. |

## CHAPTER 28 ON-CHIP DEBUG FUNCTION

The V850ES/JJ3 on-chip debug function can be implemented by the following two methods.

- Using the DCU (debug control unit)  
On-chip debug function is implemented by the on-chip DCU in the V850ES/JJ3, with using the  $\overline{\text{DRST}}$ , DCK, DMS, DDI, and DDO pins as the debug interface pins.
- Not using the DCU  
On-chip debug function is implemented by MINICUBE2 or the like, using the user resources, instead of the DCU.

The following table shows the features of the two on-chip debug functions.

**Table 28-1. On-Chip Debug Function Features**

|  |                   | Debugging Using DCU   | Debugging Without Using DCU  |
|--|-------------------|---|--|
| Debug interface pins   |                   | $\overline{\text{DRST}}$ , DCK, DMS, DDI, DDO                                 | <ul style="list-style-type: none"> <li>• When UARTA0 is used<br/>RXD0, TXD0</li> <li>• When CSIB0 is used<br/>SIB0, SOB0, SCKB0, HS (PCM0)</li> <li>• When CSIB3 is used<br/>SIB3, SOB3, SCKB3, HS (PCM0)</li> </ul> |
| Securement of user resources                                 |                   | Not required  | Required   |
| Hardware break function                                      |                   | 2 points  | 2 points   |
| Software break function                                      | Internal ROM area | 4 points  | 4 points   |
|  | Internal RAM area | 2000 points   | 2000 points  |
| Real-time RAM monitor function <sup>Note 1</sup>             |                   | Available   | Available  |
| Dynamic memory modification (DMM) function <sup>Note 2</sup> |                   | Available   | Available  |
| Mask function  |                   | $\overline{\text{Reset}}$ , NMI, INTWDT2, $\overline{\text{HLDRQ}}$ ,<br>WAIT | $\overline{\text{RESET}}$ pin  |
| ROM security function  |                   | 10-byte ID code authentication  | 10-byte ID code authentication   |
| Hardware used  |                   | NINICUBE <sup>®</sup> , etc.  | NINICUBE2, etc.  |
| Trace function   |                   | Not supported.  | Not supported.   |
| Debug interrupt interface function (DBINT)                   |                   | Not supported.  | Not supported.   |

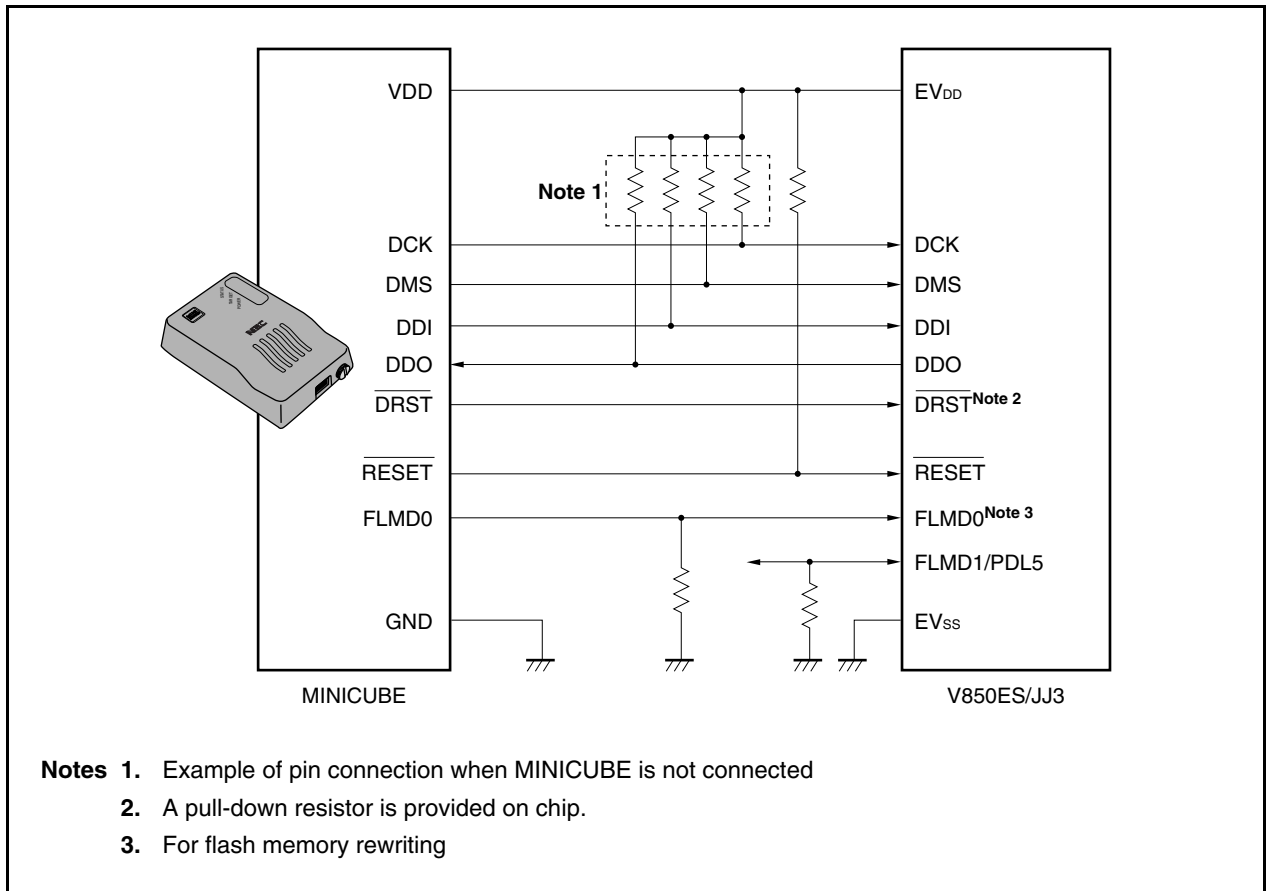
- Notes**
1. This is a function which reads out memory contents during program execution.
  2. This is a function which rewrites RAM contents during program execution.

## 28.1 Debugging with DCU

Programs can be debugged using the debug interface pins ( $\overline{\text{DRST}}$ , DCK, DMS, DDI, and DDO) to connect the on-chip debug emulator (MINICUBE).

### 28.1.1 Connection circuit example

Figure 28-1. Circuit Connection Example When Debug Interface Pins Are Used for Communication Interface



### 28.1.2 Interface signals

The interface signals are described below.

#### (1) $\overline{\text{DRST}}$

This is a reset input signal for the on-chip debug unit. It is a negative-logic signal that asynchronously initializes the debug control unit.

MINICUBE raises the  $\overline{\text{DRST}}$  signal when it detects  $V_{DD}$  of the target system after the integrated debugger is started, and starts the on-chip debug unit of the device.

When the  $\overline{\text{DRST}}$  signal goes high, a reset signal is also generated in the CPU.

When starting debugging by starting the integrated debugger, a CPU reset is always generated.

**(2) DCK**

This is a clock input signal. It supplies a 20 MHz or 10 MHz clock from MINICUBE. In the on-chip debug unit, the DMS and DDI signals are sampled at the rising edge of the DCK signal, and the data DDO is output at its falling edge.

**(3) DMS**

This is a transfer mode select signal. The transfer status in the debug unit changes depending on the level of the DMS signal.

**(4) DDI**

This is a data input signal. It is sampled in the on-chip debug unit at the rising edge of DCK.

**(5) DDO**

This is a data output signal. It is output from the on-chip debug unit at the falling edge of the DCK signal.

**(6) EV<sub>DD</sub>**

This signal is used to detect VDD of the target system. If VDD from the target system is not detected, the signals output from MINICUBE ( $\overline{\text{DRST}}$ , DCK, DMS, DDI, FLMD0, and  $\overline{\text{RESET}}$ ) go into a high-impedance state.

**(7) FLMD0**

The flash self programming function is used for the function to download data to the flash memory via the integrated debugger. During flash self programming, the FLMD0 pin must be kept high. In addition, connect a pull-down resistor to the FLMD0 pin.

The FLMD0 pin can be controlled in either of the following two ways.

**<1> To control from MINICUBE**

Connect the FLMD0 signal of MINICUBE to the FLMD0 pin.

In the normal mode, nothing is driven by MINICUBE (high impedance).

During a break, MINICUBE raises the FLMD0 pin to the high level when the download function of the integrated debugger is executed.

**<2> To control from port**

Connect any port of the device to the FLMD0 pin.

The same port as the one used by the user program to realize the flash self programming function may be used.

On the console of the integrated debugger, make a setting to raise the port pin to high level before executing the download function, or lower the port pin after executing the download function.

For details, refer to the **ID850QB Ver. 3.10 Integrated Debugger Operation User's Manual (U17435E)**.

**(8)  $\overline{\text{RESET}}$** 

This is a system reset input pin. If the  $\overline{\text{DRST}}$  pin is made invalid by the value of the OCDM0 bit of the OCDM register set by the user program, on-chip debugging cannot be executed. Therefore, reset is effected by MINICUBE, using the  $\overline{\text{RESET}}$  pin, to make the  $\overline{\text{DRST}}$  pin valid (initialization).



### 28.1.3 Maskable functions

Reset, NMI, INTWDT2,  $\overline{\text{WAIT}}$ , and  $\overline{\text{HLDRQ}}$  signals can be masked.

The maskable functions with the debugger (ID850QB) and the corresponding V850ES/JJ3 functions are listed below.

**Table 28-2. Maskable Functions**

| Maskable Functions with ID850QB | Corresponding V850ES/JJ3 Functions   |
|---------------------------------|--|
| NMI0                            | NMI pin input  |
| NMI2                            | Non-maskable interrupt request signal (INTWDT2) generation   |
| STOP                            | –  |
| HOLD                            | $\overline{\text{HLDRQ}}$ pin input  |
| RESET                           | Reset signal generation by $\overline{\text{RESET}}$ pin input, low-voltage detector, clock monitor, or watchdog timer (WDT2) overflow |
| WAIT                            | $\overline{\text{WAIT}}$ pin input   |

### 28.1.4 Register

#### (1) On-chip debug mode register (OCDM)

The OCDM register is used to select the normal operation mode or on-chip debug mode. This register is a special register and can be written only in a combination of specific sequences (see **3.4.7 Special registers**). This register is also used to specify whether a pin provided with an on-chip debug function is used as an on-chip debug pin or as an ordinary port/peripheral function pin. It also is used to disconnect the internal pull-down resistor of the P05/INTP2/ $\overline{\text{DRST}}$  pin.

The OCDM register can be written only while a low level is input to the  $\overline{\text{DRST}}$  pin.

This register can be read or written in 8-bit or 1-bit units.

After reset: 01H<sup>Note</sup> R/W Address: FFFFF9FCH

|      |   |   |   |   |   |   |   |       |
|------|---|---|---|---|---|---|---|-------|
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1 | <0>   |
| OCDM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | OCDM0 |

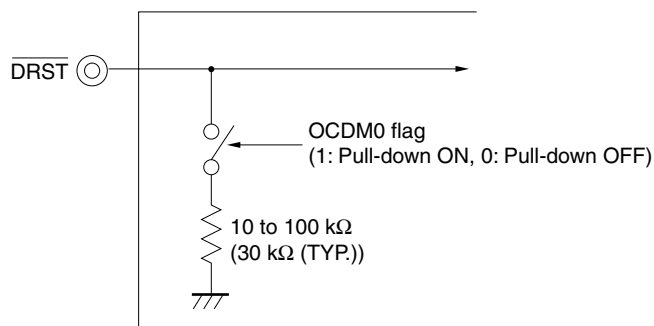
| OCDM0 | Operation mode  |
|-------|---|
| 0     | Selects normal operation mode (in which a pin that functions alternately as on-chip debug function pin is used as a port/peripheral function pin) and disconnects the on-chip pull-down resistor of the P05/INTP2/ $\overline{\text{DRST}}$ pin.  |
| 1     | When $\overline{\text{DRST}}$ pin is low:<br>Normal operation mode (in which a pin that functions alternately as an on-chip debug function pin is used as a port/peripheral function pin)<br>When $\overline{\text{DRST}}$ pin is high:<br>On-chip debug mode (in which a pin that functions alternately as an on-chip debug function pin is used as an on-chip debug mode pin) |

**Note**  $\overline{\text{RESET}}$  input sets this register to 01H. After reset by the WDT2RES signal, clock monitor (CLM), or low-voltage detector (LVI), however, the value of the OCDM0 register is retained.

**Cautions** 1. When using the DDI, DDO, DCK, and DMS pins not as on-chip debug pins but as port pins after external reset, any of the following actions must be taken.

- Input a low level to the P05/INTP2/ $\overline{\text{DRST}}$  pin.
- Set the OCDM0 bit. In this case, take the following actions.
  - <1> Clear the OCDM0 bit to 0.
  - <2> Fix the P05/INTP2/ $\overline{\text{DRST}}$  pin to low level until <1> is completed.

2. The  $\overline{\text{DRST}}$  pin has an on-chip pull-down resistor. This resistor is disconnected when the OCDM0 flag is cleared to 0.



### 28.1.5 Operation

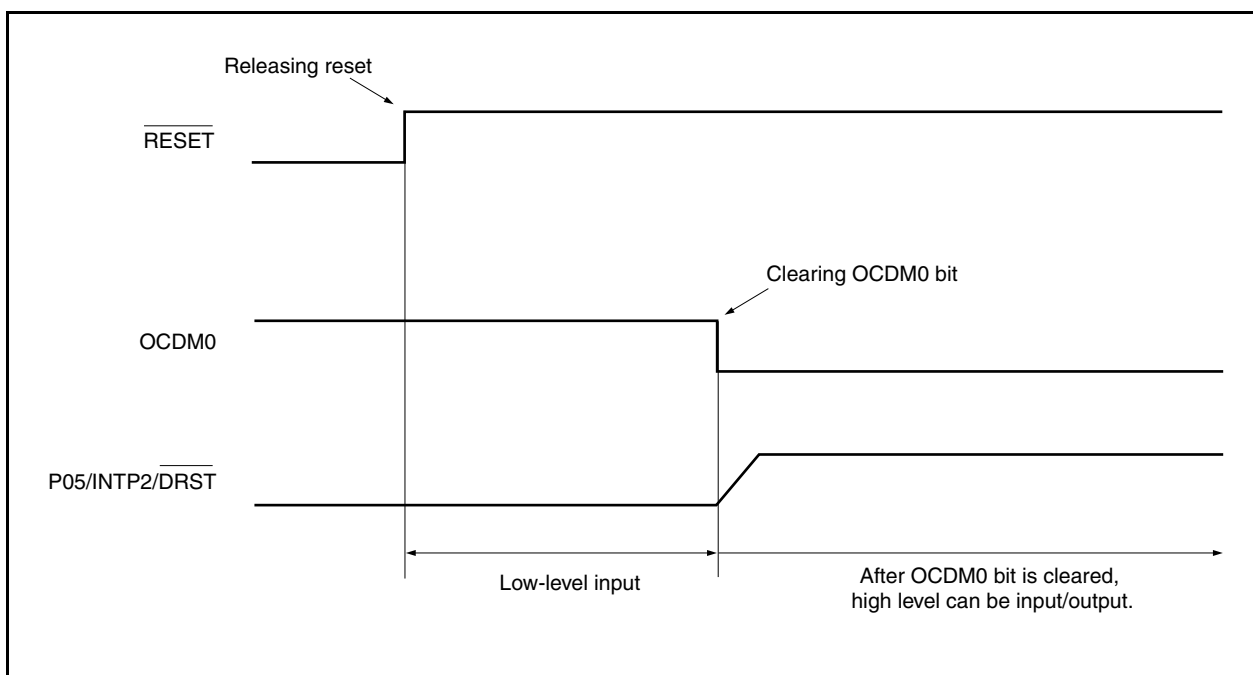
The on-chip debug function is made invalid under the conditions shown in the table below.

When this function is not used, keep the  $\overline{\text{DRST}}$  pin low until the OCDM.OCDM0 flag is cleared to 0.

| OCDM0 Flag \ $\overline{\text{DRST}}$ Pin | 0       | 1       |
|---|---------|---------|
| L   | Invalid | Invalid |
| H   | Invalid | Valid   |

**Remark** L: Low-level input  
H: High-level input

**Figure 28-2. Timing When On-Chip Debug Function Is Not Used**



### 28.1.6 Cautions

- (1) If a reset signal is input (from the target system or a reset signal from an internal reset source) during RUN (program execution), the break function may malfunction.
- (2) Even if the reset signal is masked by the mask function, the I/O buffer (port pin) may be reset if a reset signal is input from a pin.
- (3) Pin reset during a break is masked and the CPU and peripheral I/O are not reset. If pin reset or internal reset is generated as soon as the flash memory is rewritten by DMM or read by the RAM monitor function while the user program is being executed, the CPU and peripheral I/O may not be correctly reset.
- (4) In the on-chip debug mode, the DDO pin is forcibly set to the high-level output.

## 28.2 Debugging Without Using DCU

The following describes how to implement an on-chip debug function using MINICUBE2 with pins for UARTA0 (RXDA0 and TXDA0), pins for CSIB0 (SIB0, SOB0,  $\overline{\text{SCKB0}}$ , and HS (PMC0)), or pins for CSIB3 (SIB3, SOB3,  $\overline{\text{SCKB3}}$ , and HS (PMC0)) as debug interfaces, without using the DCU.

### 28.2.1 Circuit connection examples

Figure 28-3. Circuit Connection Example When UARTA0/CSIB0/CSIB3 Is Used for Communication Interface

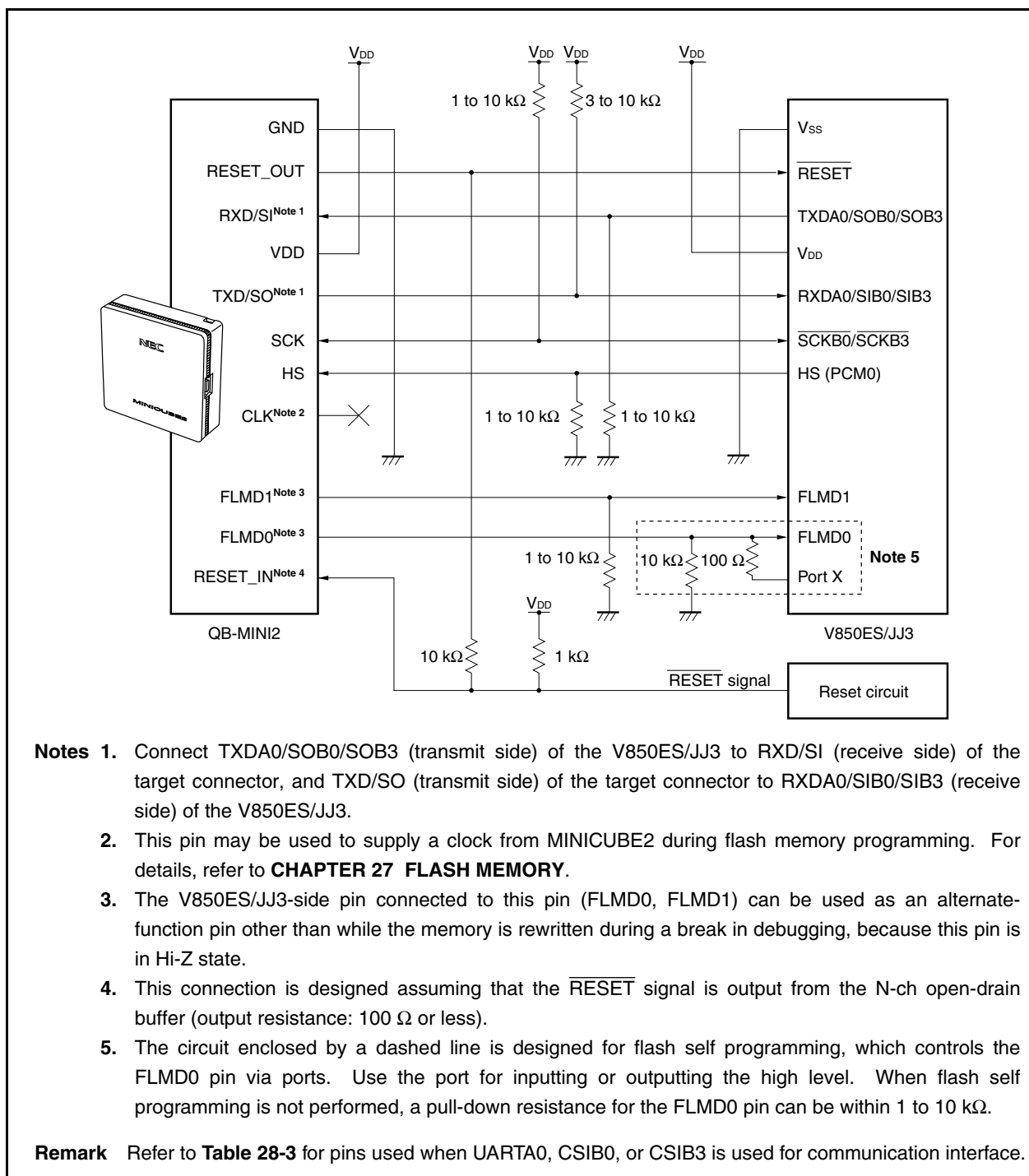


Table 28-3. Wiring Between V850ES/JJ3 and MINICUBE2

| Pin Configuration of MINICUBE2 (QB-MINI2) |        |  | With CSIB0-HS              |         | With CSIB3-HS              |         | With UARTA0                |         |
|---|--------|--|----------------------------|---------|----------------------------|---------|----------------------------|---------|
| Signal Name                               | I/O    | Pin Function   | Pin Name                   | Pin No. | Pin Name                   | Pin No. | Pin Name                   | Pin No. |
| SI/RxD                                    | Input  | Pin to receive commands and data from V850ES/JJ3               | P41/SOB0                   | 23      | P911/SOB3                  | 72      | P30/TXD0                   | 25      |
| SO/TxD                                    | Output | Pin to transmit commands and data to V850ES/JJ3                | P40/SIB0                   | 22      | P910/SIB3                  | 71      | P31/RXD0                   | 26      |
| SCK                                       | Output | Clock output pin for 3-wire serial communication               | P42/SCKB0                  | 24      | P912/SCKB3                 | 73      | Not needed                 | –       |
| CLK <sup>Note</sup>                       | Output | Clock output pin to V850ES/JJ3                                 | Not needed <sup>Note</sup> | –       | Not needed <sup>Note</sup> | –       | Not needed <sup>Note</sup> | –       |
|   |        |  | Not needed <sup>Note</sup> | –       | Not needed <sup>Note</sup> | –       | Not needed <sup>Note</sup> | –       |
| RESET_OUT                                 | Output | Reset output pin to V850ES/JJ3                                 | RESET                      | 14      | RESET                      | 14      | RESET                      | 14      |
| FLMD0                                     | Output | Output pin to set V850ES/JJ3 to debug mode or programming mode | FLMD0                      | 8       | FLMD0                      | 8       | FLMD0                      | 8       |
| FLMD1                                     | Output | Output pin to set programming mode                             | PDL5/FLMD1                 | 110     | PDL5/FLMD1                 | 110     | PDL5/FLMD1                 | 110     |
| HS  | Input  | Handshake signal for CSIO + HS communication                   | PCM0/WAIT                  | 85      | PCM0/WAIT                  | 85      | Not needed                 | –       |
| GND                                       | –      | Ground   | V <sub>SS</sub>            | 11      | V <sub>SS</sub>            | 11      | V <sub>SS</sub>            | 11      |
|   |        |  | AV <sub>SS</sub>           | 2       | AV <sub>SS</sub>           | 2       | AV <sub>SS</sub>           | 2       |
|   |        |  | EV <sub>SS</sub>           | 33, 103 | EV <sub>SS</sub>           | 33, 103 | EV <sub>SS</sub>           | 33, 103 |
| RESET_IN                                  | Input  | Reset input pin on the target system                           |                            |         |                            |         |                            |         |

**Note** It is used as the clock output of the flash programmer for MINICUBE2. For details, refer to **CHAPTER 27 FLASH MEMORY**.

### 28.2.2 Maskable functions

Only reset signals can be masked.

The maskable functions with the debugger (ID850QB) and the corresponding V850ES/JJ3 functions are listed below.

Table 28-4. Maskable Functions

| Maskable Functions with ID850QB | Corresponding V850ES/JJ3 Functions         |
|---------------------------------|--|
| NMI0                            | –  |
| NMI1                            | –  |
| NMI2                            | –  |
| STOP                            | –  |
| HOLD                            | –  |
| RESET                           | Reset signal generation by RESET pin input |
| WAIT                            | –  |

### 28.2.3 Securement of user resources

The user must prepare the following to perform communication between MINICUBE2 and the target device and implement each debug function. These items need to be set in the user program or using the compiler options.

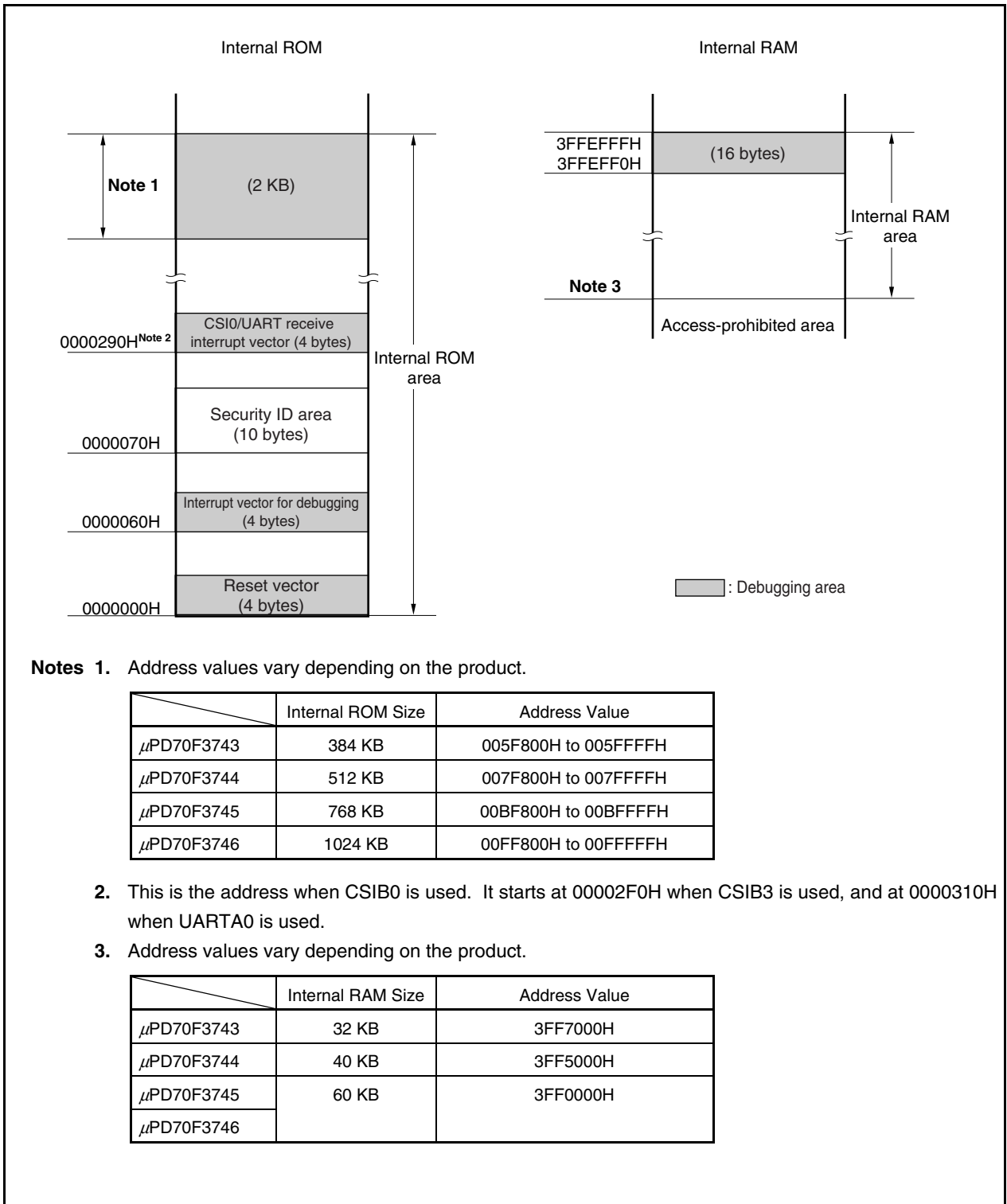
#### (1) Securement of memory space

The shaded portions in Figure 28-4 are the areas reserved for placing the debug monitor program, so user programs and data cannot be allocated in these spaces. These spaces must be secured so as not to be used by the user program.

#### (2) Security ID setting

The ID code must be embedded in the area between 0000070H and 0000079H in Figure 28-4, to prevent the memory from being read by an unauthorized person. For details, refer to **28.3 ROM Security Function**.

Figure 28-4. Memory Spaces Where Debug Monitor Programs Are Allocated



**Notes 1.** Address values vary depending on the product.

|                 | Internal ROM Size | Address Value         |
|-----------------|-------------------|-----------------------|
| $\mu$ PD70F3743 | 384 KB            | 005F800H to 005FFFFH  |
| $\mu$ PD70F3744 | 512 KB            | 007F800H to 007FFFFH  |
| $\mu$ PD70F3745 | 768 KB            | 00BF800H to 00BFFFFH  |
| $\mu$ PD70F3746 | 1024 KB           | 00FF800H to 00FFFFFFH |

<R>  
<R>

- This is the address when CSIB0 is used. It starts at 00002F0H when CSIB3 is used, and at 0000310H when UARTA0 is used.
- Address values vary depending on the product.

|                 | Internal RAM Size | Address Value |
|-----------------|-------------------|---------------|
| $\mu$ PD70F3743 | 32 KB             | 3FF7000H      |
| $\mu$ PD70F3744 | 40 KB             | 3FF5000H      |
| $\mu$ PD70F3745 | 60 KB             | 3FF0000H      |
| $\mu$ PD70F3746 |                   |               |

<R>  
<R>

**(3) Reset vector**

A reset vector includes the jump instruction for the debug monitor program.

[How to secure areas]

It is not necessary to secure this area intentionally. When downloading a program, however, the debugger rewrites the reset vector in accordance with the following cases. If the rewritten pattern does not match the following cases, the debugger generates an error (FOC34 when using the ID850QB).

**(a) When two nop instructions are placed in succession from address 0**

| Before rewriting |   | After rewriting                       |
|------------------|---|---------------------------------------|
| 0x0 nop          | → | Jumps to debug monitor program at 0x0 |
| 0x2 nop          |   | 0x4 xxxx                              |
| 0x4 xxxx         |   |                                       |

**(b) When two 0xFFFF are successively placed from address 0 (already erased device)**

| Before rewriting |   | After rewriting                       |
|------------------|---|---------------------------------------|
| 0x0 0xFFFF       | → | Jumps to debug monitor program at 0x0 |
| 0x2 0xFFFF       |   | 0x4 xxxx                              |
| 0x4 xxxx         |   |                                       |

**(c) The jr instruction is placed at address 0 (when using CA850)**

| Before rewriting |   | After rewriting                       |
|------------------|---|---------------------------------------|
| 0x0 jr disp22    | → | Jumps to debug monitor program at 0x0 |
|                  |   | 0x4 jr disp22 - 4                     |

**(d) mov32 and jmp are placed in succession from address 0 (when using IAR compiler ICCV850)**

| Before rewriting   |   | After rewriting                       |
|--------------------|---|---------------------------------------|
| 0x0 mov imm32,reg1 | → | Jumps to debug monitor program at 0x0 |
| 0x6 jmp [reg1]     |   | 0x4 mov imm32,reg1                    |
|                    |   | 0xa jmp [reg1]                        |

**(e) The jump instruction for the debug monitor program is placed at address 0**

| Before rewriting                      |   | After rewriting |
|---------------------------------------|---|-----------------|
| Jumps to debug monitor program at 0x0 | → | No change       |



**(4) Securement of area for debug monitor program**

The shaded portions in Figure 28-4 are the areas where the debug monitor program is allocated. The monitor program performs initialization processing for debug communication interface and RUN or break processing for the CPU. The internal ROM area must be filled with 0xFF. This area must not be rewritten by the user program.

[How to secure areas]

It is not necessarily required to secure this area if the user program does not use this area.

To avoid problems that may occur during the debugger startup, however, it is recommended to secure this area in advance, using the compiler.

The following shows examples for securing the area, using the NEC Electronics compiler CA850. Add the assemble source file and link directive code, as shown below.

- Assemble source (Add the following code as an assemble source file.)

```

-- Secures 2 KB space for monitor ROM section
.section "MonitorROM", const
.space 0x800, 0xff

-- Secures interrupt vector for debugging
.section "DBG0"
.space 4, 0xff

-- Secures interrupt vector for serial communication
-- Change the section name according to the serial communication mode used
.section "INTCB0R"
.space 4, 0xff

-- Secures 16-byte space for monitor RAM section
.section "MonitorRAM", bss
.lcomm monitorramsym, 16, 4 -- defines symbol monitorramsym

```

- Link directive (Add the following code to the link directive file.)

The following shows an example when the internal ROM has 1024 KB (end address is 00FFFFFFH) and internal RAM has 60 KB (end address is 3FFEFFFH).

```

MROMSEG      : !LOAD ?R V0x0ff800{
              MonitorROM = $PROGBITS ?A MonitorROM;
};

MRAMSEG      : !LOAD ?RW V0x03ffeff0{
              MonitorRAM = $NOBITS ?AW MonitorRAM;
};

```

**(5) Securement of communication serial interface**

UARTA0, CSIB0, or CSIB3 is used for communication between MINICUBE2 and the target system. The settings related to the serial interface modes are performed by the debug monitor program, but if the setting is changed by the user program, a communication error may occur.

To prevent such a problem from occurring, communication serial interface must be secured in the user program.

[How to secure communication serial interface]

- On-chip debug mode register (OCDM)
 

For the on-chip debug function using the UARTA0, CSIB0, or CSIB3, set the OCDM register functions to normal mode. Be sure to set as follows.

  - Input low level to the P05/INTP2/ $\overline{\text{DRST}}$  pin.
  - Set the OCDM0 bit as shown below.
    - <1> Clear the OCDM0 bit to 0.
    - <2> Fix the P05/INTP2/ $\overline{\text{DRST}}$  pin input to low level until the processing of <1> is complete.
- Serial interface registers
 

Do not set the registers related to CSIB0, CSIB3, or UARTA0 in the user program.
- Interrupt mask register
 

When CSIB0 is used, do not mask the transmit end interrupt (INTCB0R). When CSIB3 is used, do not mask the transmit end interrupt (INTCB3R). When UARTA0 is used, do not mask the receive end interrupt (INTUA0R).

|                                |   |   |   |   |   |   |   |   |
|--------------------------------|---|---|---|---|---|---|---|---|
| <b>(a) When CSIB0 is used</b>  |   |   |   |   |   |   |   |   |
|                                | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| CB0RIC                         | × | 0 | × | × | × | × | × | × |
| <b>(b) When CSIB3 is used</b>  |   |   |   |   |   |   |   |   |
|                                | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| CB3RIC                         | × | 0 | × | × | × | × | × | × |
| <b>(c) When UARTA0 is used</b> |   |   |   |   |   |   |   |   |
|                                | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| UA0RIC                         | × | 0 | × | × | × | × | × | × |
| <b>Remark</b> ×: don't care    |   |   |   |   |   |   |   |   |

- Port registers when UARTA0 is used

When UARTA0 is used, port registers are set to make the TXDA0 and RXDA0 pins valid by the debug monitor program. Do not change the following register settings with the user program during debugging. (The same value can be overwritten.)

|       |   |   |   |   |   |   |   |   |
|-------|---|---|---|---|---|---|---|---|
|       | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PFC3  | × | × | × | × | × | × | 0 | 0 |
|       | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PMC3L | × | × | × | × | × | × | 1 | 1 |

**Remark** ×: don't care

- Port registers when CSIB0 is used

When CSIB0 is used, port registers are set to make the SIB0, SOB0,  $\overline{\text{SCKB0}}$ , and HS (PMC0) pins valid by the debug monitor program. Do not change the following register settings with the user program during debugging. (The same value can be overwritten.)

**(a) SIB0, SOB0, and  $\overline{\text{SCKB0}}$  settings**

|      |   |   |   |   |   |   |   |   |
|------|---|---|---|---|---|---|---|---|
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PMC4 | × | × | × | × | × | 1 | 1 | 1 |
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PFC4 | × | × | × | × | × | × | 0 | 0 |

**(b) HS (PMC0 pin) settings**

|      |   |   |   |   |   |   |   |             |
|------|---|---|---|---|---|---|---|-------------|
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0           |
| PMCM | × | × | × | × | × | × | × | 0           |
|      | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0           |
| PCM  | × | × | × | × | × | × | × | <b>Note</b> |

**Note** Writing to this bit is prohibited.  
The port values corresponding to the HS pin are changed by the monitor program according to the debugger status. To perform port register settings in 8-bit units, the user program can usually use read-modify-write. If an interrupt for debugging occurs before writing, however, an unexpected operation may be performed.

**Remark** ×: don't care

- Port registers when CSIB3 is used

When CSIB3 is used, port registers are set to make the SIB3, SOB3,  $\overline{\text{SCKB3}}$ , and HS (PMC0) pins valid by the debug monitor program. Do not change the following register settings with the user program during debugging. (The same value can be overwritten.)

**(a) SIB3, SOB3, and  $\overline{\text{SCKB3}}$  settings**

|       | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|---|---|---|---|---|---|---|---|
| PMC9H | × | × | × | 1 | 1 | 1 | × | × |

|       | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|---|---|---|---|---|---|---|---|
| PFC9H | × | × | × | 1 | 1 | 1 | × | × |

**(b) HS (PMC0 pin) settings**

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

|     | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0           |
|-----|---|---|---|---|---|---|---|-------------|
| PCM | × | × | × | × | × | × | × | <b>Note</b> |

**Note** Writing to this bit is prohibited.

The port values corresponding to the HS pin are changed by the monitor program according to the debugger status. To perform port register settings in 8-bit units, the user program can usually use read-modify-write. If an interrupt for debugging occurs before writing, however, an unexpected operation may be performed.

**Remark** ×: don't care

## 28.2.4 Cautions

### (1) Handling of device that was used for debugging

Do not mount a device that was used for debugging on a mass-produced product, because the flash memory was rewritten during debugging and the number of rewrites of the flash memory cannot be guaranteed. Moreover, do not embed the debug monitor program into mass-produced products.

### (2) When breaks cannot be executed

Forced breaks cannot be executed if one of the following conditions is satisfied.

- Interrupts are disabled (DI)
- Interrupts issued for the serial interface, which is used for communication between MINICUBE2 and the target device, are masked
- Standby mode is entered while standby release by a maskable interrupt is prohibited
- Mode for communication between MINICUBE2 and the target device is UARTA0, and the main clock has been stopped

**(3) When pseudo real-time RAM monitor (RRM) function and DMM function do not operate**

The pseudo RRM function and DMM function do not operate if one of the following conditions is satisfied.

- Interrupts are disabled (DI)
- Interrupts issued for the serial interface, which is used for communication between MINICUBE2 and the target device, are masked
- Standby mode is entered while standby release by a maskable interrupt is prohibited
- Mode for communication between MINICUBE2 and the target device is UARTA0, and the main clock has been stopped
- Mode for communication between MINICUBE2 and the target device is UARTA0, and a clock different from the one specified in the debugger is used for communication

**(4) Standby release with pseudo RRM and DMM functions enabled**

The standby mode is released by the pseudo RRM function and DMM function if one of the following conditions is satisfied.

- Mode for communication between MINICUBE2 and the target device is CSIB0 or CSIB3
- Mode for communication between MINICUBE2 and the target device is UARTA0, and the main clock has been supplied.

**(5) Writing to peripheral I/O registers that requires a specific sequence, using DMM function**

Peripheral I/O registers that requires a specific sequence cannot be written with the DMM function.

**(6) Flash self programming**

If a space where the debug monitor program is allocated is rewritten by flash self programming, the debugger can no longer operate normally.

## 28.3 ROM Security Function

### 28.3.1 Security ID

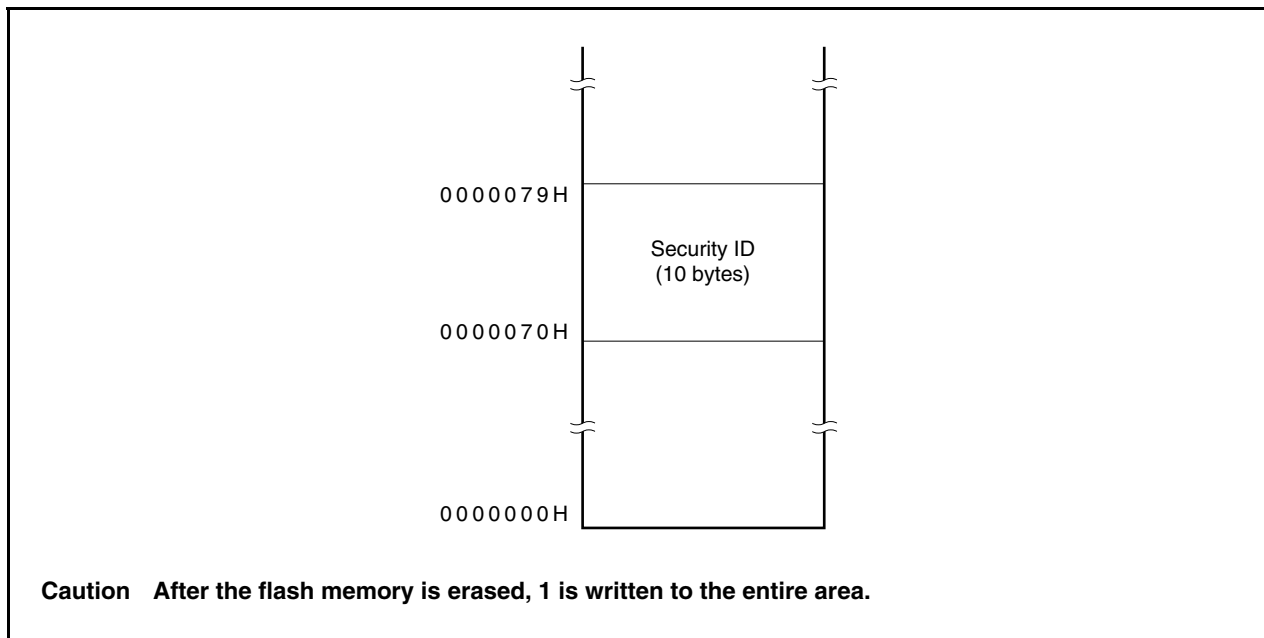
The flash memory versions of the V850ES/JJ3 perform authentication using a 10-byte ID code to prevent the contents of the flash memory from being read by an unauthorized person during on-chip debugging by the on-chip debug emulator.

Set the ID code in the 10-byte on-chip flash memory area from 0000070H to 0000079H to allow the debugger perform ID authentication.

If the IDs match, the security is released and reading flash memory and using the on-chip debug emulator are enabled.

- Set the 10-byte ID code to 0000070H to 0000079H.
- Bit 7 of 0000079H is the on-chip debug emulator enable flag.  
(0: Disable, 1: Enable)
- When the on-chip debug emulator is started, the debugger requests ID input. When the ID code input on the debugger and the ID code set in 0000070H to 0000079H match, the debugger starts.
- Debugging cannot be performed if the on-chip debug emulator enable flag is 0, even if the ID codes match.

**Figure 28-5. Security ID Area**



### 28.3.2 Setting

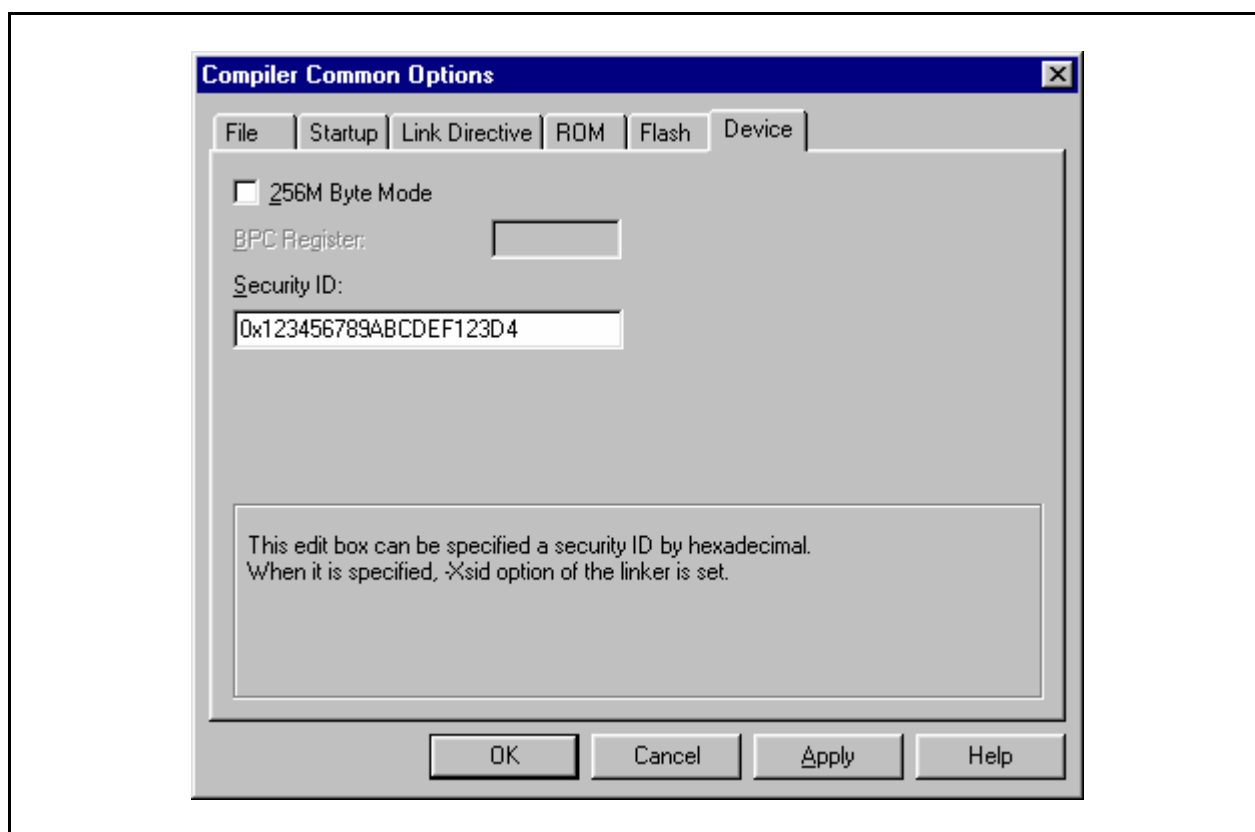
The following shows how to set the ID code as shown in Table 28-5.

When the ID code is set as shown in Table 28-5, the ID code input in the configuration dialog box of the ID850QB is "123456789ABCDEF123D4" (the ID code is case-insensitive).

**Table 28-5. ID Code**

| Address | Value |
|---------|-------|
| 0x70    | 0x12  |
| 0x71    | 0x34  |
| 0x72    | 0x56  |
| 0x73    | 0x78  |
| 0x74    | 0x9A  |
| 0x75    | 0xBC  |
| 0x76    | 0xDE  |
| 0x77    | 0XF1  |
| 0x78    | 0x23  |
| 0x79    | 0xD4  |

The ID code can be specified for the device file that supports CA850 Ver. 3.10 or later and the security ID using the PM+ compiler common option setting.



[Program example (when using CA850 Ver. 3.10 or later)]

```
#-----  
# SECURITYID  
#-----  
    .section "SECURITY_ID" --Interrupt handler address 0x70  
    .word    0x78563412    --0-3 byte code  
    .word    0xF1DEBC9A    --4-7 byte code  
    .hword   0xD423        --8-9 byte code
```

**Remark** Add the above program example to the startup files.



## CHAPTER 29 ELECTRICAL SPECIFICATIONS (TARGET)

### Absolute Maximum Ratings (T<sub>A</sub> = 25°C) (1/2)

| Parameter            | Symbol             | Conditions  | Ratings   | Unit |
|----------------------|--------------------|---|---|------|
| Supply voltage       | V <sub>DD</sub>    | V <sub>DD</sub> = EV <sub>DD</sub> = AV <sub>REF0</sub> = AV <sub>REF1</sub>                      | -0.5 to +4.6  | V    |
|                      | EV <sub>DD</sub>   | V <sub>DD</sub> = EV <sub>DD</sub> = AV <sub>REF0</sub> = AV <sub>REF1</sub>                      | -0.5 to +4.6  | V    |
|                      | AV <sub>REF0</sub> | V <sub>DD</sub> = EV <sub>DD</sub> = AV <sub>REF0</sub> = AV <sub>REF1</sub>                      | -0.5 to +4.6  | V    |
|                      | AV <sub>REF1</sub> | V <sub>DD</sub> = EV <sub>DD</sub> = AV <sub>REF0</sub> = AV <sub>REF1</sub>                      | -0.5 to +4.6  | V    |
|                      | V <sub>SS</sub>    | V <sub>SS</sub> = EV <sub>SS</sub> = AV <sub>SS</sub>   | -0.5 to +0.5  | V    |
|                      | AV <sub>SS</sub>   | V <sub>SS</sub> = EV <sub>SS</sub> = AV <sub>SS</sub>   | -0.5 to +0.5  | V    |
|                      | EV <sub>SS</sub>   | V <sub>SS</sub> = EV <sub>SS</sub> = AV <sub>SS</sub>   | -0.5 to +0.5  | V    |
| Input voltage        | V <sub>I1</sub>    | RESET, FLMD0, PCD0 to PCD3, PCM0 to PCM5, PCS0 to PCS7, PCT0 to PCT7, PDH0 to PDH7, PDL0 to PDL15 | -0.5 to EV <sub>DD</sub> + 0.5 <sup>Note 1</sup>                  | V    |
|                      | V <sub>I2</sub>    | P10, P11  | -0.5 to AV <sub>REF1</sub> + 0.5 <sup>Note 1</sup>                | V    |
|                      | V <sub>I3</sub>    | X1, X2  | -0.5 to V <sub>RO</sub> <sup>Note 2</sup> + 0.5 <sup>Note 1</sup> | V    |
|                      | V <sub>I4</sub>    | P00 to P06, P30 to P39, P40 to P42, P50 to P55, P60 to P615, P80, P81, P90 to P915                | -0.5 to +6.0  | V    |
|                      | V <sub>I5</sub>    | XT1, XT2  | -0.5 to V <sub>DD</sub> + 0.5 <sup>Note 1</sup>                   | V    |
| Analog input voltage | V <sub>IAN</sub>   | P70 to P715   | -0.5 to AV <sub>REF0</sub> + 0.5 <sup>Note 1</sup>                | V    |

- Notes**
1. Be sure not to exceed the absolute maximum ratings (MAX. value) of each supply voltage.
  2. On-chip regulator output voltage (2.5 V (TYP.))

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**Absolute Maximum Ratings (T<sub>A</sub> = 25°C) (2/2)**

| Parameter   | Symbol            | Conditions  | Ratings           | Unit   |                   |     |    |
|---|-------------------|---|-------------------|--|-------------------|-----|----|
| Output current, low   | I <sub>OL</sub>   | P00 to P06, P30 to P39, P40 to P42, P50 to P55, P60 to P615, P80, P81, P90 to P915  | Per pin           | 4  | mA                |     |    |
|   |                   |   | Total of all pins | 50   | mA                |     |    |
|   |                   | PCD0 to PCD3, PCM0 to PCM5, PCS0 to PCS7, PCT0 to PCT7, PDH0 to PDH7, PDL0 to PDL15 | Per pin           | 4  | mA                |     |    |
|   |                   |   | Total of all pins | 50   | mA                |     |    |
|   |                   | P10, P11  | Per pin           | 4  | mA                |     |    |
|   |                   |   | Total of all pins | 8  | mA                |     |    |
|   |                   | P70 to P715   | Per pin           | 4  | mA                |     |    |
|   |                   |   | Total of all pins | 20   | mA                |     |    |
|   |                   | Output current, high  | I <sub>OH</sub>   | P00 to P06, P30 to P39, P40 to P42, P50 to P55, P60 to P615, P80, P81, P90 to P915 | Per pin           | -4  | mA |
|   |                   |   |                   |  | Total of all pins | -50 | mA |
| PCD0 to PCD3, PCM0 to PCM5, PCS0 to PCS7, PCT0 to PCT7, PDH0 to PDH7, PDL0 to PDL15 | Per pin           |   |                   | -4   | mA                |     |    |
|   | Total of all pins |   |                   | -50  | mA                |     |    |
| P10, P11  | Per pin           |   |                   | -4   | mA                |     |    |
|   | Total of all pins |   |                   | -8   | mA                |     |    |
| P70 to P715   | Per pin           |   |                   | -4   | mA                |     |    |
|   | Total of all pins |   |                   | -20  | mA                |     |    |
| Operating ambient temperature   | T <sub>A</sub>    |   |                   |  | -40 to +85        | °C  |    |
| Storage temperature   | T <sub>stg</sub>  |   |                   |  | -40 to +125       | °C  |    |

**Cautions 1.** Do not directly connect the output (or I/O) pins of IC products to each other, or to V<sub>DD</sub>, V<sub>CC</sub>, and GND. Open-drain pins or open-collector pins, however, can be directly connected to each other.

Direct connection of the output pins between an IC product and an external circuit is possible, if the output pins can be set to the high-impedance state and the output timing of the external circuit is designed to avoid output conflict.

- 2.** 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. The ratings and conditions indicated for DC characteristics and AC characteristics represent the quality assurance range during normal operation.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

**Capacitance ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ )**

| Parameter       | Symbol   | Conditions  | MIN. | TYP. | MAX. | Unit |
|-----------------|----------|---|------|------|------|------|
| I/O capacitance | $C_{IO}$ | $f_x = 1\text{ MHz}$<br>Unmeasured pins returned to 0 V |      |      | 10   | pF   |

**Operating Conditions****( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ )**

| Internal System Clock Frequency   | Conditions   | Supply Voltage |             |                           | Unit |
|-----------------------------------|--|----------------|-------------|---------------------------|------|
|                                   |  | $V_{DD}$       | $EV_{DD}$   | $AV_{REF0}$ , $AV_{REF1}$ |      |
| $f_{xx} = 2.5$ to $32\text{ MHz}$ | $C = 4.7\ \mu\text{F}$ (preliminary value),<br>A/D converter stopped,<br>D/A converter stopped     | 2.85 to 3.6    | 2.85 to 3.6 | 2.85 to 3.6               | V    |
|                                   | $C = 4.7\ \mu\text{F}$ (preliminary value),<br>A/D converter operating,<br>D/A converter operating | 3.0 to 3.6     | 3.0 to 3.6  | 3.0 to 3.6                | V    |
| $f_{xt} = 32.768\text{ kHz}$      | $C = 4.7\ \mu\text{F}$ (preliminary value),<br>A/D converter stopped,<br>D/A converter stopped     | 2.85 to 3.6    | 2.85 to 3.6 | 2.85 to 3.6               | V    |

**Main Clock Oscillator Characteristics**(T<sub>A</sub> = -40 to +85°C, V<sub>DD</sub> = EV<sub>DD</sub> = AV<sub>REF0</sub> = AV<sub>REF1</sub>, V<sub>SS</sub> = EV<sub>SS</sub> = AV<sub>SS</sub> = 0 V)

| Resonator                               | Circuit Example       | Parameter   | Conditions                  | MIN.                | TYP.                            | MAX. | Unit |
|---|-----------------------|---|-----------------------------|---------------------|---------------------------------|------|------|
| Ceramic resonator/<br>Crystal resonator |                       | Oscillation frequency (f <sub>x</sub> ) <sup>Note 1</sup> |                             | 2.5                 |                                 | 10   | MHz  |
|   |                       | Oscillation stabilization time <sup>Note 2</sup>          | After reset is released     |                     | 2 <sup>16</sup> /f <sub>x</sub> |      | s    |
|   |                       |   | After STOP mode is released | 1 <sup>Note 4</sup> | <b>Note 3</b>                   |      | ms   |
| After IDLE2 mode is released            | 350 <sup>Note 4</sup> | <b>Note 3</b>   |                             | μs                  |                                 |      |      |

**Notes 1.** The oscillation frequency shown above indicates only oscillator characteristics. Use the V850ES/JJ3 so that the internal operation conditions do not exceed the ratings shown in **AC Characteristics** and **DC Characteristics**.

2. Time required from start of oscillation until the resonator stabilizes.
3. The value varies depending on the setting of the OSTS register.
4. Time required to set up the flash memory. Secure the setup time using the OSTS register.

**Cautions 1.** When using the main clock oscillator, wire as follows in the area enclosed by the broken lines in the above figure 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. When the main clock is stopped and the device is operating on the subclock, wait until the oscillation stabilization time has been secured by the program before switching back to the main clock.
  3. For the resonator selection and oscillator constant, customers are requested to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation.

**Subclock Oscillator Characteristics****( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ )**

| Resonator         | Circuit Example | Parameter   | Conditions | MIN. | TYP.   | MAX. | Unit |
|-------------------|-----------------|---|------------|------|--------|------|------|
| Crystal resonator |                 | Oscillation frequency ( $f_{XT1}$ ) <sup>Note 1</sup> |            | 32   | 32.768 | 35   | kHz  |
|                   |                 | Oscillation stabilization time <sup>Note 2</sup>      |            |      |        | 10   | s    |

**Notes** 1. The oscillation frequency shown above indicates only oscillator characteristics. Use the V850ES/JJ3 so that the internal operation conditions do not exceed the ratings shown in **AC Characteristics** and **DC Characteristics**.

2. Time required from when  $V_{DD}$  reaches the oscillation voltage range (2.85 V (MIN.)) to when the crystal resonator stabilizes.

**Cautions** 1. When using the subclock 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. The subclock oscillator is designed as a low-amplitude circuit for reducing power consumption, and is more prone to malfunction due to noise than the main clock oscillator. Particular care is therefore required with the wiring method when the subclock is used.
3. For the resonator selection and oscillator constant, customers are requested to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation.

**PLL Characteristics**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter        | Symbol    | Conditions                           | MIN. | TYP. | MAX. | Unit          |
|------------------|-----------|--------------------------------------|------|------|------|---------------|
| Input frequency  | $f_x$     | $\times 4$ mode                      | 2.5  |      | 5    | MHz           |
|                  |           | $\times 8$ mode                      | 2.5  |      | 4    | MHz           |
| Output frequency | $f_{xx}$  | $\times 4$ mode                      | 10   |      | 20   | MHz           |
|                  |           | $\times 8$ mode                      | 20   |      | 32   | MHz           |
| Lock time        | $t_{PLL}$ | After $V_{DD}$ reaches 2.85 V (MIN.) |      |      | 800  | $\mu\text{s}$ |

**Internal Oscillator Characteristics**

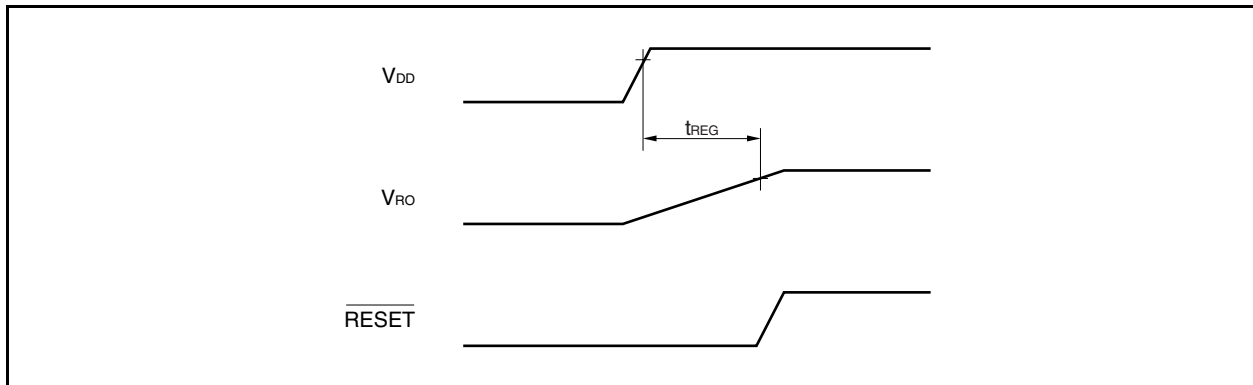
( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter        | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|------------------|--------|------------|------|------|------|------|
| Output frequency | $f_R$  |            | 100  | 220  | 400  | kHz  |

**Regulator Characteristics**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter                           | Symbol    | Conditions   | MIN. | TYP. | MAX. | Unit |
|-------------------------------------|-----------|--|------|------|------|------|
| Input voltage                       | $V_{DD}$  | $f_{xx} = 32\text{ MHz (MAX.)}$  | 2.85 |      | 3.6  | V    |
| Output voltage                      | $V_{RO}$  |  |      | 2.5  |      | V    |
| Regulator output stabilization time | $t_{REG}$ | After $V_{DD}$ reaches 2.85 V (MIN.),<br>Stabilization capacitance $C = 4.7\ \mu\text{F}$<br>(preliminary value) connected to REGC pin |      |      | 1    | ms   |



## DC Characteristics

(T<sub>A</sub> = -40 to +85°C, V<sub>DD</sub> = EV<sub>DD</sub> = AV<sub>REF0</sub> = AV<sub>REF1</sub>, V<sub>SS</sub> = EV<sub>SS</sub> = AV<sub>SS</sub> = 0 V) (1/3)

| Parameter                    | Symbol           | Conditions  | MIN.                  | TYP. | MAX.                  | Unit |
|------------------------------|------------------|---|-----------------------|------|-----------------------|------|
| Input voltage, high          | V <sub>IH1</sub> | RESET, FLMD0  | 0.8EV <sub>DD</sub>   |      | EV <sub>DD</sub>      | V    |
|                              | V <sub>IH2</sub> | P00 to P06, P30 to P37, P42, P50 to P55, P60 to P615, P80, P81, P92 to P915                   | 0.8EV <sub>DD</sub>   |      | 5.5                   | V    |
|                              | V <sub>IH3</sub> | P38, P39, P40, P41, P90, P91  | 0.7EV <sub>DD</sub>   |      | 5.5                   | V    |
|                              | V <sub>IH4</sub> | PCD0 to PCD3, PCM0 to PCM5, PCS0 to PCS7, PCT0 to PCT7, PDH0 to PDH7, PDL0 to PDL15           | 0.7EV <sub>DD</sub>   |      | EV <sub>DD</sub>      | V    |
|                              | V <sub>IH5</sub> | P70 to P715   | 0.7AV <sub>REF0</sub> |      | AV <sub>REF0</sub>    | V    |
|                              | V <sub>IH6</sub> | P10, P11  | 0.7AV <sub>REF1</sub> |      | AV <sub>REF1</sub>    | V    |
| Input voltage, low           | V <sub>IL1</sub> | RESET, FLMD0  | EV <sub>SS</sub>      |      | 0.2EV <sub>DD</sub>   | V    |
|                              | V <sub>IL2</sub> | P00 to P06, P30 to P37, P42, P50 to P55, P60 to P615, P80, P81, P92 to P915                   | EV <sub>SS</sub>      |      | 0.2EV <sub>DD</sub>   | V    |
|                              | V <sub>IL3</sub> | P38, P39, P40, P41, P90, P91  | EV <sub>SS</sub>      |      | 0.3EV <sub>DD</sub>   | V    |
|                              | V <sub>IL4</sub> | PCD0 to PCD3, PCM0 to PCM5, PCS0 to PCS7, PCT0 to PCT7, PDH0 to PDH7, PDL0 to PDL15           | EV <sub>SS</sub>      |      | 0.3EV <sub>DD</sub>   | V    |
|                              | V <sub>IL5</sub> | P70 to P715   | AV <sub>SS</sub>      |      | 0.3AV <sub>REF0</sub> | V    |
|                              | V <sub>IL6</sub> | P10, P11  | AV <sub>SS</sub>      |      | 0.3AV <sub>REF1</sub> | V    |
| Input leakage current, high  | I <sub>LIH</sub> | V <sub>I</sub> = V <sub>DD</sub> = EV <sub>DD</sub> = AV <sub>REF0</sub> = AV <sub>REF1</sub> |                       |      | 5                     | μA   |
| Input leakage current, low   | I <sub>LIL</sub> | V <sub>I</sub> = 0 V  |                       |      | -5                    | μA   |
| Output leakage current, high | I <sub>LOH</sub> | V <sub>O</sub> = V <sub>DD</sub> = EV <sub>DD</sub> = AV <sub>REF0</sub> = AV <sub>REF1</sub> |                       |      | 5                     | μA   |
| Output leakage current, low  | I <sub>LOL</sub> | V <sub>O</sub> = 0 V  |                       |      | -5                    | μA   |

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

## DC Characteristics

(T<sub>A</sub> = -40 to +85°C, V<sub>DD</sub> = EV<sub>DD</sub> = AV<sub>REF0</sub> = AV<sub>REF1</sub>, V<sub>SS</sub> = EV<sub>SS</sub> = AV<sub>SS</sub> = 0 V) (2/3)

| Parameter                   | Symbol           | Conditions  |                                      |                              | MIN.                                | TYP. | MAX.               | Unit |
|-----------------------------|------------------|---|--------------------------------------|------------------------------|-------------------------------------|------|--------------------|------|
| Output voltage, high        | V <sub>OH1</sub> | P00 to P06, P30 to P39, P40 to P42, P50 to P55, P60 to P615, P80, P81, P90 to P915  | Per pin<br>I <sub>OH</sub> = -1.0 mA | Total of all pins<br>-20 mA  | EV <sub>DD</sub> - 1.0              |      | EV <sub>DD</sub>   | V    |
|                             |                  |   | Per pin<br>I <sub>OH</sub> = -100 μA | Total of all pins<br>-6.0 mA | EV <sub>DD</sub> - 0.5              |      | EV <sub>DD</sub>   | V    |
|                             | V <sub>OH2</sub> | PCD0 to PCD3, PCM0 to PCM5, PCS0 to PCS7, PCT0 to PCT7, PDH0 to PDH7, PDL0 to PDL15 | Per pin<br>I <sub>OH</sub> = -1.0 mA | Total of all pins<br>-20 mA  | EV <sub>DD</sub> - 1.0              |      | EV <sub>DD</sub>   | V    |
|                             |                  |   | Per pin<br>I <sub>OH</sub> = -100 μA | Total of all pins<br>-5.0 mA | EV <sub>DD</sub> - 0.5              |      | EV <sub>DD</sub>   | V    |
|                             | V <sub>OH3</sub> | P70 to P715   | Per pin<br>I <sub>OH</sub> = -0.4 mA | Total of all pins<br>-6.4 mA | AV <sub>REF0</sub> - 1.0            |      | AV <sub>REF0</sub> | V    |
|                             |                  |   | Per pin<br>I <sub>OH</sub> = -100 μA | Total of all pins<br>-1.6 mA | AV <sub>REF0</sub> - 0.5            |      | AV <sub>REF0</sub> | V    |
|                             | V <sub>OH4</sub> | P10, P11  | Per pin<br>I <sub>OH</sub> = -0.4 mA | Total of all pins<br>-0.8 mA | AV <sub>REF1</sub> - 1.0            |      | AV <sub>REF1</sub> | V    |
|                             |                  |   | Per pin<br>I <sub>OH</sub> = -100 μA | Total of all pins<br>-0.2 mA | AV <sub>REF1</sub> - 0.5            |      | AV <sub>REF1</sub> | V    |
| Output voltage, low         | V <sub>OL1</sub> | P00 to P06, P30 to P37, P42, P50 to P55, P60 to P615, P80, P81, P92 to P915         | Per pin<br>I <sub>OL</sub> = 1.0 mA  | Total of all pins<br>20 mA   | 0                                   |      | 0.4                | V    |
|                             | V <sub>OL2</sub> |   | P38, P39, P40, P41, P90, P91         |                              | Per pin<br>I <sub>OL</sub> = 3.0 mA | 0    |                    | 0.4  |
|                             | V <sub>OL3</sub> | PCD0 to PCD3, PCM0 to PCM5, PCS0 to PCS7, PCT0 to PCT7, PDH0 to PDH7, PDL0 to PDL15 | Per pin<br>I <sub>OL</sub> = 1.0 mA  | Total of all pins<br>20 mA   | 0                                   |      | 0.4                | V    |
|                             | V <sub>OL4</sub> | P10, P11, P70 to P715   | Per pin<br>I <sub>OL</sub> = 0.4 mA  | Total of all pins<br>7.2 mA  | 0                                   |      | 0.4                | V    |
| Software pull-down resistor | R <sub>1</sub>   | P05   | V <sub>I</sub> = V <sub>DD</sub>     |                              | 10                                  | 20   | 100                | kΩ   |

- Remarks 1.** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.
- 2.** When the I<sub>OH</sub> and I<sub>OL</sub> conditions are not satisfied for a pin but the total value of all pins is satisfied, only that pin does not satisfy the DC characteristics.



## DC Characteristics

(T<sub>A</sub> = -40 to +85°C, V<sub>DD</sub> = EV<sub>DD</sub> = AV<sub>REF0</sub> = AV<sub>REF1</sub>, V<sub>SS</sub> = EV<sub>SS</sub> = AV<sub>SS</sub> = 0 V) (3/3)

| Parameter   | Symbol           | Conditions                          |   | MIN. | TYP. | MAX. | Unit |
|---|------------------|-------------------------------------|---|------|------|------|------|
| Supply current <sup>Note 1</sup>                  | I <sub>DD1</sub> | Normal operation                    | f <sub>XX</sub> = 32 MHz (f <sub>X</sub> = 4 MHz)                           |      | 40   | 64   | mA   |
|   |                  |                                     | f <sub>XX</sub> = 20 MHz (f <sub>X</sub> = 5 MHz)                           |      | 30   | 50   | mA   |
|   | I <sub>DD2</sub> | HALT mode                           | f <sub>XX</sub> = 32 MHz (f <sub>X</sub> = 4 MHz)                           |      | 27   | 45   | mA   |
|   |                  |                                     | f <sub>XX</sub> = 20 MHz (f <sub>X</sub> = 5 MHz)                           |      | 19   | 30   | mA   |
|   | I <sub>DD3</sub> | IDLE1 mode                          | f <sub>XX</sub> = 5 MHz (f <sub>X</sub> = 5 MHz),<br>PLL off                |      | 0.9  | 2.4  | mA   |
|   | I <sub>DD4</sub> | IDLE2 mode                          | f <sub>XX</sub> = 5 MHz (f <sub>X</sub> = 5 MHz),<br>PLL off                |      | 0.3  | 0.8  | mA   |
|   | I <sub>DD5</sub> | Subclock<br>operating mode          | f <sub>XT</sub> = 32.768 kHz,<br>main clock,<br>internal oscillator stopped |      | 80   | 600  | μA   |
|   | I <sub>DD6</sub> | Sub-IDLE mode                       | f <sub>XT</sub> = 32.768 kHz,<br>main clock,<br>internal oscillator stopped |      | 11   | 100  | μA   |
|   | I <sub>DD7</sub> | STOP mode                           | Subclock stopped, internal<br>oscillator stopped                            |      | 8    | 80   | μA   |
|   |                  |                                     | Subclock operating, internal<br>oscillator stopped                          |      | 11   | 90   | μA   |
|   |                  |                                     | Subclock stopped, internal<br>oscillator operating                          |      | 13   | 90   | μA   |
|   | I <sub>DD8</sub> | Flash memory<br>programming<br>mode | f <sub>XX</sub> = 32 MHz (f <sub>X</sub> = 4 MHz)                           |      | 45   | 74   | mA   |
| f <sub>XX</sub> = 20 MHz (f <sub>X</sub> = 5 MHz) |                  |                                     |   | 34   | 60   | mA   |      |

**Note** Total of V<sub>DD</sub> and EV<sub>DD</sub> currents. Current flowing through the output buffers, A/D converter, D/A converter, and on-chip pull-down resistor is not included.

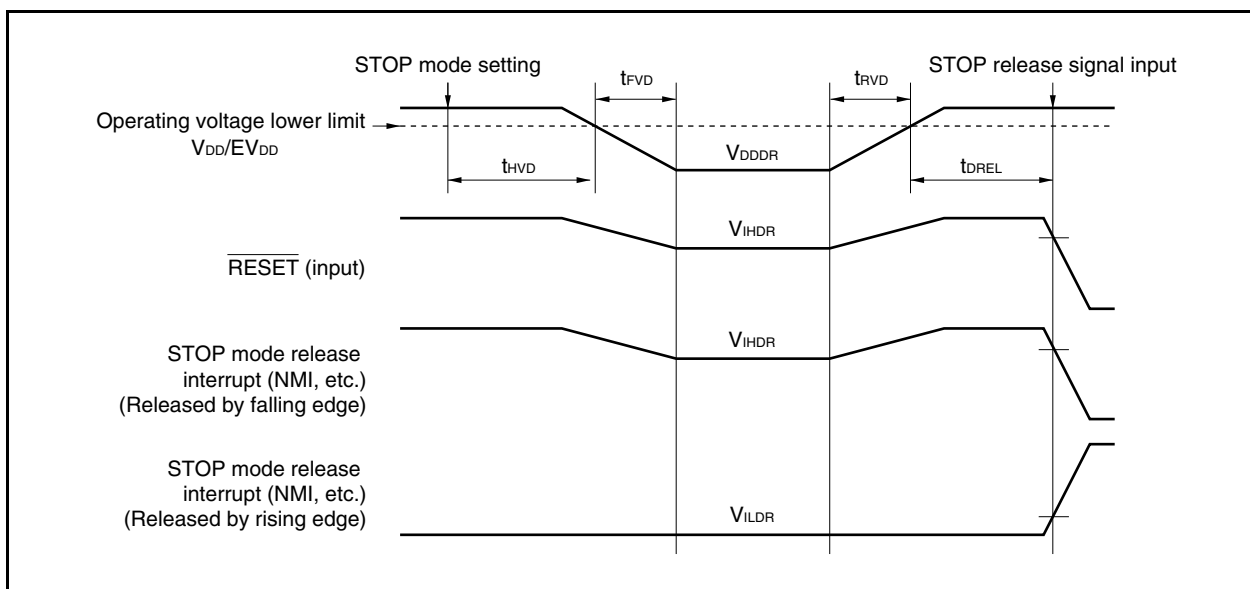
Data Retention Characteristics

In STOP mode

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ )

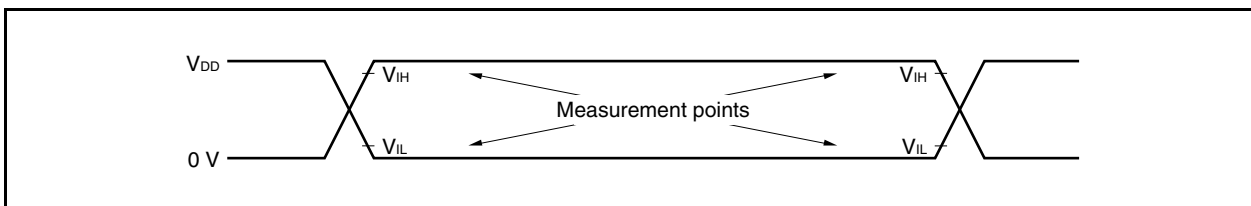
| Parameter                          | Symbol     | Conditions   | MIN.          | TYP. | MAX.          | Unit          |
|------------------------------------|------------|--|---------------|------|---------------|---------------|
| Data retention voltage             | $V_{DDDR}$ | STOP mode (all functions stopped)                            | 1.9           |      | 3.6           | V             |
| Data retention current             | $I_{DDDR}$ | STOP mode (all functions stopped), $V_{DDDR} = 2.0\text{ V}$ |               | 8    | 80            | $\mu\text{A}$ |
| Supply voltage rise time           | $t_{rVD}$  |  | 200           |      |               | $\mu\text{s}$ |
| Supply voltage fall time           | $t_{fVD}$  |  | 200           |      |               | $\mu\text{s}$ |
| Supply voltage retention time      | $t_{hVD}$  | After STOP mode setting                                      | 0             |      |               | ms            |
| STOP release signal input time     | $t_{dREL}$ | After $V_{DD}$ reaches 2.85 V (MIN.)                         | 0             |      |               | ms            |
| Data retention input voltage, high | $V_{IHDR}$ | $V_{DD} = EV_{DD} = V_{DDDR}$                                | $0.9V_{DDDR}$ |      | $V_{DDDR}$    | V             |
| Data retention input voltage, low  | $V_{ILDR}$ | $V_{DD} = EV_{DD} = V_{DDDR}$                                | 0             |      | $0.1V_{DDDR}$ | V             |

**Caution** Shifting to STOP mode and restoring from STOP mode must be performed within the rated operating range.

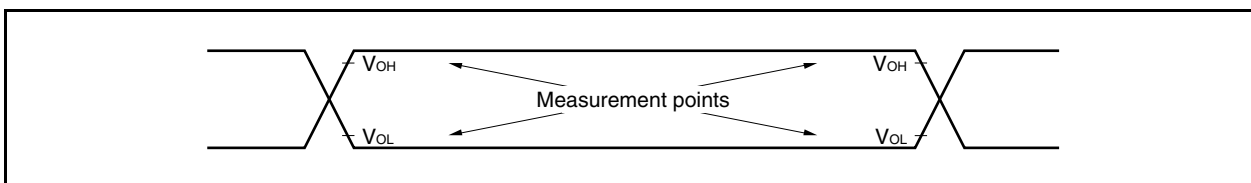


## AC Characteristics

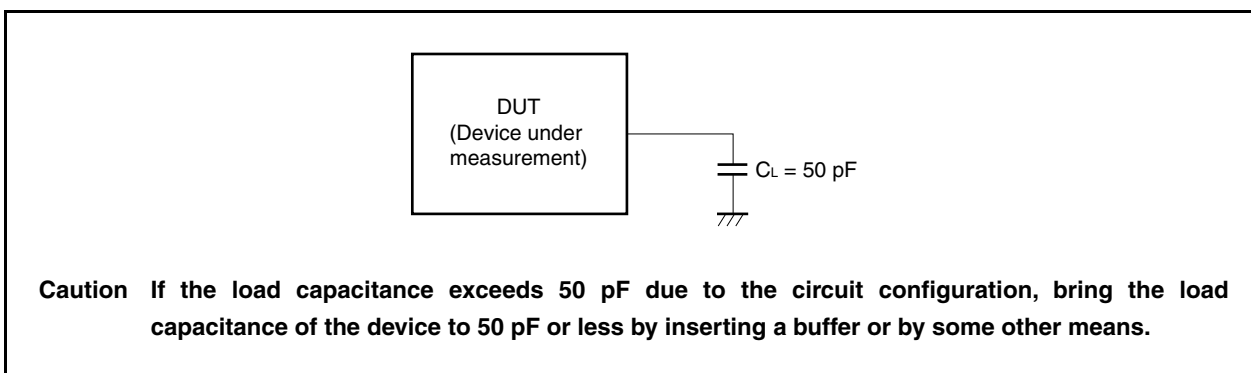
### AC Test Input Measurement Points ( $V_{DD}$ , $AV_{REF0}$ , $AV_{REF1}$ , $EV_{DD}$ )



### AC Test Output Measurement Points



### Load Conditions

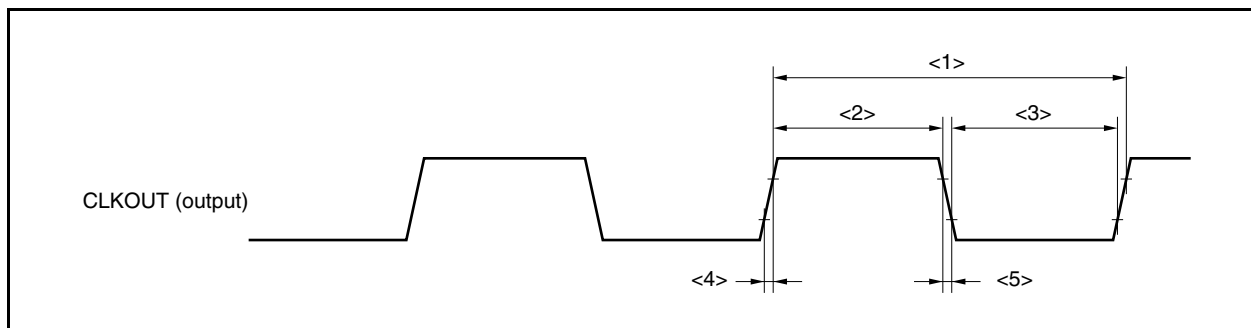


**CLKOUT Output Timing**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ )

| Parameter        | Symbol    | Conditions | MIN.            | MAX.                | Unit |
|------------------|-----------|------------|-----------------|---------------------|------|
| Output cycle     | $t_{CYK}$ | <1>        | 31.25 ns        | 31.25 $\mu\text{s}$ |      |
| High-level width | $t_{WKH}$ | <2>        | $t_{CYK}/2 - 6$ |                     | ns   |
| Low-level width  | $t_{WKL}$ | <3>        | $t_{CYK}/2 - 6$ |                     | ns   |
| Rise time        | $t_{KR}$  | <4>        |                 | 6                   | ns   |
| Fall time        | $t_{KF}$  | <5>        |                 | 6                   | ns   |

**Clock Timing**



**Bus Timing**
**(1) In multiplexed bus mode**

**Caution** When operating at  $f_{xx} > 20$  MHz, be sure to insert address hold waits and address setup waits.

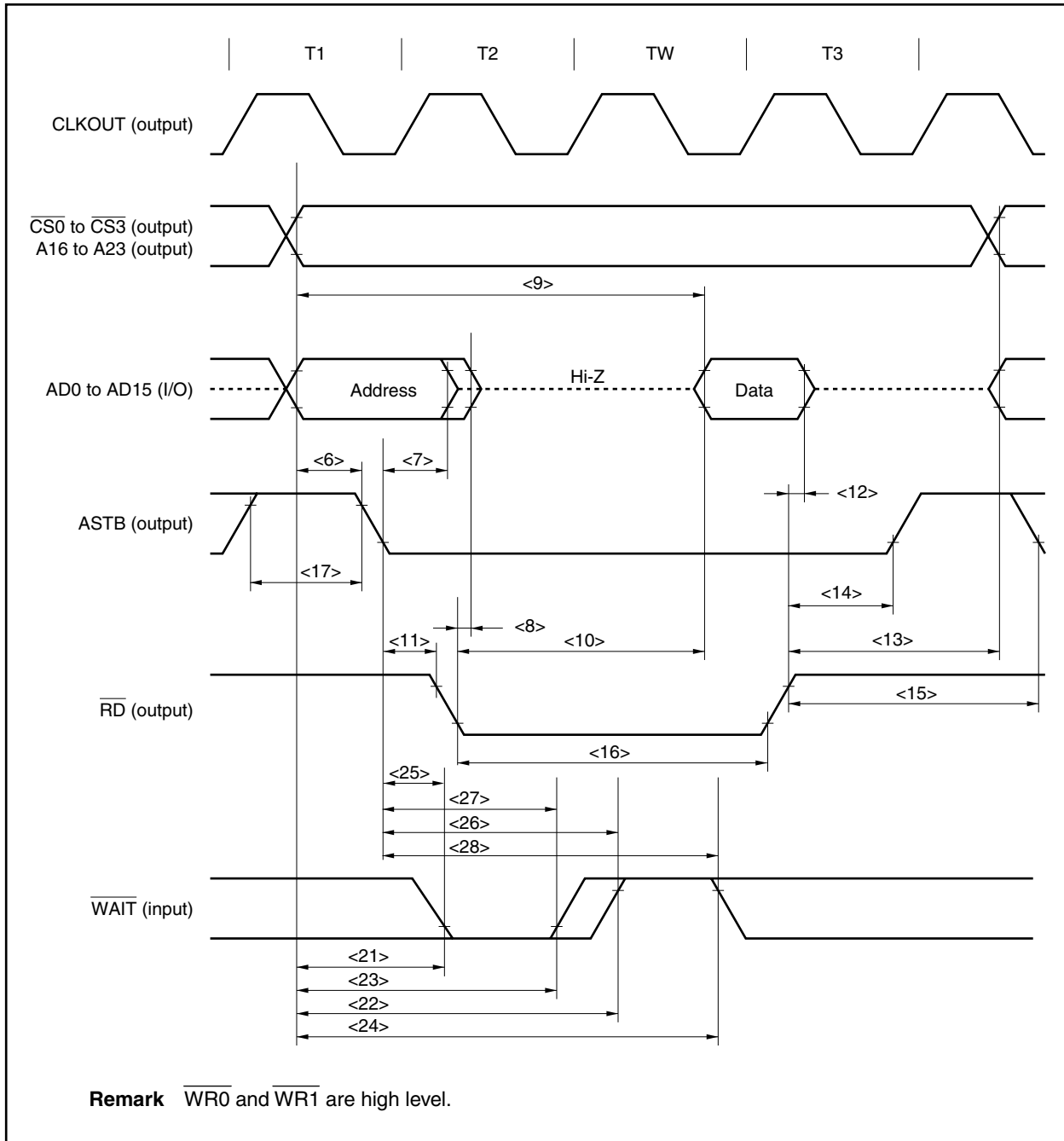
**(a) Read/write cycle (CLKOUT asynchronous)**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

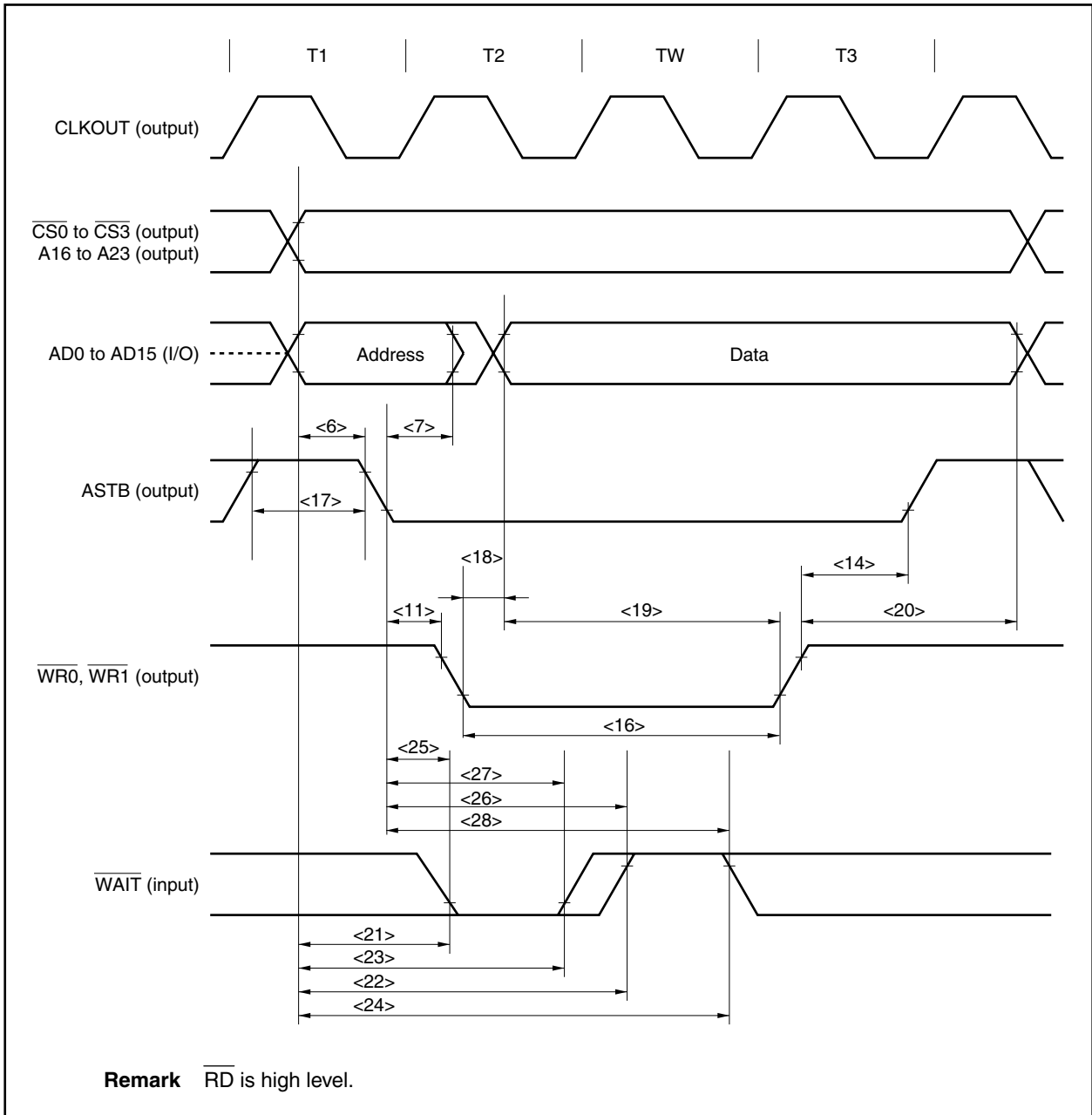
| Parameter  | Symbol        | Conditions      | MIN.                             | MAX.                                  | Unit |
|--|---------------|-----------------|----------------------------------|---------------------------------------|------|
| Address setup time (to $ASTB\downarrow$ )  | $t_{SAST}$    | <6>             | $(0.5 + t_{ASW})T - 20$          |                                       | ns   |
| Address hold time (from $ASTB\downarrow$ )                                       | $t_{HSTA}$    | <7>             | $(0.5 + t_{AHW})T - 15$          |                                       | ns   |
| Delay time from $\overline{RD}\downarrow$ to address float                       | $t_{FRDA}$    | <8>             |                                  | 16                                    | ns   |
| Data input setup time from address   | $t_{SAID}$    | <9>             |                                  | $(2 + n + t_{ASW} + t_{AHW})T - 35$   | ns   |
| Data input setup time from $\overline{RD}\downarrow$                             | $t_{SRID}$    | <10>            |                                  | $(1 + n)T - 25$                       | ns   |
| Delay time from $ASTB\downarrow$ to $\overline{RD}$ , $\overline{WRm}\downarrow$ | $t_{DSTRDWR}$ | <11>            | $(0.5 + t_{AHW})T - 15$          |                                       | ns   |
| Data input hold time (from $\overline{RD}\uparrow$ )                             | $t_{HRDID}$   | <12>            | 0                                |                                       | ns   |
| Address output time from $\overline{RD}\uparrow$                                 | $t_{DRDA}$    | <13>            | $(1 + i)T - 15$                  |                                       | ns   |
| Delay time from $\overline{RD}$ , $\overline{WRm}\uparrow$ to $ASTB\uparrow$     | $t_{DRDWRST}$ | <14>            | $0.5T - 15$                      |                                       | ns   |
| Delay time from $\overline{RD}\uparrow$ to $ASTB\downarrow$                      | $t_{DRDST}$   | <15>            | $(1.5 + i + t_{ASW})T - 15$      |                                       | ns   |
| $\overline{RD}$ , $\overline{WRm}$ low-level width                               | $t_{WRDWRL}$  | <16>            | $(1 + n)T - 15$                  |                                       | ns   |
| ASTB high-level width  | $t_{WSTH}$    | <17>            | $(1 + i + t_{ASW})T - 15$        |                                       | ns   |
| Data output time from $\overline{WRm}\downarrow$                                 | $t_{DWROD}$   | <18>            |                                  | 15                                    | ns   |
| Data output setup time (to $\overline{WRm}\uparrow$ )                            | $t_{SODWR}$   | <19>            | $(1 + n)T - 20$                  |                                       | ns   |
| Data output hold time (from $\overline{WRm}\uparrow$ )                           | $t_{HWROD}$   | <20>            | $T - 15$                         |                                       | ns   |
| $\overline{WAIT}$ setup time (to address)  | $t_{SAWT1}$   | <21> $n \geq 1$ |                                  | $(1.5 + t_{ASW} + t_{AHW})T - 35$     | ns   |
|  | $t_{SAWT2}$   | <22>            |                                  | $(1.5 + n + t_{ASW} + t_{AHW})T - 35$ | ns   |
| $\overline{WAIT}$ hold time (from address)                                       | $t_{HAWT1}$   | <23> $n \geq 1$ | $(0.5 + n + t_{ASW} + t_{AHW})T$ |                                       | ns   |
|  | $t_{HAWT2}$   | <24>            | $(1.5 + n + t_{ASW} + t_{AHW})T$ |                                       | ns   |
| $\overline{WAIT}$ setup time (to $ASTB\downarrow$ )                              | $t_{SSTWT1}$  | <25> $n \geq 1$ |                                  | $(1 + t_{AHW})T - 25$                 | ns   |
|  | $t_{SSTWT2}$  | <26>            |                                  | $(1 + n + t_{AHW})T - 25$             | ns   |
| $\overline{WAIT}$ hold time (from $ASTB\downarrow$ )                             | $t_{HSTWT1}$  | <27> $n \geq 1$ | $(n + t_{AHW})T$                 |                                       | ns   |
|  | $t_{HSTWT2}$  | <28>            | $(1 + n + t_{AHW})T$             |                                       | ns   |

- Remarks**
- $t_{ASW}$ : Number of address setup wait clocks  
 $t_{AHW}$ : Number of address hold wait clocks
  - $T = 1/f_{CPU}$  ( $f_{CPU}$ : CPU operating clock frequency)
  - $n$ : Number of wait clocks inserted in the bus cycle  
 The sampling timing changes when a programmable wait is inserted.
  - $m = 0, 1$
  - $i$ : Number of idle states inserted after a read cycle (0 or 1)
  - The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

Read Cycle (CLKOUT Asynchronous): In Multiplexed Bus Mode



Write Cycle (CLKOUT Asynchronous): In Multiplexed Bus Mode



**(b) Read/write cycle (CLKOUT synchronous): In multiplexed bus mode**

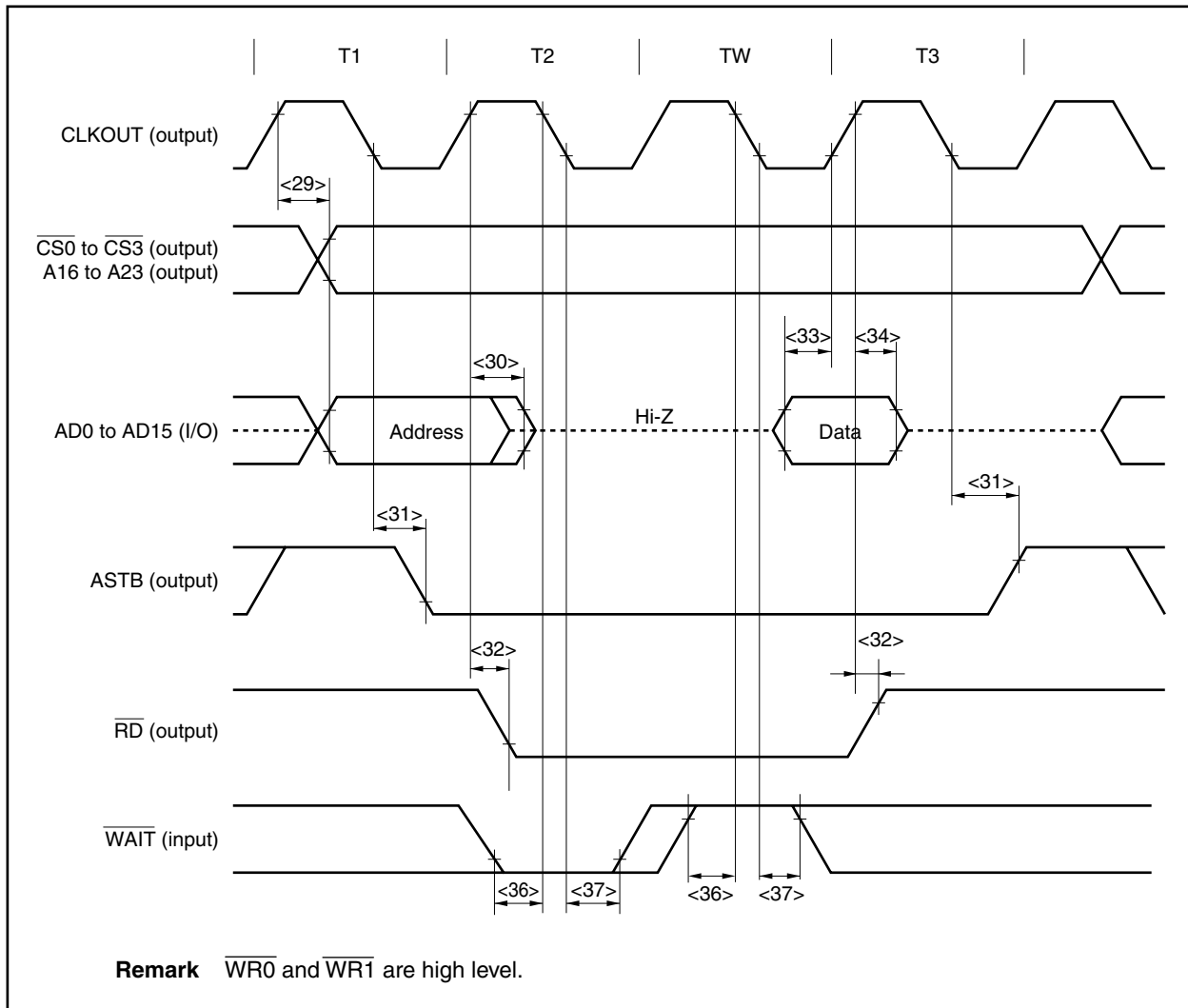
( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter   | Symbol       | Conditions | MIN. | MAX. | Unit |
|---|--------------|------------|------|------|------|
| Delay time from CLKOUT $\uparrow$ to address                            | $t_{DKA}$    | <29>       | 0    | 25   | ns   |
| Delay time from CLKOUT $\uparrow$ to address float                      | $t_{FKA}$    | <30>       | 0    | 19   | ns   |
| Delay time from CLKOUT $\downarrow$ to ASTB                             | $t_{DKST}$   | <31>       | -12  | 7    | ns   |
| Delay time from CLKOUT $\uparrow$ to $\overline{RD}$ , $\overline{WRm}$ | $t_{DKRDWR}$ | <32>       | -5   | 14   | ns   |
| Data input setup time (to CLKOUT $\uparrow$ )                           | $t_{SIDK}$   | <33>       | 15   |      | ns   |
| Data input hold time (from CLKOUT $\uparrow$ )                          | $t_{HKID}$   | <34>       | 5    |      | ns   |
| Data output delay time from CLKOUT $\uparrow$                           | $t_{DKOD}$   | <35>       |      | 19   | ns   |
| $\overline{WAIT}$ setup time (to CLKOUT $\downarrow$ )                  | $t_{SWTK}$   | <36>       | 20   |      | ns   |
| $\overline{WAIT}$ hold time (from CLKOUT $\downarrow$ )                 | $t_{HKWT}$   | <37>       | 5    |      | ns   |

**Remarks 1.**  $m = 0, 1$

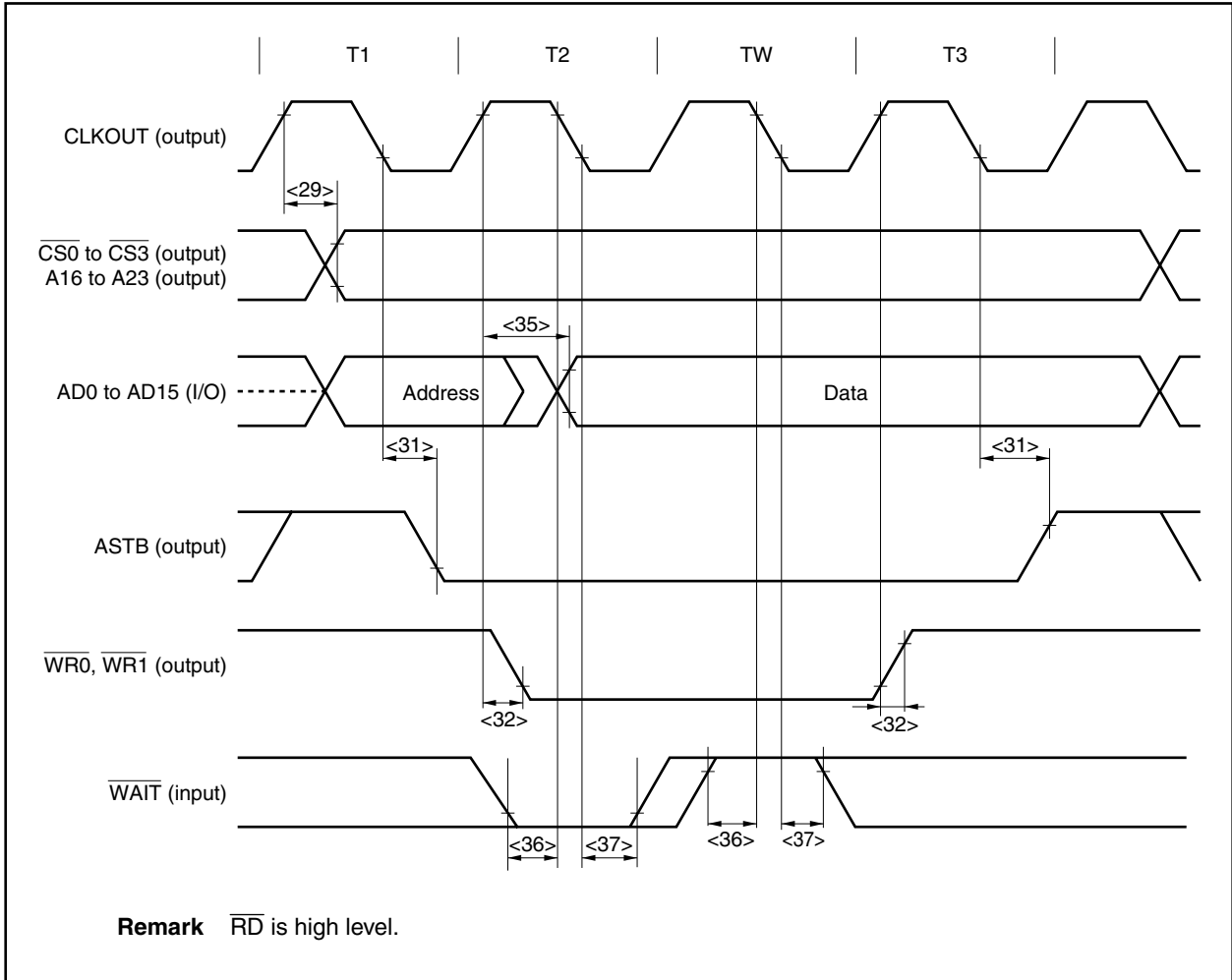
**2.** The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

**Read Cycle (CLKOUT Synchronous): In Multiplexed Bus Mode**





**Write Cycle (CLKOUT Synchronous): In Multiplexed Bus Mode**



**(2) In separate bus mode**

**Caution** When operating at  $f_{XX} > 20$  MHz, be sure to insert address hold waits, address setup waits, and data waits.

**(a) Read cycle (CLKOUT asynchronous): In separate bus mode**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter   | Symbol       | Conditions | MIN.                           | MAX.                                | Unit |
|---|--------------|------------|--------------------------------|-------------------------------------|------|
| Address setup time (to $\overline{RD}\downarrow$ )            | $t_{SARD}$   | <38>       | $(0.5 + t_{ASW})T - 27$        |                                     | ns   |
| Address hold time (from $\overline{RD}\uparrow$ )             | $t_{HARD}$   | <39>       | $IT - 3.5$                     |                                     | ns   |
| $\overline{RD}$ low-level width                               | $t_{WRDL}$   | <40>       | $(1.5 + n + t_{AHW})T - 10$    |                                     | ns   |
| Data setup time (to $\overline{RD}\uparrow$ )                 | $t_{SISD}$   | <41>       | 23                             |                                     | ns   |
| Data hold time (from $\overline{RD}\uparrow$ )                | $t_{HISD}$   | <42>       | -3.5                           |                                     | ns   |
| Data setup time (to address)                                  | $t_{SAID}$   | <43>       |                                | $(2 + n + t_{ASW} + t_{AHW})T - 40$ | ns   |
| $\overline{WAIT}$ setup time (to $\overline{RD}\downarrow$ )  | $t_{SRDWT1}$ | <44>       |                                | $(0.5 + t_{AHW})T - 25$             | ns   |
|   | $t_{SRDWT2}$ | <45>       |                                | $(0.5 + n + t_{AHW})T - 25$         | ns   |
| $\overline{WAIT}$ hold time (from $\overline{RD}\downarrow$ ) | $t_{HRDWT1}$ | <46>       | $(n - 0.5 + t_{AHW})T$         |                                     | ns   |
|   | $t_{HRDWT2}$ | <47>       | $(n + 0.5 + t_{AHW})T$         |                                     | ns   |
| $\overline{WAIT}$ setup time (to address)                     | $t_{SAWT1}$  | <48>       |                                | $(1 + t_{ASW} + t_{AHW})T - 45$     | ns   |
|   | $t_{SAWT2}$  | <49>       |                                | $(1 + n + t_{ASW} + t_{AHW})T - 45$ | ns   |
| $\overline{WAIT}$ hold time (from address)                    | $t_{HAWT1}$  | <50>       | $(n + t_{ASW} + t_{AHW})T$     |                                     | ns   |
|   | $t_{HAWT2}$  | <51>       | $(1 + n + t_{ASW} + t_{AHW})T$ |                                     | ns   |

**Remarks 1.**  $t_{ASW}$ : Number of address setup wait clocks

$t_{AHW}$ : Number of address hold wait clocks

2.  $T = 1/f_{CPU}$  ( $f_{CPU}$ : CPU operating clock frequency)

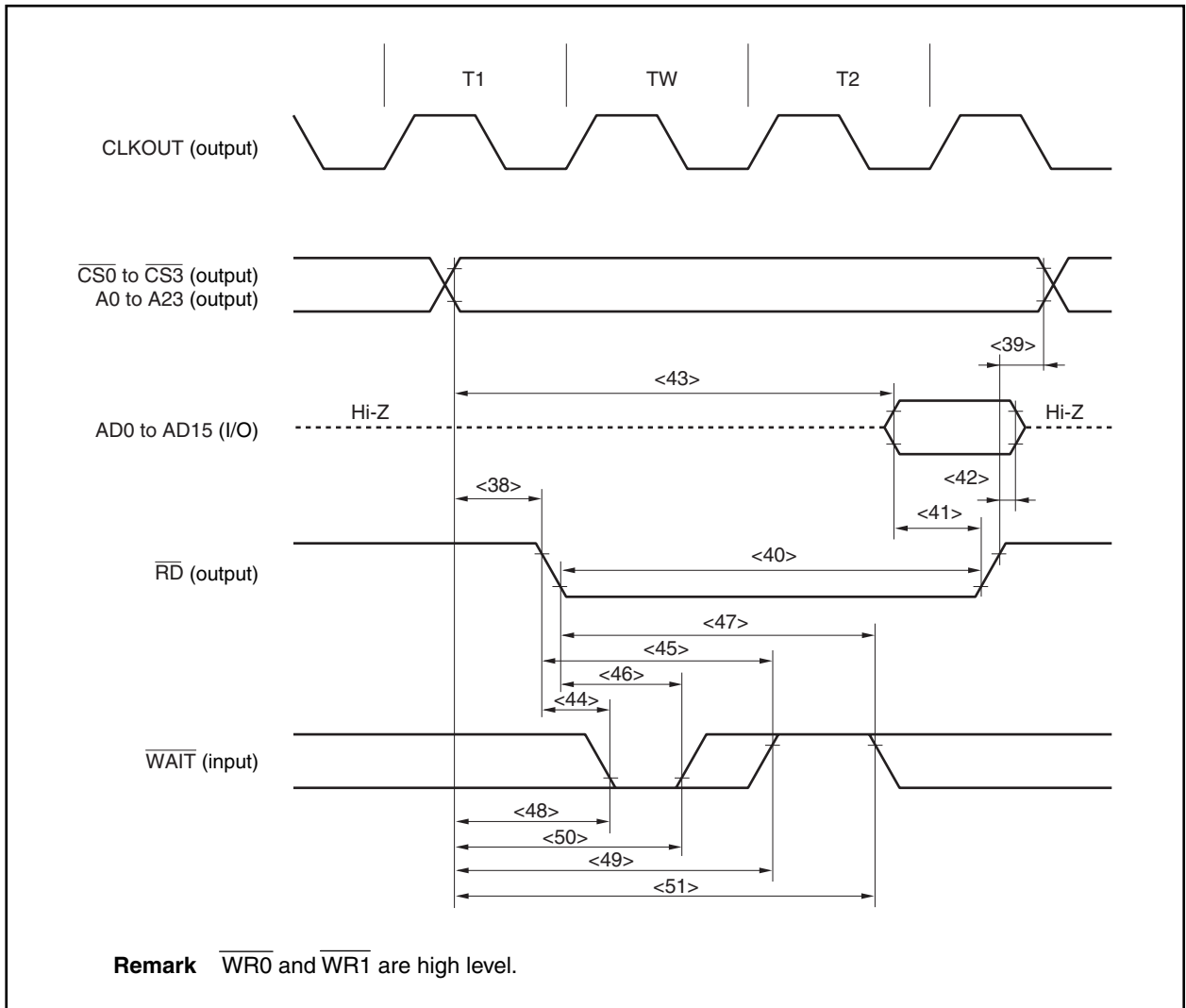
3.  $n$ : Number of wait clocks inserted in the bus cycle

The sampling timing changes when a programmable wait is inserted

4.  $i$ : Number of idle states inserted after a read cycle (0 or 1)

5. The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

Read Cycle (CLKOUT Asynchronous): In Separate Bus Mode



**(b) Write cycle (CLKOUT asynchronous): In separate bus mode**
**( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ ,  $C_L = 50\text{ pF}$ )**

| Parameter  | Symbol       | Conditions | MIN.                            | MAX.                                | Unit |
|--|--------------|------------|---------------------------------|-------------------------------------|------|
| Address setup time (to $\overline{WRm}\downarrow$ )            | $t_{SAWR}$   | <52>       | $(1 + t_{ASW} + t_{AHW})T - 27$ |                                     | ns   |
| Address hold time (from $\overline{WRm}\uparrow$ )             | $t_{HAWR}$   | <53>       | $0.5T - 6$                      |                                     | ns   |
| $\overline{WRm}$ low-level width                               | $t_{WWRL}$   | <54>       | $(0.5 + n)T - 10$               |                                     | ns   |
| Data output time from $\overline{WRm}\downarrow$               | $t_{DOSDW}$  | <55>       | -5                              |                                     | ns   |
| Data setup time (to $\overline{WRm}\uparrow$ )                 | $t_{SOSDW}$  | <56>       | $(0.5 + n)T - 20$               |                                     | ns   |
| Data hold time (from $\overline{WRm}\uparrow$ )                | $t_{HOSDW}$  | <57>       | $0.5T - 7$                      |                                     | ns   |
| Data setup time (to address)                                   | $t_{SAOD}$   | <58>       | $(1 + t_{ASW} + t_{AHW})T - 25$ |                                     | ns   |
| $\overline{WAIT}$ setup time (to $\overline{WRm}\downarrow$ )  | $t_{SWRWT1}$ | <59>       | 22                              |                                     | ns   |
|  | $t_{SWRWT2}$ | <60>       |                                 | $nT - 22$                           | ns   |
| $\overline{WAIT}$ hold time (from $\overline{WRm}\downarrow$ ) | $t_{HWRWT1}$ | <61>       | 0                               |                                     | ns   |
|  | $t_{HWRWT2}$ | <62>       | $nT$                            |                                     | ns   |
| $\overline{WAIT}$ setup time (to address)                      | $t_{SAWT1}$  | <63>       |                                 | $(1 + t_{ASW} + t_{AHW})T - 45$     | ns   |
|  | $t_{SAWT2}$  | <64>       |                                 | $(1 + n + t_{ASW} + t_{AHW})T - 45$ | ns   |
| $\overline{WAIT}$ hold time (from address)                     | $t_{HAWT1}$  | <65>       | $(n + t_{ASW} + t_{AHW})T$      |                                     | ns   |
|  | $t_{HAWT2}$  | <66>       | $(1 + n + t_{ASW} + t_{AHW})T$  |                                     | ns   |

**Remarks 1.**  $m = 0, 1$ 
**2.**  $t_{ASW}$ : Number of address setup wait clocks

 $t_{AHW}$ : Number of address hold wait clocks

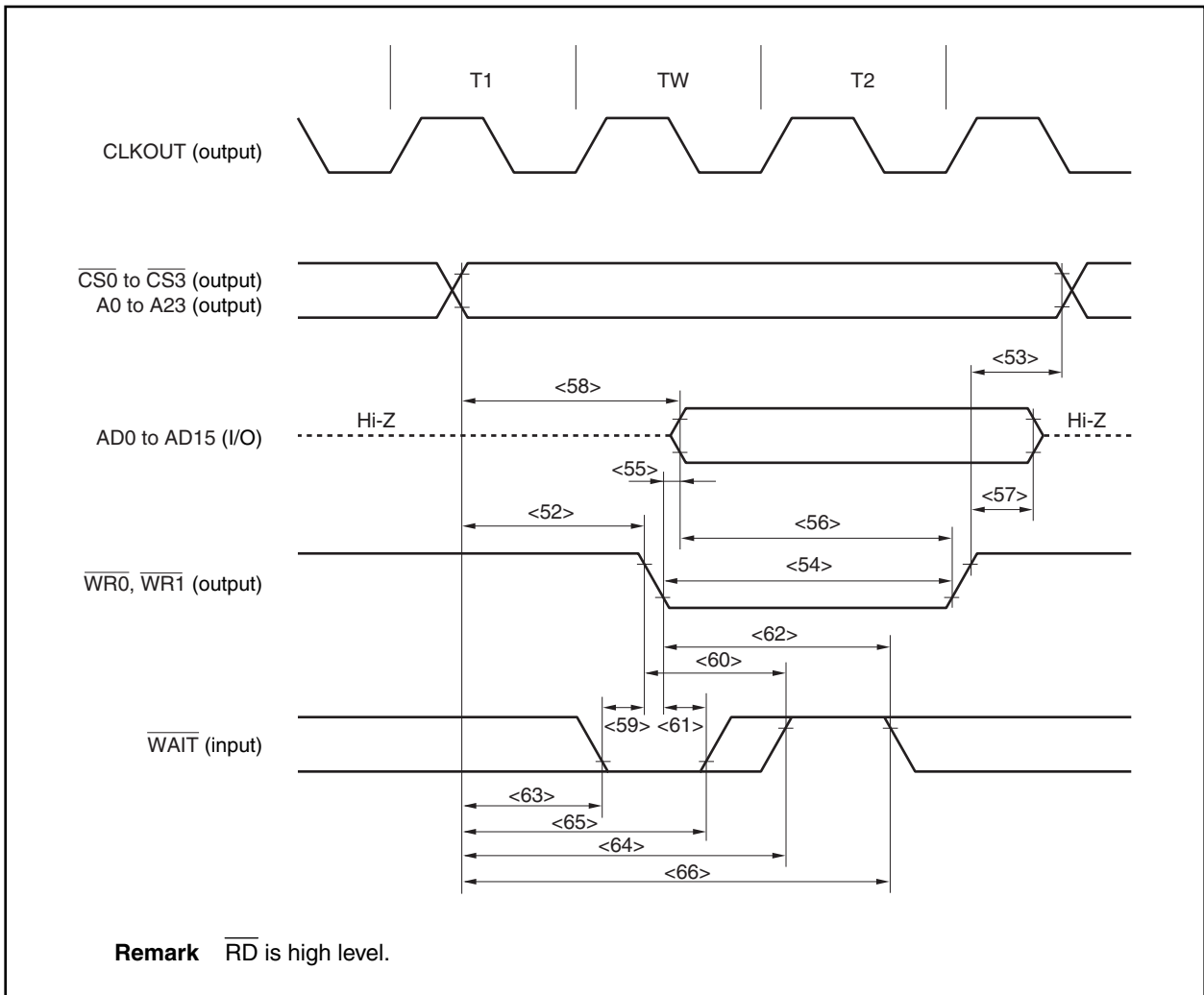
**3.**  $T = 1/f_{CPU}$  ( $f_{CPU}$ : CPU operating clock frequency)

**4.**  $n$ : Number of wait clocks inserted in the bus cycle

The sampling timing changes when a programmable wait is inserted.

**5.** The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

Write Cycle (CLKOUT Asynchronous): In Separate Bus Mode



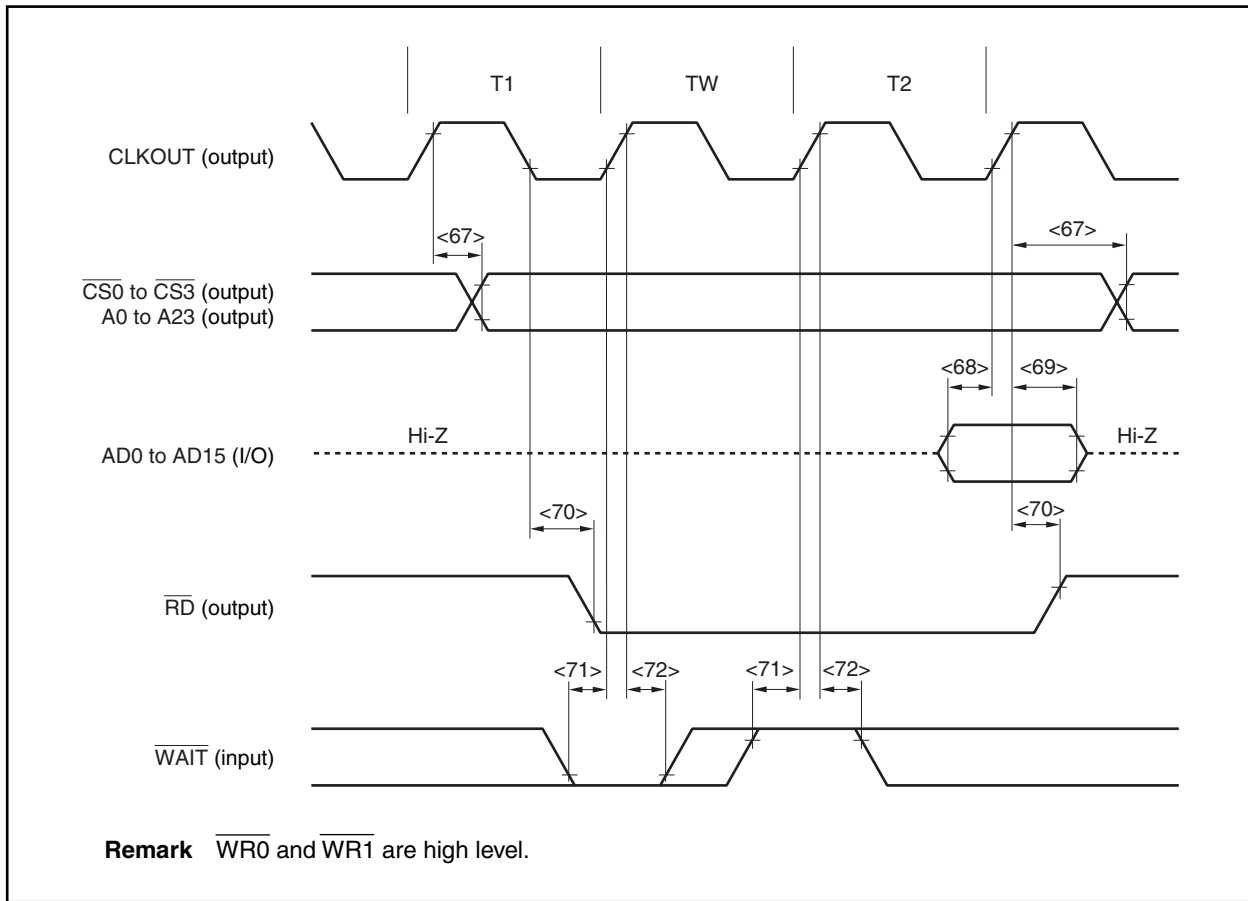
(c) Read cycle (CLKOUT synchronous): In separate bus mode

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter  | Symbol      | Conditions | MIN. | MAX. | Unit |
|--|-------------|------------|------|------|------|
| Delay time from CLKOUT $\uparrow$ to address, CS               | $t_{DKSA}$  | <67>       | 0    | 27   | ns   |
| Data input setup time (to CLKOUT $\uparrow$ )                  | $t_{SISDK}$ | <68>       | 20   |      | ns   |
| Data input hold time (from CLKOUT $\uparrow$ )                 | $t_{HKISD}$ | <69>       | 0    |      | ns   |
| Delay time from CLKOUT $\downarrow\uparrow$ to $\overline{RD}$ | $t_{DKSR}$  | <70>       | -2   | 12   | ns   |
| $\overline{WAIT}$ setup time (to CLKOUT $\uparrow$ )           | $t_{SWTK}$  | <71>       | 20   |      | ns   |
| $\overline{WAIT}$ hold time (from CLKOUT $\uparrow$ )          | $t_{HKWT}$  | <72>       | 0    |      | ns   |

**Remark** The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

Read Cycle (CLKOUT Synchronous, 1 Wait): In Separate Bus Mode



(d) Write cycle (CLKOUT synchronous): In separate bus mode

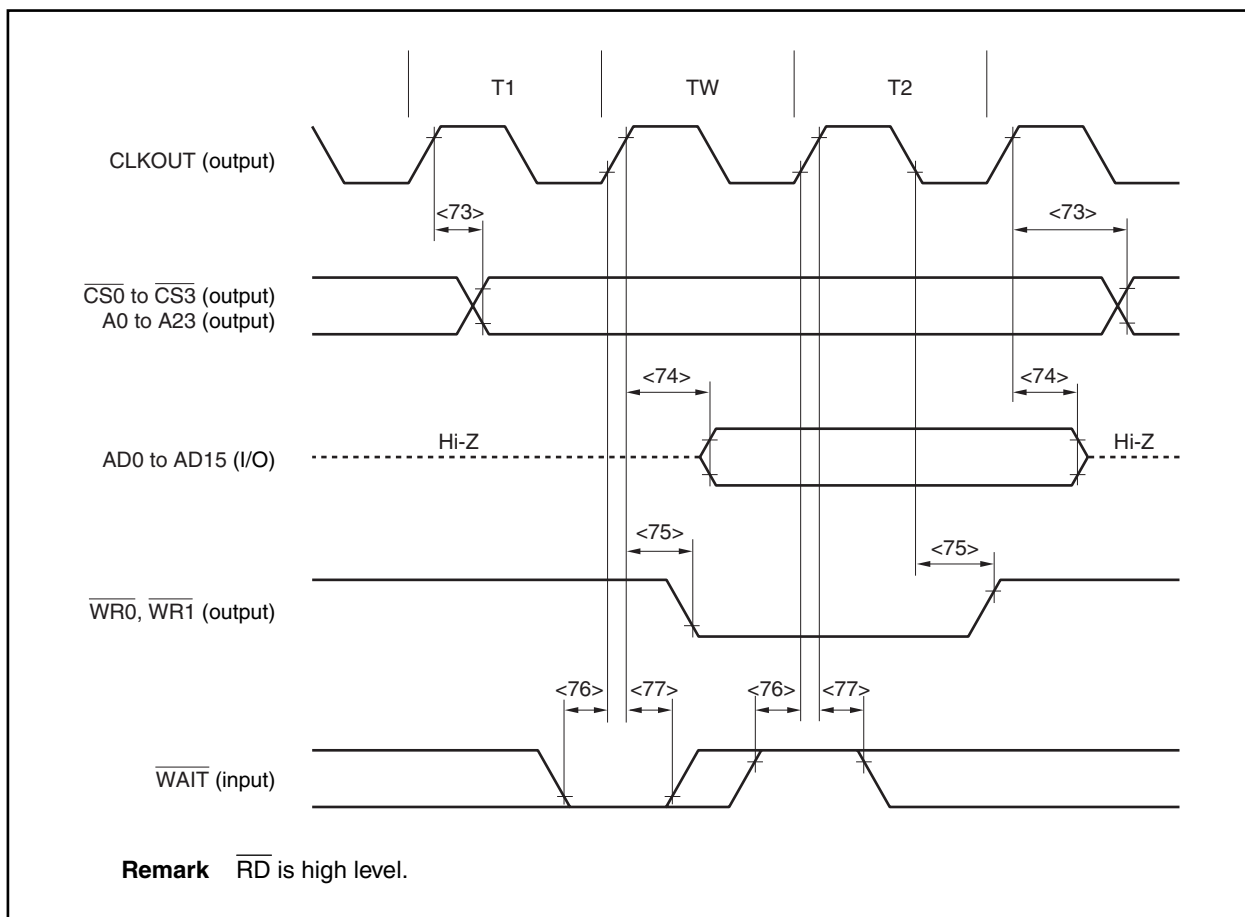
( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ ,  $C_L = 50\text{ pF}$ )

| Parameter   | Symbol     | Conditions | MIN. | MAX. | Unit |
|---|------------|------------|------|------|------|
| Delay time from CLKOUT $\uparrow$ to address, CS                | $t_{DKSA}$ | <73>       | 0    | 27   | ns   |
| Delay time from CLKOUT $\uparrow$ to data output                | $t_{DKSD}$ | <74>       | 0    | 18   | ns   |
| Delay time from CLKOUT $\uparrow\downarrow$ to $\overline{WRm}$ | $t_{DKSW}$ | <75>       | -2   | 12   | ns   |
| $\overline{WAIT}$ setup time (to CLKOUT $\uparrow$ )            | $t_{SWTK}$ | <76>       | 20   |      | ns   |
| $\overline{WAIT}$ hold time (from CLKOUT $\uparrow$ )           | $t_{HKWT}$ | <77>       | 0    |      | ns   |

Remarks 1.  $m = 0, 1$

2. The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

Write Cycle (CLKOUT Synchronous): In Separate Bus Mode



(3) Bus hold

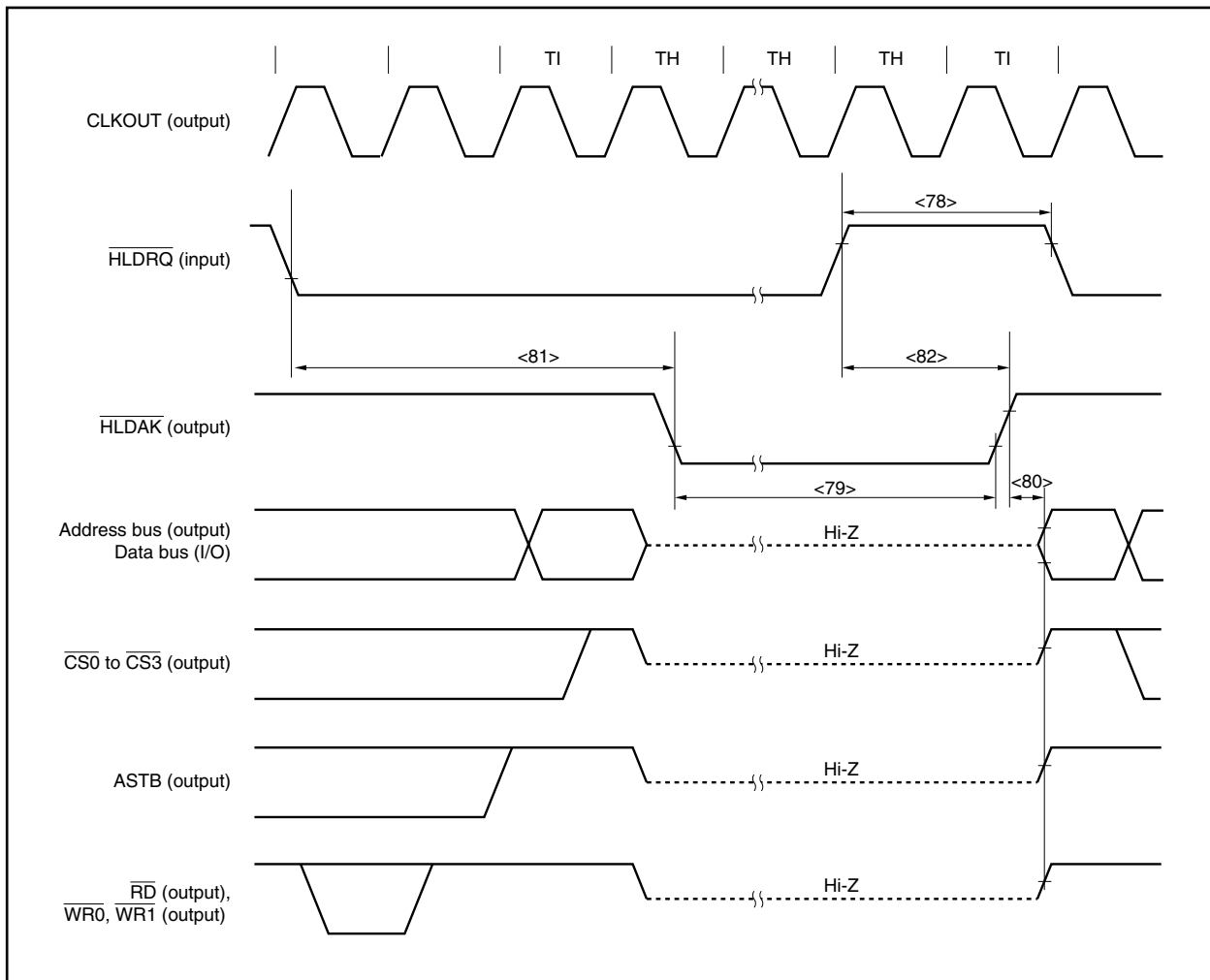
(a) CLKOUT asynchronous

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter   | Symbol              | Conditions | MIN.     | MAX.               | Unit |
|---|---------------------|------------|----------|--------------------|------|
| $\overline{\text{HLDRQ}}$ high-level width  | $t_{\text{WHQH}}$   | <78>       | $T + 10$ |                    | ns   |
| $\overline{\text{HLDK}}$ low-level width  | $t_{\text{WHAL}}$   | <79>       | $T - 15$ |                    | ns   |
| Delay time from $\overline{\text{HLDK}}\uparrow$ to bus output                            | $t_{\text{DHAC}}$   | <80>       | -3       |                    | ns   |
| Delay time from $\overline{\text{HLDRQ}}\downarrow$ to $\overline{\text{HLDK}}\downarrow$ | $t_{\text{DHQHA1}}$ | <81>       |          | $(2n + 7.5)T + 26$ | ns   |
| Delay time from $\overline{\text{HLDRQ}}\uparrow$ to $\overline{\text{HLDK}}\uparrow$     | $t_{\text{DHQHA2}}$ | <82>       | $0.5T$   | $1.5T + 26$        | ns   |

- Remarks**
- $T = 1/f_{\text{CPU}}$  ( $f_{\text{CPU}}$ : CPU operating clock frequency)
  - n: Number of wait clocks inserted in the bus cycle  
The sampling timing changes when a programmable wait is inserted.
  - The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

Bus Hold (CLKOUT Asynchronous)





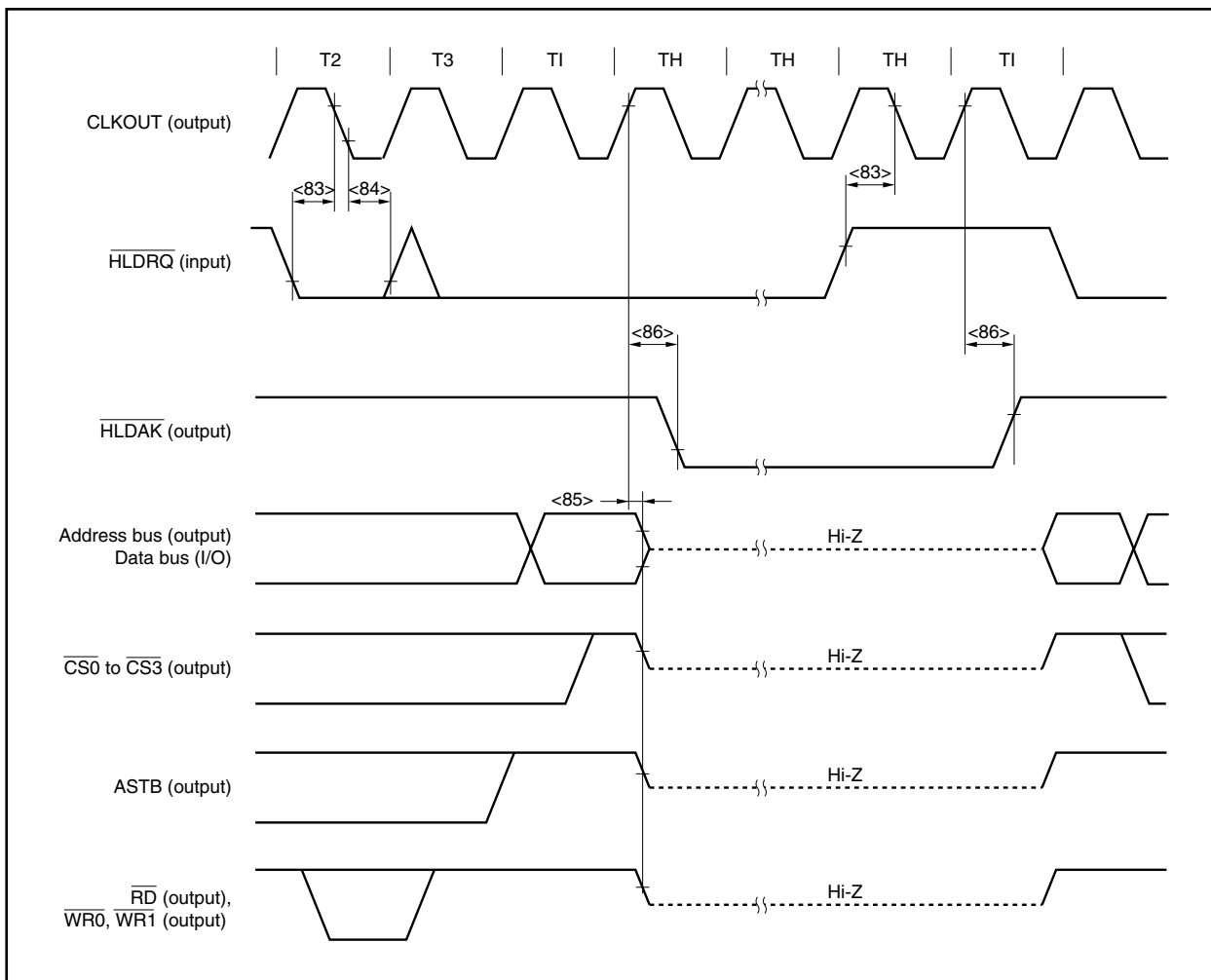
(b) CLKOUT synchronous

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter   | Symbol            | Conditions | MIN. | MAX. | Unit |
|---|-------------------|------------|------|------|------|
| $\overline{\text{HLDRQ}}$ setup time (to CLKOUT $\downarrow$ )  | $t_{\text{SHQK}}$ | <83>       | 20   |      | ns   |
| $\overline{\text{HLDRQ}}$ hold time (from CLKOUT $\downarrow$ ) | $t_{\text{HKHQ}}$ | <84>       | 5    |      | ns   |
| Delay time from CLKOUT $\uparrow$ to bus float                  | $t_{\text{DKF}}$  | <85>       |      | 19   | ns   |
| Delay time from CLKOUT $\uparrow$ to $\overline{\text{HLDAK}}$  | $t_{\text{DKHA}}$ | <86>       |      | 19   | ns   |

**Remark** The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

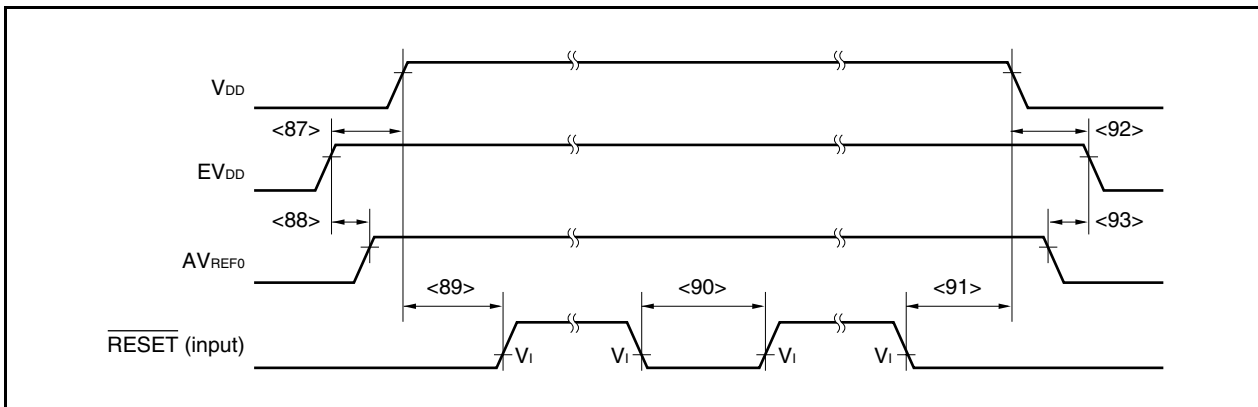
**Bus Hold (CLKOUT Synchronous)**



**Power On/Power Off/Reset Timing**

 ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{SS} = AV_{SS} = EV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter  | Symbol          | Conditions  | MIN.                      | MAX.      | Unit |
|--|-----------------|---|---------------------------|-----------|------|
| $EV_{DD}\uparrow \rightarrow V_{DD}\uparrow$               | $t_{REL}$ <87>  |   | 0                         |           | ns   |
| $EV_{DD}\uparrow \rightarrow AV_{REF0}, AV_{REF1}\uparrow$ | $t_{REA}$ <88>  |   | 0                         | $t_{REL}$ | ns   |
| $V_{DD}\uparrow \rightarrow \overline{RESET}\uparrow$      | $t_{RER}$ <89>  |   | 500 +<br>$t_{REG}^{Note}$ |           | ns   |
| $\overline{RESET}$ low-level width                         | $t_{WRSL}$ <90> | Analog noise elimination (during flash erase/writing) | 500                       |           | ns   |
|  |                 | Analog noise elimination                              | 500                       |           | ns   |
| $\overline{RESET}\downarrow \rightarrow V_{DD}\downarrow$  | $t_{FRE}$ <91>  |   | 500                       |           | ns   |
| $V_{DD}\downarrow \rightarrow EV_{DD}\downarrow$           | $t_{FEL}$ <92>  |   | 0                         |           | ns   |
| $AV_{REF0}\downarrow \rightarrow EV_{DD}\downarrow$        | $t_{FEA}$ <93>  |   | 0                         | $t_{FEL}$ | ns   |

**Note** Depends on the on-chip regulator characteristics.

**Interrupt, FLMD0 Pin Timing**

 ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter              | Symbol     | Conditions                              | MIN.            | MAX. | Unit |
|------------------------|------------|---|-----------------|------|------|
| NMI high-level width   | $t_{WNIH}$ | Analog noise elimination                | 500             |      | ns   |
| NMI low-level width    | $t_{WNIL}$ | Analog noise elimination                | 500             |      | ns   |
| INTPn high-level width | $t_{WITH}$ | $n = 0$ to 8 (Analog noise elimination) | 500             |      | ns   |
|                        |            | $n = 3$ (Digital noise elimination)     | $3T_{SMP} + 20$ |      | ns   |
| INTPn low-level width  | $t_{WITL}$ | $n = 0$ to 8 (Analog noise elimination) | 500             |      | ns   |
|                        |            | $n = 3$ (Digital noise elimination)     | $3T_{SMP} + 20$ |      | ns   |
| FLMD0 high-level width | $t_{WMDH}$ |   | 500             |      | ns   |
| FLMD0 low-level width  | $t_{WMDL}$ |   | 500             |      | ns   |

**Remark**  $T_{SMP}$ : Noise elimination sampling clock cycle

**Key Return Timing****( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)**

| Parameter            | Symbol     | Conditions               | MIN. | MAX. | Unit |
|----------------------|------------|--------------------------|------|------|------|
| KRn high-level width | $t_{WKRH}$ | Analog noise elimination | 500  |      | ns   |
| KRn low-level width  | $t_{WKRL}$ | Analog noise elimination | 500  |      | ns   |

**Remark** n = 0 to 7**Timer Timing****( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)**

| Parameter           | Symbol    | Conditions  | MIN.      | MAX. | Unit |
|---------------------|-----------|---|-----------|------|------|
| TI high-level width | $t_{TIH}$ | TIP00, TIP01, TIP10, TIP11, TIP20, TIP21,<br>TIP30, TIP31, TIP40, TIP41, TIP50, TIP51,<br>TIP60, TIP61, TIP70, TIP71, TIP80, TIP81,<br>TIQ00 to TIQ03 | $2T + 20$ |      | ns   |
| TI low-level width  | $t_{TIL}$ |   | $2T + 20$ |      | ns   |

**Remark**  $T = 1/f_{xx}$ **UART Timing****( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)**

| Parameter        | Symbol | Conditions | MIN. | MAX. | Unit |
|------------------|--------|------------|------|------|------|
| Transmit rate    |        |            |      | 625  | kbps |
| ASCK0 cycle time |        |            |      | 10   | MHz  |

**CSIB Timing**

**(1) Master mode**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter  | Symbol                                 | Conditions | MIN.                    | MAX. | Unit |
|--|--|------------|-------------------------|------|------|
| $\overline{\text{SCKBn}}$ cycle time                               | $t_{\text{KCY1}}$                      | <94>       | 125                     |      | ns   |
| $\overline{\text{SCKBn}}$ high-/low-level width                    | $t_{\text{KH1}}$ ,<br>$t_{\text{KL1}}$ | <95>       | $t_{\text{KCY1}}/2 - 8$ |      | ns   |
| SIBn setup time (to $\overline{\text{SCKBn}}\uparrow$ )            | $t_{\text{SIK1}}$                      | <96>       | 27                      |      | ns   |
| SIBn hold time (from $\overline{\text{SCKBn}}\uparrow$ )           | $t_{\text{KSI1}}$                      | <97>       | 27                      |      | ns   |
| Delay time from $\overline{\text{SCKBn}}\downarrow$ to SOBn output | $t_{\text{KSO1}}$                      | <98>       |                         | 27   | ns   |

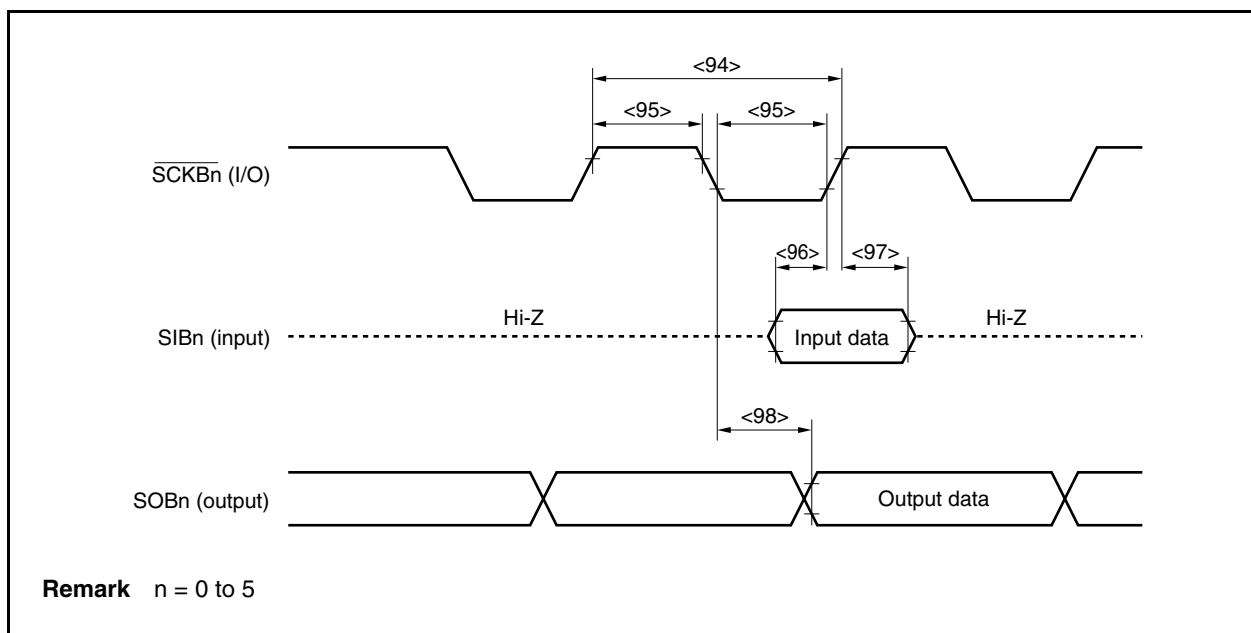
**Remark** n = 0 to 5

**(2) Slave mode**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0$  V,  $C_L = 50$  pF)

| Parameter  | Symbol                                 | Conditions | MIN. | MAX. | Unit |
|--|--|------------|------|------|------|
| $\overline{\text{SCKBn}}$ cycle time                               | $t_{\text{KCY2}}$                      | <94>       | 125  |      | ns   |
| $\overline{\text{SCKBn}}$ high-/low-level width                    | $t_{\text{KH2}}$ ,<br>$t_{\text{KL2}}$ | <95>       | 54.5 |      | ns   |
| SIBn setup time (to $\overline{\text{SCKBn}}\uparrow$ )            | $t_{\text{SIK2}}$                      | <96>       | 27   |      | ns   |
| SIBn hold time (from $\overline{\text{SCKBn}}\uparrow$ )           | $t_{\text{KSI2}}$                      | <97>       | 27   |      | ns   |
| Delay time from $\overline{\text{SCKBn}}\downarrow$ to SOBn output | $t_{\text{KSO2}}$                      | <98>       |      | 27   | ns   |

**Remark** n = 0 to 5

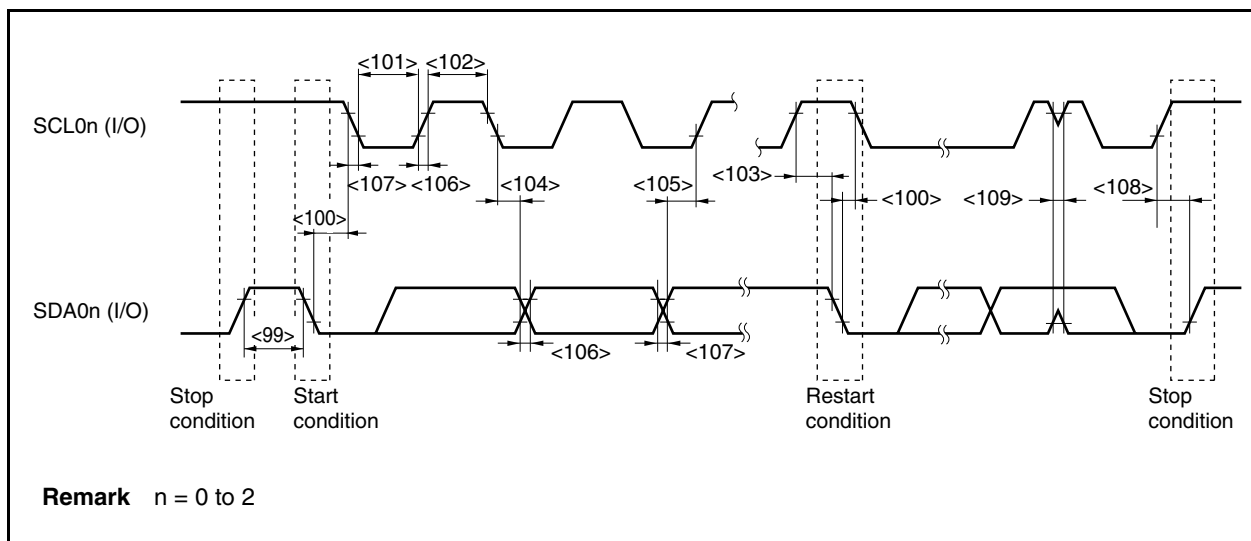


**I<sup>2</sup>C Bus Mode (T<sub>A</sub> = –40 to +85°C, V<sub>DD</sub> = EV<sub>DD</sub> = AV<sub>REF0</sub> = AV<sub>REF1</sub>, V<sub>SS</sub> = EV<sub>SS</sub> = AV<sub>SS</sub> = 0 V, C<sub>L</sub> = 50 pF)**

| Parameter  | Symbol                 |                      | Normal Mode |                     | High-Speed Mode              |                     | Unit                  |    |
|--|------------------------|----------------------|-------------|---------------------|------------------------------|---------------------|-----------------------|----|
|  |                        |                      | MIN.        | MAX.                | MIN.                         | MAX.                |                       |    |
| SCL0n clock frequency                                | f <sub>CLK</sub>       |                      | 0           | 100                 | 0                            | 400                 | kHz                   |    |
| Bus free time<br>(Between start and stop conditions) | t <sub>BUF</sub>       | <99>                 | 4.7         | –                   | 1.3                          | –                   | μs                    |    |
| Hold time <sup>Note 1</sup>                          | t <sub>HD: STA</sub>   | <100>                | 4.0         | –                   | 0.6                          | –                   | μs                    |    |
| SCL0n clock low-level width                          | t <sub>LOW</sub>       | <101>                | 4.7         | –                   | 1.3                          | –                   | μs                    |    |
| SCL0n clock high-level width                         | t <sub>HIGH</sub>      | <102>                | 4.0         | –                   | 0.6                          | –                   | μs                    |    |
| Setup time for start/restart conditions              | t <sub>SU: STA</sub>   | <103>                | 4.7         | –                   | 0.6                          | –                   | μs                    |    |
| Data hold time                                       | CBUS compatible master | t <sub>HD: DAT</sub> | <104>       | 5.0                 | –                            | –                   | –                     | μs |
|  | I <sup>2</sup> C mode  |                      |             | 0 <sup>Note 2</sup> | –                            | 0 <sup>Note 2</sup> | 0.9 <sup>Note 3</sup> | μs |
| Data setup time                                      | t <sub>SU: DAT</sub>   | <105>                | 250         | –                   | 100 <sup>Note 4</sup>        | –                   | ns                    |    |
| SDA0n and SCL0n signal rise time                     | t <sub>R</sub>         | <106>                | –           | 1000                | 20 + 0.1Cb <sup>Note 5</sup> | 300                 | ns                    |    |
| SDA0n and SCL0n signal fall time                     | t <sub>F</sub>         | <107>                | –           | 300                 | 20 + 0.1Cb <sup>Note 5</sup> | 300                 | ns                    |    |
| Stop condition setup time                            | t <sub>SU: STO</sub>   | <108>                | 4.0         | –                   | 0.6                          | –                   | μs                    |    |
| Pulse width of spike suppressed by input filter      | t <sub>SP</sub>        | <109>                | –           | –                   | 0                            | 50                  | ns                    |    |
| Capacitance load of each bus line                    | Cb                     |                      | –           | 400                 | –                            | 400                 | pF                    |    |

- Notes**
- At the start condition, the first clock pulse is generated after the hold time.
  - The system requires a minimum of 300 ns hold time internally for the SDA0n signal (at V<sub>IHmin.</sub> of SCL0n signal) in order to occupy the undefined area at the falling edge of SCL0n.
  - If the system does not extend the SCL0n signal low hold time (t<sub>LOW</sub>), only the maximum data hold time (t<sub>HD:DAT</sub>) needs to be satisfied.
  - The high-speed mode I<sup>2</sup>C bus can be used in the normal-mode I<sup>2</sup>C bus system. In this case, set the high-speed mode I<sup>2</sup>C bus so that it meets the following conditions.
    - If the system does not extend the SCL0n signal's low state hold time:  
t<sub>SU:DAT</sub> ≥ 250 ns
    - If the system extends the SCL0n signal's low state hold time:  
Transmit the following data bit to the SDA0n line prior to the SCL0n line release (t<sub>Rmax.</sub> + t<sub>SU:DAT</sub> = 1,000 + 250 = 1,250 ns: Normal mode I<sup>2</sup>C bus specification).
  - C<sub>b</sub>: Total capacitance of one bus line (unit: pF)

**Remark** n = 0 to 2

**I<sup>2</sup>C Bus Mode**

**A/D Converter**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $3.0\text{ V} \leq AV_{REF0} \leq 3.6\text{ V}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ ,  $C_L = 50\text{ pF}$ )

| Parameter                     | Symbol      | Conditions                             | MIN.      | TYP. | MAX.        | Unit          |
|-------------------------------|-------------|--|-----------|------|-------------|---------------|
| Resolution                    |             |  |           |      | 10          | bit           |
| Overall error <sup>Note</sup> |             | $3.0 \leq AV_{REF0} \leq 3.6\text{ V}$ |           |      | $\pm 0.6$   | %FSR          |
| Conversion time               | $t_{CONV}$  |  | 2.6       |      | 24          | $\mu\text{s}$ |
| Zero scale error              |             |  |           |      | $\pm 0.5$   | %FSR          |
| Full scale error              |             |  |           |      | $\pm 0.5$   | %FSR          |
| Non-linearity error           |             |  |           |      | $\pm 4.0$   | LSB           |
| Differential linearity error  |             |  |           |      | $\pm 4.0$   | LSB           |
| Analog input voltage          | $V_{IAN}$   |  | $AV_{SS}$ |      | $AV_{REF0}$ | V             |
| Reference voltage             | $AV_{REF0}$ |  | 3.0       |      | 3.6         | V             |
| $AV_{REF0}$ current           | $AI_{REF0}$ | Normal conversion mode                 |           | 3    | 6.5         | mA            |
|                               |             | High-speed conversion mode             |           | 4    | 10          | mA            |
|                               |             | When A/D converter unused              |           |      | 5           | $\mu\text{A}$ |

**Note** Excluding quantization error ( $\pm 0.05\%$ FSR).

**Caution** Do not set (read/write) alternate-function ports during A/D conversion; otherwise the conversion resolution may be degraded.

**Remark** LSB: Least Significant Bit  
FSR: Full Scale Range

**D/A Converter**
**( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $3.0\text{ V} \leq AV_{REF1} \leq 3.6\text{ V}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ ,  $C_L = 50\text{ pF}$ )**

| Parameter                             | Symbol      | Conditions               | MIN. | TYP. | MAX.      | Unit             |
|---------------------------------------|-------------|--------------------------|------|------|-----------|------------------|
| Resolution                            |             |                          |      |      | 8         | bit              |
| Overall error <sup>Note 1</sup>       |             | $R = 2\text{ M}\Omega$   |      |      | $\pm 1.2$ | %FSR             |
| Settling time                         |             | $C = 20\text{ pF}$       |      |      | 3         | $\mu\text{s}$    |
| Output resistor                       | $R_O$       | Output data 55H          |      | 6.42 |           | $\text{k}\Omega$ |
| Reference voltage                     | $AV_{REF1}$ |                          | 3.0  |      | 3.6       | V                |
| $AV_{REF1}$ current <sup>Note 2</sup> | $AI_{REF1}$ | D/A conversion operating |      | 1    | 2.5       | mA               |
|                                       |             | D/A conversion stopped   |      |      | 5         | $\mu\text{A}$    |

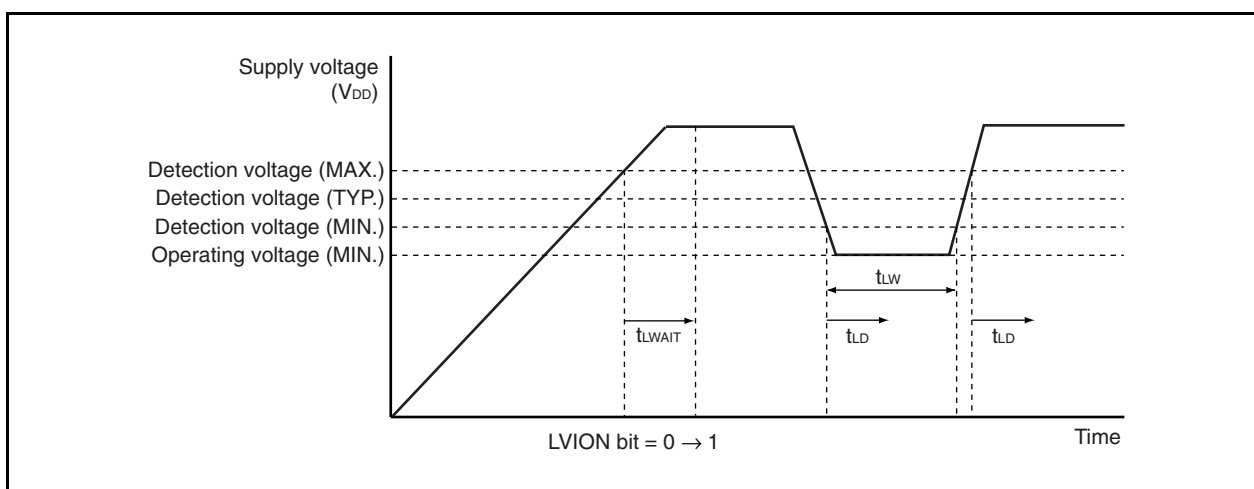
**Notes** 1. Excluding quantization error ( $\pm 0.5$  LSB).

2. Value of 1 channel of D/A converter

**Remark** R is the output pin load resistance and C is the output pin load capacitance.

**LVI Circuit Characteristics**
**( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ ,  $C_L = 50\text{ pF}$ )**

| Parameter                                 | Symbol      | Conditions  | MIN. | TYP. | MAX. | Unit |
|---|-------------|---|------|------|------|------|
| Detection voltage                         | $V_{LV10}$  |   | 2.85 | 2.95 | 3.05 | V    |
| Response time <sup>Note</sup>             | $t_{LD}$    | After $V_{DD}$ reaches $V_{LV10}$ (MAX.),<br>or after $V_{DD}$ has dropped to $V_{LV10}$ (MAX.) |      | 0.2  | 2.0  | ms   |
| Minimum pulse width                       | $t_{LW}$    |   | 0.2  |      |      | ms   |
| Reference voltage stabilization wait time | $t_{LWAIT}$ | After $V_{DD}$ reaches 2.85 V (MIN.)  |      | 0.1  | 0.2  | ms   |

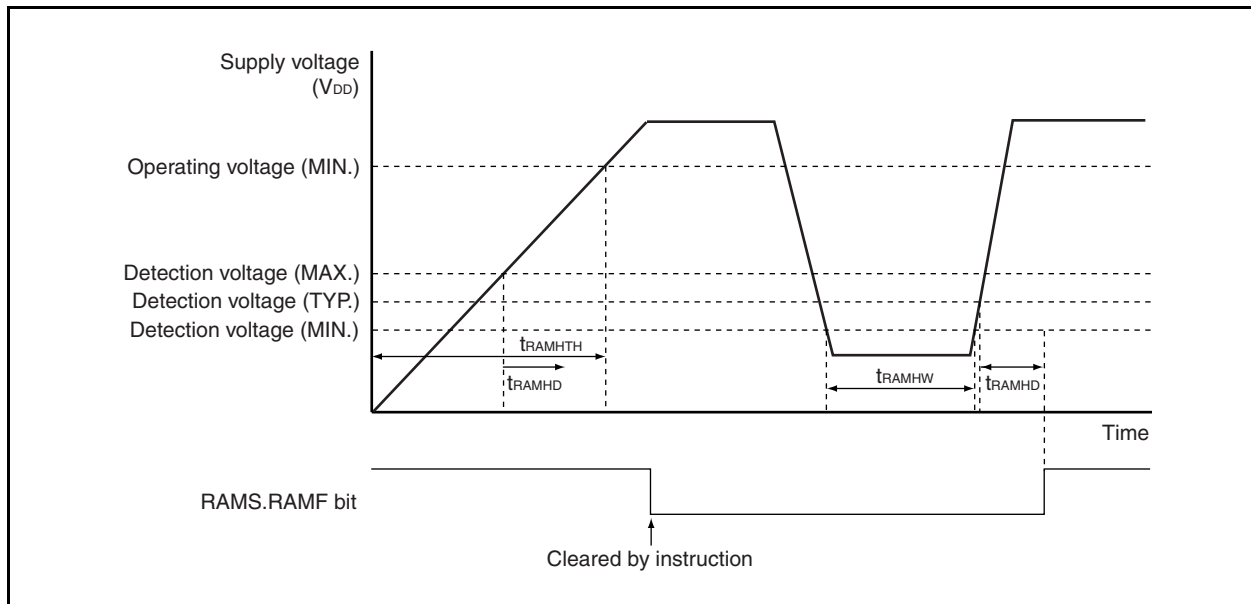
**Note** Time required to detect the detection voltage and output an interrupt or reset signal.


**RAM Retention Detection**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ ,  $C_L = 50\text{ pF}$ )

| Parameter                     | Symbol       | Conditions                            | MIN.  | TYP. | MAX. | Unit |
|-------------------------------|--------------|---------------------------------------|-------|------|------|------|
| Detection voltage             | $V_{RAMH}$   |                                       | 1.9   | 2.0  | 2.1  | V    |
| Supply voltage rise time      | $t_{RAMHTH}$ | $V_{DD} = 0$ to $2.85\text{ V}$       | 0.002 |      |      | ms   |
| Response time <sup>Note</sup> | $t_{RAMHD}$  | After $V_{DD}$ reaches $2.1\text{ V}$ |       | 0.2  | 3.0  | ms   |
| Minimum pulse width           | $t_{RAMHW}$  |                                       | 0.2   |      |      | ms   |

**Note** Time required to detect the detection voltage and set the RAMS.RAMF bit.





**Flash Memory Programming Characteristics**

( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ ,  $V_{SS} = EV_{SS} = AV_{SS} = 0\text{ V}$ ,  $C_L = 50\text{ pF}$ )

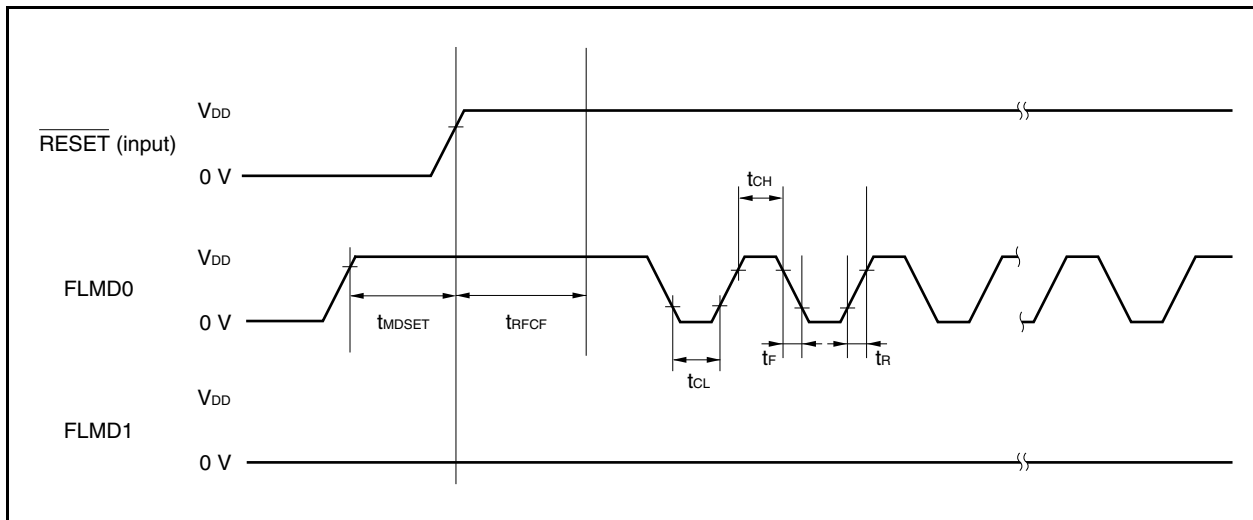
**(1) Basic characteristics**

| Parameter               | Symbol    | Conditions | MIN. | TYP. | MAX. | Unit             |
|-------------------------|-----------|------------|------|------|------|------------------|
| Operating frequency     | $f_{CPU}$ |            | 2.5  |      | 32   | MHz              |
| Supply voltage          | $V_{DD}$  |            | 2.85 |      | 3.6  | V                |
| Number of rewrites      | $C_{WRT}$ |            |      |      | 100  | times            |
| Programming temperature | $t_{PRG}$ |            | -40  |      | +85  | $^\circ\text{C}$ |

**(2) Serial write operation characteristics**

| Parameter   | Symbol          | Conditions                     | MIN. | TYP. | MAX. | Unit          |
|---|-----------------|--------------------------------|------|------|------|---------------|
| FLMD0, FLMD1 setup time                                       | $t_{MSET}$      |                                | 2    |      | 3000 | ms            |
| FLMD0 count start time from $\overline{\text{RESET}}\uparrow$ | $t_{RFCF}$      | $f_x = 2.5$ to $10\text{ MHz}$ | 800  |      |      | s             |
| FLMD0 counter high-level width/<br>low-level width            | $t_{CH}/t_{CL}$ |                                | 10   |      | 100  | $\mu\text{s}$ |
| FLMD0 counter rise time/fall time                             | $t_R/t_F$       |                                |      |      | 1    | $\mu\text{s}$ |

**Flash write mode setup timing**



**(3) Programming characteristics**

| Parameter                             | Symbol | Conditions                            | MIN. | TYP. | MAX. | Unit |
|---------------------------------------|--------|---------------------------------------|------|------|------|------|
| Chip erase time                       |        | f <sub>xx</sub> = 32 MHz, batch erase |      | 105  |      | ms   |
| Write time per 256 bytes              |        | f <sub>xx</sub> = 32 MHz              |      | 2.0  |      | ms   |
| Block internal verify time            |        | f <sub>xx</sub> = 32 MHz              |      | 10   |      | ms   |
| Block blank check time                |        | f <sub>xx</sub> = 32 MHz              |      | 0.5  |      | ms   |
| Flash memory information setting time |        | f <sub>xx</sub> = 32 MHz              |      | 30   |      | ms   |

**Caution** When writing initially to shipped products, it is counted as one rewrite for both "erase to write" and "write only".

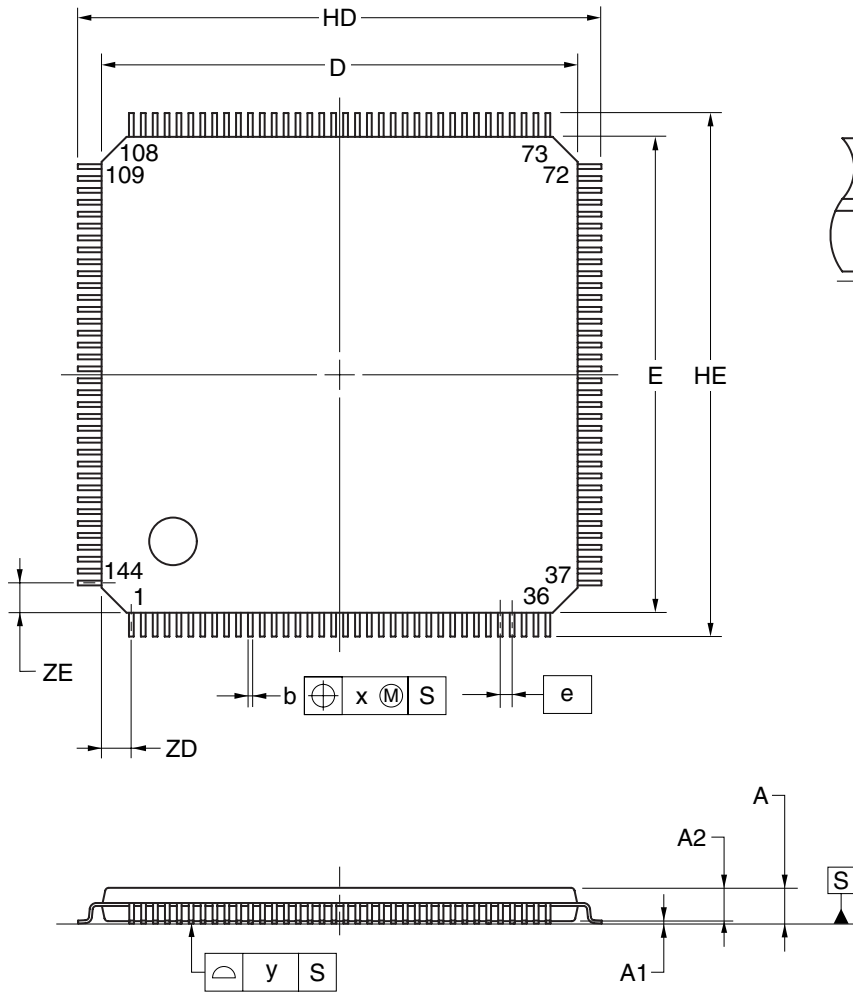
**Example (P: Write, E: Erase)**

**Shipped product** —→ P → E → P → E → P: **3 rewrites**

**Shipped product** → E → P → E → P → E → P: **3 rewrites**

CHAPTER 30 PACKAGE DRAWING

144-PIN PLASTIC LQFP (FINE PITCH) (20x20)



detail of lead end

(UNIT:mm)

| ITEM | DIMENSIONS                                |
|------|---|
| D    | 20.00±0.20                                |
| E    | 20.00±0.20                                |
| HD   | 22.00±0.20                                |
| HE   | 22.00±0.20                                |
| A    | 1.60 MAX.                                 |
| A1   | 0.10±0.05                                 |
| A2   | 1.40±0.05                                 |
| A3   | 0.25                                      |
| b    | 0.20 <sup>+0.07</sup> <sub>-0.03</sub>    |
| c    | 0.125 <sup>+0.075</sup> <sub>-0.025</sub> |
| L    | 0.50                                      |
| Lp   | 0.60±0.15                                 |
| L1   | 1.00±0.20                                 |
| θ    | 3° <sup>+5°</sup> <sub>-3°</sub>          |
| e    | 0.50                                      |
| x    | 0.08                                      |
| y    | 0.08                                      |
| ZD   | 1.25                                      |
| ZE   | 1.25                                      |

P144GJ-50-GAE-1

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## APPENDIX A DEVELOPMENT TOOLS

The following development tools are available for the development of systems that employ the V850ES/JJ3. Figure A-1 shows the development tool configuration.

- **Support for PC98-NX series**

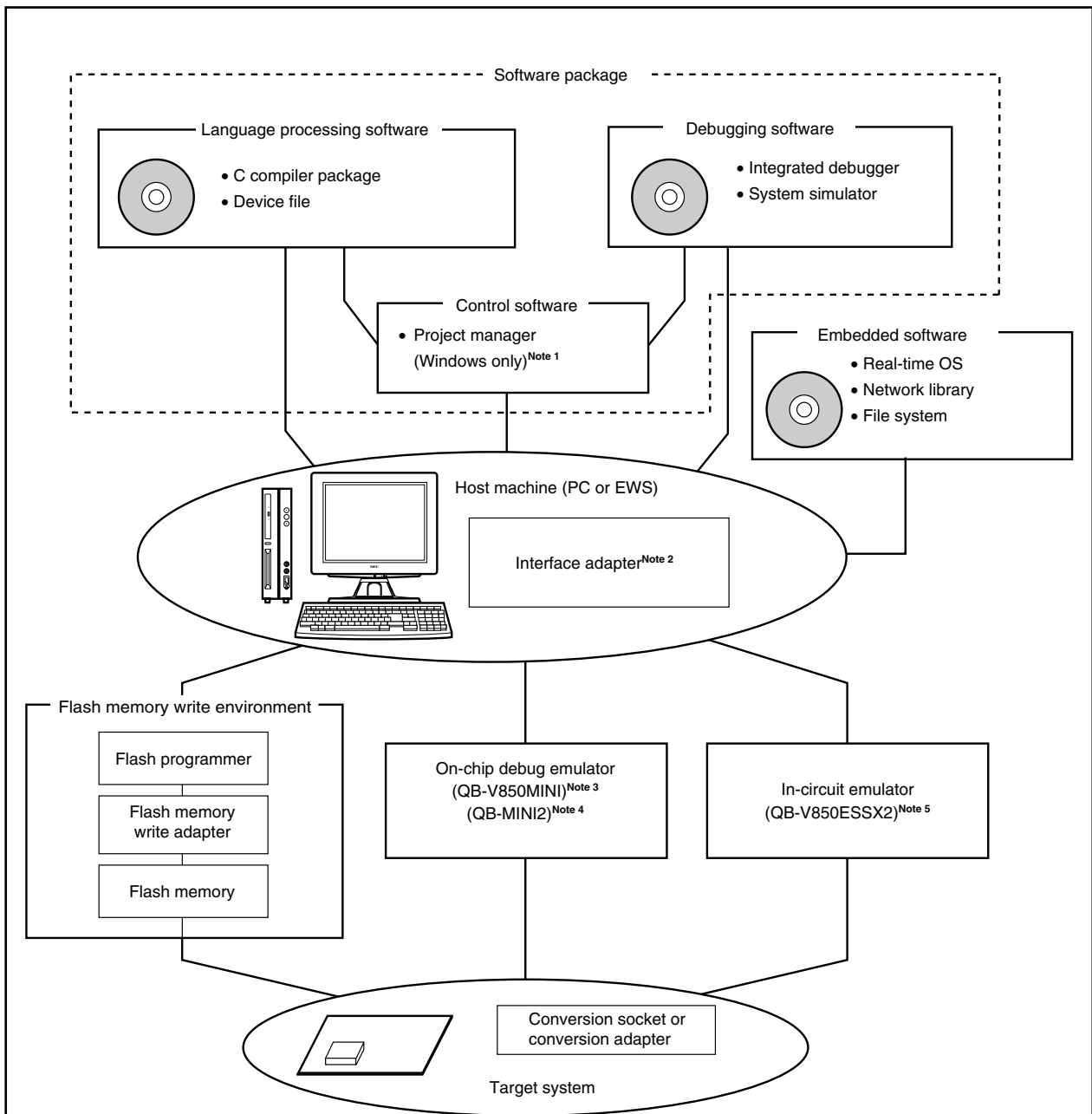
Unless otherwise specified, products supported by IBM PC/AT™ compatibles are compatible with PC98-NX series computers. When using PC98-NX series computers, refer to the explanation for IBM PC/AT compatibles.

- **Windows™**

Unless otherwise specified, "Windows" means the following OSs.

- Windows 98, 2000
- Windows Me
- Windows XP
- Windows NT™ Ver. 4.0

Figure A-1. Development Tool Configuration



- Notes**
1. Project manager PM+ is included in the C compiler package. PM+ is only used in Windows.
  2. The QB-V850MINI, QB-MINI2, and QB-V850ESSX2 support the USB interface only.
  3. The QB-V850MINI is supplied with the ID850QB, USB interface cable, OCD cable, self-check board, KEL adapter, and KEL connector. All other products are optional.
  4. The QB-MINI2 is supplied with USB interface cable, 16-pin target cable, 10-pin target cable, and 78K0-OCD board (integrated debugger is not supplied.) All other products are optional.
  5. The QB-V850ESSX2 is supplied with the ID850QB, simple flash memory programmer, power supply unit, and USB interface adapter. All other products are optional.

### A.1 Software Package

|  |   |
|--|---|
| SP850<br>Software package for V850<br>microcontrollers | Development tools (software) commonly used with V850 microcontrollers are included<br>this package. |
|  | Part number: $\mu$ SxxxxSP850   |

**Remark** xxxx in the part number differs depending on the host machine and OS used.

$\mu$ SxxxxSP850

| xxxx | Host Machine                             | OS                         | Supply Medium |
|------|--|----------------------------|---------------|
| AB17 | PC-9800 series,<br>IBM PC/AT compatibles | Windows (Japanese version) | CD-ROM        |
| BB17 |  | Windows (English version)  |               |

### A.2 Language Processing Software

|                             |  |
|-----------------------------|--|
| CA850<br>C compiler package | This compiler converts programs written in C into object codes executable with a<br>microcontroller. This compiler is started from project manager PM+.  |
|                             | Part number: $\mu$ SxxxxCA703000   |
| DF703746<br>Device file     | This file contains information peculiar to the device.<br>This device file should be used in combination with a tool (CA850, SM850, or ID850QB).<br>The corresponding OS and host machine differ depending on the tool to be used. |

**Remark** xxxx in the part number differs depending on the host machine and OS used.

$\mu$ SxxxxCA703000

| xxxx | Host Machine                             | OS  | Supply Medium |
|------|--|---|---------------|
| AB17 | PC-9800 series,<br>IBM PC/AT compatibles | Windows (Japanese version)                    | CD-ROM        |
| BB17 |  | Windows (English version)                     |               |
| 3K17 | SPARCstation™                            | SunOS™ (Rel. 4.1.4),<br>Solaris™ (Rel. 2.5.1) |               |

### A.3 Control Software

|                        |  |
|------------------------|--|
| PM+<br>Project manager | This is control software designed to enable efficient user program development in the<br>Windows environment. All operations used in development of a user program, such as<br>starting the editor, building, and starting the debugger, can be performed from PM+.<br><b>&lt;Caution&gt;</b><br>PM+ is included in C compiler package CA850.<br>It can only be used in Windows. |
|------------------------|--|

## A.4 Debugging Tools (Hardware)

### A.4.1 When using IECUBE QB-V850ESSX2

The system configuration when connecting the QB-V850ESSX2 to the host machine (PC-9821 series, PC/AT compatible) is shown below. Even if optional products are not prepared, connection is possible.

Figure A-2. System Configuration (When Using QB-V850ESSX2) (1/2)

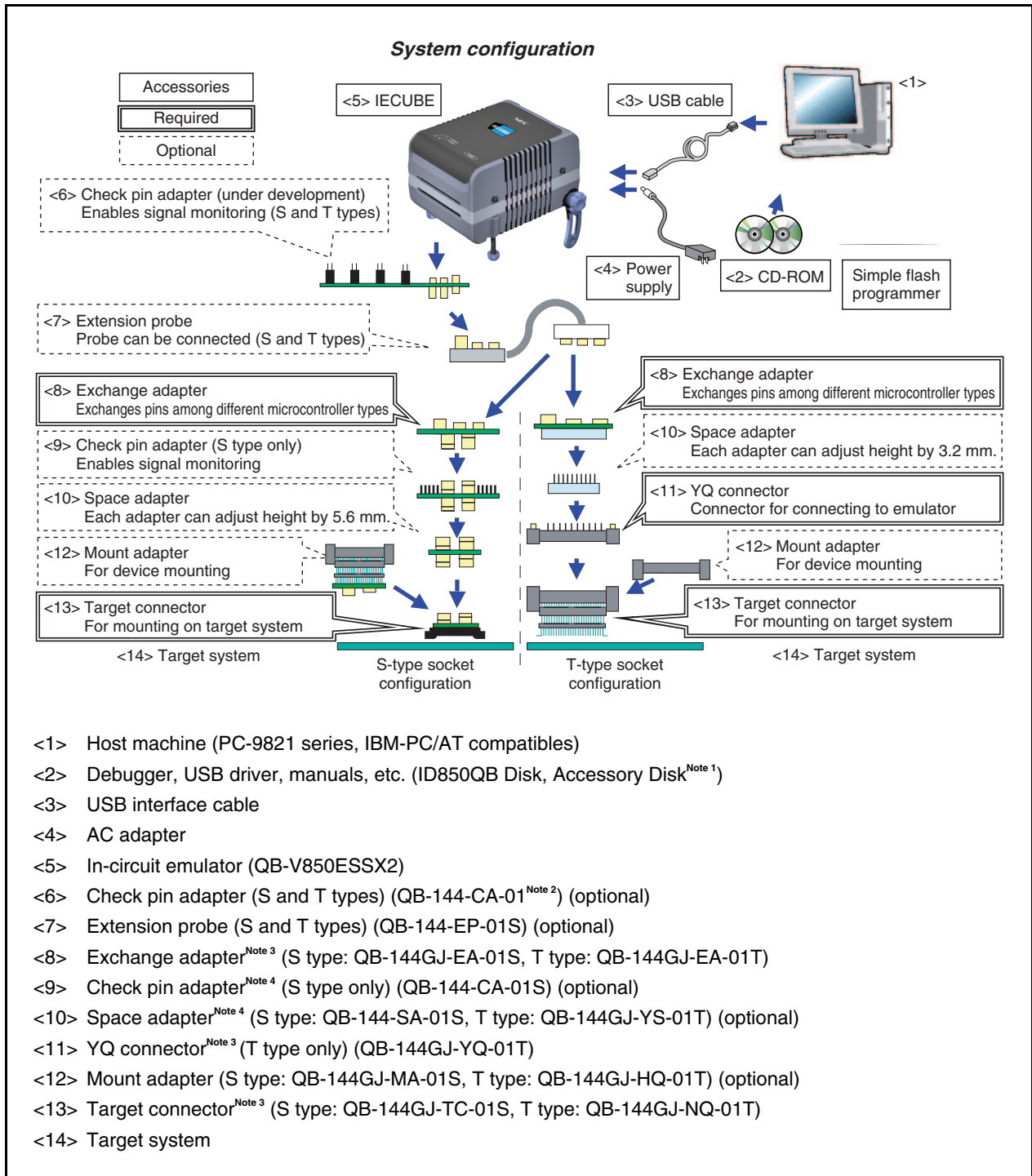


Figure A-2. System Configuration (When Using QB-V850ESSX2) (2/2)

- Notes**
1. Download the device file from the NEC Electronics website.  
<http://www.necel.com/micro/ods/eng/>
  2. Under development
  3. Supplied with the device depending on the ordering number.
    - When QB-V850ESSX2-ZZZ is ordered  
 The exchange adapter and the target connector are not supplied.
    - When QB-V850ESSX2-S144GJ is ordered  
 The QB-144GJ-EA-01S and QB-144GJ-TC-01S are supplied.
    - When QB-V850ESSX2-T144GJ is ordered  
 The QB-144GJ-EA-01T, QB-144GJ-YQ-01T, and QB-144GJ-NQ-01T are supplied.
  4. When using both <9> and <10>, the order between <9> and <10> is not cared.

|   |   |
|---|---|
| <5> QB-V850ESSX2 <sup>Note</sup><br>In-circuit emulator     | The in-circuit emulator serves to debug hardware and software when developing application systems using the V850ES/JJ3. It supports to the integrated debugger ID850QB. This emulator should be used in combination with a power supply unit and emulation probe. Use the USB interface cable to connect this emulator to the host machine. |
| <3> USB interface cable                                     | Cable to connect the host machine and the QB-V850ESSX2.   |
| <4> AC adapter  | 100 to 240 V can be supported by replacing the AC plug.   |
| <8> QB-144GJ-EA-01S<br>QB-144GJ-EA-01T<br>Exchange adapter  | Adapter to perform pin conversion.  |
| <9> QB-144-CA-01S<br>Check pin adapter                      | Adapter used in waveform monitoring using the oscilloscope, etc.  |
| <10> QB-144-SA-01S<br>QB-144GJ-YS-01T<br>Space adapter      | Adapter to adjust the height.   |
| <11> QB-144GJ-YQ-01T<br>YQ connector                        | Conversion adapter to connect the target connector and the exchange adapter.  |
| <12> QB-144GJ-MA-01S<br>QB-144GJ-HQ-01T<br>Mount adapter    | Adapter to mount the V850ES/JJ3 with socket.  |
| <13> QB-144GJ-TC-01S<br>QB-144GJ-NQ-01T<br>Target connector | Connector to solder on the target system.   |

**Note** The QB-V850ESSX2 is supplied with a power supply unit, USB interface cable, and simple flash memory programmer. It is also supplied with integrated debugger ID850QB as control software.

**Remark** The numbers in the angle brackets correspond to the numbers in Figure A-2.

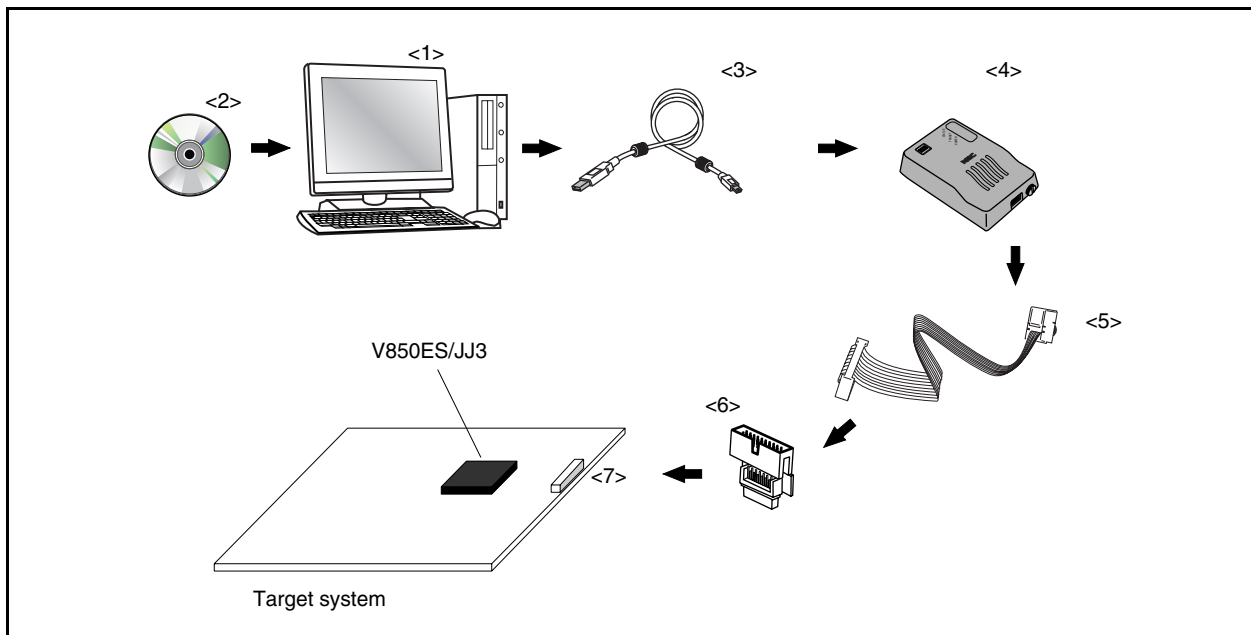


**A.4.2 When using MINICUBE QB-V850MINI**

**(1) On-chip emulation using MINICUBE**

The system configuration when connecting MINICUBE to the host machine (PC-9821 series, PC/AT compatible) is shown below.

**Figure A-3. On-Chip Emulation System Configuration**



|   |  |
|---|--|
| <1> Host machine  | PC with USB ports  |
| <2> CD-ROM <sup>Note 1</sup>                              | Contents such as integrated debugger ID850QB, N-Wire Checker, device driver, and documents are included in CD-ROM. It is supplied with MINICUBE.                     |
| <3> USB interface cable                                   | USB cable to connect the host machine and MINICUBE. It is supplied with MINICUBE. The cable length is approximately 2 m.   |
| <4> MINICUBE<br>On-chip debug emulator                    | This on-chip debug emulator serves to debug hardware and software when developing application systems using the V850ES/JJ3. It supports integrated debugger ID850QB. |
| <5> OCD cable   | Cable to connect MINICUBE and the target system. It is supplied with MINICUBE. The cable length is approximately 20 cm.  |
| <6> Connector conversion board<br>KEL adapter             | This conversion board is supplied with MINICUBE.   |
| <7> MINICUBE connector<br>KEL connector <sup>Note 2</sup> | 8830E-026-170S (supplied with MINICUBE)<br>8830E-026-170L (sold separately)  |

**Notes** 1. Download the device file from the NEC Electronics website.

<http://www.necel.com/micro/ods/eng/index.html>

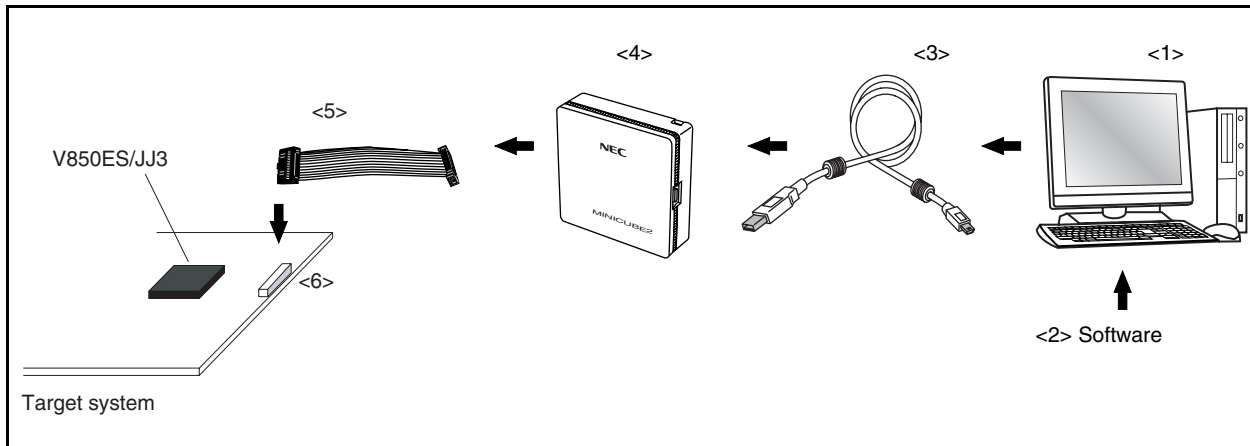
2. Product of KEL Corporation

**Remark** The numbers in the angular brackets correspond to the numbers in Figure A-3.

**A.4.3 When using MINICUBE2 QB-MINI2**

The system configuration when connecting MINICUBE2 to the host machine (PC-9821 series, PC/AT compatible) is shown below.

**Figure A-4. System Configuration of On-Chip Emulation System**



|   |   |
|---|---|
| <1> Host machine                        | PC with USB ports   |
| <2> Software                            | The integrated debugger ID850QB, device file, etc.<br>Download the device file from the NEC Electronics website.<br><a href="http://www.necel.com/micro/ods/eng/">http://www.necel.com/micro/ods/eng/</a> |
| <3> USB interface cable                 | USB cable to connect the host machine and MINICUBE. It is supplied with MINICUBE. The cable length is approximately 2 m.  |
| <4> MINICUBE2<br>On-chip debug emulator | This on-chip debug emulator serves to debug hardware and software when developing application systems using the V850ES/JJ3. It supports integrated debugger ID850QB.                                      |
| <5> 16-pin target cable                 | Cable to connect MINICUBE2 and the target system.<br>It is supplied with MINICUBE. The cable length is approximately 15 cm.   |
| <6> Target connector (sold separately)  | Use a 16-pin general-purpose connector with 2.54 mm pitch.  |

**Remark** The numbers in the angular brackets correspond to the numbers in Figure A-4.

### A.5 Debugging Tools (Software)

|   |   |
|---|---|
| SM850 (under development)<br>System simulator | This simulator is used with V850 microcontrollers. SM850 is Windows-based software. Debugging of C source and assembler files is possible during simulation of the target system operation on the host machine.<br>By using SM850, logic verification and performance verification of applications can be performed independently from hardware development. Therefore, development efficiency and software quality can be improved. It should be used in combination with the device file.<br>Part number: $\mu$ SxxxxSM703000 |
| ID850QB<br>Integrated debugger                | This debugger supports the in-circuit emulators for V850 microcontrollers. The ID850QB is Windows-based software.<br>It has improved C-compatible debugging functions and can 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.<br>It should be used in combination with the device file.<br>Part number: $\mu$ Sxxxx ID703000-QB (ID850QB)  |

**Remark** xxxx in the part number differs depending on the host machine and OS used.

$\mu$ SxxxxSM703000

$\mu$ SxxxxID703000-QB

| xxxx | Host Machine          | OS                         | Supply Medium |
|------|-----------------------|----------------------------|---------------|
| AB17 | PC-9800 series,       | Windows (Japanese version) | CD-ROM        |
| BB17 | IBM PC/AT compatibles | Windows (English version)  |               |

**A.6 Embedded Software**

|                                  |  |
|----------------------------------|--|
| RX850, RX850 Pro<br>Real-time OS | The RX850 and RX850 Pro are real-time OSs conforming to $\mu$ ITRON 3.0 specifications. A tool (configurator) for generating multiple information tables is supplied. RX850 Pro has more functions than the RX850. |
|                                  | Part number: $\mu$ SxxxxRX703000- $\Delta\Delta\Delta\Delta$ (RX850)<br>$\mu$ SxxxxRX703100- $\Delta\Delta\Delta\Delta$ (RX850 Pro)  |
| RX-FS850<br>(File system)        | This is a FAT file system function.<br>It is a file system that supports the CD-ROM file system function.<br>This file system is used with the real-time OS RX850 Pro.   |

**Caution** To purchase the RX850 or RX850 Pro, first fill in the purchase application form and sign the license agreement.

**Remark** xxxx and  $\Delta\Delta\Delta\Delta$  in the part number differ depending on the host machine and OS used.

$\mu$ SxxxxRX703000- $\Delta\Delta\Delta\Delta$

$\mu$ SxxxxRX703100- $\Delta\Delta\Delta\Delta$

| $\Delta\Delta\Delta\Delta$ | Product Outline        | Maximum Number for Use in Mass Production |
|----------------------------|------------------------|---|
| 001                        | Evaluation object      | Do not use for mass-produced product.     |
| 100K                       | Mass-production object | 0.1 million units                         |
| 001M                       |                        | 1 million units                           |
| 010M                       |                        | 10 million units                          |
| S01                        | Source program         | Object source program for mass production |

| xxxx | Host Machine                             | OS                         | Supply Medium |
|------|--|----------------------------|---------------|
| AB17 | PC-9800 series,<br>IBM PC/AT compatibles | Windows (Japanese version) | CD-ROM        |
| BB17 |  | Windows (English version)  |               |
| 3K17 | SPARCstation                             | Solaris (Rel. 2.5.1)       |               |

**A.7 Flash Memory Writing Tools**

|  |   |
|--|---|
| Flashpro IV<br>(part number: PG-FP4)<br>Flash programmer | Flash programmer dedicated to microcontrollers with on-chip flash memory.         |
| QB-MINI2 (MINICUBE2)                                     | On-chip debug emulator with programming function.                                 |
| FA-144GJ-UEN-A<br>Flash memory writing adapter           | Flash memory writing adapter used connected to the Flashpro IV, etc. (not wired). |

**Remark** FA-144GJ-UEN-A is a product of Naito Densai Machida Mfg. Co., Ltd.  
TEL: +81-42-750-4172

## APPENDIX B MAJOR DIFFERENCES BETWEEN V850ES/JJ3 AND V850ES/JJ2

Differences between the V850ES/JJ3 and V850ES/JJ2 are shown below. For details, refer to each corresponding section.

**Table B-1. Major Differences Between V850ES/JJ3 and V850ES/JJ2 (1/2)**

| Major Differences  |  | V850ES/JJ3   | V850ES/JJ2   | Refer to:  |            |
|--|--|--|--|--|------------|
| BV <sub>DD</sub> , BV <sub>SS</sub> pins                                 |  | Changed to EV <sub>DD</sub> , EV <sub>SS</sub> pins        | Provided   | Throughout   |            |
| Introduction: Minimum instruction execution time                         |  | 31.25 ns   | 50 ns  | 1.2  |            |
| Pin function: Pin status of P10/ANO0, P11/ANO1 (when power is applied)   |  | Hi-Z   | Undefined  | 2.2  |            |
| <R>  | CPU function                                     | Internal flash memory                                      | 384/512/768/1024 KB  | 128/256/384/512/640 KB   | 3.4.4 (1)  |
| <R>  |  | Internal RAM   | 32/40/60 KB  | 12/24/32/40/48 KB  | 3.4.4 (2)  |
| A/D converter: Proportion of sampling time during conversion             |  | 8/26 clocks  | 4/26 clocks  | 13.5.2   |            |
| Reset function: Firmware operation after releasing internal system reset |  | None   | Provided (refer to <b>22.3.4 (2)</b> in <b>User's Manual (U17714E)</b> )   | –  |            |
| <R>  | Low-voltage detector (LVI)                       | Low-voltage detection interrupt (INTLVI) occurrence source | When supply voltage drops or rises across the detection voltage  | When supply voltage drops below the detection voltage  | 24.3 (1)   |
|  |  | Low-voltage detection level                                | 2.85 to 3.05 V (2.95 V (TYP.))   | 2.85 to 3.15 V (3.0 V (TYP.))  | 24.3 (2)   |
|  |  | RAMS.RAMF bit set conditions                               | <ul style="list-style-type: none"> <li>Voltage lower than detection level is detected</li> <li>Set by instruction</li> </ul> | <ul style="list-style-type: none"> <li>Voltage lower than detection level is detected</li> <li>Set by instruction</li> <li>Reset by WDT2 and CLM occurs</li> <li>Reset by <math>\overline{\text{RESET}}</math> pin occurs during internal RAM accessing</li> </ul> | 24.3 (3)   |
| <R>  | CRC function                                     |  | Provided   | None   | Chapter 25 |
| Regulator: Supply clock to sub-oscillator                                |  | Supply voltage (V <sub>DD</sub> )                          | Regulator output voltage   | 26.1   |            |
| Flash memory   | Block configuration                              | Block 0 to last block: 4 KB each                           | Blocks 0 to 3: 28 KB each<br>Blocks 4 to 7: 4 KB each<br>Block 8 to last block: 64 KB each                                   | 27.2   |            |
|  | Boot area  | 64 KB  | 56 KB  |  |            |
| On-chip debug function   | Cautions on reset related to software breakpoint | None   | Provided (refer to <b>27.1.6 (3)</b> in <b>User's Manual (U17714E)</b> )   | –  |            |

**Table B-1. Major Differences Between V850ES/JJ3 and V850ES/JJ2 (2/2)**

| Major Differences                |  | V850ES/JJ3   | V850ES/JJ2                      | Refer to:  |
|----------------------------------|--|--|---------------------------------|------------|
| Electrical specifications        | Operating condition (internal system clock frequency)  | $f_{\text{xx}} = 2.5$ to 32 MHz  | $f_{\text{xx}} = 2.5$ to 20 MHz | Chapter 29 |
|                                  | Internal oscillator characteristics (output frequency) | 220 kHz (TYP.)<br>(min. and max. values are the same as those of V850ES/JJ2) | 200 kHz (TYP.)                  |            |
|                                  | DC characteristics (supply current)                    | Additional parameters exist  | –                               |            |
|                                  | Bus timing   | Changed parameters exist   | –                               |            |
|                                  | CSIB timing  | Changed parameters exist   | –                               |            |
|                                  | D/A converter (output resistance)                      | 6.42 k $\Omega$  | 3.5 k $\Omega$                  |            |
|                                  | LVI circuit characteristics (detection voltage)        | 2.85 to 3.05 V (2.95 V (TYP.))   | 2.85 to 3.15 V (3.0 V (TYP.))   |            |
|                                  | RAM retention detection (response time)                | 3.0 ms (MAX.)  | 2.0 ms (MAX.)                   |            |
| Package drawing                  |  | P144GJ-50-GAE  | S144GJ-50-UEN                   | Chapter 30 |
| Recommended soldering conditions |  | TBD  | Provided                        | –          |

## APPENDIX C REGISTER INDEX

(1/12)

| Symbol    | Name   | Unit | Page |
|-----------|--|------|------|
| ADA0CR0   | A/D conversion result register 0             | ADC  | 452  |
| ADA0CR0H  | A/D conversion result register 0H            | ADC  | 452  |
| ADA0CR1   | A/D conversion result register 1             | ADC  | 452  |
| ADA0CR1H  | A/D conversion result register 1H            | ADC  | 452  |
| ADA0CR2   | A/D conversion result register 2             | ADC  | 452  |
| ADA0CR2H  | A/D conversion result register 2H            | ADC  | 452  |
| ADA0CR3   | A/D conversion result register 3             | ADC  | 452  |
| ADA0CR3H  | A/D conversion result register 3H            | ADC  | 452  |
| ADA0CR4   | A/D conversion result register 4             | ADC  | 452  |
| ADA0CR4H  | A/D conversion result register 4H            | ADC  | 452  |
| ADA0CR5   | A/D conversion result register 5             | ADC  | 452  |
| ADA0CR5H  | A/D conversion result register 5H            | ADC  | 452  |
| ADA0CR6   | A/D conversion result register 6             | ADC  | 452  |
| ADA0CR6H  | A/D conversion result register 6H            | ADC  | 452  |
| ADA0CR7   | A/D conversion result register 7             | ADC  | 452  |
| ADA0CR7H  | A/D conversion result register 7H            | ADC  | 452  |
| ADA0CR8   | A/D conversion result register 8             | ADC  | 452  |
| ADA0CR8H  | A/D conversion result register 8H            | ADC  | 452  |
| ADA0CR9   | A/D conversion result register 9             | ADC  | 452  |
| ADA0CR9H  | A/D conversion result register 9H            | ADC  | 452  |
| ADA0CR10  | A/D conversion result register 10            | ADC  | 452  |
| ADA0CR10H | A/D conversion result register 10H           | ADC  | 452  |
| ADA0CR11  | A/D conversion result register 11            | ADC  | 452  |
| ADA0CR11H | A/D conversion result register 11H           | ADC  | 452  |
| ADA0CR12  | A/D conversion result register 12            | ADC  | 452  |
| ADA0CR12H | A/D conversion result register 12H           | ADC  | 452  |
| ADA0CR13  | A/D conversion result register 13            | ADC  | 452  |
| ADA0CR13H | A/D conversion result register 13H           | ADC  | 452  |
| ADA0CR14  | A/D conversion result register 14            | ADC  | 452  |
| ADA0CR14H | A/D conversion result register 14H           | ADC  | 452  |
| ADA0CR15  | A/D conversion result register 15            | ADC  | 452  |
| ADA0CR15H | A/D conversion result register 15H           | ADC  | 452  |
| ADA0M0    | A/D converter mode register 0                | ADC  | 445  |
| ADA0M1    | A/D converter mode register 1                | ADC  | 447  |
| ADA0M2    | A/D converter mode register 2                | ADC  | 450  |
| ADA0PFM   | Power-fail compare mode register             | ADC  | 454  |
| ADA0PFT   | Power-fail compare threshold value register  | ADC  | 455  |
| ADA0S     | A/D converter channel specification register | ADC  | 451  |
| ADIC      | Interrupt control register                   | INTC | 686  |
| AWC       | Address wait control register                | BCU  | 199  |
| BCC       | Bus cycle control register                   | BCU  | 200  |
| BSC       | Bus size configuration register              | BCU  | 188  |



| Symbol  | Name                           | Unit | Page |
|---------|--------------------------------|------|------|
| CB0CTL0 | CSIB0 control register 0       | CSI  | 523  |
| CB0CTL1 | CSIB0 control register 1       | CSI  | 526  |
| CB0CTL2 | CSIB0 control register 2       | CSI  | 527  |
| CB0RIC  | Interrupt control register     | INTC | 686  |
| CB0RX   | CSIB0 receive data register    | CSI  | 522  |
| CB0RXL  | CSIB0 receive data register L  | CSI  | 522  |
| CB0STR  | CSIB0 status register          | CSI  | 529  |
| CB0TIC  | Interrupt control register     | INTC | 686  |
| CB0TX   | CSIB0 transmit data register   | CSI  | 522  |
| CB0TXL  | CSIB0 transmit data register L | CSI  | 522  |
| CB1CTL0 | CSIB1 control register 0       | CSI  | 523  |
| CB1CTL1 | CSIB1 control register 1       | CSI  | 526  |
| CB1CTL2 | CSIB1 control register 2       | CSI  | 527  |
| CB1RIC  | Interrupt control register     | INTC | 686  |
| CB1RX   | CSIB1 receive data register    | CSI  | 522  |
| CB1RXL  | CSIB1 receive data register L  | CSI  | 522  |
| CB1STR  | CSIB1 status register          | CSI  | 529  |
| CB1TIC  | Interrupt control register     | INTC | 686  |
| CB1TX   | CSIB1 transmit data register   | CSI  | 522  |
| CB1TXL  | CSIB1 transmit data register L | CSI  | 527  |
| CB2CTL0 | CSIB2 control register 0       | CSI  | 523  |
| CB2CTL1 | CSIB2 control register 1       | CSI  | 526  |
| CB2CTL2 | CSIB2 control register 2       | CSI  | 527  |
| CB2RIC  | Interrupt control register     | INTC | 686  |
| CB2RX   | CSIB2 receive data register    | CSI  | 522  |
| CB2RXL  | CSIB2 receive data register L  | CSI  | 522  |
| CB2STR  | CSIB2 status register          | CSI  | 529  |
| CB2TIC  | Interrupt control register     | INTC | 686  |
| CB2TX   | CSIB2 transmit data register   | CSI  | 522  |
| CB2TXL  | CSIB2 transmit data register L | CSI  | 522  |
| CB3CTL0 | CSIB3 control register 0       | CSI  | 523  |
| CB3CTL1 | CSIB3 control register 1       | CSI  | 526  |
| CB3CTL2 | CSIB3 control register 2       | CSI  | 527  |
| CB3RIC  | Interrupt control register     | INTC | 686  |
| CB3RX   | CSIB3 receive data register    | CSI  | 522  |
| CB3RXL  | CSIB3 receive data register L  | CSI  | 527  |
| CB3STR  | CSIB3 status register          | CSI  | 529  |
| CB3TIC  | Interrupt control register     | INTC | 686  |
| CB3TX   | CSIB3 transmit data register   | CSI  | 522  |
| CB3TXL  | CSIB3 transmit data register L | CSI  | 522  |
| CB4CTL0 | CSIB4 control register 0       | CSI  | 523  |
| CB4CTL1 | CSIB4 control register 1       | CSI  | 526  |
| CB4CTL2 | CSIB4 control register 2       | CSI  | 527  |
| CB4RIC  | Interrupt control register     | INTC | 686  |
| CB4RX   | CSIB4 receive data register    | CSI  | 522  |

| Symbol  | Name  | Unit | Page |
|---------|---|------|------|
| CB4RXL  | CSIB4 receive data register L               | CSI  | 522  |
| CB4STR  | CSIB4 status register                       | CSI  | 529  |
| CB4TIC  | Interrupt control register                  | INTC | 686  |
| CB4TX   | CSIB4 transmit data register                | CSI  | 522  |
| CB4TXL  | CSIB4 transmit data register L              | CSI  | 522  |
| CB5CTL0 | CSIB5 control register 0                    | CSI  | 523  |
| CB5CTL1 | CSIB5 control register 1                    | CSI  | 526  |
| CB5CTL2 | CSIB5 control register 2                    | CSI  | 527  |
| CB5RIC  | Interrupt control register                  | INTC | 686  |
| CB5RX   | CSIB5 receive data register                 | CSI  | 522  |
| CB5RXL  | CSIB5 receive data register L               | CSI  | 522  |
| CB5STR  | CSIB5 status register                       | CSI  | 529  |
| CB5TIC  | Interrupt control register                  | INTC | 686  |
| CB5TX   | CSIB5 transmit data register                | CSI  | 522  |
| CB5TXL  | CSIB5 transmit data register L              | CSI  | 522  |
| CCLS    | CPU operation clock status register         | CG   | 217  |
| CKC     | Clock control register                      | CLM  | 220  |
| CLM     | Clock monitor mode register                 | CG   | 739  |
| CRC     | CRC data register                           | CRC  | 751  |
| CRCIN   | CRC input register                          | CRC  | 751  |
| CTBP    | CALLT base pointer                          | CPU  | 54   |
| CTPC    | CALLT execution status saving register      | CPU  | 53   |
| CTPSW   | CALLT execution status saving register      | CPU  | 53   |
| DA0CS0  | D/A conversion value setting register 0     | DAC  | 479  |
| DA0CS1  | D/A conversion value setting register 1     | DAC  | 479  |
| DA0M    | D/A converter mode register                 | DAC  | 478  |
| DADC0   | DMA addressing control register 0           | DMA  | 652  |
| DADC1   | DMA addressing control register 1           | DMA  | 652  |
| DADC2   | DMA addressing control register 2           | DMA  | 652  |
| DADC3   | DMA addressing control register 3           | DMA  | 652  |
| DBC0    | DMA transfer count register 0               | DMA  | 651  |
| DBC1    | DMA transfer count register 1               | DMA  | 651  |
| DBC2    | DMA transfer count register 2               | DMA  | 651  |
| DBC3    | DMA transfer count register 3               | DMA  | 651  |
| DBPC    | Exception/debug trap status saving register | CPU  | 54   |
| DBPSW   | Exception/debug trap status saving register | CPU  | 54   |
| DCHC0   | DMA channel control register 0              | DMA  | 653  |
| DCHC1   | DMA channel control register 1              | DMA  | 653  |
| DCHC2   | DMA channel control register 2              | DMA  | 653  |
| DCHC3   | DMA channel control register 3              | DMA  | 653  |
| DDA0H   | DMA destination address register 0H         | DMA  | 650  |
| DDA0L   | DMA destination address register 0L         | DMA  | 650  |
| DDA1H   | DMA destination address register 1H         | DMA  | 650  |
| DDA1L   | DMA destination address register 1L         | DMA  | 650  |
| DDA2H   | DMA destination address register 2H         | DMA  | 650  |

| Symbol | Name   | Unit             | Page |
|--------|--|------------------|------|
| DDA2L  | DMA destination address register 2L          | DMA              | 650  |
| DDA3H  | DMA destination address register 3H          | DMA              | 650  |
| DDA3L  | DMA destination address register 3L          | DMA              | 650  |
| DMAIC0 | Interrupt control register                   | INTC             | 686  |
| DMAIC1 | Interrupt control register                   | INTC             | 686  |
| DMAIC2 | Interrupt control register                   | INTC             | 686  |
| DMAIC3 | Interrupt control register                   | INTC             | 686  |
| DSA0H  | DMA source address register 0H               | DMA              | 649  |
| DSA0L  | DMA source address register 0L               | DMA              | 649  |
| DSA1H  | DMA source address register 1H               | DMA              | 649  |
| DSA1L  | DMA source address register 1L               | DMA              | 649  |
| DSA2H  | DMA source address register 2H               | DMA              | 649  |
| DSA2L  | DMA source address register 2L               | DMA              | 649  |
| DSA3H  | DMA source address register 3H               | DMA              | 649  |
| DSA3L  | DMA source address register 3L               | DMA              | 649  |
| DTFR0  | DMA trigger factor register 0                | DMA              | 654  |
| DTFR1  | DMA trigger factor register 1                | DMA              | 654  |
| DTFR2  | DMA trigger factor register 2                | DMA              | 654  |
| DTFR3  | DMA trigger factor register 3                | DMA              | 654  |
| DWC0   | Data wait control register 0                 | BCU              | 196  |
| ECR    | Interrupt source register                    | CPU              | 51   |
| EIPC   | Interrupt status saving register             | CPU              | 50   |
| EIPSW  | Interrupt status saving register             | CPU              | 50   |
| EXIMC  | External bus interface mode control register | BCU              | 187  |
| FEPC   | NMI status saving register                   | CPU              | 51   |
| FEPSW  | NMI status saving register                   | CPU              | 51   |
| IIC0   | IIC shift register 0                         | I <sup>2</sup> C | 590  |
| IIC1   | IIC shift register 1                         | I <sup>2</sup> C | 590  |
| IIC2   | IIC shift register 2                         | I <sup>2</sup> C | 590  |
| IICC0  | IIC control register 0                       | I <sup>2</sup> C | 576  |
| IICC1  | IIC control register 1                       | I <sup>2</sup> C | 576  |
| IICC2  | IIC control register 2                       | I <sup>2</sup> C | 576  |
| IICCL0 | IIC clock select register 0                  | I <sup>2</sup> C | 586  |
| IICCL1 | IIC clock select register 1                  | I <sup>2</sup> C | 586  |
| IICCL2 | IIC clock select register 2                  | I <sup>2</sup> C | 586  |
| IICF0  | IIC flag register 0                          | I <sup>2</sup> C | 584  |
| IICF1  | IIC flag register 1                          | I <sup>2</sup> C | 584  |
| IICF2  | IIC flag register 2                          | I <sup>2</sup> C | 584  |
| IICIC0 | Interrupt control register                   | INTC             | 686  |
| IICIC1 | Interrupt control register                   | INTC             | 686  |
| IICIC2 | Interrupt control register                   | INTC             | 686  |
| IICS0  | IIC status register 0                        | I <sup>2</sup> C | 581  |
| IICS1  | IIC status register 1                        | I <sup>2</sup> C | 581  |
| IICS2  | IIC status register 2                        | I <sup>2</sup> C | 581  |
| IICX0  | IIC function expansion register 0            | I <sup>2</sup> C | 587  |

| Symbol | Name  | Unit             | Page |
|--------|---|------------------|------|
| IICX1  | IIC function expansion register 1               | I <sup>2</sup> C | 587  |
| IICX2  | IIC function expansion register 2               | I <sup>2</sup> C | 587  |
| IMR0   | Interrupt mask register 0                       | INTC             | 686  |
| IMR0H  | Interrupt mask register 0H                      | INTC             | 686  |
| IMR0L  | Interrupt mask register 0L                      | INTC             | 686  |
| IMR1   | Interrupt mask register 1                       | INTC             | 686  |
| IMR1H  | Interrupt mask register 1H                      | INTC             | 686  |
| IMR1L  | Interrupt mask register 1L                      | INTC             | 686  |
| IMR2   | Interrupt mask register 2                       | INTC             | 686  |
| IMR2H  | Interrupt mask register 2H                      | INTC             | 686  |
| IMR2L  | Interrupt mask register 2L                      | INTC             | 686  |
| IMR3   | Interrupt mask register 3                       | INTC             | 686  |
| IMR3H  | Interrupt mask register 3H                      | INTC             | 686  |
| IMR3L  | Interrupt mask register 3L                      | INTC             | 686  |
| IMR4   | Interrupt mask register 4                       | INTC             | 686  |
| IMR4H  | Interrupt mask register 4H                      | INTC             | 686  |
| IMR4L  | Interrupt mask register 4L                      | INTC             | 686  |
| INTF0  | External falling edge specification register 0  | INTC             | 700  |
| INTF3  | External falling edge specification register 3  | INTC             | 701  |
| INTF8  | External falling edge specification register 8  | INTC             | 702  |
| INTF9H | External falling edge specification register 9H | INTC             | 703  |
| INTR0  | External rising edge specification register 0   | INTC             | 700  |
| INTR3  | External rising edge specification register 3   | INTC             | 701  |
| INTR8  | External rising edge specification register 8   | INTC             | 702  |
| INTR9H | External rising edge specification register 9H  | INTC             | 703  |
| ISPR   | In-service priority register                    | INTC             | 690  |
| KRIC   | Interrupt control register                      | INTC             | 686  |
| KRM    | Key return mode register                        | KR               | 708  |
| LOCKR  | Lock register                                   | CG               | 221  |
| LVIIIC | Interrupt control register                      | INTC             | 686  |
| LVIM   | Low-voltage detection register                  | LVI              | 744  |
| LVIS   | Low-voltage detection level select register     | LVI              | 745  |
| NFC    | Noise elimination control register              | INTC             | 704  |
| OCDM   | On-chip debug mode register                     | DCU              | 785  |
| OCKS0  | IIC division clock select register 0            | I <sup>2</sup> C | 590  |
| OCKS1  | IIC division clock select register 1            | I <sup>2</sup> C | 590  |
| OSTS   | Oscillation stabilization time select register  | WDT              | 713  |
| P0     | Port 0 register                                 | Port             | 93   |
| P1     | Port 1 register                                 | Port             | 97   |
| P3     | Port 3 register                                 | Port             | 99   |
| P3H    | Port 3 register H                               | Port             | 99   |
| P3L    | Port 3 register L                               | Port             | 99   |
| P4     | Port 4 register                                 | Port             | 104  |
| P5     | Port 5 register                                 | Port             | 106  |
| P6     | Port 6 register                                 | Port             | 111  |

| Symbol | Name   | Unit | Page |
|--------|--|------|------|
| P6H    | Port 6 register H                            | Port | 111  |
| P6L    | Port 6 register L                            | Port | 111  |
| P7H    | Port 7 register H                            | Port | 115  |
| P7L    | Port 7 register L                            | Port | 115  |
| P8     | Port 8 register                              | Port | 116  |
| P9     | Port 9 register                              | Port | 119  |
| P9H    | Port 9 register H                            | Port | 119  |
| P9L    | Port 9 register L                            | Port | 119  |
| PC     | Program counter                              | CPU  | 48   |
| PCC    | Processor clock control register             | CG   | 213  |
| PCD    | Port CD register                             | Port | 126  |
| PCM    | Port CM register                             | Port | 127  |
| PCS    | Port CS register                             | Port | 129  |
| PCT    | Port CT register                             | Port | 131  |
| PDH    | Port DH register                             | Port | 133  |
| PDL    | Port DL register                             | Port | 136  |
| PDLH   | Port DL register H                           | Port | 136  |
| PDLL   | Port DL register L                           | Port | 136  |
| PEMU1  | Peripheral emulation register 1              | CPU  | 749  |
| PF0    | Port 0 function register                     | Port | 96   |
| PF3    | Port 3 function register                     | Port | 103  |
| PF3H   | Port 3 function register H                   | Port | 103  |
| PF3L   | Port 3 function register L                   | Port | 103  |
| PF4    | Port 4 function register                     | Port | 105  |
| PF5    | Port 5 function register                     | Port | 109  |
| PF6    | Port 6 function register                     | Port | 113  |
| PF6H   | Port 6 function register H                   | Port | 113  |
| PF6L   | Port 6 function register L                   | Port | 113  |
| PF8    | Port 8 function register                     | Port | 117  |
| PF9    | Port 9 function register                     | Port | 125  |
| PF9H   | Port 9 function register H                   | Port | 125  |
| PF9L   | Port 9 function register L                   | Port | 125  |
| PFC0   | Port 0 function control register             | Port | 96   |
| PFC3   | Port 3 function control register             | Port | 101  |
| PFC3H  | Port 3 function control register H           | Port | 101  |
| PFC3L  | Port 3 function control register L           | Port | 101  |
| PFC4   | Port 4 function control register             | Port | 105  |
| PFC5   | Port 5 function control register             | Port | 107  |
| PFC6H  | Port 6 function control register H           | Port | 113  |
| PFC9   | Port 9 function control register             | Port | 122  |
| PFC9H  | Port 9 function control register H           | Port | 122  |
| PFC9L  | Port 9 function control register L           | Port | 122  |
| PFCE3L | Port 3 function control expansion register L | Port | 101  |
| PFCE5  | Port 5 function control expansion register   | Port | 108  |
| PFCE9  | Port 9 function control expansion register   | Port | 122  |

| Symbol | Name   | Unit | Page |
|--------|--|------|------|
| PFCE9H | Port 9 function control expansion register H | Port | 122  |
| PFCE9L | Port 9 function control expansion register L | Port | 122  |
| PIC0   | Interrupt control register                   | INTC | 686  |
| PIC1   | Interrupt control register                   | INTC | 686  |
| PIC2   | Interrupt control register                   | INTC | 686  |
| PIC3   | Interrupt control register                   | INTC | 686  |
| PIC4   | Interrupt control register                   | INTC | 686  |
| PIC5   | Interrupt control register                   | INTC | 686  |
| PIC6   | Interrupt control register                   | INTC | 686  |
| PIC7   | Interrupt control register                   | INTC | 686  |
| PIC8   | Interrupt control register                   | INTC | 686  |
| PLLCTL | PLL control register                         | CG   | 219  |
| PLLS   | PLL lockup time specification register       | CG   | 222  |
| PM0    | Port 0 mode register                         | Port | 94   |
| PM1    | Port 1 mode register                         | Port | 97   |
| PM3    | Port 3 mode register                         | Port | 99   |
| PM3H   | Port 3 mode register H                       | Port | 99   |
| PM3L   | Port 3 mode register L                       | Port | 99   |
| PM4    | Port 4 mode register                         | Port | 104  |
| PM5    | Port 5 mode register                         | Port | 106  |
| PM6    | Port 6 mode register                         | Port | 111  |
| PM6H   | Port 6 mode register H                       | Port | 111  |
| PM6L   | Port 6 mode register L                       | Port | 111  |
| PM7H   | Port 7 mode register H                       | Port | 115  |
| PM7L   | Port 7 mode register L                       | Port | 115  |
| PM8    | Port 8 mode register                         | Port | 116  |
| PM9    | Port 9 mode register                         | Port | 119  |
| PM9H   | Port 9 mode register H                       | Port | 119  |
| PM9L   | Port 9 mode register L                       | Port | 119  |
| PMC0   | Port 0 mode control register                 | Port | 95   |
| PMC3   | Port 3 mode control register                 | Port | 100  |
| PMC3H  | Port 3 mode control register H               | Port | 100  |
| PMC3L  | Port 3 mode control register L               | Port | 100  |
| PMC4   | Port 4 mode control register                 | Port | 105  |
| PMC5   | Port 5 mode control register                 | Port | 107  |
| PMC6   | Port 6 mode control register                 | Port | 112  |
| PMC6H  | Port 6 mode control register H               | Port | 112  |
| PMC6L  | Port 6 mode control register L               | Port | 112  |
| PMC8   | Port 8 mode control register                 | Port | 117  |
| PMC9   | Port 9 mode control register                 | Port | 120  |
| PMC9H  | Port 9 mode control register H               | Port | 120  |
| PMC9L  | Port 9 mode control register L               | Port | 120  |
| PMCCM  | Port CM mode control register                | Port | 128  |
| PMCCS  | Port CS mode control register                | Port | 130  |
| PM CCT | Port CT mode control register                | Port | 132  |

| Symbol    | Name                                     | Unit             | Page |
|-----------|--|------------------|------|
| PMCD      | Port CD mode register                    | Port             | 126  |
| PMCDH     | Port DH mode control register            | Port             | 134  |
| PMCDL     | Port DL mode control register            | Port             | 137  |
| PMCDLH    | Port DL mode control register H          | Port             | 137  |
| PMCDLL    | Port DL mode control register L          | Port             | 137  |
| PMCM      | Port CM mode register                    | Port             | 127  |
| PMCS      | Port CS mode register                    | Port             | 129  |
| PMCT      | Port CT mode register                    | Port             | 131  |
| PMDH      | Port DH mode register                    | Port             | 133  |
| PMDL      | Port DL mode register                    | Port             | 136  |
| PMDLH     | Port DL mode register H                  | Port             | 136  |
| PMDLL     | Port DL mode register L                  | Port             | 136  |
| PRCMD     | Command register                         | CPU              | 82   |
| PRSCM0    | Prescaler compare register 0             | WT               | 423  |
| PRSCM1    | Prescaler compare register 1             | CSI              | 566  |
| PRSCM2    | Prescaler compare register 2             | CSI              | 566  |
| PRSCM3    | Prescaler compare register 3             | CSI              | 566  |
| PRSM0     | Prescaler mode register 0                | WT               | 422  |
| PRSM1     | Prescaler mode register 1                | CSI              | 565  |
| PRSM2     | Prescaler mode register 2                | CSI              | 565  |
| PRSM3     | Prescaler mode register 3                | CSI              | 565  |
| PSC       | Power save control register              | CG               | 711  |
| PSMR      | Power save mode register                 | CG               | 712  |
| PSW       | Program status word                      | CPU              | 52   |
| r0 to r31 | General-purpose registers                | CPU              | 48   |
| RAMS      | Internal RAM data status register        | CG               | 745  |
| RCM       | Internal oscillation mode register       | CG               | 217  |
| RESF      | Reset source flag register               | Reset            | 730  |
| RTBH0     | Real-time output buffer register 0H      | RTP              | 436  |
| RTBH1     | Real-time output buffer register 1H      | RTP              | 436  |
| RTBL0     | Real-time output buffer register 0L      | RTP              | 436  |
| RTBL1     | Real-time output buffer register 1L      | RTP              | 436  |
| RTPC0     | Real-time output port control register 0 | RTP              | 438  |
| RTPC1     | Real-time output port control register 1 | RTP              | 438  |
| RTPM0     | Real-time output port mode register 0    | RTP              | 437  |
| RTPM1     | Real-time output port mode register 1    | RTP              | 437  |
| SELCNT0   | Selector operation control register 0    | Timer            | 310  |
| SVA0      | Slave address register 0                 | I <sup>2</sup> C | 591  |
| SVA1      | Slave address register 1                 | I <sup>2</sup> C | 591  |
| SVA2      | Slave address register 2                 | I <sup>2</sup> C | 591  |
| SYS       | System status register                   | CPU              | 83   |
| TM0CMP0   | TMM0 compare register 0                  | Timer            | 412  |
| TM0CTL0   | TMM0 control register 0                  | Timer            | 413  |
| TM0EQIC0  | Interrupt control register               | INTC             | 686  |
| TP0CCIC0  | Interrupt control register               | INTC             | 686  |

| Symbol   | Name                              | Unit  | Page |
|----------|-----------------------------------|-------|------|
| TP0CCIC1 | Interrupt control register        | INTC  | 686  |
| TP0CCR0  | TMP0 capture/compare register 0   | Timer | 233  |
| TP0CCR1  | TMP0 capture/compare register 1   | Timer | 235  |
| TP0CNT   | TMP0 counter read buffer register | Timer | 237  |
| TP0CTL0  | TMP0 control register 0           | Timer | 227  |
| TP0CTL1  | TMP0 control register 1           | Timer | 227  |
| TP0IOC0  | TMP0 I/O control register 0       | Timer | 229  |
| TP0IOC1  | TMP0 I/O control register 1       | Timer | 230  |
| TP0IOC2  | TMP0 I/O control register 2       | Timer | 231  |
| TP0OPT0  | TMP0 option register 0            | Timer | 232  |
| TP0OVIC  | Interrupt control register        | INTC  | 686  |
| TP1CCIC0 | Interrupt control register        | INTC  | 686  |
| TP1CCIC1 | Interrupt control register        | INTC  | 686  |
| TP1CCR0  | TMP1 capture/compare register 0   | Timer | 233  |
| TP1CCR1  | TMP1 capture/compare register 1   | Timer | 235  |
| TP1CNT   | TMP1 counter read buffer register | Timer | 237  |
| TP1CTL0  | TMP1 control register 0           | Timer | 227  |
| TP1CTL1  | TMP1 control register 1           | Timer | 227  |
| TP1IOC0  | TMP1 I/O control register 0       | Timer | 229  |
| TP1IOC1  | TMP1 I/O control register 1       | Timer | 230  |
| TP1IOC2  | TMP1 I/O control register 2       | Timer | 231  |
| TP1OPT0  | TMP1 option register 0            | Timer | 232  |
| TP1OVIC  | Interrupt control register        | INTC  | 686  |
| TP2CCIC0 | Interrupt control register        | INTC  | 686  |
| TP2CCIC1 | Interrupt control register        | INTC  | 686  |
| TP2CCR0  | TMP2 capture/compare register 0   | Timer | 233  |
| TP2CCR1  | TMP2 capture/compare register 1   | Timer | 235  |
| TP2CNT   | TMP2 counter read buffer register | Timer | 237  |
| TP2CTL0  | TMP2 control register 0           | Timer | 227  |
| TP2CTL1  | TMP2 control register 1           | Timer | 227  |
| TP2IOC0  | TMP2 I/O control register 0       | Timer | 229  |
| TP2IOC1  | TMP2 I/O control register 1       | Timer | 230  |
| TP2IOC2  | TMP2 I/O control register 2       | Timer | 231  |
| TP2OPT0  | TMP2 option register 0            | Timer | 232  |
| TP2OVIC  | Interrupt control register        | INTC  | 686  |
| TP3CCIC0 | Interrupt control register        | INTC  | 686  |
| TP3CCIC1 | Interrupt control register        | INTC  | 686  |
| TP3CCR0  | TMP3 capture/compare register 0   | Timer | 233  |
| TP3CCR1  | TMP3 capture/compare register 1   | Timer | 235  |
| TP3CNT   | TMP3 counter read buffer register | Timer | 237  |
| TP3CTL0  | TMP3 control register 0           | Timer | 227  |
| TP3CTL1  | TMP3 control register 1           | Timer | 227  |
| TP3IOC0  | TMP3 I/O control register 0       | Timer | 229  |
| TP3IOC1  | TMP3 I/O control register 1       | Timer | 230  |
| TP3IOC2  | TMP3 I/O control register 2       | Timer | 231  |



| Symbol   | Name                              | Unit  | Page |
|----------|-----------------------------------|-------|------|
| TP3OPT0  | TMP3 option register 0            | Timer | 232  |
| TP3OVIC  | Interrupt control register        | INTC  | 686  |
| TP4CCIC0 | Interrupt control register        | INTC  | 686  |
| TP4CCIC1 | Interrupt control register        | INTC  | 686  |
| TP4CCR0  | TMP4 capture/compare register 0   | Timer | 233  |
| TP4CCR1  | TMP4 capture/compare register 1   | Timer | 235  |
| TP4CNT   | TMP4 counter read buffer register | Timer | 237  |
| TP4CTL0  | TMP4 control register 0           | Timer | 227  |
| TP4CTL1  | TMP4 control register 1           | Timer | 227  |
| TP4IOC0  | TMP4 I/O control register 0       | Timer | 229  |
| TP4IOC1  | TMP4 I/O control register 1       | Timer | 230  |
| TP4IOC2  | TMP4 I/O control register 2       | Timer | 231  |
| TP4OPT0  | TMP4 option register 0            | Timer | 232  |
| TP4OVIC  | Interrupt control register        | INTC  | 686  |
| TP5CCIC0 | Interrupt control register        | INTC  | 686  |
| TP5CCIC1 | Interrupt control register        | INTC  | 686  |
| TP5CCR0  | TMP5 capture/compare register 0   | Timer | 233  |
| TP5CCR1  | TMP5 capture/compare register 1   | Timer | 235  |
| TP5CNT   | TMP5 counter read buffer register | Timer | 237  |
| TP5CTL0  | TMP5 control register 0           | Timer | 227  |
| TP5CTL1  | TMP5 control register 1           | Timer | 227  |
| TP5IOC0  | TMP5 I/O control register 0       | Timer | 229  |
| TP5IOC1  | TMP5 I/O control register 1       | Timer | 230  |
| TP5IOC2  | TMP5 I/O control register 2       | Timer | 231  |
| TP5OPT0  | TMP5 option register 0            | Timer | 232  |
| TP5OVIC  | Interrupt control register        | INTC  | 686  |
| TP6CCIC0 | Interrupt control register        | INTC  | 686  |
| TP6CCIC1 | Interrupt control register        | INTC  | 686  |
| TP6CCR0  | TMP6 capture/compare register 0   | Timer | 233  |
| TP6CCR1  | TMP6 capture/compare register 1   | Timer | 235  |
| TP6CNT   | TMP6 counter read buffer register | Timer | 237  |
| TP6CTL0  | TMP6 control register 0           | Timer | 227  |
| TP6CTL1  | TMP6 control register 1           | Timer | 227  |
| TP6IOC0  | TMP6 I/O control register 0       | Timer | 229  |
| TP6IOC1  | TMP6 I/O control register 1       | Timer | 230  |
| TP6IOC2  | TMP6 I/O control register 2       | Timer | 231  |
| TP6OPT0  | TMP6 option register 0            | Timer | 232  |
| TP6OVIC  | Interrupt control register        | INTC  | 686  |
| TP7CCIC0 | Interrupt control register        | INTC  | 686  |
| TP7CCIC1 | Interrupt control register        | INTC  | 686  |
| TP7CCR0  | TMP7 capture/compare register 0   | Timer | 233  |
| TP7CCR1  | TMP7 capture/compare register 1   | Timer | 235  |
| TP7CNT   | TMP7 counter read buffer register | Timer | 237  |
| TP7CTL0  | TMP7 control register 0           | Timer | 227  |
| TP7CTL1  | TMP7 control register 1           | Timer | 227  |

| Symbol   | Name                              | Unit  | Page |
|----------|-----------------------------------|-------|------|
| TP7IOC0  | TMP7 I/O control register 0       | Timer | 229  |
| TP7IOC1  | TMP7 I/O control register 1       | Timer | 230  |
| TP7IOC2  | TMP7 I/O control register 2       | Timer | 231  |
| TP7OPT0  | TMP7 option register 0            | Timer | 232  |
| TP7OVIC  | Interrupt control register        | INTC  | 686  |
| TP8CCIC0 | Interrupt control register        | INTC  | 686  |
| TP8CCIC1 | Interrupt control register        | INTC  | 686  |
| TP8CCR0  | TMP8 capture/compare register 0   | Timer | 233  |
| TP8CCR1  | TMP8 capture/compare register 1   | Timer | 235  |
| TP8CNT   | TMP8 counter read buffer register | Timer | 237  |
| TP8CTL0  | TMP8 control register 0           | Timer | 227  |
| TP8CTL1  | TMP8 control register 1           | Timer | 227  |
| TP8IOC0  | TMP8 I/O control register 0       | Timer | 229  |
| TP8IOC1  | TMP8 I/O control register 1       | Timer | 230  |
| TP8IOC2  | TMP8 I/O control register 2       | Timer | 231  |
| TP8OPT0  | TMP8 option register 0            | Timer | 232  |
| TP8OVIC  | Interrupt control register        | INTC  | 686  |
| TQ0CCIC0 | Interrupt control register        | INTC  | 686  |
| TQ0CCIC1 | Interrupt control register        | INTC  | 686  |
| TQ0CCIC2 | Interrupt control register        | INTC  | 686  |
| TQ0CCIC3 | Interrupt control register        | INTC  | 686  |
| TQ0CCR0  | TMQ0 capture/compare register 0   | Timer | 322  |
| TQ0CCR1  | TMQ0 capture/compare register 1   | Timer | 324  |
| TQ0CCR2  | TMQ0 capture/compare register 2   | Timer | 326  |
| TQ0CCR3  | TMQ0 capture/compare register 3   | Timer | 328  |
| TQ0CNT   | TMQ0 counter read buffer register | Timer | 330  |
| TQ0CTL0  | TMQ0 control register 0           | Timer | 316  |
| TQ0CTL1  | TMQ0 control register 1           | Timer | 317  |
| TQ0IOC0  | TMQ0 I/O control register 0       | Timer | 318  |
| TQ0IOC1  | TMQ0 I/O control register 1       | Timer | 319  |
| TQ0IOC2  | TMQ0 I/O control register 2       | Timer | 320  |
| TQ0OPT0  | TMQ0 option register 0            | Timer | 321  |
| TQ0OVIC  | Interrupt control register        | INTC  | 686  |
| UA0CTL0  | UARTA0 control register 0         | UART  | 488  |
| UA0CTL1  | UARTA0 control register 1         | UART  | 511  |
| UA0CTL2  | UARTA0 control register 2         | UART  | 512  |
| UA0OPT0  | UARTA0 option control register 0  | UART  | 490  |
| UA0RIC   | Interrupt control register        | INTC  | 686  |
| UA0RX    | UARTA0 receive data register      | UART  | 493  |
| UA0STR   | UARTA0 status register            | UART  | 491  |
| UA0TIC   | Interrupt control register        | INTC  | 686  |
| UA0TX    | UARTA0 transmit data register     | UART  | 493  |
| UA1CTL0  | UARTA1 control register 0         | UART  | 488  |
| UA1CTL1  | UARTA1 control register 1         | UART  | 511  |
| UA1CTL2  | UARTA1 control register 2         | UART  | 512  |

| Symbol  | Name                                | Unit | Page     |
|---------|-------------------------------------|------|----------|
| UA1OPT0 | UARTA1 option control register 0    | UART | 490      |
| UA1RIC  | Interrupt control register          | INTC | 686      |
| UA1RX   | UARTA1 receive data register        | UART | 493      |
| UA1STR  | UARTA1 status register              | UART | 491      |
| UA1TIC  | Interrupt control register          | INTC | 686      |
| UA1TX   | UARTA1 transmit data register       | UART | 493      |
| UA2CTL0 | UARTA2 control register 0           | UART | 488      |
| UA2CTL1 | UARTA2 control register 1           | UART | 511      |
| UA2CTL2 | UARTA2 control register 2           | UART | 512      |
| UA2OPT0 | UARTA2 option control register 0    | UART | 490      |
| UA2RIC  | Interrupt control register          | INTC | 686      |
| UA2RX   | UARTA2 receive data register        | UART | 493      |
| UA2STR  | UARTA2 status register              | UART | 491      |
| UA2TIC  | Interrupt control register          | INTC | 686      |
| UA2TX   | UARTA2 transmit data register       | UART | 493      |
| UA3CTL0 | UARTA3 control register 0           | UART | 488      |
| UA3CTL1 | UARTA3 control register 1           | UART | 511      |
| UA3CTL2 | UARTA3 control register 2           | UART | 512      |
| UA3OPT0 | UARTA3 option control register 0    | UART | 490      |
| UA3RIC  | Interrupt control register          | INTC | 686      |
| UA3RX   | UARTA3 receive data register        | UART | 493      |
| UA3STR  | UARTA3 status register              | UART | 491      |
| UA3TIC  | Interrupt control register          | INTC | 686      |
| UA3TX   | UARTA3 transmit data register       | UART | 493      |
| VSWC    | System wait control register        | CPU  | 84       |
| WDTE    | Watchdog timer enable register      | WDT  | 432      |
| WDTM2   | Watchdog timer mode register 2      | WDT  | 431, 691 |
| WTIC    | Interrupt control register          | INTC | 686      |
| WTIIC   | Interrupt control register          | INTC | 686      |
| WTM     | Watch timer operation mode register | WT   | 424      |

## APPENDIX D INSTRUCTION SET LIST

### D.1 Conventions

#### (1) Register symbols used to describe operands

| Register Symbol | Explanation  |
|-----------------|--|
| reg1            | General-purpose registers: Used as source registers.   |
| reg2            | General-purpose registers: Used mainly as destination registers. Also used as source register in some instructions.                  |
| reg3            | General-purpose registers: Used mainly to store the remainders of division results and the higher 32 bits of multiplication results. |
| bit#3           | 3-bit data for specifying the bit number   |
| immX            | X bit immediate data   |
| dispX           | X bit displacement data  |
| regID           | System register number   |
| vector          | 5-bit data that specifies the trap vector (00H to 1FH)   |
| cccc            | 4-bit data that shows the conditions code  |
| sp              | Stack pointer (r3)   |
| ep              | Element pointer (r30)  |
| listX           | X item register list   |

#### (2) Register symbols used to describe opcodes

| Register Symbol | Explanation  |
|-----------------|--|
| R               | 1-bit data of a code that specifies reg1 or regID                  |
| r               | 1-bit data of the code that specifies reg2                         |
| w               | 1-bit data of the code that specifies reg3                         |
| d               | 1-bit displacement data  |
| l               | 1-bit immediate data (indicates the higher bits of immediate data) |
| i               | 1-bit immediate data   |
| cccc            | 4-bit data that shows the condition codes                          |
| CCCC            | 4-bit data that shows the condition codes of Bcond instruction     |
| bbb             | 3-bit data for specifying the bit number                           |
| L               | 1-bit data that specifies a program register in the register list  |

**(3) Register symbols used in operations**

| Register Symbol               | Explanation  |
|-------------------------------|--|
| ←                             | Input for  |
| GR [ ]                        | General-purpose register   |
| SR [ ]                        | System register  |
| zero-extend (n)               | Expand n with zeros until word length.   |
| sign-extend (n)               | Expand n with signs until word length.   |
| load-memory (a, b)            | Read size b data from address a.   |
| store-memory (a, b, c)        | Write data b into address a in size c.   |
| load-memory-bit (a, b)        | Read bit b of address a.   |
| store-memory-bit (a, b, c)    | Write c to bit b of address a.   |
| saturated (n)                 | Execute saturated processing of n (n is a 2's complement).<br>If, as a result of calculations,<br>n ≥ 7FFFFFFFH, let it be 7FFFFFFFH.<br>n ≤ 80000000H, let it be 80000000H. |
| result                        | Reflects the results in a flag.  |
| Byte                          | Byte (8 bits)  |
| Halfword                      | Half word (16 bits)  |
| Word                          | Word (32 bits)   |
| +                             | Addition   |
| –                             | Subtraction  |
|                               | Bit concatenation  |
| ×                             | Multiplication   |
| ÷                             | Division   |
| %                             | Remainder from division results  |
| AND                           | Logical product  |
| OR                            | Logical sum  |
| XOR                           | Exclusive OR   |
| NOT                           | Logical negation   |
| logically shift left by       | Logical shift left   |
| logically shift right by      | Logical shift right  |
| arithmetically shift right by | Arithmetic shift right   |

**(4) Register symbols used in execution clock**

| Register Symbol | Explanation   |
|-----------------|---|
| i               | If executing another instruction immediately after executing the first instruction (issue).                 |
| r               | If repeating execution of the same instruction immediately after executing the first instruction (repeat).  |
| l               | If using the results of instruction execution in the instruction immediately after the execution (latency). |

**(5) Register symbols used in flag operations**

| Identifier | Explanation                                    |
|------------|--|
| (Blank)    | No change                                      |
| 0          | Clear to 0                                     |
| X          | Set or cleared in accordance with the results. |
| R          | Previously saved values are restored.          |

**(6) Condition codes**

| Condition Code<br>(cccc) | Condition Formula                         | Explanation                                   |
|--------------------------|---|---|
| 0 0 0 0                  | $OV = 1$                                  | Overflow                                      |
| 1 0 0 0                  | $OV = 0$                                  | No overflow                                   |
| 0 0 0 1                  | $CY = 1$                                  | Carry<br>Lower (Less than)                    |
| 1 0 0 1                  | $CY = 0$                                  | No carry<br>Not lower (Greater than or equal) |
| 0 0 1 0                  | $Z = 1$                                   | Zero  |
| 1 0 1 0                  | $Z = 0$                                   | Not zero                                      |
| 0 0 1 1                  | $(CY \text{ or } Z) = 1$                  | Not higher (Less than or equal)               |
| 1 0 1 1                  | $(CY \text{ or } Z) = 0$                  | Higher (Greater than)                         |
| 0 1 0 0                  | $S = 1$                                   | Negative                                      |
| 1 1 0 0                  | $S = 0$                                   | Positive                                      |
| 0 1 0 1                  | –   | Always (Unconditional)                        |
| 1 1 0 1                  | $SAT = 1$                                 | Saturated                                     |
| 0 1 1 0                  | $(S \text{ xor } OV) = 1$                 | Less than signed                              |
| 1 1 1 0                  | $(S \text{ xor } OV) = 0$                 | Greater than or equal signed                  |
| 0 1 1 1                  | $((S \text{ xor } OV) \text{ or } Z) = 1$ | Less than or equal signed                     |
| 1 1 1 1                  | $((S \text{ xor } OV) \text{ or } Z) = 0$ | Greater than signed                           |

D.2 Instruction Set (in Alphabetical Order)

(1/6)

| Mnemonic | Operand             | Opcode                               | Operation   | Execution Clock                      |   |   | Flags |    |   |   |     |  |
|----------|---------------------|--------------------------------------|---|--------------------------------------|---|---|-------|----|---|---|-----|--|
|          |                     |                                      |   | i                                    | r | l | CY    | OV | S | Z | SAT |  |
| ADD      | reg1,reg2           | rrrrr001110RRRRR                     | GR[reg2]←GR[reg2]+GR[reg1]  | 1                                    | 1 | 1 | x     | x  | x | x |     |  |
|          | imm5,reg2           | rrrrr010010iiii                      | GR[reg2]←GR[reg2]+sign-extend(imm5)   | 1                                    | 1 | 1 | x     | x  | x | x |     |  |
| ADDI     | imm16,reg1,reg2     | rrrrr110000RRRRR<br>iiiiiiiiiiiiiiii | GR[reg2]←GR[reg1]+sign-extend(imm16)  | 1                                    | 1 | 1 | x     | x  | x | x |     |  |
| AND      | reg1,reg2           | rrrrr001010RRRRR                     | GR[reg2]←GR[reg2]AND GR[reg1]   | 1                                    | 1 | 1 |       | 0  | x | x |     |  |
| ANDI     | imm16,reg1,reg2     | rrrrr110110RRRRR<br>iiiiiiiiiiiiiiii | GR[reg2]←GR[reg1]AND zero-extend(imm16)   | 1                                    | 1 | 1 |       | 0  | x | x |     |  |
| Bcond    | disp9               | dddd1011dddcccc<br><b>Note 1</b>     | if conditions are satisfied<br>then PC←PC+sign-extend(disp9)  | When conditions<br>are satisfied     | 2 | 2 | 2     |    |   |   |     |  |
|          |                     |                                      |   | When conditions<br>are not satisfied | 1 | 1 | 1     |    |   |   |     |  |
| BSH      | reg2,reg3           | rrrrr11111100000<br>wwwww01101000010 | GR[reg3]←GR[reg2] (23 : 16)    GR[reg2] (31 : 24)   <br>GR[reg2] (7 : 0)    GR[reg2] (15 : 8)   | 1                                    | 1 | 1 | x     | 0  | x | x |     |  |
| BSW      | reg2,reg3           | rrrrr11111100000<br>wwwww01101000000 | GR[reg3]←GR[reg2] (7 : 0)    GR[reg2] (15 : 8)    GR<br>[reg2] (23 : 16)    GR[reg2] (31 : 24)  | 1                                    | 1 | 1 | x     | 0  | x | x |     |  |
| CALLT    | imm6                | 0000001000iiii                       | CTPC←PC+2(return PC)<br>CTPSW←PSW<br>adr←CTBP+zero-extend(imm6 logically shift left by 1)<br>PC←CTBP+zero-extend(Load-memory(adr,Halfword)) | 4                                    | 4 | 4 |       |    |   |   |     |  |
| CLR1     | bit#3,disp16[reg1]  | 10bbb111110RRRRR<br>dddddddddddd     | adr←GR[reg1]+sign-extend(disp16)<br>Z flag←Not(Load-memory-bit(adr,bit#3))<br>Store-memory-bit(adr,bit#3,0)                                 | 3                                    | 3 | 3 |       |    |   | x |     |  |
|          | reg2,[reg1]         | rrrrr111111RRRRR<br>0000000011100100 | adr←GR[reg1]<br>Z flag←Not(Load-memory-bit(adr,reg2))<br>Store-memory-bit(adr,reg2,0)   | 3                                    | 3 | 3 |       |    |   | x |     |  |
| CMOV     | cccc,imm5,reg2,reg3 | rrrrr111111iiii<br>wwwww01100cccc0   | if conditions are satisfied<br>then GR[reg3]←sign-extended(imm5)<br>else GR[reg3]←GR[reg2]  | 1                                    | 1 | 1 |       |    |   |   |     |  |
|          | cccc,reg1,reg2,reg3 | rrrrr111111RRRRR<br>wwwww011001cccc0 | if conditions are satisfied<br>then GR[reg3]←GR[reg1]<br>else GR[reg3]←GR[reg2]   | 1                                    | 1 | 1 |       |    |   |   |     |  |
| CMP      | reg1,reg2           | rrrrr001111RRRRR                     | result←GR[reg2]-GR[reg1]  | 1                                    | 1 | 1 | x     | x  | x | x |     |  |
|          | imm5,reg2           | rrrrr010011iiii                      | result←GR[reg2]-sign-extend(imm5)   | 1                                    | 1 | 1 | x     | x  | x | x |     |  |
| CTRET    |                     | 000001111100000<br>0000000101000100  | PC←CTPC<br>PSW←CTPSW  | 3                                    | 3 | 3 | R     | R  | R | R | R   |  |
| DBRET    |                     | 000001111100000<br>0000000101000110  | PC←DBPC<br>PSW←DBPSW  | 3                                    | 3 | 3 | R     | R  | R | R | R   |  |

APPENDIX D INSTRUCTION SET LIST

(2/6)

| Mnemonic | Operand            | Opcode   | Operation  | Execution Clock |               |               | Flags |    |   |   |     |  |
|----------|--------------------|--|--|-----------------|---------------|---------------|-------|----|---|---|-----|--|
|          |                    |  |  | i               | r             | l             | CY    | OV | S | Z | SAT |  |
| DBTRAP   |                    | 1111100001000000   | DBPC←PC+2 (restored PC)<br>DBPSW←PSW<br>PSW.NP←1<br>PSW.EP←1<br>PSW.ID←1<br>PC←00000060H   | 3               | 3             | 3             |       |    |   |   |     |  |
| DI       |                    | 0000011111100000<br>0000000101100000                       | PSW.ID←1   | 1               | 1             | 1             |       |    |   |   |     |  |
| DISPOSE  | imm5,list12        | 0000011001iiiiL<br>LLLLLLLLLLLL00000                       | sp←sp+zero-extend(imm5 logically shift left by 2)<br>GR[reg in list12]←Load-memory(sp,Word)<br>sp←sp+4<br>repeat 2 steps above until all regs in list12 is loaded                | n+1<br>Note 4   | n+1<br>Note 4 | n+1<br>Note 4 |       |    |   |   |     |  |
|          | imm5,list12,[reg1] | 0000011001iiiiL<br>LLLLLLLLLLLLRRRRR<br><b>Note 5</b>      | sp←sp+zero-extend(imm5 logically shift left by 2)<br>GR[reg in list12]←Load-memory(sp,Word)<br>sp←sp+4<br>repeat 2 steps above until all regs in list12 is loaded<br>PC←GR[reg1] | n+3<br>Note 4   | n+3<br>Note 4 | n+3<br>Note 4 |       |    |   |   |     |  |
| DIV      | reg1,reg2,reg3     | rrrrr11111RRRRR<br>www01011000000                          | GR[reg2]←GR[reg2]÷GR[reg1]<br>GR[reg3]←GR[reg2]%GR[reg1]   | 35              | 35            | 35            |       | ×  | × | × |     |  |
| DIVH     | reg1,reg2          | rrrrr000010RRRRR   | GR[reg2]←GR[reg2]÷GR[reg1] <sup>Note 6</sup>   | 35              | 35            | 35            |       | ×  | × | × |     |  |
|          | reg1,reg2,reg3     | rrrrr11111RRRRR<br>www01010000000                          | GR[reg2]←GR[reg2]÷GR[reg1] <sup>Note 6</sup><br>GR[reg3]←GR[reg2]%GR[reg1]   | 35              | 35            | 35            |       | ×  | × | × |     |  |
| DIVHU    | reg1,reg2,reg3     | rrrrr11111RRRRR<br>www01010000010                          | GR[reg2]←GR[reg2]÷GR[reg1] <sup>Note 6</sup><br>GR[reg3]←GR[reg2]%GR[reg1]   | 34              | 34            | 34            |       | ×  | × | × |     |  |
| DIVU     | reg1,reg2,reg3     | rrrrr11111RRRRR<br>www01011000010                          | GR[reg2]←GR[reg2]÷GR[reg1]<br>GR[reg3]←GR[reg2]%GR[reg1]   | 34              | 34            | 34            |       | ×  | × | × |     |  |
| EI       |                    | 1000011111100000<br>0000000101100000                       | PSW.ID←0   | 1               | 1             | 1             |       |    |   |   |     |  |
| HALT     |                    | 0000011111100000<br>0000000100100000                       | Stop   | 1               | 1             | 1             |       |    |   |   |     |  |
| HSW      | reg2,reg3          | rrrrr11111100000<br>www01101000100                         | GR[reg3]←GR[reg2](15 : 0)    GR[reg2] (31 : 16)  | 1               | 1             | 1             | ×     | 0  | × | × |     |  |
| JARL     | disp22,reg2        | rrrrr11110dddddd<br>ddddddddddddddd0<br><b>Note 7</b>      | GR[reg2]←PC+4<br>PC←PC+sign-extend(disp22)   | 2               | 2             | 2             |       |    |   |   |     |  |
| JMP      | [reg1]             | 0000000011RRRRR  | PC←GR[reg1]  | 3               | 3             | 3             |       |    |   |   |     |  |
| JR       | disp22             | 0000011110dddddd<br>ddddddddddddddd0<br><b>Note 7</b>      | PC←PC+sign-extend(disp22)  | 2               | 2             | 2             |       |    |   |   |     |  |
| LD.B     | disp16[reg1],reg2  | rrrrr111000RRRRR<br>ddddddddddddddd                        | adr←GR[reg1]+sign-extend(disp16)<br>GR[reg2]←sign-extend(Load-memory(adrs,Byte))   | 1               | 1             | Note<br>11    |       |    |   |   |     |  |
| LD.BU    | disp16[reg1],reg2  | rrrrr11110bRRRRR<br>ddddddddddddddd1<br><b>Notes 8, 10</b> | adr←GR[reg1]+sign-extend(disp16)<br>GR[reg2]←zero-extend(Load-memory(adrs,Byte))   | 1               | 1             | Note<br>11    |       |    |   |   |     |  |



APPENDIX D INSTRUCTION SET LIST

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| Mnemonic | Operand            | Opcode   | Operation  | Execution Clock        |        |         | Flags |    |   |   |     |   |
|----------|--------------------|--|--|------------------------|--------|---------|-------|----|---|---|-----|---|
|          |                    |  |  | i                      | r      | l       | CY    | OV | S | Z | SAT |   |
| LD.H     | disp16[reg1],reg2  | rrrrr111001RRRRR<br>dddddddddddddd0                        | adr←GR[reg1]+sign-extend(dispatch16)<br>GR[reg2]←sign-extend(Load-memory(adr,Halfword))                              | 1                      | 1      | Note 11 |       |    |   |   |     |   |
| LDSR     | reg2,regID         | rrrrr11111RRRRR<br>0000000000100000                        | SR[regID]←GR[reg2]   | Other than regID = PSW | 1      | 1       | 1     |    |   |   |     |   |
|          |                    |  |  | regID = PSW            | 1      | 1       | 1     | ×  | × | × | ×   | × |
| LD.HU    | disp16[reg1],reg2  | rrrrr11111RRRRR<br>dddddddddddddd1                         | adr←GR[reg1]+sign-extend(dispatch16)<br>GR[reg2]←zero-extend(Load-memory(adr,Halfword))                              | 1                      | 1      | Note 11 |       |    |   |   |     |   |
| LD.W     | disp16[reg1],reg2  | rrrrr111001RRRRR<br>dddddddddddddd1                        | adr←GR[reg1]+sign-extend(dispatch16)<br>GR[reg2]←Load-memory(adr,Word)   | 1                      | 1      | Note 11 |       |    |   |   |     |   |
| MOV      | reg1,reg2          | rrrrr00000RRRRR  | GR[reg2]←GR[reg1]  | 1                      | 1      | 1       |       |    |   |   |     |   |
|          | imm5,reg2          | rrrrr010000iiii  | GR[reg2]←sign-extend(imm5)   | 1                      | 1      | 1       |       |    |   |   |     |   |
|          | imm32,reg1         | 00000110001RRRRR<br>iiiiiiiiiiiiiiii<br>llllllllllllllllll | GR[reg1]←imm32   | 2                      | 2      | 2       |       |    |   |   |     |   |
| MOVEA    | imm16,reg1,reg2    | rrrrr110001RRRRR<br>iiiiiiiiiiiiiiii                       | GR[reg2]←GR[reg1]+sign-extend(imm16)   | 1                      | 1      | 1       |       |    |   |   |     |   |
| MOVHI    | imm16,reg1,reg2    | rrrrr110010RRRRR<br>iiiiiiiiiiiiiiii                       | GR[reg2]←GR[reg1]+(imm16 ll 0 <sup>16</sup> )  | 1                      | 1      | 1       |       |    |   |   |     |   |
| MUL      | reg1,reg2,reg3     | rrrrr11111RRRRR<br>wwwww01000100000                        | GR[reg3] ll GR[reg2]←GR[reg2]xGR[reg1]   | 1                      | 4      | 5       |       |    |   |   |     |   |
|          | imm9,reg2,reg3     | rrrrr11111iiii<br>wwwww01001llll00                         | GR[reg3] ll GR[reg2]←GR[reg2]xsign-extend(imm9)  | 1                      | 4      | 5       |       |    |   |   |     |   |
| MULH     | reg1,reg2          | rrrrr000111RRRRR   | GR[reg2]←GR[reg2] <sup>Note 6</sup> xGR[reg1] <sup>Note 6</sup>  | 1                      | 1      | 2       |       |    |   |   |     |   |
|          | imm5,reg2          | rrrrr010111iiii  | GR[reg2]←GR[reg2] <sup>Note 6</sup> xsign-extend(imm5)   | 1                      | 1      | 2       |       |    |   |   |     |   |
| MULHI    | imm16,reg1,reg2    | rrrrr110111RRRRR<br>iiiiiiiiiiiiiiii                       | GR[reg2]←GR[reg1] <sup>Note 6</sup> ximm16   | 1                      | 1      | 2       |       |    |   |   |     |   |
| MULU     | reg1,reg2,reg3     | rrrrr11111RRRRR<br>wwwww01000100010                        | GR[reg3] ll GR[reg2]←GR[reg2]xGR[reg1]   | 1                      | 4      | 5       |       |    |   |   |     |   |
|          | imm9,reg2,reg3     | rrrrr11111iiii<br>wwwww01001llll10                         | GR[reg3] ll GR[reg2]←GR[reg2]xzero-extend(imm9)  | 1                      | 4      | 5       |       |    |   |   |     |   |
| NOP      |                    | 0000000000000000   | Pass at least one clock cycle doing nothing.   | 1                      | 1      | 1       |       |    |   |   |     |   |
| NOT      | reg1,reg2          | rrrrr000001RRRRR   | GR[reg2]←NOT(GR[reg1])   | 1                      | 1      | 1       | 0     | ×  | × |   |     |   |
| NOT1     | bit#3,disp16[reg1] | 01bbb111110RRRRR<br>dddddddddddddd                         | adr←GR[reg1]+sign-extend(dispatch16)<br>Z flag←Not(Load-memory-bit(adr,bit#3))<br>Store-memory-bit(adr,bit#3,Z flag) | Note 3                 | Note 3 | Note 3  |       |    |   | × |     |   |
|          | reg2,[reg1]        | rrrrr11111RRRRR<br>0000000011100010                        | adr←GR[reg1]<br>Z flag←Not(Load-memory-bit(adr,reg2))<br>Store-memory-bit(adr,reg2,Z flag)                           | Note 3                 | Note 3 | Note 3  |       |    |   | × |     |   |

APPENDIX D INSTRUCTION SET LIST

(4/6)

| Mnemonic | Operand                                   | Opcode  | Operation   | Execution Clock          |                          |                          | Flags |    |   |   |     |
|----------|---|---|---|--------------------------|--------------------------|--------------------------|-------|----|---|---|-----|
|          |   |   |   | i                        | r                        | l                        | CY    | OV | S | Z | SAT |
| OR       | reg1,reg2                                 | rrrrr001000RRRRR  | GR[reg2]←GR[reg2]OR GR[reg1]  | 1                        | 1                        | 1                        |       | 0  | × | × |     |
| ORI      | imm16,reg1,reg2                           | rrrrr110100RRRRR<br>iiiiiiiiiiiiiiii                                      | GR[reg2]←GR[reg1]OR zero-extend(imm16)  | 1                        | 1                        | 1                        |       | 0  | × | × |     |
| PREPARE  | list12,imm5                               | 0000011110iiiiL<br>LLLLLLLLLLLL00001                                      | Store-memory(sp-4,GR[reg in list12],Word)<br>sp←sp-4<br>repeat 1 step above until all regs in list12 is stored<br>sp←sp-zero-extend(imm5)                             | n+1<br>Note 4            | n+1<br>Note 4            | n+1<br>Note 4            |       |    |   |   |     |
|          | list12,imm5,<br>sp/imm <sup>Note 15</sup> | 0000011110iiiiL<br>LLLLLLLLLLLLff011<br>imm16/imm32<br><br><b>Note 16</b> | Store-memory(sp-4,GR[reg in list12],Word)<br>sp←sp+4<br>repeat 1 step above until all regs in list12 is stored<br>sp←sp-zero-extend (imm5)<br>ep←sp/imm               | n+2<br>Note 4<br>Note 17 | n+2<br>Note 4<br>Note 17 | n+2<br>Note 4<br>Note 17 |       |    |   |   |     |
| RETI     |   | 000001111100000<br>0000000101000000                                       | if PSW.EP=1<br>then PC ←EIPC<br>PSW ←EIPSW<br>else if PSW.NP=1<br>then PC ←FEPC<br>PSW ←FEPSW<br>else PC ←EIPC<br>PSW ←EIPSW  | 3                        | 3                        | 3                        | R     | R  | R | R | R   |
| SAR      | reg1,reg2                                 | rrrrr111111RRRRR<br>0000000010100000                                      | GR[reg2]←GR[reg2]arithmetically shift right<br>by GR[reg1]  | 1                        | 1                        | 1                        | ×     | 0  | × | × |     |
|          | imm5,reg2                                 | rrrrr010101iiii   | GR[reg2]←GR[reg2]arithmetically shift right<br>by zero-extend (imm5)  | 1                        | 1                        | 1                        | ×     | 0  | × | × |     |
| SASF     | cccc,reg2                                 | rrrrr1111110cccc<br>0000001000000000                                      | if conditions are satisfied<br>then GR[reg2]←(GR[reg2]Logically shift left by 1)<br>OR 00000001H<br>else GR[reg2]←(GR[reg2]Logically shift left by 1)<br>OR 00000000H | 1                        | 1                        | 1                        |       |    |   |   |     |
| SATADD   | reg1,reg2                                 | rrrrr000110RRRRR  | GR[reg2]←saturated(GR[reg2]+GR[reg1])   | 1                        | 1                        | 1                        | ×     | ×  | × | × | ×   |
|          | imm5,reg2                                 | rrrrr010001iiii   | GR[reg2]←saturated(GR[reg2]+sign-extend(imm5))  | 1                        | 1                        | 1                        | ×     | ×  | × | × | ×   |
| SATSUB   | reg1,reg2                                 | rrrrr000101RRRRR  | GR[reg2]←saturated(GR[reg2]-GR[reg1])   | 1                        | 1                        | 1                        | ×     | ×  | × | × | ×   |
| SATSUBI  | imm16,reg1,reg2                           | rrrrr110011RRRRR<br>iiiiiiiiiiiiiiii                                      | GR[reg2]←saturated(GR[reg1]-sign-extend(imm16))   | 1                        | 1                        | 1                        | ×     | ×  | × | × | ×   |
| SATSUBR  | reg1,reg2                                 | rrrrr000100RRRRR  | GR[reg2]←saturated(GR[reg1]-GR[reg2])   | 1                        | 1                        | 1                        | ×     | ×  | × | × | ×   |
| SETF     | cccc,reg2                                 | rrrrr1111110cccc<br>0000000000000000                                      | If conditions are satisfied<br>then GR[reg2]←00000001H<br>else GR[reg2]←00000000H   | 1                        | 1                        | 1                        |       |    |   |   |     |

APPENDIX D INSTRUCTION SET LIST

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| Mnemonic | Operand            | Opcode  | Operation  | Execution Clock |             |             | Flags |    |   |   |     |
|----------|--------------------|---|--|-----------------|-------------|-------------|-------|----|---|---|-----|
|          |                    |   |  | i               | r           | l           | CY    | OV | S | Z | SAT |
| SET1     | bit#3,disp16[reg1] | 00bbb111110RRRRR<br>dddddddddddddd            | adr←GR[reg1]+sign-extend(disp16)<br>Z flag←Not (Load-memory-bit(adr,bit#3))<br>Store-memory-bit(adr,bit#3,1) | 3<br>Note 3     | 3<br>Note 3 | 3<br>Note 3 |       |    |   | × |     |
|          | reg2,[reg1]        | rrrrr11111RRRRR<br>0000000011100000           | adr←GR[reg1]<br>Z flag←Not(Load-memory-bit(adr,reg2))<br>Store-memory-bit(adr,reg2,1)                        | 3<br>Note 3     | 3<br>Note 3 | 3<br>Note 3 |       |    |   | × |     |
| SHL      | reg1,reg2          | rrrrr11111RRRRR<br>0000000011000000           | GR[reg2]←GR[reg2] logically shift left by GR[reg1]   | 1               | 1           | 1           | ×     | 0  | × | × |     |
|          | imm5,reg2          | rrrrr010110iiii                               | GR[reg2]←GR[reg2] logically shift left by zero-extend(imm5)  | 1               | 1           | 1           | ×     | 0  | × | × |     |
| SHR      | reg1,reg2          | rrrrr11111RRRRR<br>0000000010000000           | GR[reg2]←GR[reg2] logically shift right by GR[reg1]  | 1               | 1           | 1           | ×     | 0  | × | × |     |
|          | imm5,reg2          | rrrrr010100iiii                               | GR[reg2]←GR[reg2] logically shift right by zero-extend(imm5)   | 1               | 1           | 1           | ×     | 0  | × | × |     |
| SLD.B    | disp7[ep],reg2     | rrrrr0110dddddd                               | adr←ep+zero-extend(disp7)<br>GR[reg2]←sign-extend(Load-memory(adr,Byte))                                     | 1               | 1           | Note 9      |       |    |   |   |     |
| SLD.BU   | disp4[ep],reg2     | rrrrr0000110dddd<br>Note 18                   | adr←ep+zero-extend(disp4)<br>GR[reg2]←zero-extend(Load-memory(adr,Byte))                                     | 1               | 1           | Note 9      |       |    |   |   |     |
| SLD.H    | disp8[ep],reg2     | rrrrr1000dddddd<br>Note 19                    | adr←ep+zero-extend(disp8)<br>GR[reg2]←sign-extend(Load-memory(adr,Halfword))                                 | 1               | 1           | Note 9      |       |    |   |   |     |
| SLD.HU   | disp5[ep],reg2     | rrrrr0000111dddd<br>Notes 18, 20              | adr←ep+zero-extend(disp5)<br>GR[reg2]←zero-extend(Load-memory(adr,Halfword))                                 | 1               | 1           | Note 9      |       |    |   |   |     |
| SLD.W    | disp8[ep],reg2     | rrrrr1010dddddd0<br>Note 21                   | adr←ep+zero-extend(disp8)<br>GR[reg2]←Load-memory(adr,Word)  | 1               | 1           | Note 9      |       |    |   |   |     |
| SST.B    | reg2,disp7[ep]     | rrrrr0111dddddd                               | adr←ep+zero-extend(disp7)<br>Store-memory(adr,GR[reg2],Byte)   | 1               | 1           | 1           |       |    |   |   |     |
| SST.H    | reg2,disp8[ep]     | rrrrr1001dddddd<br>Note 19                    | adr←ep+zero-extend(disp8)<br>Store-memory(adr,GR[reg2],Halfword)   | 1               | 1           | 1           |       |    |   |   |     |
| SST.W    | reg2,disp8[ep]     | rrrrr1010dddddd1<br>Note 21                   | adr←ep+zero-extend(disp8)<br>Store-memory(adr,GR[reg2],Word)   | 1               | 1           | 1           |       |    |   |   |     |
| ST.B     | reg2,disp16[reg1]  | rrrrr111010RRRRR<br>dddddddddddddd            | adr←GR[reg1]+sign-extend(disp16)<br>Store-memory(adr,GR[reg2],Byte)  | 1               | 1           | 1           |       |    |   |   |     |
| ST.H     | reg2,disp16[reg1]  | rrrrr111011RRRRR<br>dddddddddddddd0<br>Note 8 | adr←GR[reg1]+sign-extend(disp16)<br>Store-memory (adr,GR[reg2], Halfword)                                    | 1               | 1           | 1           |       |    |   |   |     |
| ST.W     | reg2,disp16[reg1]  | rrrrr111011RRRRR<br>dddddddddddddd1<br>Note 8 | adr←GR[reg1]+sign-extend(disp16)<br>Store-memory (adr,GR[reg2], Word)  | 1               | 1           | 1           |       |    |   |   |     |
| STSR     | regID,reg2         | rrrrr11111RRRRR<br>0000000010000000           | GR[reg2]←SR[regID]   | 1               | 1           | 1           |       |    |   |   |     |



**Notes 12.** In this instruction, for convenience of mnemonic description, the source register is made reg2, but the reg1 field is used in the opcode. Therefore, the meaning of register specification in the mnemonic description and in the opcode differs from other instructions.

rrrrr = regID specification

RRRRR = reg2 specification

**13.** iiii: Lower 5 bits of imm9.

IIII: Higher 4 bits of imm9.

**14.** Do not specify the same register for general-purpose registers reg1 and reg3.

**15.** sp/imm: specified by bits 19 and 20 of the sub-opcode.

**16.** ff = 00: Load sp in ep.

01: Load sign expanded 16-bit immediate data (bits 47 to 32) in ep.

10: Load 16-bit logically left shifted 16-bit immediate data (bits 47 to 32) in ep.

11: Load 32-bit immediate data (bits 63 to 32) in ep.

**17.** If imm = imm32, n + 3 clocks.

**18.** rrrrr: Other than 00000.

**19.** ddddddd: Higher 7 bits of disp8.

**20.** dddd: Higher 4 bits of disp5.

**21.** ddddddd: Higher 6 bits of disp8.

## APPENDIX E 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

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| Chapter   | Classification | Function      | Details of Function  | Cautions  | Page                           |
|-----------|----------------|---------------|--|---|--------------------------------|
| Chapter 1 | Hard           | Introduction  | FLMD0  | Connect these pins to V <sub>ss</sub> in the normal mode.   | p. 23 <input type="checkbox"/> |
|           |                |               | REGC   | Connect the REGC pin to V <sub>ss</sub> via a 4.7 μF (preliminary value) capacitor.   | p. 23 <input type="checkbox"/> |
| Chapter 2 | Soft           | Pin functions | P05  | Incorporates a pull-down resistor. It can be disconnected by clearing the OCDM.OCDM0 bit.   | p. 30 <input type="checkbox"/> |
|           | Hard           |               | DDO  | In the on-chip debug mode, high-level output is forcibly set.   | p. 35 <input type="checkbox"/> |
|           | Soft           |               | KR0 to KR7   | Connect a pull-up resistor externally.  | p. 36 <input type="checkbox"/> |
|           |                |               | NMI  | The NMI pin alternately functions as the P02 pin. If functions as the P02 pin after reset. To enable the NMI pin, set the PMC0.PMC02 bit to 1. The initial setting of the NMI pin is “No edge detected”. Select the NMI pin valid edge using INTF0 and INTR0 registers.                               | p. 36 <input type="checkbox"/> |
|           | Hard           |               | When power is turned on                                      | When the power is turned on, the following pin may output an undefined level temporarily, even during reset.<br>• P53/SIB2/KR3/TIQ00/TOQ00/RTP03/DDO pin  | p. 45 <input type="checkbox"/> |
| Chapter 3 | Soft           | CPU functions | EIPC register, EIPSW register, FEPC register, FEPSW register | Because only one set of these registers is available, the contents of these registers must be saved by program if multiple interrupts are enabled.  | p. 49 <input type="checkbox"/> |
|           |                |               | EIPC, FEPC, CTPC registers                                   | Even if EIPC or FEPC, or bit 0 of CTPC is set to 1 by the LDSR instruction, bit 0 is ignored when execution is returned to the main routine by the RETI instruction after interrupt servicing (this is because bit 0 of the PC is fixed to 0). Set an even value to EIPC, FEPC, and CTPC (bit 0 = 0). | p. 49 <input type="checkbox"/> |
|           |                |               | Program space  | Because the 4 KB area of addresses 03FFF000H to 03FFFFFFH is an on-chip peripheral I/O area, instructions cannot be fetched from this area. Therefore, do not execute an operation in which the result of a branch address calculation affects this area.   | p. 57 <input type="checkbox"/> |
|           |                |               | On-chip peripheral I/O area                                  | When a register is accessed in word units, a word area is accessed twice in halfword units in the order of lower area and higher area, with the lower 2 bits of the address ignored.  | p. 64 <input type="checkbox"/> |
|           |                |               |  | If a register that can be accessed in byte units is accessed in halfword units, the higher 8 bits are undefined when the register is read, and data is written to the lower 8 bits.   | p. 64 <input type="checkbox"/> |
|           |                |               |  | Addresses not defined as registers are reserved for future expansion. The operation is undefined and not guaranteed when these addresses are accessed.  | p. 64 <input type="checkbox"/> |
|           |                |               | Internal RAM area  | If a branch instruction is at the upper limit of the internal RAM area, a prefetch operation (invalid fetch) straddling the on-chip peripheral I/O area does not occur.   | p. 65 <input type="checkbox"/> |

| Chapter    | Chapter Classification | Function   | Details of Function                                 | Cautions   | Page                           |                          |   |                                |
|------------|------------------------|--|---|--|--------------------------------|--------------------------|---|--------------------------------|
| Chapter 3  | Soft                   | CPU functions  | Setting data to special registers                   | Five NOP instructions or more must be inserted immediately after setting the IDLE1 mode, IDLE2 mode, or STOP mode (by setting the PSC.STP bit to 1).   | p. 81 <input type="checkbox"/> |                          |   |                                |
|            |                        |  |   | When a store instruction is executed to store data in the command register, interrupts are not acknowledged. This is because it is assumed that steps <3> and <4> above are performed by successive store instructions. If another instruction is placed between <3> and <4>, and if an interrupt is acknowledged by that instruction, the above sequence may not be established, causing malfunction. | p. 81 <input type="checkbox"/> |                          |   |                                |
|            |                        |  |   | Although dummy data is written to the PRCMD register, use the same general-purpose register used to set the special register (<4> in Example) to write data to the PRCMD register (<3> in Example). The same applies when a general-purpose register is used for addressing.   | p. 81 <input type="checkbox"/> |                          |   |                                |
|            |                        |  | SYS register  | If 0 is written to the PRERR bit of the SYS register, which is not a special register, immediately after a write access to the PRCMD register, the PRERR bit is cleared to 0 (the write access takes precedence).  | p. 83 <input type="checkbox"/> |                          |   |                                |
|            |                        |  |   | If data is written to the PRCMD register, which is not a special register, immediately after a write access to the PRCMD register, the PRERR bit is set to 1.  | p. 83 <input type="checkbox"/> |                          |   |                                |
|            |                        |  | Registers to be set first                           | Be sure to set the following registers first when using the V850ES/JJ3. <ul style="list-style-type: none"> <li>• System wait control register (VSWC)</li> <li>• On-chip debug mode register (OCDM)</li> <li>• Watchdog timer mode register 2 (WDTM2)</li> </ul>  | p. 84 <input type="checkbox"/> |                          |   |                                |
|            |                        |  | VSWC register                                       | Three clocks are required to access an on-chip peripheral I/O register (without a wait cycle). The V850ES/JJ3 requires wait cycles according to the operating frequency. Set the following value to the VSWC register in accordance with the frequency used.   | p. 84 <input type="checkbox"/> |                          |   |                                |
|            |                        |  | Accessing specific on-chip peripheral I/O registers | Accessing the above registers is prohibited in the following statuses. If a wait cycle is generated, it can only be cleared by a reset. <ul style="list-style-type: none"> <li>• When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>• When the CPU operates with the internal oscillation clock</li> </ul>   | p. 85 <input type="checkbox"/> |                          |   |                                |
|            |                        |  | Chapter 4   | Hard   | Port functions                 | Basic port configuration | Ports 0, 3 to 6, 8, and 9 are 5 V tolerant. | p. 87 <input type="checkbox"/> |
|            |                        |  |   |  |                                |                          | Soft  | PFn register                   |
| Hard, soft | Port 0                 | The $\overline{DRST}$ pin is used for on-chip debugging. If on-chip debugging is not used, fix the $\overline{P05/INTP2/DRST}$ pin to low level between when the reset signal of the $\overline{RESET}$ pin is released and when the OCDM.OCDM0 bit is cleared (0). For details, see <b>4.6.3 Cautions on on-chip debug pins</b> . |   | p. 93 <input type="checkbox"/>   |                                |                          |   |                                |
|            |                        | Hard   |   | The P00 to P06 pins have hysteresis characteristics in the input mode of the alternate function, but do not have hysteresis characteristics in the port mode.  | p. 93 <input type="checkbox"/> |                          |   |                                |
| Soft       | PMC0 register          | The $\overline{P05/INTP2/DRST}$ pin becomes the $\overline{DRST}$ pin regardless of the value of the PMC05 bit when the OCDM.OCDM0 bit = 1.  |   | p. 95 <input type="checkbox"/>   |                                |                          |   |                                |
|            |                        | PF0 register   |   | When an output pin is pulled up at $EV_{DD}$ or higher, be sure to set the PF0n bit to 1.  | p. 96 <input type="checkbox"/> |                          |   |                                |
|            |                        | P1 register  |   | Do not read or write the P1 register during D/A conversion (see <b>14.4.3 Cautions</b> ).  | p. 97 <input type="checkbox"/> |                          |   |                                |
|            |                        | PM1 register   |   | When using P1n as alternate functions (ANOn pin output), set the PM1n bit to 1.  | p. 97 <input type="checkbox"/> |                          |   |                                |

| Chapter   | Classification | Function       | Details of Function           | Cautions   | Page  |
|-----------|----------------|----------------|-------------------------------|--|---|
| Chapter 4 | Soft           | Port functions | PM1 register                  | When using one of the P10 and P11 pins as an I/O port and the other as a D/A output pin, do so in an application where the port I/O level does not change during D/A output.   | p. 97 <input type="checkbox"/>  |
|           |                |                | Port 3                        | The P31 to P35, P38, and P39 pins have hysteresis characteristics in the input mode of the alternate-function pin, but do not have the hysteresis characteristics in the port mode.  | p. 98 <input type="checkbox"/>  |
|           | Soft           |                | P3 register                   | To read/write bits 8 to 15 of the P3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the P3H register.  | p. 99 <input type="checkbox"/>  |
|           |                |                | PM3 register                  | To read/write bits 8 to 15 of the PM3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PM3H register.  | p. 99 <input type="checkbox"/>  |
|           |                |                | PMC3 register                 | Be sure to clear bits 15 to 10, 7, and 6 to "0".   | p. 100 <input type="checkbox"/>   |
|           |                |                |                               | To read/write bits 8 to 15 of the PMC3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMC3H register.  | p. 100 <input type="checkbox"/>   |
|           |                |                | PFC3 register                 | To read/write bits 8 to 15 of the PFC3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PFC3H register.  | p. 101 <input type="checkbox"/>   |
|           |                |                | PFCE3L register               | Be sure to clear bits 7 to 3, 1, and 0 to "0".   | p. 101 <input type="checkbox"/>   |
|           |                |                | PFC31/RXDA0 input/INTP7 input | The INTP7 pin and RXDA0 pin are alternate-function pins. When using the pin as the RXDA0 pin, disable edge detection for the INTP7 alternate-function pin. (Clear the INTF3.INTF31 bit and the INTR3.INTR31 bit to 0.) When using the pin as the INTP7 pin, stop UARTA0 reception. (Clear the UA0CTL0.UA0RXE bit to 0.)                                    | p. 102 <input type="checkbox"/>   |
|           |                |                | PF3 register                  | When an output pin is pulled up at EV <sub>DD</sub> or higher, be sure to set the PF3n bit to 1.   | p. 103 <input type="checkbox"/>   |
|           |                |                |                               | To read/write bits 8 to 15 of the PF3 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PF3H register.  | p. 103 <input type="checkbox"/>   |
|           |                |                | Hard                          | Port 4   | The P40 to P42 pins have hysteresis characteristics in the input mode of the alternate-function pin, but do not have the hysteresis characteristics in the port mode. |
|           | Soft           |                |                               | PF4 register   | When an output pin is pulled up at EV <sub>DD</sub> or higher, be sure to set the PF4n bit to 1.  |
|           | Hard, soft     |                | Port 5                        | The DDI, DDO, DCK, and DMS pins are used for on-chip debugging. If on-chip debugging is not used, fix the P05/INTP2/ $\overline{\text{DRST}}$ pin to low level between when the reset signal of the $\overline{\text{RESET}}$ pin is released and when the OCDM.OCDM0 bit is cleared (0).<br>For details, see <b>4.6.3 Cautions on on-chip debug pins.</b> | p. 106 <input type="checkbox"/>   |
|           |                |                |                               | When the power is turned on, the P53 pin may output undefined level temporarily, even during reset.  | p. 106 <input type="checkbox"/>   |
|           | Hard           |                | Port 5                        | The P50 to P55 pins have hysteresis characteristics in the input mode of the alternate function, but do not have hysteresis characteristics in the port mode.  | p. 106 <input type="checkbox"/>   |
|           |                |                |                               | Soft   | Port 5 alternate function specifications  |
|           | Soft           |                | Port 5                        | PF5 register   | When an output pin is pulled up at EV <sub>DD</sub> or higher, be sure to set the PF5n bit to 1.  |
| Hard      |                | Port 6         |                               | The P66, P68 to P610, P612, and P613 pins have hysteresis characteristics in the input mode of the alternate-function pin, but do not have the hysteresis characteristics in the port mode.  | p. 110 <input type="checkbox"/>   |



| Chapter   | Chapter Classification  | Function  | Details of Function          | Cautions  | Page   |                                 |
|-----------|---|---|------------------------------|---|--|---------------------------------|
| Chapter 4 | Soft  | Functions   | P6 register                  | To read/write bits 8 to 15 of the P6 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the P6H register.     | p. 111 <input type="checkbox"/>  |                                 |
|           |   |   | PM6 register                 | To read/write bits 8 to 15 of the PM6 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PM6H register.   | p. 111 <input type="checkbox"/>  |                                 |
|           |   |   | PMC6 register                | To read/write bits 8 to 15 of the PMC6 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMC6H register. | p. 112 <input type="checkbox"/>  |                                 |
|           |   |   | PF6 register                 | When an output pin is pulled up at EV <sub>DD</sub> or higher, be sure to set the PF6n bit to 1.                            | p. 113 <input type="checkbox"/>  |                                 |
|           |   |   |                              | To read/write bits 8 to 15 of the PF6 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PF6H register.   | p. 113 <input type="checkbox"/>  |                                 |
|           |   |   | P7H register, P7L register   | Do not read or write the P7H and P7L registers during A/D conversion (see <b>13.6 (4) Alternate I/O</b> ).                  | p. 115 <input type="checkbox"/>  |                                 |
|           |   |   | PM7H register, PM7L register | When using the P7n pin as its alternate function (ANIn pin), set the PM7n bit to 1.   | p. 115 <input type="checkbox"/>  |                                 |
|           |   |   | Hard                         | Port 8  | The P80 pin has hysteresis characteristics in the input mode of the alternate-function pin, but does not have the hysteresis characteristics in the port mode.   | p. 116 <input type="checkbox"/> |
|           |   |   | Soft                         | PMC8 register   | The INTp8 and RXDA3 pins are alternate-function pins. When using the RXDA3 pin, disable detection of the edge of the INTp8 pin (INTF8.INTF80 bit = 0 and INTR8.INTR80 bit = 0). When using the INTp8 pin, stop the reception operation of UAR3 (UA3CTL0.UA3RXE bit = 0). | p. 117 <input type="checkbox"/> |
|           |   |   |                              | PF8 register  | When an output pin is pulled up at EV <sub>DD</sub> or higher, be sure to set the PF8n bit to 1.   | p. 117 <input type="checkbox"/> |
|           |   |   | Hard                         | Port 9  | The P90 to P97, P99, P910, and P912 to P915 pins have hysteresis characteristics in the input mode of the alternate-function pin, but do not have the hysteresis characteristics in the port mode.   | p. 118 <input type="checkbox"/> |
|           |   |   | Soft                         | P9 register   | To read/write bits 8 to 15 of the P9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the P9H register.  | p. 119 <input type="checkbox"/> |
|           |   |   |                              | PM9 register  | To read/write bits 8 to 15 of the PM9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PM9H register.  | p. 119 <input type="checkbox"/> |
|           |   |   |                              | PMC9 register   | To read/write bits 8 to 15 of the PMC9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMC9H register.  | p. 120 <input type="checkbox"/> |
|           | When using the A0 to A15 pins as the alternate functions of the P90 to P915 pins, be sure to set all 16 bits of the PMC9 register to FFFFH at once. | p. 121 <input type="checkbox"/>   |                              |   |  |                                 |
|           | PFC9 register   | When performing separate address bus output (A0 to A15), set the PMC9 register to FFFFH for all 16 bits at once after clearing the PFC9 or PFCE9 register to 0000H.   |                              | p. 122 <input type="checkbox"/>   |  |                                 |
|           |   | To read/write bits 8 to 15 of the PFC9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PFC9H register.   |                              | p. 122 <input type="checkbox"/>   |  |                                 |
|           | PFCE9 register  | When performing separate address bus output (A0 to A15), set the PMC9 register to FFFFH for all 16 bits at once after clearing the PFC9 or PFCE9 register to 0000H.   |                              | p. 122 <input type="checkbox"/>   |  |                                 |
|           |   | To read/write bits 8 to 15 of the PFCE9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PFCE9H register.   |                              | p. 122 <input type="checkbox"/>   |  |                                 |
|           | Specification of port 9 alternate function  | The RXDA1 and KR7 pins must not be used at the same time. When using the RXDA1 pin, do not use the KR7 pin. When using the KR7 pin, do not use the RXDA1 pin (it is recommended to set the PFC91 bit to 1 and clear the PFCE91 bit to 0). |                              | p. 124 <input type="checkbox"/>   |  |                                 |
|           | PF9 register  | When an output pin is pulled up at EV <sub>DD</sub> or higher, be sure to set the PF9n bit to 1.  |                              | p. 125 <input type="checkbox"/>   |  |                                 |
|           |   | To read/write bits 8 to 15 of the PF9 register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PF9H register.   |                              | p. 125 <input type="checkbox"/>   |  |                                 |
|           | PDL register  | To read/write bits 8 to 15 of the PDL register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PDLH register.   |                              | p. 136 <input type="checkbox"/>   |  |                                 |

| Chapter   | Classification | Function       | Details of Function   | Cautions   | Page  |
|-----------|----------------|----------------|---|--|---|
| Chapter 4 | Soft           | Port functions | PMDL register   | To read/write bits 8 to 15 of the PMDL register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMDLH register.  | p. 136 <input type="checkbox"/>   |
|           |                |                | PMCDL register  | When the SMSEL bit of the EXIMC register = 1 (separate mode) and the BS30 to BS00 bits of the BSC register = 0 (8-bit bus width), do not specify the AD8 to AD15 pins.   | p. 137 <input type="checkbox"/>   |
|           |                |                |   | To read/write bits 8 to 15 of the PMCDL register in 8-bit or 1-bit units, specify them as bits 0 to 7 of the PMCDLH register.  | p. 137 <input type="checkbox"/>   |
|           |                |                | Using port pins as alternate-function pins  | The INTP7 pin and RXDA0 pin are alternate-function pins. When using the pin as the RXDA0 pin, disable edge detection for the INTP7 alternate-function pin. (Clear the INTF3.INTF31 bit and the INRT3.INTR31 bit to 0.) When using the pin as the INTP7 pin, stop UARTA0 reception. (Clear the UA0CTL0.UA0RXE bit to 0.)  | p. 171 <input type="checkbox"/>   |
|           |                |                |   | Between the P10 and P11 pins, when one pin is used as the I/O port, and the other pin is used as the D/A output pin (ANO0, ANO1), make sure that the port I/O level does not change during D/A output.   | p. 171 <input type="checkbox"/>   |
|           |                |                |   | The INTP8 pin and RXDA3 pin are alternate-function pins. When using the pin as the RXDA3 pin, disable edge detection for the INTP8 alternate-function pin. (Clear the INTF8.INTF80 bit and the INTR8.INTR80 bit to 0.) When using the pin as the INTP8 pin, stop UARTA3 reception. (Clear the UA0CTL3.UA3RXE bit to 0.)  | p. 174 <input type="checkbox"/>   |
|           |                |                |   | When setting pins A0 to A15 as the alternate function, set the PMC9 register to FFFFH for all 16 bits at once.   | p. 175 <input type="checkbox"/>   |
|           |                |                |   | The RXDA1 and KR7 pins must not be used at the same time. When using the RXDA1 pin, do not use the KR7 pin. When using the KR7 pin, do not use the RXDA1 pin (it is recommended to set the PFC91 bit to 1 and clear the PFCE91 bit to 0).  | p. 175 <input type="checkbox"/>   |
|           |                |                |   | When setting pins A0 to A15 as the alternate function, set the PMC9 register to FFFFH for all 16 bits at once.   | p. 176 <input type="checkbox"/>   |
|           |                |                |   | Cautions on switching from port mode to alternate-function mode  | To switch from the port mode to alternate-function mode in the following order.<br><1> Set the PFn registerNote: N-ch open-drain setting<br><2> Set the PFCn and PFCEn registers: Alternate-function selection<br><3> Set the corresponding bit of the PMCn register to 1: Switch to alternate-function mode<br><br>If the PMCn register is set first, note with caution that, at that moment or depending on the change of the pin states in accordance with the setting of the PFn, PFCn, and PFCEn registers, unexpected operations may occur. |
|           |                |                | Regardless of the port mode/alternate-function mode, the Pn register is read and written as follows.<br>• Pn register read: Read the port output latch value (when PMn.PMnm bit = 0), or read the pin states (PMn.PMnm bit = 1).<br>• Pn register write: Write to the port output latch |  | p. 179 <input type="checkbox"/>   |
|           |                |                | Cautions on alternate-function mode (input)   | The input signal to the alternate-function block is low level when the PMCn.PMCnm bit is 0 due to the output of the PMCn register set value and the pin level. Thus, depending on the port setting and alternatefunction operation enable timing, unexpected operations may occur. Therefore, switch between the mode and alternate-function mode in the following sequence.<br>• To switch from port mode to alternate-function mode (input)<br>Set the pins to the alternate-function mode using the PMCn register and then enable the alternatefunction operation.<br>• To switch from alternate-function mode (input) to port mode<br>Stop the alternate-function operation and then switch the pins to the port mode. | p. 180 <input type="checkbox"/>   |

| Chapter   | Chapter Classification | Function              | Details of Function  | Caution   | Page  |
|-----------|------------------------|-----------------------|--|---|---|
| Chapter 4 | Soft                   | Port functions        | PFn.PFnm bit in port mode  | In port mode, the PFn.PFnm bit is valid only in the output mode (PMn.PMnm bit = 0). In the input mode (PMnm bit = 1), the value of the PFnm bit is not reflected in the buffer.   | p. 181 <input type="checkbox"/>   |
|           |                        |                       | Caution on bit manipulation instruction for port n register (Pn) | When a 1-bit manipulation instruction is executed on a port that provides both input and output functions, the value of the output latch of an input port that is not subject to manipulation may be written in addition to the targeted bit. Therefore, it is recommended to rewrite the output latch when switching a port from input mode to output mode.  | p. 182 <input type="checkbox"/>   |
|           | Hard, soft             |                       | Caution on on-chip debug pins                                    | The following action must be taken if on-chip debugging is not used.<br><ul style="list-style-type: none"> <li>Clear the OCDM0 bit of the OCDM register (special register) (0)</li> </ul> At this time, fix the P05/INTP2/ $\overline{\text{DRST}}$ pin to low level from when reset by the $\overline{\text{RESET}}$ pin is released until the above action is taken.<br>If a high level is input to the $\overline{\text{DRST}}$ pin before the above action is taken, it may cause a malfunction (CPU deadlock).<br>Handle the P05 pin with the utmost care. | p. 183 <input type="checkbox"/>   |
|           |                        |                       |  | After reset by the WDT2RES signal, clock monitor (CLM), or low-voltage detector (LVI), the P05/INTP2/ $\overline{\text{DRST}}$ pin is not initialized to function as an on-chip debug pin ( $\overline{\text{DRST}}$ ). The OCDM register holds the current value.  | p. 183 <input type="checkbox"/>   |
|           |                        |                       |  | Caution on P05/INTP2/ $\overline{\text{DRST}}$ pin  | The P05/INTP2/ $\overline{\text{DRST}}$ pin has an internal pull-down resistor (30 k $\Omega$ TYP.). After a reset by the $\overline{\text{RESET}}$ pin, a pull-down resistor is connected. The pull-down resistor is disconnected when the OCDM0 bit is cleared (0). |
|           | Hard                   |                       | Caution on P53 pin when power is turned on                       | When the power is turned on, the following pin may output an undefined level temporarily, even during reset.<br><ul style="list-style-type: none"> <li>P53/SIB2/KR3/TIQ00/TOQ00/RTP03/DDO pin</li> </ul>  | p. 183 <input type="checkbox"/>   |
|           |                        |                       |  | Hysteresis characteristics  | In port mode, the following port pins do not have hysteresis characteristics.<br>P00 to P06<br>P31 to P35, P38, P39<br>P40 to P42<br>P50 to P55<br>P66, P68 to P610, P612, P613<br>P80<br>P90 to P97, P99, P910, P912 to P915   |
| Chapter 5 | Soft                   | Bus control functions | Pin status when internal ROM                                     | When a write access is performed to the internal ROM area, address, data, and control signals are activated in the same way as access to the external memory area.  | p. 185 <input type="checkbox"/>   |
|           |                        |                       | EXIMC register   | Set the EXIMC register from the internal ROM or internal RAM area before making an external access.<br>After setting the EXIMC register, be sure to insert a NOP instruction.   | p. 187 <input type="checkbox"/>   |
|           |                        |                       | BSC register   | Write to the BSC register after reset, and then do not change the set values. Also, do not access an external memory area until the initial settings of the BSC register are complete.  | p. 188 <input type="checkbox"/>   |
|           |                        |                       |  | Be sure to set bits 14, 12, 10, and 8 to "1", and clear bits 15, 13, 11, 9, 7, 5, 3, and 1 to "0".  | p. 188 <input type="checkbox"/>   |
|           |                        |                       | DWC0 register  | The internal ROM and internal RAM areas are not subject to programmable wait, and are always accessed without a wait state. The on-chip peripheral I/O area is also not subject to programmable wait, and only wait control from each peripheral function is performed.   | p. 196 <input type="checkbox"/>   |

| Chapter  | Classification   | Function                        | Details of Function | Cautions   | Page                            |              |  |                                 |
|--|--|---------------------------------|---------------------|--|---------------------------------|--------------|--|---------------------------------|
| Chapter 5  | Soft   | Bus control functions           | DWC0 register       | Write to the DWC0 register after reset, and then do not change the set values. Also, do not access an external memory area until the initial settings of the DWC0 register are complete. | p. 196 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 |                     | When V850ES/JJ3 is used in separate bus mode and operated at $f_{xx} > 20$ MHz, be sure to insert one or more wait.  | p. 196 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 |                     | Be sure to clear bits 15, 11, 7, and 3 to "0".   | p. 196 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 | AWC register        | Address setup wait and address hold wait cycles are not inserted when the internal ROM area, internal RAM area, and on-chip peripheral I/O areas are accessed.                           | p. 199 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 |                     | Write to the AWC register after reset, and then do not change the set values. Also, do not access an external memory area until the initial settings of the AWC register are complete.   | p. 199 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 |                     | When V850ES/JJ3 is operated at $f_{xx} > 20$ MHz, be sure to insert the address hold wait and the address setup wait.  | p. 199 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 |                     | Be sure to set bits 15 to 8 to "1".  | p. 199 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 | BCC register        | The internal ROM, internal RAM, and on-chip peripheral I/O areas are not subject to idle state insertion.  | p. 200 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 |                     | Write to the BCC register after reset, and then do not change the set values. Also, do not access an external memory area until the initial settings of the BCC register are complete.   | p. 200 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 |                     | Be sure to set bits 15, 13, 11, and 9 to "1", and clear bits 14, 12, 10, 8, 6, 4, 2, and 0 to "0".   | p. 200 <input type="checkbox"/> |              |  |                                 |
|  |  |                                 | Chapter 6           | Soft   | Clock generation function       | PCC register | Do not change the CPU clock (by using the CK3 to CK0 bits) while CLKOUT is being output.   | p. 214 <input type="checkbox"/> |
|  |  |                                 |                     |  |                                 |              | Use a bit manipulation instruction to manipulate the CK3 bit. When using an 8-bit manipulation instruction, do not change the set values of the CK2 to CK0 bits. | p. 214 <input type="checkbox"/> |
| When stopping the main clock, stop the PLL. Also stop the operations of the on-chip peripheral functions operating with the main clock.  | p. 215 <input type="checkbox"/>  |                                 |                     |  |                                 |              |  |                                 |
| If the following conditions are not satisfied, change the CK2 to CK0 bits so that the conditions are satisfied, then change to the subclock operation mode.<br>Internal system clock ( $f_{CLK}$ ) > Subclock ( $f_{XT}$ : 32.768 kHz) × 4                   | p. 215 <input type="checkbox"/>  |                                 |                     |  |                                 |              |  |                                 |
| Enable operation of the on-chip peripheral functions operating with the main clock only after the oscillation of the main clock stabilizes. If their operations are enabled before the lapse of the oscillation stabilization time, a malfunction may occur. | p. 216 <input type="checkbox"/>  |                                 |                     |  |                                 |              |  |                                 |
| RCM register   | The internal oscillator cannot be stopped while the CPU is operating on the internal oscillation clock (CCLS.CCLSIF bit = 1). Do not set the RSTOP bit to 1.   | p. 217 <input type="checkbox"/> |                     |  |                                 |              |  |                                 |
|  | The internal oscillator oscillates if the CCLS.CCLSIF bit is set to 1 (when WDT overflow occurs during oscillation stabilization) even when the RSTOP bit is set to 1. At this time, the RSTOP bit remains being set to 1. | p. 217 <input type="checkbox"/> |                     |  |                                 |              |  |                                 |
| PLLCTL register  | When the PLLON bit is cleared to 0, the SELPLL bit is automatically cleared to 0 (clockthrough mode).  | p. 219 <input type="checkbox"/> |                     |  |                                 |              |  |                                 |
|  | The SELPLL bit can be set to 1 only when the PLL clock frequency is stabilized. If not (unlocked), "0" is written to the SELPLL bit if data is written to it.  | p. 219 <input type="checkbox"/> |                     |  |                                 |              |  |                                 |
| CKC register   | The PLL mode cannot be used at $f_x = 5.0$ to 10.0 MHz.  | p. 220 <input type="checkbox"/> |                     |  |                                 |              |  |                                 |
|  | Before changing the multiplication factor between 4 and 8 by using the CKC register, set the clock-through mode and stop the PLL.  | p. 220 <input type="checkbox"/> |                     |  |                                 |              |  |                                 |
|  | Be sure to set bits 3 and 1 to "1" and clear bits 7 to 4 and 2 to "0".   | p. 220 <input type="checkbox"/> |                     |  |                                 |              |  |                                 |

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|------------------|--|------------------------------------|--|---|---------------------------------|
| Chapter 6        | Soft   | Clock generation function          | LOCKR register   | The LOCK register does not reflect the lock status of the PLL in real time.   | p. 221 <input type="checkbox"/> |
|                  |  |                                    | PLLS register  | Set so that the lockup time is 800 $\mu$ s or longer.   | p. 222 <input type="checkbox"/> |
|                  |  |                                    |  | Do not change the PLLS register setting during the lockup period.   | p. 222 <input type="checkbox"/> |
| Chapter 7        | Soft   | 16-bit timer/event counter P (TMP) | TPnCTL0 register   | Set the TPnCKS2 to TPnCKS0 bits when the TPnCE bit = 0. When the value of the TPnCE bit is changed from 0 to 1, the TPnCKS2 to TPnCKS0 bits can be set simultaneously.  | p. 227 <input type="checkbox"/> |
|                  |  |                                    |  | Be sure to clear bits 3 to 6 to "0".  | p. 227 <input type="checkbox"/> |
|                  |  |                                    | TPnCTL1 register   | The TPnEST bit is valid only in the external trigger pulse output mode or one-shot pulse output mode. In any other mode, writing 1 to this bit is ignored.  | p. 228 <input type="checkbox"/> |
|                  |  |                                    |  | External event count input is selected in the external event count mode regardless of the value of the TPnEEE bit.  | p. 228 <input type="checkbox"/> |
|                  |  |                                    |  | Set the TPnEEE and TPnMD2 to TPnMD0 bits when the TPnCTL0.TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) The operation is not guaranteed when rewriting is performed with the TPnCE bit = 1. If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again. | p. 228 <input type="checkbox"/> |
|                  |  |                                    |  | Be sure to clear bits 3, 4, and 7 to "0".   | p. 228 <input type="checkbox"/> |
|                  |  |                                    | TPnIOC0 register   | Rewrite the TPnOL1, TPnOE1, TPnOLO, and TPnOE0 bits when the TPnCTL0.TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again.  | p. 229 <input type="checkbox"/> |
|                  |  |                                    |  | Even if the TPnOLm bit is manipulated when the TPnCE and TPnOEm bits are 0, the TOPnm pin output level varies (m = 0, 1).   | p. 229 <input type="checkbox"/> |
|                  |  |                                    | TPnIOC1 register   | Rewrite the TPnIS3 to TPnIS0 bits when the TPnCTL0.TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again.  | p. 230 <input type="checkbox"/> |
|                  |  |                                    |  | The TPnIS3 to TPnIS0 bits are valid only in the freerunning timer mode and the pulse width measurement mode. In all other modes, a capture operation is not possible.   | p. 230 <input type="checkbox"/> |
|                  |  |                                    | TPnIOC2 register   | Rewrite the TPnEES1, TPnEES0, TPnETS1, and TPnETS0 bits when the TPnCTL0.TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again.  | p. 231 <input type="checkbox"/> |
|                  |  |                                    |  | The TPnEES1 and TPnEES0 bits are valid only when the TPnCTL1.TPnEEE bit = 1 or when the external event count mode (TPnCTL1.TPnMD2 to TPnCTL1.TPnMD0 bits = 001) has been set.   | p. 231 <input type="checkbox"/> |
|                  |  |                                    |  | The TPnETS1 and TPnETS0 bits are valid only when the external trigger pulse output mode (TPnCTL1.TPnMD2 to TPnCTL1.TPnMD0 bits = 010) or the one-shot pulse output mode (TPnCTL1.TPnMD2 to TPnCTL1.TPnMD0 = 011) is set.  | p. 231 <input type="checkbox"/> |
|                  |  |                                    | TPnOPT0 register   | Rewrite the TPnCCS1 and TPnCCS0 bits when the TPnCE bit = 0. (The same value can be written when the TPnCE bit = 1.) If rewriting was mistakenly performed, clear the TPnCE bit to 0 and then set the bits again.   | p. 232 <input type="checkbox"/> |
|                  |  |                                    |  | Be sure to clear bits 1 to 3, 6, and 7 to "0".  | p. 232 <input type="checkbox"/> |
| TPnCCR0 register | Accessing the TPnCCR0 register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers.</b> | p. 233 <input type="checkbox"/>    |  |   |                                 |
|                  |  |                                    | <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul> |   |                                 |

| Chapter  | Classification  | Function                           | Details of Function   | Cautions   | Page                            |
|--|---|------------------------------------|---|--|---------------------------------|
| Chapter 7  | Soft  | 16-bit timer/event counter P (TMP) | TPnCCR1 register  | Accessing the TPnCCR1 register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul> | p. 235 <input type="checkbox"/> |
|  |   |                                    | TPnCNT register   | Accessing the TPnCNT register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul>  | p. 237 <input type="checkbox"/> |
|  |   |                                    | Operation   | To use the external event count mode, specify that the valid edge of the TIPn0 pin capture trigger input is not detected (by clearing the TPnIOC1.TPnIS1 and TPnIOC1.TPnIS0 bits to "00").   | p. 238 <input type="checkbox"/> |
|  |   |                                    |   | When using the external trigger pulse output mode, one-shot pulse output mode, and pulse width measurement mode, select the internal clock as the count clock (by clearing the TPnCTL1.TPnEEE bit to 0).   | p. 238 <input type="checkbox"/> |
|  |   |                                    | Interval timer mode (TPnMD2 to TPnMD0 bits = 000)           | This bit can be set to 1 only when the interrupt request signals (INTTPnCC0 and INTTPnCC1) are masked by the interrupt mask flags (TPnCCMK0 and TPnCCMK1) and timer output (TOPn1) is performed at the same time. However, set the TPnCCR0 and TPnCCR1 registers to the same value (see <b>7.5.1 (2) (d) Operation of TPnCCR1 register</b> ).                          | p. 240 <input type="checkbox"/> |
|  |   |                                    | Notes on rewriting TPnCCR0 register                         | To change the value of the TPnCCR0 register to a smaller value, stop counting once and then change the set value.<br>If the value of the TPnCCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.  | p. 245 <input type="checkbox"/> |
|  |   |                                    | Register setting for operation in external event count mode | When an external clock is used as the count clock, the external clock can be input only from the TIPn0 pin. At this time, set the TPnIOC1.TPnIS1 and TPnIOC1.TPnIS0 bits to 00 (capture trigger input (TIPn0 pin): no edge detection).   | p. 251 <input type="checkbox"/> |
|  |   |                                    | External event count mode (TPnMD2 to TPnMD0 bits = 001)     | In the external event count mode, do not set the TPnCCR0 register to 0000H.  | p. 253 <input type="checkbox"/> |
|  |   |                                    |   | In the external event count mode, use of the timer output is disabled. If performing timer output using external event count input, set the interval timer mode, and select the operation enabled by the external event count input for the count clock (TPnCTL1.TPnMD2 to TPnCTL1.TPnMD0 bits = 000, TPnCTL1.TPnEEE bit = 1).   | p. 253 <input type="checkbox"/> |
|  |   |                                    | Notes on rewriting the TPnCCR0 register                     | To change the value of the TPnCCR0 register to a smaller value, stop counting once and then change the set value.<br>If the value of the TPnCCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.  | p. 254 <input type="checkbox"/> |
|  |   |                                    | TPnIOC0, TPnOE0, TPnOL0 bits                                | Clear this bit to 0 when the TOPn0 pin is not used in the external trigger pulse output mode.  | p. 259 <input type="checkbox"/> |
|  |   |                                    | Note on changing pulse width during operation               | To change the PWM waveform while the counter is operating, write the TPnCCR1 register last.<br>Rewrite the TPnCCRm register after writing the TPnCCR1 register after the INTTPnCC0 signal is detected.   | p. 263 <input type="checkbox"/> |
|  |   |                                    | TPnIOC0.TPnOE0, TPnOL0 bits                                 | Clear this bit to 0 when the TOPn0 pin is not used in the one-shot pulse output mode.  | p. 271 <input type="checkbox"/> |
| Register setting for operation in one-shot pulse output mode | One-shot pulses are not output even in the one-shot pulse output mode, if the value set in the TPnCCR1 register is greater than that set in the TPnCCR0 register. | p. 272 <input type="checkbox"/>    |   |  |                                 |

| Chapter           | Classification  | Function                           | Details of Function                | Cautions  | Page                            |
|-------------------|---|------------------------------------|------------------------------------|---|---------------------------------|
| Chapter 7         | Soft  | 16-bit timer/event counter P (TMP) | Note on rewriting TPnCCRM register | To change the set value of the TPnCCRM register to a smaller value, stop counting once, and then change the set value.<br>If the value of the TPnCCRM register is rewritten to a smaller value during counting, the 16-bit counter may overflow.  | p. 274 <input type="checkbox"/> |
|                   |   |                                    | TPnIOC0.TPnOE0, TPnOLO bits        | Clear this bit to 0 when the TOPn0 pin is not used in the PWM output mode.  | p. 278 <input type="checkbox"/> |
|                   |   |                                    | Selector function                  | When using the selector function, be sure to set the port/timer alternate function pins for TMP to be connected to the capture trigger input.   | p. 309 <input type="checkbox"/> |
|                   |   |                                    |                                    | Disable the peripheral I/Os to be connected (TMP/UARTA) before setting the selector function.   | p. 309 <input type="checkbox"/> |
|                   |   |                                    | SELCNT0 register                   | When setting the ISEL3, ISEL4, or ISEL6 bit to 1, be sure to set the corresponding alternate-function pin to the capture trigger input.   | p. 310 <input type="checkbox"/> |
|                   |   |                                    |                                    | Be sure to clear bits 7, 5, and 2 to 0 to "0".  | p. 310 <input type="checkbox"/> |
| Capture operation | When the capture operation is used and a slow clock is selected as the count clock, FFFFH, not 0000H, may be captured in the TPnCCR0 and TPnCCR1 registers if the capture trigger is input immediately after the TPnCE bit is set to 1. | p. 311 <input type="checkbox"/>    |                                    |   |                                 |
| Chapter 8         | Soft  | 16-bit timer/event counter Q (TMQ) | TQ0CTL0 register                   | Set the TQ0CKS2 to TQ0CKS0 bits when the TQ0CE bit = 0. When the value of the TQ0CE bit is changed from 0 to 1, the TQ0CKS2 to TQ0CKS0 bits can be set simultaneously.  | p. 316 <input type="checkbox"/> |
|                   |   |                                    |                                    | Be sure to clear bits 3 to 6 to "0".  | p. 316 <input type="checkbox"/> |
|                   |   |                                    | TQ0CTL1 register                   | The TQ0EST bit is valid only in the external trigger pulse output mode or one-shot pulse output mode. In any other mode, writing 1 to this bit is ignored.  | p. 317 <input type="checkbox"/> |
|                   |   |                                    |                                    | External event count input is selected in the external event count mode regardless of the value of the TQ0EEE bit.  | p. 317 <input type="checkbox"/> |
|                   |   |                                    |                                    | Set the TQ0EEE and TQ0MD2 to TQ0MD0 bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) The operation is not guaranteed when rewriting is performed with the TQ0CE bit = 1. If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again. | p. 317 <input type="checkbox"/> |
|                   |   |                                    |                                    | Be sure to clear bits 3, 4, and 7 to "0".   | p. 317 <input type="checkbox"/> |
|                   |   |                                    | TQ0IOC0 register                   | Rewrite the TQ0OLm and TQ0OEm bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.   | p. 318 <input type="checkbox"/> |
|                   |   |                                    |                                    | Even if the TQ0OLm bit is manipulated when the TQ0CE and TQ0OEm bits are 0, the TQ0m pin output level varies.   | p. 318 <input type="checkbox"/> |
|                   |   |                                    | TQ0IOC1 register                   | Rewrite the TQ0IS7 to TQ0IS0 bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.  | p. 319 <input type="checkbox"/> |
|                   |   |                                    |                                    | The TQ0IS7 to TQ0IS0 bits are valid only in the freerunning timer mode and the pulse width measurement mode. In all other modes, a capture operation is not possible.   | p. 319 <input type="checkbox"/> |
|                   |   |                                    | TQ0IOC2 register                   | Rewrite the TQ0EES1, TQ0EES0, TQ0ETS1, and TQ0ETS0 bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.  | p. 320 <input type="checkbox"/> |
|                   |   |                                    |                                    | The TQ0EES1 and TQ0EES0 bits are valid only when the TQ0CTL1.TQ0EEE bit = 1 or when the external event count mode (TQ0CTL1.TQ0MD2 to TQ0CTL1.TQ0MD0 bits = 001) has been set.   | p. 320 <input type="checkbox"/> |

| Chapter            | Classification   | Function                           | Details of Function  | Cautions   | Page                            |
|--------------------|--|------------------------------------|--|--|---------------------------------|
| Chapter 8          | Soft   | 16-bit timer/event counter Q (TMQ) | TQ0IOC2 register   | The TQ0ETS1 and TQ0ETS0 bits are valid only when the external trigger pulse output mode (TQ0CTL1.TQ0MD2 to TQ0CTL1.TQ0MD0 bits = 010) or the one-shot pulse output mode (TQ0CTL1.TQ0MD2 to TQ0CTL1.TQ0MD0 = 011) is set.   | p. 320 <input type="checkbox"/> |
|                    |  |                                    | TQ0OPT0 register   | Rewrite the TQ0CCS3 to TQ0CCS0 bits when the TQ0CTL0.TQ0CE bit = 0. (The same value can be written when the TQ0CE bit = 1.) If rewriting was mistakenly performed, clear the TQ0CE bit to 0 and then set the bits again.   | p. 321 <input type="checkbox"/> |
|                    |  |                                    |  | Be sure to clear bits 1 to 3 to "0".   | p. 321 <input type="checkbox"/> |
|                    |  |                                    | TQ0CCR0 register   | Accessing the TQ0CCR0 register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul> | p. 322 <input type="checkbox"/> |
|                    |  |                                    | TQ0CCR1 register   | Accessing the TQ0CCR1 register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul> | p. 324 <input type="checkbox"/> |
|                    |  |                                    | TQ0CCR2 register   | Accessing the TQ0CCR2 register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul> | p. 326 <input type="checkbox"/> |
|                    |  |                                    | TQ0CCR3 register   | Accessing the TQ0CCR3 register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul> | p. 328 <input type="checkbox"/> |
|                    |  |                                    | TQ0CNT register  | Accessing the TQ0CNT register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul>  | p. 330 <input type="checkbox"/> |
|                    |  |                                    | External event count mode  | To use the external event count mode, specify that the valid edge of the TIQ00 pin capture trigger input is not detected (by clearing the TQ0IOC1.TQ0IS1 and TQ0IOC1.TQ0IS0 bits to "00").   | p. 331 <input type="checkbox"/> |
|                    |  |                                    | External trigger pulse output mode, one-shot pulse output mode, pulse width measurement mode | When using the external trigger pulse output mode, one-shot pulse output mode, and pulse width measurement mode, select the internal clock as the count clock (by clearing the TQ0CTL1.TQ0EEE bit to 0).   | p. 331 <input type="checkbox"/> |
| TQ0CTL1.TQ0EEE bit | This bit can be set to 1 only when the interrupt request signals (INTTQ0CC0 and INTTQ0CCk) are masked by the interrupt mask flags (TQ0CCMK0 to TQ0CCMKk) and the timer output (TQ0Qk) is performed at the same time. However, the TQ0CCR0 and TQ0CCRk registers must be set to the same value (see <b>8.5.1 (2) (d) Operation of TQ0CCR1 to TQ0CCR3 registers</b> ). | p. 333 <input type="checkbox"/>    |  |  |                                 |



| Chapter   | Classification | Function                           | Details of Function  | Cautions   | Page                                  |
|-----------|----------------|------------------------------------|--|--|---------------------------------------|
| Chapter 8 | Soft           | 16-bit timer/event counter Q (TMQ) | Notes on rewriting TQ0CCR0 register                          | To change the value of the TQ0CCR0 register to a smaller value, stop counting once and then change the set value.<br>If the value of the TQ0CCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.  | pp. 337, 346 <input type="checkbox"/> |
|           |                |                                    | Register setting for operation in external event count mode  | When an external clock is used as the count clock, the external clock can be input only from the TIQ00 pin. At this time, set the TQ0IOC1.TQ0IS1 and TQ0IOC1.TQ0IS0 bits to 00 (capture trigger input (TIQ00 pin): no edge detection).   | p. 343 <input type="checkbox"/>       |
|           |                |                                    | External event count mode (TQ0MD2 to TQ0MD0 bits = 001)      | In the external event count mode, do not set the TQ0CCR0 register to 0000H.  | p. 345 <input type="checkbox"/>       |
|           |                |                                    |  | In the external event count mode, use of the timer output is disabled. If performing timer output using external event count input, set the interval timer mode, and select the operation enabled by the external event count input for the count clock (TQ0CTL1.TQ0MD2 to TQ0CTL1.TQ0MD0 bits = 000, TQ0CTL1.TQ0EEE bit = 1). | p. 345 <input type="checkbox"/>       |
|           |                |                                    | TQ0IOC0.TQ0OE0, TQ0OL0 bits                                  | Clear this bit to 0 when the TOQ00 pin is not used in the external trigger pulse output mode.  | p. 353 <input type="checkbox"/>       |
|           |                |                                    | Note on changing pulse width during operation                | To change the PWM waveform while the counter is operating, write the TQ0CCR1 register last.<br>Rewrite the TQ0CCRk register after writing the TQ0CCR1 register after the INTTQ0CC0 signal is detected.   | p. 357 <input type="checkbox"/>       |
|           |                |                                    | TQ0IOC0.TQ0OE0, TQ0OL0 bits                                  | Clear this bit to 0 when the TOQ00 pin is not used in the one-shot pulse output mode.  | p. 366 <input type="checkbox"/>       |
|           |                |                                    | Register setting for operation in one-shot pulse output mode | One-shot pulses are not output even in the one-shot pulse output mode, if the value set in the TQ0CCRk register is greater than that set in the TQ0CCR0 register.  | p. 367 <input type="checkbox"/>       |
|           |                |                                    | Note on rewriting TQ0CCRM register                           | To change the set value of the TQ0CCRM register to a smaller value, stop counting once, and then change the set value.<br>If the value of the TQ0CCR0 register is rewritten to a smaller value during counting, the 16-bit counter may overflow.   | p. 370 <input type="checkbox"/>       |
|           |                |                                    | TQ0IC0.TQ0OE0, TQ0OL0 bits                                   | Clear this bit to 0 when the TOQ00 pin is not used in the PWM output mode.   | p. 375 <input type="checkbox"/>       |
|           |                |                                    | Capture operation  | When the capture operation is used and a slow clock is selected as the count clock, FFFFH, not 0000H, may be captured in the TQ0CCR0, TQ0CCR1, TQ0CCR2, and TQ0CCR3 registers if the capture trigger is input immediately after the TQ0CE bit is set to 1.   | p. 410 <input type="checkbox"/>       |
| Chapter 9 | Soft           | 16-bit interval timer M (TMM)      | TM0CTL0 register   | Set the TM0CKS2 to TM0CKS0 bits when TM0CE bit = 0.<br>When changing the value of TM0CE from 0 to 1, it is not possible to set the value of the TM0CKS2 to TM0CKS0 bits simultaneously.  | p. 413 <input type="checkbox"/>       |
|           |                |                                    |  | Be sure to clear bits 3 to 6 to "0".   | p. 413 <input type="checkbox"/>       |
|           |                |                                    | Operation in interval timer mode                             | Do not set the TM0CMP0 register to FFFFH.  | pp. 414, 417 <input type="checkbox"/> |
|           |                |                                    | Count start  | It takes the 16-bit counter up to the following time to start counting after the TM0CTL0.TM0CE bit is set to 1, depending on the count clock selected.   | p. 418 <input type="checkbox"/>       |

| Chapter    | Classification | Function                      | Details of Function          | Cautions  | Page                            |
|------------|----------------|-------------------------------|------------------------------|---|---------------------------------|
| Chapter 9  | Soft           | 16-bit interval timer M (TMM) | TM0CMP0, TM0CTL0 registers   | Rewriting the TM0CMP0 and TM0CTL0 registers is prohibited while TMM0 is operating.<br>If these registers are rewritten while the TMOCE bit is 1, the operation cannot be guaranteed.<br>If they are rewritten by mistake, clear the TM0CTL0.TMOCE bit to 0, and re-set the registers.   | p. 418 <input type="checkbox"/> |
| Chapter 10 | Soft           | Watch timer functions         | PRSM0 register               | Do not change the values of the BGCS00 and BGCS01 bits during watch timer operation.  | p. 422 <input type="checkbox"/> |
|            |                |                               |                              | Set the PRSM0 register before setting the BGCE0 bit to 1.   | p. 422 <input type="checkbox"/> |
|            |                |                               |                              | Set the PRSM0 and PRSCM0 registers according to the main clock frequency that is used so as to obtain an $f_{BRG}$ frequency of 32.768 kHz.   | p. 422 <input type="checkbox"/> |
|            |                |                               | PRSCM0 register              | Do not rewrite the PRSCM0 register during watch timer operation.  | p. 423 <input type="checkbox"/> |
|            |                |                               |                              | Set the PRSCM0 register before setting the PRSM0.BGCE0 bit to 1.  | p. 423 <input type="checkbox"/> |
|            | Hard           | Watch timer functions         | WTM register                 | Set the PRSM0 and PRSCM0 registers according to the main clock frequency that is used so as to obtain an $f_{BRG}$ frequency of 32.768 kHz.   | p. 423 <input type="checkbox"/> |
|            |                |                               |                              | Rewrite the WTM2 to WTM7 bits while both the WTM0 and WTM1 bits are 0.  | p. 425 <input type="checkbox"/> |
|            |                |                               |                              | Some time is required before the first watch timer interrupt request signal (INTWT) is generated after operation is enabled (WTM.WTM1 and WTM.WTM0 bits = 1).   | p. 428 <input type="checkbox"/> |
|            |                |                               |                              | It takes 0.515625 seconds (max.) for the first INTWT signal to be generated ( $2^9 \times 1/32768 = 0.015625$ seconds longer (max.)).<br>The INTWT signal is then generated every 0.5 seconds.  | p. 428 <input type="checkbox"/> |
|            |                |                               |                              | Caution   |                                 |
| Chapter 11 | Soft           | Watchdog timer 2 function     | Default-start watchdog timer | Watchdog timer 2 automatically starts in the reset mode following reset release. When watchdog timer 2 is not used, either stop its operation before reset is executed via this function, or clear watchdog timer 2 once and stop it within the next interval time.<br>Also, write to the WDTM2 register for verification purposes only once, even if the default settings (reset mode, interval time: $f_{\text{r}}/2^{19}$ ) do not need to be changed. | p. 429 <input type="checkbox"/> |
|            |                |                               |                              | For the non-maskable interrupt servicing due to a non-maskable interrupt request signal (INTWDT2), see <b>19.2.2 (2) From INTWDT2 signal</b> .  | p. 429 <input type="checkbox"/> |
|            |                |                               | WDTM2 register               | Accessing the WDTM2 register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> .<br>• When the CPU operates with the subclock and the main clock oscillation is stopped<br>• When the CPU operates with the internal oscillation clock   | p. 431 <input type="checkbox"/> |
|            |                |                               |                              | For details of the WDCS20 to WDCS24 bits, see <b>Table 11-2 Watchdog Timer 2 Clock Selection</b> .  | p. 431 <input type="checkbox"/> |
|            |                |                               |                              | Although watchdog timer 2 can be stopped just by stopping the operation of the internal oscillator, clear the WDTM2 register to 00H to securely stop the timer (to avoid selection of the main clock or subclock due to an erroneous write operation).  | p. 431 <input type="checkbox"/> |
|            |                |                               |                              | If the WDTM2 register is rewritten twice after reset, an overflow signal is forcibly generated and the counter is reset.  | p. 431 <input type="checkbox"/> |
|            |                |                               |                              | To intentionally generate an overflow signal, write data to the WDTM2 register only twice, or write a value other than "ACH" to the WDTE register only once. However, when watchdog timer 2 is set to stop operation, an overflow signal is not generated even if data is written to the WDTM2 register only twice, or a value other than "ACH" is written to the WDTE register only once.  | p. 431 <input type="checkbox"/> |

| Chapter                | Chapter Classification   | Function                        | Details of Function       | Cautions   | Page                            |
|------------------------|--|---------------------------------|---------------------------|--|---------------------------------|
| Chapter 11             | Soft   | Watchdog timer 2 function       | WDTM2 register            | To stop the operation of watchdog timer 2, set the RCM.RSTP bit to 1 (to stop the internal oscillator) and write 00H in the WDTM2 register. If the RCM.RSTP bit cannot be set to 1, set the WDSCS23 bit to 1 (2 <sup>n</sup> /f <sub>xx</sub> is selected and the clock can be stopped in the IDLE1, IDLW2, sub-IDLE, and subclock operation modes).   | p. 431 <input type="checkbox"/> |
|                        |  |                                 | WDTE register             | When a value other than "ACH" is written to the WDTE register, an overflow signal is forcibly output.  | p. 432 <input type="checkbox"/> |
|                        |  |                                 |                           | When a 1-bit memory manipulation instruction is executed for the WDTE register, an overflow signal is forcibly output.   | p. 432 <input type="checkbox"/> |
|                        |  |                                 |                           | To intentionally generate an overflow signal, write a value other than "ACH" to the WDTE register only once, or write data to the WDTM2 register only twice. However, when the watchdog timer 2 is set to stop operation, an overflow signal is not generated even if data is written to the WDTM2 register only twice, or a value other than "ACH" is written to the WDTE register only once. | p. 432 <input type="checkbox"/> |
|                        |  |                                 |                           | The read value of the WDTE register is "9AH" (which differs from written value "ACH").   | p. 432 <input type="checkbox"/> |
| Chapter 12             | Soft   | Real-time output function (RTO) | RTBLn, RTBHn registers    | When writing to bits 6 and 7 of the RTBHn register, always write 0.  | p. 436 <input type="checkbox"/> |
|                        |  |                                 |                           | Accessing the RTBLn and RTBHn registers is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul>                | p. 436 <input type="checkbox"/> |
|                        |  |                                 |                           | After setting the real-time output port, set output data to the RTBLn and RTBHn registers by the time a realtime output trigger is generated.  | p. 436 <input type="checkbox"/> |
|                        |  |                                 | RTPMn register            | By enabling the real-time output operation (RTPCn.RTPOEn bit = 1), the bits enabled to real-time output among the RTPn0 to RTPn5 signals perform realtime output, and the bits set to port mode output 0.  | p. 437 <input type="checkbox"/> |
|                        |  |                                 |                           | If real-time output is disabled (RTPOEn bit = 0), the real-time output pins (RTPn0 to RTPn5) all output 0, regardless of the RTPMn register setting.   | p. 437 <input type="checkbox"/> |
|                        |  |                                 |                           | In order to use this register as the real-time output pins (RTPn0 to RTPn5), set these pins as real-time output port pins using the PMC and PFC registers.   | p. 437 <input type="checkbox"/> |
|                        |  |                                 | RTPCn register            | Set the RTPEGn, BYTEn, and EXTRn bits only when RTPOEn bit = 0.  | p. 438 <input type="checkbox"/> |
|                        |  |                                 | Realtime output operation | Prevent the following conflicts by software. <ul style="list-style-type: none"> <li>Conflict between real-time output disable/enable switching (RTPOEn bit) and selected real-time output trigger.</li> <li>Conflict between writing to the RTBHn and RTBLn registers in the real-time output enabled status and the selected real-time output trigger.</li> </ul>                             | p. 440 <input type="checkbox"/> |
|                        |  |                                 | Initialization            | Before performing initialization, disable real-time output (RTPOEn bit = 0).   | p. 440 <input type="checkbox"/> |
| RTBHn, RTBLn registers | Once real-time output has been disabled (RTPOEn bit = 0), be sure to initialize the RTBHn and RTBLn registers before enabling real-time output again (RTPOEn bit = 0 → 1). | p. 440 <input type="checkbox"/> |                           |  |                                 |
| Chapter 13             | Hard   | A/D converter                   | ANI0 to ANI15 pins        | Make sure that the voltages input to the ANI0 to ANI15 pins do not exceed the rated values.<br>In particular if a voltage of AV <sub>REF0</sub> or higher is input to a channel, the conversion value of that channel becomes undefined, and the conversion values of the other channels may also be affected.   | p. 444 <input type="checkbox"/> |
|                        | Soft   |                                 | ADA0M0 register           | Accessing the ADA0M0 register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul>                          | p. 446 <input type="checkbox"/> |

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| Chapter 13 | Soft                   | A/D converter | ADA0M0 register   | A write operation to bit 0 is ignored.   | p. 446 <input type="checkbox"/> |
|            |                        |               |   | Changing the ADA0M1.ADA0FR2 to ADA0M1.ADA0FR0 bits is prohibited while A/D conversion is enabled (ADA0CE bit = 1).   | p. 446 <input type="checkbox"/> |
|            |                        |               |   | When writing data to the ADA0M0, ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register in the following modes, stop the A/D conversion by clearing the ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.<br><ul style="list-style-type: none"> <li>• Normal conversion mode</li> <li>• One-shot select mode/one-shot scan mode in high-speed conversion mode</li> </ul> If the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers are written in the other modes during A/D conversion (ADA0EF bit = 1), the following will be performed according to the mode.<br><ul style="list-style-type: none"> <li>• In software trigger mode<br/>A/D conversion is stopped and started again from the beginning.</li> <li>• In hardware trigger mode<br/>A/D conversion is stopped, and the trigger standby status is set.</li> </ul> | p. 446 <input type="checkbox"/> |
|            |                        |               |   | To select the external trigger mode/timer trigger mode (ADA0TMD bit = 1), set the high-speed conversion mode (ADA0M1.ADA0HS1 bit = 1). Do not input a trigger during stabilization time that is inserted once after the A/D conversion operation is enabled (ADA0CE bit = 1).  | p. 446 <input type="checkbox"/> |
|            |                        |               |   | When not using the A/D converter, stop the operation by setting the ADA0CE bit to 0 to reduce the power consumption.   | p. 446 <input type="checkbox"/> |
|            |                        |               | ADA0M1 register   | Changing the ADA0M1 register is prohibited while A/D conversion is enabled (ADA0M0.ADA0CE bit = 1).  | p. 447 <input type="checkbox"/> |
|            |                        |               |   | To select the external trigger mode/timer trigger mode (ADA0M0.ADA0TMD bit = 1), set the high-speed conversion mode (ADA0HS1 bit = 1). Do not input a trigger during stabilization time that is inserted once after the A/D conversion operation is enabled (ADA0CE bit = 1).  | p. 447 <input type="checkbox"/> |
|            |                        |               |   | Be sure to clear bits 6 to 4 to "0".   | p. 447 <input type="checkbox"/> |
|            |                        |               | Conversion time selection in normal conversion mode (ADA0HS1 bit = 0)     | Set as $2.6 \mu s \leq \text{conversion time} \leq 10.4 \mu s$ .   | p. 448 <input type="checkbox"/> |
|            |                        |               |   | During A/D conversion, if the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers are written or trigger is input, reconversion is carried out. However, if the stabilization time end timing conflicts with the writing to these registers, or if the stabilization time end timing conflicts with the trigger input, the stabilization time of 64 clocks is reinserted.<br>If a conflict occurs again with the reinserted stabilization time end timing, the stabilization time is reinserted. Therefore do not set the trigger input interval and control register write interval to 64 clocks or below.  | p. 448 <input type="checkbox"/> |
|            |                        |               | Conversion time selection in high-speed conversion mode (ADA0HS1 bit = 1) | Set as $2.6 \mu s \leq \text{conversion time} \leq 10.4 \mu s$ .   | p. 449 <input type="checkbox"/> |
|            |                        |               |   | In the high-speed conversion mode, rewriting of the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers and trigger input are prohibited during the stabilization time.  | p. 449 <input type="checkbox"/> |
|            |                        |               | ADA0M2 register   | When writing data to the ADA0M2 register in the following modes, stop the A/D conversion by clearing the ADA0M0.ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.<br><ul style="list-style-type: none"> <li>• Normal conversion mode</li> <li>• One-shot select mode/one-shot scan mode in high-speed conversion mode</li> </ul>   | p. 450 <input type="checkbox"/> |
|            |                        |               |   | Be sure to clear bits 7 to 2 to "0".   | p. 450 <input type="checkbox"/> |

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|--------------------------------|---|---------------------------------|-----------------------------|---|--------------------------------------|---------------------------------|
| Chapter 13                     | Soft  | A/D converter                   | ADA0S register              | When writing data to the ADA0S register in the following modes, stop the A/D conversion by clearing the AD0M0.ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.   | p. 451 <input type="checkbox"/>      |                                 |
|                                |   |                                 |                             | <ul style="list-style-type: none"> <li>• Normal conversion mode</li> <li>• One-shot select mode/one-shot scan mode in high-speed conversion mode</li> </ul>   |                                      |                                 |
|                                |   |                                 |                             |   | Be sure to clear bits 7 to 4 to "0". | p. 451 <input type="checkbox"/> |
|                                |   |                                 | ADA0CRn, ADA0CRnH registers | Accessing the ADA0CRn and ADA0CRnH registers is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> .   | p. 452 <input type="checkbox"/>      |                                 |
|                                |   |                                 |                             | <ul style="list-style-type: none"> <li>• When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>• When the CPU operates with the internal oscillation clock</li> </ul>  |                                      |                                 |
|                                |   |                                 |                             | A write operation to the ADA0M0 and ADA0S registers may cause the contents of the ADA0CRn register to become undefined. After the conversion, read the conversion result before writing to the ADA0M0 and ADA0S registers. Correct conversion results may not be read if a sequence other than the above is used.   | p. 452 <input type="checkbox"/>      |                                 |
|                                |   |                                 | ADA0PFM register            | In the select mode, the 8-bit data set to the ADA0PFT register is compared with the value of the ADA0CRnH register specified by the ADA0S register. If the result matches the condition specified by the ADA0PFC bit, the conversion result is stored in the ADA0CRn register and the INTAD signal is generated. If it does not match, however, the interrupt signal is not generated.  | p. 454 <input type="checkbox"/>      |                                 |
|                                |   |                                 |                             | In the scan mode, the 8-bit data set to the ADA0PFT register is compared with the contents of the ADA0CR0H register. If the result matches the condition specified by the ADA0PFC bit, the conversion result is stored in the ADA0CR0 register and the INTAD signal is generated. If it does not match, however, the INTAD signal is not generated. Regardless of the comparison result, the scan operation is continued and the conversion result is stored in the ADA0CRn register until the scan operation is completed. However, the INTAD signal is not generated after the scan operation has been completed. | p. 454 <input type="checkbox"/>      |                                 |
|                                |   |                                 |                             | When writing data to the ADA0PFM register in the following modes, stop the A/D conversion by clearing the AD0M0.ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1.   | p. 454 <input type="checkbox"/>      |                                 |
|                                |   |                                 |                             | <ul style="list-style-type: none"> <li>• Normal conversion mode</li> <li>• One-shot select mode/one-shot scan mode in high-speed conversion mode</li> </ul>   |                                      |                                 |
| ADA0PFT register               | When writing data to the ADA0PFT register in the following modes, stop the A/D conversion by clearing the AD0M0.ADA0CE bit to 0. After the data is written to the register, enable the A/D conversion again by setting the ADA0CE bit to 1. | p. 455 <input type="checkbox"/> |                             |   |                                      |                                 |
|                                | <ul style="list-style-type: none"> <li>• Normal conversion mode</li> <li>• One-shot select mode/one-shot scan mode in high-speed conversion mode</li> </ul>   |                                 |                             |   |                                      |                                 |
| External trigger mode          | To select the external trigger mode, set the high-speed conversion mode. Do not input a trigger during stabilization time that is inserted once after the A/D conversion operation is enabled (ADA0M0.ADA0CE bit = 1).                      | p. 458 <input type="checkbox"/> |                             |   |                                      |                                 |
| Timer trigger mode             | To select the timer trigger mode, set the high-speed conversion mode. Do not input a trigger during stabilization time that is inserted once after the A/D conversion operation is enabled (ADA0M0.ADA0CE bit = 1).                         | p. 459 <input type="checkbox"/> |                             |   |                                      |                                 |
| When A/D converter is not used | When the A/D converter is not used, the power consumption can be reduced by clearing the ADA0M0.ADA0CE bit to 0.  | p. 469 <input type="checkbox"/> |                             |   |                                      |                                 |

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|------------|----------------|------------------------|--|---|---------------------------------|
| Chapter 13 | Soft           | A/D converter          | Input range of ANI0 to ANI15 pins  | Input the voltage within the specified range to the ANI0 to ANI15 pins. If a voltage equal to or higher than $AV_{REF0}$ or equal to or lower than $AV_{SS}$ (even within the range of the absolute maximum ratings) is input to any of these pins, the conversion value of that channel is undefined, and the conversion value of the other channels may also be affected.   | p. 469 <input type="checkbox"/> |
|            |                |                        | Countermeasures against noise  | To maintain the 10-bit resolution, the ANI0 to ANI15 pins must be effectively protected from noise. The influence of noise increases as the output impedance of the analog input source becomes higher. To lower the noise, connecting an external capacitor as shown in Figure 13-12 is recommended.   | p. 469 <input type="checkbox"/> |
|            |                |                        | Alternate I/O  | The analog input pins (ANI0 to ANI15) function alternately as port pins. When selecting one of the ANI0 to ANI15 pins to execute A/D conversion, do not execute an instruction to read an input port or write to an output port during conversion as the conversion resolution may drop.<br>Also the conversion resolution may drop at the pins set as output port pins during A/D conversion if the output current fluctuates due to the effect of the external circuit connected to the port pins.<br>If a digital pulse is applied to a pin adjacent to the pin whose input signal is being converted, the A/D conversion value may not be as expected due to the influence of coupling noise. Therefore, do not apply a pulse to a pin adjacent to the pin undergoing A/D conversion. | p. 469 <input type="checkbox"/> |
|            |                |                        | Interrupt request flag (ADIF)  | The interrupt request flag (ADIF) is not cleared even if the contents of the ADA0S register are changed. If the analog input pin is changed during A/D conversion, therefore, the result of converting the previously selected analog input signal may be stored and the conversion end interrupt request flag may be set immediately before the ADA0S register is rewritten. If the ADIF flag is read immediately after the ADA0S register is rewritten, the ADIF flag may be set even though the A/D conversion of the newly selected analog input pin has not been completed. When A/D conversion is stopped, clear the ADIF flag before resuming conversion.  | p. 470 <input type="checkbox"/> |
|            | Hard           | AV <sub>REF0</sub> pin | (a) The AV <sub>REF0</sub> pin is used as the power supply pin of the A/D converter and also supplies power to the alternate-function ports. In an application where a backup power supply is used, be sure to supply the same voltage as V <sub>DD</sub> to the AV <sub>REF0</sub> pin as shown in Figure 13-15.<br>(b) The AV <sub>REF0</sub> pin is also used as the reference voltage pin of the A/D converter. If the source supplying power to the AV <sub>REF0</sub> pin has a high impedance or if the power supply has a low current supply capability, the reference voltage may fluctuate due to the current that flows during conversion (especially, immediately after the conversion operation enable bit ADA0CE has been set to 1). As a result, the conversion accuracy may drop. To avoid this, it is recommended to connect a capacitor across the AV <sub>REF0</sub> and AV <sub>SS</sub> pins to suppress the reference voltage fluctuation as shown in Figure 13-15.<br>(c) If the source supplying power to the AV <sub>REF0</sub> pin has a high DC resistance (for example, because of insertion of a diode), the voltage when conversion is enabled may be lower than the voltage when conversion is stopped, because of a voltage drop caused by the A/D conversion current. | p. 471 <input type="checkbox"/>   |                                 |
|            |                |                        | Reading ADA0CRn register   | When the ADA0M0 to ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register is written, the contents of the ADA0CRn register may be undefined. Read the conversion result after completion of conversion and before writing to the ADA0M0 to ADA0M2, ADA0S, ADA0PFM, or ADA0PFT register. Also, when an external/timer trigger is acknowledged, the contents of the ADA0CRn register may be undefined. Read the conversion result after completion of conversion and before the next external/timer trigger is acknowledged. The correct conversion result may not be read at a timing different from the above.   | p. 471 <input type="checkbox"/> |
|            |                | Soft                   |  |   |                                 |

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|------------|----------------|---------------|--|--|---------------------------------|
| Chapter 13 | Soft           | A/D converter | Standby mode                                     | <p>Because the A/D converter stops operating in the STOP mode, conversion results are invalid, so power consumption can be reduced. Operations are resumed after the STOP mode is released, but the A/D conversion results after the STOP mode is released are invalid. When using the A/D converter after the STOP mode is released, before setting the STOP mode or releasing the STOP mode, clear the ADA0M0.ADA0CE bit to 0 then set the ADA0CE bit to 1 after releasing the STOP mode.</p> <p>In the IDLE1, IDLE2, or subclock operation mode, operation continues. To lower the power consumption, therefore, clear the ADA0M0.ADA0CE bit to 0. In the IDLE1 and IDLE2 modes, since the analog input voltage value cannot be retained, the A/D conversion results after the IDLE1 and IDLE2 modes are released are invalid.</p> <p>The results of conversions before the IDLE1 and IDLE2 modes were set are valid.</p>   | p. 471 <input type="checkbox"/> |
|            |                |               | High-speed conversion mode                       | In the high-speed conversion mode, rewriting of the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers and trigger input during the stabilization time are prohibited.  | p. 472 <input type="checkbox"/> |
|            |                |               | A/D conversion time                              | <p>A/D conversion time is the total time of stabilization time, conversion time, wait time, and trigger response time (for details of these times, refer to Table 13-2 Conversion Time Selection in Normal Conversion Mode (ADA0HS1 Bit = 0) and Table 13-3 Conversion Time Selection in High-Speed Conversion Mode (ADA0HS1 Bit = 1)).</p> <p>During A/D conversion in the normal conversion mode, if the ADA0M0, ADA0M2, ADA0S, ADA0PFM, and ADA0PFT registers are written or a trigger is input, reconversion is carried out. However, if the stabilization time end timing conflicts with the writing to these registers, or if the stabilization time end timing conflicts with the trigger input, the stabilization time of 64 clocks is reinserted.</p> <p>If a conflict occurs again with the reinserted stabilization time end timing, the stabilization time is reinserted.</p> <p>Therefore do not set the trigger input interval and control register write interval to 64 clocks or below.</p>                                | p. 472 <input type="checkbox"/> |
|            |                |               | Variation of A/D conversion results              | The results of the A/D conversion may vary depending on the fluctuation of the supply voltage, or may be affected by noise. To reduce the variation, take counteractive measures with the program such as averaging the A/D conversion results.  | p. 472 <input type="checkbox"/> |
|            | Hard           |               | A/D conversion result hysteresis characteristics | <p>The successive comparison type A/D converter holds the analog input voltage in the internal sample &amp; hold capacitor and then performs A/D conversion. After the A/D conversion has finished, the analog input voltage remains in the internal sample &amp; hold capacitor. As a result, the following phenomena may occur.</p> <ul style="list-style-type: none"> <li>• When the same channel is used for A/D conversions, if the voltage is higher or lower than the previous A/D conversion, then hysteresis characteristics may appear where the conversion result is affected by the previous value. Thus, even if the conversion is performed at the same potential, the result may vary.</li> <li>• When switching the analog input channel, hysteresis characteristics may appear where the conversion result is affected by the previous channel value. This is because one A/D converter is used for the A/D conversions. Thus, even if the conversion is performed at the same potential, the result may vary.</li> </ul> | p. 472 <input type="checkbox"/> |
| Chapter 14 | Hard           | D/A converter | D/A converter                                    | DAC0 and DAC1 share the AV <sub>REF1</sub> pin.  | p. 477 <input type="checkbox"/> |
|            |                |               |  | DAC0 and DAC1 share the AV <sub>SS</sub> pin. The AV <sub>SS</sub> pin is also shared by the A/D converter.  | p. 477 <input type="checkbox"/> |

| Chapter                                      | Classification   | Function   | Details of Function      | Cautions  | Page                            |
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| Chapter 14                                   | Hard   | D/A converter  | DA0M register            | The output trigger in the real-time output mode (DA0MDn bit = 1) is as follows.<br><ul style="list-style-type: none"> <li>When n = 0: INTTP2CC0 signal (see <b>CHAPTER 7 16-BIT TIMER/EVENT COUNTER P (TMP)</b>)</li> <li>When n = 1: INTTP3CC0 signal (see <b>CHAPTER 7 16-BIT TIMER/EVENT COUNTER P (TMP)</b>)</li> </ul> | p. 478 <input type="checkbox"/> |
|  |  |  | DA0CS0, DA0CS1 registers | In the real-time output mode (DA0M.DA0MDn bit = 1), set the DA0CSn register before the INTTP2CC0/INTTP3CC0 signals are generated. D/A conversion starts when the INTTP2CC0/INTTP3CC0 signals are generated.   | p. 479 <input type="checkbox"/> |
|  |  |  | Cautions                 | Do not change the set value of the DA0CSn register while the trigger signal is being issued in the real-time output mode.   | p. 481 <input type="checkbox"/> |
|  | Before changing the operation mode, be sure to clear the DA0M.DA0CEn bit to 0.   |  |                          | p. 481 <input type="checkbox"/>   |                                 |
|  | When using one of the P10/AN00 and P11/AN01 pins as an I/O port and the other as a D/A output pin, do so in an application where the port I/O level does not change during D/A output.   |  |                          | p. 481 <input type="checkbox"/>   |                                 |
|  | Make sure that $AV_{REF0} = V_{DD} = AV_{REF1} = 3.0$ to $3.6$ V. If this range is exceeded, the operation is not guaranteed.  |  |                          | p. 481 <input type="checkbox"/>   |                                 |
|  | Apply power to $AV_{REF1}$ at the same timing as $AV_{REF0}$ .   |  |                          | p. 481 <input type="checkbox"/>   |                                 |
|  | No current can be output from the ANOn pin (n = 0, 1) because the output impedance of the D/A converter is high. When connecting a resistor of 2 MΩ or less, insert a JFET input operational amplifier between the resistor and the ANOn pin.  |  |                          | p. 481 <input type="checkbox"/>   |                                 |
|  | Because the D/A converter stops operation in the STOP mode, the ANO0 and ANO1 pins go into a highimpedance state, and the power consumption can be reduced.<br>In the IDLE1, IDLE2, or subclock operation mode, however, the operation continues. To lower the power consumption, therefore, clear the DA0M.DA0CEn bit to 0. |  |                          | p. 481 <input type="checkbox"/>   |                                 |
|  | Chapter 15   |  | Soft                     | Asynchronous serial interface A (UARTA)   | CSIB4 and UARTA0 mode switching |
| UARTA2 and I <sup>2</sup> C00 mode switching |  | The transmit/receive operation of UARTA2 and I <sup>2</sup> C00 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.   |                          |   | p. 483 <input type="checkbox"/> |
| UARTA1 and I <sup>2</sup> C02 mode switching |  | The transmit/receive operation of UARTA1 and I <sup>2</sup> C02 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.   |                          |   | p. 484 <input type="checkbox"/> |
| UAnOPT0 register                             |  | Do not set the UAnSRT and UAnSTT bits (to 1) during SBF reception (UAnSRF bit = 1).  |                          |   | p. 490 <input type="checkbox"/> |
| SBF reception                                |  | If SBF is transmitted during a data reception, a framing error occurs.   |                          |   | p. 500 <input type="checkbox"/> |
|  |  | Do not set the SBF reception trigger bit (UAnSRT) and SBF transmission trigger bit (UAnSTT) to 1 during an SBF reception (UAnSRF = 1).   |                          |   | p. 500 <input type="checkbox"/> |
| Continuous transmission                      |  | When initializing transmissions during the execution of continuous transmissions, make sure that the UAnSTR.UAnTSF bit is 0, then perform the initialization. Transmit data that is initialized when the UAnTSF bit is 1 cannot be guaranteed. |                          |   | p. 503 <input type="checkbox"/> |
| UART reception                               |  | Be sure to read the UAnRX register even when a reception error occurs. If the UAnRX register is not read, an overrun error occurs during reception of the next data, and reception errors continue occurring indefinitely.                     |                          |   | p. 505 <input type="checkbox"/> |
|  |  | The operation during reception is performed assuming that there is only one stop bit. A second stop bit is ignored.  |                          |   | p. 505 <input type="checkbox"/> |



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| Chapter 15 | Soft           | Asynchronous serial interface A (UARTA) | UART reception   | When reception is completed, read the UAnRX register after the reception complete interrupt request signal (INTUAnR) has been generated, and clear the UAnPWR or UAnRXE bit to 0. If the UAnPWR or UAnRXE bit is cleared to 0 before the INTUAnR signal is generated, the read value of the UAnRX register cannot be guaranteed.  | p. 505 <input type="checkbox"/> |
|            |                |   |  | If receive completion processing (INTUAnR signal generation) of UARTAn and the UAnPWR bit = 0 or UAnRXE bit = 0 conflict, the INTUAnR signal may be generated in spite of these being no data stored in the UAnRX register. To complete reception without waiting INTUAnR signal generation, be sure to clear (0) the interrupt request flag (UAnRIF) of the UAnRIC register, after setting (1) the interrupt mask flag (UAnRMK) of the interrupt control register (UAnRIC) and then set (1) the UAnPWR bit = 0 or UAnRXE bit = 0.                                      | p. 505 <input type="checkbox"/> |
|            |                |   | Reception errors   | When an INTUAnR signal is generated, the UAnSTR register must be read to check for errors.  | p. 506 <input type="checkbox"/> |
|            |                |   |  | If a receive error interrupt occurs during continuous reception, read the contents of the UAnSTR register must be read before the next reception is completed, then perform error processing.   | p. 507 <input type="checkbox"/> |
|            |                |   | LIN function   | When using the LIN function, fix the UAnPS1 and UAnPS0 bits of the UAnCTL0 register to 00.  | p. 508 <input type="checkbox"/> |
|            |                |   | UAnCTL1 register   | Clear the UAnCTL0.UAnPWR bit to 0 before rewriting the UAnCTL1 register.  | p. 511 <input type="checkbox"/> |
|            |                |   | UAnCTL2 register   | Clear the UAnCTL0.UAnPWR bit to 0 or clear the UAnTXE and UAnRXE bits to 00 before rewriting the UAnCTL2 register.  | p. 512 <input type="checkbox"/> |
|            |                |   | Baud rate error  | The baud rate error during transmission must be within the error tolerance on the receiving side.   | p. 513 <input type="checkbox"/> |
|            |                |   |  | The baud rate error during reception must satisfy the range indicated in (5) Allowable baud rate range during reception.  | p. 513 <input type="checkbox"/> |
|            |                |   | Allowable baud rate range during reception                                   | The baud rate error during reception must be set within the allowable error range using the following equation.   | p. 515 <input type="checkbox"/> |
|            |                |   | When the clock supply to UARTAn is stopped                                   | When the clock supply to UARTAn is stopped (for example, in IDLE1, IDLE2, or STOP mode), the operation stops with each register retaining the value it had immediately before the clock supply was stopped. The TXDAn pin output also holds and outputs the value it had immediately before the clock supply was stopped. However, the operation is not guaranteed after the clock supply is resumed. Therefore, after the clock supply is resumed, the circuits should be initialized by setting the UAnCTL0.UAnPWR, UAnCTL0.UAnRXEn, and UAnCTL0.UAnTXEn bits to 000. | p. 518 <input type="checkbox"/> |
|            |                |   | RXDA1 pin KR7 pin  | The RXDA1 and KR7 pins must not be used at the same time. To use the RXDA1 pin, do not use the KR7 pin. To use the KR7 pin, do not use the RXDA1 pin (it is recommended to set the PFC91 bit to 1 and clear PFCE91 bit to 0).   | p. 518 <input type="checkbox"/> |
|            |                |   | Performing the transfer of transmit data and receive data using DMA transfer | In UARTAn, the interrupt caused by a communication error does not occur. When performing the transfer of transmit data and receive data using DMA transfer, error processing cannot be performed even if errors (parity, overrun, framing) occur during transfer. Either read the UAnSTR register after DMA transfer has been completed to make sure that there are no errors, or read the UAnSTR register during communication to check for errors.  | p. 518 <input type="checkbox"/> |

| Chapter                    | Classification   | Function                                 | Details of Function                                       | Cautions  | Page                                  |
|----------------------------|--|--|---|---|---------------------------------------|
| Chapter 15                 | Soft   | Asynchronous serial interface A (UARTA)  | Start up UARTAn   | Start up the UARTAn in the following sequence.<br><1> Set the UAnCTL0.UAnPWR bit to 1.<br><2> Set the ports.<br><3> Set the UAnCTL0.UAnTXE bit to 1, UAnCTL0.UAnRXE bit to 1.   | p. 518 <input type="checkbox"/>       |
|                            |  |  | Stop UARTAn   | Stop the UARTAn in the following sequence.<br><1> Set the UAnCTL0.UAnTXE bit to 0, UAnCTL0.UAnRXE bit to 0.<br><2> Set the ports and set the UAnCTL0.UAnPWR bit to 0 (it is not a problem if port setting is not changed).  | p. 518 <input type="checkbox"/>       |
|                            |  |  | Transmit mode   | In transmit mode (UAnCTL0.UAnPWR bit = 1 and UAnCTL0.UAnTXE bit = 1), do not overwrite the same value to the UAnTX register by software because transmission starts by writing to this register. To transmit the same value continuously, overwrite the same value.   | p. 518 <input type="checkbox"/>       |
|                            |  |  | Continuous transmission                                   | In continuous transmission, the communication rate from the stop bit to the next start bit is extended 2 base clocks more than usual. However, the reception side initializes the timing by detecting the start bit, so the reception result is not affected.   | p. 518 <input type="checkbox"/>       |
| Chapter 16                 | Soft   | 3-wire variable-length serial I/O (CSIB) | CSIB4 and UARTA0 mode switching                           | The transmit/receive operation of CSIB4 and UARTA0 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.   | p. 519 <input type="checkbox"/>       |
|                            |  |  | CSIB0 and I <sup>2</sup> C01 mode switching               | The transmit/receive operation of CSIB0 and I <sup>2</sup> C01 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.   | p. 520 <input type="checkbox"/>       |
|                            |  |  | CBnCTL0 register  | To forcibly suspend transmission/reception, clear the CBnPWR bit to 0 instead of the CBnRXE and CBnTXE bits. At this time, the clock output is stopped.   | p. 523 <input type="checkbox"/>       |
|                            |  |  |   | Be sure to clear bits 3 and 2 to "0".   | p. 525 <input type="checkbox"/>       |
|                            |  |  | CBnCTL1 register  | The CBnCTL1 register can be rewritten only when the CBnCTL0.CBnPWR bit = 0.   | p. 526 <input type="checkbox"/>       |
|                            |  |  |   | Set the communication clock (f <sub>CLK</sub> ) to 8 MHz or lower.  | p. 526 <input type="checkbox"/>       |
|                            |  |  | CBnCTL2 register  | The CBnCTL2 register can be rewritten only when the CBnCTL0.CBnPWR bit = 0 or when both the CBnTXE and CBnRXE bits = 0.   | p. 527 <input type="checkbox"/>       |
|                            |  |  | Continuous transfer mode (master mode, transmission mode) | In continuous transmission mode, the reception completion interrupt request signal (INTCBnR) is not generated.  | p. 544 <input type="checkbox"/>       |
|                            |  |  | Continuous transfer mode (slave mode, transmission mode)  | In continuous transmission mode, the reception completion interrupt request signal (INTCBnR) is not generated.  | p. 553 <input type="checkbox"/>       |
|                            |  |  | Clock timing  | In single transfer mode, writing to the CBnTX register with the CBnTSF bit set to 1 is ignored. This has no influence on the operation during transfer. For example, if the next data is written to the CBnTX register when DMA is started by generating the INTCBnR signal, the written data is not transferred because the CBnTSF bit is set to 1. Use the continuous transfer mode, not the single transfer mode, for such applications. | pp. 562, 563 <input type="checkbox"/> |
| PRSM1 to PRSM3 registers   | Do not rewrite the PRSMm register during operation.              | p. 565 <input type="checkbox"/>          |   |   |                                       |
|                            | Set the PRSMm register before setting the BGCEm bit to 1.        | p. 565 <input type="checkbox"/>          |   |   |                                       |
| PRSCM1 to PRSCM3 registers | Do not rewrite the PRSCMm register during operation.             | p. 566 <input type="checkbox"/>          |   |   |                                       |
|                            | Set the PRSCMm register before setting the PRSMm.BGCEm bit to 1. | p. 566 <input type="checkbox"/>          |   |   |                                       |

| Chapter    | Chapter Classification | Function                                 | Details of Function   | Caution   | Page                            |
|------------|------------------------|--|---|---|---------------------------------|
| Chapter 16 | Soft                   | 3-wire variable-length serial I/O (CSIB) | Baud rate generation  | Set f <sub>BRGM</sub> to 8 MHz or lower.  | p. 566 <input type="checkbox"/> |
|            |                        |  | When transferring transmit data and receive data using DMA transfer | When transferring transmit data and receive data using DMA transfer, error processing cannot be performed even if an overrun error occurs during serial transfer. Check that the no overrun error has occurred by reading the CBnSTR.CBnOVE bit after DMA transfer has been completed.  | p. 567 <input type="checkbox"/> |
|            |                        |  | CBnCTL0 register<br>CBnCTL1 register<br>CBnCTL2 register            | In regards to registers that are forbidden from being rewritten during operations (CBnCTL0.CBnPWR bit = 1), if rewriting has been carried out by mistake during operations, set the CBnCTL0.CBnPWR bit to 0 once, then initialize CSIBn. Registers to which rewriting during operation are prohibited are shown below. <ul style="list-style-type: none"> <li>• CBnCTL0 register: CBnTXE, CBnRXE, CBnDIR, CBnTMS bits</li> <li>• CBnCTL1 register: CBnCKP, CBnDAP, CBnCKS2 to CBnCKS0 bits</li> <li>• CBnCTL2 register: CBnCL3 to CBnCL0 bits</li> </ul>  | p. 567 <input type="checkbox"/> |
|            |                        |  | Communication types 2, 4  | In communication type 2 and 4 (CBnCTL1.CBnDAP bit = 1), the CBnSTR.CBnTSF bit is cleared half a SCKBn clock after occurrence of a reception complete interrupt (INTCBnR).<br>In the single transfer mode, writing the next transmit data is ignored during communication (CBnTSF bit = 1), and the next communication is not started. Also if reception-only communication (CBnCTL0.CBnTXE bit = 0, CBnCTL0.CBnRXE bit = 1) is set, the next communication is not started even if the receive data is read during communication (CBnTSF bit = 1).<br>Therefore, when using the single transfer mode with communication type 2 or 4 (CBnDAP bit = 1), pay particular attention to the following. <ul style="list-style-type: none"> <li>• To start the next transmission, confirm that CBnTSF bit = 0 and then write the transmit data to the CBnTX register.</li> <li>• To perform the next reception continuously when reception-only communication (CBnTXE bit = 0, CBnRXE bit = 1) is set, confirm that CBnTSF bit = 0 and then read the CBnRX register.</li> </ul> Or, use the continuous transfer mode instead of the single transfer mode. Use of the continuous transfer mode is recommend especially for using DMA. | p. 567 <input type="checkbox"/> |
| Chapter 17 | Soft                   | I <sup>2</sup> C bus                     | I <sup>2</sup> C bus  | To use the I <sup>2</sup> C bus function, use the P38/SDA00, P39/SCL00, P40/SDA01, P41/SCL01, P90/SDA02, and P91/SCL02 pins as the serial transmit/receive data I/O pins (SDA00 to SDA02) and serial clock I/O pins (SCL00 to SCL02), respectively, and set them to N-ch open-drain output.   | p. 568 <input type="checkbox"/> |
|            |                        |  | UARTA2 and I <sup>2</sup> C00 mode switching                        | The transmit/receive operation of UARTA2 and I <sup>2</sup> C00 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.  | p. 568 <input type="checkbox"/> |
|            |                        |  | CSIB0 and I <sup>2</sup> C01 mode switching                         | The transmit/receive operation of CSIB0 and I <sup>2</sup> C01 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.   | p. 569 <input type="checkbox"/> |
|            |                        |  | UARTA1 and I <sup>2</sup> C02 mode switching                        | The transmit/receive operation of UARTA1 and I <sup>2</sup> C02 is not guaranteed if these functions are switched during transmission or reception. Be sure to disable the one that is not used.  | p. 570 <input type="checkbox"/> |
|            |                        |  | IICC0 to IICC2 registers  | If the I <sup>2</sup> Cn operation is enabled (IICEn bit = 1) when the SCL0n line is high level and the SDA0n line is low level, the start condition is detected immediately. To avoid this, after enabling the I <sup>2</sup> Cn operation, immediately set the LRELn bit to 1 with a bit manipulation instruction.  | p. 577 <input type="checkbox"/> |

| Chapter    | Chapter Classification | Function             | Details of Function  | Cautions  | Page                            |
|------------|------------------------|----------------------|--|---|---------------------------------|
| Chapter 17 | Soft                   | I <sup>2</sup> C bus | IICC0 to IICC2 registers   | Set the SPTn bit to 1 only in master mode. However, when the IICRSVn bit is 0, the SPTn bit must be set to 1 and a stop condition generated before the first stop condition is detected following the switch to the operation enabled status. For details, see <b>17.15 Cautions</b> .  | p. 580 <input type="checkbox"/> |
|            |                        |                      |  | When the TRCn bit = 1, the WRELn bit is set to 1 during the ninth clock and the wait state is canceled, after which the TRCn bit is cleared to 0 and the SDA0n line is set to high impedance.   | p. 580 <input type="checkbox"/> |
|            |                        |                      | IICS0 to IICS2 registers   | Accessing the IICSn register is prohibited in the following statuses. For details, see <b>3.4.8 (2) Accessing specific on-chip peripheral I/O registers</b> .<br><ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul>   | p. 581 <input type="checkbox"/> |
|            |                        |                      |  | The TRCn bit is cleared to 0 and SDA0n line becomes high impedance when the WRELn bit is set to 1 and the wait state is canceled to 0 at the ninth clock by TRCn bit = 1.   | p. 582 <input type="checkbox"/> |
|            |                        |                      | IICF0 to IICF2 registers   | Write the STCENn bit only when operation is stopped (IICEn bit = 0).  | p. 585 <input type="checkbox"/> |
|            |                        |                      |  | When the STCENn bit = 1, the bus released status (IICBSYn bit = 0) is recognized regardless of the actual bus status immediately after the I <sup>2</sup> Cn bus operation is enabled. Therefore, to issue the first start condition (STTn bit = 1), it is necessary to confirm that the bus has been released, so as to not disturb other communications.  | p. 585 <input type="checkbox"/> |
|            |                        |                      |  | Write the IICRSVn bit only when operation is stopped (IICEn bit = 0).   | p. 585 <input type="checkbox"/> |
|            |                        |                      | IICCL0 to IICCL2 registers   | Be sure to clear bits 7 and 6 to "0".   | p. 586 <input type="checkbox"/> |
|            |                        |                      | I <sup>2</sup> C0n transfer clock setting method                         | Since the selection clock is f <sub>xx</sub> regardless of the value set to the OCKS0 register, clear the OCKS0 register to 00H (I <sup>2</sup> C division clock stopped status).   | p. 588 <input type="checkbox"/> |
|            |                        |                      |  | Since the selection clock is f <sub>xx</sub> regardless of the value set to the OCKS1 register, clear the OCKS1 register to 00H (I <sup>2</sup> C division clock stopped status).   | p. 589 <input type="checkbox"/> |
|            |                        |                      | Start condition  | When the IICn.IICEn bit of the V850ES/JJ3 is set to 1 while communications with other devices are in progress, the start condition may be detected depending on the status of the communication line. Be sure to set the IICn.IICEn bit to 1 when the SCL0n and SDA0n lines are high level.   | p. 593 <input type="checkbox"/> |
|            |                        |                      | Status during arbitration and interrupt request signal generation timing | When the IICn.WTIMn bit = 1, an INTIICn signal occurs at the falling edge of the ninth clock. When the WTIMn bit = 0 and the extension code's slave address is received, an INTIICn signal occurs at the falling edge of the eighth clock (n = 0 to 2).   | p. 625 <input type="checkbox"/> |
|            |                        |                      |  | When there is a possibility that arbitration will occur, set the SPIEn bit to 1 for master device operation (n = 0 to 2).   | p. 625 <input type="checkbox"/> |
|            |                        |                      | When IICFn.STCENn bit = 0  | Immediately after the I <sup>2</sup> C0n operation is enabled, the bus communication status (IICFn.IICBSYn bit = 1) is recognized regardless of the actual bus status. To execute master communication in the status where a stop condition has not been detected, generate a stop condition and then release the bus before starting the master communication.<br>Use the following sequence for generating a stop condition.<br><1> Set the IICCLn register.<br><2> Set the IICn.IICEn bit.<br><3> Set the IICn.SPTn bit. | p. 631 <input type="checkbox"/> |
|            |                        |                      | When IICFn.STCENn bit = 1  | Immediately after I <sup>2</sup> C0n operation is enabled, the bus released status (IICBSYn bit = 0) is recognized regardless of the actual bus status. To generate the first start condition (IICn.STTn bit = 1), it is necessary to confirm that the bus has been released, so as to not disturb other communications.  | p. 631 <input type="checkbox"/> |

| Chapter                  | Classification   | Function                                | Details of Function                                    | Cautions  | Page                                    |
|--------------------------|--|---|--|---|---|
| Chapter 17               | Soft   | I <sup>2</sup> C bus                    | When communication among other devices are in progress | When the IICn.IICEn bit of the V850ES/JJ3 is set to 1 while communications among other devices are in progress, the start condition may be detected depending on the status of the communication line. Be sure to set the IICn.IICEn bit to 1 when the SCL0n and SDA0n lines are high level.  | p. 631 <input type="checkbox"/>         |
|                          |  |   | Operation enable                                       | Determine the operation clock frequency by the IICCLn, IICXn, and OCKSm registers before enabling the operation (IICn.IICEn bit = 1). To change the operation clock frequency, clear the IICn.IICEn bit to 0 once.  | p. 631 <input type="checkbox"/>         |
|                          |  |   | IICn.STTn, SPTn bits                                   | After the IICn.STTn and IICn.SPTn bits have been set to 1, they must not be re-set without being cleared to 0 first.  | p. 631 <input type="checkbox"/>         |
|                          |  |   | Transmission reservation                               | If transmission has been reserved, set the IICn.SPIEn bit to 1 so that an interrupt request is generated by the detection of a stop condition. After an interrupt request has been generated, the wait state will be released by writing communication data to I <sup>2</sup> Cn, then transferring will begin. If an interrupt is not generated by the detection of a stop condition, transmission will halt in the wait state because an interrupt request was not generated. However, it is not necessary to set the SPIEn bit to 1 for the software to detect the IICn.MSTSn bit. | p. 631 <input type="checkbox"/>         |
|                          |  |   | Master operation in single master system               | Release the I <sup>2</sup> C0n bus (SCL0n, SDA0n pins = high level) in conformity with the specifications of the product in communication.<br>For example, when the EEPROMTM outputs a low level to the SDA0n pin, set the SCL0n pin to the output port and output clock pulses from that output port until when the SDA0n pin is constantly high level.  | p. 633 <input type="checkbox"/>         |
|                          |  |   | Master operation in multimaster system                 | Confirm that the bus release status (IICCLn.CLDn bit = 1, IICCLn.DADn bit = 1) has been maintained for a certain period (1 frame, for example). When the SDA0n pin is constantly low level, determine whether to release the I <sup>2</sup> C0n bus (SCL0n, SDA0n pins = high level) by referring to the specifications of the product in communication.  | p. 634 <input type="checkbox"/>         |
|                          |  |   |  | Conform the transmission and reception formats to the specifications of the product in communication.   | p. 636 <input type="checkbox"/>         |
|                          |  |   |  | When using the V850ES/JJ3 as the master in the multimaster system, read the IICn.MSTSn bit for each INTIICn interrupt occurrence to confirm the arbitration result.   | p. 636 <input type="checkbox"/>         |
|                          |  |   |  | When using the V850ES/JJ3 as the slave in the multimaster system, confirm the status using the IICn and IICFn registers for each INTIICn interrupt occurrence to determine the next processing.   | p. 636 <input type="checkbox"/>         |
|                          |  |   | Slave wait cancellation                                | To cancel slave wait, write FFH to IICn or set WRELn.   | pp. 641 to 643 <input type="checkbox"/> |
| Master wait cancellation | To cancel master wait, write FFH to IICn or set WRELn. | pp. 644 to 646 <input type="checkbox"/> |  |   |   |
| Chapter 18               | Soft   | DMA function (DMA controller)           | DSA0 to DSA3 registers                                 | Be sure to clear bits 14 to 10 of the DSAnH register to 0.<br>Set the DSAnH and DSAnL registers at the following timing when DMA transfer is disabled (DCHCn.Enn bit = 0). <ul style="list-style-type: none"> <li>• Period from after reset to start of first DMA transfer</li> <li>• Period from after channel initialization by DCHCn.INITn bit to start of DMA transfer</li> <li>• Period from after completion of DMA transfer (DCHCn.TCn bit = 1) to start of the next DMA transfer</li> </ul>   | p. 649 <input type="checkbox"/>         |
|                          |  |   |  |   | p. 649 <input type="checkbox"/>         |

| Chapter    | Classification | Function                      | Details of Function      | Cautions  | Page                            |
|------------|----------------|-------------------------------|--------------------------|---|---------------------------------|
| Chapter 18 | Soft           | DMA function (DMA controller) | DSA0 to DSA3 registers   | When the value of the DSAn register is read, two 16-bit registers, DSAnH and DSAnL, are read. If reading and updating conflict, the value being updated may be read (see <b>18.13 Cautions</b> ).   | p. 649 <input type="checkbox"/> |
|            |                |                               |                          | Following reset, set the DSAnH, DSAnL, DDAnH, DDAnL, and DBCn registers before starting DMA transfer. If these registers are not set, the operation when DMA transfer is started is not guaranteed.   | p. 649 <input type="checkbox"/> |
|            |                |                               | DDA0 to DDA3 registers   | Be sure to clear bits 14 to 10 of the DDAnH register to 0.  | p. 650 <input type="checkbox"/> |
|            |                |                               |                          | Set the DDAnH and DDAnL registers at the following timing when DMA transfer is disabled (DCHCn.Enn bit = 0). <ul style="list-style-type: none"> <li>• Period from after reset to start of first DMA transfer</li> <li>• Period from after channel initialization by DCHCn.INITn bit to start of DMA transfer</li> <li>• Period from after completion of DMA transfer (DCHCn.TCn bit = 1) to start of the next DMA transfer</li> </ul> | p. 650 <input type="checkbox"/> |
|            |                |                               |                          | When the value of the DDAn register is read, two 16-bit registers, DDAnH and DDAnL, are read. If reading and updating conflict, a value being updated may be read (see <b>18.13 Cautions</b> ).   | p. 650 <input type="checkbox"/> |
|            |                |                               |                          | Following reset, set the DSAnH, DSAnL, DDAnH, DDAnL, and DBCn registers before starting DMA transfer. If these registers are not set, the operation when DMA transfer is started is not guaranteed.   | p. 650 <input type="checkbox"/> |
|            |                |                               | DBC0 to DBC3 registers   | Set the DBCn register at the following timing when DMA transfer is disabled (DCHCn.Enn bit = 0). <ul style="list-style-type: none"> <li>• Period from after reset to start of first DMA transfer</li> <li>• Period from after channel initialization by DCHCn.INITn bit to start of DMA transfer</li> <li>• Period from after completion of DMA transfer (DCHCn.TCn bit = 1) to start of the next DMA transfer</li> </ul>             | p. 651 <input type="checkbox"/> |
|            |                |                               |                          | Following reset, set the DSAnH, DSAnL, DDAnH, DDAnL, and DBCn registers before starting DMA transfer. If these registers are not set, the operation when DMA transfer is started is not guaranteed.   | p. 651 <input type="checkbox"/> |
|            |                |                               | DADC0 to DADC3 registers | Be sure to clear bits 15, 13 to 8, and 3 to 0 of the DADCn register to "0".   | p. 652 <input type="checkbox"/> |
|            |                |                               |                          | Set the DADCn register at the following timing when DMA transfer is disabled (DCHCn.Enn bit = 0). <ul style="list-style-type: none"> <li>• Period from after reset to start of first DMA transfer</li> <li>• Period from after channel initialization by DCHCn.INITn bit to start of DMA transfer</li> <li>• Period from after completion of DMA transfer (DCHCn.TCn bit = 1) to start of the next DMA transfer</li> </ul>            | p. 652 <input type="checkbox"/> |
|            |                |                               |                          | The DS0 bit specifies the size of the transfer data, and does not control bus sizing. If 8-bit data (DS0 bit = 0) is set, therefore, the lower data bus is not always used.   | p. 652 <input type="checkbox"/> |
|            |                |                               |                          | If the transfer data size is set to 16 bits (DS0 bit = 1), transfer cannot be started from an odd address. Transfer is always started from an address with the first bit of the lower address aligned to 0.   | p. 652 <input type="checkbox"/> |
|            |                |                               |                          | If DMA transfer is executed on an on-chip peripheral I/O register (as the transfer source or destination), be sure to specify the same transfer size as the register size. For example, to execute DMA transfer on an 8-bit register, be sure to specify 8-bit transfer.  | p. 652 <input type="checkbox"/> |

| Chapter    | Classification | Function                      | Details of Function               | Cautions   | Page   |
|------------|----------------|-------------------------------|-----------------------------------|--|--|
| Chapter 18 | Soft           | DMA function (DMA controller) | DCHC0 to DCHC3 registers          | The TCn bit is read-only.  | p. 653 <input type="checkbox"/>  |
|            |                |                               |                                   | The INITn and STGn bits are write-only.  | p. 653 <input type="checkbox"/>  |
|            |                |                               |                                   | Be sure to clear bits 6 to 3 of the DCHCn register to 0.   | p. 653 <input type="checkbox"/>  |
|            |                |                               |                                   | When DMA transfer is completed (when a terminal count is generated), the Enn bit is cleared to 0 and then the TCn bit is set to 1. If the DCHCn register is read while its bits are being updated, a value indicating "transfer not completed and transfer is disabled" (TCn bit = 0 and Enn bit = 0) may be read.   | p. 653 <input type="checkbox"/>  |
|            |                |                               | DTFR0 to DTFR3 registers          | Do not set the DFn bit to 1 by software. Write 0 to this bit to clear a DMA transfer request if an interrupt that is specified as the cause of starting DMA transfer occurs while DMA transfer is disabled.  | p. 654 <input type="checkbox"/>  |
|            |                |                               |                                   | Set the IFCn5 to IFCn0 bits at the following timing when DMA transfer is disabled (DCHCn.Enn bit = 0). <ul style="list-style-type: none"> <li>Period from after reset to start of first DMA transfer</li> <li>Period from after channel initialization by DCHCn.INITn bit to start of DMA transfer</li> <li>Period from after completion of DMA transfer (DCHCn.TCn bit = 1) to start of the next DMA transfer</li> </ul>  | p. 654 <input type="checkbox"/>  |
|            |                |                               |                                   | An interrupt request that is generated in the standby mode (IDEL1, IDLE2, STOP, or sub-IDLE mode) does not start the DMA transfer cycle (nor is the DFn bit set to 1).   | p. 654 <input type="checkbox"/>  |
|            |                |                               |                                   | If a DMA start factor is selected by the IFCn5 to IFCn0 bits, the DFn bit is set to 1 when an interrupt occurs from the selected on-chip peripheral I/O, regardless of whether the DMA transfer is enabled or disabled. If DMA is enabled in this status, DMA transfer is immediately started.   | p. 654 <input type="checkbox"/>  |
|            |                |                               |                                   | Relationship between transfer targets  | The operation is not guaranteed for combinations of transfer destination and source marked with "x" in Table 18-2. |
|            |                |                               | Request by on-chip peripheral I/O | Two start factors (software trigger and hardware trigger) cannot be used for one DMA channel. If two start factors are simultaneously generated for one DMA channel, only one of them is valid. The start factor that is valid cannot be identified.   | p. 659 <input type="checkbox"/>  |
|            |                |                               |                                   | A new transfer request that is generated after the preceding DMA transfer request was generated or in the preceding DMA transfer cycle is ignored (cleared).   | p. 659 <input type="checkbox"/>  |
|            |                |                               |                                   | The transfer request interval of the same DMA channel varies depending on the setting of bus wait in the DMA transfer cycle, the start status of the other channels, or the external bus hold request. In particular, as described in Caution 2, a new transfer request that is generated for the same channel before the DMA transfer cycle or during the DMA transfer cycle is ignored. Therefore, the transfer request intervals for the same DMA channel must be sufficiently separated by the system. When the software trigger is used, completion of the DMA transfer cycle that was generated before can be checked by updating the DBCn register. | p. 659 <input type="checkbox"/>  |
|            |                |                               | Caution for VSWC register         | When using the DMAC, be sure to set an appropriate value, in accordance with the operating frequency, to the VSWC register.<br>When the default value (77H) of the VSWC register is used, or if an inappropriate value is set to the VSWC register, the operation is not correctly performed (for details of the VSWC register, see 3.4.8 (1) (a) <b>System wait control register (VSWC)</b> ).  | p. 665 <input type="checkbox"/>  |

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| Chapter 18 | Soft           | DMA function (DMA controller)  | Caution for DMA transfer executed on internal RAM   | <p>When executing the following instructions located in the internal RAM, do not execute a DMA transfer that transfers data to/from the internal RAM (transfer source/destination), because the CPU may not operate correctly afterward.</p> <ul style="list-style-type: none"> <li>• Bit manipulation instruction located in internal RAM (SET1, CLR1, or NOT1)</li> <li>• Data access instruction to misaligned address located in internal RAM</li> </ul> <p>Conversely, when executing a DMA transfer to transfer data to/from the internal RAM (transfer source/destination), do not execute the above two instructions.</p>  | p. 665 <input type="checkbox"/> |
|            |                | Caution for reading DCHCn.TCn bit                                    | The TCn bit is cleared to 0 when it is read, but it is not automatically cleared even if it is read at a specific timing. To accurately clear the TCn bit, add the following processing.                                  | <p>(a) When waiting for completion of DMA transfer by polling TCn bit<br/>Confirm that the TCn bit has been set to 1 (after TCn bit = 1 is read), and then read the TCn bit three more times.</p> <p>(b) When reading TCn bit in interrupt servicing routine<br/>Execute reading the TCn bit three times.</p>  | p. 665 <input type="checkbox"/> |
|            |                | DMA transfer initialization procedure (setting DCHCn.INITn bit to 1) | Even if the INITn bit is set to 1 when the channel executing DMA transfer is to be initialized, the channel may not be initialized. To accurately initialize the channel, execute either of the following two procedures. | <p>(a) Temporarily stop transfer of all DMA channels<br/>Initialize the channel executing DMA transfer using the procedure in &lt;1&gt; to &lt;7&gt; below.</p> <p>Note, however, that TCn bit is cleared to 0 when step &lt;5&gt; is executed. Make sure that the other processing programs do not expect that the TCn bit is 1.</p> <p>&lt;1&gt; Disable interrupts (DI).</p> <p>&lt;2&gt; Read the DCHCn.Enn bit of DMA channels other than the one to be forcibly terminated, and transfer the value to a general-purpose register.</p> <p>&lt;3&gt; Clear the Enn bit of the DMA channels used (including the channel to be forcibly terminated) to 0. To clear the Enn bit of the last DMA channel, execute the clear instruction twice. If the target of DMA transfer (transfer source/destination) is the internal RAM, execute the instruction three times.</p> <p>Example: Execute instructions in the following order if channels 0, 1, and 2 are used (if the target of transfer is not the internal RAM).</p> <ul style="list-style-type: none"> <li>• Clear DHC0.E00 bit to 0.</li> <li>• Clear DHC1.E11 bit to 0.</li> <li>• Clear DHC2.E22 bit to 0.</li> <li>• Clear DHC2.E22 bit to 0 again.</li> </ul> <p>&lt;4&gt; Set the INITn bit of the channel to be forcibly terminated to 1.</p> <p>&lt;5&gt; Read the TCn bit of each channel not to be forcibly terminated. If both the TCn bit and the Enn bit read in &lt;2&gt; are 1 (logical product (AND) is 1), clear the saved Enn bit to 0.</p> <p>&lt;6&gt; After the operation in &lt;5&gt;, write the Enn bit value to the DHCn register.</p> <p>&lt;7&gt; Enable interrupts (EI).</p> | p. 666 <input type="checkbox"/> |
|            |                |  | Be sure to execute step <5> above to prevent illegal setting of the Enn bit of the channels whose DMA transfer has been normally completed between <2> and <3>.   |  | p. 666 <input type="checkbox"/> |
|            |                |  | (b) Repeatedly execute setting INITn bit until transfer is forcibly terminated correctly  | <p>&lt;1&gt; Suppress a request from the DMA request source of the channel to be forcibly terminated (stop operation of the on-chip peripheral I/O).</p> <p>&lt;2&gt; Check that the DMA transfer request of the channel to be forcibly terminated is not held pending, by using the DTFRn.DFn bit. If a DMA transfer request is held pending, wait until execution of the pending request is completed.</p> <p>&lt;3&gt; When it has been confirmed that the DMA request of the channel to be forcibly terminated is not held pending, clear the Enn bit to 0.</p>  | p. 667 <input type="checkbox"/> |



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| Chapter 18 | Soft                   | DMA function (DMA controller) | DMA transfer initialization procedure (setting DCHCn.INITn bit to 1) | <p>&lt;4&gt; Again, clear the Enn bit of the channel to be forcibly terminated. If the target of transfer for the channel to be forcibly terminated (transfer source/destination) is the internal RAM, execute this operation once more.</p> <p>&lt;5&gt; Copy the initial number of transfers of the channel to be forcibly terminated to a general-purpose register.</p> <p>&lt;6&gt; Set the INITn bit of the channel to be forcibly terminated to 1.</p> <p>&lt;7&gt; Read the value of the DBCn register of the channel to be forcibly terminated, and compare it with the value copied in &lt;5&gt;. If the two values do not match, repeat operations &lt;6&gt; and &lt;7&gt;.</p>   | p. 667 <input type="checkbox"/> |
|            |                        |                               | Procedure of temporarily stopping DMA transfer (clearing Enn bit)    | <p>Stop and resume the DMA transfer under execution using the following procedure.</p> <p>&lt;1&gt; Suppress a transfer request from the DMA request source (stop the operation of the on-chip peripheral I/O).</p> <p>&lt;2&gt; Check the DMA transfer request is not held pending, by using the DFn bit (check if the DFn bit = 0).<br/>If a request is pending, wait until execution of the pending DMA transfer request is completed.</p> <p>&lt;3&gt; If it has been confirmed that no DMA transfer request is held pending, clear the Enn bit to 0 (this operation stops DMA transfer).</p> <p>&lt;4&gt; Set the Enn bit to 1 to resume DMA transfer.</p> <p>&lt;5&gt; Resume the operation of the DMA request source that has been stopped (start the operation of the onchip peripheral I/O).</p> | p. 667 <input type="checkbox"/> |
|            |                        |                               | Memory boundary  | The operation is not guaranteed if the address of the transfer source or destination exceeds the area of the DMA target (external memory, internal RAM, or on-chip peripheral I/O) during DMA transfer.   | p. 667 <input type="checkbox"/> |
|            |                        |                               | Transferring misaligned data   | DMA transfer of misaligned data with a 16-bit bus width is not supported. If an odd address is specified as the transfer source or destination, the least significant bit of the address is forcibly assumed to be 0.   | p. 667 <input type="checkbox"/> |
|            |                        |                               | Bus arbitration for CPU  | <p>Because the DMA controller has a higher priority bus mastership than the CPU, a CPU access that takes place during DMA transfer is held pending until the DMA transfer cycle is completed and the bus is released to the CPU.</p> <p>However, the CPU can access the external memory, on-chip peripheral I/O, and internal RAM to/from which DMA transfer is not being executed.</p> <ul style="list-style-type: none"> <li>• The CPU can access the internal RAM when DMA transfer is being executed between the external memory and on-chip peripheral I/O.</li> <li>• The CPU can access the internal RAM and on-chip peripheral I/O when DMA transfer is being executed between the external memory and external memory.</li> </ul>  | p. 668 <input type="checkbox"/> |
|            |                        |                               | Registers/bits that must not be rewritten during DMA operation       | <p>Set the following registers at the following timing when a DMA operation is not under execution.</p> <p>[Registers]</p> <ul style="list-style-type: none"> <li>• DSAH, DSAHL, DDAH, DDAHL, DBCn, and DADCn registers</li> <li>• DTFRn.IFCn5 to DTFRn.IFCn0 bits</li> </ul> <p>[Timing of setting]</p> <ul style="list-style-type: none"> <li>• Period from after reset to start of the first DMA transfer</li> <li>• Time after channel initialization to start of DMA transfer</li> <li>• Period from after completion of DMA transfer (TCn bit = 1) to start of the next DMA transfer</li> </ul>   | p. 668 <input type="checkbox"/> |
|            |                        |                               | DSAHL register<br>DDAHL register<br>DADCn register<br>DCHCn register | <p>Be sure to set the following register bits to 0.</p> <ul style="list-style-type: none"> <li>• Bits 14 to 10 of DSAHL register</li> <li>• Bits 14 to 10 of DDAHL register</li> <li>• Bits 15, 13 to 8, and 3 to 0 of DADCn register</li> <li>• Bits 6 to 3 of DCHCn register</li> </ul>   | p. 668 <input type="checkbox"/> |

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| Chapter 18   | Soft                            | DMA function (DMA controller)           | DMA start factor                       | Do not start two or more DMA channels with the same start factor. If two or more channels are started with the same factor, DMA for which a channel has already been set may be started or a DMA channel with a lower priority may be acknowledged earlier than a DMA channel with a higher priority. The operation cannot be guaranteed.   | p. 668 <input type="checkbox"/>         |
|  |                                 |   | Read values of DSAn and DDAn registers | <p>Values in the middle of updating may be read from the DSAn and DDAn registers during DMA transfer (n = 0 to 3).<br/>For example, if the DSAnH register and then the DSAnL register are read when the DMA transfer source address (DSAn register) is 0000FFFFH and the count direction is incremental (DADCn.SAD1 and DADCn.SAD0 bits = 00), the value of the DSAn register differs as follows, depending on whether DMA transfer is executed immediately after the DSAnH register is read.</p> <p>(a) If DMA transfer does not occur while DSAn register is read<br/>                     &lt;1&gt; Read value of DSAnH register: DSAnH = 0000H<br/>                     &lt;2&gt; Read value of DSAnL register: DSAnL = FFFFH</p> <p>(b) If DMA transfer occurs while DSAn register is read<br/>                     &lt;1&gt; Read value of DSAnH register: DSAnH = 0000H<br/>                     &lt;2&gt; Occurrence of DMA transfer<br/>                     &lt;3&gt; Incrementing DSAn register: DSAn = 00100000H<br/>                     &lt;4&gt; Read value of DSAnL register: DSAnL = 0000H</p> | p. 669 <input type="checkbox"/>         |
| Chapter 19   | Soft                            | Interrupt/exception processing function | Non-maskable interrupts                | For the non-maskable interrupt servicing executed by the non-maskable interrupt request signal (INTWDT2), see <b>19.2.2 (2) From INTWDT2 signal</b> .   | p. 674 <input type="checkbox"/>         |
|  |                                 |   |  | When the EP and NP bits are changed by the LDSR instruction during non-maskable interrupt servicing, in order to restore the PC and PSW correctly during recovery by the RETI instruction, it is necessary to set the EP bit back to 0 and the NP bit back to 1 using the LDSR instruction immediately before the RETI instruction.   | p. 677 <input type="checkbox"/>         |
|  |                                 |   | Maskable interrupt                     | When the EP and NP bits are changed by the LDSR instruction during maskable interrupt servicing, in order to restore the PC and PSW correctly during recovery by the RETI instruction, it is necessary to set the EP bit back to 0 and the NP bit back to 0 using the LDSR instruction immediately before the RETI instruction.   | p. 681 <input type="checkbox"/>         |
|  |                                 |   | Multiple interrupt                     | To perform multiple interrupt servicing, the values of the EIPC and EIPSW registers must be saved before executing the EI instruction. When returning from multiple interrupt servicing, restore the values of EIPC and EIPSW after executing the DI instruction.   | pp. 683 to 685 <input type="checkbox"/> |
|  |                                 |   | Interrupt control register             | Disable interrupts (DI) or mask the interrupt to read the xxICn.xxIFn bit. If the xxIFn bit is read while interrupts are enabled (EI) or while the interrupt is unmasked, the correct value may not be read when acknowledging an interrupt and reading the bit conflict.   | p. 686 <input type="checkbox"/>         |
|  |                                 |   |  | The flag xxIFn is reset automatically by the hardware if an interrupt request signal is acknowledged.   | p. 686 <input type="checkbox"/>         |
|  |                                 |   | IMR0 to IMR4 registers                 | The device file defines the xxICn.xxMKn bit as a reserved word. If a bit is manipulated using the name of xxMKn, the contents of the xxICn register, instead of the IMRm register, are rewritten (as a result, the contents of the IMRm register are also rewritten).   | p. 688 <input type="checkbox"/>         |
| To read bits 8 to 15 of the IMR0 to IMR4 registers in 8-bit or 1-bit units, specify them as bits 0 to 7 of IMR0H to IMR4H registers.                         | p. 689 <input type="checkbox"/> |   |  |   |   |
| Set bits 13 to 15 of the IMR4 register and bits 7 to 14 of the IMR3 register to 1. If the setting of these bits is changed, the operation is not guaranteed. | p. 689 <input type="checkbox"/> |   |  |   |   |

| Chapter    | Classification | Function                                | Details of Function                            | Cautions   | Page                            |
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| Chapter 19 | Soft           | Interrupt/exception processing function | ISPR register                                  | If an interrupt is acknowledged while the ISPR register is being read in the interrupt enabled (EI) status, the value of the ISPR register after the bits of the register have been set by acknowledging the interrupt may be read. To accurately read the value of the ISPR register before an interrupt is acknowledged, read the register while interrupts are disabled (DI). | p. 690 <input type="checkbox"/> |
|            |                |   | Restoration from software exception processing | When the EP and NP bits are changed by the LDSR instruction during the software exception processing, in order to restore the PC and PSW correctly during recovery by the RETI instruction, it is necessary to set the EP bit back to 1 and the NP bit back to 0 using the LDSR instruction immediately before the RETI instruction.   | p. 693 <input type="checkbox"/> |
|            |                |   | Illegal opcode definition                      | Since it is possible to assign this instruction to an illegal opcode in the future, it is recommended that it not be used.   | p. 695 <input type="checkbox"/> |
|            |                |   | Restoration from exception trap                | DBPC and DBPSW can be accessed only during the interval between the execution of an illegal opcode and the DBRET instruction.  | p. 696 <input type="checkbox"/> |
|            |                |   | Restoration from debug trap                    | DBPC and DBPSW can be accessed only during the interval between the execution of the DBTRAP instruction and the DBRET instruction.   | p. 698 <input type="checkbox"/> |
|            |                |   | INTF0, INTR0 registers                         | When the function is changed from the external interrupt function (alternate function) to the port function, an edge may be detected. Therefore, clear the INTF0n and INTR0n bits to 00, and then set the port mode.   | p. 700 <input type="checkbox"/> |
|            |                |   |  | Be sure to clear the INTF0n and INTR0n bits to 00 when these registers are not used as the NMI or INTP0 to INTP3 pins.   | p. 700 <input type="checkbox"/> |
|            |                |   | INTF3, INTR3 registers                         | When the function is changed from the external interrupt function (alternate function) to the port function, an edge may be detected. Therefore, clear the INTF31 and INTR31 bits to 00, and then set the port mode.   | p. 701 <input type="checkbox"/> |
|            |                |   |  | The INTP7 pin and RXDA0 pin are alternate-function pins. When using the pin as the RXDA0 pin, disable edge detection for the INTP7 alternate-function pin (clear the INTF3.INTF31 bit and the INTR3.INTR31 bit to 0). When using the pin as the INTP7 pin, stop UARTA0 reception (clear the UA0CTL0.UA0RXE bit to 0).  | p. 701 <input type="checkbox"/> |
|            |                |   |  | Be sure to clear the INTF31 and INTR31 bits to 00 when these registers are not used as INTP7 pin.  | p. 701 <input type="checkbox"/> |
|            |                |   | INTF8, INTR8 registers                         | When the function is changed from the external interrupt function (alternate function) to the port function, an edge may be detected. Therefore, clear the INTF80 and INTR80 bits to 00, and then set the port mode.   | p. 702 <input type="checkbox"/> |
|            |                |   |  | The INTP8 pin and RXDA3 pin are alternate-function pins. When using the pin as the RXDA3 pin, disable edge detection for the INTP8 alternate-function pin (clear the INTF8.INTF80 bit and the INTR8.INTR80 bit to 0). When using the pin as the INTP8 pin, stop UARTA3 reception (clear the UA3CTL0.UA3RXE bit to 0).  | p. 702 <input type="checkbox"/> |
|            |                |   |  | Be sure to clear the INTF80 and INTR80 bits to 00 when these registers are not used as INTP8 pin.  | p. 702 <input type="checkbox"/> |
|            |                |   | INTF9H, INTR9H registers                       | When the function is changed from the external interrupt function (alternate function) to the port function, an edge may be detected. Therefore, clear the INTF9n and INTR9n bits to 0, and then set the port mode.  | p. 703 <input type="checkbox"/> |
|            |                |   |  | Be sure to clear the INTF9n and INTR9n bits to 00 when these registers are not used as INTP4 to INTP6 pins.  | p. 703 <input type="checkbox"/> |

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| Chapter 19 | Soft           | Interrupt/exception processing function | NFC register                   | After the sampling clock has been changed, it takes 3 sampling clocks to initialize the digital noise eliminator. Therefore, if an INTP3 valid edge is input within these 3 sampling clocks after the sampling clock has been changed, an interrupt request signal may be generated.<br>Therefore, be careful about the following points when using the interrupt and DMA functions.<br><ul style="list-style-type: none"> <li>When using the interrupt function, after the 3 sampling clocks have elapsed, enable interrupts after the interrupt request flag (PIC3.PIF3 bit) has been cleared.</li> <li>When using the DMA function (started by INTP3), enable DMA after 3 sampling clocks have elapsed.</li> </ul> | p. 704 <input type="checkbox"/> |
|            |                |   | NMI pin                        | The NMI pin and P02 pin are an alternate-function pin, and function as a normal port pin after being reset. To enable the NMI pin, validate the NMI pin with the PMCO register. The initial setting of the NMI pin is "No edge detected". Select the NMI pin valid edge using the INTF0 and INTR0 registers.  | p. 706 <input type="checkbox"/> |
| Chapter 20 | Soft           | Key interrupt function                  | KRM register                   | Rewrite the KRM register after once clearing the KRM register to 00H.<br>If the KRM register is changed, an interrupt request signal (INTKR) may be generated. To prevent this, change the KRM register after disabling interrupts (DI) or masking, then clear the interrupt request flag (KRIC.KRIF bit) to 0, and enable interrupts (EI) or clear the mask.   | p. 708 <input type="checkbox"/> |
|            |                |   | KR0 to KR7 pins                | If a low level is input to any of the KR0 to KR7 pins, the INTKR signal is not generated even if the falling edge of another pin is input.  | p. 708 <input type="checkbox"/> |
|            |                |   | RXDA1 pin<br>KR7 pin           | The RXDA1 and KR7 pins must not be used at the same time. To use the RXDA1 pin, do not use the KR7 pin.<br>To use the KR7 pin, do not use the RXDA1 pin (it is recommended to set the PFC91 bit to 1 and clear PFCE91 bit to 0).  | p. 708 <input type="checkbox"/> |
|            |                |   | Use the key interrupt function | To use the key interrupt function, be sure to set the port pin to the key return pin and then enable the operation with the KRM register. To switch from the key return pin to the port pin, disable the operation with the KRM register and then set the port pin.   | p. 708 <input type="checkbox"/> |
|            |                |   | PSC register                   | Before setting the IDLE1, IDLE2, STOP, or sub-IDLE mode, set the PSMR.PSM1 and PSMR.PSM0 bits and then set the STP bit.<br>Settings of the NMI1M, NMI0M, and INTM bits are invalid when HALT mode is released.<br>If the NMI1M, NMI0M, or INTM bit is set to 1 at the same time the STP bit is set to 1, the setting of NMI1M, NMI0M, or INTM bit becomes invalid. If there is an unmasked interrupt request signal being held pending when the IDLE1/IDLE2/STOP mode is set, set the bit corresponding to the interrupt request signal (NMI1M, NMI0M, or INTM) to 1, and then set the STP bit to 1.  | p. 711 <input type="checkbox"/> |
| Chapter 21 | Soft           | Standby function                        | PSMR register                  | Be sure to clear bits 2 to 7 to "0".<br>The PSM0 and PSM1 bits are valid only when the PSC.STP bit is 1.  | p. 712 <input type="checkbox"/> |
|            |                |   | OSTS register                  | The wait time following release of the STOP mode does not include the time until the clock oscillation starts ("a" in the figure below) following release of the STOP mode, regardless of whether the STOP mode is released by reset or the occurrence of an interrupt request signal.<br>Be sure to clear bits 3 to 7 to "0".<br>The oscillation stabilization time following reset release is $2^{16}/f_x$ (because the initial value of the OSTS register = 06H).  | p. 713 <input type="checkbox"/> |
|            |                |   | OSTS register                  | Be sure to clear bits 3 to 7 to "0".  | p. 713 <input type="checkbox"/> |
|            |                |   | OSTS register                  | The oscillation stabilization time following reset release is $2^{16}/f_x$ (because the initial value of the OSTS register = 06H).  | p. 713 <input type="checkbox"/> |
|            |                |   | HALT mode                      | Insert five or more NOP instructions after the HALT instruction.  | p. 714 <input type="checkbox"/> |

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| Chapter 21 | Soft                   | Standby function | HALT mode                         | If the HALT instruction is executed while an unmasked interrupt request signal is being held pending, the status shifts to HALT mode, but the HALT mode is then released immediately by the pending interrupt request.   | p. 714 <input type="checkbox"/> |
|            |                        |                  | IDLE1 mode                        | Insert five or more NOP instructions after the instruction that stores data in the PSC register to set the IDLE1 mode.   | p. 716 <input type="checkbox"/> |
|            |                        |                  |                                   | If the IDLE1 mode is set while an unmasked interrupt request signal is being held pending, the IDLE1 mode is released immediately by the pending interrupt request.  | p. 716 <input type="checkbox"/> |
|            |                        |                  | Releasing IDLE1 mode              | An interrupt request signal that is disabled by setting the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits to 1 becomes invalid and IDLE1 mode is not released.   | p. 716 <input type="checkbox"/> |
|            |                        |                  | IDLE2 mode                        | Insert five or more NOP instructions after the instruction that stores data in the PSC register to set the IDLE2 mode.   | p. 718 <input type="checkbox"/> |
|            |                        |                  |                                   | If the IDLE2 mode is set while an unmasked interrupt request signal is being held pending, the IDLE2 mode is released immediately by the pending interrupt request.  | p. 718 <input type="checkbox"/> |
|            |                        |                  | Releasing IDLE2 mode              | The interrupt request signal that is disabled by setting the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits to 1 becomes invalid and IDLE2 mode is not released.  | p. 718 <input type="checkbox"/> |
|            |                        |                  | STOP mode                         | Insert five or more NOP instructions after the instruction that stores data in the PSC register to set the STOP mode.  | p. 721 <input type="checkbox"/> |
|            |                        |                  |                                   | If the STOP mode is set while an unmasked interrupt request signal is being held pending, the STOP mode is released immediately by the pending interrupt request.  | p. 721 <input type="checkbox"/> |
|            |                        |                  | Releasing STOP mode               | The interrupt request that is disabled by setting the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits to 1 becomes invalid and STOP mode is not released.  | p. 721 <input type="checkbox"/> |
|            |                        |                  | Subclock operation mode           | When manipulating the CK3 bit, do not change the set values of the PCC.CK2 to PCC.CK0 bits (using a bit manipulation instruction to manipulate the bit is recommended). For details of the PCC register, see <b>6.3 (1) Processor clock control register (PCC)</b> . | p. 725 <input type="checkbox"/> |
|            |                        |                  |                                   | If the following conditions are not satisfied, change the CK2 to CK0 bits so that the conditions are satisfied and set the subclock operation mode.<br>Internal system clock ( $f_{CLK}$ ) > Subclock ( $f_{XT} = 32.768 \text{ kHz}$ ) $\times$ 4                   | p. 725 <input type="checkbox"/> |
|            |                        |                  | Releasing subclock operation mode | When manipulating the CK3 bit, do not change the set values of the CK2 to CK0 bits (using a bit manipulation instruction to manipulate the bit is recommended). For details of the PCC register, see <b>6.3 (1) Processor clock control register (PCC)</b> .         | p. 725 <input type="checkbox"/> |
|            |                        |                  |                                   | Be sure to stop the PLL (PLLCTL.PLLON bit = 0) before stopping the main clock.   | p. 726 <input type="checkbox"/> |
|            |                        |                  |                                   | When the CPU is operating on the subclock and main clock oscillation is stopped, accessing a register in which a wait occurs is disabled. If a wait is generated, it can be released only by reset (see <b>3.4.8 (2)</b> ).  | p. 726 <input type="checkbox"/> |
|            |                        |                  | Sub-IDLE mode                     | Following the store instruction to the PSC register for setting the sub-IDLE mode, insert the five or more NOP instructions.   | p. 727 <input type="checkbox"/> |
|            |                        |                  |                                   | If the sub-IDLE mode is set while an unmasked interrupt request signal is being held pending, the sub-IDLE mode is then released immediately by the pending interrupt request.   | p. 727 <input type="checkbox"/> |
|            |                        |                  | Releasing sub-IDLE mode           | The interrupt request signal that is disabled by setting the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits to 1 becomes invalid and sub-IDLE mode is not released.   | p. 727 <input type="checkbox"/> |

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| Chapter 21     | Soft                                   | Standby function                                       | Releasing sub-IDLE mode  | When the sub-IDLE mode is released, 12 cycles of the subclock (about 366 $\mu$ s) elapse from when the interrupt request signal that releases the sub-IDLE mode is generated to when the mode is released.  | p. 727 <input type="checkbox"/> |
|                |  |  | Operating status in sub-IDLE mode  | Be sure to stop the PLL (PLLCTL.PLLON bit = 0) before stopping the main clock.  | p. 728 <input type="checkbox"/> |
|                |  |  |  | To realize low power consumption, stop the A/D and D/A converters before shifting to the sub-IDLE mode.   | p. 728 <input type="checkbox"/> |
| Chapter 22     | Soft                                   | Reset function   | Emergency operation mode   | In emergency operation mode, do not access on-chip peripheral I/O registers other than registers used for interrupts, port function, WDT2, or timer M, each of which can operate with the internal oscillation clock. In addition, operation of CSIB0 to CSIB5 and UARTA0 using the externally input clock is also prohibited in this mode. | p. 729 <input type="checkbox"/> |
|                |  |  | Reset function   | An LVI circuit internal reset does not reset the LVI circuit.   | p. 729 <input type="checkbox"/> |
|                |  |  | RESF register  | Only "0" can be written to each bit of this register. If writing "0" conflicts with setting the flag (occurrence of reset), setting the flag takes precedence.  | p. 730 <input type="checkbox"/> |
|                | Hard                                   | Hardware status on $\overline{\text{RESET}}$ pin input | When the power is turned on, the following pin may output an undefined level temporarily, even during reset.<br>• P53/SIB2/KR3/TIQ00/TOQ00/RTP03/DDO pin   | p. 731 <input type="checkbox"/>   |                                 |
|                |  |  | The OCDM register is initialized by the $\overline{\text{RESET}}$ pin input. Therefore, note with caution that, if a high level is input to the P05/DRST pin after a reset release before the OCDM.OCDM0 bit is cleared, the on-chip debug mode is entered. For details, see <b>CHAPTER 4 PORT FUNCTIONS</b> . | p. 731 <input type="checkbox"/>   |                                 |
| Chapter 23     | Soft                                   | Clock monitor  | CLM register   | Once the CLME bit has been set to 1, it cannot be cleared to 0 by any means other than reset.   | p. 739 <input type="checkbox"/> |
|                |  |  |  | When a reset by the clock monitor occurs, the CLME bit is cleared to 0 and the RESF.CLMRF bit is set to 1.  | p. 739 <input type="checkbox"/> |
|                |  |  | Internal oscillator  | The internal oscillator can be stopped by setting the RCM.RSTOP bit to 1.   | p. 740 <input type="checkbox"/> |
|                |  |  |  | The clock monitor is stopped while the internal oscillator is stopped.  | p. 740 <input type="checkbox"/> |
|                |  |  |  | The internal oscillator cannot be stopped by software.  | p. 740 <input type="checkbox"/> |
| Chapter 24     | Soft                                   | Low-voltage detector (LVI)                             | LVIM register  | When the LVION and LVIMD bits to 1, the low-voltage detector cannot be stopped until the reset request due to other than the low-voltage detection is generated.  | p. 744 <input type="checkbox"/> |
|                |  |  |  | When the LVION bit is set to 1, the comparator in the LVI circuit starts operating. Wait 0.2 ms or longer by software before checking the voltage at the LVIF bit after the LVION bit is set.   | p. 744 <input type="checkbox"/> |
|                |  |  |  | Be sure to clear bits 6 to 2 to "0".  | p. 744 <input type="checkbox"/> |
|                |  |  | LVIS register  | This register cannot be written until a reset request due to something other than low-voltage detection is generated after the LVIM.LVION and LVIM.LVIMD bits are set to 1.   | p. 745 <input type="checkbox"/> |
|                |  |  |  | Be sure to clear bits 7 to 1 to "0".  | p. 745 <input type="checkbox"/> |
|                |  |  | To use for internal reset signal   | If the LVIMD bit is set to 1, the contents of the LVIM and LVIS registers cannot be changed until a reset request other than LVI is generated.  | p. 746 <input type="checkbox"/> |
|                |  |  | To use for interrupt   | When the INTLVI signal is generated, confirm, using the LVIM/LVIF bit, whether the INTLVI signal is generated due to a supply voltage drop or rise across the detected voltage.   | p. 747 <input type="checkbox"/> |
| PEMU1 register | This bit is not automatically cleared. | p. 749 <input type="checkbox"/>                        |  |   |                                 |

| Chapter    | Chapter Classification   | Function  | Details of Function             | Caution  | Page                                    |
|------------|--|---|---------------------------------|--|---|
| Chapter 25 | Soft   | CRC function  | CRC register                    | Accessing the CRC register is prohibited in the following statuses. For details, refer to <b>3.4.9 (2) Accessing specific on-chip peripheral I/O registers</b> . <ul style="list-style-type: none"> <li>When the CPU operates with the subclock and the main clock oscillation is stopped</li> <li>When the CPU operates with the internal oscillation clock</li> </ul>  | p. 751 <input type="checkbox"/>         |
| Chapter 26 | Hard   | Regulator   | Regulator                       | Use the regulator with a setting of $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ .   | p. 755 <input type="checkbox"/>         |
| Chapter 27 | Hard   | Flash memory  | FLMD1 pin                       | Connect the FLMD1 pin to the flash programmer or connect to a GND via a pull-down resistor on the board.   | pp. 763 to 765 <input type="checkbox"/> |
|            |  |   | PG-FP4                          | Wire these pins as shown in Figure 27-6, or connect them to GND via pull-down resistor on board.   | p. 765 <input type="checkbox"/>         |
|            |  |   |                                 | Clock cannot be supplied via the CLK pin of the flash programmer. Create an oscillator on board and supply the clock.  | p. 765 <input type="checkbox"/>         |
|            |  |   | FA-144GJ-UEN-A                  | Be sure to connect the REGC pin to GND via a 4.7 $\mu$ F (preliminary value) capacitor.  | pp. 766, 767 <input type="checkbox"/>   |
|            |  |   |                                 | A clock cannot be supplied from the CLK pin of the flash programmer. Create an oscillator on the board and supply the clock from that oscillator.  | pp. 766, 767 <input type="checkbox"/>   |
|            |  |   |                                 | Wire the FLMD1 pin as shown below, or connect it to GND on board via a pull-down resistor.   | p. 769 <input type="checkbox"/>         |
|            |  |   |                                 | Supply a clock by creating an oscillator on the flash writing adapter (enclosed by the broken lines).  | p. 769 <input type="checkbox"/>         |
|            |  |   |                                 | Do not input a high level to the $\overline{DRST}$ pin.  | p. 769 <input type="checkbox"/>         |
|            |  |   | Selection of communication mode | When UARTA0 is selected, the receive clock is calculated based on the reset command sent from the dedicated flash programmer after receiving the FLMD0 pulse.  | p. 771 <input type="checkbox"/>         |
|            |  |   | FLMD1 pin                       | If the $V_{DD}$ signal is input to the FLMD1 pin from another device during on-board writing and immediately after reset, isolate this signal.   | p. 773 <input type="checkbox"/>         |
| FLMD0 pin  | Make sure that the FLMD0 pin is at 0 V when reset is released. | p. 780 <input type="checkbox"/>   |                                 |  |   |
| Chapter 28 | Hard, soft   | On-chip debug function  | OCDM register                   | When using the DDI, DDO, DCK, and DMS pins not as on-chip debug pins but as port pins after external reset, any of the following actions must be taken. <ul style="list-style-type: none"> <li>Input a low level to the P05/INTP2/<math>\overline{DRST}</math> pin.</li> <li>Set the OCDM0 bit. In this case, take the following actions. <ul style="list-style-type: none"> <li>&lt;1&gt; Clear the OCDM0 bit to 0.</li> <li>&lt;2&gt; Fix the P05/INTP2/<math>\overline{DRST}</math> pin to low level until &lt;1&gt; is completed.</li> </ul> </li> </ul> | p. 786 <input type="checkbox"/>         |
|            |  |   |                                 | The $\overline{DRST}$ pin has an on-chip pull-down resistor. This resistor is disconnected when the OCDM0 flag is cleared to 0.  | p. 786 <input type="checkbox"/>         |
|            | Soft   |   | Cautions (DUC)                  | If a reset signal is input (from the target system or a reset signal from an internal reset source) during RUN (program execution), the break function may malfunction.  | p. 787 <input type="checkbox"/>         |
|            |  |   |                                 | Even if the reset signal is masked by the mask function, the I/O buffer (port pin) may be reset if a reset signal is input from a pin.   | p. 787 <input type="checkbox"/>         |
|            |  | Pin reset during a break is masked and the CPU and peripheral I/O are not reset. If pin reset or internal reset is generated as soon as the flash memory is rewritten by DMM or read by the RAM monitor function while the user program is being executed, the CPU and peripheral I/O may not be correctly reset. | p. 787 <input type="checkbox"/> |  |   |

| Chapter   | Classification                  | Function                           | Details of Function   | Cautions   | Page                            |
|---|---------------------------------|------------------------------------|---|--|---------------------------------|
| Chapter 28  | Hard                            | On-chip debug function             | Cautions (DUC)  | In the on-chip debug mode, the DDO pin is forcibly set to the high-level output.   | p. 787 <input type="checkbox"/> |
|   |                                 |                                    | Cautions (other than DUC)   | Do not mount a device that was used for debugging on a mass-produced product, because the flash memory was rewritten during debugging and the number of rewrites of the flash memory cannot be guaranteed.<br>Moreover, do not embed the debug monitor program into mass-produced products.  | p. 796 <input type="checkbox"/> |
|   | Soft                            |                                    | Forced breaks cannot be executed if one of the following conditions is satisfied.   | p. 796 <input type="checkbox"/>  |                                 |
|   |                                 |                                    | <ul style="list-style-type: none"> <li>• Interrupts are disabled (DI)</li> <li>• Interrupts issued for the serial interface, which is used for communication between MINICUBE2 and the target device, are masked</li> <li>• Standby mode is entered while standby release by a maskable interrupt is prohibited</li> <li>• Mode for communication between MINICUBE2 and the target device is UARTA0, and the main clock has been stopped</li> </ul>   |  |                                 |
|   |                                 |                                    | The pseudo RRM function and DMM function do not operate if one of the following conditions is satisfied.  | p. 797 <input type="checkbox"/>  |                                 |
|   |                                 |                                    | <ul style="list-style-type: none"> <li>• Interrupts are disabled (DI)</li> <li>• Interrupts issued for the serial interface, which is used for communication between MINICUBE2 and the target device, are masked</li> <li>• Standby mode is entered while standby release by a maskable interrupt is prohibited</li> <li>• Mode for communication between MINICUBE2 and the target device is UARTA0, and the main clock has been stopped</li> <li>• Mode for communication between MINICUBE2 and the target device is UARTA0, and a clock different from the one specified in the debugger is used for communication</li> </ul> |  |                                 |
|   |                                 |                                    | The standby mode is released by the pseudo RRM function and DMM function if one of the following conditions is satisfied.   | p. 797 <input type="checkbox"/>  |                                 |
| <ul style="list-style-type: none"> <li>• Mode for communication between MINICUBE2 and the target device is CSIB0 or CSIB3</li> <li>• Mode for communication between MINICUBE2 and the target device is UARTA0, and the main clock has been supplied.</li> </ul> |                                 |                                    |   |  |                                 |
| Peripheral I/O registers that requires a specific sequence cannot be written with the DMM function.   | p. 797 <input type="checkbox"/> |                                    |   |  |                                 |
|   |                                 |                                    | If a space where the debug monitor program is allocated is rewritten by flash self programming, the debugger can no longer operate normally.  | p. 797 <input type="checkbox"/>  |                                 |
|   |                                 |                                    | Security ID   | After the flash memory is erased, 1 is written to the entire area.   | p. 798 <input type="checkbox"/> |
| Chapter 29  | Hard                            | Electrical specifications (target) | Absolute maximum ratings  | Be sure not to exceed the absolute maximum ratings (MAX. value) of each supply voltage.  | p. 801 <input type="checkbox"/> |
|   |                                 |                                    |   | Do not directly connect the output (or I/O) pins of IC products to each other, or to V <sub>DD</sub> , V <sub>CC</sub> , and GND. Open-drain pins or open-collector pins, however, can be directly connected to each other.<br>Direct connection of the output pins between an IC product and an external circuit is possible, if the output pins can be set to the high-impedance state and the output timing of the external circuit is designed to avoid output conflict. | p. 802 <input type="checkbox"/> |



| Chapter    | Classification | Function                            | Details of Function  | Cautions  | Page   |
|------------|----------------|-------------------------------------|--|---|--|
| Chapter 29 | Hard           | Electrical specifications (target)  | 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. The ratings and conditions indicated for DC characteristics and AC characteristics represent the quality assurance range during normal operation.   | p. 802 <input type="checkbox"/>  |
|            |                |                                     | Main clock oscillator characteristics  | The oscillation frequency shown above indicates only oscillator characteristics. Use the V850ES/JJ3 so that the internal operation conditions do not exceed the ratings shown in AC Characteristics and DC Characteristics.   | p. 804 <input type="checkbox"/>  |
|            |                |                                     |  | Time required to set up the flash memory. Secure the setup time using the OSTs register.  | p. 804 <input type="checkbox"/>  |
|            |                |                                     |  | When using the main clock oscillator, wire as follows in the area enclosed by the broken lines in the above figure 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> | p. 804 <input type="checkbox"/>  |
|            |                |                                     | Soft   |   | When the main clock is stopped and the device is operating on the subclock, wait until the oscillation stabilization time has been secured by the program before switching back to the main clock. |
|            | Hard           |                                     |  | For the resonator selection and oscillator constant, customers are requested to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation.   | p. 804 <input type="checkbox"/>  |
|            |                | Subclock oscillator characteristics | The oscillation frequency shown above indicates only oscillator characteristics. Use the V850ES/JJ3 so that the internal operation conditions do not exceed the ratings shown in AC Characteristics and DC Characteristics.  | p. 805 <input type="checkbox"/>   |  |
|            |                |                                     | When using the subclock 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> | p. 805 <input type="checkbox"/>   |  |

| Chapter    | Classification | Function                           | Details of Function                 | Cautions  | Page                            |                  |   |                                 |
|------------|----------------|------------------------------------|-------------------------------------|---|---------------------------------|------------------|---|---------------------------------|
| Chapter 29 | Hard           | Electrical specifications (target) | Subclock oscillator characteristics | The subclock oscillator is designed as a low-amplitude circuit for reducing power consumption, and is more prone to malfunction due to noise than the main clock oscillator. Particular care is therefore required with the wiring method when the subclock is used.  | p. 805 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    |                                     | For the resonator selection and oscillator constant, customers are requested to either evaluate the oscillation themselves or apply to the resonator manufacturer for evaluation.   | p. 805 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    | Data retention characteristics      | Shifting to STOP mode and restoring from STOP mode must be performed within the rated operating range.  | p. 810 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    | AC characteristics                  | If the load capacitance exceeds 50 pF due to the circuit configuration, bring the load capacitance of the device to 50 pF or less by inserting a buffer or by some other means.   | p. 811 <input type="checkbox"/> |                  |   |                                 |
|            | Soft           |                                    | Bus timing (multiplexed bus mode)   | When operating at $f_{xx} > 20$ MHz, be sure to insert address hold waits and address setup waits.  | p. 813 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    | Bus timing (separate bus mode)      | When operating at $f_{xx} > 20$ MHz, be sure to insert address hold waits, address setup waits, and data waits.   | p. 818 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    | I <sup>2</sup> C bus mode           | At the start condition, the first clock pulse is generated after the hold time.   | p. 829 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    |                                     | The system requires a minimum of 300 ns hold time internally for the SDA0n signal (at $V_{IHmin}$ . of SCL0n signal) in order to occupy the undefined area at the falling edge of SCL0n.  | p. 829 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    |                                     | If the system does not extend the SCL0n signal low hold time ( $t_{LOW}$ ), only the maximum data hold time ( $t_{HD:DAT}$ ) needs to be satisfied.   | p. 829 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    |                                     | The high-speed mode I <sup>2</sup> C bus can be used in the normal-mode I <sup>2</sup> C bus system. In this case, set the high-speed mode I <sup>2</sup> C bus so that it meets the following conditions. <ul style="list-style-type: none"> <li>• If the system does not extend the SCL0n signal's low state hold time: <math>t_{SU:DAT} \geq 250</math> ns</li> <li>• If the system extends the SCL0n signal's low state hold time: Transmit the following data bit to the SDA0n line prior to the SCL0n line release (<math>t_{Rmax.} + t_{SU:DAT} = 1,000 + 250 = 1,250</math> ns: Normal mode I<sup>2</sup>C bus specification).</li> </ul> | p. 829 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    | A/D converter                       | Do not set (read/write) alternate-function ports during A/D conversion; otherwise the conversion resolution may be degraded.  | p. 830 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    | Programming characteristics         | When writing initially to shipped products, it is counted as one rewrite for both "erase to write" and "write only".<br>Example (P: Write, E: Erase)<br>Shipped product →P→E→P→E→P: 3 rewrites<br>Shipped product →E→P→E→P→E→P: 3 rewrites  | p. 834 <input type="checkbox"/> |                  |   |                                 |
|            |                |                                    | Appendix A                          | Soft  | Development tool                | RX850, RX850 Pro | To purchase the RX850 or RX850 Pro, first fill in the purchase application form and sign the license agreement. | p. 844 <input type="checkbox"/> |
|            |                |                                    | Appendix D                          | Soft  | Instruction set list            | Instruction set  | Do not specify the same register for general-purpose registers reg1 and reg3.                                   | p. 869 <input type="checkbox"/> |

## APPENDIX F REVISION HISTORY

## F.1 Major Revisions in This Edition

| Page       | Description   |
|------------|---|
| Throughout | Addition of $\mu$ PD70F3743 and $\mu$ PD70F3744   |
| p. 60      | Addition of <b>3.4.4 (1) (a) Internal ROM (384 KB)</b>                                      |
| p. 60      | Addition of <b>3.4.4 (1) (b) Internal ROM (512 KB)</b>                                      |
| p. 62      | Addition of <b>3.4.4 (2) (a) Internal RAM (32 KB)</b>                                       |
| p. 62      | Addition of <b>3.4.4 (2) (b) Internal RAM (40 KB)</b>                                       |
| p. 142     | Modification of <b>Figure 4-8 Block Diagram of Type D-2</b>                                 |
| p. 145     | Modification of <b>Figure 4-11 Block Diagram of Type E-2</b>                                |
| p. 146     | Modification of <b>Figure 4-12 Block Diagram of Type E-3</b>                                |
| p. 147     | Modification of <b>Figure 4-13 Block Diagram of Type G-1</b>                                |
| p. 148     | Modification of <b>Figure 4-14 Block Diagram of Type G-2</b>                                |
| p. 149     | Modification of <b>Figure 4-15 Block Diagram of Type G-3</b>                                |
| p. 150     | Modification of <b>Figure 4-16 Block Diagram of Type G-5</b>                                |
| p. 151     | Modification of <b>Figure 4-17 Block Diagram of Type G-6</b>                                |
| p. 152     | Modification of <b>Figure 4-18 Block Diagram of Type G-12</b>                               |
| p. 154     | Modification of <b>Figure 4-20 Block Diagram of Type L-2</b>                                |
| p. 156     | Modification of <b>Figure 4-22 Block Diagram of Type N-2</b>                                |
| p. 158     | Modification of <b>Figure 4-24 Block Diagram of Type U-1</b>                                |
| p. 159     | Modification of <b>Figure 4-25 Block Diagram of Type U-5</b>                                |
| p. 160     | Modification of <b>Figure 4-26 Block Diagram of Type U-6</b>                                |
| p. 161     | Modification of <b>Figure 4-27 Block Diagram of Type U-7</b>                                |
| p. 162     | Modification of <b>Figure 4-28 Block Diagram of Type U-8</b>                                |
| p. 163     | Modification of <b>Figure 4-29 Block Diagram of Type U-9</b>                                |
| p. 164     | Modification of <b>Figure 4-30 Block Diagram of Type U-10</b>                               |
| p. 165     | Modification of <b>Figure 4-31 Block Diagram of Type U-11</b>                               |
| p. 166     | Modification of <b>Figure 4-32 Block Diagram of Type U-12</b>                               |
| p. 167     | Modification of <b>Figure 4-33 Block Diagram of Type U-13</b>                               |
| p. 168     | Modification of <b>Figure 4-34 Block Diagram of Type U-14</b>                               |
| p. 169     | Modification of <b>Figure 4-35 Block Diagram of Type U-15</b>                               |
| p. 170     | Modification of <b>Figure 4-36 Block Diagram of Type AA-1</b>                               |
| p. 487     | Modification of <b>15.3 (5) UARTn status register (UANSTR)</b>                              |
| p. 757     | Modification of description in <b>27.1 Features</b>   |
| p. 759     | Modification of <b>Figure 27-1 Flash Memory Mapping</b>                                     |
| p. 791     | Modification of <b>Figure 28-4 Memory Spaces Where Debug Monitor Programs Are Allocated</b> |
| p. 846     | Modification of <b>Table B-1 Major Differences Between V850ES/JJ3 and V850ES/JJ2</b>        |
| p. 907     | Addition of <b>APPENDIX F REVISION HISTORY</b>  |

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[A2C00039344](#) [T1022NSE7MQB](#) [T1022NXN7PQB](#) [T1023NSE7MQA](#) [T1024NXE7PQA](#) [T1042NSE7MQB](#) [T1042NSN7MQB](#)  
[T1042NXN7WQB](#) [T2080NSE8TTB](#) [T2080NSN8PTB](#) [T2080NXE8TTB](#) [T2081NXN8TTB](#) [R5F101AFASP#V0](#) [MC68302CEH20C](#)  
[TS68040MF33A](#) [MPC8260ACVVMIBB](#) [MPC8280CZUPEA](#) [MPC8313ECVRAFFC](#) [MPC8313ECVRAGDC](#) [MPC8313EVRADDC](#)  
[MPC8313EVRAFFC](#) [MPC8313VRADDC](#) [MPC8314CVRAGDA](#)